4.6 Electromagnetic Fields and Electromagnetic Interference

4.6.1 Introduction

This section describes the affected environment and environmental consequences related to electromagnetic fields (EMF) and electromagnetic interference (EMI) from operations of the BART Extension. EMF is associated with electromagnetic radiation, which is energy in the form of photons. Radiation energy spreads as it travels and has many natural and human-made sources. The electromagnetic spectrum, the scientific name given to radiation energy, includes light, radio waves, and X-rays, among other energy forms. For purposes of describing the EMF setting and effects for the BART Extension, human-made sources of radiation energy and associated EMF are relevant.

4.6.2 Environmental and Regulatory Setting

4.6.2.1 Environmental Setting

This section discusses the existing conditions related to EMF and EMI in the BART Extension area, including staging areas.

Because EMF levels are typically site-specific, the existing EMF environment along the corridor varies depending upon location. For example, commercial and industrial centers using major electrical systems and areas near high-voltage lines or other power transmission networks would likely have higher EMF levels than residential and undeveloped areas. Land uses within urbanized areas vary from industrial to commercial to residential. Table 4.6-1 shows measurements to establish EMF levels. Although these measurements were taken in 2003, these are considered valid in 2015 because background EMF levels typically change little over time in urban areas such as the area along the alignment. New development since 2003 has typically been urban infill that has not resulted in substantial new sources of EMF. It is anticipated that the range of EMF levels presented below represents the existing range of EMF levels along the alignment.

Table 4.6-1: EMF Levels along BART Extension

Location	Vertical Field Peak (in Gauss / μT)
Southwest corner of 28th and Santa Clara Streets	1.7 G / 170 μT
At Berryessa Road crossing of right-of-way	1.1 G / 110 μT
Center island of Montague Expressway (east side) at North Capitol Avenue (Tasman East light rail line right-of-way)	1.4 G / 140 μT
Along north side of Santa Clara Street between Market Street and North 1st Street	.9 – 1.4 G 90 – 140 μT
Along north side of Santa Clara Street between Terraine Street and Notre Dame Street	1.0 – 1.4 G 100 μT – 140 μT
At Caltrain Depot on Railroad Avenue at Palm Drive, Santa Clara (near airport)	.9 – 1.1 G 90 μT – 110 μT

Source: Earth Tech, Inc. 2003.
μT = microTesla

Medical facilities with magnetic resonance imaging are particularly susceptible to EMF because high EMF levels can interfere with the equipment.

The closest medical facilities (with imaging facilities) to the BART Extension Alternative where EMF interference would be of concern are listed below.

- Regional Medical Center of San Jose (225 N Jackson Avenue, San Jose, CA 95116), approximately 1 mile to the east of the BART Extension Alternative.
- Santa Clara Valley Medical Center and Valley Specialty Center (751 S Bascom Avenue, San Jose, CA 95128), approximately 2 miles to the southwest of the BART Extension Alternative.
- Santa Clara Imaging Center (1825 Civic Center Drive, Santa Clara, CA 95050), approximately 1.1 miles to the west of the BART Extension Alternative.

  The San Jose Medical Center was analyzed as a medical facility with magnetic resonance imaging as part of the 2004 FEIR. However, the Medical Center has since moved and is located more than 8 miles to the south of the BART Extension Alternative.

4.6.2.2 Regulatory Setting

The commonly known human-made sources of EMF are electrical systems such as electronics, telecommunications, electric motors, and other electrically powered devices. The radiation from these sources is invisible, non-ionizing, and low frequency. Generally, in most living environments, the level of such radiation plus background natural sources of EMF are low and not considered hazardous. Under extreme conditions, however, EMF can become intense, and hazards include shock and burn. Such conditions are nevertheless rare. The more pertinent concern over EMF exposure is the potential biological and health effects to individuals as the number of EMF-generating activities increases. As more sources of EMF are introduced, the extent and level of human exposure increases. The potential biological and health effects are under much study and intense debate.

Another concern over EMF generation is the potential interference to other electromagnetic systems that can result when new or more intense sources of radiation are introduced into the environment. These effects are better understood than health effects and are well documented. Electromagnetic interference (EMI) may include interruption, obstruction, or other degradation in the effective performance of electronics and electrical equipment. Depending upon the critical nature of this equipment, the effects can have serious consequences for the health and safety of individuals. Perhaps of less concern, but nonetheless important, is that the efficiency of affected systems may be reduced.

With the increasing number of personal computer systems in use in homes and businesses, a common problem is magnetic interference to computer monitors when used near alternating current (AC) or varying direct current (DC) magnetic fields. Computer monitors, particularly large screen monitors, are susceptible to interference created from nearby electrical sources, such as electrical panels, transformers, currents within internal systems wiring, and transmission and distribution lines.

Data corruption can also occur on magnetic or film media from very high magnetic fields. It is commonplace for data files to be transported using pocket-size magnetic or film media, particularly floppy or zip diskettes. The potential for computer monitor interference and data corruption on magnetic media from the operation of BART Extension Alternative is extremely small. It is worth noting that magnetic media materials (e.g., fare cards, credit cards, laptop computers with hard drives) are routinely carried by passengers on DC-powered transit systems throughout the world, with no reported negative effects.

As the name implies, EMF has electrical and magnetic field components. With respect to electrical systems, electric fields result from the strength of the electric charge (voltage), with DC generating stronger EMFs than AC at a given voltage, while magnetic fields result from the motion of the charge (current). Electric field strength is measured in units of volts per meter (V/m) and is greater the higher the voltage. Field strength deteriorates rapidly with distance from the source. Magnetic field strength has several units of measure; the most commonly used are milligauss (mG) and microTesla (µT). Ten milligauss equal one microTesla. Magnetic fields also deteriorate with distance but readily pass through most objects. Magnetic fields are typically the radiation of concern when evaluating EMFs.

Although modern society increasingly relies on electromagnetic systems, strong EMF fields are not associated with the normal living and working environment. Examples of EMF intensities from human activities include the following.

- Overhead power transmission line: 32 to 57 mG (range of exposure to utility workers).
- Household appliances: 8 to 165 mG (at a distance of 27 cm, or 12 inches).
- Computer video display: 2 to 4 mG (at 35 cm, or 16 inches).

- Rail vehicle (electrically powered): 400 mG (at 110 cm, or 43 inches from the vehicle floor) to 1,500 mG (at floor level).[1]

For comparison, in the natural environment apart from human activity, the earth's static magnetic field varies from 300 mG (30 µT) at the equator to more than 600 mG (60 µT) at the magnetic poles. In San Jose and Santa Clara, the earth has a natural static magnetic field of about 510 mG (approximately 50 µT).

Although short-term human health effects from exposure to elevated levels of EMFs are well established, such as effects on the central nervous system and heating of the body, the long-term effects from exposure to lower levels of EMFs continue to be studied. Several reports have proposed a link between EMF exposures and such health problems as cancer, including childhood leukemia. The preponderance of authoritative scientific studies, however, has found no firm evidence of long-term health risks from low-intensity EMF exposures. Despite the lack of scientific evidence of harm, the public continues to express concern, and health and regulatory agencies continue to study the matter.

Neither the federal government nor the state has set standards for EMF exposures. The Federal Drug Administration, Federal Communications Commission, U.S. Department of Defense, and the U.S. Environmental Protection Agency at various times have considered guidelines. The California Department of Education has established a policy of "prudent avoidance" for the location of schools in the vicinity of high-voltage power lines. Several states and other countries have standards for electrical field exposures.

The American Conference of Governmental Industrial Hygienists (ACGIH) publishes annual threshold limit values (TLVs) for chemical substances and physical agents, as well as biological exposure indices (BEIs). In the 2013 TLVs and BEIs published by the ACGIH, threshold limit values are recommended for static (DC) magnetic flux densities to which it is believed that nearly all persons may be repeatedly exposed day after day without adverse health effects. According to ACGIH, these values may be used as guides in the control of exposure to static magnetic fields but should not be regarded as fine lines between safe and dangerous levels.

The ACGIH guidelines suggest that routine occupational exposures should not exceed 60,000 µT to the whole body, or 600,000 µT to the body's limbs on a daily, time-weighted average basis (ACGIH 2013). Recommended ceiling values are 2 Tesla (2,000,000 µT) for whole body, and 5 T for the limbs. Safety hazards may exist from the mechanical forces exerted by the magnetic field upon ferromagnetic tools and medical implants. Cardiac pacemakers and similar medical electronic device wearers should not be exposed to field levels exceeding 0.5 T (500,000 µT). These values are listed in Table 4.6-2.

[1] *Safety of High Speed Guided Ground Transportation Systems, EMF Exposure Environments Summary Reports*, Federal Railroad Administration, August 1993.

Table 4.6-2: ACGIH Guidelines for EMF Exposure

Body	Whole Body	Limbs
Daily Average	60,000 µT	600,000 µT
Ceiling Values	2T	5T
Medical Device Wearers	0.5T	N/A
Sources: ACGIH 2013. T = Tesla µT = microTesla		

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published reference levels for general public exposure to time-varying magnetic fields (unperturbed root mean square values) of 40,000 µT for frequencies below 1 hertz (International Commission on Non-Ionizing Radiation Protection 1998). This reference level is given for the condition of maximum coupling of the field to the exposed individual, thereby providing maximum protection. The value is obtained from the basic restrictions by mathematical modeling and by extrapolation from the results of laboratory investigation. The ICNIRP guidelines on limits of exposure to static magnetic fields suggest that continuous exposure of the general public should not exceed a magnetic flux density of 40,000 µT (International Commission on Non-Ionizing Radiation Protection 1994).

The guidelines published by ICNIRP and ACGIH both recommend exposure limits well above those typically found within the passenger or pedestrian exposure fields from BART. Because the BART Extension would employ the same vehicles and propulsion system as those currently in use on BART, EMF influence on operators or passengers within the vehicles would not change from current operation levels.

4.6.3 Methodology

For the present analysis, a computer model was designed to calculate the worst-case static magnetic field strength that could result from BART Extension operations. An at-grade rail profile was developed in the model with the third rail located inside, or between, the running rails for each track. In each case modeled, a maximum third rail current of 12,000 amperes was used for simulation of a 10-car train under maximum load operation. This condition does not exist for extended operating periods, but typically only for short durations during maximum acceleration. Other moderating features that BART typically employs were omitted, such as multiple traction power substations and propulsion cross-bonding, which equalizes and distributes rail currents. This model is designed to illustrate the maximum potential field possible under normal operation. The earth’s magnetic field of 50 µT, as it exists in San Jose and Santa Clara, was used as a reference.

4.6.4 Environmental Consequences and Mitigation Measures

4.6.4.1 No Build Alternative

The No Build Alternative consists of the existing transit and roadway networks and planned and programmed improvements in the BART Extension vicinity that are identified in the Bay Area's Regional Transportation Plan (RTP), *Transportation 2035 Plan for the San Francisco Bay Area*, adopted by the Metropolitan Transportation Commission in 2009; the *Valley Transportation Plan 2040*, adopted by VTA in 2014; and the *Expressway Plan 2040 Study* (County of Santa Clara Roads and Airports Department 2015). The No Build Alternative would not introduce major new EMF generators into the BART Extension vicinity. Transit improvements would be primarily related to expanded bus service. Although bus systems may have electrical systems that would generate EMF, the potential exposure to riders would differ little from the exposure an individual would experience when riding in a non-electric private automobile. Therefore, the No Build Alternative would have *no adverse effect* related to EMF.

4.6.4.2 BART Extension Alternative

The BART Extension would result in new sources of EMF generation, and exposure of passengers and individuals working on the systems or passing in the vicinity of such systems. The main sources of EMF generation would include train power distribution systems; traction power substations with connecting lines to the major utility lines; passenger facilities, with their various electrical systems for lighting, communications, utilities, fare machines, and other systems, and their proximity to power distribution networks; and electrically powered rail passenger vehicles. Because the BART Extension would use DC traction power, contributions to the magnetic field levels of the ambient power frequency (60 hertz AC) would be negligible.

Tables 4.6-3 and 4.6-4 show the measured EMF values found above and below BART rails. The values in these tables are well below the guidelines presented in Table 4.6-2.

Table 4.6-3: Vertical Field Peak Measurements above Existing, Operating BART Tracks at Hopyard Overpass, Pleasanton for Reference

Location	Vertical Field Peak (in Gauss / µT)
Over eastbound Interstate 580 lanes – approximately 14 meters (46 feet) above rails, approximately 35° from rail center	2.1 G / 210 µT
Over eastbound I-580 lanes – approximately 14 meters (46 feet) above rails, directly over rail center	2.1 G / 210 µT
Source: Earth Tech, Inc. 2003.	

Table 4.6-4: Vertical Field Peak Measurements below Existing, Operating BART Pleasanton Line at Rodeo Park Underpass at BART/Interstate 580 for Reference

Location	Vertical Field Peak (in Gauss / µT)
Approximately 6 meters (20 feet) directly below eastbound rails – no train present	1.7 G / 170 µT
Approximately 6 meters (20 feet) directly below eastbound rails – six-car train moving overhead	1.8 G / 180 µT
Approximately 10 meters (33 feet) directly below and between eastbound and westbound rails.	2.0 G / 200 µT[a]

Source: EarthTech, Inc. 2003.
[a] Fairly constant field, with or without train movement overhead.
µT = microTesla

EMF intensities associated with trains vary considerably. The greatest potential fields would be within the electric rail vehicle. Therefore, the greatest potential for exposure would be for passengers, train operators, and attendants onboard the train. Passengers and workers would also be exposed to EMF fields in stations, and further exposure would occur to workers at traction power substations. Strong fields that carry a greater possibility of health risks would not be associated with these environments, however. The field strengths of electrified rail systems would be below maximum recommended exposure levels. Representative field measurements taken outside of existing BART stations are shown in Table 4.6-5.

Table 4.6-5: Vertical Field Peak and Range Measurements for Reference

Location	Range	Vertical Field Peak (in Gauss / µT)
Church of Christ, Pleasanton parking lot	Approximately 50 meters (164 feet) south of BART rails (with and without trains)	2.0 G / 200 µT
Church of Christ, Pleasanton parking lot	Approximately 100 meters (329 feet) south of BART rails (with and without trains)	1.9 G / 190 µT
Background field measurement between Dublin and Livermore	15 miles east of the end of BART tracks	1.3 – 1.7 G 130 µT – 170 µT
Background field measurement between Dublin and Livermore	15 miles east of the end of BART on farm	.8 – 1.4 G 80 µT – 140 µT

Source: EarthTech, Inc. 2003.
µT = microTesla

Measurements of DC magnetic fields were taken along the south wall of a substation at the Pleasanton Station where public exposure might occur. Additional measurements were taken at all three levels at the Lake Merritt Station. The values found at these BART stations are shown in Table 4.6-6. Field strengths onboard BART trains, which contain major propulsion equipment below floor level, show measurements ranging from 1,600 to 2,000 mG total (USDOT et al. 2002). These values are equal to 160 to 200 µT, which is well within the ACGIH and ICNIRP guideline thresholds.

Table 4.6-6: Vertical Field Peak Measurements at Representative BART Stations

Location	Vertical Field Peak (in Gauss / µT)
Between Pleasanton Station and BART rails, parking lot center – max. along south wall of substation	2.2 G / 220 µT
Lake Merritt Station – platform level between rail centers	1.3 G / 130 µT
Lake Merritt Station – Level 1, approximately 7 meters (23 feet) directly above southbound rails	1.7 G / 170 µT
Lake Merritt Station – Level 2, street level, approximately 15 meters (49 feet) directly above southbound rails	1.9 G / 190 µT
Source: Earth Tech, Inc. 2003. µT = microTesla	

The results of the modeling show that static magnetic field levels above 50 µT do not extend beyond 10.0 meters (32.8 feet) from the center of the tracks. This finding is based on two trains running in opposite directions on two parallel tracks. Electric currents are assumed to be evenly distributed between the power rails (i.e., the third rails) and the running rails (i.e., the iron rails on which BART trains run), which return very low voltage current to electric power substations. Under conditions when electric currents are not evenly distributed (e.g., if only one of the third rails is supplying power to a train or return currents are not balanced among the running rails), static magnetic field levels above 50 µT can extend to approximately 15.0 meters (49.2 feet) from the center to the BART tracks. At approximately 15.0 meters (49.2 feet), static magnetic field strength returns to the normal background level when there are no other sources of static electric currents present.

BART trains would run underground in tunnels for much of the alignment, which would significantly reduce exposure. The Twin-Bore is typically 40 feet below ground level and the Single-Bore is typically 70 feet below ground level. The distance between the underground tunnel, power lines, and any EMF sensitive device aboveground in the medical centers are adequate to reduce possible EMF interference from BART Extension operations, as demonstrated by the model discussed above. This analysis assumes the sensitive devices/equipment are at ground level. The Regional Medical Center of San Jose is approximately 1 mile to the east of the BART Extension Alternative, and the elevation difference between the nearest part of the tunnel and the facility elevation would be at least 20 feet depending on the boring option. The Santa Clara Valley Medical Center and Valley Specialty Center is approximately 2 miles to the southwest of the BART Extension Alternative, and the elevation difference between the nearest part of the tunnel and the facility elevation would be at least 20 feet. The Santa Clara Imaging Center is approximately 1.1 miles to the west of the BART Extension Alternative, and the alignment would be at-grade at this location. Because of the distances and depths, there would be no adverse effects to these medical facilities related to EMF.

The measurements and models presented in this section demonstrate that exposure levels for BART Extension passengers and operators, passengers and BART employees in a station, and other BART Extension workers would be well below the guidelines for preventing health effects. Therefore, the potential for non-users, businesses, and residences at ground level to experience EMF exposures from BART Extension would be minimal, and present evidence suggests that there would be no demonstrable health risks from exposure to EMF. Therefore, the Build Conditions would have *no adverse effect* related to EMF.

An EMF Control and Test Plan will be included in the general contractor specifications to maintain awareness of the possible effects of BART Extension construction and operation, as well as provide field measurement for, and confirmation of, the final design. The plan will include EMF limits (based on ICNIRP and ACGIH guidelines) in the design and construction specifications and require testing and measurement of the final installed system.

Because EMF intensities and exposures from BART Extension operations would be below thresholds indicating potential health risks, no mitigation measures are necessary.

4.6.5 NEPA Conclusion

The BART Extension Alternative would have *no adverse effect* under NEPA. No mitigation measures are necessary.

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