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**MISSOURI PUBLIC SERVICE COMMISSION**

**FILE NO. EA-2015-0146**

# SURREBUTTAL TESTIMONY

**OF**

**WILLIAM H. BAILEY, Ph.D.**

**ON**

**BEHALF OF**

**AMEREN TRANSMISSION COMPANY OF ILLINOIS**

**Bowie, Maryland**
**November 16, 2015**

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**OF**
**WILLIAM H. BAILEY, Ph.D.**

**FILE NO. EA-2015-1046**

## I. QUALIFICATIONS

**Q. Please state your name, business address, and present position.**

A. My name is William H. Bailey, Ph.D. My business address is 17000 Science Drive, Suite 200, Bowie, MD 21705. I am a Principal Scientist in the Center for Occupational and Environmental Health Risk Assessment in Exponent, Inc.'s (Exponent) Health Sciences Practice.

**Q. What is the nature of Exponent's business?**

A. Exponent is a scientific research and engineering firm engaged in a broad spectrum of activities in science and technology.

**Q. What is your educational background?**

A. I earned a Ph.D. in neuropsychology from the City University of New York. I received two additional years of training in neurochemistry at The Rockefeller University in New York City under a fellowship from the National Institutes of Health. My education includes a BA from Dartmouth College received in 1966 and an MBA from the University of Chicago awarded in 1969.

**Q. Please describe your professional background and experience.**

A. I am a scientist and researcher focusing on environmental health sciences. My work involves reviewing, analyzing, and conducting health research. Much of my work over the past 30 years in the field of bioelectromagnetics relates to the exposure and potential biological, environmental, and health effects associated with electrical facilities and devices, including electric utility facilities, electrified railroad lines, industrial equipment,

appliances, and medical devices that produce electromagnetic fields across a wide range of frequencies. Since 1986, I have been a visiting research scientist at the Cornell University Weill Medical College. I also have been a visiting lecturer at Rutgers University, the University of Texas (San Antonio), and the Harvard School of Public Health in the field of bioelectromagnetics. From 1983 through 1987, I was head of the Laboratory of Neuropharmacology and Environmental Toxicology at the New York State Institute for Basic Research. For the previous seven years, I was an Assistant Professor in Neurochemistry at The Rockefeller University in New York City. This appointment followed two years of postdoctoral training in neurochemistry also at The Rockefeller University in New York City. I am a member of The Rockefeller University Chapter of Sigma Xi, a national scientific honor society; the Health Physics Society; the International Committee on Electromagnetic Safety (ICES), Subcommittees 3 and 4 – Safety Levels with Respect to Human Exposure to Fields; the Bioelectromagnetics Society; the IEEE Engineering in Medicine and Biology Society; the Conseil International des Grands Réseaux Électriques; the American Association for the Advancement of Science; the New York Academy of Sciences; the Society for Neuroscience; the Air & Waste Management Association; the Society for Risk Analysis; and the International Society of Exposure Analysis.

**Q. Have you served as a reviewer and scientific advisor on health-related issues for state and federal agencies or scientific organizations?**

A. Yes. I have reviewed research for the National Institutes of Health, the National Science Foundation, and other government agencies. Specifically regarding transmission lines, I served on a Scientific Advisory Panel convened by the Minnesota Environmental Quality

Board to review the health and safety aspects of a high-voltage transmission line. In addition, I served as a consultant regarding transmission line health and safety issues for the Vermont Department of Public Service, the New York State Department of Environmental Conservation, and the staffs of the Maryland Public Service Commission and the Maryland Department of Natural Resources.

I have also worked with the National Institute of Occupational Safety and Health, the Oak Ridge National Laboratories, the U.S. Department of Energy, and the Federal Railroad Administration to review and evaluate health issues related to electric and magnetic fields (EMF) from power lines and other sources. In addition, I assisted the U.S. EMF Research and Policy Information Dissemination (RAPID) program to evaluate biological and exposure research as part of its overall risk assessment process.

Further, I worked with scientists from 10 countries to evaluate possible hazards from exposure to static electric and magnetic fields and extremely low frequency (ELF) EMF for the International Agency for Research in Cancer (IARC), a division of the World Health Organization (WHO), located in Lyon, France. I also was an invited participant in the workshop convened by the International Committee on Non-Ionizing Radiation Protection (ICNIRP) to update guidelines for human exposures to alternating current (AC) EMF. I have reviewed ICNIRP's draft guidelines for direct current and AC magnetic fields as well.

Most recently, I have served as an advisor to the U.S. Department of Energy and several government agencies in Canada and the Netherlands on topics relating to scientific research on EMF health and safety.

**Q. Have you published or presented your research in bioelectromagnetics and other areas to the scientific community?**

A. Yes. I have published or presented more than 50 scientific papers on this and related subjects. These publications and presentations are listed in my *curriculum vitae*, attached as **Schedule WHB-SR1**.

## II. PURPOSE OF SURREBUTTAL TESTIMONY

**Q. On whose behalf are you testifying in the current proceeding?**

A. I am testifying on behalf of Ameren Transmission Company of Illinois (ATXI) in support of its request for a Certificate of Public Convenience and Necessity for a transmission line project in northeast Missouri.

**Q. What is the purpose of your surrebuttal testimony?**

A. I have been asked to assess the scientific issues related to potential health effects of magnetic fields raised in the testimony of Dennis Smith, D.O.,[1] and Janet Akers, both witnesses on behalf of Neighbors United Against Ameren's Power Line, and raised in the testimony of witnesses at the Commission's local public hearings as these concerns relate to the proposed Mark Twain Transmission Project.

**Q. Would you briefly summarize the main conclusions of your testimony regarding the effects of EMF from the Mark Twain Project on public and animal health?**

A. Yes. They are:

- Dr. Smith's interpretations of scientific research and public health literature on EMF (magnetic fields) are not supported by the few 'cherry-picked' studies he cites and are

[1] Neither Dr. Smith nor other witnesses identify what they mean by the abbreviation EMF. Typically, in this context, scientists use EMF to refer to both electric and magnetic fields at the power frequency of 60 Hertz. From the context of submissions, however, I understand them to be referring to just the magnetic field associated with the operation of the power system, and the proposed line in particular. Except when referring to the use of EMF by others, I use EMF to refer to both electric and magnetic fields.

inconsistent with current reviews of the literature by national and international health and scientific agencies.

- New research on topics of childhood leukemia and brain cancer, and neurodegenerative disease yields a very different perspective than offered by Dr. Smith; consideration of new epidemiology studies on these topics shows a lack of association with exposure to magnetic fields.
- Dr. Smith cites two reviews of cellular studies that were narrowly aimed at supporting hypotheses involving alleged effects of magnetic fields and purported mechanisms for such effects. He selected these two studies from a vast sea of studies on this topic to frame his opinions. The claims made in these two reviews are shown to be unpersuasive and the author of one of the reviews claims that magnetic fields are "safe" for human exposure.
- A number of concerns were raised in local public hearings about livestock, bees, and stray voltage that are not supported by scientific research.
- Several persons were concerned about pacemakers and defibrillators but the levels of electric and magnetic fields from the Project are below recommended exposure limits for these medical devices.
- Calculations of the electric and magnetic fields (EMF) levels during operation of the new transmission lines in 2021 show that the Project will comply with limits on public exposure published by two international organizations well into the future. Magnetic fields diminish with distance from the Project and the levels at the closest residences are calculated to be similar to the range of magnetic fields that would be measured in residences in the absence of a transmission line.
- The conclusions of multiple health and scientific agencies about EMF and health, including the most recent conclusions of the Scientific Committee of European Union issued in 2015, are wholly consistent with the current assessment of the World Health Organization "[b]ased on a recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields."

## III. EXPOSURE TO ELECTRIC AND MAGNETIC FIELDS

**Q. What are electric and magnetic fields?**

A. Electric charges are contained in objects in our environment. When the numbers of positive and negative charges in an object are equal, the object is described as electrically neutral. When the object contains more of one charge or the other, the net charge gives

rise to an electric field. Magnetic fields are created by the movement of electric charges or by the movement of electrons in certain materials such as permanent magnets. Electricity is the movement of electric charges. Consequently, both electric fields and magnetic fields are properties of the space surrounding anything that generates, transmits, or uses electricity. Electric fields occur when voltage is applied to these objects, while magnetic fields result from the current flowing through these objects. Just as the heat from a radiator decreases as one moves farther away, the levels of both electric fields and magnetic fields decrease with distance from the source. Electric fields are blocked by most conductive objects (such as trees, fences, and walls, as well as the human body), while magnetic fields are not.

**Q. How are the intensities of electric and magnetic fields measured?**

Electric fields are measured in units of volts per meter (V/m) or kilovolts per meter (kV/m), where 1 kV/m is equal to 1,000 V/m. Magnetic fields in the United States are most commonly measured in units of gauss (G) or milligauss (mG), where 1 G is equal to 1,000 mG.

**Q. Are all electric and magnetic fields the same?**

A. No. Both electric and magnetic fields are characterized by their frequency (i.e., the number of times full cycles of field direction change each second). Frequency is measured in units of Hertz (Hz). A related characteristic is wavelength, which is inversely related to frequency—the lower the frequency, the longer the wavelength and vice versa. The frequency and wavelength of EMF, however, greatly affect how these fields interact with physical material and living cells or organisms.

**Q. What is the frequency of the electric and magnetic fields associated with the proposed Mark Twain Transmission Project?**

A. The transmission lines and adjunct facilities will be sources of EMF that oscillate at a dominant frequency of 60 Hz. These AC fields are virtually everywhere in our communities because all lines, devices, appliances, wiring, etc., connected to our AC electric power system produce EMF at this frequency. By way of clarification, the acronym EMF is typically used by scientific and engineering professionals in this context to refer to AC EMF in the ELF range between 30 and 300 Hz, which includes the power frequencies of 60 Hz in North America and 50 Hz in Europe and elsewhere. The general public often uses EMF to refer to just magnetic fields or to these fields at other frequencies such as the static (i.e., ~0 Hz) geomagnetic field of the earth or the radiofrequency fields produced by mobile phones in the frequency range of about 800 megahertz to 2.7 gigahertz. For this reason, the abbreviation ELF EMF is used sometimes to avoid confusion, and when discussing either the magnetic field or the electric field specifically, they should be described separately.

**Q. What are the background levels of AC electric fields and magnetic fields that people encounter in daily life?**

A. Magnetic fields at ELF frequencies in homes in the United States average about 1 mG, when not near a particular source. In the immediate vicinity of household electrical appliances and power tools, ELF magnetic field levels rise to several hundreds of mG and sometimes higher. ELF electric fields are typically below 20 V/m in households in the United States and derive mostly from indoor sources because buildings shield AC electric fields from outside sources.

**Q. What are the sources of electric and magnetic fields in the Mark Twain Transmission Project?**

ATXI has applied for two new transmission lines that will be sources of EMF along the proposed line routes:

1. A 345-kilovolt (kV) transmission line, approximately 60 miles in length, is proposed to connect a new switching station near Palmyra, Missouri (the Maywood Substation) to a new substation located near Kirksville, Missouri (the Zachary Substation). A second segment of this new 345-kV line proceeds from the Zachary Substation 23 miles north to the "Wind Zone," where a future wind farm could connect, and then another 12 miles to the Iowa border *en route* to the Ottumwa Substation in Ottumwa, Iowa. The phase conductors would be configured in a triangular delta arrangement and supported on steel monopoles 90 to 130 feet in height within a 150-foot right of way (ROW).
2. A new 2.2 mile 161-kV transmission line is proposed to connect the new Zachary Substation with the existing Adair Substation. The phase conductors will be supported on one side of double-circuit steel monopoles 70 to 100 feet in height within a 100-foot ROW.

Another component of the Project is the Zachary Substation, which is also a source of EMF, but in contrast to the transmission lines that connect to substations, the equipment within is unlikely to increase EMF levels much beyond the boundaries of the sites. As noted in IEEE Standard 1127, Guide for the Design, Construction, and Operation of Electric Power Substations for Community Acceptance for Substations:

*In a substation, the strongest fields near the perimeter fence come from the transmission and distribution lines entering and leaving the substation. The strength of fields from equipment inside the fence decreases rapidly with distance, reaching very low levels at relatively short distances beyond substation fences* (p. 6).

## IV. RESPONSE TO THE REBUTTAL TESTIMONY OF DENNIS SMITH, D.O.

**Q. Have you reviewed the Rebuttal Testimony of Dennis Smith, D.O.?**

A. Yes.

**Q. Can you briefly summarize your assessment of the Rebuttal Testimony filed by Dr. Smith?**

A. Dr. Smith's Rebuttal Testimony contains a number of errors that render his conclusions scientifically invalid. Moreover, his conclusions are inconsistent with those of major reviews conducted by multidisciplinary expert panels on behalf of a number of well-respected national and international health and scientific agencies. The principal limitations of his Rebuttal Testimony include, among others, the lack of clearly articulated methods for selecting and presenting studies; selective reference to studies that he assumes support his conclusion; the erroneous interpretation of the IARC classification system of carcinogens; the misunderstanding of research recommendations and hazard evaluations conducted by the WHO; and the selective reporting and misreading of scientific studies. I will elaborate on each of these points in more detail.

### i. WEIGHT-OF-EVIDENCE SCIENTIFIC APPROACH

**Q. Could you please explain the proper scientific methods for reviewing and drawing valid conclusions from the scientific literature?**

A. The generally accepted method for health risk evaluation (i.e., the evaluation of the scientific literature for evidence for or against a potential causal association between an environmental exposure and health outcomes), is the weight-of-evidence approach. This is a standard scientific method and is employed by regulatory, scientific, and health agencies worldwide.

**Q. Please describe the weight-of-evidence approach.**

A. The weight-of-evidence approach includes the systematic identification and review of the relevant literature for a specific exposure and potentially related health outcomes. The reviewed scientific literature includes epidemiologic studies of humans observed in their natural environments, laboratory studies of experimental animals (*in vivo* studies), and laboratory studies of cells and tissues (*in vitro* studies). These types of studies provide complementary information regarding potential biological and health effects of the exposure in question. Each of the identified studies in these scientific areas is then individually evaluated for their overall quality. The scientific quality of each study determines how much weight the individual study receives in the overall evaluation. High quality studies are given greater weight, while lower quality studies contribute less, and poor quality studies are sometimes given no weight at all.

**Q. Has the weight-of-evidence approach been applied to the evaluation of ELF EMF by authoritative expert panels?**

A. Yes. Multidisciplinary expert panels on behalf of a number of national and international health and scientific agencies have reviewed the available scientific literature on potential health effects of ELF EMF using this approach. These evaluations include those conducted in 1999 by the National Institute of Environmental Health Sciences (NIEHS),

in 2002 by the IARC, in 2007 by the WHO, in 2010 by ICNIRP, and most recently in 2015, by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). While these reviews acknowledged the limited epidemiologic evidence with respect to ELF magnetic fields and childhood leukemia, they also concluded that experimental evidence does not support a cause-and-effect relationship with any cancer. No adverse health effects were identified in association with exposure to ELF electric fields.

On its website, the WHO currently states that *"[b]ased on a recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields."* The WHO website also states that *"[w]ith more and more research data available, it has become increasingly unlikely that exposure to electromagnetic fields constitutes a serious health hazard."*[2]

**Q. Does the Rebuttal Testimony of Dr. Smith indicate that he objectively identified and weighed the scientific research he reviewed in formulating his opinions?**

A. No. My rationale for this conclusion is summarized below.

**ii. <u>EVALUATION OF CARCINOGENICITY</u>**

**Q. Dr. Smith refers to the International Agency for Research on Cancer on p. 4, lines 26-27, of his Rebuttal Testimony. What is the International Agency for Research on Cancer?**

A. As stated on the WHO's website, *"The International Agency for Research on Cancer (IARC) is part of the World Health Organization. IARC coordinates and conducts both*

[2] http://www.who.int/peh-emf/about/WhatisEMF/en/index1.html

*epidemiological and laboratory research into the causes of human cancer."*[3] A principal activity of the IARC is to evaluate the potential relationship of exposures to chemicals, physical agents, biologic exposures, and lifestyle characteristics in community and occupational environments to cancer. IARC assembles multidisciplinary teams of scientists to review these exposures. The results of these reviews are published in monographs and the detailed evaluation is summarized by a categorical classification process.

**Q. Can you briefly explain the IARC classification process for carcinogenicity?**

A. The IARC classification of carcinogenicity is based on a weight-of-evidence evaluation of two main streams of evidence: epidemiologic studies in humans and *in vivo* laboratory studies of experimental animals.[4] The overall evidence from human and animal studies is then separately categorized into one of four categories: (1) sufficient, (2) limited, (3) inadequate evidence of carcinogenicity, or (4) evidence suggesting lack of carcinogenicity. Based on a combination of the two streams of evidence, the exposure is then classified into one of five mutually exclusive categories: **Group 1** (carcinogenic to humans); **Group 2A** (probably carcinogenic to humans); **Group 2B** (possibly carcinogenic to humans); **Group 3** (not classifiable as to its carcinogenicity to humans); and **Group 4** (probably not carcinogenic to humans). The Group 1 classification typically requires sufficient evidence from studies of humans, and the Group 2A classification is used when there is limited evidence from studies of humans and sufficient evidence from experimental animal studies. The Group 2B classification is

[3] http://www.who.int/ionizing_radiation/research/iarc/en/

[4] A third component, from *in vitro* laboratory studies of cells and tissues, also may supplement epidemiologic and *in vivo* evidence, particularly when they confirm a relevant mechanism of action, but since responses observed in isolated cells and tissue may not occur in a living animal, these studies provide less relevant data to the overall weight-of-evidence evaluation than epidemiology or *in vivo* studies.

used for an agent when there is limited evidence from studies of humans and less than sufficient evidence from animal studies. Group 3 is used when the evidence of carcinogenicity is inadequate in studies of humans and inadequate or limited evidence in studies of experimental animals. Finally, Group 4 is used when there is evidence suggesting lack of carcinogenicity in studies of humans and experimental animals. This classification system is summarized in Table 1 below.

**Table 1. IARC criteria for classifying exposure as to the strength of the evidence for carcinogenicity**

| Group | Criteria |
|---|---|
| **Group 1**<br>*Carcinogenic to humans* | • Sufficient evidence of carcinogenicity in humans |
| **Group 2A**<br>*Probably carcinogenic to humans* | • Limited evidence of carcinogenicity in humans and<br>• Sufficient evidence of carcinogenicity in experimental animals |
| **Group 2B**<br>*Possibly carcinogenic to humans* | • Limited evidence of carcinogenicity in humans and<br>• Less than sufficient evidence of carcinogenicity in experimental animals |
| **Group 3**<br>*Not classifiable as to its carcinogenicity to humans* | • Inadequate evidence of carcinogenicity in humans and<br>• Inadequate or limited evidence of carcinogenicity in experimental animals |
| **Group 4**<br>*Probably not carcinogenic to humans* | • Evidence suggesting lack of carcinogenicity in humans<br>• Evidence suggesting lack of carcinogenicity in experimental animals |

**Q. How were ELF fields classified by IARC?**

A. ELF electric fields were categorized in Group 3 (as were static electric fields and static magnetic fields) based on inadequate evidence and lack of carcinogenicity data in humans and laboratory animals, respectively. ELF AC magnetic fields were classified into Group 2B, based on limited evidence of carcinogenicity in humans and inadequate evidence in laboratory animals.

This means that the IARC review did not identify sufficient evidence from either human or animal studies to support a conclusion that ELF AC magnetic fields are a cause of

cancer. It classified ELF AC magnetic fields into Group 2B based on limited epidemiologic evidence from childhood leukemia studies, which means that some epidemiologic studies reported an association that was credible, but chance, bias, and confounding could not be ruled out as explanation. Overall, however, results of laboratory animal studies did not support an association.

**Q. Dr. Smith states that IARC has classified EMF in its Group 2B classification (possibly carcinogenic to humans) based on exposure to transmission lines and links to childhood leukemia and "other health problems such as breast cancer" (Smith Rebuttal Testimony, p. 4, lines 24-27). Is his understanding of the IARC report correct?**

A. Dr. Smith's Rebuttal Testimony contains three errors on p. 4, lines 24-27. First, the conclusions of the IARC report were based on observational epidemiologic studies which, at that time, involved very few transmission lines. The bulk of the exposure in those studies derived from low voltage distribution lines which run in front of or behind most of our homes. Second, Dr. Smith does not define what he means by the term EMF; he appears to be using EMF as shorthand to refer to magnetic fields. The IARC report concluded that there is *"limited evidence in humans for the carcinogenicity of extremely low frequency magnetic fields in relation to childhood leukaemia* [sic]*"* which led to the conclusion that AC magnetic fields *"are possibly carcinogenic to humans (Group 2B),"* and classified the evidence for the carcinogenicity of AC electric fields and static electric and magnetic fields (as are found in nature) as *"inadequate"* (IARC, 2002, p. 27). Third, for all other cancers (including breast cancer) the IARC considered the human epidemiological data as *"inadequate."* Breast cancer specifically was not a factor in the

overall evaluation as stated in the IARC report and within four years the scientific evidence was so strong against an association of magnetic fields with breast cancer that the WHO concluded *"in some cases (for example, for cardiovascular disease or breast cancer) the evidence is sufficient to give confidence that magnetic fields do not cause the disease"* (WHO, 2007, p.12).

**Q. In the preceding paragraph you refer to conclusions of a review of EMF research by the WHO in 2007. What is the conclusion of the WHO about EMF and health today?**

A. The WHO's website states *"[b]ased on a recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields."*[5] The "recent in-depth review" referred to as the basis for the WHO's conclusion above is its 2007 Environmental Health Criteria Report 238 (WHO, 2007). While a number of research studies have been published since the WHO evaluation, these results have not provided sufficient evidence to alter the conclusions of WHO report. The conclusions of more recent reviews (e.g., ICNIRP, 2010, and SCENIHR, 2015) are consistent with the conclusions of the 2007 WHO evaluation.

**Q. On p. 4, lines 4-22, of his Rebuttal Testimony, Dr. Smith attempts to refute the current conclusion of the WHO regarding EMF and health by claiming that its conclusion *"fails to show that ongoing concerns about adverse health effects [of EMF]"* that he believes were voiced by the WHO itself in its 2007 Research Agenda for Extremely Low Frequency Fields (Schedule DS-03). Is this a valid criticism of the WHO?**

[5] http://who.int/peh-emf/about/WhatisEMF/en/index1.html

A. No. The 2007 Environmental Health Criteria 238 report, which is the in-depth review that is referred to by the WHO in its conclusion on its website, contains *"Recommendations for Research"* in Section 1.2. The WHO explains that *"[i]dentifying the gaps in the knowledge concerning the possible health effects of exposure to ELF fields is an essential part of this health risk assessment"* (WHO, 2007, p. 14). The recommendations in the separate document cited by Dr. Smith in Schedule DS-03[6] are the same as those included in the 2007 Environmental Health Criteria 238 report (WHO, 2007).

The WHO is telling us that although it has not confirmed any health effects of EMF exposure, a prudent approach would be to continue research to make sure that even the smallest possibility of a risk has not been overlooked. This is a prudent approach because virtually all persons in developed countries are exposed to EMF from many sources, so even a small risk would be of public health importance. That is, the motivation of research recommendations is to "*reduce the uncertainty in the current scientific information* [regarding magnetic fields]" (Schedule DS-03, p. 2), and is not the indication of major health concerns.[7] As the WHO explains on its website, the *"scientific knowledge in this area is now more extensive than for most chemicals,"* and despite the extensive scientific scrutiny and research that has been conducted over almost four decades, no adverse health effects have been confirmed at ELF EMF levels found in our environment, including exposure levels found near high-voltage transmission lines.

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[6] http://www.who.int/peh-emf/research/elf_research_agenda_2007.pdf

[7] As stated in Schedule DS-03, p. 1, *"[f]ollowing a standard health risk assessment process, it was concluded that there were no substantive health issues related to ELF electric fields at levels generally encountered by members of the public. Thus this Research Agenda addresses further research concerning the possible acute and long term effects of exposure to ELF magnetic field."*

**Q. Have other international organizations reached similar conclusions as the WHO with regard to EMF and health?**

A. Yes, evaluations by other national and international health agencies of ongoing and continued research since 2007 have produced similar conclusions and have not confirmed any adverse health effects in relation to ELF EMF exposure; the current scientific consensus remains unchanged. For example, the European Union's SCENIHR that regularly reviews relevant EMF scientific literature issued its most recent review earlier in 2015. The 2015 SCENIHR report updated its previous reports from 2009 and 2007. The 2015 SCENIHR conclusions are consistent with those expressed by the WHO; that is, the currently available scientific evidence does not confirm the existence of adverse health effects in relation to ELF EMF exposure.

**Q. Could you please provide specific examples of research recommendations included in the WHO evaluation, and can you explain whether these recommendations were addressed by recent research?**

A. Yes. The 2007 WHO Research Agenda for Extremely Low Frequency Fields included research recommendations in various scientific fields that were ordered according to the *"weight each research activity carries in human health risk assessment."* High priority research was defined as *"[s]tudies to fill important gaps in knowledge that are needed to significantly reduce the uncertainty in the current scientific information relevant to health risk assessment"* (Schedule DS-03)). Recommendations included epidemiologic studies, laboratory studies in humans, animals, and cellular systems, and laboratory studies to identify a biophysical mechanism to explain a carcinogenic effect. In the field of epidemiology, the discipline ranked as providing the most weight in a human risk

assessment, the WHO included the following three recommendations with high priority: 1) pooled analyses of existing childhood brain tumor studies; 2) updates of existing pooled analyses of childhood leukemia with new information; and 3) further study of the risk of amyotrophic lateral sclerosis (ALS) in "electric occupations." All of these recommendations have been addressed.

The first of these recommendations was addressed by the study of Kheifets *et al.*, (2010a), titled *"A pooled analysis of extremely low-frequency magnetic fields and childhood brain tumors,"* published in the American Journal of Epidemiology. This study, which combined original primary data from ten previously published epidemiologic studies of ELF EMF exposure and childhood brain tumors, and included data on close to 20,000 children from several countries worldwide, reported *no association between ELF EMF exposure and brain cancer development among children.*

The second recommendation was addressed by the study of Kheifets et al. (2010b), titled "*Pooled analysis of recent studies on magnetic fields and childhood leukemia,*" published in the British Journal of Cancer. This pooled analysis combined original primary data from seven epidemiologic studies of ELF EMF and childhood leukemia published between 2000 and 2010. The authors reported that *"the association is weaker in the most recently conducted studies"* (Kheifets *et al.*, 2010b, p. 1128) and they reported that the observed associations were not statistically significant in the more recently published studies.

The third recommendation was addressed by several recently published epidemiologic studies. These include, among others, a meta-analysis of Vergara *et al.* (2013) that combined published data from 42 studies of occupational exposure to ELF EMF and

neurodegenerative diseases including ALS. For ALS, the authors reported "weak associations" with occupational titles but not with estimated EMF levels; they concluded that overall their *"results do not support MF [magnetic fields] as the explanation for observed associations"* (Vergara *et al.*, 2013, p. 135). Several recent epidemiologic studies specifically addressed the potential association between ALS and residential proximity to high voltage power lines in Switzerland, Brazil, Denmark and the Netherlands (Huss *et al.*, 2009; Marcilio *et al.*, 2011; Frei *et al.*, 2013; Seelen *et al.*, 2014). None of these studies reported an association between living close to power lines and developing or dying of ALS. Overall, the most recent SCENIHR report (2015) concluded that "*[e]pidemiological studies do not provide convincing evidence of an increased risk of neurodegenerative diseases, including dementia, related to ELF MF [magnetic field] exposure*" (p. 186).

**Q. Dr. Smith states that the WHO Research Agenda *"places High Priority"* on research in three specific areas, *"which include childhood brain tumor studies, childhood leukemia, and amyotrophic lateral sclerosis"* [emphasis added] (Smith Rebuttal Testimony, p. 4, lines 9-19). Do you agree with his identification of these topics as of particular concern?**

A. No. First, the 2007 WHO Research Agenda for Extremely Low Frequency Fields did not recommend new studies on childhood brain and leukemia, just the pooling of the results of previous studies.

Second, while new studies on ALS were given high priority as listed by Dr. Smith, the more recent epidemiologic studies published since 2007 have substantially reduced uncertainty about a potential effect of ELF EMF on ALS development. While further

research on Alzheimer's disease and miscarriage was not identified with high priority, based on recently published studies, similar conclusions may be reached about these outcomes, as well. As the 2015 SCENIHR report concluded, based on review of the most recent scientific evidence, *"[e]pidemiological studies do not provide convincing evidence of an increased risk of neurodegenerative diseases, including dementia, related to ELF MF exposure. Furthermore, they show no evidence for adverse pregnancy outcomes in relation to ELF MF [magnetic fields]"* (p. 186).

**Q. Dr. Smith points to a 2013 study published in British Journal of Cancer and attached as Schedule DS-06 as "new evidence" linking EMF to childhood leukemia (Smith Rebuttal Testimony, p. 5, lines 16-21). What is the significance of this study?**

A. This is an epidemiologic study evaluating the potential relationship between residential proximity to high-voltage transmission lines and development of childhood leukemia (Sermauge-Faure *et al.*, 2014). The research team included all the 2,779 cases of acute leukemia cases that were diagnosed in France under the age of 15 years during the years 2002 through 2007. For each of the 6 study years, 5,000 control children (a total of 30,000) were randomly selected from the French tax databases that included information of children in each household in France. The investigators used geographical information systems (GIS) to determine the distance from the home address at diagnosis for children with leukemia and the home address at the year of inclusion for the control children to the nearest high-voltage power line with voltages between 63 kV and 400 kV. This distance to the nearest high-voltage line was used to evaluate potential exposure. The study did not measure or compute actual exposure of the included children to magnetic fields.

Contrary to the impression left by Dr. Smith, there is no reason to suggest that this study provides new or stronger evidence in favor of a causal relationship. Overall, there was no statistically significant difference between the distances of cases and controls to high-voltage transmission lines. The authors of the study quite rightly point to a lack of systematic bias in the process that identified cases and controls for inclusion in the study. But, just as Dr. Smith does not mention that there was no reliable association reported in this study, he also does not mention that there are other sources of bias and error that are significant. Notably, the main exposure metric that was relied upon in the study was distance of residential address to the nearest power lines.

Distance to power lines is but one of the many characteristics that determine exposure to magnetic fields. The actual exposure is also determined by the load on the line and the configuration of the line, in addition to any additional sources in the home. Distance in itself is a poor predictor of actual magnetic field exposure. In addition, distance determination was based on GIS, and not actual distance measurements. As it has been pointed out by several investigators (e.g., Bonnet-Belfais *et al.*, 2013; Chang *et al.*, 2014), GIS-based distance assessment is fraught with limitations. In particular, the GIS-based distance assessment model has not been validated in the French study, and for 30% of the cases and 23% of the controls in the study, no exact address was available, potentially resulting in substantial misclassification of the distance-based exposure measure. This is particularly concerning for residences closer to the line, where magnetic field levels change substantially with distance.

**Q. Have other notable epidemiologic studies of EMF and childhood leukemia been published in recent years that provide new data in this area, other than the previously discussed French study?**

A. Yes. A number of epidemiologic studies of EMF and childhood leukemia from the United Kingdom, Denmark, Italy, and a smaller study from the Czech Republic, have been published in recent years that used either measured magnetic fields or distance to power lines as an exposure metric (Jirik *et al.*, 2012; Bunch *et al.*, 2014; Magnani *et al.*, 2014; Pedersen *et al.*, 2014). Overall, none of these studies reported a consistent association between the estimated exposure and childhood leukemia. The largest of these studies from the United Kingdom (Bunch *et al.*, 2014) included over 53,000 childhood cancer cases diagnosed between 1962 and 2008 and over 66,000 healthy children as controls and reported no association for any of the cancer types, including leukemia, and residential distance to high voltage power lines (132 kV – 400 kV). The Bunch *et al.* (2014) study was an update to previous studies by this research group (Draper *et al.*, 2005; Kroll *et al.*, 2012).

Although two recent studies from Iran (Sohrabi *et al.*, 2010; Tabrizi and Bigdoli, 2015) reported associations with childhood leukemia, methodological limitations in these studies preclude drawing any firm conclusions from them. In one of them (Sohrabi *et al.*, 2010), the authors reported that a higher proportion of cases than controls lived within 600 meters of a transmission line; no shorter distance was evaluated. At 600 meters from a transmission line, however, no increases in magnetic fields would be anticipated, thus the study provides no reliable information on a relationship between magnetic fields and

childhood leukemia.[8] The other Iranian study included a very small number of cases (22 children with leukemia) and provided no information on how exposure to EMF was determined; thus, no inference on actual EMF exposure could be drawn from the study. Overall, recently published epidemiologic studies on EMF and childhood leukemia have provided no new data to support or strengthen the previously reported associations.

**Q. Dr. Smith cites a 2009 study by Blank and Goodman[9] as an example of "recent research that demonstrates damage at a cellular level" (Smith Rebuttal Testimony, p. 5, lines 3-14). Do you agree with his reliance on this paper and his claim that it refutes the argument that "there has been no plausible explanation for the causation of cancer [by magnetic fields]"?**

A. No. First, to draw a sweeping conclusion from a single paper is contrary to the weight-of-evidence method discussed earlier in my testimony and contrary to scientific practice as explained by Sir Colin Berry in "Reproducibility in experimentation – the implications for regulatory toxicology":

> *The important thing is not to pay attention to any single or remarkable finding but to wait for verification – and here we run into the problem of politics and the use of data from imperfect studies in policy making" (p. 415).*

Assessing all the results from relevant studies is the only valid approach to making science-based assessments and decisions. There are other studies both before and after 2009 that fail to confirm damage to DNA from magnetic fields. Dr. Smith has "cherry-picked" a publication that supports his opinion rather than framing a judgement based on all the data.

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[8] This study is included in Data Request Response 8b from Neighbors United Against Ameren's Power Line.
[9] See Schedule DS-05.

Second, the Blank and Goodman paper is not a report of an experimental study but rather a review of previous studies and an opinion piece designed to serve up and promote their hypotheses. No less than 24 of the papers cited are authored by Blank, Goodman, or both. They cite no studies reporting contrary findings. Only a few of the citations to publications in the review are dated 2007 or later and earlier research studies by Goodman and Blank were reviewed by the WHO in its 2007 report. As shown in highlighted text on pp. 327, 334, and 359 of the WHO report included in Schedule WHB-SR2, multiple investigators have been unable to replicate the findings that form the basis for the claims made by Blank and Goodman in their 2009 paper.

The conclusion of the WHO in 2007 regarding effects of magnetic fields on cells was that:

- Generally, studies of the effects of ELF magnetic field exposure of cells have shown no induction of genotoxicity [DNA damage] at fields below 50 mT [50,000 mG] [emphasis added] (p. 347).
- Many other cellular studies, for example on cell proliferation, apoptosis, calcium signaling, intercellular communication, heat shock protein expression and malignant transformation, have produced inconsistent or inconclusive results [emphasis added] (p. 347).

**Q. What other errors did Dr. Smith make when he relied on this single study?**

A. He apparently concludes that the Blank and Goodman study provides a "plausible mechanism for the causation of cancer" (Smith Rebuttal Testimony, p. 5, lines 3-6). Activation of DNA to produce proteins, however, is the way in which proteins are synthetized and does not mean that DNA is damaged. In fact, the research of Drs. Blank

and Goodman did not include tests for DNA damage (i.e., mutations), which would indeed be relevant to the assessment of potential cancer risks. Other scientists have conducted such tests and the results, in aggregate, do not suggest a genotoxic effect of magnetic fields. In 1999, the NIEHS concluded that there was *"no conclusive evidence that genotoxic effects result from ELF- EMF exposures"* (p. 26). After evaluating eight more years of research on this topic, the WHO Task Group summarized their discussion of research on DNA damage by stating, *"[g]enerally, studies of the effects of ELF magnetic field exposure of cells have shown no induction of genotoxicity at fields below 50 [millitesla] [500,000 mG]"* (p. 26).

Subsequent to the publication of the report by the WHO Task Group, scientists at Health Canada reported that human subjects exposed for 4 hours to magnetic fields of 2,000 mG did not exhibit any evidence of greater DNA damage in their blood than that obtained from controls (Albert *et al.*, 2009).

**Q. Dr. Smith relies on the paper by Blank and Goodman to suggest that magnetic fields at low levels of 5-10 mG produce cellular damage (Smith Rebuttal Testimony, p. 5, lines 8-11). Does this testimony suggest to you that he is aware that the year before, Dr. Blank and his colleagues in fact advocated for the use of 60-Hz magnetic fields at an intensity of at least 80 mG in therapeutic applications?**

A. It does not. Dr. Blank proposed that magnetic fields be used to stimulate the production of stress proteins as a means of protecting tissues against the harmful effects of a lack of oxygen to the heart (George *et al.*, 2008). They state:

> *The use of EMFs for the induction of hsp70 for post-ischemia reperfusion treatment has clear advantages over the invasive elevated temperature treatment*

*efforts tested to date. Non-ionizing EMF induction of hsp70 is safe, efficient and practical ...*

*... a safe, non-invasive method of augmenting endogenous defense mechanisms as a therapeutic tool, such as EMF exposure, has significant clinical potential* (p. 822).

Thus, Dr. Blank's own publication asserts that magnetic fields at a level higher than discussed in his 2009 paper is "safe" for human use.

**Q. Dr. Smith presents an article "Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects" (Smith Rebuttal Testimony, Schedule DS-07) as evidence for both *"therapeutic and harmful effects of exposure to EMF"* (Smith Rebuttal Testimony, p. 6, line 1). What reliable evidence does this single paper provide about the possibility of long-term effects of EMF on health?**

A Again, Dr. Smith focuses on a review paper whose aim is to present a hypothesis (Pall, 2013). Pall hypothesizes that effects of static magnetic fields, ELF magnetic fields, and radiofrequency fields are due to interactions with voltage-gated calcium channels (VGCC). Like the paper by Blank and Goodman (2009) cited by Dr. Smith in his Rebuttal Testimony, almost all of the studies cited in support of this hypothesis are studies of cells *in vitro* where the author suspects that VGGC may be involved in the observed responses to fields.

The two biological effects that the article attempts to explain are the use of EMF to stimulate bone growth and damage to DNA. The studies of ELF magnetic fields that were reviewed, however, did not involve measurements on bone cells. While very

intense magnetic fields at varying frequencies and pulsed waveforms have been used to accelerate bone healing, the characteristics of these fields are totally different than the 60-Hz magnetic fields associated with the use of electricity. A different type of exposure involving combined exposure to ELF magnetic fields and static magnetic fields also has been studied but appears not to be clinically effective in bone healing (Behrens *et al.*, 2013; Mollon *et al.*, 2008).

Regarding the hypothesized involvement of VGCCs to EMF increases in peroxynitrite as an indicator of damage to DNA, Pall cites four studies, three of which involve exposures to radiofrequency fields and only one to ELF magnetic fields. This latter unreplicated study reported that 50-Hz magnetic fields at 1 milliTesla (10,000 mG) increased levels of 3-nitrotyrosine in the liver of rats exposed for 4 hours each day for 45 days, but did not report any measurements related to VGCC (Erdal *et al.*, 2008). No measurements of DNA damage were included.

Hence, the hypothesis proposed in the Pall (2013) paper cited by Dr. Smith is not convincingly supported even by the research cited in the paper. Magnetic fields at a frequency of 60 Hz, like those associated with our electric system, are effective in promoting bone healing, and as pointed out above, the WHO (2007) does not indicate that EMF magnetic fields damage DNA at the levels associated with the Mark Twain Transmission Project. Regarding studies of DNA damage in laboratory animals, the WHO 2007 report states:

> *No effects of ELF magnetic fields have been seen after long-term exposures in other rodent genotoxicity models, such as the dominant lethal assay in mice (Kowalczuk et al., 1995), sister chromatid exchange in rats and micronuclei in*

*mice (Abramsson-Zetterberg & Grawe, 2001; Huuskonen et al., 1998a; Huuskonen et al., 1998b)* (p. 321).

**Q. Dr. Smith states "... industry and supporters downplay the risk of EMF to health ... " (p. 3). Have you reviewed the information provided on EMF by AXTI to the public?**

A. Yes, I requested that ATXI provide me with the brochure they prepared on EMF to communicate with the public ("Answering Your Questions about Electromagnetic Fields").[10]

**Q. Did the ATXI EMF brochure cite reputable public health and scientific organizations as sources of information?**

A. Yes. The summary of research on EMF and health in the brochure covered typical questions about human health including cancer and pacemakers, and questions about effects on animals and crops. The information provided was based upon and consistent with the communication materials on this topic published by the NIEHS, the WHO, the United States Environmental Protection Agency (EPA), ICNIRP, and the American Conference of Governmental Industrial Hygienists.

**Q. Dr. Smith quotes the ATXI EMF brochure to characterize the magnetic fields from a 345-kV line as "Ameren levels at the edge of Right-of-Way for 345 kV transmission lines (75 ft) are typically at or below 90 mG."[11] Are the levels of magnetic fields from this specific Project far below 90 mG at the edge of the ROW?**

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[10] http://www.ilriverstransmission.com/Portals/23/forms/Ameren_EMF_brochure_2014.pdf
[11] *Ibid.*

A. Yes. Our engineers have calculated the EMF for four sections of the Project. The calculated magnetic fields at the ROW edge and at 100 feet beyond the ROW edge summarized from Schedule WHB-SR3, are as follows:

**Table 2. Calculated magnetic fields for Project segments (average loading)**

| Project Segment | 100 feet from -ROW edge | -ROW edge | +ROW edge | 100 feet from +ROW edge |
|---|---|---|---|---|
| Wind Zone – Ottumwa (XS-1; 345 kV) | 1.9 | 8.2† | 9.5†† | 2.0 |
| Zachary – Wind Zone (XS-2; 345 kV) | 4.8 | 21† | 24†† | 5.1 |
| Maywood – Zachary (XS-3; 345 kV) | 3.7 | 16* | 19** | 4.0 |
| Zachary – Adair (XS-4; 161 kV) | 2.1 | 13* | 9.1** | 1.7 |

*South edge of ROW; †West edge of ROW; **North edge of ROW; ††East edge of ROW

The calculated magnetic fields at the edges of the ROW of the Project are a fraction of the value given in the brochure and are similar to those found under low voltage distribution lines (Savitz *et al.*, 1989).

**Q. To the best of your knowledge are the calculated magnetic field values at nearby residences considerably lower than those calculated at the edges of the ROW and at 100 feet from either side of the ROW as shown in Table 2?**

A. Yes. I am informed by Christopher J. Wood, an engineer with Burns & McDonnell Engineering Company, Inc., who is a witness in this case, that the closest residences to the proposed line are still much further away than 100 feet. Table 3 summarizes the calculated magnetic field levels that represent the most likely magnetic field level for any given day at the closest residence as identified by Mr. Wood:

**Table 3. Calculated magnetic fields at average loading from the proposed Mark Twain Transmission Line at closest residence**

| Section | Distance from ROW center to closest residence (feet) | Calculated magnetic field (mG) |
|---|---|---|
| Wind Zone – Ottumwa (XS-1) | > 300 | 0.7 |
| Zachary – Wind Zone (XS-2) | ±146 | 7.3 |
| Maywood – Zachary (XS-3) | ±235 | 2.2 |
| Zachary – Adair (XS-4) | ±235 | 0.8 |

The magnetic field levels in Table 3, and at more distant residences, will fall in the range of magnetic field levels similar to those that would be measured in residences in the absence of a transmission line (Savitz *et al.*, 1989). At periods of peak line loading that might prevail for a few hours or days during the year the magnetic field could be higher than shown in Schedule WHB-SR3. At distances greater than about 200 feet from the center of the ROW, however, the magnetic field level at both average and peak loading are reduced to low levels.

**Q. What inference can the Commission draw about EMF and health based upon the Rebuttal Testimony of Dr. Smith?**

A. In my opinion, the Commission cannot draw any inference from Dr. Smith's Rebuttal Testimony, as he does not provide a systematic assessment of the literature, but only cherry picks evidence and presents (and in some cases misunderstands) a handful of the papers that he assumes support his view of adverse effects of ELF magnetic fields. His conclusions are contrary to conclusions of multidisciplinary panels that conducted

weight-of-evidence evaluations on behalf of authoritative national and international health and scientific agencies.

## V. RESPONSE TO ADDITIONAL EMF-RELATED SUBMISSIONS

**Q. Janet Akers, a farmer and President of the Missouri Cattlemen's Association, has filed Rebuttal Testimony against the Project on behalf of Neighbors United Against Ameren's Power Line and voiced concerns about "how the Project will impact the health and well-being of our cattle, not to mention our families"[12] (Akers Rebuttal Testimony, p. 3, lines 20-21). What does research by scientists and veterinarians show about effects of transmission lines and EMF on cattle or other livestock?**

A. While most of the EMF-related health research has focused on human health, considerable scientific attention has been given to potential effects of ELF EMF on livestock with significant economic impact, most notably cattle, sheep, and swine. Cattle are the most extensively investigated species among farm animals in the EMF literature. Farm surveys and field observation, overall, have not identified any systematic differences in health, behavior, and productivity of livestock on farms intersected by high-voltage power lines compared to farms without such lines. A series of well-designed experimental studies were conducted by Canadian researchers to assess potential effects of EMF at levels much higher than could be anticipated in the current Project, on various behavioral, reproductive, and productivity parameters in dairy cattle. While the authors reported small variations in some of the parameters, overall, no

[12] Similar concerns about potential effects of the proposed line on livestock including cattle were also recorded in Volume 2 of the transcript of the October 19, 2015, local public meeting in Shelbyville by Nancy Rainey (p. 27), Michael Barrick (pp. 36, 38), Clayton Hawkins (pp. 47-48), and Janice Phillips (pp. 83-84); in Volume 3 of the transcript of the October 26, 2015, local public hearing in Queen City by Kaitlyn Meyer (p. 76) and Jeb Weaver (pp. 78-79); and in Volume 4 of the transcript of the October 27, 2015,local public hearing in Kirksville by Marsha Salassa (p. 99), Barbara Stone (p. 172), and Roger Billington (p.204).

systematic differences were noted; these differences were within physiological variations and, overall, did not show consistent pattern with ELF EMF exposure. Studies on sheep or swine are less systematic and smaller in number; however, these studies reported no consistent and replicated adverse effects.

**Q. A number of persons who testified at local public hearings expressed concern about "stray voltage."[13] What is stray voltage and does the proposed Mark Twain Transmission Line pose a likely threat to cattle, other livestock, or people?**

A. If an animal or person contacts a metal object that is electrified from on-farm wiring or there are electric defects in a device connected to that wiring or the local distribution line servicing the farm, they may experience current flow through the body if the metal object is at a different electrical potential. Stray voltage can be a problem particularly in dairy barns and typically arises due to poor grounding of electrical equipment on the farm and sometimes is related to distribution lines supplying farms. Symptoms of stray voltage in farm animals can include reduced milk 'let down' and udder infections in cows, reduced food and water intake, and restlessness and avoidance of the barn. Since transmission lines are only connected to substations and not tapped off to farms and residences, they are not sources of any constant voltage to contact surfaces in barns. Thus, the Mark Twain Transmission Line would not be a source of stray voltage.

**Q. But if stray voltage does not occur from transmission lines, then what can account for a small shock that a person might experience directly under a transmission line and making contact with an ungrounded vehicle?**

[13] As recorded in Volume 3 of the transcript of the October 26, 2015, local public hearing in Queen City by John Hoffman (p. 37), Jeb Weaver (pp. 78-79), and Debra Leunen (pp. 85-86) and as recorded in Volume 4 of the transcript of the October 27, 2015, local public hearing in Kirksville by Deborah Games (p.133).

A. The electric field from a high-voltage transmission line can couple to and charge large metal objects or long electric fences that run adjacent and parallel to the ROW edge that are not grounded. Our engineers report that most vehicles are sufficiently grounded, and standard utility practice calls for grounding large fixed objects, such as a metal building, to prevent shocks. In any event, transmission lines are required to adhere to the National Electric Safety Code to prevent harmful shocks (IEEE/ANSI, 2012).

**Q. Several comments were made in public hearings that EMF is classified by IARC the same as cigarette smoking.[14] How do these exposures compare to the recent classification of certain meats by IARC? Are ELF EMF and tobacco smoke classified similarly by IARC?**

A. No, ELF EMF is classified quite differently by IARC than exposures from cigarette smoking and consumption of certain meats.

While IARC applies the same principles for the evaluation of all exposures, the conclusions are vastly different for tobacco smoke and ELF fields. Tobacco smoke and second-hand tobacco smoke were classified as Group 1 (carcinogenic to humans) based on sufficient evidence in humans for a number of cancers (e.g., cancer of the lung, pharynx, larynx, esophagus, and stomach) and sufficient evidence for carcinogenicity in experimental animals (IARC, 2004).

Recently, IARC classified processed meat as carcinogenic to humans (Group 1), based on sufficient evidence in humans that the consumption of processed meat causes colorectal cancer, and they classified red meat as probably carcinogenic to humans (Group 2A)

[14] http://monographs.iarc.fr/ENG/Monographs/vol83/mono83-1.pdf

based on limited evidence that the consumption of red meat causes cancer in humans and strong mechanistic evidence supporting a carcinogenic effect.[15]

The conclusions of IARC are fundamentally different regarding EMF than for tobacco and meats. ELF magnetic fields were not classified as either a known carcinogen or probably carcinogenic to humans. The evidence was considered as limited from childhood leukemia epidemiologic studies, and the evidence was considered as inadequate from human studies for all other cancer and non-cancer health outcomes. The evidence from experimental animal studies also was considered as inadequate for ELF magnetic fields. ELF magnetic fields therefore were classified in Group 2B (possibly carcinogenic to humans). For ELF electric fields the evidence was considered inadequate from both human and experimental studies, and was classified in Group 3 (not classifiable as to its carcinogenicity to humans).

**Q. A number of persons at public meetings voiced concerns about the potential effect of the lines on implanted cardiac pacemakers or defibrillators.[16] Is it likely that the EMF from the line would interfere with the operation of these devices to cause harm to these persons?**

A. No. The likelihood is vanishingly small. Sensing of electrical impulses of the heart is key to the normal functioning of implanted cardiac devices, such as pacemakers or implanted cardioverter defibrillators. If these devices sense electric signals from other sources those may, in principle, result in electromagnetic interference. Power lines,

[15] https://www.iarc.fr/en/media-centre/pr/2015/pdfs/pr240_E.pdf

[16] Concerns about potential effects of the proposed line on pacemakers or defibrillators were recorded in Volume 2 of the transcript of the October 19, 2015, local public meeting in Shelbyville by Roger Barrick (pp. 36, 38), Clayton Hawkins (pp. 47-48), Jack Mann (pp. 57, 58), Marian Spring (pp. 74-75), Noble Hawkins (p. 59), John Bambrick (p. 111), and Kathy Stiefel (p. 125). Similar concerns were recorded in Volume 3 of the transcript of the October 26, 2015, local public hearing in Queen City by Tandy Hawkins (p. 63), Debra Leunen (pp. 85-86), and Keith Kerby (p. 58).

however, are not typical sources of such interference. A search, conducted in November 2015, of the Manufacturer and User Facility Device Experience database[17] maintained by the United States Food and Drug Administration has not identified episodes of electromagnetic interference with implanted cardiac devices due to EMF from AC power lines. Indeed, modern implanted medical devices incorporate various technological safeguards (e.g., shielding by titanium casing, the presence of bipolar leads, and electrical filtering) to minimize the potential for interference (Dyrda and Khairy, 2008). A recently developed procedure by the European Committee for Electrotechnical Standardization to assess the potential risk to workers with an active implantable medical device provides guidelines for reference levels that are sufficient to ensure compliance (CENELEC 50527-1:2010). For ELF EMF exposure, the recommended reference levels are 5.0 kV/m and 100 microtesla (i.e., 1,000 mG) for general exposure at locations where people spend significant time (EU, 1999). These exposure levels will not be exceeded under the proposed line as shown by calculations provided in **Schedule WHB-SR3**, and the closest residences are quite far away where the EMF levels would be much lower.

**Q. What concerns have been raised by the counties through which the proposed line would pass?**

A. The counties of Schuyler, Shelby, Adair, and Knox have submitted resolutions opposing the Project on multiple grounds that include the following claims:

> *Whereas, high-voltage transmission lines <u>are proven to cause</u> health risks. They have been linked by the National Institute of Environmental Health Studies [sic] to an increase in childhood leukemia and The World Health Organization has*

[17] https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfmaude/search.cfm

*stated that electromagnetic fields (EMFs) probably cause acute, biological effects and should be regarded as possible human carcinogens* [emphasis added].

The county of Marion also opposes the Project because it "*negatively impacts the citizens of Marion County.*" It is not clear if health concerns were among the negative impacts alleged in this resolution.

**Q. Do their claims accurately reflect the conclusions of NIEHS or the WHO on the topic of EMF and health and therefore mislead the reader? If they do not, please explain why not?**

A. No, they do not. Neither agency has concluded that EMF at the levels found in the everyday environment from sources like transmission lines, distribution lines, appliances, electric motors, or building wiring are harmful to human health or that that such sources cause acute biological effects harmful to organisms.

**Q. What are the conclusions of these health agencies on EMF and health?**

A. At the conclusion of its six-year Electric and Magnetic Fields Research and Public Information Dissemination (RAPID) Program in 1999 designed to provide scientific evidence to determine whether exposure to power-frequency EMF involves a potential risk to human health, the NIEHS stated:

*The NIEHS believes that the probability that ELF-EMF exposure is truly a health hazard is currently small. The weak epidemiological associations and lack of any laboratory support for these associations provide only marginal, scientific support that exposure to this agent is causing any degree of harm. The scientific evidence suggesting that extremely low frequency EMF exposures pose any health risk is weak* (p. 3).

The WHO, as part of its charter to protect public health, and in response to public concern over potential health effects of EMF exposure, established the International EMF Project in 1996. The purpose of the International EMF Project was to assess the scientific evidence on possible health effects of EMF in the frequency range from 0 to 300 GHz, and encourage focused research to fill gaps in scientific knowledge and to facilitate the development of internationally acceptable standards limiting EMF exposure. In 2007, the WHO published the results of its multi-year review and evaluation of EMF research in an Environmental Health Criteria report. That report concluded:

> *Acute biological effects [i.e., short-term, transient health effects such as a small shock] have been established for exposure to ELF electric and magnetic fields in the frequency range up to 100 kHz that may have adverse consequences on health. Therefore, exposure limits are needed. International guidelines exist that have addressed this issue. Compliance with these guidelines provides adequate protection. Consistent epidemiological evidence suggests that chronic low-intensity ELF magnetic field exposure is associated with an increased risk of childhood leukaemia. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted (p. 355).*

**Q. What are the international guidelines referred to by the WHO? Will the Project comply with these guidelines?**

A. International guidelines have been developed by ICNIRP and the International Committee on Electromagnetic Safety (ICES). These organizations have reviewed the scientific literature to identify adverse effects of exposure to EMF. Based on their

reviews they have identified neurostimulation of tissues as a potential adverse effect of high exposures, and after applying suitable safety factors, they derived limits on the level of the electric field to be induced in tissues, termed Basic Restrictions, to avoid such effects. To identify exposure levels for the general public that would not cause these limits to be exceeded at 60 Hz, ICNIRP provided Reference Levels of 4.17 kV/m and 2,000 mG (ICNIRP, 2010). Similarly, ICES identifies Maximum Permissible Exposures of 5 kV/m (10 kV/m on transmission line ROWs) and 9,040 mG as screening values (ICES, 2002).

The anticipated EMF levels near the proposed Project will be below both the ICNIRP and ICES guideline values.

**Q. Teri Page reported at the Kirksville public hearing that she home-schools her two children and was concerned about EMF.[18] Is her residence close enough to the proposed line that the EMF from the line could be measured?**

A. According to Christopher J. Wood, a witness for ATXI, Ms. Page's residence is at least approximately 1,660 feet from the proposed transmission line. Based on the modeling of the proposed configuration of the line and expected loadings summarized in Schedule WHB-SR3, the EMF from the line would not be measureable at her residence.

**Q. Included in the transcripts of some of the public hearings on the Project were anecdotal reports of cancer developing in individuals who had lived near a high-voltage transmission line.[19] Do these reports provide scientific evidence for a causal association between living next to power lines and development of leukemia or other cancers?**

[18] Recorded in Volume 4 of the transcript of the October 27, 2015, local public hearing in Kirksville.
Recorded in transcript local public hearings in Shelbyville, October 19, 2015 (Colin O, Brian, Volume 2, p. 101) and Queen City, October 26, 2015 (Glen Shively, Volume 3, p. 128).

A. No. Individual case reports cannot serve as the basis for scientific inference for causation. As discussed above, health risk assessments need to collectively weigh the evidence from all available relevant studies in the areas of epidemiology, and *in vivo*, and *in vitro* laboratory studies. For most cancer and non-cancer health outcomes, the evaluations conducted by multidisciplinary health panels concluded that the evidence is not sufficient or even limited to support a causal association with EMF. As discussed above, the association reported for childhood leukemia was considered limited, which implies that chance, bias, and confounding could not be ruled out as an explanation. In addition, as the authoritative health and scientific agencies concluded, the consistently negative *in vivo* animal studies and the lack of a known biophysical mechanism to explain a carcinogenic effect, argue against a causal association.

**Q. Some submissions expressed concerns about effects of ELF EMF on bees' health and productivity.[20] Do you think that the studies cited suggest a threat to bees near the proposed 161-kV and 345-kV transmission lines?**

A. No direct effects of either ELF electric fields or magnetic fields on bees have been demonstrated in scientific studies. Initial studies in the early 1980s reported adverse effects on beehives placed under 765-kV transmission lines at ELF electric fields levels of 7 kV/m and above (Greenberg *et al.*, 1981a, 1981b). These effects, however, were later demonstrated by the same team of investigators to be the result of electric shocks suffered by the bees due to induced currents in metallic components of the hives and not a direct effect of ELF electric fields on bees (Bindokas *et al.*, 1988a, b; Bindokas *et al.*, 1989). In fact, the abstract of Bindokas *et al.* (1988b) was referenced by Neighbors

[20] Recorded in the transcript of local public hearings in Queen City, October 26, 2015 (Julia/Jack Scott, Volume 3, pp. 52-54; Margaret Hollenbeck, Volume 3, p. 66) and Kirksville, October 27, 2015 (Clifford Hollenbeck, Volume 4, pp. 77-80).

United Against Ameren's Power Line in their Exhibit 6 (documents submitted by Mr. Clifford Hollenbeck);[21] at the Kirksville local public meeting; as stated, this study provides evidence that effects on bees are due to electric shocks in the hives and not direct effects of ELF electric fields. Bindokas *et al.* (1988) states in their Abstract: *"We concluded that biological effects seen in bee colonies under a transmission line are primarily the result of electric shock from induced hive currents."* The electric fields from the proposed 345-kV line are much lower than a 765-kV transmission line (see Schedule WHB-SR3) and if a bee keeper wanted to put hives on the ROW, grounding of the hives, shielding the hives with grounded metal covers, or using nonconductive hives would easily prevent exposure to the bees in the hives. No direct effects of electric fields on bees have been demonstrated at levels below 100 kV/m.

With respect to magnetic fields, bees have been shown to be very sensitive to detection of **static** magnetic fields (e.g., the natural geomagnetic field of the earth), which they may use for orientation. This is discussed, for example, in the second paper in Exhibit-6 (Ferrari, 2014), which concludes that bees may detect changes of less than 1 mG in the **static** geomagnetic field. This sensitivity to **static** magnetic fields, however, is in sharp contrast to the lack of sensitivity for **time-varying** fields including **ELF** fields. At the frequency of **60 Hz** (i.e., the frequency of the magnetic field associated with the Mark Twain Transmission Line), the threshold of sensitivity for detection was demonstrated to be at 4,300 mG (Kirschvink *et al.*, 1997). This value of sensitivity to magnetic fields at **60 Hz** is more than 4,000-fold higher than the threshold of sensitivity of bees to **static**

[21] Recorded in the transcript of local public hearing in Kirksville, October 27, 2015 (Clifford Hollenbeck, Volume 4, p. 80).

magnetic fields, and orders of magnitude higher than the **ELF** magnetic fields that are anticipated near or directly under the Mark Twain Transmission Line.

Studies of native bees in power line corridors, with and without measurements of ELF EMF (Russell *et al.*, 2005; Russell *et al*, 2013), reported observing more spatially and numerically rare species and richer bee communities in transmission line corridors than at the grassy fields away from transmission lines. The study by Russell *et al* (2013) that evaluated native bee abundance, development, and behavior in transmission line corridors, and also included ELF magnetic field measurements, reported no indication of negative impacts of EMF from high-voltage transmission lines. The author concluded that power line corridors, with the use of integrated vegetation management, could serve as habitat for bees and other insects. The presence of power lines and the associated ELF EMF have not been associated with adverse effects on the investigated parameters.

A third document dealing with bees was a print out from a Facebook page submitted by Neighbors United Against Ameren's Power Line.[22] Its not a scientific study or observation from a peer-reviewed scientific publication. Thus, it has no scientific merit in assessing any potential adverse effect. In addition the printout alleges adverse effects of radiofrequency fields related to cell phones, which are not the same as ELF EMF.

**Q. Do the rebuttal testimonies, public comments, and submissions you have reviewed about the Mark Twain Transmission Project provide reliable evidence that contradicts the assessments of health and safety issues associated with ELF EMF performed by panels of experts on behalf of national and international health and scientific agencies?**

A. No.

[22] Data Request Response 8 d.

**Q. Based on your own review and evaluation of the research literature on exposure to ELF EMF, do the levels of these fields associated with the operation of the proposed Mark Twain Transmission Project pose any known risk to human health?**

Q. My conclusion, made to a reasonable degree of scientific certainty, is no. The WHO and other scientific and health agencies have thoroughly considered this issue and have concluded that, on balance, the scientific weight of evidence does not support the conclusion that ELF EMF causes any long-term adverse health effects. Recent research does not provide evidence to alter this overall conclusion. The conclusions of the WHO and other agencies apply to all sources of these fields in our environment, including power distribution lines, transmission lines, and electrical appliances. In addition, EMF levels at the edge of the ROW, and beyond the ROW edge would be well below international standards, which are protective of public health.

**Q. Does it conclude your testimony?**

A. Yes.

## VI. ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AC | Alternating current |
| ALS | Amyotrophic lateral sclerosis |
| ATXI | Ameren Transmission Company of Illinois |
| ELF | Extremely low frequency |
| EMF | Electric and magnetic fields |
| EPA | Environmental Protection Agency |
| Exponent | Exponent, Inc. |
| G | Gauss |
| GIS | Geographic Information Systems |
| Hz | Hertz |
| IARC | International Agency for Research on Cancer |
| ICES | International Committee on Electromagnetic Safety |
| ICNIRP | International Commission on Non-Ionizing Radiation Protection |
| kV | Kilovolt |
| kV/m | Kilovolts per meter |
| mG | Milligauss |
| NIEHS | National Institute of Environmental Health Sciences |
| ROW | Right of way |
| SCENIHR | Scientific Committee on Emerging and Newly Identified Health Risks |
| WHO | World Health Organization |
| VGCC | Voltage-gated calcium channels |
| V/m | Volts per meter |

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BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

| | | |
|---|---|---|
| In the Matter of the Application of Ameren Transmission Company of Illinois for Other Relief or, in the Alternative, a Certificate of Public Convenience and Necessity Authorizing it to Construct, Install, Own, Operate, Maintain and Otherwise Control and Manage a 345,000-volt Electric Transmission Line from Palmyra, Missouri, to the Iowa Border and an Associated Substation Near Kirksville, Missouri. | ) ) ) ) ) ) ) | File No. EA-2015-0146 |

AFFIDAVIT OF WILLIAM H. BAILEY

STATE OF Maryland )
) ss
COUNTY OF Talbot )

William H. Bailey, being first duly sworn on his oath, states:

1. My name is William H. Bailey. I work in New York, New York, and I am employed by Exponent.

2. Attached hereto and made a part hereof for all purposes is my Surrebuttal Testimony on behalf of Ameren Transmission Company of Illinois consisting of 48 pages, and Schedule(s) WHB-SR1 - WHB-SR3 all of which have been prepared in written form for introduction into evidence in the above-referenced docket.

3. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded are true and correct.

William H. Bailey

Subscribed and sworn to before me this 16 day of November, 2015.

Notary Public

My commission expires: 9-5-18

RICHARD A. PRICE
NOTARY PUBLIC STATE OF MARYLAND
My Commission Expires September 9-5-18

NOTARY PUBLIC

Exponent
17000 Science Drive
Suite 200
Bowie, Maryland 20715

telephone 301-291-2500
facsimile 301-291-2599
www.exponent.com

**William H. Bailey, Ph.D.**
**Principal Scientist**

**Professional Profile**

Dr. William H. Bailey is a Principal Scientist in Exponent's Health Sciences practice. Dr. Bailey specializes in applying state-of-the-art assessment methods to environmental and occupational health issues. His 30 years of training and experience include laboratory and epidemiologic research, health risk assessment, and comprehensive exposure analysis. Dr. Bailey has investigated exposures to alternating current, direct current, and radiofrequency electromagnetic fields, 'stray voltage', and electrical shock, as well as to a variety of chemical agents and air pollutants. He is particularly well known for his research on potential health effects of electromagnetic fields and has served as an advisor to numerous state, federal, and international agencies. Currently, he is involved in research on exposures to marine life from submarine cables and respiratory exposures to ultrafine- and nanoparticles. Dr. Bailey is a visiting scientist at the Cornell University Medical College and has lectured at Rutgers University, the University of Texas (San Antonio), and the Harvard School of Public Health. He was formerly Head of the Laboratory of Neuropharmacology and Environmental Toxicology at the New York State Institute for Basic Research, Staten Island, New York, and an Assistant Professor and NIH postdoctoral fellow in Neurochemistry at The Rockefeller University in New York.

**Academic Credentials and Professional Honors**

Ph.D., Neuropsychology, City University of New York, 1975
M.B.A., University of Chicago, 1969
B.A., Dartmouth College, 1966

Sigma Xi; The Institute of Electrical and Electronics Engineers/International Committee on Electromagnetic Safety (Subcommitee 3, Safety Levels with Respect to Human Exposure to Fields (0 to –3 kHz) and Subcommittee 4, Safety Levels with Respect to Human Exposure to Radiofrequency Fields (3 kHz to 3 GHz); Elected member of the Committee on Man and Radiation (COMAR) of the IEEE Engineering in Medicine and Biology Society, 1998–2001

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Bailey WH. Avoidance behavior in rats with hereditary hypothalamic diabetes insipidus. Dissertation, City University of New York, 1975.

**Selected Invited Presentations**

Bailey WH. Measurements of charged aerosols around DC transmission lines and other locations. International Committee on Electromagnetic Safety TC95/ Subcommittee 3: Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0 – 3 kHz, December 2011.

Bailey WH, Erdreich LS. Human sensitivity and variability in response to electromagnetic fields: Implications for standard setting. International Workshop on EMF Dosimetry and Biophysical Aspects Relevant to Setting Exposure Guidelines. International Commission on Non-Ionizing Radiation Protection, Berlin, March 2006.

Bailey WH. Research-based approach to setting electric and magnetic field exposure guidelines (0-3000 Hz). IEEE Committee on Electromagnetic Safety, December 2005.

Bailey WH. Conference Keynote Presentation. Research supporting 50/60 Hz electric and magnetic field exposure guidelines. Canadian Radiation Protection Association, Annual Conference, Winnipeg, June 2005.

Bailey WH. Scientific methodology for assessing public health issues: A case study of EMF. Canadian Radiation Protection Association, Annual Conference, Public Information for Teachers, Winnipeg, June 2005.

Bailey WH. Assessment of potential environmental effects of electromagnetic fields from submarine cables. Connecticut Academy of Science and Engineering, Long Island Sound Bottomlands Symposium: Study of Benthic Habitats, July 2004.

De Santo RS, Coe M, Bailey WH. Environmental justice assessment and the use of GIS tools and methods. National Association of Environmental Professionals, 27th Annual Conference, Dearborn, MI, June 2002.

Bailey WH. Applications to enhance safety: Research to understand and control potential risks. Human Factors and Safety Research, Volpe National Transportation Systems Center/Dutch Ministry of Transport, Cambridge, MA, November 2000.

Bailey WH. EMF health effects review. EMF Exposure Guideline Workshop, Brussels Belgium, June 2000.

Bailey WH. Dealing with uncertainty when formulating guidelines. EMF Exposure Guideline Workshop, Brussels Belgium, June 2000.

Bailey WH. Field parameters: Policy implications. EMF Engineering Review Symposium, Status and Summary of EMF Engineering Research, Charleston, SC, April 1998.

Bailey WH. Principles of risk assessment: Application to current issues. Symposium on EMF Risk Perception and Communication, World Health Organization, Ottawa, Canada, August 1998.

Bailey WH. Current guidelines for occupational exposure to power frequency magnetic fields. EPRI EMF Seminar, New Research Horizons, March 1997.

Bailey WH. Methods to assess potential health risks of cell telephone electromagnetic fields. IBC Conference—Cell Telephones: Is there a Health Risk? Washington, DC, June 1997.

Bailey WH. Principles of risk assessment and their limitations. Symposium on Risk Perception, Risk Communication and its Application to EMF Exposure, International Commission on Non-Ionizing Radiation Protection, Vienna, Austria, October 1997.

Bailey WH. Probabilistic approach for setting guidelines to limit induction effects. IEEE Standards Coordinating Committee 28: Non-Ionizing Radiation, Subcommittee 3 (0–3 kHz), June 1997.

Bailey WH. Power frequency field exposure guidelines. IEEE Standards Coordinating Committee 28: Non-Ionizing Radiation, Subcommittee 3 (0–3 kHz), June 1996.

Bailey WH. Epidemiology and experimental studies. American Industrial Hygiene Conference, Washington, DC, May 1996.

Bailey WH. Review of 60 Hz epidemiology studies. EMF Workshop, Canadian Radiation Protection Association, Ontario, Canada, June 1993.

Bailey WH. Biological and health research on electric and magnetic fields. American Industrial Hygiene Association, Fredrickton, New Brunswick, Canada, October 1992.

Bailey WH. Electromagnetic fields and health. Institute of Electrical and Electronics Engineers, Bethlehem, PA, January 1992.

Bailey WH, Weiss JM. Psychological factors in experimental heart pathology. Visiting Scholar Presentation, National Heart Lung and Blood Institute, March 1977.

**Presentations**

Williams AI, Bailey WH. Toxicologic assessment of air ion exposures in laboratory animals. Poster presentation at 53rd Annual Meeting of the Society of Toxicology, Phoenix, AZ, March 26, 2014.

Perez V, Alexander DD, Bailey WH. Air ions and mood outcomes: A review and meta-analysis. Poster presentation at the American College of Epidemiology, Chicago, IL, September 8–11, 2012.

Shkolnikov Y, Bailey WH. Electromagnetic interference and exposure from household wireless networks. Product Safety Engineering Society Meeting, San Diego, CA October 2011.

Nestler E, Trichas T, Pembroke A, Bailey W. Will undersea power cables from offshore wind projects affect sharks? North American Offshore Wind Conference & Exhibition, Atlantic City, NJ, October 2010.

Nestler E, Pembroke A, Bailey W. Effects of EMFs from undersea power lines on marine species. Energy Ocean International, Ft. Lauderdale, FL, June 2010.

Pembroke A, Bailey W. Effects of EMFs from undersea power cables on elasmobranchs and other marine species. Windpower 2010 Conference and Exhibition, Dallas, TX, 2010.

Bailey WH. Clarifying the neurological basis for ELF guidelines. Workshop on Practical Implementation of ELF and RF Guidelines. The Bioelectromagnetics Society 29th Annual Meeting, Kanazawa, Japan, June 2007.

Sun B, Urban B, Bailey W. AERMOD simulation of near-field dispersion of natural gas plume from accidental pipeline rupture. Air and Waste Management Association: Health Environments: Rebirth and Renewal, New Orleans, LA, June 2006.

Bailey WH, Johnson G, Bracken TD. Method for measuring charge on aerosol particles near AC transmission lines. Joint Meeting of The Biolectromagnetics Society and The European BioElectromagnetics Association, Dublin Ireland, June 2005.

Bailey WH, Bracken TD, Senior RS. Long-term monitoring of static electric field and space charge near AC transmission Lines. The Bioelectromagnetics Society, 26th Annual Meeting, Washington, DC, June 2004.

Bailey WH, Erdreich L, Waller L, Mariano K. Childhood leukemia in relation to 25-Hz and 60-Hz magnetic fields along the Washington DC—Boston rail line. Society for Epidemiologic Research, 35th Annual Meeting, Palm Desert CA, June 2002. American Journal of Epidemiology 2002; 155:S38.

Erdreich L, Klauenberg BJ, Bailey WH, Murphy MR. Comparing radiofrequency standards around the world. Health Physics Society 43rd Annual Meeting, Minneapolis, MN, July 1998.

Bracken TD, Senior RS, Rankin RF, Bailey WH, Kavet R. Relevance of occupational guidelines to utility worker magnetic-field exposures. Second World Congress for Electricity and Magnetism in Biology and Medicine, Bologna, Italy, June 1997.

Weil DE, Erdreich LS, Bailey WH. Are 60-Hz magnetic fields cancer causing agents? Mechanisms and Prevention of Environmentally Caused Cancers, The Lovelace Institutes 1995 Annual Symposium, La Fonda, Santa Fe, NM, October 1995.

Bailey WH. Neurobiological research on extremely-low-frequency electric and magnetic fields: A review to guide future research. Sixteenth Annual Meeting of the Bioelectromagnetics Society, Copenhagen, Denmark, June 1994.

Blondin J-P, Nguyen D-H, Sbeghen J, Maruvada PS, Plante M, Bailey WH, Goulet D. The perception of DC electric fields and ion currents in human observers. Annual Meeting of the Canadian Psychological Association, Penticton, British Columbia, Canada, June 1994.

Erdreich LS, Bailey WH, Weil DE. Science, standards and public policy challenges for ELF fields. American Public Health Association 122nd Annual Meeting, Washington, DC, October 1994.

Bailey WH, Charry JM. Particle deposition on simulated VDT operators: Influence of DC electric fields. 10th Annual Meeting of the Bioelectromagnetics Society, June 1988.

Charry JM, Bailey WH. Contribution of charge on VDTs and simulated VDT operators to DC electric fields at facial surfaces. 10th Annual Meeting of the Bioelectromagnetics Society, June 1988.

Bailey WH, Charry, JM. Dosimetric response of rats to small air ions: Importance of relative humidity. EPRI/DOE Contractors Review, November 1986. Charry JM, Bailey WH, Bracken TD (eds). DC electric fields, air ions and respirable particulate levels in proximity to VDTs. International Conference on VDTs and Health, Stockholm, Sweden, June 12–15 1986.

Charry JM, Bailey WH. Air ion and DC field strengths at $10^4$ ions/cm$^3$ in the Rockefeller University Small Animal Exposure Chambers. EPRI/DOE Contractors Review, November 1985.

Charry JM, Bailey WH. DC Electrical environment in proximity to VDTs. 7th Annual Meeting of the Bioelectromagnetics Society, June 1985.

Bailey WH, Collins RL, Lahita RG. Cerebral lateralization: Association with serum antibodies to DNA in selected bred mouse lines. Society for Neuroscience, 1985.

Kavet R, Bailey WH, Charry JM. Respiratory neuroendocrine cells: A plausible site for air ion effects. Seventh Annual Meeting of The Bioelectromagnetics Society, June 1985.

Bailey WH, Charry JM. Measurement of neurotransmitter release and utilization in selected brain regions of rats exposed to DC electric fields and atmospheric space charge. 23rd Hanford Life Sciences Symposium, Richland, WA, October 1984.

Bailey WH, Charry JM, Weiss JM, Cardle K, Shapiro M. Regional analysis of biogenic amine turnover in rat brain after exposure to electrically charged air molecules (air ions). Society for Neuroscience, 1983.

Bailey WH. Biological effects of air ions: Fact and fancy. American Institute of Medical Climatology Conference on Environmental Ions and Related Biological Effects, October 1982.

Goodman PA, Weiss JM, Hoffman LJ, Ambrose MJ, Bailey WH, Charry, JM. Reversal of behavioral depression by infusion of an A2 adrenergic agonist into the locus coeruleus. Society for Neuroscience, November 1982.

Charry JM, Bailey WH. Biochemical and behavioral effects of small air ions. Electric Power Research Institute Workshop, April 1981.

Bailey WH, Alsonso DR, Weiss JM, Chin S. Predictability: A psychologic/ behavioral variable affecting stress-induced myocardial pathology in the rat. Society for Neuroscience, November 1980.

Salman SL, Weiss JM, Bailey WH, Joh TH. Relationship between endogenous brain tyrosine hydroxylase and social behavior of rats. Society of Neuroscience, November 1980.

Bailey WH, Maclusky S. Appearance of creatine kinase isoenzymes in rat plasma following myocardial injury produced by isoproterenol. Fed Assoc Soc Exp Biol, April 1978.

Bailey WH, Maclusky S. Appearance of creatine kinase isoenzymes in rat plasma following myocardial injury by isoproterenol. Fed Proc 1978; 37:889.

Bailey WH, Weiss JM. Effect of ACTH 4-10 on passive avoidance of rats lacking vasopressin (Brattleboro strain). Eastern Psychological Association, April 1976.

**Prior Experience**

President, Bailey Research Associates, Inc., 1991–2000
Vice President, Environmental Research Information, Inc., 1987–1990
Head of Laboratory of Environmental Toxicology and Neuropharmacology, New York State Institute for Basic Research, 1983–1987
Assistant Professor, The Rockefeller University, 1976–1983

**Academic Appointment**

- Visiting Fellow, Department of Pharmacology, Cornell University Medical College, New York, NY, 1986–present

**Prior Academic Appointments**

- Visiting Scientist, The Jackson Laboratory, Bar Harbor, ME, 1984–1985
- Head, Laboratory of Neuropharmacology and Environmental Toxicology, NYS Institute for Basic Research in Developmental Disabilities, Staten Island, NY, 1983–1987
- Assistant Professor, The Rockefeller University, New York, NY, 1976–1983
- Postdoctoral Fellow, Neurochemistry, The Rockefeller University, New York, NY, 1974–1976
- Dissertation Research, The Rockefeller University, New York, NY, 1972–1974
- CUNY Research Fellow, Dept. of Psychology, Queens College, City University of New York, Flushing, NY, 1969–1971
- Clinical Research Assistant, Department of Psychiatry, University of Chicago; Psychiatric Psychosomatic Inst., Michael Reese Hospital, and Illinois State Psychiatric Inst, Chicago, IL, 1968–1969

**Teaching Appointments**

- Lecturer, University of Texas Health Science Center, Center for Environmental Radiation Toxicology, San Antonio, TX, 1998
- Lecturer, Harvard School of Public Health, Office of Continuing Education, Boston, MA, 1995, 1997
- Lecturer, Rutgers University, Office of Continuing Education, New Brunswick, NJ, 1991–1995
- Adjunct Assistant Professor, Queens College, CUNY, Flushing, NY, 1978
- Lecturer, Queens College, CUNY, Flushing, NY, 1969–1974

**Editorship**

- Associate Editor, Non-Ionizing Radiation, *Health Physics*, 1996–present

**Advisory Positions**

- RWTH Aachen University. Workshop on human perception thresholds in static electric fields from high-voltage direct current (HVDC) transmission lines, 2015
- ZonMw – Netherlands Organization for Health Research and Development, 2012; 2007-2008, reviewer for National Programme on EMF and Health
- US Bureau of Ocean Energy Management, Regulation and Enforcement, 2009–2010
- Canadian National Collaborating Centre for Environmental Health, reviewer of Centre reports, 2008
- Island Regulatory and Appeals Commission, province of Prince Edward Island, Canada, 2008
- National Institute of Environmental Health Sciences/ National Institutes of Health, Review Committee, Neurotoxicology, Superfund Hazardous Substances Basic Research and Training Program, 2004
- National Institute of Environmental Health Sciences, Review Committee Role of Air Pollutants in Cardiovascular Disease, 2004
- Working Group on Non-Ionizing Radiation, Static and Extremely Low-Frequency Electromagnetic Fields, International Agency for Research on Cancer, 2000–2002
- Working Group, EMF Risk Perception and Communication, World Health Organization, 1998–2005
- Member, International Committee on Electromagnetic Safety, Subcommittee 3 - Safety Levels with Respect to Human Exposure to Fields (0 to 3 kHz) and Subcommitee 4 - Safety Levels with Respect to Human Exposure (3kHz to 3GHz) Institute of Electrical and Electronics Engineers (IEEE), 1996–present
- Invited participant, National Institute of Environmental Health Sciences EMF Science Review Symposium: Clinical and In Vivo Laboratory Findings, 1998
- Working Group, EMF Risk Perception and Communication, International Commission on Non-Ionizing Radiation Protection, 1997
- U.S. Department of Energy, RAPID EMF Engineering Review, 1997

- Oak Ridge National Laboratory, 1996
- American Arbitration Association International Center for Dispute Resolution, 1995–1996
- U.S. Department of Energy, 1995
- National Institute for Occupational Safety and Health, 1994–1995
- Federal Rail Administration, 1993–1996
- U.S. Forest Service, 1993
- New York State Department of Environmental Conservation, 1993
- National Science Foundation
- National Institutes of Health, Special Study Section—Electromagnetics, 1991–1993
- Maryland Public Service Commission and Maryland Department of Natural Resources, Scientific Advisor on health issues pertaining to HVAC Transmission Lines, 1988–1989
- Scientific advisor on biological aspects of electromagnetic fields, Electric Power Research Institute, Palo Alto, CA, 1985–1989
- U.S. Public Health Service, NIMH: Psychopharmacology and Neuropsychology Review Committee, 1984
- Consultant on biochemical analysis, Colgan Institute of Nutritional Science, Carlsbad, CA, 1982–1983
- Behavioral Medicine Abstracts, Editor, animal behavior and physiology, 1981–1983
- Consultant on biological and behavioral effects of high-voltage DC transmission lines, Vermont Department of Public Service, Montpelier, VT, 1981–1982
- Scientific advisory committee on health and safety effects of a high-voltage DC transmission line, Minnesota Environmental Quality Board, St. Paul, MN, 1981–1982
- Consultant on biochemical diagnostics, Biokinetix Corp., Stamford, CT, 1978–1980

**Professional Affiliations**

- The Health Physics Society (Affiliate of the International Radiation Protection Society)
- Society for Risk Analysis
- International Society of Exposure Analysis
- New York Academy of Sciences
- American Association for the Advancement of Science
- Air and Waste Management Association
- Society for Neuroscience/International Brain Research Organization
- Bioelectromagnetics Society
- The Institute of Electrical and Electronics Engineers/Engineering in Medicine and Biology Society
- Conseil International des Grands Réseaux Électriques

Note: The magnetic field values in the WHO report are given in units of microTesla and milliTesla (mT). These values can be converted to units of milligauss (mG) used in the United States by multiplying by 10 (i.e., 1 μT = 10 mG and 1 mT = 1,000 mG.

### *11.4.2 Expression of oncogenes and cancer-related genes*

Oncogene expression has been extensively investigated under exposure to ELF magnetic fields. The first reports of an effect of ELF magnetic fields on gene expression came from the Goodman group, who showed an upregulation of the c-myc proto-oncogene in human HL60 cells under exposure ranging from 0.57 to 570 μT. The effect was shown to be a "window effect" (maximum effect at 5.7 μT, no effect at lower and higher levels of exposure), dependent on $Ca^{2+}$. An "EMF-responsive element" (EMRE), required for the induction of c-myc expression, was identified in the c-myc promoter and corresponded to nCTCTn sequences (Goodman et al., 1989; Goodman et al., 1992; Karabakhtsian et al., 1994; Lin & Lee, 1994; Wei, Goodman & Henderson, 1990). Recently, using c-myc-EMRE expression vectors linked to luciferase or CAT (chloramphenicol transferase) in HeLa cells, the presence of EMRE was associated with a response to ELF magnetic field exposure (Lin et al., 2001).

However, over the years, several replication studies have failed to confirm these findings on c-myc at the transcriptional level in HL60 and other cells at different exposure levels (Balcer-Kubiczek et al., 1998; Balcer-Kubiczek et al., 2000; Boorman et al., 2000b; Czerska et al., 1992; Desjobert et al., 1995; Greene et al., 1993; Jahreis et al., 1998; Lacy-Hulbert et al., 1995; Loberg et al., 1999; Miyakoshi et al., 1996; Morehouse & Owen, 2000a; Owen, 1998; Parker & Winters, 1992; Saffer & Thurston, 1995).

Moreover, while sparse positive findings on the expression of diverse oncogenes either at the transcriptional or protein level have been published (Campbell-Beachler et al., 1998; Lagroye & Poncy, 1998; Phillips et al., 1993; Phillips, 1993; Rao & Henderson, 1996), a number of others studies have reported an absence of effects, including effects on a number of other cancer-related genes (Balcer-Kubiczek et al., 1998; Balcer-Kubiczek et al., 2000; Loberg et al., 1999; Miller et al., 1999).

resulted in a transient but significant up-regulation of c-jun, p21 and egr-1 mRNA levels. The level of egr-1 after exposure in the specified conditions was similar to the basal level found in wild-type cells. It is reported that other intermittent or continuous exposures did not induce similar effects in p53-deficient ES cells. It was suggested that that the balance between positive and negative regulators of cell cycle may be transiently altered in ES cells lacking a functional p53 gene.

The effect of ELF magnetic fields on the expression of heat shock proteins (hsps) has also been investigated. Hsps are known as chaperones, in that they assist other proteins to assemble correctly, target the appropriate cellular compartment and prevent unfolding. As a superfamily of proteins, they modulate a wide range of functions such as thermotolerance, anti-apoptosis function, immunogenicity, etc. Some of the hsps are constitutively expressed, while a number of others are inducible after the cells have been exposed to a wide range of stress signals (heat, heavy metals, etc). Some hsp proteins have also been shown to be expressed at atypical levels in tumour cells or tissue. Such observations have led to suggestions that hsps could be used as biomarkers for cellular stress in general. Their use as biomarkers for carcinogenesis is not widely validated.

In a series of papers from the Goodman group, a 60 Hz, 8 μT magnetic field was shown to increase the transcription of the heat shock genes hsp70 and SSA1 in HL60 cells and the yeast *Saccharomyces cerevisiae*, respectively (1.8-fold in 20 min) (Goodman et al., 1994). This group used the same exposure conditions — with longer exposures in some papers — and different cell lines to show that ELF magnetic fields activated heat shock factor 1 (HSF1), enhanced binding of the c-myc protein to sites within the heat shock protein promoter region and enhanced the DNA binding activity of different transcription factors such as AP1 in the hsp70 promoter region by contrast to heat shock (Lin et al., 1997; 1998a; 1998b; 1999). An increase in the hsp70 protein was also observed, with a maximum increase of 40% in normal human breast cells (HTB124) (Han et al., 1998). Moreover, an electromagnetic field response element EMRE (nCTCTn sequence) was identified in the hsp70 promoter (3 sequences) as well as in the case of c-myc (8 sequences in the promoter) (Goodman & Blank, 1998).

Pipkin et al. (1999) also showed that inducible hsp70 (hsp70B) was overexpressed after ELF magnetic field exposure (60 Hz, 1 mT), but the field strength required for the effect was higher than that reported by the Goodman group.

In a recent paper, Tokalov & Gutzeit (2004) studied the expression of a number of genes from the hsp family (hsp27, 60, 70A, 70B, 70C, 75, 78, 90, 90 and hsc70) in HL60 cells under exposure to a 50 Hz magnetic field at different strengths (10–140 μT) with or without heat shock (43 °C) for 30 minutes. Only the three hsp70 genes were overexpressed after exposure to magnetic fields alone, with a maximum induction at 80 μT and almost background levels of expression at 100 and 140 μT. Moreover, when exposure to

a 100 μT magnetic field was concomitant to heat shock, the expression of the hsp70 genes was stronger than that with either treatment alone.

In contrast, other groups did not find any effects of ELF magnetic fields on hsps including hsp70 in other cell lines (Balcer-Kubiczek et al., 2000; Kang et al., 1998; Miyakoshi et al., 2000a; Parker & Winters, 1992). However, Miyakoshi et al. (2000a) showed that magnetic field exposure suppressed hsp70 expression induced by heat treatment (40–42 °C).

In a replication study of the work of the Goodman group, Morehouse & Owen (2000b) observed no significant effect on the induction of hsp70 expression and HSF-HSE binding in HL60 cells exposed to a 6.3 or 8.0 μT, 60 Hz magnetic field. Recently, Coulton et al. (2004) found no effect on the expression of hsp27, hsp70A (constitutive) and hsp70B (inducible) genes in human peripheral blood cells exposed to 50 Hz magnetic fields (20–100 μT) for 2 or 4 h. They concluded that these genes in human normal blood cells were not responsive to ELF magnetic fields

The in vitro studies on gene expression are summarized in Table 81.

### *11.4.3 Differentiation, proliferation and apoptosis*

Only a few papers have dealt with differentiation, proliferation and apoptosis in recent years.

Ventura et al. (2005) exposed GTR1 embryonic stem cells to a 50 Hz, 0.8 mT magnetic field for 3 or 10 days, i.e. at the time of differentiation state for embryonic bodies and puromycin-selected cardiomyocytes, respectively. They showed that, under exposure, both embryonic bodies and cardiomyocytes overexpressed mRNA for two transcription factors known to be essential in cardiogenesis (GATA-4 and Nkx-2.5), as well as prodynorphin mRNA and the dynorphin protein, all involved in cardiac differentiation. This was correlated with the increased expression of two cardiac-specific mRNAs (a-myosin heavy chain and myosin light chain 2V) in magnetic field exposed cells and a significant increase in the number of beating cells within the 10 days of exposure.

Manni et al. (2004) exposed human oral keratinocytes to a 2 mT, 50 Hz magnetic field for up to 15 days. Exposure resulted in a number of changes with respect to sham-exposed samples that were correlated to cellular differentiation. The authors noted modifications in cells shape and morphology with a different actin distribution and an increased expression in involucrin and -catenin (markers of differentiation and adhesion) along with a decreased expression of epidermal growth factor receptors. These effects were accompanied by a diminished clonogenic capacity and a decreased cellular growth.

# Engineering Assessment

## Scope and Limitations

At the request of Ameren Transmission Company of Illinois (ATXI), Exponent conducted specific modeling and evaluations of the electrical environment of the Mark Twain Transmission Project. Specifically, Kevin L. Graf, B.S., M.S., Ph.D., employed by Exponent Inc., conducted an engineering assessment involving the modeling of electric and magnetic fields associated with the operation of the proposed Mark Twain Transmission Project. John D. Martens, Ph.D., M.B.A., P.E., CFEI (Missouri P.E., License No. 2010036256), also employed by Exponent, has reviewed this work.

This report presents the findings to date in this matter pertaining to the issues Exponent's engineers were asked to address. In the analysis, Exponent has relied upon transmission line design geometry, forecasted line loadings, specifications, and various other types of information provided by the client. Exponent cannot verify the correctness of this input data, and relies on the client for the data's accuracy. ATXI has confirmed to Exponent that the data contained herein are not subject to Critical Energy Infrastructure Information restrictions. Although Exponent has exercised usual and customary care in the conduct of this analysis, the responsibility for the design and operation of the project remains fully with the client.

The findings presented herein are made to a reasonable degree of engineering and scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available, through any additional work, or review of additional work performed by others.

The scope of services performed during this investigation may not adequately address the needs of other users of this report other than for permitting of this project, and any re-use of this report or its findings, conclusions, or recommendations presented herein are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. No guarantee or warranty as to future life or performance of any reviewed condition is expressed or implied.

John D. Martens, P.E.

## Introduction

Exponent computed electric and magnetic-field (EMF) levels for four sections of the proposed transmission line route for the Mark Twain Transmission Project. The cross sections (XS-1 – XS-4) of the right-of-way (ROW) where the line configurations were modeled are labeled on a map of the proposed transmission line route in Figure 1 with directional arrows shown for each cross section indicating the view of calculations (e.g., looking north in XS-1). Cross sections XS-1, XS-2, and XS-3 each contain only the proposed 345-kilovolt (kV) line and are identical in physical modeled configuration, differing only in the current loading level in each cross section. XS-1 represents that portion of the route between the Wind Zone (an assumed future wind generation facility) and Ottumwa Substation, XS-2 represents the route between the Zachary Substation and the Wind Zone, and XS-3 represents the route between the Maywood and Zachary Substations. XS-4 contains only the proposed 161-kV line, and represents the portion of the route between the Zachary and Adair Substations.

Typical steel pole structures for the 345-kV and 161-kV lines are presented in Figure 2. The 345-kV line will be supported on 110-foot high steel pole single-circuit delta structures. The 161-kV line will be supported on 85-foot high steel pole double-circuit structures. While the 161-kV double-circuit structure is capable of supporting two transmission lines, it will only support the single proposed 161-kV line for this project in XS-4. As depicted for XS-4 facing west, the three conductors of the 161-kV line will be on the left (south) side of the double-circuit structure.

In XS-1, XS-2, and XS-3, the 345-kV steel pole structure will be located at the center of a 150-foot ROW, and will be the only transmission line structures on the ROW. Phasing of the 345-kV line has been modeled as B-A-C top to bottom. In XS-4, the 161-kV steel pole structures will be located at the center of a 100-foot ROW, and will be the only transmission line structure on the ROW. Phasing of the 161-kV line has been modeled as A-B-C top to bottom. Projected annual average and peak loading for the 345-kV and 161-kV lines in each cross section are summarized in Table 1 for calendar year 2021.

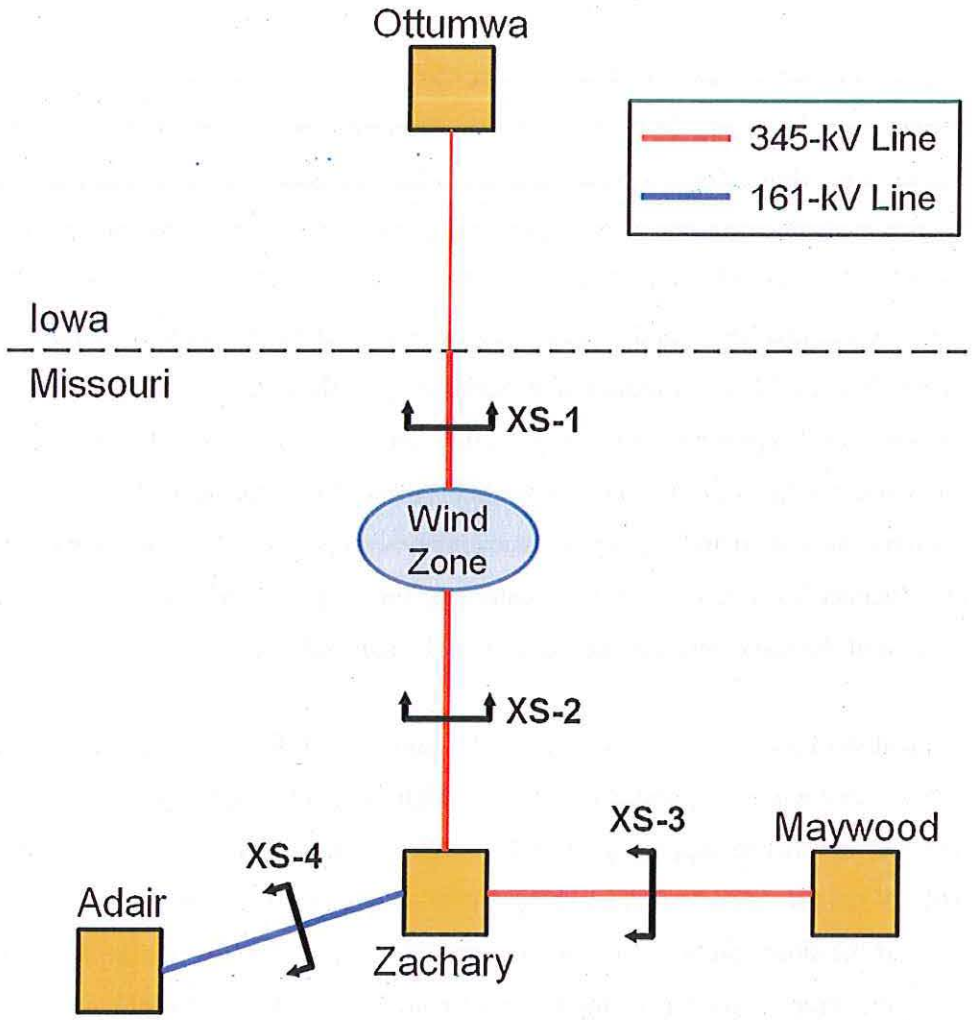
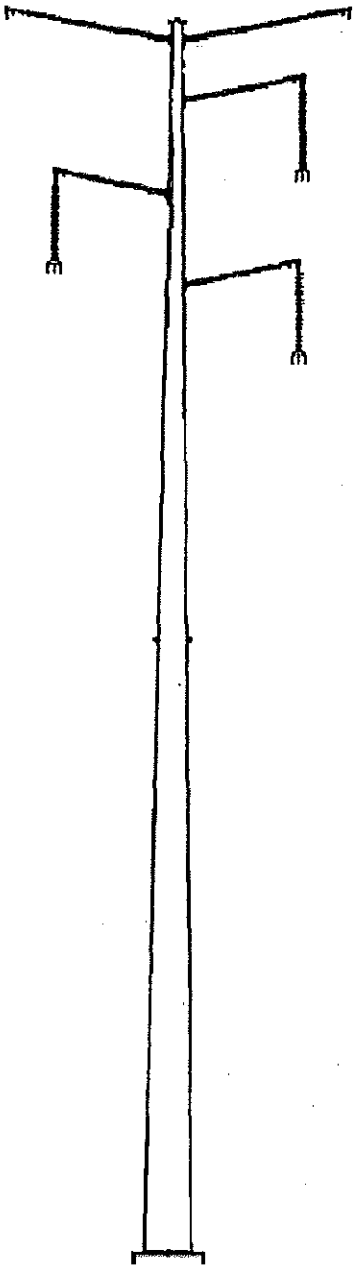



Figure 1. Schematic view of the proposed transmission line sections of the Mark Twain Project. Representative cross sections XS-1, XS-2, XS-3, and XS-4 are labeled.

345-kV Tangent Single Circuit
Steel Pole Structure



161-kV Tangent Double Circuit
Steel Pole Structure

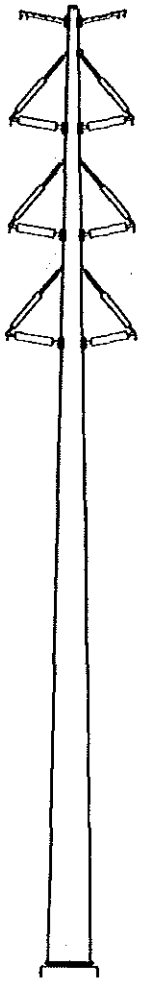


Figure 2. Typical steel pole structures for the 345-kV and 161-kV lines.

## Methodology

EMF levels were calculated using computer algorithms developed by the Bonneville Power Administration,[1] which have been shown to accurately predict field levels near transmission lines.[2] EMF levels were calculated for each of the four representative cross sections XS-1 through XS-4 at a location mid-span between structures where conductors are closest to the ground.

Calculations were performed along a transect perpendicular to the path of the transmission lines, with each conductor modeled as infinite in length above a flat earth, and parallel to each other conductor. EMF levels were calculated as the root-mean-square value of the resultant field at 1 meter above ground in accordance with IEEE Std. C95.3.1-2010 and IEEE Std. 644-1994 (Rev. 2008).[3] Electric-field levels were computed assuming a 5% overvoltage condition to ensure that all calculated values represent the maximum expected values along the projected route.

Expected load flows were derived from hourly flows of power across each transmission line for all scenarios and years modeled by witness Todd Schatzki, Ph.D., of the Analysis Group, Inc. Hourly flows are the result of the security-constrained economic dispatch, as modeled in PROMOD, a program used to simulate the operation of the regional generation and transmission system. The data set for the PROMOD analysis is the same data set used by MISO in its MVP Study, which is based on the MISO Transmission Expansion Plan 2011. These loading data for the year 2021 are summarized in Table 1 below and were used in computing magnetic-field levels. The descriptors of average and peak are used here apply to

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[1] Bonneville Power Administration (BPA). Corona and Field Effects Computer Program. Portland, OR: Bonneville Power Administration, 1991.

[2] See, for example, Chartier VL and Dickson LD. Results of Magnetic Field Measurements Conducted on Ross-Lexington 230-kV Line. Report No. ELE-90-98. Portland, OR: Bonneville Power Administration, 1990; Perrin N, Aggarwal RP, Bracken TD, Rankin RF. Survey of Magnetic Fields near BPA 230-kV and 500-kV Transmission Lines. Portland, OR: Portland State University, 1991.

[3] Institute of Electrical and Electronics Engineers (IEEE). Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines. ANSI/IEEE Std. 644-1994. New York: IEEE, 1994, Rev. 2008; Institute of Electrical and Electronics Engineers (IEEE). IEEE Recommended Practice for Measurements and Computations of Electric, Magnetic, and Electromagnetic fields with respect to Human Exposure to Such Fields, 0 Hz to 100 kHz (IEEE Std. C95.3.1-2010). New York: IEEE, 2010.

typical normal and high loading as might occur for a few hours or days during the year, respectively.

**Table 1. Projected annual average and peak loading for calendar year 2021**

| Cross Section | Circuit Voltage | Average Load (MW) | Peak Load (MW) |
|---|---|---|---|
| XS-1 | 345-kV | 152 | 531 |
| XS-2 | 345-kV | 389 | 796 |
| XS-3 | 345-kV | 301 | 525 |
| XS-4 | 161-kV | 93 | 342 |

## Results

The results of EMF calculations for each of the four representative cross-sections of segments of the proposed project are summarized in Table 2 through Table 4, and complete modeling results are presented in Figure 3 through Figure 10.

Each table presents the field levels at five locations on the respective ROW for each cross section: 100 feet beyond the left (–) ROW edge; at the left (–) ROW edge; the maximum value anywhere on the ROW; at the right (+) ROW edge; and 100 feet beyond the right (+) ROW edge.

Table 2 and Table 3 summarize the magnetic-field levels for average and peak loading, respectively; Table 4 summarizes the electric-field levels (loading does not affect the calculated electric-field levels). Each figure presents a plot of the electric- or magnetic-field levels for a given cross section. Figure 3 through Figure 6 show the magnetic-field levels for XS-1 through XS-4, respectively, for both average and peak loading. Figure 7 through Figure 10 show the electric-field levels for XS-1 through XS-4, respectively.

The maximum magnetic-field level at the ROW edge for both average and peak loading occurs at the eastern ROW edge of XS-2—24 milligauss (mG) for average loading and 50 mG for peak loading. The maximum occurs in XS-2 primarily because average and peak loadings are

highest in this cross section. At 100 feet beyond the ROW edge, the calculated magnetic-field levels fall to 10 mG or less in all cross sections.

The maximum electric-field level at the ROW edge is 1.1 kilovolts per meter (kV/m), which occurs at the western edge of XS-1 and XS-2, and the southern edge of XS-3. At 100 feet beyond the ROW edge, the calculated electric-field levels fall to 0.2 kV/m or less in all cross sections. Calculated electric-field levels are the same for XS-1, XS-2, and XS-3 because each of these three cross sections is identical except for their average and peak loading, and loading does not affect the calculated electric-field levels. Calculated electric-field levels are lower in XS-4 where the line voltage is 161-kV as opposed to 345-kV.

There are no engineering standards or guidelines in Missouri for levels of EMF from transmission lines. Ameren Transmission Company of Illinois (ATXI) is required, however, to meet requirements of the 2012 American National Electrical Safety Code design guidelines that limit induced current under overhead transmission lines to prevent harmful electric shock.

**Table 2. Magnetic-field levels (mG) at average loading**

| | Location | | | | |
|---|---|---|---|---|---|
| Cross Section | 100 ft beyond −ROW edge | −ROW edge | Max on ROW | +ROW edge | 100 ft beyond +ROW edge |
| XS-1 | 1.9 | 8.2 | 36 | 9.5 | 2.0 |
| XS-2 | 4.8 | 21 | 92 | 24 | 5.1 |
| XS-3 | 3.7 | 16 | 71 | 19 | 4.0 |
| XS-4 | 2.1 | 13 | 29 | 9.1 | 1.7 |

Table 3. Magnetic-field levels (mG) at peak loading

| Cross Section | Location | | | | |
|---|---|---|---|---|---|
| | 100 ft beyond −ROW edge | −ROW edge | Max on ROW | +ROW edge | 100 ft beyond +ROW edge |
| XS-1 | 6.5 | 29 | 126 | 33 | 7.0 |
| XS-2 | 9.8 | 43 | 188 | 50 | 10 |
| XS-3 | 6.4 | 28 | 124 | 33 | 6.9 |
| XS-4 | 7.5 | 47 | 106 | 33 | 6.3 |

Table 4. Electric-field levels (kV/m)

| Cross Section | Location | | | | |
|---|---|---|---|---|---|
| | 100 ft beyond −ROW edge | −ROW edge | Max on ROW | +ROW edge | 100 ft beyond +ROW edge |
| XS-1 | 0.2 | 1.1 | 4.8 | 0.9 | 0.1 |
| XS-2 | 0.2 | 1.1 | 4.8 | 0.9 | 0.1 |
| XS-3 | 0.2 | 1.1 | 4.8 | 0.9 | 0.1 |
| XS-4 | <0.1 | 0.2 | 1.5 | 0.1 | <0.1 |

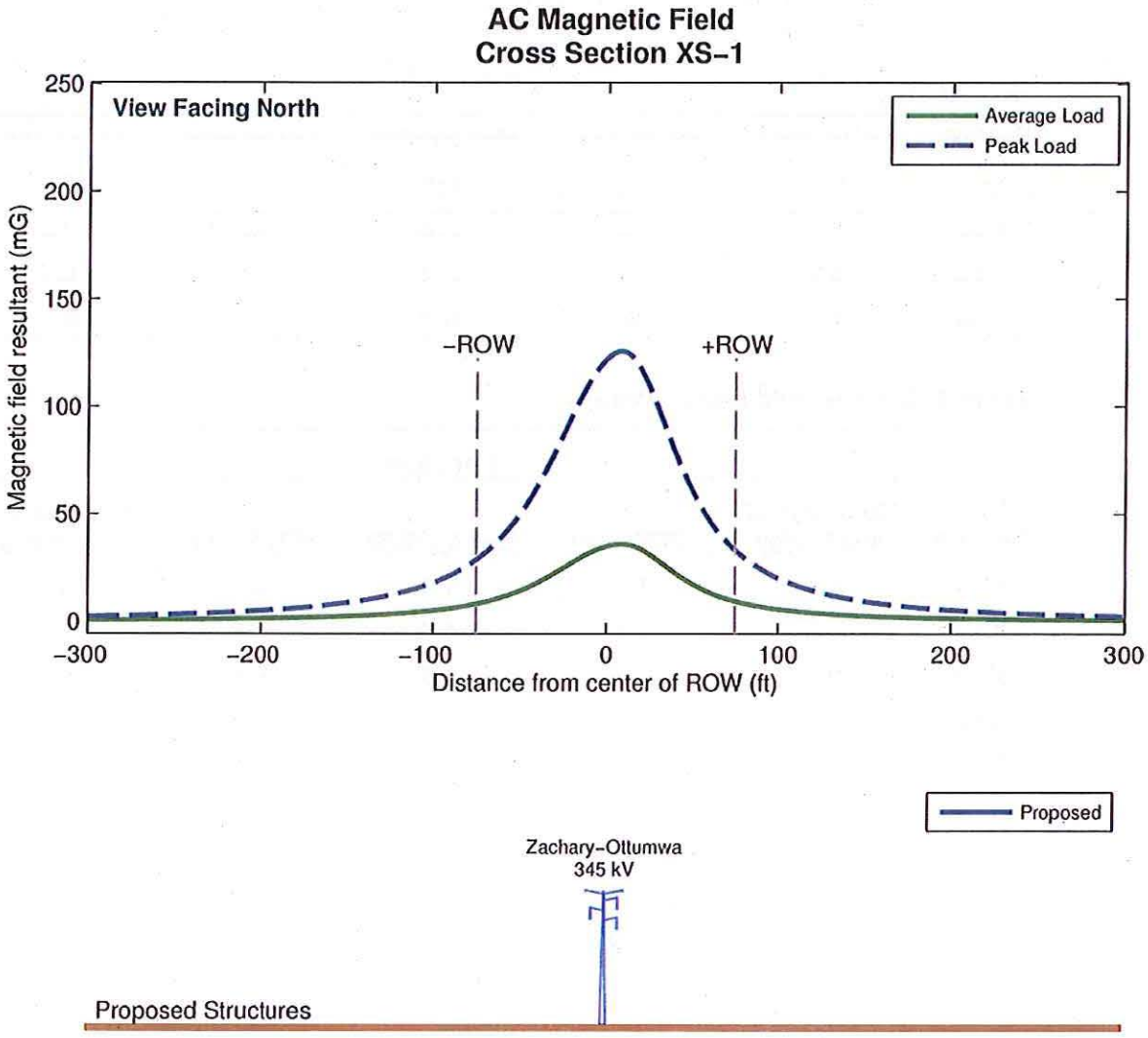


Figure 3. Magnetic-field levels calculated for average and peak loading for XS-1.

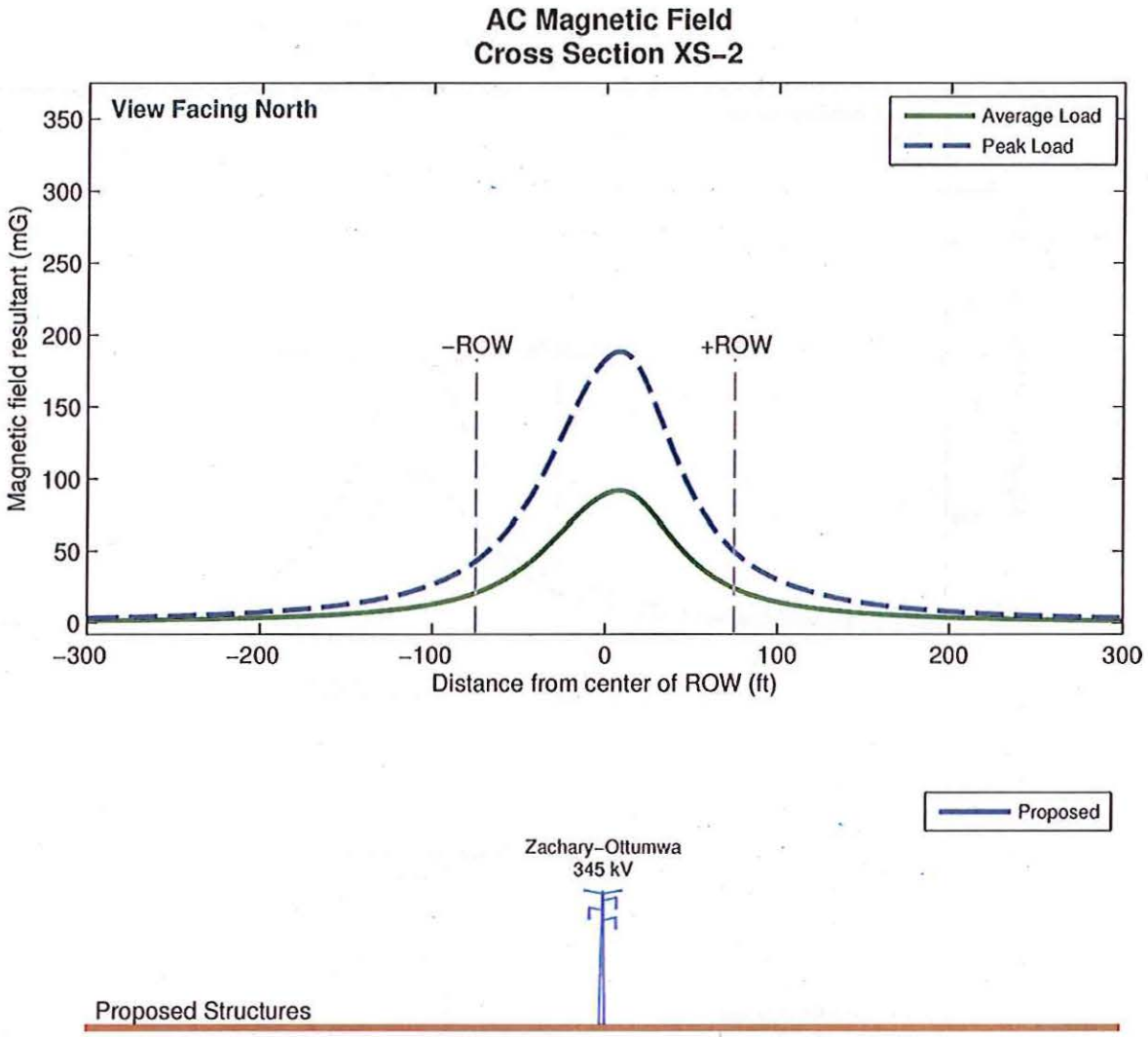


Figure 4. Magnetic-field levels calculated for average and peak loading for XS-2.

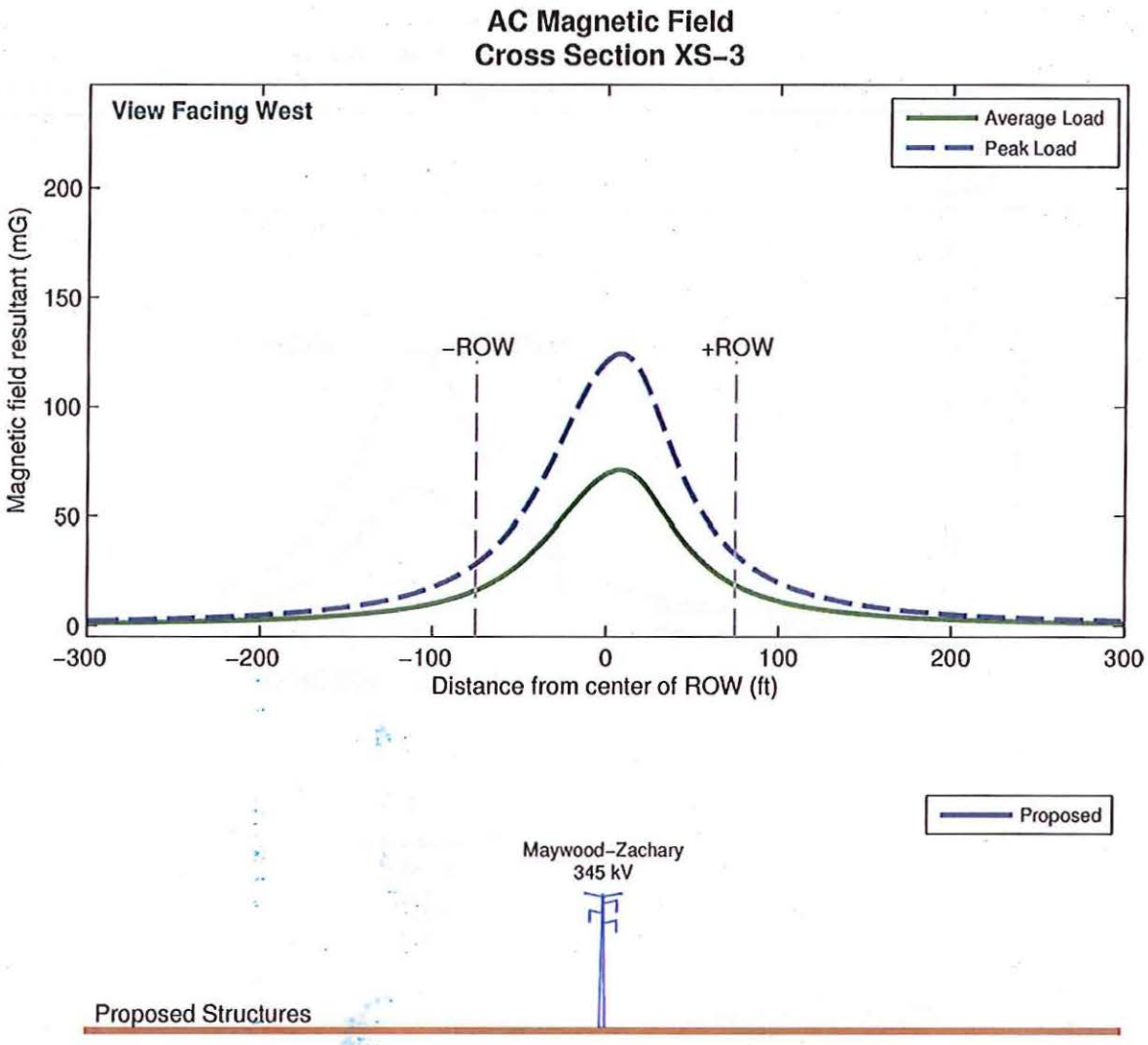


Figure 5. Magnetic-field levels calculated for average and peak loading for XS-3.

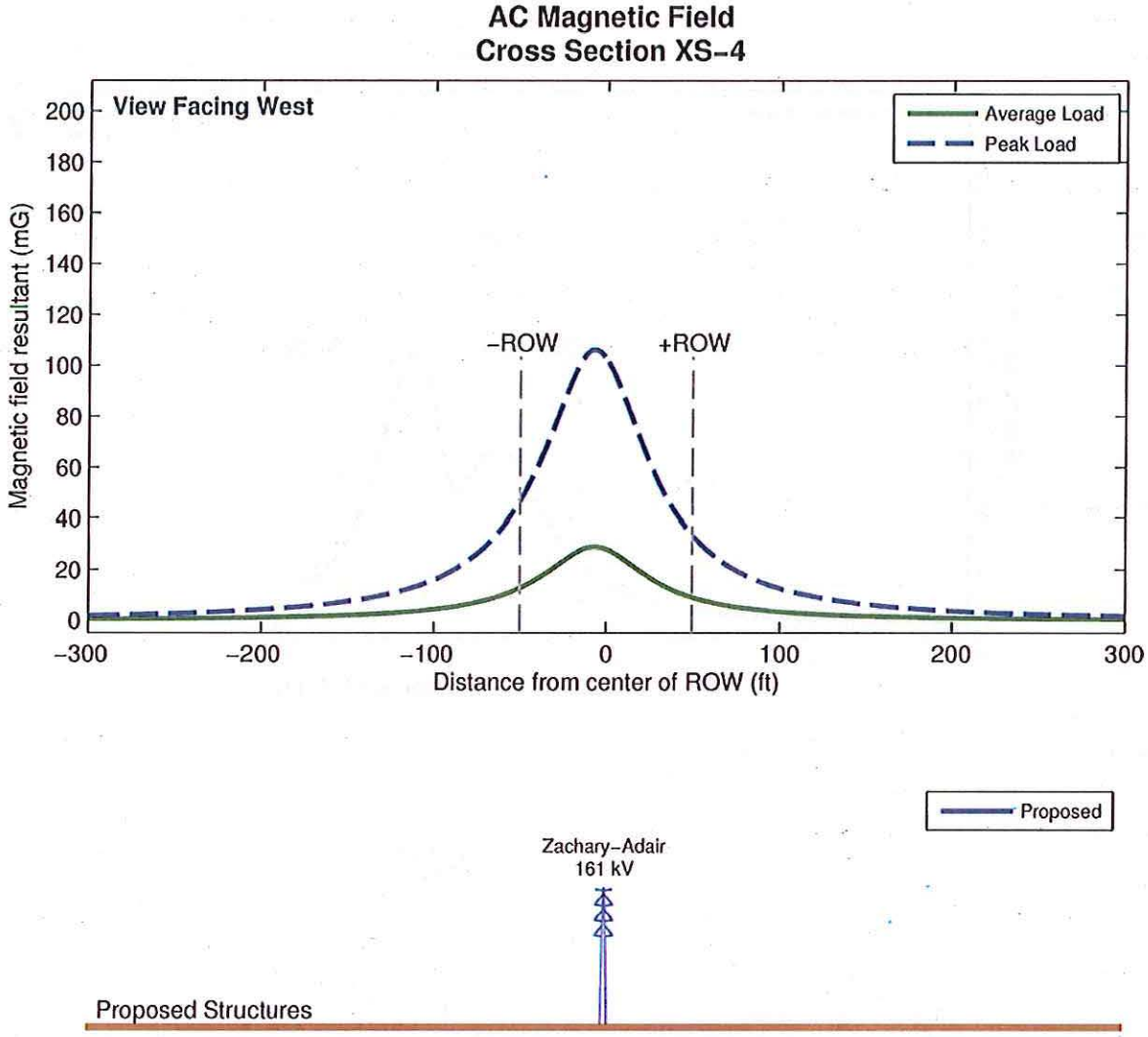


Figure 6. Magnetic-field levels calculated for average and peak loading for XS-4.

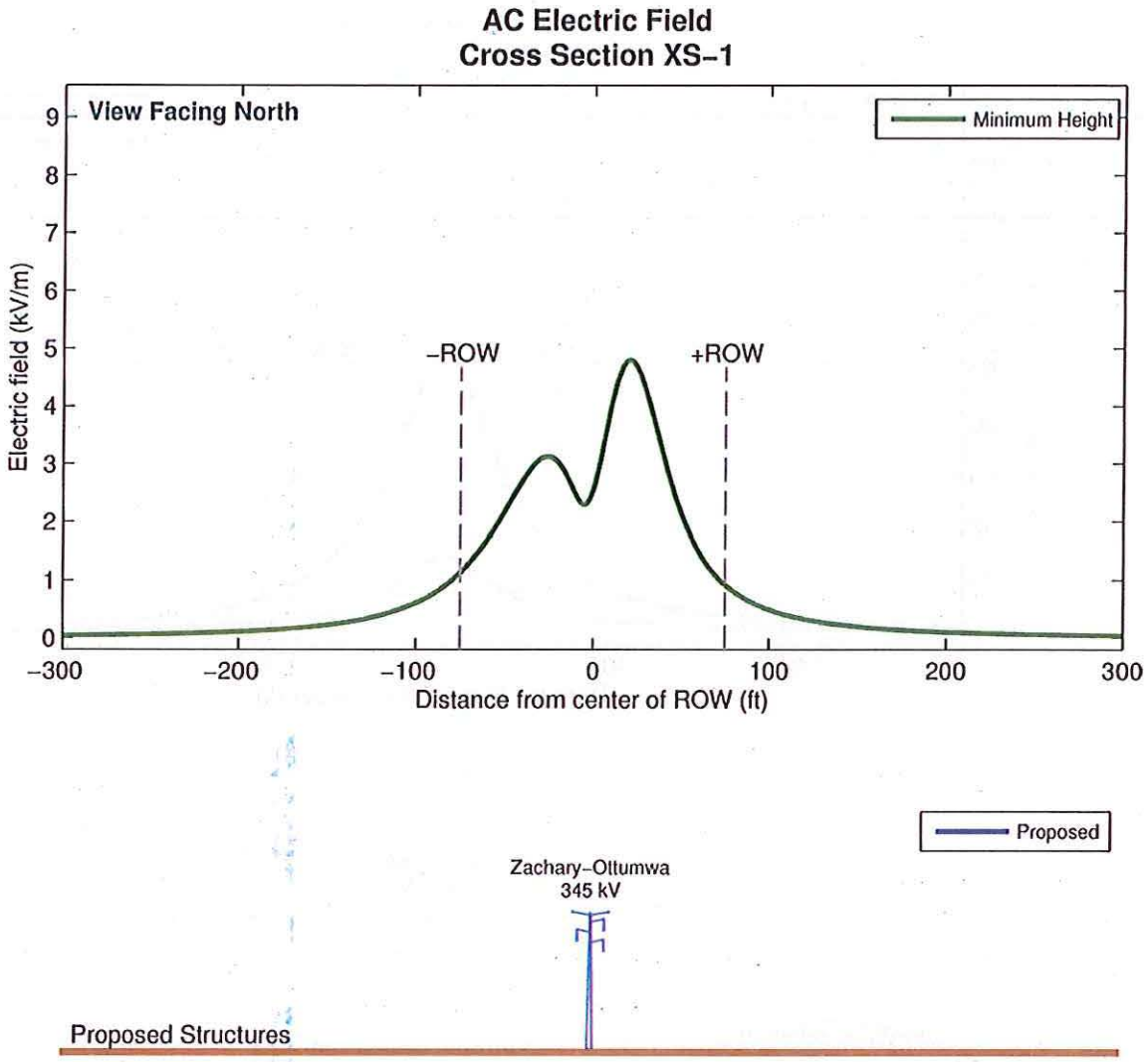


Figure 7. Electric-field levels calculated for XS-1.

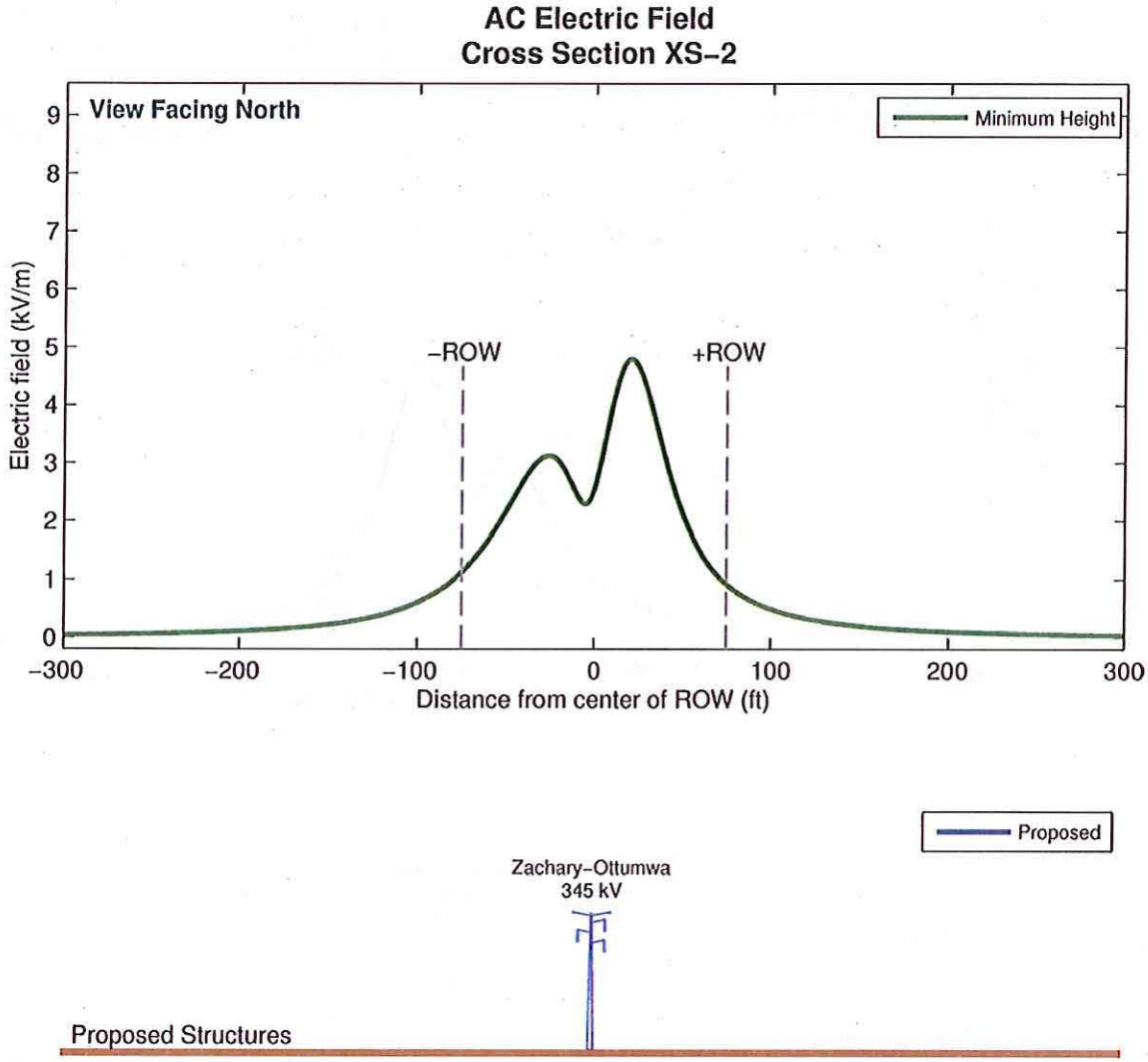


Figure 8. Electric-field levels calculated for XS-2.

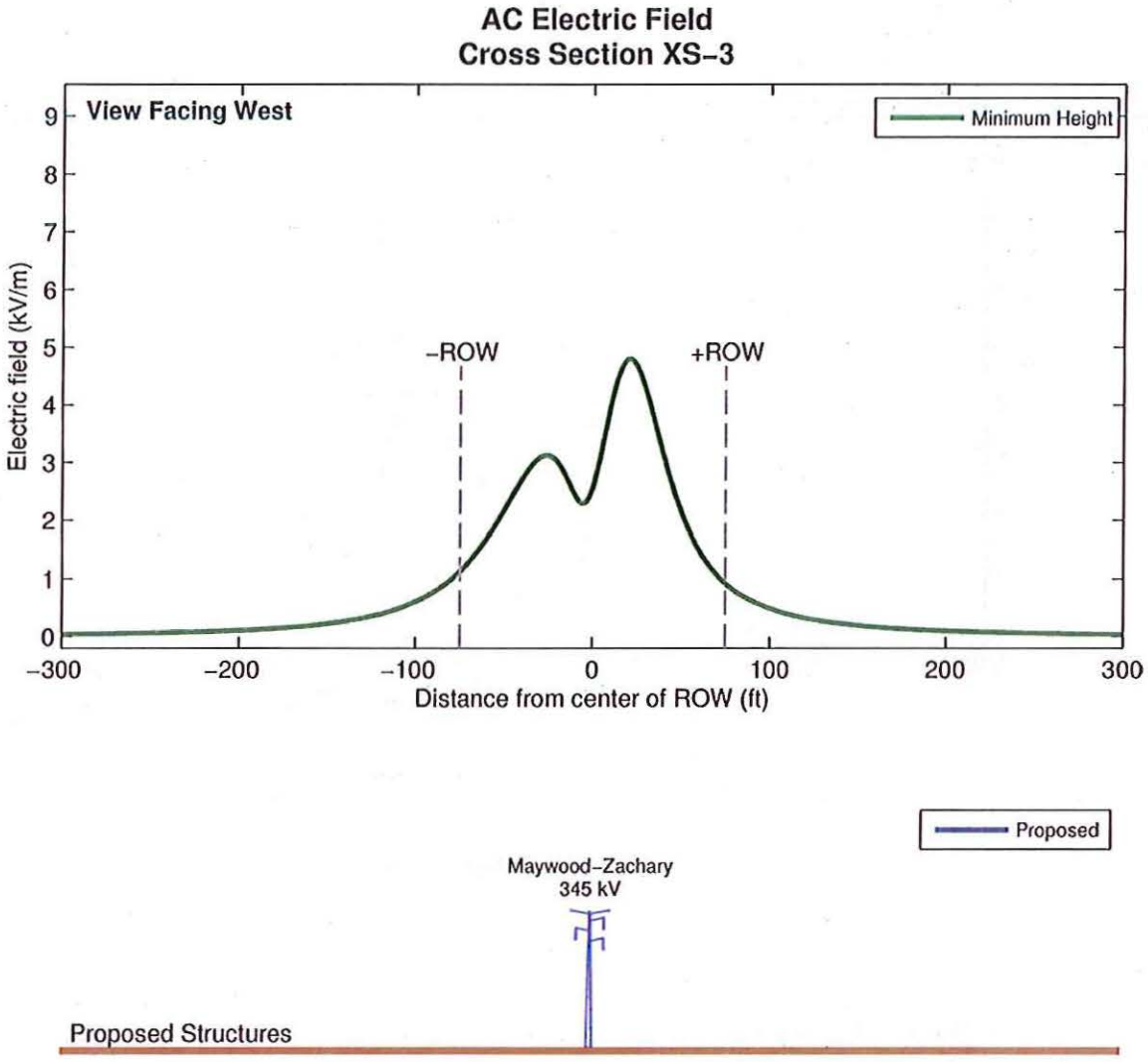


Figure 9. Electric-field levels calculated for XS-3.

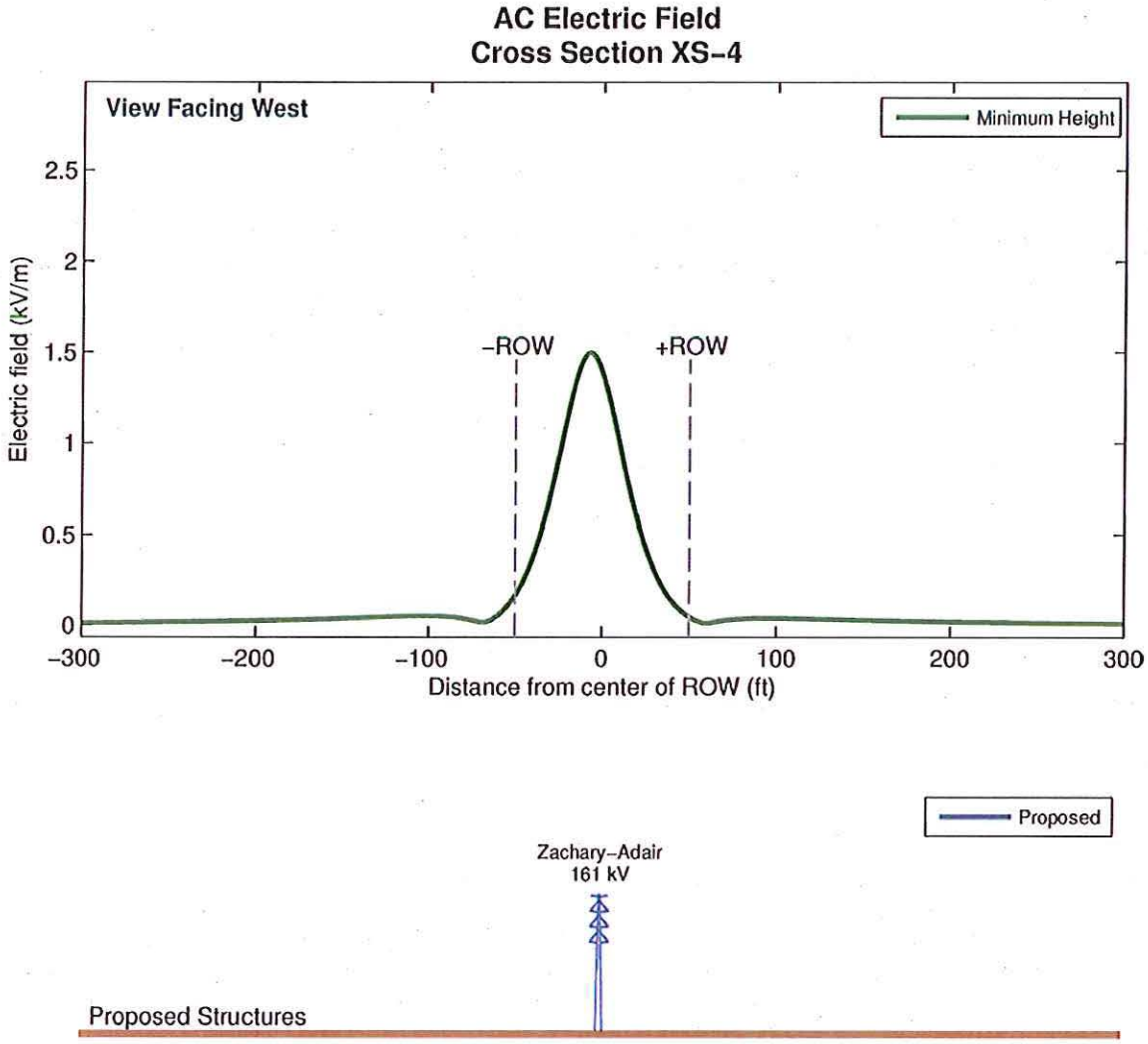


Figure 10. Electric-field levels calculated for XS-4.