C.9 PUBLIC HEALTH, SAFETY AND NUISANCE

This section provides information regarding electric and magnetic fields (EMF) associated with electric utility facilities and the potential effects related to public health, safety and nuisance. Over the past several years, there has been increasing public awareness and concern regarding the potential health effects associated with electric power systems. For the Tri-Valley 2002 Capacity Increase project, additional concerns related to power line fields include corona and audible noise; radio, television, electronic equipment interference; induced currents and shock hazards; affects on cardiac pacemakers; downed power lines due to wind or earthquake; underground power line faults; and fire hazard.

C.9.1 ENVIRONMENTAL BASELINE AND REGULATORY SETTING

C.9.1.1 Overhead and Underground Power Systems

Electric utility power systems are made up of generating plants, high-voltage transmission lines (above 69 kV) and low–voltage distribution lines (below 69 kV). Transmission and distribution lines were originally developed as a system of energized overhead wires supported by wood or steel structures. Placing electric power lines underground has become more common as technology developed insulated cables that could be placed either directly in the ground or in conduit systems.

At distribution voltages (e.g., under 50 kV), the cost differential between overhead and underground construction has decreased to a point where the use of underground has become more prevalent. From a reliability perspective, distribution lines are typically built as looped circuits and are divided into small sections so that a single cable failure will only affect a relatively small number of customers. In addition, stocking spare distribution cable is not cost-prohibitive, so in the event of a failure the repair time can be kept to a minimum.

In contrast, the cost differential between overhead and underground construction for transmission lines (e.g., over 50 kV) is very large, which is the primary reason that underground technology has not seen widespread use at transmission voltage. Although improvements in underground cable insulation and use of concrete encased duct bank construction have both resulted in improved reliability for high-voltage underground lines, the fact that loss of a transmission circuit can affect a very large number of customers, coupled with the longer repair time associated with these more complex systems, results in limited application of overhead transmission lines.

Underground Power Line Safety and Reliability

The public recognizes electricity, whether from house wiring, neighborhood distribution lines, or transmission lines, as a potential shock and fire hazard. Local, state, and national codes regulate the design, construction and operation of all electrical facilities. These codes include minimum insulation levels and clearances that needed to be provided for correct operation and to safeguard workers and the public. Due to the differences between overhead and underground lines, they each must meet different code requirements and they use different materials. Overhead lines typically use a bare overhead wire attached to insulators supported on wood or steel structures. For underground lines an insulated cable is used, which is either direct-buried or placed in ducts.

The primary differences between underground distribution lines, which are very common in cities and neighborhoods across the country, and underground transmission lines is the size of cable used and the type and amount of insulation on the cable. Underground transmission lines have been much less common because of their high relative cost and the time needed to develop insulation materials at higher voltages. Experience with underground transmission lines covers over 30 years with installation in a full range of land use areas from congested downtown areas, to commercial, residential and even submarine environments. In Northern California today there are multiple underground segments within PG&E Co.'s service area and eight different transmission segments totaling 17.5 miles in the Sacramento Municipal Utility District's service area at 115 kV and 230 kV.

In the event of transmission line failures or cable faults the public is protected from shocks through high speed relaying and circuit breakers that detect faults and de-energize the transmission line in fractions of a second. Further, for underground installations of the type proposed by PG&E Co., several feet of earth and concrete separate the public from the cables.

Underground power lines do provide a reliable means to transmit power. A reliability benefit of underground lines is that they are protected from vehicle collisions or wind-blown debris, which both contribute to outages for overhead lines. Underground lines are susceptible to dig-in by construction contractor's equipment; however, in new transmission installations it is typical to place a concrete cap above the cables or to encase them in a concrete duct entirely (as proposed by PG&E Co.) to protect from this type of outage. In the event of a transmission line outage, overhead facilities are typically quicker to repair since the materials needed are much more common.

Methods to address repair times for underground cables, due to the long manufacturing time for underground cables, include stocking several thousand feet of spare cable and spacing vaults every few thousand feet so any damaged cable can be more quickly replaced. This EIR recommends that the Commission consider including similar conditions in any CPCN which may be granted to PG&E Co., in the interest of system reliability.

For more information about underground transmission technnologies, applications and performance, please see Appendix 2 ("Technology and Environmental Assessment Guide on Underground HV Power Transmission"), and Appendix 3 ("PG&E Co. Information on Underground Transmission Lines").

C.9.1.2 Electric and Magnetic Fields (EMF)

The Proposed Project consists of a number of substations and transmission lines across a relatively large geographic area extending from Highway 680 between San Ramon and Pleasanton on the west to the area of Altamont Pass in the east. The project area contains a mixture of developed/urbanized lands near the cities of San Ramon, Dublin, Pleasanton, and Livermore and undeveloped areas generally to the north and east of the cities listed above. In the developed areas near cities, existing electric and magnetic fields will be more prevalent from the use of electronic appliances or equipment and existing electric transmission and distribution lines. In the undeveloped and natural areas in the northern and eastern portion of the study region, electric and magnetic fields are anticipated to be less common but still present in the vicinity of existing power line corridors.

Defining EMF

Electric and magnetic fields are separate phenomena and occur both naturally and as a result of human activity across a broad electrical spectrum. Naturally-occurring electric and magnetic fields are caused by the weather and the earth's geomagnetic field. These fields also occur from human activity, caused by technological application of the electromagnetic spectrum for uses such as communications, appliances, and the generation, transmission, and local distribution of electricity.

The electric and magnetic fields from power lines change their direction over time. The rate of this change in direction is referred to as a frequency, and represents the number of times the fields change direction each second. For power lines in the United States, the frequency of change is 60 times per second and is defined as 60 Hertz (Hz) power. In Europe and many other countries, the frequency of electric power is 50 Hz. Radio and communication waves operate at much higher frequencies: 500,000 Hz to 1,000,000,000 Hz. The information presented in this document is limited to the EMF from power lines at frequencies of 50 or 60 Hz.

Electric power flows across transmission systems from generating sources to serve electrical loads within the community. The apparent power flowing over a transmission line is determined by the transmission line's voltage and the current. The higher the voltage level of the transmission line, the lower the amount of current needed to deliver the same amount of power. For example, a 115 kV transmission line with 200 amps of current will transmit approximately 40,000 kilowatts (kW), and a 230 kV transmission line requires only 100 amps of current to deliver the same 40,000 kW.

Electric Fields

Electric fields from power lines are created whenever the lines are energized, with the strength of the field dependent directly on the voltage of the line creating it. Electric field strength is typically described in terms of kilovolts per meter (kV/m). Electric field strength attenuates rapidly as the distance from the source increases. Electric fields are shielded by most objects or materials such as trees or houses.

At reasonably close distances, electric fields of sufficient strength in the vicinity of power lines can cause the same phenomena as the static electricity experienced on a dry winter day, or with clothing just removed from a clothes dryer, and may result in electric discharges when touching long metal fences or large vehicles. An acknowledged potential impact to public health from electric transmission lines is the hazard of electric shock. Electric shocks from transmission lines are generally the result of accidental or unintentional contact by the public with the energized wires.

Magnetic Fields

Magnetic fields from power lines are created whenever current flows through power lines at any voltage. The strength of the field is directly dependent on the current in the line. Magnetic field strength is typically measured in milligauss (mG). Similar to electric fields, magnetic field strength attenuates rapidly with distance from the source. Unlike electric fields, magnetic fields are not easily shielded by objects or materials.

The nature of a magnetic field can be illustrated by considering a household appliance. When the appliance is energized by being plugged into an outlet but not turned on so no current would be flowing through it, an electric field will be generated around the cord and appliance, but no magnetic field will be present. If the appliance is switched on, the electric field will still be present and a magnetic field will be created. The electric field strength is directly related to the magnitude of the voltage from the outlet and the magnetic field strength is directly related to the magnitude of the current flowing in the cord and appliance.

Electric and magnetic fields exist in the environment both naturally and as a result of human activities. The geomagnetic field of the earth ranges from 500 to 700 mG (Carstensen, 1987). In areas not immediately adjacent to transmission lines, electric and magnetic fields exist as a result of other electric power uses such as neighborhood distribution lines, household wiring, and electrical equipment or appliances. Public exposure to these fields is widespread and encompasses a very broad range of field intensities and durations. Research on ambient magnetic fields in homes and buildings in several western states found average magnetic field levels within rooms to be approximately 1 mG, while in the immediate area of appliances, the measured values ranged from 9 to 20 mG (Severson et al., 1988, and Silva, 1988). Tables C.9-1 and C.9-2 indicate typical sources and levels of electric and magnetic field exposure the general public experiences from appliances.

Table C.9-1 Typical Electric Field Values for Appliances, at 12 Inches

Appliance	Electric Field Strength (kV/m)
Electric Blanket	0.25*
Broiler	0.13
Stereo	0.09
Refrigerator	0.06
Iron	0.06
Hand Mixer	0.05
Phonographs	0.04
Coffee Pot	0.03

1 to 10 kV/m next to blanket wires (Enertech, 1985)

Table C.9-2 Magnetic Field From Household Appliances

Appliance	Magnetic Field (mG)	
	12" Distant	Maximum
Electric Range	3 to 30	100 to 1,200
Electric Oven	2 to 25	10 to 50
Garbage Disposal	10 to 20	850 to 1,250
Refrigerator	0.3 to 3	4 to 15
Clothes Washer	2 to 30	10 to 400
Clothes Dryer	1 to 3	3 to 80
Coffee Maker	0.8 to 1	15 to 250
Toaster	0.6 to 8	70 to 150
Crock Pot	0.8 to 1	15 to 80
Iron	1 to 3	90 to 300
Can Opener	35 to 250	10,000 to 20,000
Mixer	6 to 100	500 to 7,000
Blender, Popper, Processor	6 to 20	250 to 1,050
Vacuum Cleaner	20 to 200	2,000 to 8,000
Portable Heater	1 to 40	100 to 1,100
Fans/blowers	0.4 to 40	20 to 300
Hair Dryer	1 to 70	60 to 20,000
Electric Shaver	1 to 100	150 to 15,000
Color TV	9 to 20	150 to 500
Fluorescent Fixture	2 to 40	140 to 2,000
Fluorescent Desk Lamp	6 to 20	400 to 3,500
Circular Saws	10 to 250	2,000 to 10,000
Electric Drill	25 to 35	4,000 to 8,000

Gauger, 1985

Public Health and EMF Studies

For more than 20 years, questions regarding the potential effects within the environment of electric and magnetic fields from power lines have been asked, and research has been conducted to provide some basis for response. Earlier studies focused primarily on interactions with the electric fields from power lines. In the late 1970s, the subject of magnetic field interactions began to receive additional public attention and research levels have increased.

A substantial amount of research investigating both electric and magnetic fields has been conducted over the past 15 years; however, much of the body of national and international research regarding EMF and public health risks remains contradictory or inconclusive.

Scientists have found that electric and magnetic fields can produce a number of biological effects (Carstenson, 1987). These range from slowed heart rates to changes in the rate at which the body produces various compounds. Some of these effects are apparently related to the electric field while others are thought to be due to the magnetic field. These effects have been difficult to determine and often are only detectable at field strengths well in excess of those to which the public is exposed from power lines or household wiring and appliances. Although it has been found that EMF causes biological effects, there is no scientific basis to conclude that any of these biological effects have negative implications for public health at the field levels associated with power lines.

Research related to EMF can be grouped into three general categories: cellular level studies, animal and human experiments, and epidemiological studies. These studies have provided mixed results; with some studies showing an apparent relationship between magnetic fields and health effects while other similar studies do not.

Since 1979, public interest and concern specifically regarding magnetic fields from power lines has increased. This increase has generally been attributed to publication of the results of an epidemiological study (Wertheimer and Leeper, 1979). This study observed an association between the wiring configuration of distribution power lines outside of homes in Denver and the incidence of childhood cancer. Following publication of the Wertheimer and Leeper study, more than 50 major epidemiological studies regarding EMF have been conducted.

Scientific Panel Reviews

Numerous panels of expert scientists have convened to review the data relevant to the question of whether exposure to power-frequency EMF is associated with adverse health effects. These evaluations have been conducted in order to advise governmental agencies or professional standard-setting groups. These panels of scientists first evaluate the available studies individually, not only to determine what specific information they can offer, but also in terms of their experimental design, methods of data collection, analysis, and suitability of the authors' conclusions to the nature and quality of the data presented. Subsequently, the individual studies, with their previously identified strengths and weaknesses, are evaluated collectively in an effort to identify whether there is a consistent pattern or trend in the data that would lead to a determination of possible or probable hazards to human health resulting from exposure to these fields.

These reviews include those prepared by international agencies such as the World Health Organization (WHO, 1984 and WHO, 1987) and the international Non-Ionizing Radiation Committee of the International Radiation Protection Association (IRPA/INIRC, 1990) as well as governmental agencies of a number of countries, such as the U.S. EPA, the National Radiological Protection Board of the United Kingdom, and the French and Danish Ministries of Health.

All of these panels have concluded that the body of data, as large as it is, does not provide evidence to conclude that exposure to EMF of the magnitude expected during the operation of electric transmission lines causes cancer or otherwise constitutes a health hazard.

In May 1999 the National Institute of Environmental Health Sciences (NIEHS) submitted to Congress its report titled, *Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields*, containing mixed conclusions regarding EMF and health effects. The conclusions of this report state "using criteria developed by the International Agency for Research on Cancer, none of the Working Group considered the evidence strong enough to label ELF-EMF exposure as a known human carcinogen or probable human carcinogen. However, a majority of the members of this Working Group concluded that exposure to power-line frequency ELF-EMF is a possible carcinogen." Congress has not taken any action following issuance of this report and further research is being conducted since this Working Group was unable to determine that EMF does result in any health effects.

Policies, Standards, and Regulations

A number of counties, states, and local governments have adopted or considered regulations or policies related to EMF exposure. The reasons for these actions have been varied; in general, however, the actions can be attributed to addressing public reaction to and perception of EMF as opposed to responding to the findings of any specific scientific research. Following is a brief summary of activity in this area.

International Activity

The International Radiation Protection Association, in cooperation with the World Health Organization, has published recommended guidelines (INRC, 1998) for electric and magnetic field exposures. For the general public, the limits are 4.2 kV/m for electric fields, and 830 mG for magnetic fields. Neither of these organizations has any governmental authority nor recognized jurisdiction to enforce these guidelines. However, because they were developed by a broad base of scientists, these guidelines have been given merit and are considered by utilities and regulators when reviewing EMF levels from electric power lines.

National Activity

Although the U.S. EPA has conducted investigations into EMF related to power lines and health risks, no national standards have been established. The number of studies sponsored by the U.S. EPA, the Electric Power Research Institute (EPRI), and other institutions has increased dramatically in the past few years. Several bills addressing EMF have been introduced at the congressional level and have provided funding for research; however, no bill has been enacted that would regulate EMF levels.

The 1999 NIEHS report to Congress suggested that the evidence supporting EMF exposure as a health hazard was insufficient to warrant aggressive regulatory actions. The report did suggest passive measures to educate the public and regulators on means aimed at reducing exposures. NIEHS also suggested that the power industry continue its practice of siting lines to reduce exposures and to explore ways to reduce the creation of magnetic fields around lines.

State Activity

Several states have adopted limits of electric field strength within transmission line ROWs. Florida and New York are the only states that currently limit the intensity of magnetic fields from transmission lines. These regulations include limits within the ROW as well as at the edge of the ROW and cover a broad range of values. Table C.9-3 lists the states regulating EMF and their respective limits. The magnetic field limits were based on an objective of preventing field levels from increasing beyond levels currently experienced by the public and are not based upon any link between scientific data and health risks (Morgan, 1991).

Elsewhere in the United States, several agencies and municipalities have taken action regarding EMF policies. These actions have been varied and include requirements that the fields be considered in the siting of new facilities. The manner in which EMF is considered has taken several forms. In a few instances, a concept referred to as "prudent avoidance" has been adopted. Prudent avoidance, a concept proposed by Dr. Granger Morgan of Carnegie-Mellon University, is defined as "…limiting exposures which can be avoided with small investments of money and effort." (Morgan, 1991) Some municipalities or regulating agencies have proposed limitations on field strength, requirements for siting of lines away from residences and schools, and, in some instances, moratoria on the construction of new transmission lines. The origin of these individual actions has been varied, with some initiated by regulators at the time of new transmission line proposals within their community, and some by public grass-roots efforts.

Table C.9-3: EMF Regulated Limits (by State)

State	Electric Field (kV/m)	Magnetic Field (mG)	Location	Application
500 kV Lines Florida (codified)	10		in ROW	Single Circuit
	2	200	edge of ROW	Single Circuit
	2	250	edge of ROW	Double Circuit
230 kV Lines or less Florida (codified)	8		in ROW	
	2	150	edge of ROW	230 kV Lines or less
Minnesota	8		in ROW	> 200 kV
Montana (codified)	1		edge of ROW	> 69 kV
	7		in ROW	road crossings
New Jersey	3	under consideration	edge of ROW	Guideline for complaints
New York	1.6	200	edge of ROW	> 125 kV, > 1 mile
	7		in ROW	public roads
	11		in ROW	public roads
	11.8		in ROW	other terrain
North Dakota	9		in ROW	Informal
Oregon (codified)	9		in ROW	230 kV, 10 miles

Source: Public Utilities Commission of Texas

In 1991, CPUC initiated an investigation into electric and magnetic fields associated with electric power facilities. This investigation explored the approach to potential mitigation measures for reducing public health impacts and possible development of policies, procedures or regulations. Following input from interested parties the CPUC did implement a decision (93-11-03), which requires the use of low-cost or no-cost mitigation measures for electric facilities requiring certification under General Order 131 (such as the subject of this EIR). This decision also implemented a number of EMF measurement, research, and education programs. The CPUC did not adopt any specific limits or regulation on EMF levels related to electric power facilities. See Section C.9.2.1.1 for further details of the CPUC's order.

California Research Programs. In coordination with the California Department of Health Services (DHS), the CPUC sponsors the California EMF Program, which conducts a wide range of research, and advisory programs. This program and its components are described in detail on two Internet websites:

http://www.dnai.com/~emf/
http://www.cpuc.ca.gov/divisions/energy/environmental/emf/emfopen.htm

The EMF program under the CPUC and DHS is briefly described in the following sections.

Creation of the California EMF Program. CPUC Decision 93-11-013 (also described in Section C.9.2.1.1 following) created the California Electric and Magnetic Fields (EMF) Program to research and provide education and technical assistance on the possible health effects of exposure to electric and magnetic fields from powerlines and other uses of electricity. In addition to funding research and policy analysis on this issue, the EMF program provides education and technical assistance to government agencies, professional organizations, businesses, and members of the general public. Under the CPUC decision, this program is funded by money provided by the state's investor-owned utilities and is based in the DHS. The California EMF program produces periodic reports to the CPUC, and its goal is to make the research, policy analysis, and educational products useful to the CPUC in future decision-making. This Program is currently scheduled to end by December 31, 2001.

Program Organization. The DHS has assigned Dr. Raymond Richard Neutra of the Division of Environmental and Occupational Disease Control to head the EMF Program. Funding for the EMF program became available on January 1, 1994, and the Public Health Institute (PHI, formally the California Public Health Foundation) became the program's nonprofit fiscal manager on April 30, 1994. PHI assists DHS by staffing the Stakeholders Advisory Consultants (SAC), overseeing the extramural research unit and its subcontracts, and handling the fiscal and administrative matters of the education unit. After the formation of the SAC and an international search, the research director joined the staff on February 1, 1995.

Stakeholders Advisory Consultants. The CPUC decision that created the California EMF Program states that the involvement of stakeholders and the public is very important to the development of effective EMF policies. This decision asks DHS to determine what form of stakeholder and public involvement best meets its needs. DHS decided that the most appropriate role for the SAC would be to advise the program on the development of the research projects and on budgetary matters, and to monitor its progress to ensure that the scientific and technical staff can exercise their responsibility and authority to carry out an effective program on behalf of the CPUC. The EMF program assembled the SAC in 1994 and they have met several times a year since then.

One important function of the SAC is to serve as a forum where all citizens can ask questions and express their concerns about the possibility of health effects from exposure to EMF and express their opinions about EMF policy. All SAC meetings are open to the general public. Stakeholders' concerns about the research projects have surfaced through discussions that extended in some cases over several quarterly meetings. For some important issues, such as conflict of interest and property values research, consensus was not possible. In these cases the program tries to find solutions that are technically and scientifically sound while being responsive to the basic concerns of the various stakeholders.

Research Unit. The goal of the Research Unit is to help answer the following four questions that decision-makers face as they deal with the EMF issue:

- Is there a health problem? (risk research)
- Where is the problem? (exposure assessment and analysis)
- What can be done about it? (mitigation research)
- What should policymakers do, or what are the policy options and their pros and cons? (policy analysis)

In order to answer these questions, the program's research priority areas are policy analysis, exposure assessment, epidemiology, and electrical engineering and mitigation.

Education and Technical Assistance Unit. The goals of the Education and Technical Assistance unit are to:

- Provide a trustworthy and balanced source information about potential EMF health risks and mitigation options
- Provide technical and consultative services to state and local officials, professional organizations, and the public about EMF exposures and health risks thought to be related to EMF
- Facilitate and maximize opportunities for public input into program projects and goals and provide support and training to enable stakeholders to use and remain informed about the research program results
- Coordinate actions within DHS, with other California state and local agencies, and with programs sponsored by the federal government, other state governments, and investor-owned and municipal utilities
- Act as liaison between the program's Stakeholders Advisory Consultants and staff by organizing and facilitating meetings and preparing and distributing meeting minutes

- Provide education and support for stakeholders and the public through the program newsletter, and prepare and distribute important program materials.

To accomplish these goals, Education and Technical Assistance staff write and distribute educational materials, organize meetings and workshops for stakeholders and the general public, produce a newsletter to keep stakeholders and interested parties informed of program activities, and respond by telephone, mail, and electronic mail to questions raised by members of the public.

***Program Synthesis Projects*.** This is the final phase of the EMF program, during which the research results will be reviewed and used as the basis for preparing reports and products to inform future discussions on this issue. As a result of SAC discussions, the DHS decided to pursue a program synthesis that includes four elements:

- An evaluation of the evidence of risk based on results of this program as well as other research
- A policy integration document to help decision-makers use the policy analyses' results
- A well thought-out process for releasing the data collected in and results of the research projects
- Opportunities for potential end-users of the research effort to familiarize themselves with complex technical documents

The addition of this program synthesis required two applications to the CPUC for no-cost extensions of the program.

C.9.1.3 Other Field Related Public Concerns

Other public concerns related to electric power facility projects, which are safety or nuisance issues, include corona and audible noise; Radio/Television/Electronic equipment interference; induced currents and shock hazards; and cardiac pacemakers.

Corona and Audible Noise

Corona is the breakdown of air very near conductors and occurs when the electric field is locally intensified by irregularities on the conductor surface such as scratches or water drops. Corona, as an issue for transmission lines, is more significant for extra-high voltage lines of 345 kV or above but will occur on lower voltage lines during rain or fog conditions. The physical manifestations of corona include a crackling or hissing noise and very small amounts of light. Besides the nuisance aspects of corona, it results in undesirable power loss over a transmission line. Therefore the design of transmission lines incorporates sufficiently large conductor and smooth edged hardware, which limit or eliminate corona.

Radio/Television/Electronic Equipment Interference

Although corona can generate high frequency energy, which may interfere with broadcast signals or electronic equipment, this is generally not a problem for transmission lines. The Institute of Electrical and Electronic Engineers (IEEE) has published a design guide (Radio Noise Subcommittee 1971) which is used to limit conductor surface gradients so as to avoid electronic interference. There are two facilities in relatively close proximity to the Project alternatives, for which high frequency emissions may be a concern. These facilities are the FAA communications systems at the Livermore Airport and the Federal communications facility near Lorraine and Raymond Roads.

Gap discharges or arcs can also be a source of high frequency energy. Gap discharges occur when an arc forms across a gap in loose or worn line hardware. It is estimated that over 90 percent of interference problems for electric transmission lines are due to gap discharges. Line hardware is designed to be problem-free, but wind motion, corrosion and other factors can create a gap discharge condition. Gap discharges can be located and when they occur can be remedied by utilities.

Electric fields from power lines do not typically pose interference problems for electronic equipment in businesses since the equipment is shielded by buildings and walls. However, magnetic fields can penetrate buildings and walls thereby interacting with electronic equipment. Depending upon the sensitivity of equipment, the magnetic fields can interfere with equipment operation. Review of this phenomenon in regard to the sensitivity of electrical equipment identifies a number of thresholds for magnetic field interference. Interference with typical computer monitors can be detected at magnetic field levels of 10 milligauss (mG) and above, while large screen or high-resolution monitors can be susceptible to interference at levels as low as 5 mG. Other specialized equipment, such as medical equipment or testing equipment can be sensitive at levels below 5 milligauss.

The most common electronic equipment that can be susceptible to magnetic field interference is probably personal computer monitors. Magnetic field interference results in disturbances to the image displayed on the monitor, often described as screen distortion, "jitter," or other visual defects. In most cases it is annoying, and at its worst, it can prevent use of the monitor. This type of interference is a recognized problem in the video monitor industry. As a result, there are manufacturers who specialize in monitor interference solutions and shielding equipment. Possible solutions to this problem include: relocation of the monitor, use of magnetic shield enclosures, software programs, and replacement of cathode ray tube monitors with liquid crystal displays that are not susceptible to magnetic field interference. Equipment that may be susceptible to very low magnetic field strengths are typically installed in specialized and controlled environments since even building wiring, lights, and other equipment can generate magnetic fields of 5 mG or higher.

Induced Currents and Shock Hazards

Power line fields can induce voltages and currents on conductive objects, such as metal roofs or buildings, fences, and vehicles. When a person or animal comes in contact with a conductive object a perceptible current or small secondary shock may occur. Secondary shocks cause no physiological harm; however, they may present a nuisance.

Cardiac Pacemakers

An area of concern related to electric fields from transmission lines has been the possibility of interference with cardiac pacemakers. There are two general types of pacemakers: asynchronous and synchronous. The asynchronous pacemaker pulses at a predetermined rate. It is practically immune to interference because it has no sensing circuitry and is not exceptionally complex. The synchronous pacemaker, however, pulses only when its sensing circuitry determines that pacing is necessary. Interference from transmission line electric field may cause a spurious signal on the pacemaker's sensing circuitry. However, when these pacemakers detect a spurious signal, such as a 60 Hz signal, they are programmed to revert to an asynchronous or fixed pacing mode of operation, returning to synchronous operation within a specified time after the signal is no longer detected. Cardiovascular specialists do not consider prolonged asynchronous pacing a problem. As mentioned before, some pacemakers are designed to operate that way. Periods of operation in this mode are commonly induced by cardiologists to check pacemaker performance. So, while transmission line electric fields may interfere with the normal operation of some of the older model pacemakers, the result of the interference is generally not harmful, and is of short duration (EPRI, 1985 and 1979).

Wind, Earthquake and Fire Hazards

Transmission line structures used to support overhead transmission lines must meet the requirements of the California Public Utilities Commission, General Order No. 95, Rules for Overhead Electric Line Construction. This design code and the National Electrical Safety Code include loading requirements related to wind conditions. Transmission support structures are designed to withstand different combinations of loading conditions including extreme winds. These design requirements include use of safety factors that consider the type of loading as well as the type of material used, e.g. wood, steel or concrete. Failures of transmission line support structures are extremely rare and are typically the result of anomalous loading conditions such as tornadoes or ice-storms.

Overhead transmission lines consist of a system of support structures and interconnecting wire that is inherently flexible. Industry experience has demonstrated that under earthquake conditions structure and member vibrations generally do not occur or cause design problems. Overhead transmission lines are designed for dynamic loading under variable wind conditions that generally exceed earthquake loads. Underground transmission lines are susceptible to ground motion and displacements that may occur under earthquake loading. Earthquake conditions could result in damage or faults to underground transmission lines. The proposed underground transmission line segment uses solid dielectric cable, which does not present the environmental or fire hazards that may be associated with oil-filled cable types. Refer to Appendix 3, Technology and Environmental Assessment Guide on Underground HV Power Transmission for additional discussion of underground transmission.

Electrical arcing from power lines can represent a fire hazard. This phenomenon is more prevalent for lower voltage distribution lines since these lines are typically on shorter structures and in much greater proximity to trees and vegetation. Fire hazards from high voltage transmission lines are greatly reduced through the use of taller structures and wider right-of-ways. Further, transmission line right-of-ways are cleared of trees to control this hazard. Fire hazards due to a fallen conductor from an overhead line or ruptured underground cable are minimal due to system protection features. Both overhead and underground high voltage transmission lines include system protection designed to safeguard the public and line equipment. These protection systems consist of transmission line relays and circuit breakers that are designed to rapidly detect faults and cut-off power flow to avoid shock and fire hazards. This equipment is typically set to operate in 2 to 3 cycles, representing a time interval range from 2/60 of a second to 3/60 of a second.

C.9.2 ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES FOR THE PROPOSED PROJECT

This section focuses on the environmental impacts of power line fields from the proposed Tri-Valley 2002 Capacity Increase Project. The project's anticipated EMF levels are reviewed relative to existing fields, and policies/guidelines to assess impacts and to determine mitigation measures. The other public concerns identified in Section C.9.1.3 are also addressed as they relate to power line fields.

C.9.2.1 Definition and Use of Significance Criteria

This Section defines the standards used to determine the significance of impacts resulting from the Proposed Project. Generally, the basis for the determining the significance of impacts is by comparison with existing standards or regulations, and in the absence of regulations, is based on existing conditions in the project area from similar facilities in place today.

C.9.2.1.1 *Electric and Magnetic Fields (EMFs)*

As discussed in Section C.9.1, there is no scientific conclusion that there are negative public health impacts due to EMF at the levels expected from electric power facilities. Further, there are no federal or state standards limiting human exposure to EMFs from transmission lines or substation facilities in California. In other states, the standards or limits which have been adopted were based on an objective of keeping the field levels from new power lines similar to the field levels from existing lines.

CPUC No-Cost/Low-Cost EMF Mitigation Policy

In Decision No. 93-11-03, the CPUC addressed mitigation of EMF for regulated utility facilities and implemented the following recommendations:

- No-cost and low-cost steps to reduce EMF levels
- Workshops to develop EMF design guidelines
- Uniform residential and workplace programs
- Stakeholder and public involvement
- A four-year education program
- A four-year non-experimental and administrative research program
- An authorization of federal experimental research conducted under the National Energy Policy Act of 1992.

The no/low-cost mitigation was to be applied to new and reconstructed facilities and is applicable to the Tri-Valley 2002 Capacity Increase Project. The decision included considerable discussion as to the meaning of "low-cost," and stated the following:

> "From Edison's analysis and DRA's few percentage points criteria, it is logical to define low cost to be in the range of 4 percent of the total cost of a budgeted project. We direct the utilities to use 4 percent as a benchmark in developing their EMF mitigation guidelines. We will not establish 4 percent as an absolute cap at this time because we do not want to arbitrarily eliminate a potential measure that might be available but cost more than the 4 percent figure. Conversely, the utilities are encouraged to use effective measures that cost less than 4 percent. Given the evolving body of research on EMF measures, we feel that 4 percent provides the utilities with sufficient guidance without hindering their ability to seek out or develop innovative measures and to reduce the cost to implement known measures.
>
> We further endorse the concept put forward by [Pacific Gas & Electric] and [San Diego Gas & Electric] that a mitigation measure should achieve some noticeable reduction. PG&E Co. and SDG&E define significant EMF reduction as 15 percent and 20 percent, respectively. Again we decline to adopt specific numbers because there is not sufficient scientific evidence upon which to base such findings."

C.9.2.1.2 *Other Field Related Public Concerns*

Corona and Audible Noise

There are no standards or regulations pertaining to corona levels on electric power facilities. The U.S. EPA has conducted extensive studies to identify the effects of certain sound levels on public health and welfare and has developed noise guidelines. These guidelines typically form the basis for community zoning requirements related to noise levels, for residential areas the EPA guidelines indicate noise should not exceed 55 decibels (dBA) between 7 AM and 10 PM or 45 dBA between 10 PM and 7 AM.

Radio/Television/Electronic Equipment Interference

There are no local, state or federal regulations with specific limits on high frequency emissions from electric power facilities. Federal Communication Commission (FCC) regulations require that transmission lines be operated so that no harmful interference is produced (FCC regulations, section 15.25).

Induced Currents and Shock Hazards

The National Electrical Safety Code (NESC) specifies that transmission lines be designed to limit short circuit current from vehicles or large objects near the line to no more than 5 milliampere (mA). CPUC General Order 95 and the NESC also address shock hazards to the public by providing guidelines on minimum clearances to be maintained for practical safeguarding of persons during the installation, operation, or maintenance of overhead transmission lines and their associated equipment.

Cardiac Pacemakers

It has been reported that synchronous pacemakers can be affected by electric fields between 2 kV/m and 9 kV/m (EPRI, 1985; 1979). When a synchronous pacemaker is in a field in this range, a few older model pacemakers may revert to an asynchronous mode.

C.9.2.2 Environmental Impacts and Mitigation Measures

C.9.2.2.1 *Electric and Magnetic Fields (EMFs)*

EMFs levels in the project area would not change during construction of the Proposed Project, since the lines would not be energized during construction. When the transmission lines are energized, there would be some long-term impacts to the surrounding environment due to EMFs. For the overhead portion of the transmission lines these impacts are anticipated to be very localized. Using an optimized phase arrangement for the North Area transmission line segment, the magnetic field calculated by PG&E Co. will vary from approximately 56 mG within the right-of-way to 18 mG at the edge of the right-of-way (50 ft), diminishing to 5 mG at 100 feet from the line. For the overhead portion of the South Area transmission line segment, the magnetic field calculated by PG&E Co. will vary from approximately 41 mG within the right-of-way to 15 mG at the edge of the right-of-way (50 ft), diminishing to 6 mG at 100 feet from the line.

For the underground portions of the proposed transmission line in the South Area, the EMF levels are also localized. The magnetic field due to buried transmission lines depends primarily on the spacing and arrangement of the underground cables but is also influenced by the type of buried construction, such as pipe-type cables or solid dielectric cables. Refer to Appendix 2, Technology and Environmental Assessment Guide on Underground HV Power Transmission for additional discussion of underground transmission. In the areas where underground transmission cable is proposed, magnetic fields may be higher immediately above the cable since the field source would be much closer to the ground surface than for overhead conductors. However, due to the close spacing of the underground cables, the magnetic field is more concentrated near underground transmission cables and decreases more rapidly as you move away from the cable resulting in greatly reduced fields compared with overhead portions of the line. For the underground portion of the South Area transmission line segment, the magnetic field calculated by PG&E Co. will vary from approximately 29 mG within the right-of-way to 6 mG at the edge of the right-of-way (15 ft), diminishing to below 1 mG at 50 feet from the line.

Methods to Reduce EMF

EMF levels from transmission lines can be reduced in three primary ways: shielding, field cancellation, or increasing the distance from the source. Shielding, which primarily reduces exposure to electric fields, can be actively accomplished by placing trees or other physical barriers along the transmission line right-of-way (ROW). Shielding also results from existing structures the public may use or occupy along the line. Since electric fields can be blocked by most materials, shielding is effective for the electric fields but is of limited effectiveness for magnetic fields.

Field cancellation is achieved in two ways. First, when the configuration places the conductors closer together, the interference, or cancellation, of the fields from each wire is enhanced. This technique has practical limitations because of the potential for short circuits if the wires are placed too close together. There are also worker safety issues to consider if spacing is reduced. Second, in instances where more than three phase wires are used, such as in the Proposed Project, cancellation can be accomplished by arranging different phase wires from different circuits near to each other.

The distance between the source of fields and the public can be increased by either placing the wires higher aboveground, burying underground cables deeper, or by increasing the width of the ROW. For transmission lines, this method can prove effective in reducing fields because the reduction of the field strength drops rapidly with distance.

In accordance with CPUC Decision 93-11-013 (see Section C.9.2.1.1), PG&E Co. proposes to incorporate "no cost" and "low cost" magnetic field reduction steps in the proposed transmission and substation facilities. PG&E Co.'s Transmission and Substation EMF Design Guidelines (developed in response to the CPUC's order) include the following measures that may be available to reduce the magnetic field strength levels from electric power facilities:

- Increase distance from conductors and equipment
- Reduce conductor spacing
- Minimize current
- Optimize phase configuration

As prescribed by G.0.131-D, the EMF Management Plans provided by PG&E Co. include the following project information:

- A description of the project (cost, design, length, location, etc.)
- A description of the surrounding land uses using priority criteria classifications
- No-cost options to be implemented
- Priority areas where low-cost measures are to be applied
- Measures considered for magnetic field reduction and cost reduction
- A conclusion that states which options were selected and how areas were treated equivalently or why low-cost measures cannot be applied to this project

Based upon magnetic field analysis furnished by PG&E Co., incorporation of an optimized phase configuration as a low cost field reduction measure will result in a reduction of the magnetic field at the edge of the right-of-way. For the North Area transmission segments the field reduction from optimized phasing is 50%, for the overhead portion of the South Area transmission segment the reduction is 13%. For the underground portion of the South Area transmission segment both an optimized phase configuration and a triangular phase arrangement to reduce conductor spacing results in a reduction of

35%. Increasing the distance from conductors as a field reduction measure has a more pronounced effect immediately beneath overhead lines or above underground lines but is less effective when considering field levels at the edge of the right-of-way. Increasing the height or depth of the transmission line may greatly increase the cost of the project resulting in only minimal field reduction when remaining within the low cost threshold identified by the CPUC. For example, burying the underground portion of the South Area transmission segment 2 feet deeper, reduces the magnetic field 21%, from 6.3 mG to 5.0 mG, at a cost of approximately $1.6 million. In addition the increase in structure height necessary to accomplish a pronounced field reduction may significantly increase visual impacts for the project.

While there is continuing public concern about the health effects of EMFs, the conclusion of completed research supports the conclusion that EMF from power lines is an adverse, but not significant, impact of the Proposed Project (**Class III**). At final project design and construction stages, PG&E Co. will incorporate mitigation measures consistent with the CPUC No-Cost/Low-Cost EMF Mitigation Policy. No further mitigation measures are recommended.

C.9.2.2.2 *Other Field-Related Public Concerns*

Corona and Audible Noise

There may be some periodic impacts due to corona and audible noise during rain and fog conditions. Any low level hissing or crackling, although adverse, would only be noticeable in close proximity to the line and is not considered significant (**Class III**).

Radio and Television Interference

Corona or gap discharges related to high frequency radio and television interference impacts are dependent upon several factors including the strength of broadcast signals and is anticipated to be very localized if it occurs. Individual sources of adverse radio/television interference impacts can be located and corrected on the power lines. Conversely, magnetic field interference with electronic equipment such as computer monitors can be corrected through the use of software, shielding or changes at the monitor location. The following mitigation measures are recommended to reduce the potential impacts of interference (**Class II**):

PS-1 As part of the design and construction process, the Applicant shall limit the conductor surface electric gradient in accordance with the IEEE Radio Noise Design Guide.

PS-2 After energizing the transmission line, the Applicant shall respond to and document all radio/ television/equipment interference complaints received and the responsive action taken. These records shall be made available to the CPUC for review upon request. All unresolved disputes shall be referred by the Applicant, within 90 days, to the CPUC's Energy Division for resolution.

Induced Currents and Shock Hazards in Joint Use Corridors

Induced currents and voltages on conducting objects near the proposed transmission lines represent a potential significant impact that can be mitigated. These impacts do not pose a threat in the environment if the conducting objects are properly grounded, and the following mitigation measure is recommended to reduce the potential impacts of induced currents (**Class II**):

PS-3 As part of the siting and construction process, the Applicant shall identify objects (such as fences, conductors, and pipelines) that have the potential for induced voltages and work with the affected parties to determine proper grounding procedures (CPUC G095 and the NESC do not have specific requirements for grounding). The Applicant shall install all necessary grounding measures prior to energizing the line. Thirty days prior to energizing the line, the Applicant shall notify in writing, subject to the review and approval of the CPUC Energy Division, all property owners within and adjacent to the Proposed Project ROW of the date the line is to be energized. The written notice shall provide a contact person and telephone number for answering questions regarding the line and guidelines on what activities should be limited or restricted within the ROW. The Applicant shall respond to and document all complaints received and the responsive action taken. These records shall be made available to the Lead Agencies for review upon request. All unresolved disputes shall be deferred by the Applicant to the Lead Agencies for resolution.

The written notice shall describe the nature and operation of the line, and the Applicant's responsibilities with respect to grounding all conducting objects. In addition, the notice shall describe the property owner's responsibilities with respect to notification for any new objects, which may require grounding, and guidelines for maintaining the safety of the ROW.

Cardiac Pacemakers

The electric fields associated with the Proposed Project's and Alternatives' transmission lines may be of sufficient magnitude to impact operation of a few older model pacemakers, resulting in them reverting to an asynchronous pacing. Cardiovascular specialists do not consider prolonged asynchronous pacing to be a problem; periods of operation in this mode are commonly induced by cardiologists to check pacemaker performance. Therefore, while the transmission line's electric field may impact operation of some older model pacemakers, the result of the interference is of short duration and is not considered significant or harmful (**Class III**). No mitigation measures are required or recommended.

C.9.2.3 Unavoidable Significant Impacts

EMF and other public concerns and safety hazard impacts can be controlled through proper design and routing of the Tri-Valley 2002 Capacity Increase Project and the incorporation of the mitigation measures defined in this section. For this reason, there will be no unavoidable significant public safety and health impacts from the Proposed Project.

C.9.3 ALTERNATIVE ALIGNMENTS AND SUBSTATION SITES

C.9.3.1 Pleasanton Area Alternatives

The transmission line alternatives in the Pleasanton area (S1, S2, S4) all generally include placing significant portions of the line underground from the area of the Tesla-Newark corridor to Vineyard substation. From an EMF perspective, the electric and magnetic field impacts for an underground line would be even more localized than for overhead lines. All of the alternatives would have reduced field strengths and their impacts are considered adverse but less than significant (**Class III**). No further EMF mitigation measures are recommended. Potential shock induced and public safety hazards would be reduced by placing the line underground. These impacts for all of the alternatives are considered adverse but less than significant (**Class III**). No further mitigation measures are recommended. Because of the similarity for underground transmission line construction, the environmental impacts, cumulative impacts and mitigation measures, and unavoidable significant impacts will be similar to those discussed in Section C.9.2.2.1 for the Proposed underground segment of the South Area line.

The local generation alternative in Pleasanton would have electric and magnetic fields associated with the facility and its transmission connection to the Vineyard substation. The EMF from a generating facility is primarily associated with its switchyard and would be the same as discussed for electric substations. These impacts are considered adverse but less than significant (**Class III**). No further mitigation measures are recommended. The local generation alternative may have less EMF impact than the Proposed Project or other Pleasanton area alternatives since only a short segment of transmission line would be needed to interconnect with Vineyard substation. However, the power output from the local generation alternative could increase the power flowing on existing transmission lines. This higher power flow could result in higher current levels on transmission lines and therefore higher EMF on existing transmission lines.

C.9.3.2 Dublin Area Alternatives

Both of the transmission line alternatives in the Dublin area (D1 & D2) include placing a portion of the transmission line underground, unlike the Proposed North Area line. From an EMF perspective, the electric and magnetic field impacts for the overhead portion of the line is the same as for the Proposed Project (North Area), for the underground portion of the alternatives the EMF impacts would be less than the Proposed Project (North Area) since the fields would be even more localized than for overhead lines. Both of the alternatives would have reduced field strengths and their impacts are considered adverse but less than significant (**Class III**). No further EMF mitigation measures are recommended. Potential shock induced and public safety hazards would be reduced by placing the line underground. These impacts for these alternatives are considered adverse but less than significant (**Class III**). No further mitigation measures are recommended. Because of the similarity for underground transmission line construction, the environmental impacts, cumulative impacts and mitigation measures, and unavoidable significant impacts will be similar to those discussed in Section C.9.2.2.1 for the proposed underground segment of the South Area line. Generally, the EMF impacts for the alternatives are less due to reducing the overall number of miles of overhead transmission line constructed.

C.9.3.3 Livermore Area Alternatives

North Area Alternatives P1, P2, and L1 in the Livermore area all utilize underground transmission line construction in lieu of overhead line. Although the alternatives are also in an undeveloped area, like the Proposed Project, their EMF impacts would be less than the Proposed Project since the fields would be even more localized than for overhead lines. These three alternatives would have reduced field strengths and their impacts are considered adverse but less than significant (**Class III**). No further EMF mitigation measures are recommended. Potential shock induced and public safety hazards would be reduced by placing the line underground; these impacts for all of the alternatives are considered adverse but less than significant (**Class III**). No further mitigation measures are recommended. Because of the similarity for underground transmission line construction, the environmental impacts, cumulative impacts and mitigation measures, and unavoidable significant impacts will be similar to those discussed in Section C.9.2.2.1 for the Proposed underground segment of the South Area line.

Alternative L2 in the Livermore area includes both overhead and underground transmission line construction in the developed and developing portion of the city. While the entire proposed route is in an open, sparsely developed area, the underground portion of alternative L2 is near Las Positas College, development in the vicinity of Highway 580, and the Livermore airport. The field impacts would be greater than the Proposed Project due to the location in these developed lands, even though the fields would be more localized than for overhead lines. From an EMF perspective, the electric and magnetic field impacts for the overhead portion of the line along Isabel Avenue would be greater than the Proposed Project due to the location within developed lands . The EMF impacts of this alternative are considered adverse but less than significant (**Class III**). No further EMF mitigation measures are recommended. For the overhead portion of this alternative the potential shock induced and public safety hazards would be similar to the Proposed Project and are considered adverse but less than significant (**Class III**). No further mitigation measures are recommended. Because of the similarity for underground transmission line construction, the environmental impacts, cumulative impacts and mitigation measures, and unavoidable significant impacts will be similar to those discussed in Section C.9.2.2.1 for the proposed underground segment of the Vineyard line.

C.9.4 ALTERNATIVE TO PHASE 2

Construction of a double circuit 230 kV transmission line in the Stanislaus corridor is similar to the proposed Phase 2 Tesla connection since both are primarily located in undeveloped lands. From an EMF perspective, both the Stanislaus alternative and the Phase 2 Tesla connection would use the same construction and have the same electric and magnetic fields. However, since the Stanislaus alternative would be in an existing transmission corridor with existing EMF the alternative's overall impacts would be less than for the proposed Phase 2 Tesla connection. It is anticipated that an optimum phase arrangement would also be used for the Stanislaus alternative to manage magnetic field levels and the EMF impacts of this alternative would be considered adverse but less than significant (**Class III**). No further EMF mitigation measures are recommended. The potential shock induced and public safety hazards would be similar to the Proposed Project and are considered adverse but less than significant (**Class III**). No further mitigation measures are recommended.

C.9.5 MITIGATION MONITORING PROGRAM

Table C.9-4 presents a summary of impacts of the Proposed Project and the Mitigation Monitoring Program recommended for mitigating public health, safety and nuisance impacts. This program outlines the location, responsible party, required monitoring activities, effectiveness criteria, and timing of each monitoring activity.

Table C.9-4 Mitigation Monitoring Program

Impact	Mitigation Measure	Location	Monitoring/Reporting Action	Effectiveness Criteria	Responsible Agency	Timing
Proposed Project and Alternative Routes						
Radio and Television Interference. (Class II).	**PS-1** Conductor selection to consider surface gradient design criteria.	All overhead transmission line segments.	Submit engineering report for selected conductor and analysis of surface gradient.	Engineering report shall present analysis of surface gradient and demonstrate compliance to IEEE Radio Noise Guide.	CPUC	Prior to construction.
Radio and Television Interference. (Class II).	**PS-2** Respond to interference complaints.	All overhead transmission line segments.)	Document complaints and action taken. Submit summary to CPUC each year for first two years of operation. Unresolved complaints submitted to CPUC.	Complaint summary demonstrates a lack of interference complaints or remedies utilized to resolve interference.	CPUC	First two years of operation.
Induced currents and shock hazards. (Class II).	**PS-3** Install grounding for metal buildings, fences, etc.	All overhead transmission line segments.)	Document criteria for installing grounding and tabulate locations where grounding installed.	Design prevents electric shocks to public.	CPUC	Prior to energizing transmission line.
Electric and magnetic Fields. (Class III).	No-cost, low-cost field reduction measures determined by PG&E Co..	Entire transmission line route.)	Document no-cost, low-cost measures incorporated in line design.	Report documents amount of field reduction obtained through mitigation measures.	CPUC	Prior to construction.

C.9.6 REFERENCES

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