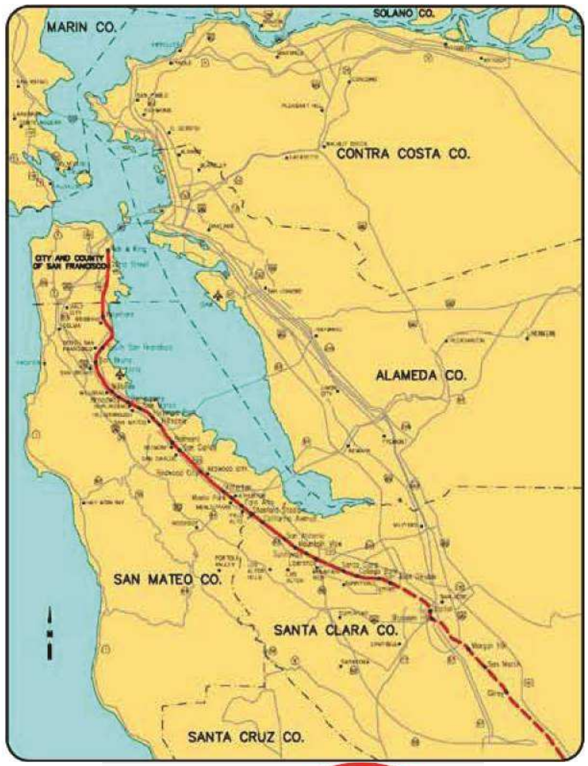
SAN FRANCISCO BAY AREA



Caltrain®

PENINSULA CORRIDOR JOINT POWERS BOARD

DESIGN BUILD ELECTRIFICATION PROJECT

CONTRACT NO. 14-PCJPB-P-053

New Rail System EMC Ambient Survey Procedure

CDRL 31517-002

REVISION 0

May 9, 2024

TURNER ENGINEERING CORPORATION

PGH WONG ENGINEERING INC.

Balfour Beatty Infrastructure Inc.

Revision History		
Date	**Rev.**	**Change**
May 9, 2024	0	Initial release.

This Page Intentionally Left Blank.

Table of Contents

List of Figures

References

Contractor RAM Program Plan - Reference Information		
Publisher	**Document Number**	**Title**
JPB	Contract Documents Volume 3 Part A Section 1	Scope of Work
JPB	Contract Documents Volume 3 Part A Section 3	Design Criteria

PCEP EMC Program - Reference Information		
Publisher	**Document Number**	**Title**
Turner Engineering Corporation	31517	EMC Ambient Survey Procedure
Turner Engineering Corporation	31517-001	Pre-existing EMC Ambient Survey Results
Turner Engineering Corporation	31510	EMC Control Plan
STV	33080	Stray Current and Atmospheric Study

List of Acronyms

Acronym	Definition
BART	Bay Area Rapid Transit
BBII	Balfour Beatty Infrastructure Inc.
CalMod	Caltrain Modernization Program
CFR	Code of Federal Regulations
DC	Direct Current
EIR	Environmental Impact Report
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
EMU	Electric Multiple Unit
GHz	Gigahertz
Hz	Hertz
JPB	Joint Powers Board
kHz	Kilohertz
MHz	Megahertz
OCS	Overhead Contact System
PCEP	Peninsula Corridor Electrification Project
ROW	Right-of-way
SFO	San Francisco International Airport
SJC	Mineta San Jose International Airport
Tenco	Turner Engineering Corporation
TPS	Traction Power System
VAC	Voltage, Alternating Current
VHF	Very High Frequency
VTA	Santa Clara Valley Transportation Agency

1 Introduction

The Peninsula Corridor Electrification Project (PCEP) is a key element of the Joint Powers Board (JPB) Caltrain Modernization program (CalMod). CalMod will upgrade the performance, operations, capacity, and safety of the commuter rail system between San Francisco and San Jose. Caltrain will eventually operate in a blended system with California High-Speed Rail. The PCEP will deploy a 2x25 kV 60 Hz Traction Power System (TPS) and Overhead Contact System (OCS).

Balfour Beatty Infrastructure, Inc. (BBII) is the PCEP Design Build Contractor, in Contract No. 14-PCJPB-P-053, DB Peninsula Corridor Electrification Program (DB Contract). As part of its work, BBII established a PCEP Electromagnetic Compatibility (EMC) Program with the PCEP EMC Control Plan (CDRL #31510) that will:

- Guide and coordinate the PCEP EMC design, analysis, test, documentation, and certification activities between all participants through all project phases and stages
- Work to achieve EMC with equipment and facilities of Caltrain passengers, workers, and neighbors identified in the EMC program
- Comply with applicable regulatory requirements, including EMC requirements in 49CFR 200-299, particularly Parts 236 and 238, for all PCEP systems
- Fulfill the PCEP EMC requirements in the DB Contract.

In the PCEP EMC Program, BBII is conducting three sets of EMC Ambient Surveys:
1. Pre-existing EMC Ambient Survey
2. New Rail System EMC Ambient Survey (Also referred to as the Revenue Service EMC Ambient Survey)
3. One Year Monitoring EMC Ambient Survey.

The Pre-existing EMC Ambient Survey is complete and accomplished the following tasks:

- Survey for sensitive receptors adjacent to the Caltrain right-of-way (ROW) including research facilities, universities, hospitals, and industrial facilities with sensitive equipment.
- Survey for potential electromagnetic interference (EMI) emitters that could interfere with sensitive Caltrain equipment.
- Measure ambient electric field levels from 10 kHz to 6 GHz and ambient magnetic field levels from DC to 800 Hz at representative locations along the Caltrain ROW before power-up of the PCEP electrification system.

This New Rail System EMC Ambient Survey will measure the electric field and magnetic fields, at the same locations as the Pre-existing EMC Ambient Survey, during Pre-Revenue Testing with 8 electric multiple unit (EMU) trainsets running the full length of the Caltrain corridor in the testing and commissioning phase prior to revenue service. The Pre-Revenue Testing will simulate Revenue Service on the Caltrain corridor.

The One Year Monitoring EMC Ambient Survey will measure the electric field and magnetic field levels, at the same locations, one year after the New Rail System EMC Survey.

If the New Rail System EMC Ambient Survey or One Year Monitoring EMC Ambient Survey document emissions that are disruptive to sensitive receptors near the Caltrain ROW, BBII will:

- Propose EMI mitigations as necessary based on survey findings and measurements.

- Provide a report documenting survey findings, ambient electric and magnetic field measurements, and preliminary recommendations.

The PCEP will notify JPB if electromagnetic emissions field (EMF) exceed the IEEE, American Conference of Governmental Industrial Hygienists (ACGIH), or International Commission on Non-Ionizing Radiation Protection (ICNIRP) EMF exposure thresholds specified in CDRL #31510 EMCP.

The EMC Ambient Survey Procedure, CDRL 31517, attached in Appendix R-1, generally provides the procedure for carrying out the measurements for the three sets of EMC Ambient Surveys. This New Rail System Service EMC Ambient Survey Procedure provides additional information for carrying out the New Rail System Service and One Year Monitoring EMC Ambient Surveys, following the completion of the Pre-Existing EMC Ambient Survey and power-up of the PCEP electrification system.

Appendix R-1 omits EMC Ambient Survey Procedure Appendix C and D since they are not relevant to this New Rail System EMC Ambient Survey. Appendix C and D can be referenced in original document CDRL 31517.

1.1 New Rail System EMC Ambient Surveys Objective

The objectives of the New Rail System EMC Ambient Surveys is to:

- Measure the electromagnetic fields along the Caltrain ROW during pre-revenue service testing along the full length of the Caltrain corridor

- Determine the potential impacts of the PCEP on nearby sensitive receptors, and determine necessary mitigations.

The objective of this procedure is to document plans for measurement site selection, performance of measurements, collection of data, and reporting for New Rail System EMC Ambient Surveys following the completion of the Pre-Existing EMC Ambient Survey and power-up of the PCEP electrification system.

The New Rail System EMC Ambient Survey will include:

- Radiated and Magnetic Measurements at 12 sites, per procedure in Appendix R-1
- Magnetic Measurements at 3 Traction Power Substation sensitive sites, per procedure in Appendix R-1
- Stray Current Measurements at 3 sites, per procedure in Appendix R-2

1.2 EMI Outreach Program Scope

The New Rail System EMC Ambient Survey scope is to measurement and record the ambient electromagnetic environment along the Caltrain ROW during train operation after construction, to determine the potential impacts of Caltrain with PCEP on:

- Stakeholders within 300 ft of the centerline of the track or the lateral power feeders

- Specified potentially facilities such as San Francisco International (SFO) and Mineta San Jose International (SJC) Airports; BART, Santa Clara VTA, and Union Pacific Railroad; and others

The PCEP scope does not include effects of electromagnetic sources other than the PCEP.

The scope does not include the electromagnetic fields generated by existing or new Caltrain rolling stock. The contract with Stadler, the Caltrain EMU trainset supplier, requires that Stadler document the new Caltrain EMU trainset electromagnetic fields in a Radiated Emissions Test Report.

The surveys will measure the electromagnetic fields from the PCEP traction electrification system created by the current draw from the new Caltrain EMU trainsets, and also radiated emissions from the new EMU trainsets. If the electromagnetic field emissions have increased compared to pre-PCEP operations, the EMC Survey test team will compare the electromagnetic field emissions measured during PCEP operation against the Ambient Survey electromagnetic emissions and the EMU trainset radiated emissions to determine the source of the increased electromagnetic field emissions.

1.3 Neighborhood Complaint

If a PCEP neighbor makes a complaint about EMI caused by PCEP, the procedure the JPB should follow is:

1. JPB receives complaint from neighbor

2. If JPB deems the complaint valid, JPB instructs BBII to investigate the complaint

3. BBII meets with the neighbor to understand the complaint
4. As required, BBII will measure the radiated and magnetic levels near the neighbor
5. BBII will determine if any significant radiated or magnetic field levels are caused by the PCEP
6. If PCEP is the source of the EMI, then BBII will work with PCEP to develop a solution.

2 Requirements and Organization

2.1 EMC Ambient Survey Organization

The BBII team members with EMC Ambient Survey responsibilities are:

- Turner Engineering Corporation (Tenco)
- PGH Wong
- BBII

Tenco is the PCEP EMC Engineer and will conduct all three sets of EMC Ambient Surveys. Tenco is responsible to provide:

- Test engineers
- Measurement equipment
- Data media and survey consumables
- Measurement operation, data collection, recording, and reporting.

PGH Wong is the PCEP principal engineer, and BBII is the PCEP prime contractor. Together PGH Wong and BBII will monitor and support Tenco, and are responsible to provide:

- Information needed to determine suitable measurement locations, including PCEP plans, logistics, and design information

- Permissions if needed from owners or authorities to set up and operate measurement equipment at the measurement locations

- Staff to coordinate with the owners and authorities on measurement days. Access to the ROW is not required.

2.2 EMC Ambient Survey Requirements

DB Contract Vol 3, Part A, Section 1, Article 4.9.3.7 specifies that BBII shall conduct an EMI and EMC "investigation study along the electrification corridor for the following 4 types of electrical equipment and systems, and to suggest suitable mitigation measures if deemed necessary:

- Existing systems and equipment of the railroad (prior to electrification);

- New railway systems and equipment (installed as a part of the Project or thereafter);

- External systems or equipment, located outside the ROW but in close proximity to the tracks (up to 30 feet from the centerline of the near track, or within 30 feet from lateral power feeders); and

- External systems and equipment, located between 30 and 300 feet from the nearby track, or from lateral power feeders."

DB Contract Vol 3, Part A, Section 3, Chapter 26 specifies that the PCEP “systems equipment and facilities shall work with and not interfere with other systems equipment and facilities as well as with neighbor equipment and facilities”.

DB Contract Vol 3, Part A, Section 9, Article 7 specifies that BBII shall survey the electromagnetic characteristics along the Caltrain ROW in the design phase, before construction begins, after full revenue service begins using the energized OCS and EMUs, and one year after full revenue service began.

DB Contract Vol 3, Part A, Section 9, EMF-2 states:

- “Conduct a due diligence assessment to identify potentially sensitive facilities along the project route (The EIR list of facilities was only a list of example facilities, not a comprehensive list of potentially sensitive facilities).

- Work with the JPB and make a good faith effort to coordinate with local cities, UCSF, France Telecom, Health Diagnostics, Valley Radiological, Palo Alto Medical Foundation, St. Jude Medical Center, Evans Analytical, Motorola and Intel (and any other facilities located adjacent to the ROW with sensitive equipment and requesting such consultation) to determine whether their facilities would be susceptible to EMI effects.

- Complete a pre-construction survey at each site identified as a potentially sensitive facility. During final design, the D-B shall evaluate the specific EMI levels associated with the electrified JPB system at the identified sensitive facilities and determine the appropriate controls necessary to avoid disruption of sensitive equipment prior to testing and commissioning of the system"

DB Contract Vol 3, Part A, Section 9, EMF-2 also requires:

- “Work with Union Pacific, SCVTA, BART and other rail operators during project design to ensure that signal systems and other sensitive electric equipment for other freight or passenger rail facilities are not disrupted by EMI from the PCEP OCS…”

3 Radiated and Magnetic Field Measurements

3.1 Radiated and Magnetic Field Measurement Location

The BBII team will conduct measurements at 12 representative locations along the Caltrain ROW at the same locations as the Pre-Existing EMC Ambient Survey. Appendix R-1 Section 3.4 lists the locations.

The New Rail System EMC Ambient Survey will employ the same measurement equipment, measurement calibration, measurement bands, measurement planning, and measurement methods used for the Pre-existing EMC Ambient Survey measurements.

Appendix R-1 Section 3.5 shows the measurement sequence
Appendix R-1 Section 4 shows the radiated electric field measurement procedure
Appendix R-1 Section 5 shows the magnetic field measurement procedure
Appendix R-1 Section 6 shows the measurement report format

3.2 Magnetic Field Only Measurement Locations

During the New Rail System EMC Ambient Survey and the One Year Monitoring EMC Ambient Survey, the BBII team will measure the magnetic field inside TPS-1 to record the magnetic field inside a traction power facility generated by the Traction Electrification System equipment.

Figure 3-1 is a marked up schematic of TPS-1 showing the magnetic field survey locations.

It shows three planned measurement points at the following traction power substation locations:

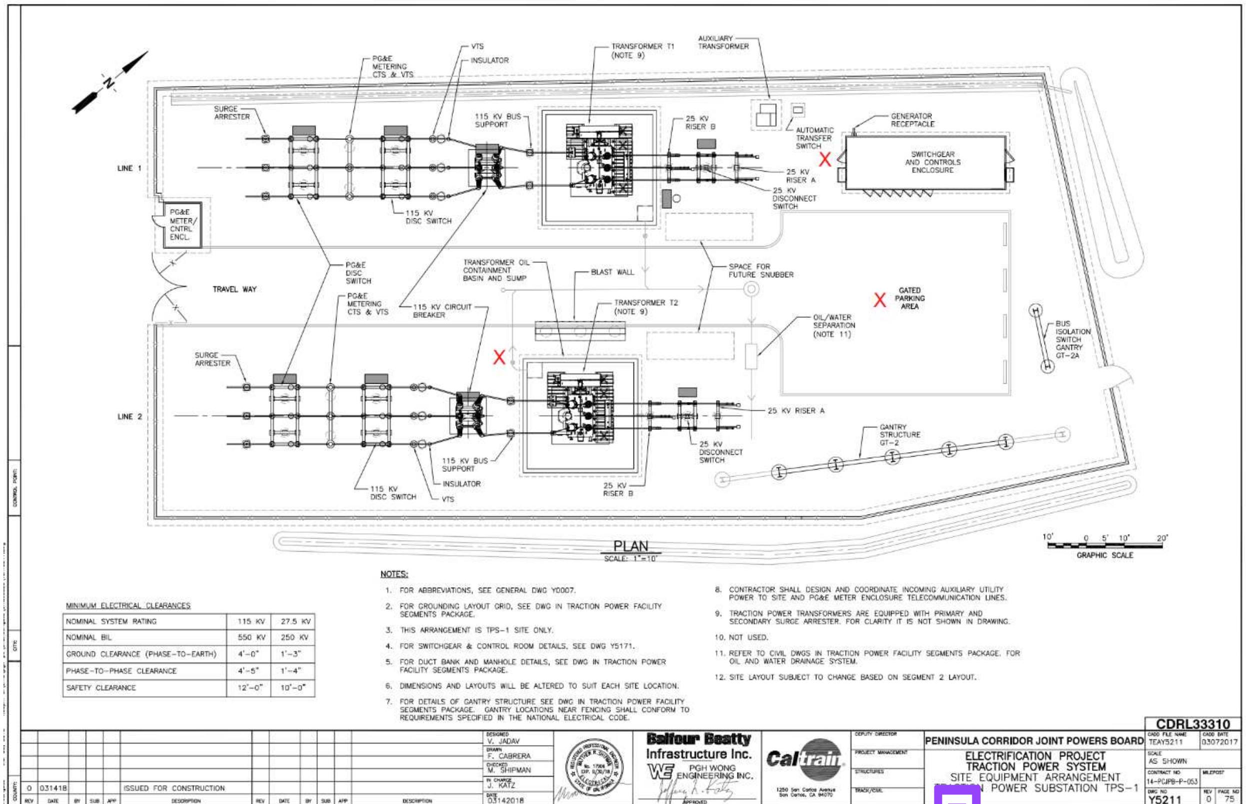
- Center of the Gated Parking Area
- Outside the door of the Switchgear and Controls Enclosure
- Outside the entry way to Transformer T2

The New Rail System EMC Ambient Survey will employ the same measurement equipment, measurement calibration, measurement bands, measurement planning, and measurement methods used for the Pre-existing EMC Ambient Survey measurements.

Appendix R-1 Section 5 shows the magnetic field measurement procedure
Appendix R-1 Section 6 shows the measurement report format

FIGURE 3-1
TPS-1 Survey Locations

`



X = Magnetic Field Measurement Point

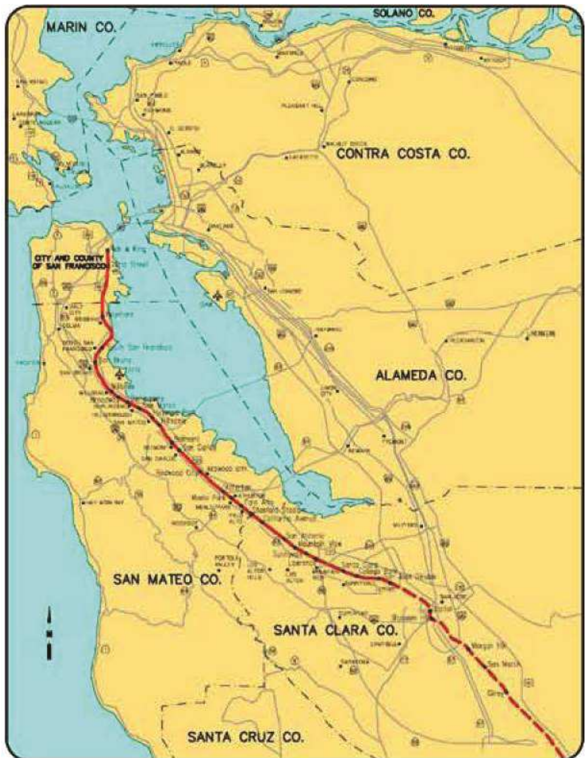
4 Stray Current Measurement

The BBII team will conduct stray current measurements at 3 locations along the Caltrain ROW, consistent with the recommendations of CDRL 33080 Stray Current and Atmospheric Study. Appendix R-2 shows the procedure, measurement locations, equipment, sequence, and forms.

Appendix R-1

EMC Ambient Survey Procedure

SAN FRANCISCO BAY AREA



Caltrain®

PENINSULA CORRIDOR JOINT POWERS BOARD

DESIGN BUILD
ELECTRIFICATION PROJECT

CONTRACT NO. 14-PCJPB-P-053
EMC Ambient Survey Procedure
CDRL 31517 – Final

REVISION 1

April 23, 2019

TURNER ENGINEERING CORPORATION

PGH WONG ENGINEERING INC.

Balfour Beatty Infrastructure Inc.

Revision History Record

Revision No.	Date	Reason for Revision
0	10/05/2018	Final Release
1	04/23/2019	Removed CBOSS Communication Based Overlay Signal System from List of Acronyms. Section 1 EMI Outreach Program Scope revised Section 1.3 Neighborhood Complaint added. Section 2.2 EMC Ambient Survey Requirements revised Table 3-1 revised to clearly separate Susceptibility Categories and Environment Categories. Figure 3-1 Survey Overview Map revised

This Page Intentionally Left Blank.

Table of Contents

References

Contractor RAM Program Plan - Reference Information		
Publisher	**Document Number**	**Title**
JPB	Contract Documents Volume 3 Part A Section 1	Scope of Work
JPB	Contract Documents Volume 3 Part A Section 3	Design Criteria

List of Figures

List of Tables

List of Acronyms

Acronym	Definition
AC	Alternating Current
BART	Bay Area Rapid Transit
BBII	Balfour Beatty Infrastructure Inc.
CalMod	Caltrain Modernization Program
CFR	Code of Federal Regulations
DC	Direct Current
EIR	Environmental Impact Report
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
EMU	Electric Multiple Unit
GHz	Gigahertz
Hz	Hertz
JPB	Joint Powers Board
kHz	Kilohertz
MHz	Megahertz
OCS	Overhead Contact System
PCEP	Peninsula Corridor Electrification Project
PTC	Positive Train Control
RFI	Request for Information
RFP	Request for Proposal
ROW	Right-of-way
SFMTA	San Francisco Municipal Transportation Agency
SFO	San Francisco International Airport
SJC	Mineta San Jose International Airport
Tenco	Turner Engineering Corporation
TPS	Traction Power System
UPRR	Union Pacific Railroad
VAC	Voltage, Alternating Current
VHF	Very High Frequency
VTA	Santa Clara Valley Transportation Agency

1 Introduction

The Peninsula Corridor Electrification Project (PCEP) is a key element of the Joint Powers Board (JPB) Caltrain Modernization program (CalMod). CalMod will upgrade the performance, operations, capacity, and safety of the commuter rail system between San Francisco and San Jose. Caltrain will eventually operate in a blended system with California High-Speed Rail. The PCEP will deploy a 2x25 kV 60 Hz Traction Power System (TPS) and Overhead Contact System (OCS).

Balfour Beatty Infrastructure, Inc. (BBII) is the PCEP Design Build Contractor, in Contract No. 14-PCJPB-P-053, DB Peninsula Corridor Electrification Program (DB Contract). As part of its work, BBII established a PCEP Electromagnetic Compatibility (EMC) Program with the PCEP EMC Control Plan (CDRL #31510) that will:

- Guide and coordinate the PCEP EMC design, analysis, test, documentation, and certification activities between all participants through all project phases and stages
- Work to achieve EMC with equipment and facilities of Caltrain passengers, workers, and neighbors identified in the EMC program
- Comply with applicable regulatory requirements, including EMC requirements in 49CFR 200-299, particularly Parts 236 and 238, for all PCEP systems
- Fulfill the PCEP EMC requirements in the DB Contract.

In the PCEP EMC Program, BBII is conducting three sets of EMC Ambient Surveys:

1. Pre-existing EMC Ambient Survey
2. Revenue Service EMC Survey
3. One Year Monitoring EMC Survey.

The Pre-existing EMC Survey will:

- Survey for sensitive receptors adjacent to the Caltrain right-of-way (ROW) including research facilities, universities, hospitals, and industrial facilities with sensitive equipment.
- Survey for potential electromagnetic interference (EMI) emitters that could interfere with sensitive Caltrain equipment.
- Measure ambient electric field levels from 10 kHz to 6 GHz and ambient magnetic field levels from DC to 800 Hz at representative locations along the Caltrain ROW before power-up of the PCEP electrification system.

The Revenue Service EMC Survey will measure the same electric field and magnetic field levels, at the same locations, after electric multiple unit (EMU) trainsets begin running the full length of the Caltrain corridor in revenue service.

The One Year Monitoring EMC Survey will measure the same electric field and magnetic field levels, at the same locations, one year after Revenue Service EMC Survey.

If the Revenue Service EMC Survey or One Year Monitoring EMC Survey document emissions that are disruptive to sensitive receptors near the Caltrain ROW, BBII will:

- Propose EMI mitigations as necessary based on survey findings and measurements.
- Provide a report documenting survey findings, ambient electric and magnetic field measurements, and preliminary recommendations.

The PCEP will notify JPB if electromagnetic emissions field (EMF) exceed the IEEE, American Conference of Governmental Industrial Hygienists (ACGIH), or International Commission on Non-Ionizing Radiation Protection (ICNIRP) EMF exposure thresholds specified in CDRL #31510 EMCP.

This EMC Ambient Survey Procedure provides the procedure for carrying out the measurements for the EMC Ambient Surveys.

1.1 EMC Ambient Surveys Objective

The objectives of the EMC Ambient Surveys are to:

- Measure the existing ambient electromagnetic fields along the Caltrain ROW before power-up of the PCEP electrification system
- Measure the electromagnetic fields along the Caltrain ROW after revenue service along the full length of the Caltrain corridor
- Measure the electromagnetic fields along the Caltrain ROW one year after revenue service began
- Determine the potential impacts of the PCEP on nearby sensitive receptors, and determine necessary mitigations.

The objective of this procedure is to document plans for measurement site selection, performance of measurements, collection of data, and reporting.

1.2 EMI Outreach Program Scope

The Pre-Existing EMC Ambient Survey scope is the measurement and recording of the ambient electromagnetic environment along the Caltrain ROW prior to construction, to determine the potential impacts of Caltrain with PCEP on:

- Stakeholders within 300 ft of the centerline of the track or the lateral power feeders
- Specified potentially facilities such as San Francisco International (SFO) and Mineta San Jose International (SJC) Airports; BART, Santa Clara VTA, and Union Pacific Railroad; and others

The PCEP scope does not include effects of electromagnetic sources other than the PCEP.

The scope does not include the electromagnetic fields generated by existing or new Caltrain rolling stock. The contract with Stadler, the Caltrain EMU trainset supplier, requires that Stadler document the new Caltrain EMU trainset electromagnetic fields in a Radiated Emissions Test Report.

The PCEP scope includes Revenue Service and One Year Monitoring EMC Ambient Surveys. When the new Caltrain EMU trainsets are operating, the surveys will measure the electromagnetic fields from the PCEP traction electrification system created by the current draw from the new Caltrain EMU trainsets, and also radiated emissions from the new EMU trainsets. If the electromagnetic field emissions have increased compared to pre-PCEP operations, the EMC Survey test team will compare the electromagnetic field emissions measured during PCEP operation against the Ambient Survey electromagnetic emissions and the EMU trainset radiated emissions to determine the source of the increased electromagnetic field emissions.

1.3 Neighborhood Complaint

If a PCEP neighbor makes a complaint about EMI caused by PCEP, the procedure the JPB should follow are:

1. JPB receives complaint from neighbor
2. If JPB deems the complaint valid, JPB instructs BBII to investigate the complaint
3. BBII meets with the neighbor to understand the complaint
4. As required, BBII will measure the radiated and magnetic levels near the neighbor
5. BBII will determine if any significant radiated or magnetic field levels are caused by the PCEP
6. If PCEP is the source of the EMI, then BBII will work with PCEP to develop a solution.

2 Requirements and Organization

2.1 EMC Ambient Survey Organization

The BBII team members with EMC Ambient Survey responsibilities are:

- Turner Engineering Corporation (Tenco)
- PGH Wong
- BBII

Tenco is the PCEP EMC Engineer and will conduct the EMC Ambient Survey. Tenco is responsible to provide:

- Test engineers
- Measurement equipment
- Data media and survey consumables
- Measurement operation, data collection, recording, and reporting.

PGH Wong is the PCEP principal engineer, and BBII is the PCEP prime contractor. Together PGH Wong and BBII will monitor and support Tenco, and are responsible to provide:

- Information needed to determine suitable measurement locations, including PCEP plans, logistics, and design information
- Permissions if needed from owners or authorities to set up and operate measurement equipment at the measurement locations
- Staff to coordinate with the owners and authorities on measurement days. Access to the ROW is not required.

2.2 EMC Ambient Survey Requirements

DB Contract Vol 3, Part A, Section 1, Article 4.9.3.7 specifies that BBII shall conduct an EMI and EMC "investigation study along the electrification corridor for the following 4 types of electrical equipment and systems, and to suggest suitable mitigation measures if deemed necessary:

- Existing systems and equipment of the railroad (prior to electrification);
- New railway systems and equipment (installed as a part of the Project or thereafter);
- External systems or equipment, located outside the ROW but in close proximity to the tracks (up to 30 feet from the centerline of the near track, or within 30 feet from lateral power feeders); and
- External systems and equipment, located between 30 and 300 feet from the nearby track, or from lateral power feeders."

DB Contract Vol 3, Part A, Section 3, Chapter 26 specifies that the PCEP “systems equipment and facilities shall work with and not interfere with other systems equipment and facilities as well as with neighbor equipment and facilities”.

DB Contract Vol 3, Part A, Section 9, Article 7 specifies that BBII shall survey the electromagnetic characteristics along the Caltrain ROW in the design phase, before construction begins, after full revenue service begins using the energized OCS and EMUs, and one year after full revenue service began.

DB Contract Vol 3, Part A, Section 9, EMF-2 states:

- “Conduct a due diligence assessment to identify potentially sensitive facilities along the project route (The EIR list of facilities was only a list of example facilities, not a comprehensive list of potentially sensitive facilities).
- □□rk with the JPB and make a good faith effort to coordinate with local cities, UCSF, France Telecom, Health Diagnostics, Valley Radiological, Palo Alto Medical Foundation, St. Jude Medical Center, Evans Analytical, Motorola and Intel (and any other facilities located adjacent to the ROW with sensitive equipment and requesting such consultation) to determine whether their facilities would be susceptible to EMI effects.
- Complete a pre-construction survey at each site identified as a potentially sensitive facility. During final design, the D-B shall evaluate the specific EMI levels associated with the electrified JPB system at the identified sensitive facilities and determine the appropriate controls necessary to avoid disruption of sensitive equipment prior to testing and commissioning of the system"

DB Contract Vol 3, Part A, Section 9, EMF-2 also requires:

- “Work with Union Pacific, SCVTA, BART and other rail operators during project design to ensure that signal systems and other sensitive electric equipment for other freight or passenger rail facilities are not disrupted by EMI from the PCEP OCS…”

3 Survey Locations

Tenco will conduct measurements at approximately 12 representative locations along the Caltrain ROW. Locations will include:

- Specific sensitive receptors adjacent to the ROW
- Worst case ambient EMF locations, such as under high voltage power lines or near significant emitters such as TV broadcast stations
- “Quiet” sites, where the BBII team expects low ambient EMF levels
- Where the BBII team expects worst case Caltrain EMF levels
- Locations with significant public interaction

3.1 Sensitive Receptors

To select sensitive receptor locations, BBII considered sensitive receptors in the following groups, per DB Contract Vol 3, Part A, Section 1, Article 4.9.3.7:

1. Existing JPB systems and equipment
2. New PCEP and CalMod systems and equipment, including new EMU trainsets, installed as part of CalMod or thereafter
3. External systems and equipment, located outside the ROW but within 30 ft of the centerline of the track or the lateral power feeders
4. External systems and equipment located between 30 and 300 ft from the centerline of the track or the lateral power feeders
5. Other sensitive facilities that may be affected by the electromagnetic fields produced by the PCEP, consistent with the PCEP Environmental Impact Report (EIR).

BBII identified possible sensitive receptors using:

- Parcel data from San Francisco, San Mateo, and Santa Clara counties
- Publicly available business listings
- Google Earth mapping software

BBII assigned each sensitive receptor to a susceptibility category and environmental category considering the business type of the sensitive receptor and the location. Table 3-1 lists the sensitive receptor categories.

TABLE 3-1

Sensitive Receptor Categories					
Site Categories		**Susceptibility Categories**		**Environment Categories**	
1	Existing JPB systems and equipment	A	Routine	A	Quiet
2	New PCEP systems and equipment	B	Sensitive	B	Moderate
3	External systems or equipment, w/in 30 ft of track centerline	C	Very Sensitive	C	Noisy
4	External systems or equipment, 30 - 300 ft from track centerline	D	Extremely Sensitive	D	Very Noisy
5	Other sensitive facilities that may be affected by PCEP electromagnetic fields				

The next steps are:

Group 1: For sensitive receptors in group 1, BBII will send JPB a request for information (RFI). This RFI will ask if JPB owns any sensitive equipment susceptible to EMFs emitted by new PCEP equipment. BBII expects that all such JPB-owned equipment is already covered in the PCEP scope of work, e.g., existing cable study, track circuits, communications, etc.

Group 2: For sensitive receptors in group 2, BBII will:

- Design and build the PCEP to operate within the DB Contract specifications. Further, BBII will ensure that its suppliers provide equipment that meets PCEP EMC requirements per the PCEP EMC Control Plan.
- Prepare a RFI to the EMU supplier, Stadler, per section 3.2.2 and provide it to JPB. This RFI will ask if the EMUs contain any sensitive equipment susceptible to EMFs emitted by the new PCEP equipment. BBII expects that all such EMU equipment is already covered in the design of a service proven EMU meant for operation in the PCEP environment.

Groups 3-5: For sensitive receptors in groups 3 to 5, the Survey sites with potential sensitive receptors will be:

- Sites listed in DB Contract Vol 3 Part A Section 9, EMF-2: UCSF, France Telecom, Health Diagnostics, Valley Radiological, Palo Alto Medical Foundation, St. Jude Medical Center, Evans Analytical, Motorola and Intel

- SFO and SJC: The Survey will cover communications, navigation, and surveillance equipment at SFO and SJC, since high radio frequency emissions near airports could affect airport operations. Sensitive electrical systems and equipment at airports and other facilities include:
  - Sensitive facility receivers, including VHF frequencies
  - Local radio frequencies other than VHF
  - Aviation navigation systems
  - Sensitive facilities surveillance systems
  - Local communication systems including those for aviation, emergency services, and other transit providers
- Adjacent railroads:
  - Union Pacific Railroad (UPRR)
  - Santa Clara Valley Transportation Authority (VTA)
  - Bay Area Rapid Transit (BART)
  - San Francisco Municipal Transportation Agency (SFMTA)
- Emergency services providers, including police departments, fire stations, and emergency medical services.

3.2 EMI Emitters

To select emitter locations, BBII considered EMI emitters adjacent to the Caltrain ROW whose emissions range from 10 kHz to 6 GHZ. Potential EMI emitters will include:

- Rail transportation – freight trains, radio-controlled freight trains, passenger rail
- Technical facilities – hospitals, medical centers, research facilities, educational facilities
- Transmitters – radio and TV, police, fire, emergency medical technicians, military
- Power utilities – transmission and distribution lines, substations, switching stations
- Commercial – business parks, manufacturers, banks
- Other

BBII identified other EMI emitters using:

- FCC licensing data
- Google Earth mapping software

3.3 Representative Locations

After identifying sensitive receptors and EMI emitters, BBII performed a geospatial cluster analysis of locations to determine an adequate number of representative locations for taking measurements.

Locations included those identified in DB Contract Vol 3, Part A, Section 9 EMF-2, and other locations representing relatively distinct electromagnetic environments. Representative locations were selected from at least each distinct electromagnetic environment along the Caltrain ROW.

Unless otherwise constrained or guided, the measurement point at each location was chosen to be near the centerline of the track. The measurement point may be:

- 100 ft (30 m) or 50 ft (15 m) from the track centerline, consistent with UMTA-MA-06-0153-85-11, method RT/RE01A, the broadly used standard for transit radiated electric field measurements. Measure background with no train present, and measure several trains passing.
- At another suitable location close to a point of interest such as an emitter or potential victim. Note the distance to the track centerline and to the point of interest.

Unless otherwise constrained, the antenna should point toward the track. The antenna should be mounted 6 ft (2 m) above ground level. If the terrain requires a different height above the ground, the test engineers will record the actual height in the measurement log.

If possible, there should be no fence or other significant metal structure above rail level between the measurement point and the antenna, or immediately behind or to the sides of the measurement point. For obstructed locations, the survey log will note the in-situ construction materials, such as reinforced concrete highway supports.

There should be a safe area for the test engineers and measurement equipment, and to park a survey van.

The measurement equipment needs 120 VAC power, which may be provided by connection to a utility or a generator.

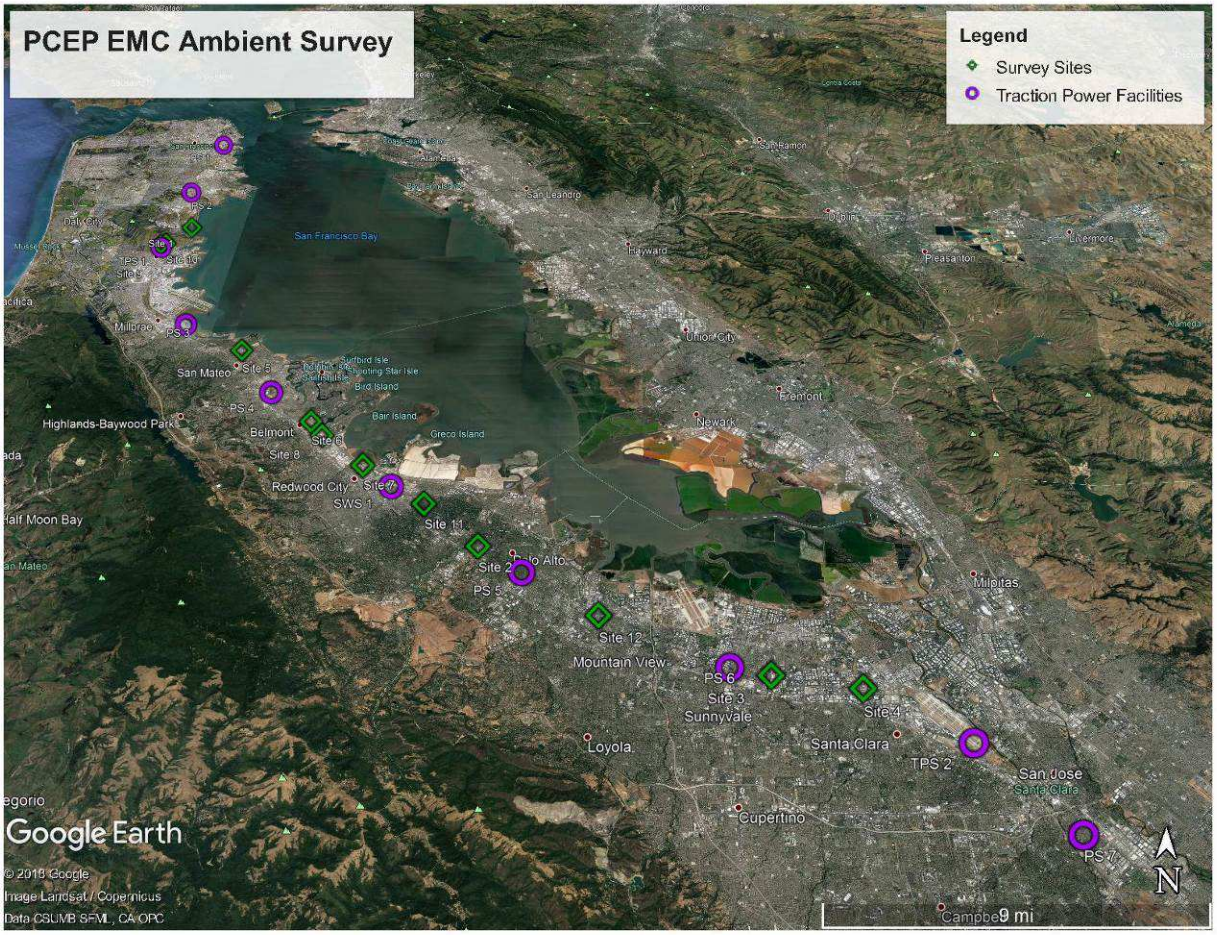
3.4 Measurement Location

DB Contract Vol 3 Part A Section 9, EMF-2 identifies 18 sites for consideration in the EMC Ambient Survey. The BBII team has identified an additional 639 potential sensitive receptors in the PCEP corridor. Of these 657 locations, BBII selected 12 representative locations at which to measure the ambient electromagnetic environment. These measurement sites represent the full range of sensitive receptor categories from Table 3-1 present in the PCEP corridor, as well as 2 quiet sites.

Figure 3-1 is an overview map. It shows:

- The 12 representative measurement sites shown as green diamonds
- Planned PCEP traction power facility locations shown as purple circles.

FIGURE 3-1
Survey Overview Map



3.4.1 Electric and Magnetic Field Measurement Locations

Table 3-2 lists the 12 representative measurement sites and their characteristics.

BBII will measure electric and magnetic fields at each of the 12 sites, during each of the three EMC Ambient Surveys.

TABLE 3-2

Representative Measurement Sites

ID	Location	Dist. from Track (ft)	No. Receptors in Area	Sensitive Receptor Categories Covered			Caltrain Facilities
				Site	Susc.	Env.	
1	5000 Sierra Point Pkwy, Brisbane	100	12	4, 5	A, B, C	B	NA
2	Palo Alto Medical Foundation 795 El Camino Real, Palo Alto, CA 94304	75	1	5	C	B	Palo Alto Station, 1,500 ft
3	120 San Lucar Ct, Sunnyvale	50	5	4, 5	B, C	B	NA
4	2368 Walsh Ave, Santa Clara	30	21	5	A, B, C	B	NA
5	159 S B St, San Mateo	40	11	5	A, B, C	B	San Mateo Station, 50 ft
6	565 Bragato Rd, San Carlos	90	6	4, 5	A, B, C	B	NA
7	2401 Broadway, Redwood City	30	10	4, 5	A, B	B	SWS 1, 1200 ft Redwood City Station, 0 ft
8	700 El Camino Real, San Carlos	50	6	4, 5	A, B	B	San Carlos Station, 400 ft
9	590 Dubuque Ave, South San Francisco	50	7	3, 4, 5	A, B	C	TPS 1, 400 ft S San Francisco Station, 200 ft
10	Two Corporate Dr, South San Francisco	80	5	5	A, B	C	TPS 1, 500 ft S San Francisco Station, 1200 ft
11	98 McCormick Ln, Atherton	40	NA	NA	A	A	Quiet Site
12	2000 Crisanto Ave, Mountain View	40	NA	NA	A	A	Quiet Site

Appendix B provides further details for each representative measurement site.

Appendix C lists all of the 657 potential sensitive receptors.

3.4.2 Magnetic Field Only Measurement Locations

During the Revenue Service EMC Ambient Survey and the One Year Monitoring EMC Ambient Survey the BBII team will measure the magnetic field inside TPS-1 to record the magnetic field inside a traction power facility generated by the Traction Electrification System equipment.

3.5 Measurement Sequence

The test engineers will:

1. Perform measurements during daytime, between 8 am and 6 pm
2. Use a passenger van to transport the measurement equipment to, and to provide shade and shelter at, a predetermined set or representative locations
3. At each location, park in a safe location and set out traffic cones as necessary
4. Set up two or three measurement antennas connected by cable to equipment in the van
5. Set up a 120 VAC power connection
6. Record data for up to 2 hrs
7. Pack up and move to the next location

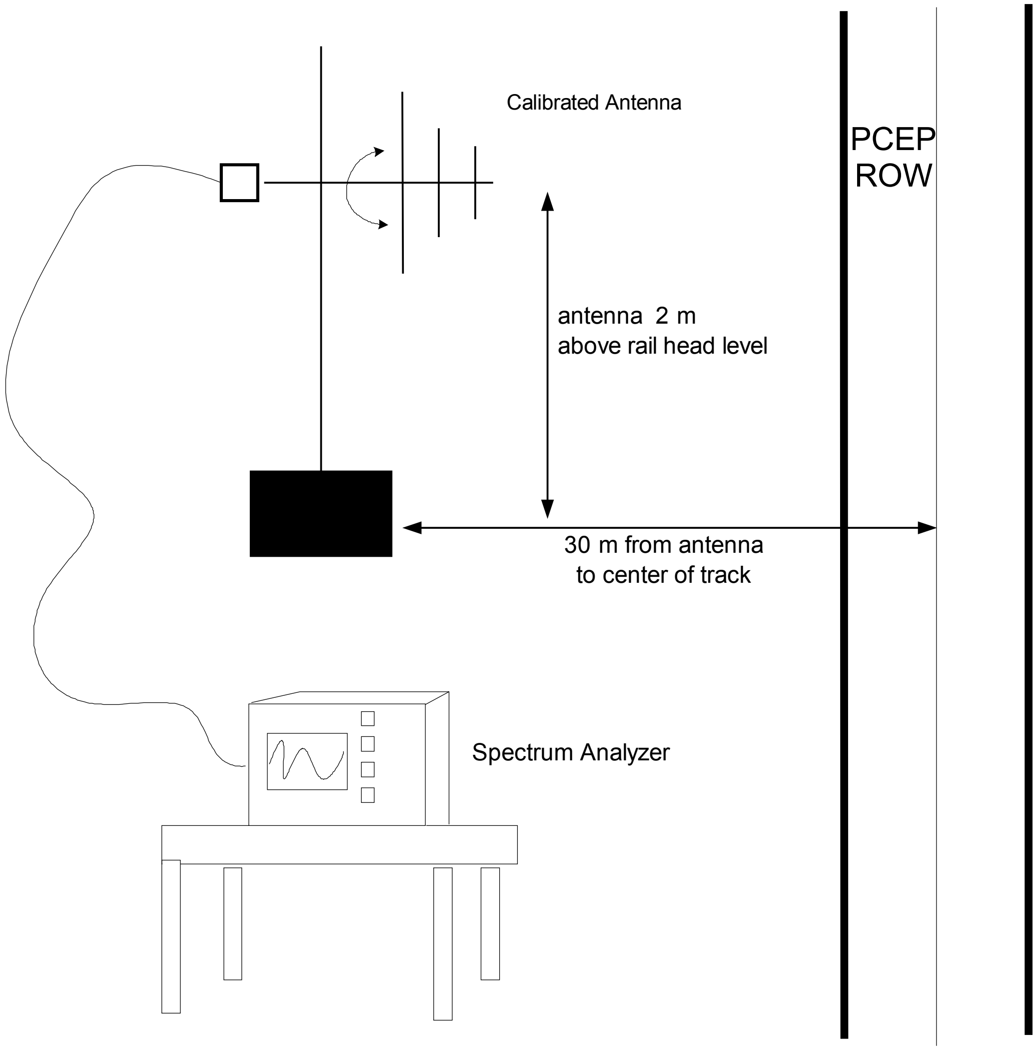
The purpose of the measurements after PCEP operation begins is to record peak electric field and magnetic field levels. Therefore, in the Revenue Service EMC Survey and the One Year Monitoring EMC Survey, the test engineers will measure electromagnetic levels during peak EMU traffic. The test engineers do not plan to measure electromagnetic levels during lower traffic periods such as Saturdays, Sundays, or during a service reduction.

The Revenue Service and One Year Monitoring EMC Ambient Survey will measure the electromagnetic fields from the PCEP traction electrification system created by the current draw from the new Caltrain EMU trainsets and also the radiated emissions from the new EMU trainsets. If the electromagnetic field emissions during PCEP operations have increased compared to pre-PCEP operations, the EMC Survey test team will compare the measured electromagnetic field emissions during PCEP operations against the Ambient Survey electromagnetic emissions and the EMU trainset radiated emissions to determine the source of the increased electromagnetic field emissions.

4 Radiated Electric Field Measurement

Figure 4-1 shows the equipment setup for the radiated electric field measurement.

FIGURE 4-1
Radiated Electric Field Measurement Equipment Setup



4.1 Measurement Equipment

Table 4-1 lists the radiated electric field measurement equipment.

TABLE 4-1

Radiated Electric Field Measurement Equipment List

#	Item	Comment
1	KT-9010A-507/P07/EDP 10 Hz – 7 GHz EXA Signal Analyzer with KT-N6141A/2TP EMI Measurement application or equivalent	For measuring EMI field intensity between 10 Hz and 6 GHz.
2	PC Software, KT-N6141A/2TP EMI Measurement application or equivalent	For transfer of data from Spectrum Analyzer to PC
3	Inkjet Printer, or equivalent	For plotting emission spectra. Compatible with spectrum analyzer.
4	A.H Systems SAS-550-1: Active Monopole Antenna or equivalent, 10 kHz to 60 MHz	Calibrated antenna for Bands 1 – 4
5	A.H. Systems SAS-521F-7: Bilogical Antenna or equivalent, 25 MHz to 7 GHz	Calibrated antenna for Bands 5 - 7
6	Adjustable Antenna Tripod	To support antennas
7	Laptop computer	For control of printer and storage of survey data results
8	AC Power Source	AC line, generator, or car battery inverter.

The following subsections describe the major measurement equipment items.

4.1.1 RF Spectrum Analyzer

The Keysight Technologies KT-9010A-507/P07/EDP Spectrum Analyzer measures intensity of the RF field over a frequency range of 10 kHz to 6 GHz. It:

- Measures and documents the field intensity received from calibrated antennas, on two traces, showing the maximum and minimum measured signal at each frequency.
- Converts received signals from calibrated antennas into standard dBμV/m units.
- Stores system configuration including antenna factors and cable losses.
- Has amplitude accuracy better than ±0.7 dB, adequate for the task.
- Displays Limit Lines to indicate EMI specification limits.

The spectrum analyzer will be connected to a laptop or PC by ethernet cable for data acquisition, storage, and printing.

The test engineers will use standard techniques to assure calibration of the impulse bandwidth of the spectrum analyzers. For spectrum analyzers whose intermediate frequency (IF) stages have Gaussian passbands, such as the Keysight Technologies spectrum analyzer described here, the impulse bandwidth is 1.4 times the resolution bandwidth (-3 dB bandwidth), and is approximately equal to the -6 dB IF bandwidth.

4.1.2 Antennas

The test engineers will mount antennas on a tripod with the antenna base plate 6 ft above rail level where possible. The measurements will orient the antennas as follows:

Active Monopole Antenna: The active monopole antenna covers the frequency of 10 kHz to 60 MHz. Measurements taken with this antenna are oriented vertically.

Bilogical Antenna: The bilogical antenna is a wide operating range antenna which covers the frequency range of 25 MHz to 7 GHz. The name “bilogical” indicates that the antenna combines the characteristics and response of a biconical and log periodic antenna. Measurements taken with this antenna are oriented vertically, with the axis perpendicular to the ground, or oriented horizontally, with the axis parallel to the track.

Calibrated antennas receive and convert electrical field intensities into electrical signals with a known antenna conversion factor. These antenna conversion factors are provided by the antenna supplier, and are entered into the spectrum analyzer to display received signals in units of the corresponding electrical field intensity.

4.2 Spectrum Analyzer Calibration

The test engineers will perform the following steps to verify proper orientation of the radiated electric field measurement equipment:

1. Turn on the spectrum analyzer and let it warm up.
2. Calibrate the spectrum analyzer per the user’s manual.
3. Verify cable loss matches the calibration record. The internal calibrator can be used for this measurement.
4. Verify antennas are operating properly, and that the active monopole is not saturated by a nearby AM broadcast antenna.

4.3 Measurement Bands

The test engineers will perform broadband emission measurements in the range of 10 kHz to 6 GHz using active rod, Bi-logical antennas for horizontal and vertical polarizations as appropriate.

The test engineers will divide measurements into eight measurement bands, shown in Table 4-2.

The test engineers will use the active rod antenna to cover the range from 10 kHz to 30 MHz, in five measurement subbands. Per the UMTA procedure, Tenco will measure with the active rod oriented vertically. The active rod antenna is omni-directional, so a single measurement will record fields in all compass directions.

The test engineers will use the Bi-logical antenna to cover the range from 30 MHz to 6 GHz, for both horizontal and vertical polarization.

TABLE 4-2

Table 4-2
Radiated Emissions Measurement Bands

ID	Band Frequency Range	Antenna	Antenna Orientation	Resolution Bandwidth
B0	10 kHz – 160 kHz	Active Monopole	Vertical	1 kHz
B1	150 kHz – 650 kHz	Active Monopole	Vertical	10 kHz
B2	500 kHz – 3 MHz	Active Monopole	Vertical	10 kHz
B3	2.5 MHz – 7.5 MHz	Active Monopole	Vertical	10 kHz
B4	5 MHz – 30 MHz	Active Monopole	Vertical	100 kHz
B5h	25 MHz – 325 MHz	Bilogical	Horizontal	100 kHz
B5v	25 MHz – 325 MHz	Bilogical	Vertical	100 kHz
B6h	300 MHz – 1.3 GHz	Bilogical	Horizontal	300 kHz
B6v	300 MHz – 1.3 GHz	Bilogical	Vertical	300 kHz
B7h	1 GHz – 6 GHz	Bilogical	Horizontal	300 kHz
B7v	1 GHz – 6 GHz	Bilogical	Vertical	300 kHz

Consistent with the broadly used standard Radiated Interference in Rapid Transit Systems, Volume II: Suggested Test Procedures, UMTA-MA-06-0153-85-11, method RT/RE01A, "Broadband Emissions of Rapid Transit Vehicles - 140 kHz to 400 MHz" (RSTP), the test engineers will modify the antenna factors to include a broadband correction factor for the specified spectrum analyzer resolution bandwidth. The correction factors are:

- 36.5 dB for 10 kHz
- 15.5 dB for 100 kHz
- 7.0 dB for 300 kHz

4.4 Site Diagram

The test engineers will make a detailed diagram of the measurement site, showing location, measurement point, nearby structures, emitters, Caltrain ROW, and other significant objects. The site diagram will include the measurement site latitude and longitude and photographs of the measurement site.

The BBII team will provide a map showing all measurement sites and the Caltrain ROW.

4.5 Radiated Measurement Planning

The test engineers will arrange measurements to measure worst-case (maximum and minimum) radiated emissions, considering time of day, intermittent events, and local actions. Ambient radiated electric field conditions change frequently because neighbor radio and energy sources continually vary their operating conditions.

The test engineers will perform sufficient repeated measurements to identify worst-case conditions and characterize their amplitude, frequency, duration, and repetition at each measurement site. If high emissions are measured, the test engineers will reorient the antenna and record the direction in which the highest emission level is measured.

4.6 Radiated Electrical Field Measurement Method

For each measurement, the test engineers will maintain a log of measurement type and band, measurement equipment configuration, measurement duration, external event or condition descriptions, comments, summary of measured data, and other relevant information. If the measurement includes a train, motor vehicle, or airplane, the test engineers will note it.

4.6.1 Radiated Electrical Field Measurement Steps

1. Setup at the measurement site.

2. Calibrate the spectrum analyzer. Attach antenna to the spectrum analyzer. Set the spectrum analyzer to display the measurement band. Set the spectrum analyzer reference level offset to 0.

3. With the spectrum analyzer set to Min/Max hold, measure and record for 5 s time intervals. Reset trace from time to time to compare old peaks to present levels. Observe signal through range of conditions at particular site, such as traffic nearby, etc.

4. Identify and characterize worst-case conditions. Print the full emission spectrum.

4.6.2 Broadband Emission Evaluation

To identify broadband emissions observed at a particular frequency and polarization as a distinct wayside emission, the emission level must exceed the corresponding observed ambient broadband level by 10 dB or more. The frequency in question must be at least twice the impulse bandwidth from any ambient narrowband signal greater than the observed broadband emission levels.

If a questionable signal is found that would be excluded under these criteria, the test engineers will re-measure it later under similar conditions to determine whether the emission is an ambient variation or an actual wayside emission.

A set of regular peaks displayed on the spectrum analyzer could be either a set of harmonics emissions or the record of a periodic sequence of impulses. If such a set is found:

1. Note the peaks in the log
2. Make another measurement with all settings the same but with a different spectrum analyzer sweep speed
    - If the peaks change spacing on the screen, they are a sequence of impulses
    - If the peaks maintain a constant spacing, they are a set of harmonics
3. Record the results in the log

4.6.3 Field Reduction of Data

The test engineers will set up the spectrum analyzer to account for antenna factors, calibration factors, gain, and conversion units so that the emission amplitudes are recorded in dBμV/m/MHz. Test engineers will plot or print the spectrum analyzer data on completion of each frequency measurement run, annotating the measurement results as appropriate.

The test engineers will print out and save the data for each valid measurement run.

The test engineers will characterize the measurement and note:

- Key emissions in the measurement
- The extent to which the minimum and maximum traces differ, reflecting the broadband noise present
- Changes between the measurement and recent similar measurements
- Similarities or differences to other measurements in the same band at other locations
- Whether there is a set of periodic impulses or a set of harmonics
- Whether the measurement is an apparent worst case

4.6.4 Measurement Data Collection

The test engineers will collect data, including for measurement equipment calibration and each ambient site measurement. Appendix A provides measurement forms.

Equipment Calibration: Record calibration data for each major measurement equipment item. Calibration data will include the following:

- Measurement equipment item
- Manufacturer
- Model
- Serial number
- Calibration date
- Calibration source
- Reference number
- Notes

Measurement Log: Maintain a measurement run log, recording the following for each measurement:

- Date
- Time
- Performed by
- Location
- Site conditions
- Event
- Run number

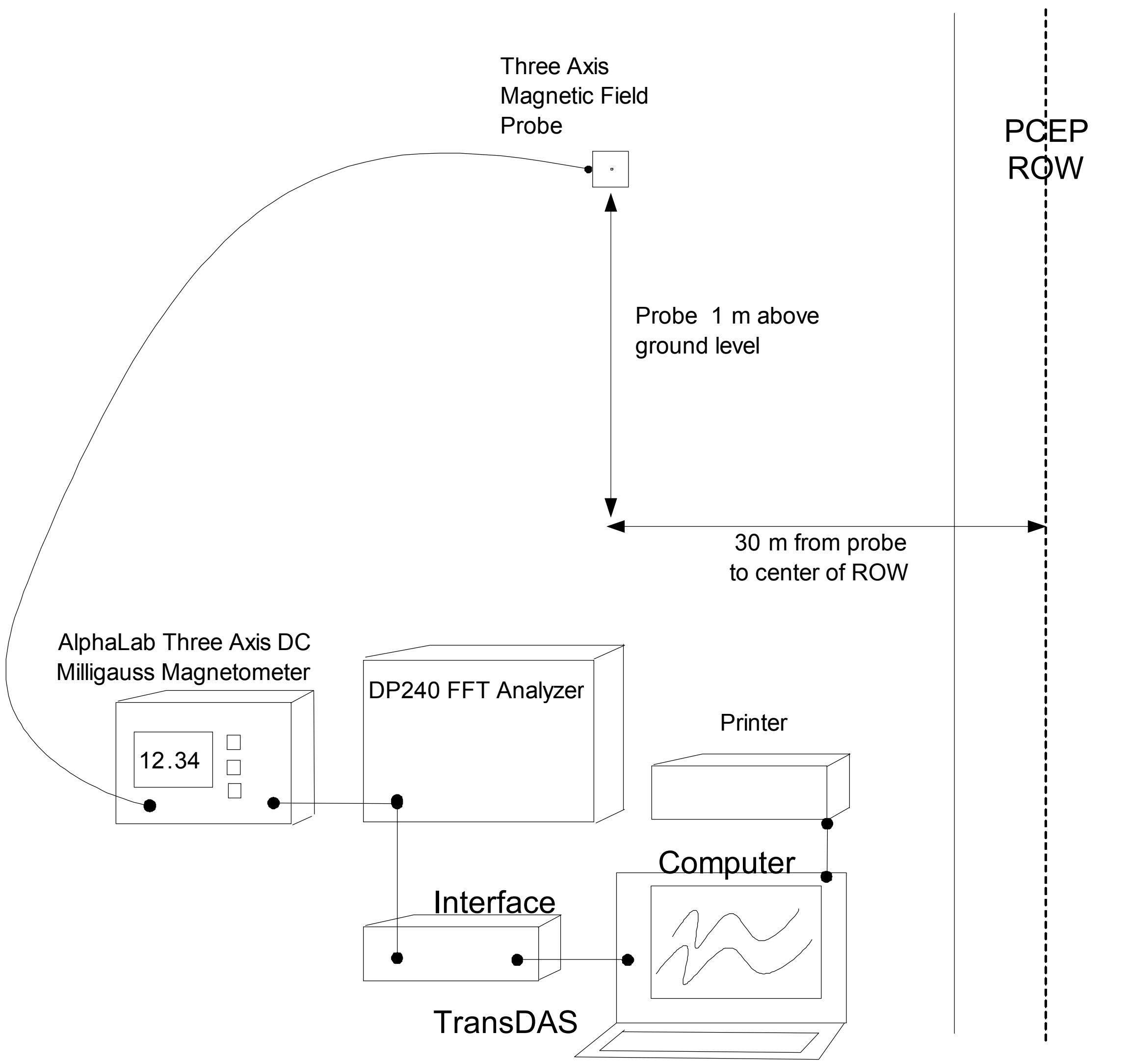
- Identification number for plot
- Measurement type
- Frequency band
- Measurement configuration data such as attenuation settings
- Summary results
- Notes

5 Magnetic Field Measurements

The magnetic field measurements include the static and AC magnetic fields from DC to 800 Hz, in three axes, at a height of 3.3 ft (1 m) above the ground. The purpose is to find and record the strongest magnetic field strengths, vectors, and magnitudes, and changes related to ambient conditions.

Figure 5-1 shows the measurement equipment setup for the magnetic field measurement.

FIGURE 5-1
Magnetic Field Measurement Equipment Setup



The earth's static (or DC) total magnetic field in San Francisco is about 483 mG, according to the NOAA National Centers for Environmental Information (https://www.ngdc.noaa.gov/geomag-web/#igrfwmm). The static magnetic field at any measurement point is significantly affected by nearby composition of the earth, and by the presence of large steel objects nearby (bridges, steel buildings, etc.). Fluctuations in the magnetic field with durations of 1 to 10 seconds are caused by passing steel vehicles (cars, buses, trucks, trains), and by the presence of fluctuating DC currents in nearby cables.

To measure the changes in DC magnetic field, the equipment must measure the magnetic field in three axes, subtract out the steady or 'offset' component to get the Delta DC Field, measure the three axis changes in the Delta DC Field, and calculate a combined Delta DC Field magnitude. The magnetometer and probe measure the DC field in three axes. The test engineers will use the Tenco TransDAS to subtract the offsets; measures the changes; calculates the combined Delta DC Field magnitude; and displays, records, and prints the results.

The magnetometer and probe measure the AC field in three axes. The Tenco TransDAS filters out two selected frequency components for each of the three axes (such as at 60 Hz and 80 Hz; presents the amplitude of the three axis selected frequency components; calculates a combined AC Field magnitude; and displays, records, and prints the results.

The AC magnetic field at a measurement site is most strongly due to AC currents in utility power cables, if any are nearby.

5.1 Measurement Equipment

Table 5-1 lists the magnetic field measurement measurement equipment.

TABLE 5-1

Magnetic Field Measurement Equipment List		
#	Item	Comment
1	Four Channel FFT Signal Analyzer, Data Physics ACE DP240 or equivalent	For measuring emission signals, typically FFT spectra
2	AlphaLab Inc. Three Axis DC Milligauss Magnetometer with Analog Outputs, or equivalent	For measuring magnetic field
3	Inkjet Printer, or equivalent	For plotting emission spectra. Compatible with 35670A Analyzer
4	Adjustable Antenna Tripod, non-metallic	To support magnetic field probe
5	AC Power Source	AC line, generator, or car battery inverter.
6	Tenco TransDas™ Data Acquisition System	Data Acquisition System
7	Laptop computer	For control of printer and storage of survey data results

The following subsections describe the major measurement equipment items.

5.1.1 Three-Axis DC Milligauss Magnetometer and Three-Axis Probe

The test engineers will use an AlphaLab Three Axis DC Milligauss Magnetometer and Three-Axis Probe to measure and display the amplitude of the magnetic field in each of three axes in the frequency range of static to 900 Hz (@ -3 dB), for fields of amplitude from 0.01 mG to 2 G. The magnetometer includes, for each axis, digital displays, offset controls, zero controls, and range controls.

The magnetometer has an analog output for each of three axes, each of which is proportional to the magnetic field. The three analog outputs will be connected to the Dynamic Signal Analyzer, so the AC frequency components of the magnetic field can be measured and processed. The three-axis probe is a one-inch cube which mounts three sensors, and is sensitive to magnetic fields transverse to each flat surface.

5.1.2 Dynamic Signal Analyzer

The Data Physics DP240 Signal Analyzer performs the following tasks:

- Measures the magnetometer outputs
- Converts from measured voltages into engineering units Gauss or Tesla
- Processes measured data to determine and display frequency components over the selected range
- Measures time sequence (waterfalls) or peak hold amplitudes
- Records to disk and prints out results on paper

5.1.3 Tenco TransDAS Data Acquisition System

The Tenco TransDAS is a laptop-based data acquisition system that uses the LabVIEW software development and operating environment to control data acquisition and perform analysis. A USB-connected, high-speed data acquisition module samples analog input signals at an aggregate of up to 500,000 samples per second and digitizes the result. The Tenco TransDAS stores the results in memory and calculates the quantities of interest for the test. The Tenco TransDAS provides fully annotated stripchart-type displays of selected variables versus time, with selectable calculation, processing, scaling, and labeling.

For this project, the Tenco TransDas performs the following tasks:

- Measures, records, and prints out the magnetometer outputs in an annotated stripchart format.
- Provide for input or selected DC offsets for each axis, subtracts the DC offset from DC magnetometer readings, combines the Delta DC Field components to get DC Field magnitude, selects two AC frequency components, filters two AC frequency components for each of the three axes, and combines two sets of AC axis frequency components to get AC Field magnitude at select frequencies.
- Converts from measured voltages to engineering units Gauss or Tesla
- Filters and displays incoming waveforms
- Records and displays the DC slow variation of the magnitude of a selected frequency component
- Records to disk and prints out results on paper

5.2 Measurement Bands

The test engineers will perform narrowband emission measurements in the range of static to 800 Hz, using the magnetometer, probe, and dynamic signal analyzer. The test engineers will measure and process emissions in three axes to determine the orientation of the highest field.

The test engineers will measure magnetic field at the frequencies and bands listed in table 5-2.

TABLE 5-2

Magnetic Field Measurement Bands	
ID	**Frequency Range**
FM0	DC
FM1	60 Hz
FM2	100 Hz - 1000 Hz
FM3	20 Hz - 1000 Hz
FM4	20 Hz - 200 Hz

If a measurement shows high levels of magnetic fields at a specific frequency, the test engineers will make a following measurement to zoom in on that frequency.

5.2.1 Narrowband Measurements

The expected magnetic field components will be the earth's magnetic field, AC magnetic fields due to nearby 60 Hz utility power cables, and other AC magnetic fields due to other frequency currents in nearby cables.

Since all these expected components are narrowband in nature, the test engineers will make these measurements with a narrowband mode and calibration. The dynamic signal analyzer and TransDAS are suitable instruments for making narrowband measurements.

5.3 Magnetometer Calibration

The test engineers will perform the following steps to verify proper operation of the magnetometer:

1. Turn on the magnetometer and let it warm up
2. After warm up, check the static magnetic field offset of each axis
    - Check the axis reading
    - Flip the probe cube over
        - If the magnetometer is properly zeroed, the axis reading should go from +xyz to -xyz
    - Repeat for each axis
    - Restore the probe to the nominal position
3. Check that the magnitude of the static electric field is close to the expected value for San Francisco

5.4 Site Diagram

The test engineers will make a detailed diagram of the measurement site, showing location, measurement point, nearby structures, emitters, Caltrain ROW, and other significant objects. The site diagram will include the measurement site latitude and longitude and photographs of the measurement site.

The BBII team will provide a map showing all measurement sites and the Caltrain ROW.

5.5 Magnetic Field Measurement Planning

The test engineers will arrange measurements to measure worst-case (maximum and minimum) magnetic field conditions, considering time of day, intermittent events, and local actions. Ambient magnetic field conditions change frequently because neighbor energy sources continually vary their operating conditions.

The test engineers will perform sufficient repeated measurements to identify worst-case conditions and characterize their amplitude, frequency, duration, and repetition at each measurement site.

5.6 Magnetic Field Measurement Method

For each measurement, the test engineers will maintain a log of the measurement type, measurement equipment, configuration, external event or condition description, comments, summary of measured data, and other relevant information. If the measurement includes a train, motor vehicle, or airplane, the test engineer will note it. The test engineer will record the magnetometer probe axis which detects the peak level.

5.6.1 Magnetic Field Measurement Steps

The steps are:

1. Setup at the measurement site.

2. Calibrate the magnetometer.

3. With the Tenco TransDas and Data Physics DP240 set Max/Min, measure and record for 30 s time intervals. Observe measurements through range of conditions at particular site, such as traffic nearby, etc.

4. Identify and characterize worst-case conditions. Print the results.

5.6.2 Narrowband Emission Evaluation

The test engineer will measure magnetic field emissions and record narrowband levels.

5.6.3 Field Reduction of Data

The test engineers will set up the dynamic signal analyzer to display measurements in Gauss (G). The test engineers will print out and save the data for each valid measurement run.

The test engineers will characterize each measurement, noting:

- Key emissions in the measurement
- Changes between the measurement and recent similar measurements
- Similarities or differences to other measurements in the same band at other locations
- Whether the measurement is an apparent worst case

5.6.4 Measurement Data Collection

The test engineers will collect data, including for measurement equipment and each ambient site measurement.

Equipment Calibration: Record calibration data for each major measurement equipment item. Calibration data will include the following:

- Measurement equipment item
- Manufacturer
- Model
- Serial number
- Calibration date
- Calibration source
- Reference number
- Notes

Measurement Log: Maintain a measurement run log, recording the following for each measurement:

- Date
- Time
- Performed by
- Location
- Site conditions
- Event
- Run number
- Identification number for plot
- Measurement type
- Frequency band

- Measurement configuration data such as attenuation settings
- Summary results
- Notes

6 Measurement Report Format

The test engineers will document the measurement results in a measurement report compliant with this procedure, and provide it to BBII for system-level evaluation. The measurement report will consist of sections including or equivalent to the following:

Section 1, Introduction: The Introduction section provides the purpose, scope, applicable requirements, participants, reference documents, measurement procedure overview, and organization for the rest of the report.

Section 2, Measurement Results and Conclusions: The Measurement Results and Conclusions section provides tables of:

- Radiated electric field:
  - For each frequency band, worst-case emitters, including amplitude and frequency of emission, location, conditions, and preliminary assessment of impact.
  - For each frequency band, most quiet condition
  - Notes on potential victim locations in the section.
- Magnetic field:
  - From static to 800 Hz, worst-case fields, including amplitude and frequency of emission, location, conditions, and preliminary assessment of impact.
  - From static to 800 Hz, most quiet condition
  - Notes on potential victim locations in the section.

The section also provides the measurement schedule and scope and a top level index of all measurements; it identifies, references, and describes the most important results, and states conclusions.

Section 3, Caltrain Alignment and Measurement Sites: The Caltrain Alignment section describes the actual measurement locations relative to the proposed Alignment. It provides maps showing the site and the Caltrain ROW. It provides a detailed diagram and photographs for each site.

Section 4, Measurement Equipment Configuration: The Measurement Equipment Configuration section describes the measurement equipment configuration, including a measurement equipment connection diagram, a list of measurement equipment with model numbers, and instrument calibration dates and calibration certificates.

This section provides complete information on the scale or conversion factors which apply to all survey data, including Antenna or Probe outputs, data-time series charts, and Analyzer plots. It provides initial setup calibration data, which demonstrates that the Antennas, the RF Spectrum Analyzer, Magnetometer, Dynamic Signal Analyzer, transducers, and external instruments give correct, accurate, and repeatable results.

Section 5, Measurement Procedure: The Measurement Procedure section summarizes the measurement steps, and describes any differences between the "as-performed" measurement steps and the measurement steps.

Section 6, Measurements and Data: The Measurements and Data section describes significant measurement results, conclusions, or considerations. This section summarizes all data collected during the measurements. It includes a log and index of all measurements, print outs, and spectral plots. The log includes the Date, Survey Participants, Location, and notes for all measurements. It provides the Measurement Number, Measurement Type and Time; IDs of hardcopies and data files; measurement description; measurement configuration data such as gain settings; summary result; and notes.

Appendix A

EMI/RFI Survey Forms

EMI/RFI Survey measurement forms follow:

- Measurement Equipment Calibration Record
- EMI/RFI Survey Configuration Record
- EMI/RFI Survey Run Log
- EMI/RFI Survey Directory, Electric Field and Magnetic Field
- Survey Site Plan

Recorded by: ______________________________ **Date:** __________________________

PCEP EMI/RFI Survey Measurement Equipment Calibration Record				
#	**Item**	**Manufacturer**	**Model/Serial Number**	**Calibration / Date**
1	RF Signal Analyzer with EMI Measurement application	Keysight Technologies	KT-9010A-507/P07/EDP KT-N6141A/2TP	
2	PC Software, EMI Measurement application	Keysight Technologies	KT-N6141A/2TP	
3	Active Monopole Antenna 10 kHz to 60 MHz	A.H. Systems, Inc.	SAS-550-1	
4	Bilogical Antenna 25 MHz to 7 GHz	A.H. Systems	SAS-521F-7	
5	Laptop computer	Lenovo		
6	TransDAS Data Acquisition System	Tenco	TransDas	
7	Three Axis DC Milligauss Magnetometer with Analog Outputs	AlphaLab Inc.	Model #3AMG	
8	Four Channel FFT Signal Analyzer	Data Physics	DP240 or equiv.	
9	Printer	Brother	MFC-J280W	
10				
11				
12				

PCEP EMI/RFI Survey Log

Date: ____________________ **Time:** ________________ **Weather:** ________________________ **Performed By:** ____

Line: ________________________ **Location:** ____________________________________ **Notes:**____

Measurement ID	Time	Type	Frequency Band	Location	Conditions	Results
1						
2						
3						
4						
5						
6						
7						
8						
9						
0						

Date: ____________________ **Time:** ________________ **Weather:** _________________ **Performed By:** ____

Line: ________________________ **Location:** ___________________________________ **Notes:**____

PCEP EMI/RFI Survey Radiated Electric Field Measurement Directory

Site		Frequency Band							
		B0: 10 to 160 kHz Monopole Vertical 1 kHz res bw	**B1: 150 to 650 kHz** Monopole Vertical 10 kHz res bw	**B2: 500 kHz to 3 MHz** Monopole Vertical 10 kHz res bw	**B3: 2.5 to 7.5 MHz** Monopole Vertical 10 kHz res bw	**B4: 5 to 30 MHz** Monopole Vertical 100 kHz res bw	**B5: 25 to 325 MHz (Note V or H polarity)** Bilogical, 100 kHz res bw	**B6: 0.3 to 1.3 GHz (Note V or H polarity)** Bilogical, 300 kHz res bw	**B7: 1 GHz to 6 GHz (Note V or H polarity)** Bilogical, 300 kHz res bw

Date: ____________ Time: ____________ Weather: ____________ Performed By: ______________________________

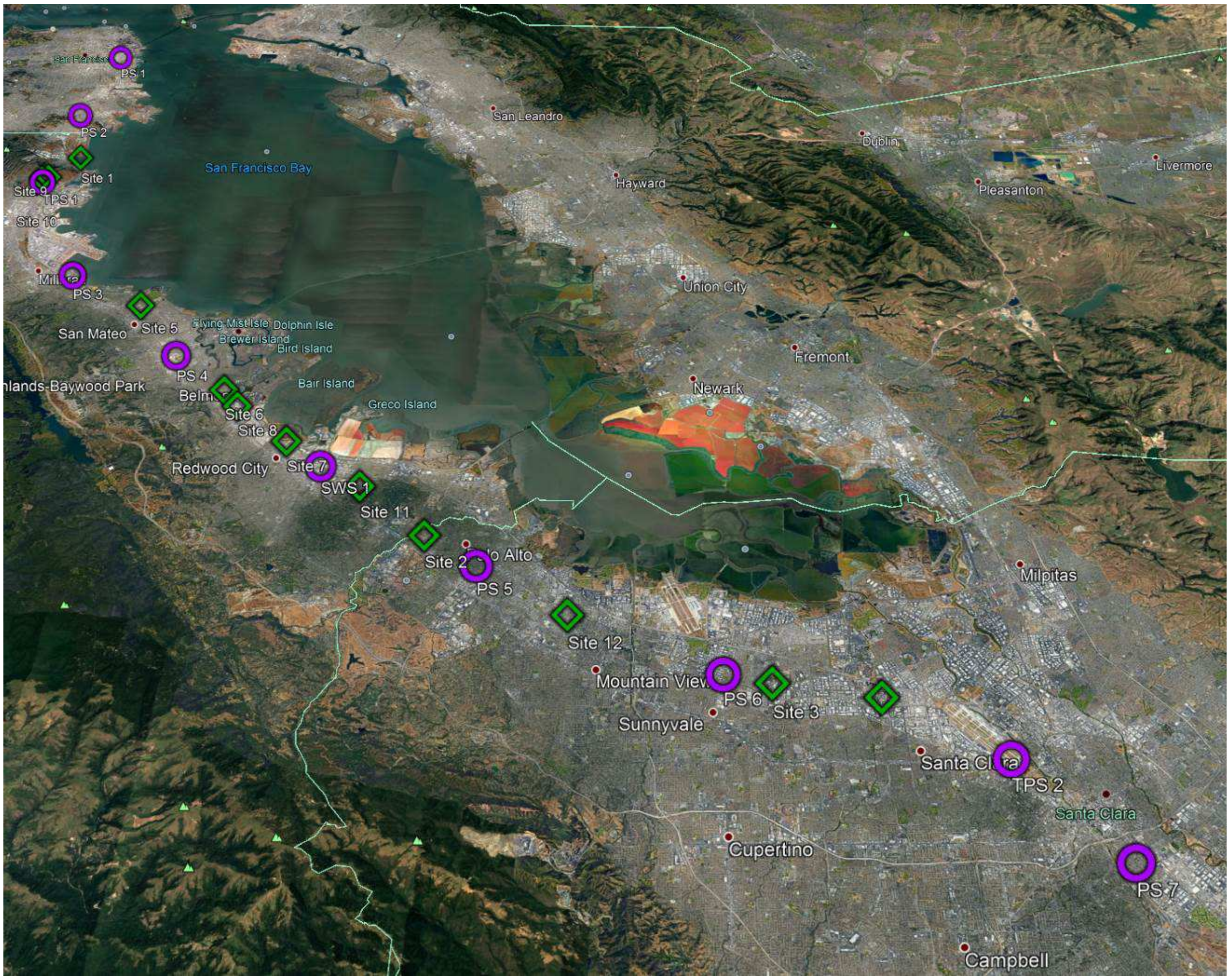
Line: ______________ Location: ______________________ Notes:______________________________

PCEP EMI/RFI Survey Magnetic Field Measurement Directory						
Site		FM0: DC	FM1: 60 Hz	FM2: 100 Hz - 1000 Hz	FM3: 20 Hz - 1000 Hz	FM4: 20 Hz - 200 Hz

Appendix B

Measurement Sites

Overview: Measurement Sites and Traction Power Facilities



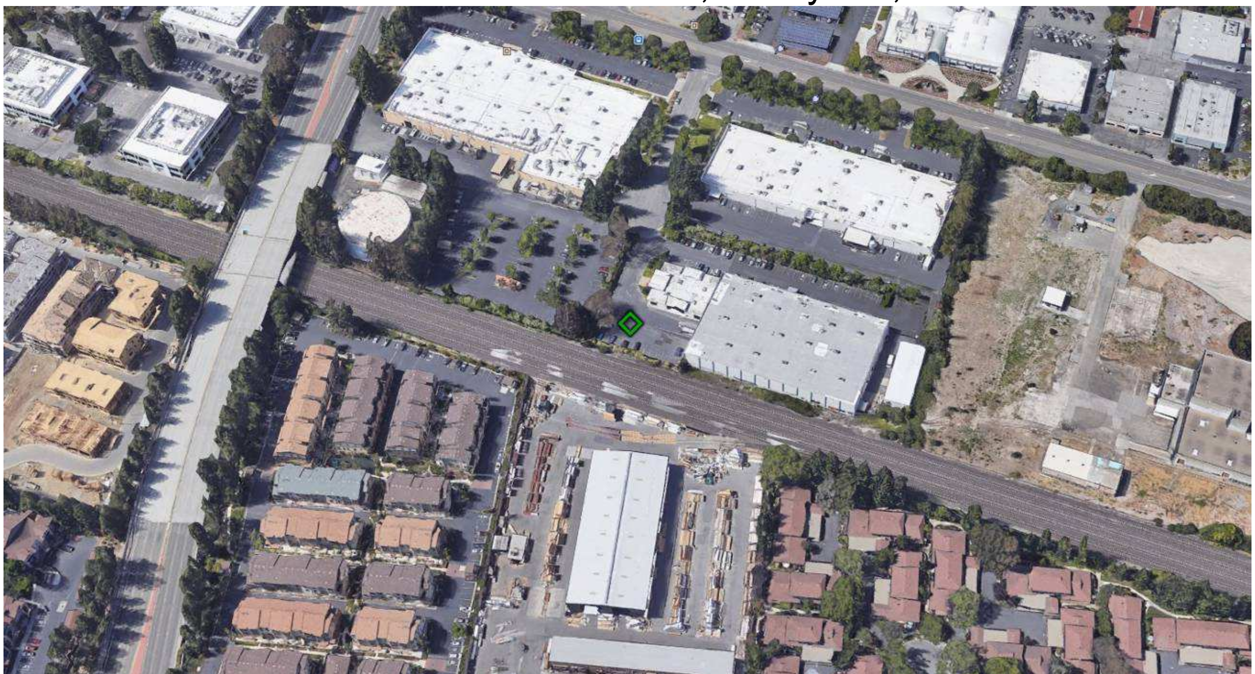
Site 1: 5000 Sierra Point Pkwy, Brisbane, CA

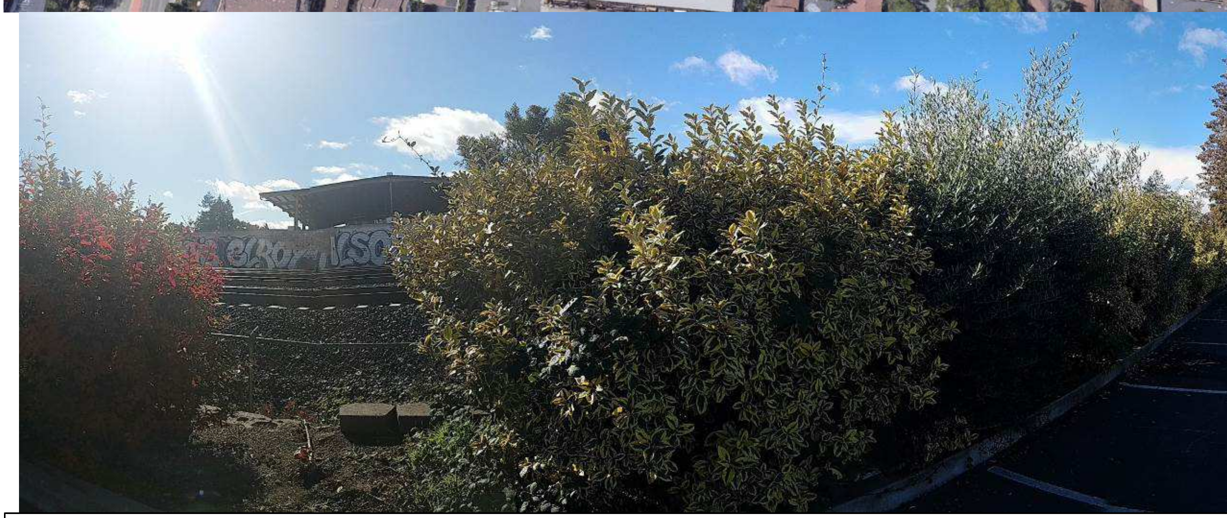
Nearby Receptor Description					
ID #	Name	Type	Site Cat.	Susc. Cat.	Env. Cat
177	AFFYMETRIX, INC.	LABORATORY ANALYTICAL INSTRUMENTS	5	C	B
206	EPOCH BIOSCIENCES, INC.	PHYSICIANS & SURGEONS EQUIP & SUPLS-MFRS	5	A	B
273	LIFEMASTERS SUPPORTED SELFCARE	TELEPHONE COMMUNICATION, EXCEPT RADIO	5	B	B
348	TOSOH BIOSCIENCE, INC.	MEDICAL EQUIPMENT AND SUPPLIES	4	A	B
528	ACHAOGEN INC	BIOLOGICAL RESEARCH	5	B	B
550	FLUIDIGM CORPORATION	BIOLOGICAL RESEARCH	5	B	B
554	GENESOFT INC	COMMERCIAL PHYSICAL RESEARCH	5	B	B
558	HANA BIOSCIENCES, INC.	COMMERCIAL PHYSICAL RESEARCH	5	B	B
568	NODALITY	BIOLOGICAL RESEARCH	5	B	B
591	ACTELION LTD	NONCOMMERCIAL RESEARCH ORGANIZATIONS	5	B	B
596	NEORX CORPORATION	NONCOMMERCIAL RESEARCH ORGANIZATIONS	5	B	B
604	VERACYTE, INC.	NONCOMMERCIAL BIOLOGICAL RESEARCH ORGANIZATION	5	B	B

Site 2: 795 El Camino Real, Palo Alto, CA 94304

Nearby Receptor Description					
ID #	Name	Type	Site Cat.	Susc. Cat.	Env. Cat
R11	Palo Alto Medical Foundation	Medical facility	5	C	B

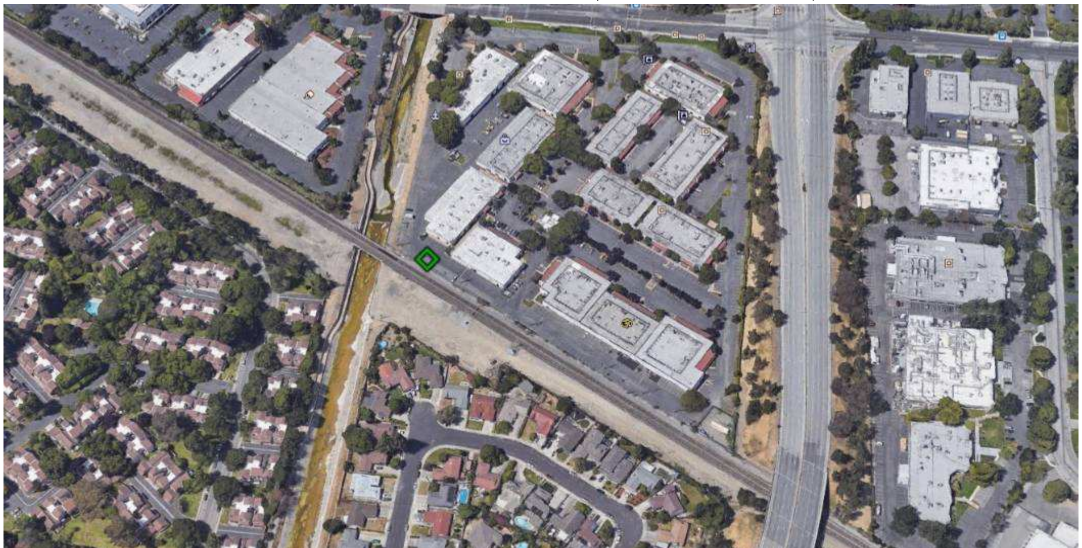
Site 3: 120 San Lucar Ct, Sunnyvale, CA





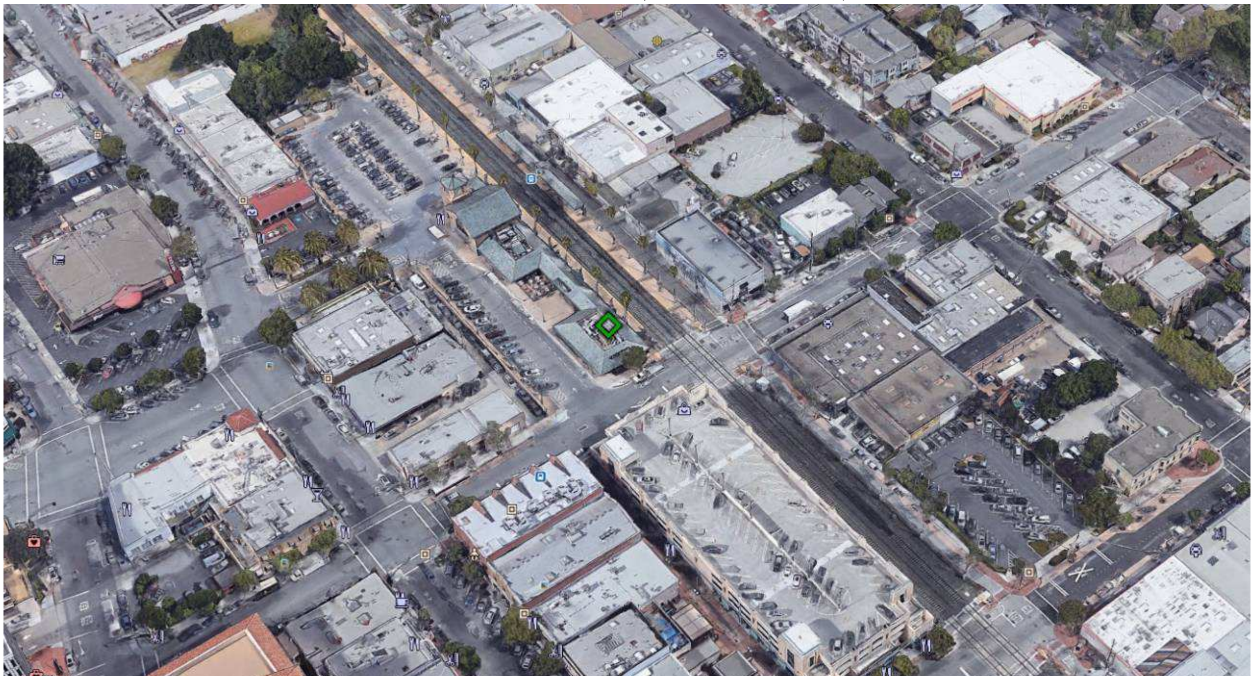
Nearby Receptor Description					
ID#	Name	Type	Site Cat.	Susc. Cat.	Env. Cat
25	COLFAX INTERNATIONAL	ELECTRONIC COMPUTERS	4	B	B
487	BUSINESS ENGINE	TESTING LABORATORIES	4	C	B
573	PHARMOUT LABORATORY INC	COMMERCIAL PHYSICAL RESEARCH	5	B	B
605	AMER	LABORATORIES-TESTING	4	B	B
606	GIGA TEST LABS	LABORATORIES-TESTING	4	B	B

Site 4: 2368 Walsh Ave, Santa Clara, CA



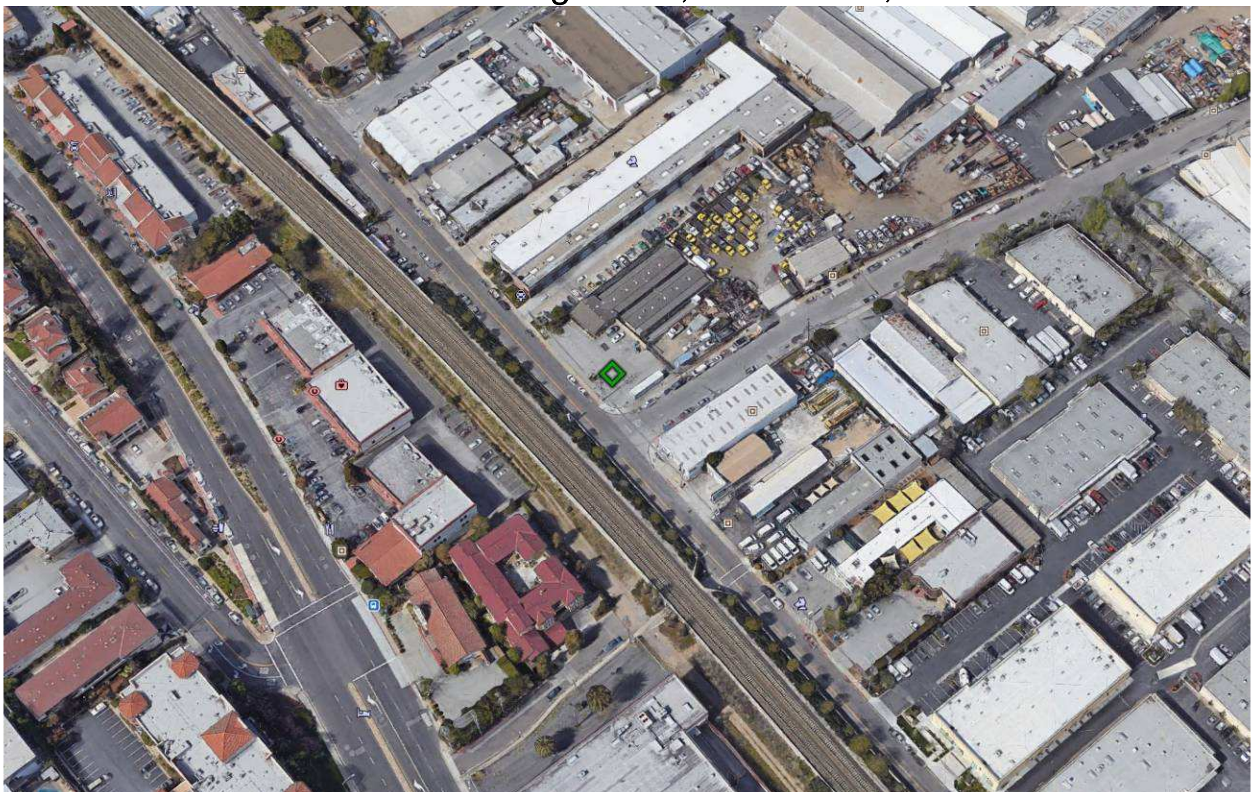
Nearby Receptor Description					
ID #	**Name**	**Type**	**Site Cat.**	**Susc. Cat.**	**Env. Cat**
1	BJS ENTERPRISES	ELECTRIC POWER SYSTEMS CONTRACTORS	5	A	B
24	ADVANCED NET SOLUTIONS	ELECTRONIC COMPUTERS, NEC	5	B	B
27	CORE MICROSYSTEMS	ELECTRONIC COMPUTERS	5	B	B
73	USAPEX CORP	PRINTED & ETCHED CIRCUITS-MFRS	5	A	B
74	USAPEX CORP	PRINTED CIRCUIT BOARDS	5	A	B
91	DELTA DESIGN INC	SEMICONDUCTORS AND RELATED DEVICES	5	B	B
92	DRS TECHNOLOGIES INC	RADIATION SENSORS	5	c	B
95	FIB USA INC	SEMICONDUCTORS & RELATED DEVICES (MFRS)	5	B	B
116	POLYSTAK INC	SEMICONDUCTORS & RELATED DEVICES	5	B	B
119	SENTIR	SEMICONDUCTORS AND RELATED DEVICES	5	B	B
164	COHU, INC.	TEST EQUIPMENT FOR ELECTRONIC AND ELECTRIC MEASUREMENT	5	C	B
165	EMULATION TECHNOLOGY	INSTRUMENTS FOR MEASURING AND TESTING OF ELECTRICITY AND ELECTRICAL SIGNALS (AUTOMOTIVE AMMETERS AND VOLTMETERS)	5	C	B
174	TEKTRONIX INC	INSTRUMENTS TO MEASURE ELECTRICITY	5	C	B
216	MERIT SENSOR SYSTEMS INC	SURGICAL MED INSTRS	5	A	B
251	IJAK SOLUTIONS INC	CELLULAR TELEPHONES (SERVICES)	5	A	B
290	VERIZON BUSINESS	TELECOMMUNICATIONS SERVICES	5	B	B
307	DIGITAL 5	COMMUNICATION SERVICES, NEC	5	B	B
344	SHIMADZU PRECISION INSTRUMENTS	MEDICAL AND HOSPITAL EQUIPMENT	5	A	B
356	ENTEST WEST INC	ELECTRONIC TESTING EQUIPMENT (WHLS)	5	B	B
357	EASTERN ELECTRONICS USA INC	COMMUNICATION EQUIPMENT	5	B	B
531	ALCOR BIOSEPARATIONS	COMMERCIAL PHYSICAL RESEARCH	5	B	B

Site 5: 159 S B St, San Mateo, CA



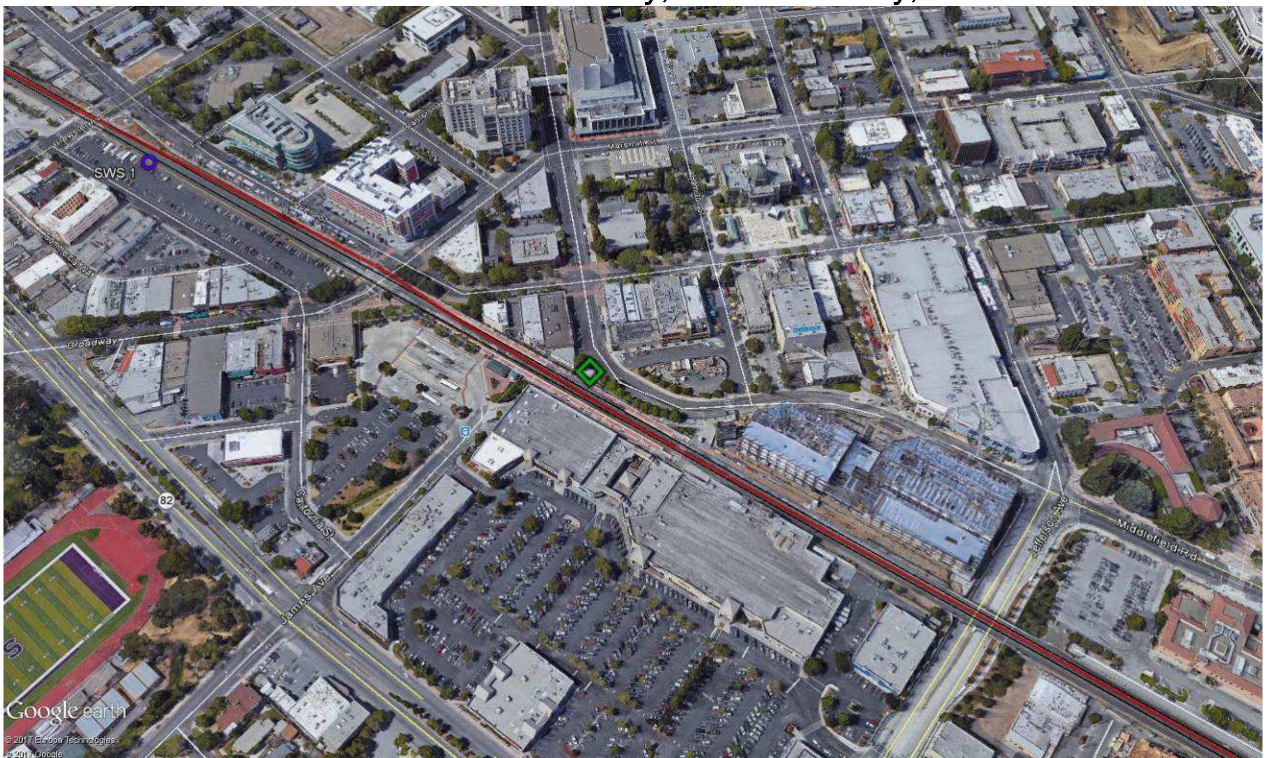
Nearby Receptor Description					
ID#	**Name**	**Type**	**Site Cat.**	**Susc. Cat.**	**Env. Cat**
42	WALLTECH	POWER, DISTRIBUTION & SPECIALTY TRANSFORMERS	5	B	B
144	NEURAL ID	MAGNETIC DISKS AND DRUMS	5	A	B
285	ROUTESCIENCE TECHNOLOGIES INC	TELEPHONE COMMUNICATION, EXCEPT RADIO	5	B	B
385	HANGER PROSTHETICS & ORTHOTICS	MEDICAL APPARATUS AND SUPPLIES	5	B	B
401	ALLERGY CLINIC	PHYSICIANS & SURGEONS	5	A	B
407	CHEN, YUNG MD	PHYSICIANS & SURGEONS	5	A	B
416	GELLER, ALBERT S MD	PHYSICIANS & SURGEONS	5	A	B
429	LAANE, CHRISTINA J MD	PHYSICIANS & SURGEONS	5	A	B
431	LIANG, WEN MD	PHYSICIANS & SURGEONS	5	A	B
464	TAN, CHRISTINA MD	PHYSICIANS & SURGEONS	5	A	B
493	QUEST DGNSTICS CLNICAL LABS DE	MEDICAL LABORATORIES	5	C	B

Site 6: 565 Bragato Rd, San Carlos, CA



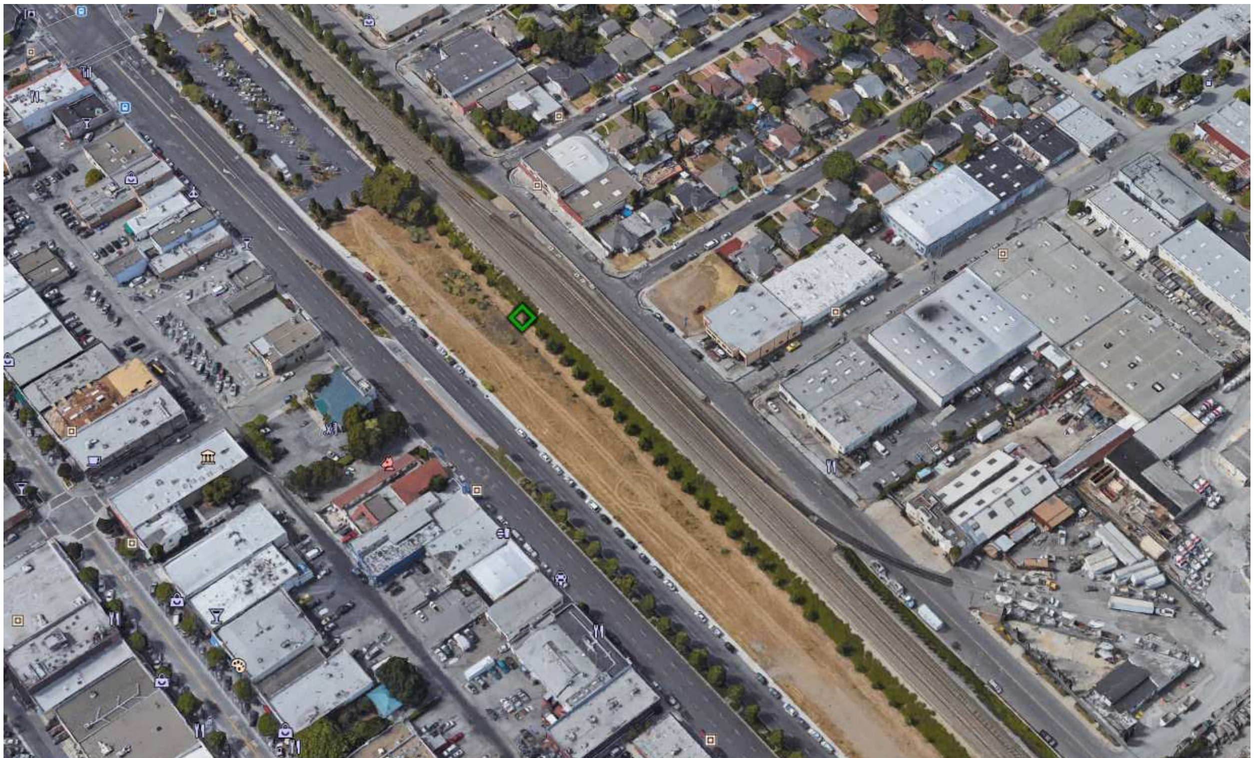
Nearby Receptor Description					
ID#	**Name**	**Type**	**Site Cat.**	**Susc. Cat.**	**Env. Cat**
186	INFORMATION PROCESSING SYSTEMS OF CALIFORNIA, INC.	GEOPHYSICAL AND METEOROLOGICAL TESTING EQUIPMENT	5	C	B
190	PROFESSIONAL COMM SVCS	GEOPHYSICAL AND METEOROLOGICAL TESTING EQUIPMENT	5	C	B
377	A V INTEGRATORS	TELEPHONE AND COMMUNICATION EQUIPMENT	5	B	B
396	TRANSPARENT VIDEO SYSTEMS	SATELLITE EQUIP & SYSTEMS-SVC & REPAIR	5	A	B
527	TEKAMAKI LP	LIGHTING ENGINEERS	4	A	B
529	ACTIVE SPECTRUM INC	COMMERCIAL PHYSICAL RESEARCH	5	B	B

Site 7: 2401 Broadway, Redwood City, CA



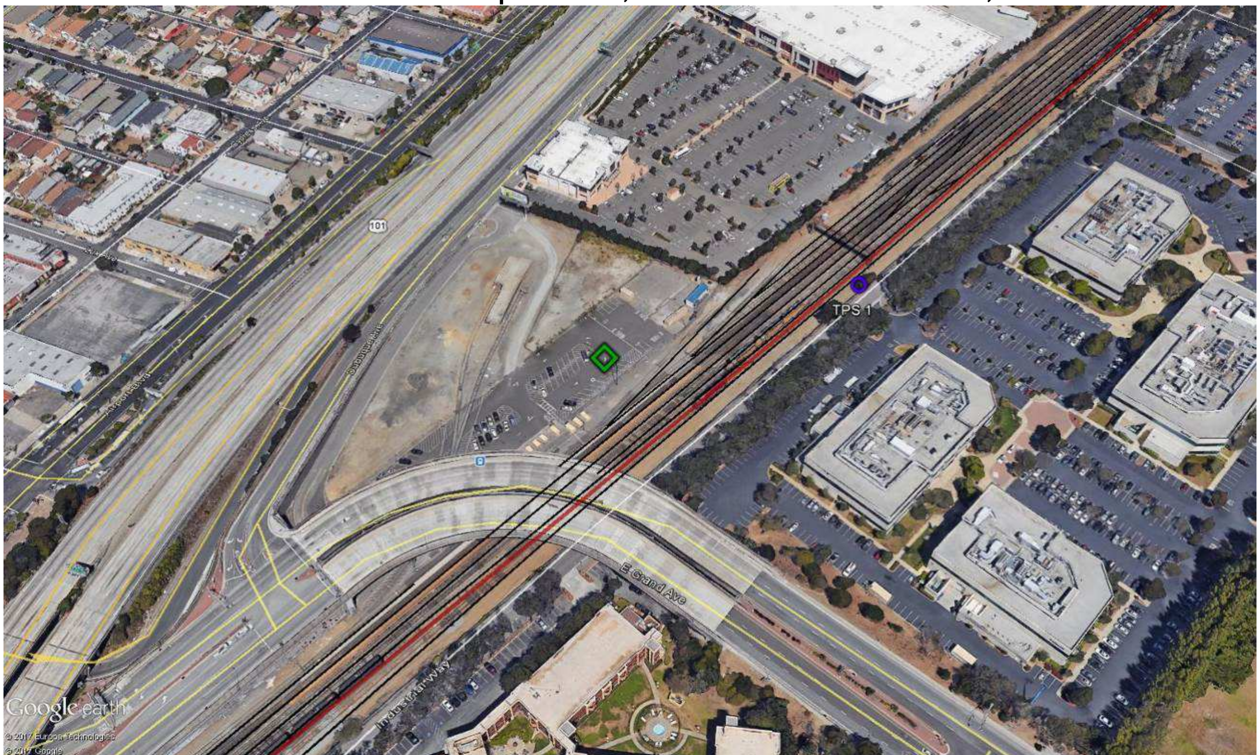
Nearby Receptor Description					
ID#	Name	Type	Site Cat.	Susc. Cat.	Env. Cat
195	BD VENTURES L.L.C	SURGICAL AND MEDICAL INSTRUMENTS AND APPARATUS	4	A	B
215	MANOA MEDICAL	SURGICAL AND MEDICAL INSTRUMENTS	5	A	B
254	METRO PCS	CELLULAR TELEPHONES (SERVICES)	5	A	B
297	ALPHA COMMUNICATIONS	COMMUNICATION SERVICES, NEC	5	B	B
359	PARROT CELLULAR 14	TELEPHONE AND TELEGRAPHIC EQUIPMENT	5	B	B
373	BAYCHEM	CHEMICALS (WHLS)	5	A	B
384	ENTREPRENEURIAL VENTURES INC	TELEPHONE AND COMMUNICATION EQUIPMENT	5	B	B
480	YEE, BRIAN DDS	DENTISTS	4	B	B

Site 8: 700 El Camino Real, San Carlos, CA



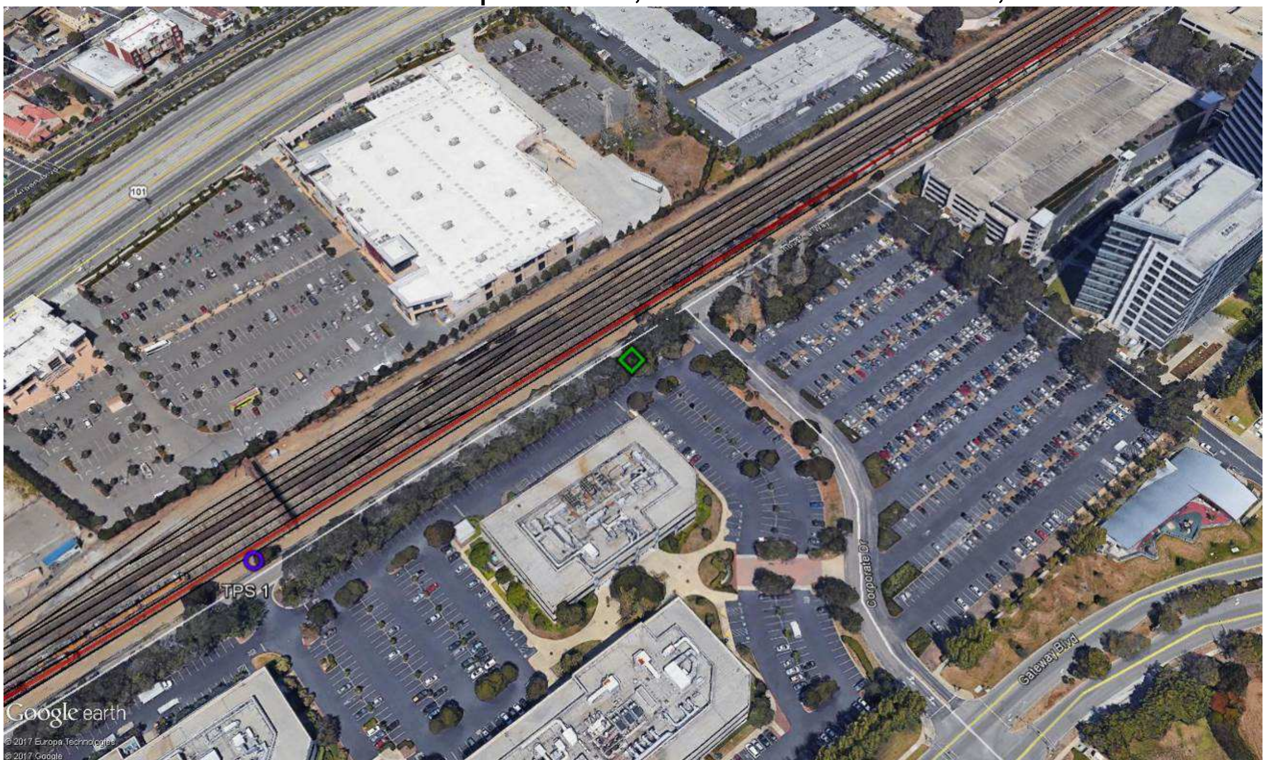
Nearby Receptor Description					
ID#	Name	Type	Site Cat.	Susc. Cat.	Env. Cat
223	SERVICOR INC	PHYSICIANS & SURGEONS EQUIP & SUPLS-MFRS	5	A	B
321	STAT COMMUNICATION	COMMUNICATION SERVICES, NEC	5	B	B
405	BRAUNSTEIN, RICHARD B MD	PHYSICIANS & SURGEONS	4	A	B
468	TRAN, NINH MD	PHYSICIANS & SURGEONS	4	A	B
481	CLAR, MELINDA	DENTAL HYGIENISTS	5	A	B
525	CALIFORNIA MEDICAL ASSOCIATION	MEDICAL FIELD-RELATED ASSOCIATIONS	5	A	B

Site 9: 590 Dubuque Ave, South San Francisco, CA



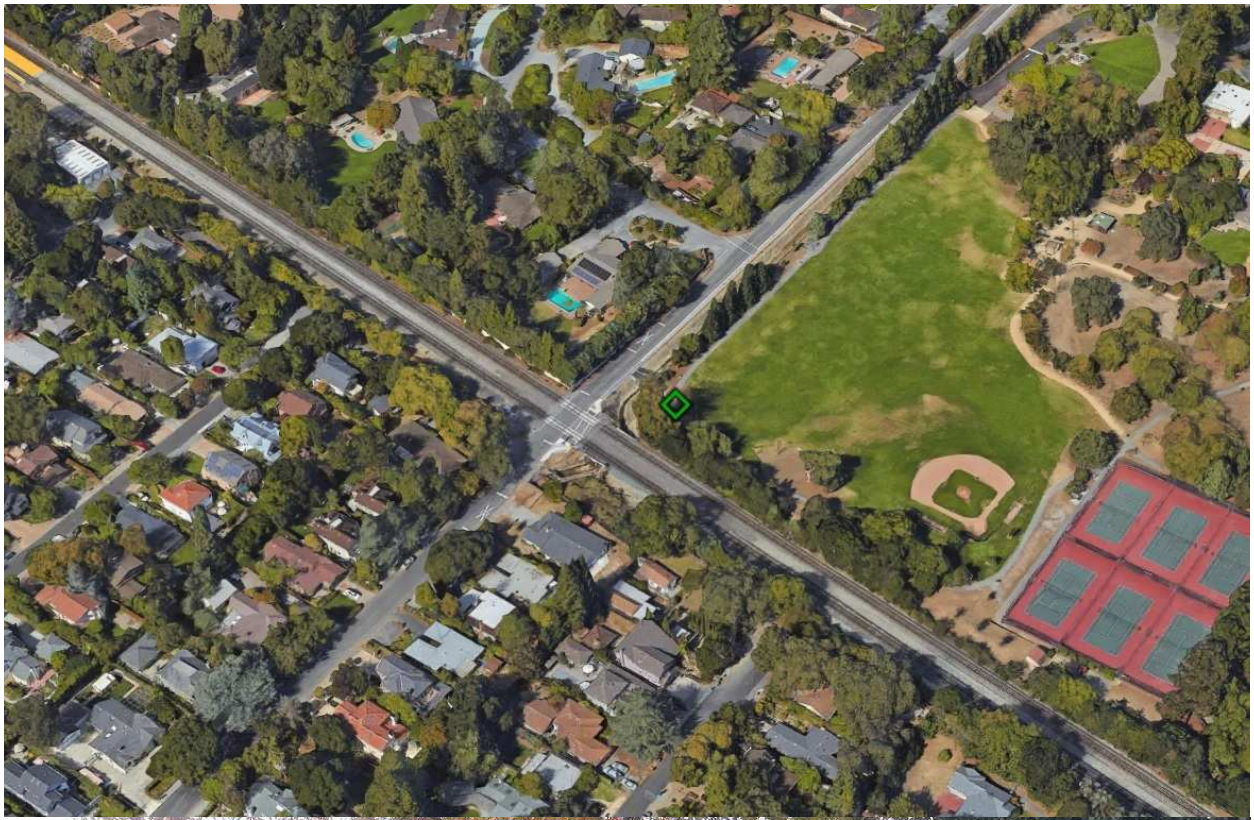
Nearby Receptor Description					
ID #	Name	Type	Site Cat.	Susc. Cat.	Env. Cat
352	PREDICANT BIOSCIENCES INC	SCIENTIFIC AND ENGINEERING EQUIPMENT AND SUPPLIES	5	B	C
398	PENINSULA COML KIT EQP CO	AIRCRAFT AND HEAVY EQUIPMENT REPAIR SERVICES	3	A	C
548	FIBROGEN INC	COMMERCIAL PHYSICAL RESEARCH	4	B	C
569	NODALITY, INC.	BIOLOGICAL RESEARCH	5	B	C
579	RENOVIS INC	BIOLOGICAL RESEARCH	5	B	C
581	SOLAZYME, INC.	BIOTECHNICAL RESEARCH, COMMERCIAL	4	B	C
603	TRELLIS BIOSCIENCE INC.	NONCOMMERCIAL BIOLOGICAL RESEARCH ORGANIZATION	5	B	C

Site 10: Two Corporate Dr, South San Francisco, CA



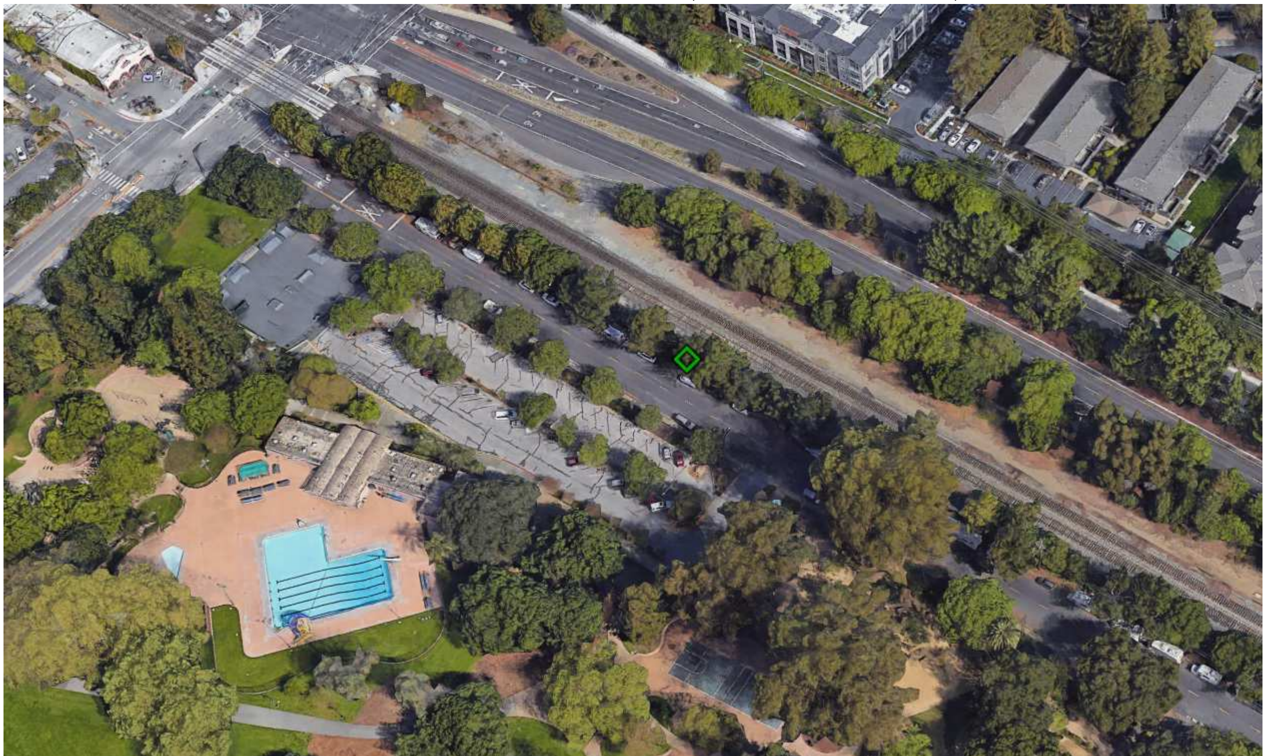
Nearby Receptor Description					
ID #	**Name**	**Type**	**Site Cat.**	**Susc. Cat.**	**Env. Cat**
13	NET CLERK INC	CHEMICAL PREPARATIONS, NEC	5	A	B
50	NETVERSANT	TELEPHONE AND TELEGRAPH APPARATUS	5	B	B
52	UNITED TELECOM INC	TELEPHONE AND TELEGRAPH APPARATUS	5	B	B
556	GLOBAL SOLUTIONS FOR INFECTIOUS DISEASES	COMMERCIAL PHYSICAL RESEARCH; NEC	5	B	B
560	INPRO BIOTECHNOLOGY INC	BIOLOGICAL RESEARCH	5	B	B

Site 11: 98 McCormick Ln, Atherton, CA



Nearby Receptor Description					
ID #	Name	Type	Site Cat.	Susc. Cat.	Env. Cat
NA	Quiet Site	Quiet Site	NA	NA	NA

Site 12: 2000 Crisanto Ave, Mountain View, CA

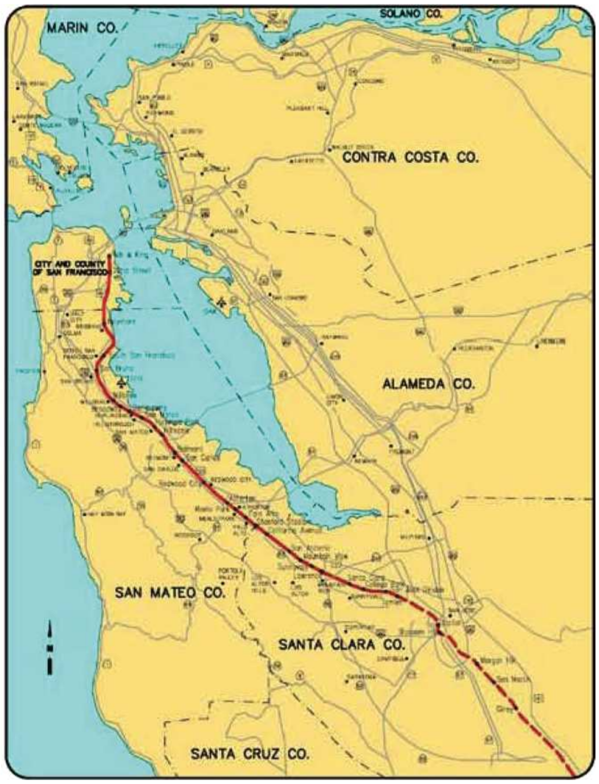


Nearby Receptor Description					
ID#	Name	Type	Site Cat.	Susc. Cat.	Env. Cat
NA	Quiet Site	Quiet Site	NA	NA	NA

Appendix R-2

New Rail System
Stray Current Procedure

SAN FRANCISCO BAY AREA



Caltrain®

PENINSULA CORRIDOR JOINT POWERS BOARD

DESIGN BUILD ELECTRIFICATION PROJECT

CONTRACT NO. 14-PCJPB-P-053

New Rail System Stray Current Procedure

REVISION 0

May 9, 2024

TURNER ENGINEERING CORPORATION

PGH WONG ENGINEERING INC.

Balfour Beatty Infrastructure Inc.

Appendix R-2 Stray Current Procedure

Revision History		
Date	**Rev.**	**Change**
May 9, 2024	0	Initial release.

Table of Contents

1 Stray Current Introduction and Objective

For the Caltrain Peninsula Corridor Electrification Project (PCEP), STV performed and reported on baseline stray current in CDRL 33080 – Stray Current and Atmospheric Corrosion Study Final ("Baseline Study") in 2017, prior to PCEP construction and electrification. In the Baseline Study, STV measured stray current along the PCEP corridor, primarily on fencing at the interface areas between fixed structures such as fire hydrants, and between the future AC PCEP line and existing MUNI, BART, and VTA DC powered rail lines. The purpose was to quantify existing DC leakage current from MUNI, BART or VTA, and AC leakage current from utility power usage.

For stray currents, the Baseline Study concluded that:

- DC potential measurements taken along the PCEP alignment and adjacent to MUNI, BART, and VTA showed a negligible to mild stray DC current level at three locations.

- AC potential measurements taken along the PCEP alignment and adjacent to MUNI, BART, and VTA showed a negligible stray AC current level.

1.1 DC Baseline Measurements and Evaluation

Table 1-1 shows NACE 10B189 Stray Current Versus Corrosion Potential designations and remediation recommendations for measured DC stray current levels. NACE categorizes DC stray current as negligible, mild, moderate, or severe. The Baseline Study recommended follow-up stray current measurements as part of system integration testing at test sites which had mild stray DC current levels, for comparison of energized conditions to baseline values.

Table 1-1
DC Stray Current Versus Corrosion Potential and Testing
NACE 10B189

Total Time Weighted Variation in Structure-to-Earth Potential, mV DC	Stray Current Activity Designation	Typical Suggested Remedy
<25	Negligible	No Further Action
25 to 75	Mild	No Further Action; Flag for Future Testing
75 to 150	Moderate	Increase Testing Frequency, Analyze Impact to CP Systems
>150	Severe	Troubleshoot and Repair

The following three test sites, listed in Appendix A-6 and A-8 of the Baseline Study, had mild stray DC current levels, with values reported as Change in Time Weighted Structure-to-Earth Potential:

1. California Drive, South-End and North-End Fence Span, 9/14/2017 (A-6, 6)
   - 65.5 mV DC at the South-End Fence Span
   - 53.5 mV DC at the North-End Fence Span
2. Hydrant at 5th and King, 9/11/2017 (A-8, 5)
   - 29.0 mV DC
3. Hydrant 3 at Bayshore & Blanken, 8/30/2017 (A-8, 6)
   - 41.0 mV DC

This procedure notes that while the Baseline Study executive summary said STV measured mild DC stray current levels at five test sites, only three test sites were actually categorized as mild.

1.2 AC Baseline Measurements and Evaluation

For AC potentials, NACE SP0177-2014 recommends mitigation for all AC potentials over 15 VAC, for personnel safety. The Baseline Study found that all recorded AC stray current were well below the 15 VAC criteria for standard step-touch potentials regarding personnel safety.

1.3 Objective and Content

The objective of the follow-up stray current test is to repeat the AC and DC stray current tests at these three locations to determine if the stray current levels have changed. If additional testing shows DC stray current stays at mild levels, no additional mitigation is required.

This follow-up stray current test procedure provides AC and DC stray current measurement steps to repeat the measurements made in the Baseline Study in 2017.

This procedure references the Baseline Study and the STV Field Notes, which summarize test location descriptions and test setup diagrams from the Baseline Study.

2 Stray Current Measurement

2.1 Test Setups

Figure 2-1 shows the equipment setup for stray current measurement on a fence span. Figure 2-2 shows the equipment setup for stray current measurement on a fire hydrant.

Figure 2-1
Fence Stray Current Measurement Equipment Setup

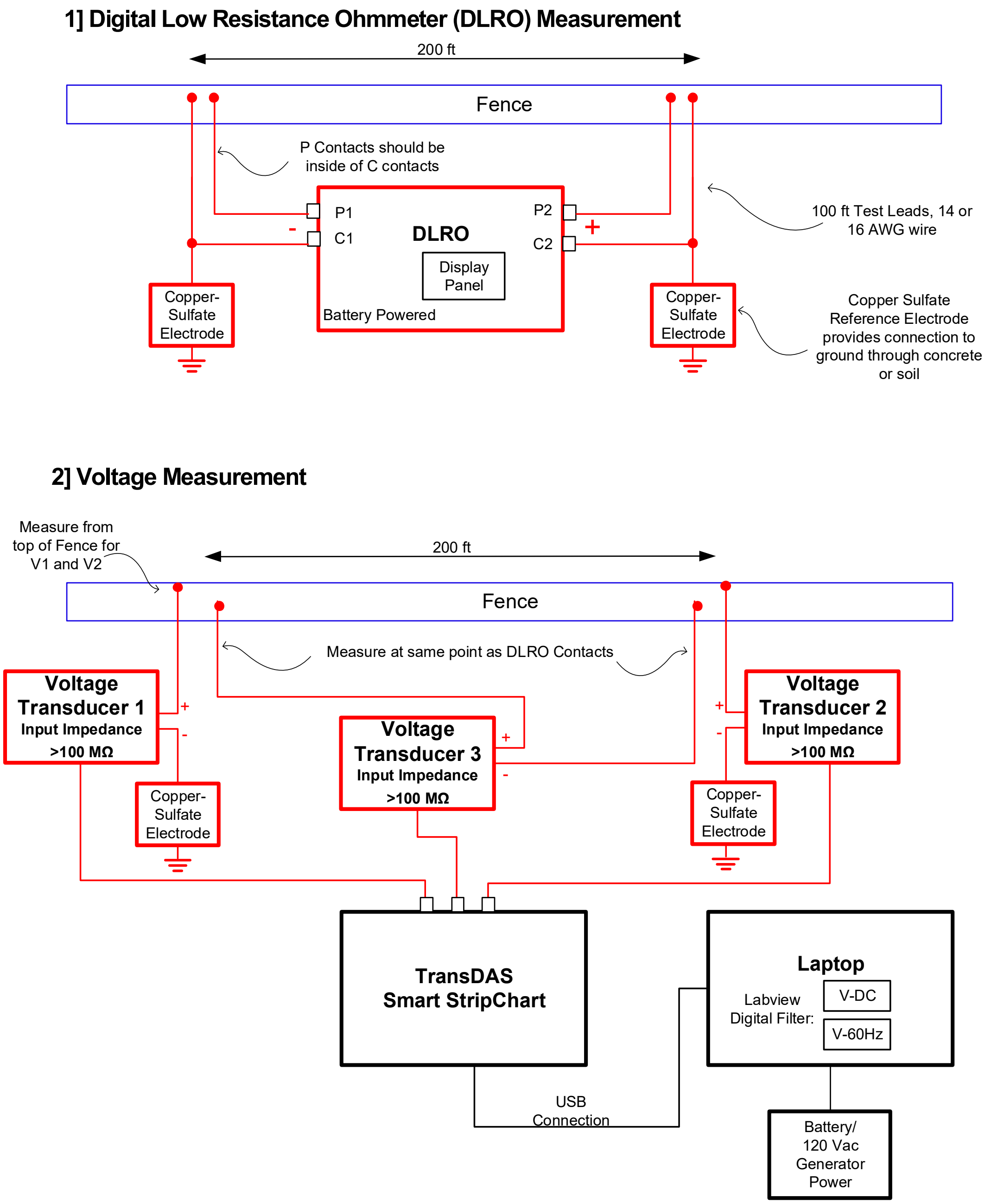
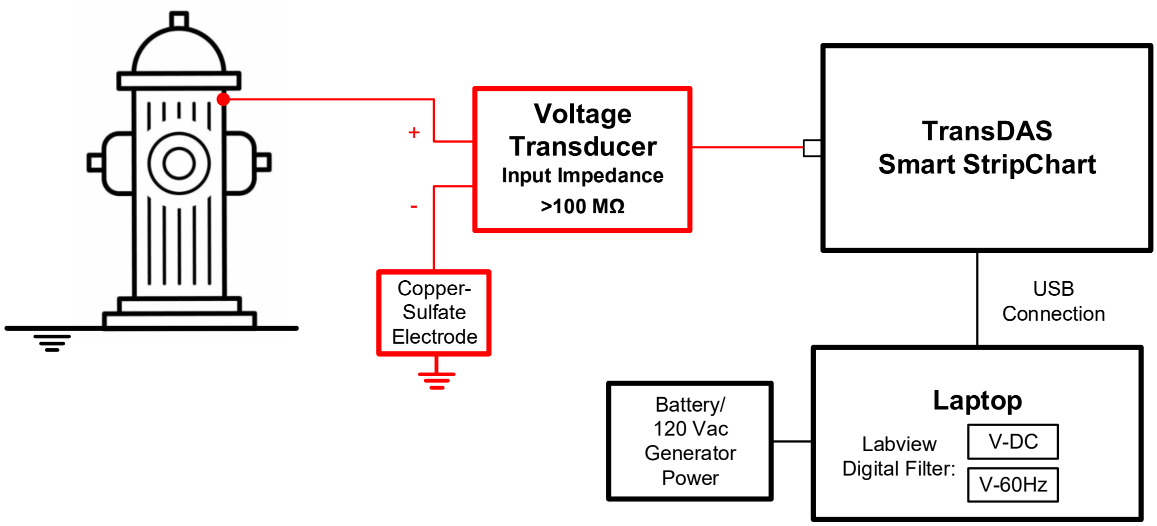


Figure 2-2
Fire Hydrant Stray Current Measurement Equipment Setup



2.2 Stray Current Test Sites

2.2.1 Site 1: Fence on California Drive South of Millbrae Station

Site 1 is at a 200 ft fence section, between the Millbrae station parking lot and the ROW on California Drive between Murchison and Trousdale Drive. Tenco will perform measurements at the South end and North end of the fence span. Tenco will measure resistance and voltage, per Figure 2-1.

Approximate Site 1 GPS Coordinates: **37.596607, -122.383443.**

Figure 2-3 is a diagram of the test site. Figure 2-4 shows an aerial view of Site 1, and Figure 2-5 shows a street view of Site 1.

STV described the pre-construction Site 1 measurement from 9/14/2017 on Page 26 of the STV Field Notes, and the results are shown in the Baseline Study Report Appendix A-6, ID 6.

Figure 2-3
Site 1: Test diagram of Fence on California Drive South of Millbrae Station

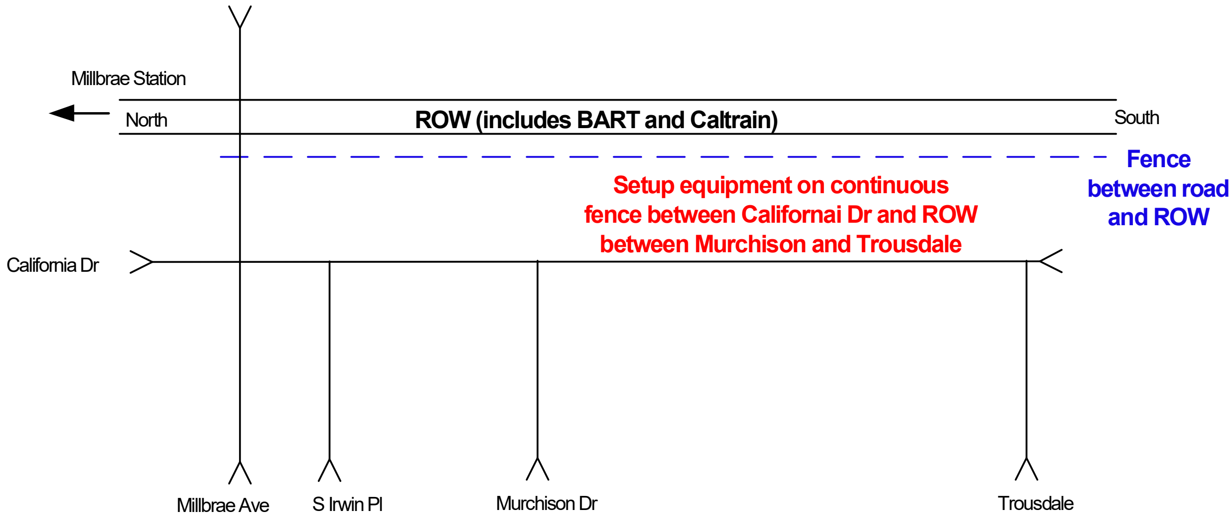


Figure 2-4
Site 1: Aerial View of Fence on California Drive South of Millbrae Station

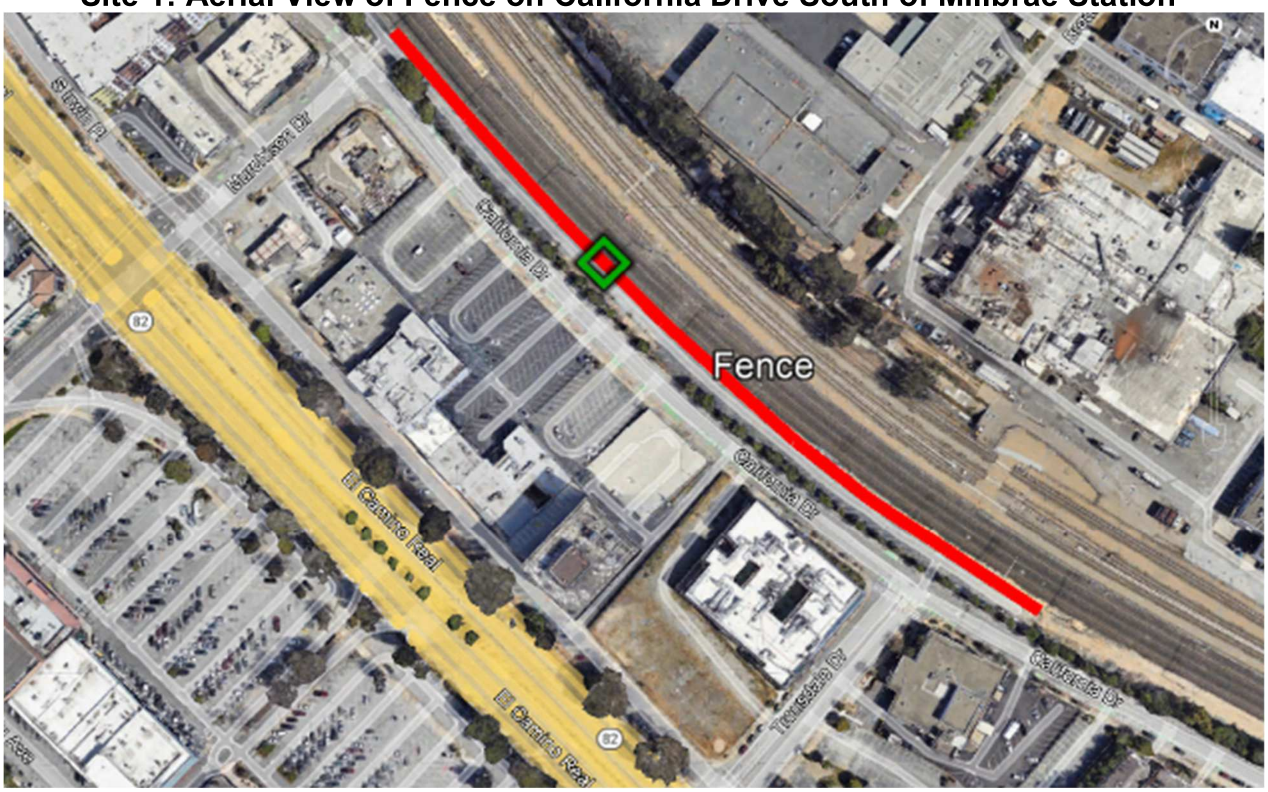


Figure 2-5
Site 1: Street View of Fence on California Drive South of Millbrae Station

2.2.2 Site 2: Fire Hydrant Labelled "12" on 5th and King Street

Site 2 is at a fire hydrant labeled "12" on 5th and King Street near San Francisco Station. Tenco will only measure voltage, per Figure 2-2.

Approximate Site 2 GPS Coordinates: **37.774222, -122.396442.**

Figure 2-6 shows an aerial view of Site 2, and Figure 2-7 shows a street view of Site 2.

STV described the pre-construction Site 2 measurement from 9/11/2017 on Page 16 of the STV Field Notes (second location on the page), and the results are shown in the Baseline Study Report Appendix A-8, ID 5.

Figure 2-6
Site 2: Aerial View of Fire Hydrant Labeled “12” on 5th and King Street

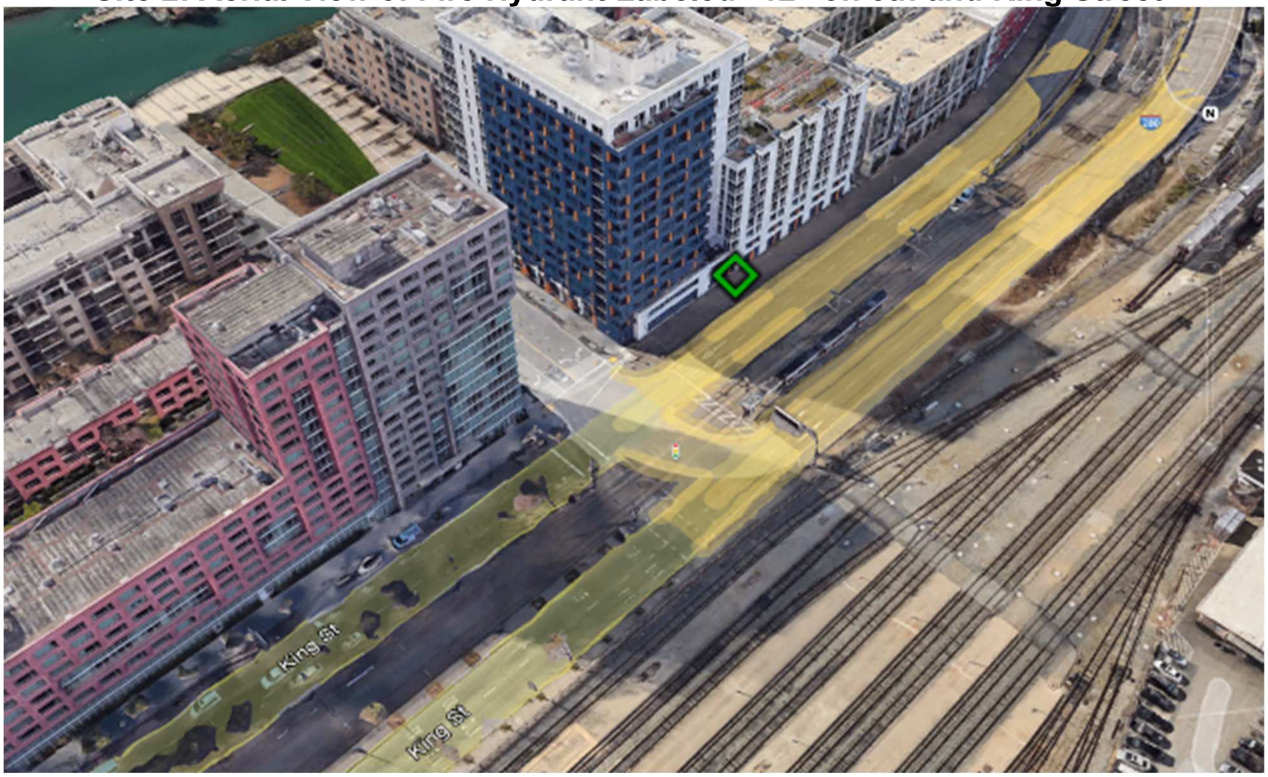


Figure 2-7
Site 2: Street View of Fire Hydrant Labeled “12” on 5th and King Street

2.2.3 Site 3: Fire Hydrant Labeled "8" on Bayshore Blvd and Blanken Ave

Site 3 is at a fire hydrant labeled "8" on Bayshore Blvd and Blanken Ave, on the North side of Blanken. Tenco will only measure voltage, per Figure 2-2.

Approximate Site 3 GPS Coordinates: **37.712228, -122.401333.**

Figure 2-8 shows an aerial view of Site 3, and Figure 2-9 shows a street view of Site 3.

STV described the pre-construction Site 3 measurement from 8/30/2017 on Page 12 of the STV Field Notes (first location on the page), and the results are shown in the Baseline Study Report Appendix A-8, ID 6. The Baseline Study Report refers to this as "Fire Hydrant 3" to distinguish it from other hydrants at the same intersection.

Figure 2-8
Site 3: Aerial View of Fire Hydrant Labeled "8" on Bayshore Blvd and Blanken Ave

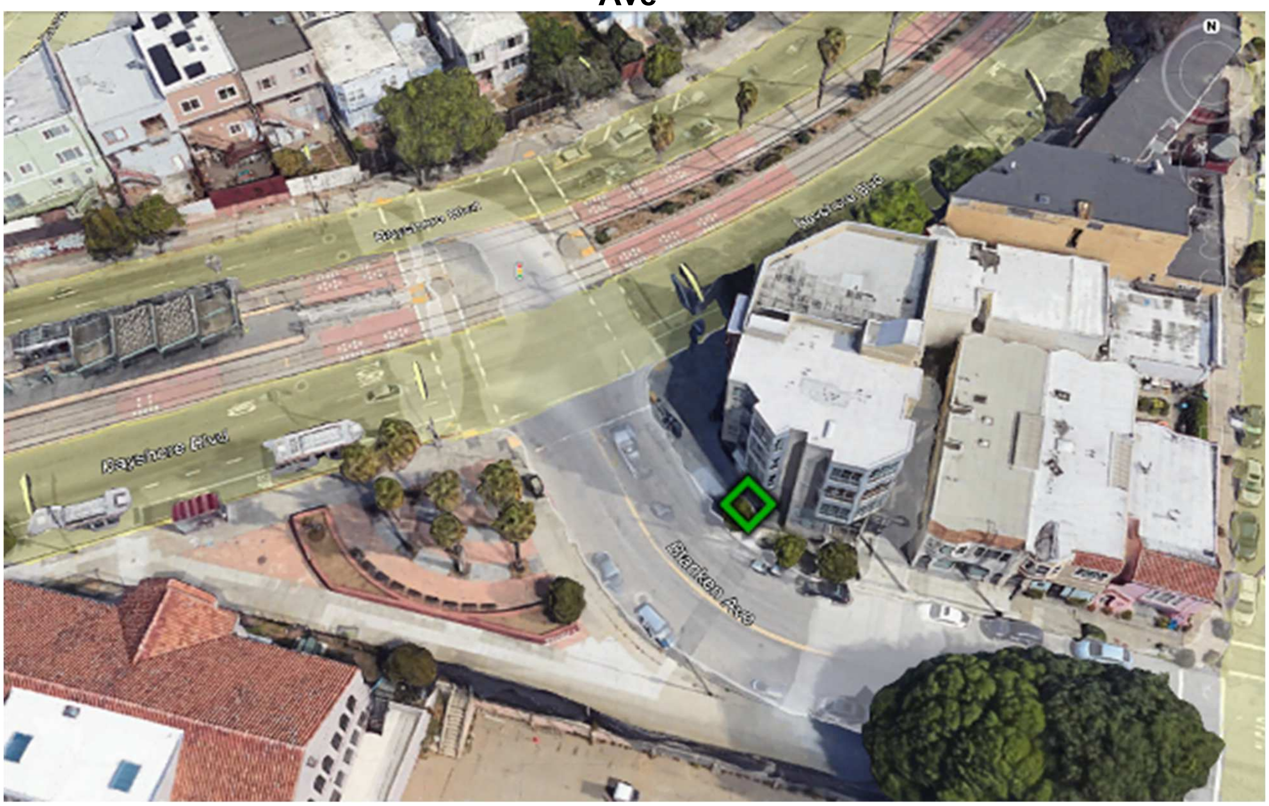
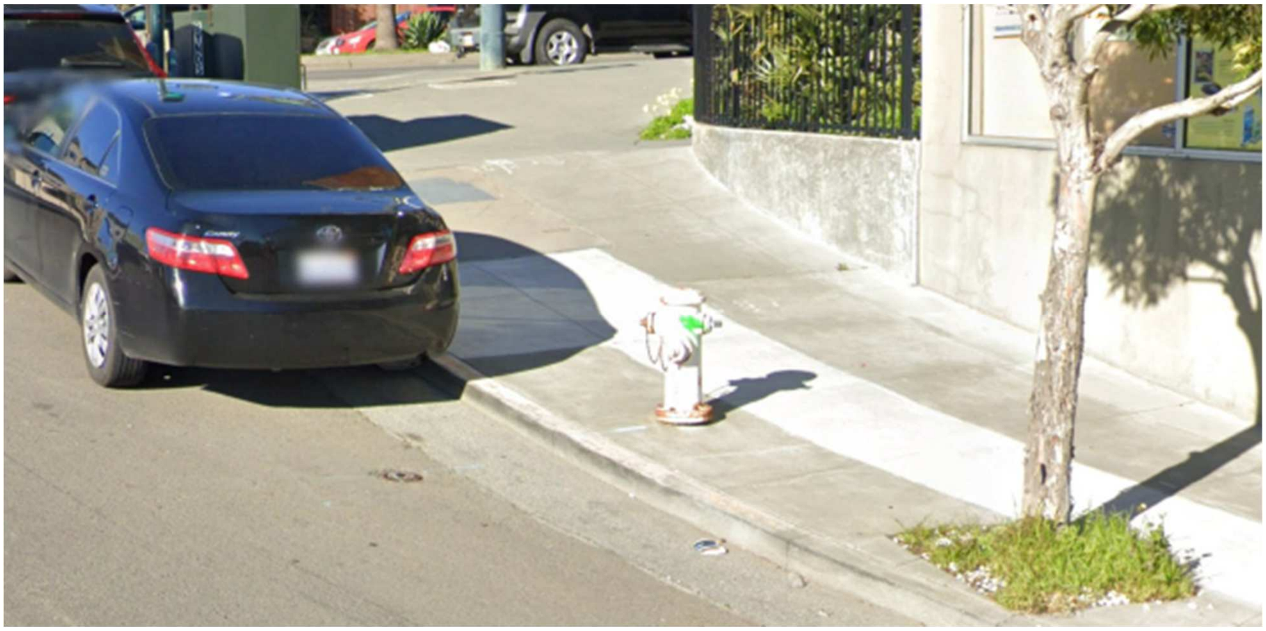


Figure 2-9
Site 3: Street View of Fire Hydrant Labeled "8" on Bayshore Blvd and Blanken Ave



2.3 Measurement Equipment

Table 2-1 lists the stray current field measurement equipment.

Table 2-1
Stray Current Measurement Equipment List

#	Item	Comment
1	Voltage Transducer: *Model to be confirmed before testing*	To measure structure to earth potential during test, and potential drop across fence span. Specs: High input impedance (greater than 100 MΩ), DC and AC measurement capability, 1 mV to 1 VDC range with 1 mV precision, and 10 mV to 100 VAC range
2	Digital Low Resistance Ohmmeter (DLRO)	To measure resistance across fence span
3	Copper-Copper Sulfate Electrode (CuCuSO4)	To provide a conductive surface between test leads and ground
4	TransDAS Smart Stripchart Recorder	To record voltage signals vs time during test
5	Fluke Digital Volt Meter (DVM)	To measure real-time structure to earth potential during, for reference
6	Laptop computer	For data acquisition control and storage of survey data results
7	AC Power Source	AC line, generator, or car battery inverter.

The following subsections describe the major measurement equipment items.

2.3.1 Voltage Transducer

Tenco will select a Voltage Transducer to measure structure to earth potential, and potential drop across fence span, with the following specs:

- High input impedance (greater than 100 MΩ), or ability to equip with high series input resistance
- DC and AC measurement capability
- 1 mV to 1 VDC range with 1mV precision
- 10 mV to 100 VAC range.

2.3.2 Digital Low Resistance Ohmmeter

The Megger Digital Low Resistance Ohmmeter 10 (Megger DLRO10) will measure resistance for fence span tests. The Megger DLRO10 resistance measurement range is 0.1 $\mu\Omega$ to 2 kΩ, with a maximum test current of 10 ADC, which is automatically selected according to the value of resistance being tested.

The Megger DRLO10 will use:

- Four terminal measurement, which removes the test lead resistance from the measured value.
- Auto current reversal, which eliminates the effect of standing voltages across the test sample.

A resistance measurement takes approximately 2.5 s and includes a measurement with forward current, reverse current and a display of the average. The instrument is powered by a rechargeable Lithium ion (Li-ion) battery.

2.3.3 TransDAS Smart Stripchart Recorder

TransDAS is a PC-based data acquisition system which uses the LabVIEW software development and operating environment. A high-speed data acquisition board inside the TransDAS PC samples each input signal at a 51.2 kHz rate, and digitizes the result. TransDAS stores the results in memory and calculates the quantities of interest for the test. TransDAS provides stripchart-type displays of selected variables versus time, with selectable scaling and labeling.

TransDAS also includes outputs which can be programmed to generate outputs proportional to computed or processed variables, as well as sinusoid or other selected waveforms.

2.4 Measurement Bands

The test engineers will perform stray current tests at DC and AC bands. For AC stray current tests, the test team will observe 60 Hz +/- 3 Hz, using a digital filter.

2.5 Site Diagram

The test engineers will make a detailed diagram of the measurement site, showing location, fence or fire hydrant measurement points, gaps in potential measurement structures, nearby structures, Caltrain ROW, nearby intersections, and other significant objects, such as gas meters, sewers, and other fire hydrants. The site diagram will include the measurement site latitude and longitude and photographs of the measurement site.

The report will provide a map showing all measurement sites and the Caltrain ROW.

2.6 Stray Current Measurement Planning

The test engineers will arrange measurements to measure worst-case stray current, considering time of day, intermittent events, and local actions. Stray current should be measured during times when Caltrain EMUs and neighboring MUNI, VTA, or BART trains are active.

If moderate or severe stray currents are measured, the test engineers will repeat tests at that site.

2.7 Stray Current Measurement Method

For each measurement, the test engineers will measure structure-to-earth potentials. For the fence span measurement, the test engineers will measure the resistance and continuity of the fencing using the DLRO to determine the resistance levels and allow for the calculation of current flow through the fence. The team will measure over 30 minutes and calculate time weighted potential measurements.

Table 1-1 shows the NACE 10B189 Stray Current Versus Corrosion Potential designations.

The test team will measure at one fence location and two fire hydrant locations. During the Baseline Study, STV measured at exposed metallic objects such as piping or fire hydrants to determine the impact of stray current leakage in areas where fences were not available.

As an alternate method for fire hydrant tests, if there are other safely-accessible fire hydrants, gas meters, or light poles in the area, which don't require crossing an active road, the test team may measure resistance and voltage drop between the designated fire hydrant and the secondary hydrant/gas meter/light pole, using the DLRO. This would allow the test team to calculate current flowing between the two metallic structures at that location.

The test team will maintain a test log of measurement type, location, time, span length if applicable, measurement equipment configuration, measurement duration, external event or condition descriptions, comments, summary of measured data, and other relevant information. If the measurement includes a PCEP train or a train on neighboring BART, MUNI, or VTA tracks, the test engineers will note the time that the train passed in the test log.

2.7.1 Stray Current Measurement Steps

1. Setup at the measurement site:
    a. Identify test location for the fence or fire hydrant connections, based on Section 2.1 of this procedure.
    b. Mark a 200 ft span on fence (not applicable for fire hydrant tests)
    c. Draw site diagram showing 200 ft span

2. For the fence location, setup DLRO per Figure 2-1 of this procedure:
    a. Set scale to 1A/2.5 ohm
    b. Measure and record Average, Forward, and Reverse resistance

3. Setup Voltage Potential Measurement, per Figure 2-1 of this procedure for fence measurements, and Figure 2-2 for fire hydrant measurements:
    a. For Structure to Ground connection: Connect positive voltage transducer test lead to top of fence/hydrant. Connect negative test lead to Copper-Sulfate Electrode, and connect Copper-Sulfate Electrode to ground.
    b. For Fence-span connection, connect to voltage transducer test leads to span 200 ft of the fence.
    c. Connect all three voltage transducers to TransDAS.

4. Using the Fluke DVM, measure initial voltage potential (DC and AC) for reference

5. Measure Voltage over 30 minutes.

6. Export test data and calculate stray current evaluation metrics in spreadsheet:
    a. Start and stop time
    b. Span length (ft)
    c. Unweighted values (DC and AC):
        - Average Structure-to-Earth Potential (unweighted)
        - Maximum Structure-to-Earth Potential (unweighted)
        - Minimum Structure-to-Earth Potential (unweighted)
        - Change in Peak Structure-to-Earth Potential (max - min peak value)
    d. Time Weighted values (DC and AC):
        - Average Time Weighted Structure-to-Earth Potential
        - Maximum Time Weighted Structure-to-Earth Potential
        - Minimum Time Weighted Structure-to-Earth Potential
        - Change in Time Weighted Structure-to-Earth Potential (max - min weighted value)
    e. Stray Current Calculation, for Tests with DLRO (I= V/R).
    f. Peak Activity Rating (Negligible, Mild, Moderate, Severe), per NACE categories in Table 1-1 of this procedure.
    g. Time Weighted Activity Rating (Negligible, Mild, Moderate, Severe) , per NACE categories in Table 1-1 of this procedure.

7. Identify whether additional action is required.

2.7.2 Measurement Data Collection

The test engineers will collect data, including for measurement equipment calibration and each ambient site measurement. Appendix A provides measurement forms.

Equipment Calibration: Record calibration data for each major measurement equipment item. Calibration data will include the following:

- Measurement equipment item
- Manufacturer

- Model
- Serial number
- Calibration date
- Calibration source
- Reference number
- Notes

Measurement Log: Maintain a measurement run log, recording the following for each measurement:

- Date
- Time
- Performed by
- Location
- Site conditions
- Event
- Run number
- Identification number for plot
- Measurement type
- Frequency band
- Measurement configuration data
- Summary results
- Notes.

3 Stray Current Survey Forms

The following survey forms are attached:

- PCEP Stray Current Survey Measurement Equipment Calibration Record
- PCEP Stray Current Survey Run Log
- PCEP Stray Current Survey Site Plan.

Recorded by: ______________________________ **Date:** _________________________

•PCEP Stray Current Survey Measurement Equipment Calibration Record				
#	**Item**	**Manufacturer**	**Model/Serial Number**	**Calibration / Date**
1	Digital Low Resistance Ohmmeter (DLRO)	Megger	DLRO10	
2	Voltage Transducer			
3	TransDAS	Tenco		
4	Fluke DVM	Fluke		

PCEP Stray Current Survey Run Log

Date: ____________________ **Time:** ________________ **Weather:** ________________________ **Performed By:** ____

Line: ________________________ **Location:** ____________________________________ **Notes:** ____

Measurement ID	Time	Type	Frequency	Location	Conditions	Results
1						
2						
3						
4						
5						
6						
7						
8						
9						

Date: ____________________Time: _______________________ Performed By: ____

Configuration: ________________________________ Location: ____

PCEP Stray Current Survey Site Plan