AC INTERFERENCE AND INDUCED CURRENT TOUCH STUDY

Prepared for:

NV5
San Diego Gas & Electric
Sycamore-Peñasquitos 230 Kilovolt
Underground Transmission Line Project

Prepared By:

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EXECUTIVE SUMMARY

ARK Engineering & Technical Services, Inc. was contracted by NV5 to investigate potential alternating current (AC) electrical interference effects on nearby coated parallel metallic pipelines which may occur as a result of the operation of the proposed San Diego Gas & Electric (SDG&E) Sycamore to Peñasquitos 230 Kilovolt (kV) Transmission Line (Project), in accordance with Mitigation Measure Utilities-4 of the Project's Final Environmental Impact Report (FEIR). This analysis and report pertains specifically to the approximately eleven point four (11.4) mile long underground portion of the Project. The proposed 230 kV transmission line under study will be located in San Diego, California. ARK Engineering and NV5 identified seven (7) SDG&E coated metallic pipelines within the roadway that parallel the proposed 230 kV circuit route. No other pipeline parallelisms susceptible to high induced AC touch or corrosion potentials were identified within a 100 foot radius of the underground portion of the 230 kV circuit (UG circuit).

This report identifies potential AC electrical interference effects on the seven (7) coated metallic pipelines and presents the predicted AC interference pipeline potentials during projected future maximum load conditions on the UG circuit, as provided by NV5. Fault conditions on the UG circuit were also modeled to determine AC inductive and conductive coupling effects to these existing pipelines. Construction details, including conductor arrangement, were considered as part of the modeling effort.

For the pipelines under study, a maximum induced AC pipeline potential of approximately three (3) Volts, with respect to remote earth, was computed for the 4" gas pipeline at approximate GPS location 32.905195°N, 117.084795°W. At this location, the 4" pipeline will exit a region of parallelism with the UG circuit at Avenida Magnifica.

In addition, AC current density calculations associated with AC corrosion mechanisms were completed for the metallic pipelines. A maximum AC density of fifty-nine (59) Amps per meters squared (A/m^2) was calculated for the 4" gas pipeline at approximate GPS location 32.905195°N, 117.084795°W. This is the same location where the maximum induced AC pipeline potential was computed, as referenced above.

During simulated single phase-to-ground fault conditions on the UG circuit, the maximum total pipeline coating stress voltage levels were computed. This is the sum of the inductive and conductive AC interference effects on the pipelines.

The maximum pipeline coating stress voltage was calculated at one hundred nineteen (119) Volts. This maximum value was computed on the 8" pipeline at approximate GPS location 32.916581°N, 117.068783°W. At this location, this existing 8" pipeline will be located approximately thirty (30) feet from a UG circuit vault.

Based upon the results of the analysis completed, induced AC touch voltages and corrosion potentials on the metallic pipelines parallel to the UG circuit route will not present a threat to public safety or pipeline integrity.

In addition, aboveground and underground metallic objects in the vicinity of the UG transmission line that may potentially present a shock hazard to the public, due to induced AC currents or voltages, have been identified and analyzed by ARK Engineering in compliance with Mitigation Measure Hazards-7 of the FEIR. From the identified metallic objects, eight (8) pipeline regulator stations were determined to be of concern due to their proximity to the UG circuit. These stations were therefore analyzed for touch and step hazards using IEEE Standard 80 design limits for electric substation facilities and using a 15 Volt maximum acceptable touch voltage limit under steady-state conditions. The computed touch and step voltages at these stations were calculated below these design limits.

Based upon the results of the analysis conducted, AC touch and step potentials on the aboveground and belowground metallic objects along the UG underground circuit route will not present a threat to public safety.

In conclusion, no additional AC mitigation is recommended for these nearby pipelines or other metallic objects as a result of the operation of the UG circuit.

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1. INTRODUCTION

1.1 Introduction

ARK Engineering & Technical Services, Inc. was contracted by NV5 to investigate potential alternating current (AC) electrical interference effects on nearby coated metallic pipelines which may occur as a result of the operation of the proposed San Diego Gas & Electric (SDG&E) Sycamore to Peñasquitos 230 Kilovolt Transmission Line Project, in accordance with Mitigation Measure (MM) Utilities-4 and Hazards-7 of the Project's Final Environmental Impact Report (FEIR).

This analysis and report pertains specifically to the approximately eleven point four (11.4) mile long underground portion of the Project located in San Diego, California.

ARK Engineering and NV5 identified seven (7) coated metallic pipelines within the roadway that will parallel the UG circuit route. Induced AC touch and corrosion potentials were analyzed for these pipelines during projected future maximum load conditions on the UG circuit, as provided by NV5. Several other pipelines were identified within a 100 foot radius of the proposed 230kV circuit[1], however these pipelines are not susceptible to high induced AC touch or corrosion potentials because they are either uncoated or are made of nonconductive materials, such as polyvinyl chloride (PVC) or concrete. PVC and concrete pipelines located near the Project included potable water mains, recycled water mains, sewer mains, storm drains, and gas lines. Underground *uncoated* metallic pipelines, such as potable water mains, recycled water mains, and the Second San Diego Aqueduct, are essentially continuously grounded through their contact with the local soil. Accordingly, there were no other pipeline parallelisms susceptible to high induced AC touch or corrosion potentials identified along the underground 230 kV alignment.

In addition, aboveground and underground metallic objects in the vicinity of the UG transmission line that may potentially present a shock hazard to the public, due to induced currents or voltages, have been identified by ARK Engineering. These objects were analyzed for touch and step hazards using IEEE Standard 80 design limits for electric substation facilities and using a 15 Volt maximum acceptable touch voltage limit under steady-state conditions.

When metallic pipelines are located in proximity to high voltage electric transmission circuits, the pipelines can incur high induced voltages and currents due to AC interference effects.

AC interference effects decrease with increased distance between the pipelines and the electric transmission circuits.

As a basis of this analysis, a 100 foot radius from the UG circuit route was established as the baseline for determining AC interference effects to pipelines along the route.

Pipelines incurring high induced AC voltages and currents can cause a number of safety issues if not mitigated effectively. The possible effects of this AC interference include: personnel subject to electric shock up to a lethal level, accelerated corrosion, arcing through pipeline coating, arcing across insulators, disbondment or degradation of coating, or possibly perforation of the pipeline.

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[1] Table 4.17-1 Utilities that Cross or Run Parallel to the Proposed Project from the FEIR was reviewed to identify potential nearby pipelines.

This final report presents the computed steady state induced AC pipeline potentials for the identified metallic pipelines located along the proposed underground circuit route. Simulated fault conditions on the UG circuit were also modeled to determine pipeline coating stress voltages. Projected future maximum load conditions and single-phase-to-ground fault current values, provided by NV5, were used to predict worst-case scenarios caused by inductive and conductive AC electrical interference effects to the nearby metallic pipelines.

AC interference simulation programs within the Current Distribution, Electromagnetic Fields, Ground and Soil Structure Analysis (CDEGS) software package[2] were used as part of this project to model the proposed electric circuit route and estimate the levels of induced and conductive AC voltage on the metallic pipelines. These programs are also used to evaluate the effectiveness of any proposed protection designs. The conclusions in this report are based upon pipeline and power line data provided by NV5 as well as results from CDEGS.

1.2 Joint Facility Corridor Overview

The AC interference and corrosion areas of concern associated with MM Utilities-4, where the UG circuit will parallel underground metallic pipelines, are outlined below:

- From Scranton Road to El Camino Drive, a 4” gas pipeline will parallel the proposed circuit.
- From Carroll Road to Trade Street, a 4” gas pipeline will parallel the proposed circuit.
- From Miralani Drive to Activity Road, a 4” gas pipeline will parallel the proposed circuit.
- From Black Mountain Road to Kearny Mesa Road, a 6” gas pipeline will parallel the proposed circuit.
- From the Northbound “on” ramp for the Tuskegee Airmen Highway to Elliot Field Access Drive, a 4” gas pipeline will parallel the proposed circuit.
- From Elliot Field Access Drive to Avenida Magnifica, a 4” gas pipeline will parallel the proposed circuit.
- From Semillion Boulevard to Stonebridge Parkway, an 8” gas pipeline will parallel the proposed circuit.

Appendix A includes maps for each area of concern.

These areas of concern have been determined by ARK Engineering using the available pipeline information in conjunction with industry experience. Worst-case AC interference effects occur on coated metallic pipelines which parallel high voltage electric transmission circuits for extended distances. Coated metallic pipelines which parallel the UG circuit within 100 feet for extended distances were included in the completed analysis, therefore the results presented

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[2] See http://www.sestech.com/Products/SoftPackages/CDEGS.htm for more information on the CDEGS software package including links to published scientific validation studies..

in this report represent the worst-case AC interference effects. Uncoated metallic pipelines, coated metallic pipelines which cross the UG circuit, and coated metallic pipelines which parallel the UG circuit outside of 100 feet will all be subject to significantly lower AC interference levels than the worst-case scenarios included in this report.

Similarly, aboveground and belowground metallic objects which will be located within 100 feet of the UG circuit vaults were included in this analysis, as objects located near vaults would be subject to worst-case AC touch and step voltages associated with a shock hazard, as described in MM Hazards-7.

1.3 Objectives & Project Tasks

The primary objectives of this study were as follows:

- ➢ Determine the AC electrical interference effects to underground metallic utility facilities with corrosion potential during steady state and fault conditions on the UG circuit in accordance with MM Utilities-4.
- ➢ Identify aboveground and belowground metallic objects and evaluate the conductive and inductive interference effects of the UG circuit on them in accordance with MM Hazards-7.
- ➢ Assess the AC density on the existing pipelines for the potential threat of AC corrosion effects.
- ➢ Perform calculations to determine the likelihood of AC corrosion effects to the existing pipelines.
- ➢ If AC corrosion effects are likely, based upon these calculations, determine if AC mitigation is required to reduce or eliminate the likelihood of AC corrosion effects.
- ➢ If required, recommend AC mitigation methods (such as grounding features) to reduce touch and step voltages for aboveground and belowground metallic objects, such as pipeline regulator stations.
- ➢ If required, recommend AC mitigation methods to reduce the induced steady state AC pipeline potentials to less than 15 Volts at all locations on the existing pipelines.
- ➢ If required, recommend AC mitigation methods to reduce fault-induced coating-stress voltages on the existing pipelines to less than 2,500 Volts, for protection of the pipeline coating and to reduce or eliminate AC corrosion effects.

The project tasks associated with this portion of the AC interference analysis consist of the following:

- ➢ Inductive Interference Analysis - Circuit models for the existing parallel metallic pipelines and the UG electric transmission circuit were developed and used to determine magnetically induced pipeline potentials during steady state and fault conditions on the UG circuit.

  This task is described in Section 3, and detailed results are presented in Appendix B.

- Conductive Interference Analysis - The effects of single phase-to-ground faults of the UG electric transmission circuit on the SDG&E pipelines identified in Section 1.2 were studied. These results were used to calculate coating-stress voltages along the pipelines, as well as touch and step voltages on aboveground metallic objects.

  This task is described in Section 3, and detailed results are presented in Appendix B.

1.4 A Brief Perspective on Electromagnetic Interference Mechanisms

The flow of energy transmitted by electric power is not totally confined within the power conductors. A variety of factors influence the spatial density of energy in the environment surrounding underground circuits, including the distance between the phase and shield conductors, the arrangement of the phase conductors, and the method of grounding the phase conductor metallic sheaths. Additionally, this spatial density decreases sharply with an increase in distance from the conductors. Metallic conductors such as pipelines that are located near electric transmission circuits may capture a portion of the energy encompassed by the conductors' paths, particularly under unfavorable circumstances such as long parallel exposures and fault conditions. In such cases, currents and voltages may develop along the conductors' lengths.

Metallic conductors within a one hundred (100) foot radius of the UG circuit were included in this analysis.

Due to the optimized circuit configuration and grounding, worst-case AC interference levels within this 100 foot radius were computed below the limits for public safety and pipeline integrity. As mentioned previously, AC interference levels will decrease with an increase in distance from the electric transmission circuit conductors, therefore no further investigation was necessary outside of this 100-ft radius.

The electromagnetic interference mechanisms at low frequencies have been traditionally divided into three (3) categories: capacitive, inductive and conductive coupling. These categories and their possible effects are illustrated in Figure 1-1.

The capacitive coupling effect occurs in aboveground electric circuits and aboveground piping systems and is only included here for explanation purposes.

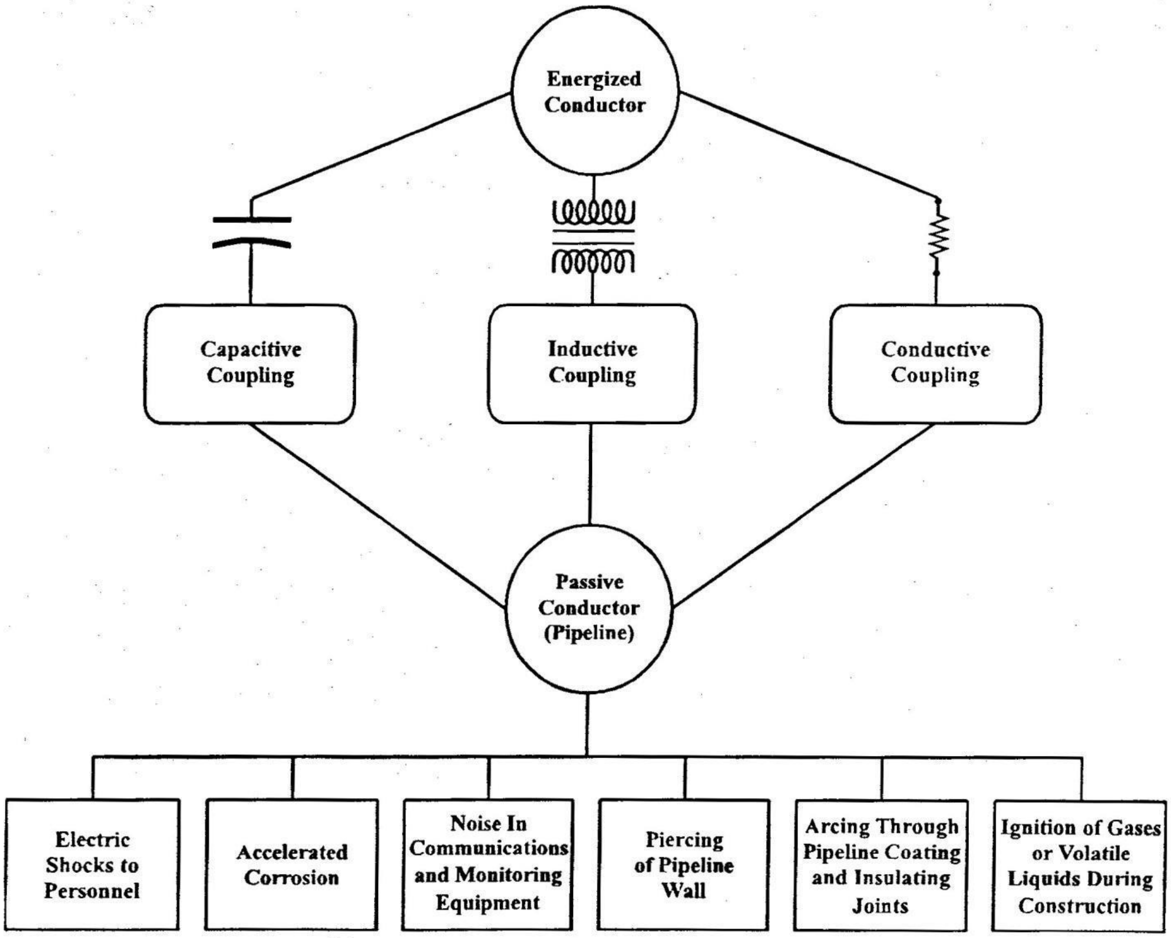


Figure 1-1: Interference Mechanisms and Effects on Pipeline

1.4.1 Capacitive Coupling

Mechanism:

Electrostatic or capacitive coupling results from the electric field gradient established between aboveground energized transmission circuit conductors and the earth. When the transmission circuit voltage is very high, a significant electric field gradient exists near the transmission circuit. Large conductors, which are near and parallel to the transmission circuit and insulated from the earth, are liable to accumulate a significant electric charge, which represents a danger to people. Typically, such conductors include: equipment isolated from the earth, vehicles with rubber tires, aboveground pipelines, or pipelines under construction in dry areas when no precautions have been taken to establish adequate grounding for the pipeline lengths not yet installed in the ground. Hazards range from slight nuisance shocks to ignition of nearby volatile liquids with the accompanying risk of explosion, or electrocution.

AC Interference Protection Practices:

Buried pipelines are relatively immune to AC interference due to capacitive coupling because, despite even an excellent coating, the length of exposure within the surrounding soil makes for an adequate ground to dissipate any significant charge that might otherwise accumulate. Aboveground pipelines, including pipelines under construction (which may or may not be buried in part), do not naturally have this protection**.** One means of protection is periodic grounding to earth, via ground rods, or other ground conductors judiciously placed so as to be unaffected by ground currents emanating from nearby electric transmission circuit vaults during a fault.

1.4.2 Inductive Coupling

Mechanism:

Electromagnetic or inductive interference in a passive conductor (pipeline) results from an alternating current in another energized conductor (power line), which is more or less parallel to the first. This level of interference increases with decreasing separation and angle between the conductors, as well as with increasing current magnitude and frequency in the energized conductor. The combination of a high soil resistivity and passive conductors with good electrical characteristics (good coating, high conductivity and low permeability) also result in high-induced currents.

Maximum potential values occur at discontinuities in either the energized or the passive conductor. When a transmission circuit and a pipeline are interacting, such discontinuities take the form of rapid changes in separation between the pipeline and transmission circuit, termination of the pipeline or an insulating junction in the pipeline (which amounts to the same thing), sudden changes in pipeline coating characteristics, a junction between two (2) or more pipelines or transposition of transmission phase conductors. Note that the induction effects on pipelines during normal power line operating conditions are small compared to the induction effects experienced by a pipeline during a power line fault. The most severe kind of fault is a single-phase-to-ground fault during which high currents circulate in one of the power line phases and are not attenuated by any similar currents in other phases. Hence, mitigation methods, which suffice for single-phase fault conditions, are often adequate for other conditions. It must be noted however, that the longer duration of the resulting potentials in the pipeline during steady state conditions makes the problem important to investigate from a perspective of human safety.

Unlike conductive interference, which tends to be a rather local phenomenon, inductive interference acts upon the entire length of the pipeline that is near to the power lines.

The large potentials induced onto a pipeline during a fault can destroy insulated junctions, pierce holes in lengths of coating, and puncture pipeline walls. Equipment electrically connected to the pipeline, such as cathodic protection devices, communications equipment, and monitoring equipment can be damaged, and personnel exposed to metallic surfaces, which are continuous with the pipeline, can experience electrical shocks. Accelerated corrosion is another possible result. Implementing appropriate grounding measures, as discussed below, can prevent this situation.

Although a pipeline equipped with grounding measures appropriate to deal with phase-to-ground faults does not usually present a great safety hazard during normal conditions, several problems can still exist due to low magnitude induced alternating currents. Accelerated corrosion of steel can result if not offset by increased cathodic protection. This may mean a shortened life for sacrificial and impressed current anode beds. Small amounts of AC can also render impractical the use of a pipeline as a communication channel for data such as pressure and temperature readings to pumping and compressor stations.

Protection Practices:

Pipeline Coating Resistance - The coating resistance of the pipeline should be chosen as low as corrosion considerations permit. Pipeline coating resistance plays an important role in determining pipeline potentials during a fault condition. During a fault condition, on an electric transmission circuit, the pipeline coating conducts significant amounts of current and should be regarded more as a poor grounding system than an insulator. When this perspective is assumed, it is seen that lowering pipeline coating resistance and bonding grounded conductors to the pipeline steel are two (2) applications of the same principle.

Pipeline Section Length - In theory, the potential induced electromagnetically in a pipeline section insulated at both ends is roughly proportional to the length of the exposed region. When this relationship no longer holds, the pipeline is said to have exceeded its characteristic length. The maximum potential value in a section (with respect to remote ground) occurs at each extremity with roughly the same magnitude and opposite phase. This means that each insulating junction is subjected to a stress voltage that is double the peak value in the section. If insulating junctions are inserted frequently enough along a pipeline, then the section size is kept to a minimum, and consequently, so are the peak voltages in the pipeline. This constitutes one possible protection method. However, this thorough segmentation can result in very high construction and pipeline cathodic protection costs.

Grounding - Grounding of a pipeline, as a protection against the significant voltages that appear during an electrical fault condition, is one of the most effective protection measures available. A pipeline should be grounded at appropriate locations throughout its length. Typical grounding locations include: all termination points, both extremities of a segment which is grounded at both ends by an insulating junction, just before and just after a pipeline crosses a power line at a shallow angle, and any other important point of discontinuity likely to result in high induced voltages during a fault condition. Such points include locations where the passive conductor:

- Suddenly veers away from the power line
- Suddenly changes coating characteristics
- Emerges from the earth, or returns to the earth

Other locations where high-induced voltages are likely include points where power line phases are transposed and points where two (2) or more pipelines meet.

In order not to load cathodic protection installations significantly, grounds should be made of an adequate sacrificial material such as zinc or should be made via solid-state-isolator or polarization cells. These solid-state decoupling devices (SSD) should be properly sized, spaced and physically secured to withstand the current resulting during a power line fault. Caution should be taken to locate grounds far enough away from any nearby power line structure, so that the soil potential near the ground does not rise to undesirable values during a power line fault condition. Soil potentials drop off rather quickly around a faulted structure injecting currents into the earth, so this is not an extremely difficult proposition.

Buried Mitigation Systems - A highly effective means of reducing excessive AC pipeline potentials is the installation of gradient control wires or matting. These methods reduce both inductive and conductive interference. These gradient control wires consist of one or more bare conductors which are buried parallel and near to the pipeline and which are regularly connected to the pipeline. These wires provide grounding for the pipeline and thus lower the absolute value of the pipeline potential (i.e., the potential with respect to remote earth). They also raise earth potentials in the vicinity of the pipeline such that the difference in potential between the pipeline and local earth is reduced. As a result, touch voltages are significantly reduced.

1.4.3 Conductive Coupling

Mechanism:

When a single phase-to-ground fault occurs at a power line structure (such as an underground vault), the structure injects a large magnitude current into the earth, raising soil potentials in the vicinity of the structure. If a pipeline is located near such a faulted structure, then the earth around the pipeline will be at a relatively high potential with respect to the pipeline potential. The pipeline potential will typically remain relatively low, especially if the pipeline coating has a high resistance. The difference in potential between the pipeline metal and the earth surface above the pipeline is the touch voltage to which a person would be subjected when standing near the pipeline and touching an exposed metallic appurtenance of the pipeline.

If the pipeline is perpendicular to the power line, then no induction will occur and the conductive component described above will constitute the entirety of the touch voltages and coating stress voltages appearing on the pipeline. If the pipeline is not perpendicular to the power line, then an induced potential peak will appear in the pipeline near the fault location. Based on previous AC interference studies, the induced potential peak in the pipeline is typically on the order of one hundred and fifty-five degrees (155^o) out of phase with the potential of the faulted structure and therefore with the potentials of the soil energized by the structure. Thus, the pipeline steel potential due to induction is essentially opposite in sign to the soil potentials due to conduction. Therefore, inductive and conductive effects reinforce each other in terms of coating stress voltages and touch voltages.

Protection Practices:

The magnitude of the conductive interference is primarily a function of the following factors:

- GPR of Transmission Circuit Structure. Soil potentials and touch voltages due to conductive coupling are directly proportional to the ground potential rise (GPR) of the transmission circuit structure. This GPR value is a property of the entire transmission circuit system.

- Separation Distance. Although soil potentials and therefore touch voltages obviously decrease with increasing distance away from the faulted structure, the rate of decrease varies considerably from site to site, depending upon the soil structure, as described below.

- Size of Structure Grounding System. Soil potentials decrease much more sharply with increasing distance away from a small grounding system than that from a large grounding system. Conductive interference can be minimized by limiting the use of counterpoise conductors and ground rods, by the power company, at sites where pipelines are in close proximity to the electric transmission system structures.

- Soil Structure. When the soil in which the structure grounding system is buried has a significantly higher resistivity than the deeper soil layers (particularly if the lower resistivity layers are not far below the structure grounding system), earth surface potentials decay relatively sharply with increasing distance away from the structure. When the inverse is true, i.e., when the structure grounding system is in low resistivity soil, which is under laid by higher resistivity layers, earth surface potentials may decay very slowly.

- Pipeline Coating Resistance. When a pipeline has a low ground resistance (e.g., due to coating deterioration over time), the pipeline collects a significant amount of current from the surrounding soil and rises in potential. At the same time, earth surface potentials in the vicinity of the pipeline decrease due to the influence of the pipeline. As a result, the potential difference between the pipeline and the earth surface can be significantly reduced.

When a conductive interference problem is present, touch voltages can be reduced by: either reducing earth surface potentials in the vicinity of the pipeline, raising the pipeline potentials near the faulted structure, or a combination of these two (2) actions. The most effective mitigation systems perform both of these actions.

1.5 A Brief Perspective on AC Corrosion Mechanisms

1.5.1 AC Corrosion Mechanism

AC corrosion is the metal loss that occurs from AC current leaving a metallic pipeline at a point where there is a discontinuity in the protective coating that exposes the unprotected surface to the environment (i.e. a holiday). The mechanism of AC corrosion occurs when AC current leaves the pipeline through a holiday in low resistance soil conditions.

1.5.2 Mitigation of AC Corrosion

The main factors that influence the AC corrosion phenomena are:

- Induced AC pipeline voltage
- DC polarization of the pipeline
- Size of coating faults (holidays)
- Local soil resistivity at pipe depth

The induced AC pipeline voltage is considered the most important parameter when evaluating the likelihood of AC corrosion on a buried pipeline section.

The likelihood of AC corrosion can be reduced through mitigation of the induced AC pipeline voltage. The European Standard BS EN 15280:2013 “Evaluation of AC Corrosion Likelihood of Buried Pipelines - Application to Cathodically Protected Pipelines” recommends that AC pipeline voltages should not exceed the following:

- Ten (10) Volts where the local soil resistivity is greater than 25 ohm-meters
- Four (4) Volts where the local soil resistivity is less than 25 ohm-meters

These AC pipeline voltage limits are derived in part by calculating AC density at pipeline coating holidays. Since the AC current is mainly discharged to earth through the exposed steel at pipeline coating holidays, the AC corrosion rate can vary proportionately with increasing AC density at a coating holiday.

European Standard CEN/TS 15280 offers the following guidelines:

The pipeline is considered protected from AC corrosion if the root mean square (RMS) AC density is lower than 30 A/m^2. In practice, the evaluation of AC corrosion likelihood is done on a broader basis:

- Current density lower than 30 A/m^2: no or low likelihood of AC Corrosion effects

- Current density between 30 and 100 A/m^2: medium likelihood of AC Corrosion
- Current density higher than 100 A/m^2: very high likelihood of AC Corrosion

If the soil resistivity and the pipeline AC voltage are known, the risk of AC corrosion can be determined using the following formula (Equation 1) to calculate the current density at a holiday location.

$$I = (8 * V_{AC}) / (\rho * \pi * d) \qquad \text{(Equation 1)}$$

Where:

i = Current Density (A/m^2)

V_{AC} = Pipe-to-Soil Voltage (Volts)

ρ = Soil Resistivity (ohm-meters)

d = Holiday diameter (meters)

1.5.3 Determining Steady State Pipeline AC Voltage Limits

The primary factor in calculating AC density at coating holidays is induced AC voltage on the pipeline at these coating holidays. Since local soil does not typically change significantly, lowering the induced AC pipeline voltage (by adding protection measures) also lowers the local AC density.

To analyze the possible AC corrosion effects on this pipeline section, calculations were completed to determine the AC current density exiting the pipeline, assuming a one (1) cm^2 circular coating holiday at each soil resistivity location.

1.6 Definitions

AC Electrical Interference (Electromagnetic Interference): A coupling of energy from an electrical source (such as an electrical power line) to a metallic conductor (such as a pipeline) which at low frequencies (in the range of power system frequencies) occurs in the form of three different mechanisms; capacitive, conductive and inductive coupling. Electrical interference can produce induced voltages and currents in the metallic conductors that may result in safety hazards and/or damage to equipment.

Coating Stress Voltage: This is the potential difference between the outer surface of a conductor (e.g., pipelines, cables, etc.) coating and the metal surface of the conductor, and results from inductive and conductive potentials.

Capacitive Coupling: Capacitive coupling occurs as a result of an energized electrical source (e.g., power line) that produces a power line voltage between a conductor (such as a pipeline) and earth where the conductor is electrically insulated from the earth. An electric field gradient from the electrical source induces a voltage onto the conductor insulated from earth, which varies primarily according to the distance between the source and the conductor, the voltage of the source and the length of parallelism.

Conductive Coupling: When a fault current flows from the power line conductor to ground, a potential rise is produced in the soil with regard to remote earth. A conductor, which is located in the influence area of the ground for the power line structure, is subject to a potential difference between the local earth and the conductor potential. Conductive coupling is a localized phenomenon that acts upon the earth in the vicinity of the flow of current to ground.

Conductive Earth Potential: This is the potential that is induced onto a conductor due to the energization of the surrounding earth by the current leaking from the power line structure.

Dielectric Breakdown: The potential gradient at which electric failure or breakdown occurs. In this case, it is pertinent to the coating of the pipeline and the potential at which damage to the coating will occur.

Earth Surface Potential: When a single-phase-to-ground fault occurs at a power line structure, the structure injects a large magnitude current into the earth and therefore raises soil potentials in the vicinity of the structure. These potentials are referred to as earth surface potentials.

Fault Condition: A fault condition is a physical condition that causes a device, a component, or an element to fail to perform such as a short circuit or a broken wire. As a result, an abnormally high current flows from one conductor to ground or to another conductor.

Holiday: A point where there is a discontinuity in the protective coating on a metallic pipeline that exposes the unprotected surface to the environment.

Inductive Coupling: Inductive coupling is an association of two (2) or more circuits with one another by means of inductance mutual to the circuits. The coupling results from alternating current in an energized conductor (e.g., power line) which is more or less parallel with a passive (non-energized) conductor. Inductive coupling acts upon the entire length of a conductor.

Inductive Pipeline Potential: The potential induced onto a pipeline during steady state or fault conditions that results from the mutual coupling between the energized conductor (power line) and the pipeline.

Load Condition: A load condition for a circuit is the amount of rated operating electrical power that is transmitted in that circuit under normal operating conditions for a specific period of time.

Local Earth: Local earth is the earth in the vicinity of a conductor, which is raised to a potential, typically, as a result of the flow of fault current to ground. In the case of a pipeline, which has a good coating and does not have grounding conductors connected to the pipeline where the earth potential rise occurs, the "local" earth will be the same as the "remote" earth.

Permeability: Permeability is a term used to express various relationships between magnetic induction and magnetizing force.

Potential Difference: The relative voltage at a point in an electric circuit or field with respect to a reference point in the same circuit or field.

Remote Earth: Remote earth is a location of the earth away from where the origin of the earth potential rise occurs that represents a potential of zero Volts.

Steady State Condition: A steady state condition for a power system is a normal operating condition where there is negligible change in the electrical power transmitted in a circuit over a long period of time.

Step Voltage: The difference in surface potential experienced by a person bridging a distance of 1 meter with his feet without contacting any other grounded conducting object.

Touch Voltage: The potential difference between the Ground Potential Rise and the surface potential at a point where a person is standing with his hand in contact with a grounded structure.

1.7 Mitigation System Design Objectives

An AC mitigation system designed to protect a pipeline subject to AC interference effects must achieve the following four (4) objectives:

i. During worst-case steady state load conditions on the electric transmission circuits, reduce AC pipeline potentials with respect to local earth to acceptable levels for the safety of operating personnel and the public.

ii. During fault conditions on the electric transmission circuits, ensure that pipeline coating stress voltages remain within acceptable limits in order to prevent damage to the coating or even to the pipeline steel.

Damage to the coating can result in accelerated corrosion of the pipeline itself. Coating damage can occur at voltages on the order of one thousand (1,000) to two thousand (2,000) Volts for bitumen coated pipelines, whereas damage to polyethylene or fusion bonded epoxy coated pipelines occurs at higher voltages, i.e., greater than five thousand (5,000) Volts.

iii. During fault conditions on the electric transmission circuits, ensure the safety of the public and of operating personnel at accessible aboveground and belowground metallic objects.

ANSI/IEEE Standard 80 specifies safety criteria for determining maximum acceptable touch and step voltages during fault conditions. Special precautions must be taken by maintenance personnel when excavating inaccessible portions of the pipeline to ensure safety in case of a fault condition.

iv. During worst-case steady state load conditions on the electric transmission circuits, reduce AC current densities through coating holidays to prevent possible AC corrosion mechanisms on the pipeline.

Table 1-1 depicts the design criteria for the San Diego Gas & Electric pipelines under study.

Table 1-1: Design Criteria for Personnel Safety and Protection Against Damage to the Pipelines' Coating

Criteria	Steady State Maximum[1] (Volts)	Fault Maximum (Volts)
Exposed Pipeline Appurtenance Touch Voltage	15	-----
Exposed Pipeline Appurtenance Step Voltage	15	-----
Buried Pipeline Touch Voltage	15	-----
AC Current Density Through 1 cm^2 Coating Holiday	100 A/m^2 (Current)	
Coating Stress Voltage	-----	2,500

[1] With respect to "Local Earth"

2. FIELD DATA

2.1 Physical Layout

The proposed UG circuit under study will be approximately eleven point four (11.4) miles long, located in San Diego, California. Seven (7) coated metallic pipelines will parallel the 230 kV circuit, in various locations, as described in Table 2-1.

Table 2-1: Regions of Influence Caused by the Proposed Electric Transmission Circuit

Pipeline Company	Pipeline Diameter (in.)	Pipeline GPS Range
San Diego Gas & Electric	4	Parallelism from Scranton Road to El Camino Drive
	4	Parallelism from Carroll Road to Trade Street
	4	Parallelism from Miralani Drive to Activity Road
	6	Parallelism from Black Mountain Road to Kearny Mesa Road
	4	Parallelism from the Northbound “on” ramp for the Tuskegee Airmen Highway to Elliot Field Access Drive
	4	Parallelism from Elliot Field Access Drive to Avenida Magnifica
	8	Parallelism from Semillion Boulevard to Stonebridge Parkway

2.2 Pipeline Data

The effective coating resistance of a pipeline is a conservative value obtained from previous research on coating resistances for in-service pipelines.

Coating Resistance of pipelines: 400,000 ohm-ft^2

The characteristics used for the pipelines, obtained from previous research on steel pipelines, are as follows:

- Relative resistivity: 10 (with respect to annealed copper)
- Relative permeability: 300 (with respect to free space)

The characteristics used for the pipelines, provided by NV5, are identified in table 2-2.

Table 2-2: Pipeline Characteristics

Pipeline Diameter (in.)	Minimum Depth of Cover (ft.)	Pipeline Wall Thickness (in.)	Pipeline Coating Type
4	3	0.237	Coal Tar Enamel
4	3	0.237	Coal Tar Enamel
4	3	0.237	Coal Tar Enamel
6	3	0.28	Coal Tar Enamel
4	3	0.237	Coal Tar Enamel
4	3	0.237	Coal Tar Enamel
8	3	0.322	Coal Tar Enamel

2.3 Soil Resistivity Measurements

This AC electrical interference analysis was based on soil resistivity measurements recorded by ARK Engineering personnel for a previous analysis on an overhead portion of the Project. These measurements were recorded using equipment and procedures developed especially for this type of AC interference study.

Soil resistivity measurements are used to calculate the ground resistance of electric transmission line structures, assess the gradient control performance of AC mitigation systems and gradient control mats, as well as to determine the conductive coupling of the pipeline through the earth from the nearby faulted electric transmission circuit. The conductive coupling has an important effect on touch and step voltages at proximate valve sites and on pipeline coating-stress voltages.

Past experience has shown the need for a special measurement methodology for environments that are subject to electrical noise due to the presence of nearby high voltage electric transmission circuits. When conventional methods are used, the instrumentation can pick up noise from the nearby electric power circuits and indicate resistivity values much higher than reality at large electrode spacing, suggesting that deeper soil layers offer poorer grounding than they actually may. Resistance readings can be inflated by a factor of four (4) or more. This error can result in conservative AC protection designs.

2.3.1 Soil Resistivity Measurement Methodology

Measurements conducted by ARK Engineering personnel were based upon the industry recognized Wenner four-pin method, in accordance with IEEE Standard 81, "IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System".

The electrode spacing varied from one point five-two (1.52) meters to sixty point nine-six (60.96) meters.

Apparent resistivity values that correspond to the measured resistance values can be calculated using the expression:

$$\rho = 2\pi aR$$

Where:

ρ = Apparent soil resistivity, in ohm-meters (Ω-m)

a = Electrode separation, in meters (m)

R = Measured resistance, in ohms (Ω)

In practice, four rods are placed in a straight line at intervals "a", driven to a depth that does not exceed one-tenth of "a" (0.1*a).

This results in the approximate average resistance of the soil to a depth of "a" meters.

2.3.2 Soil Resistivity Data

Soil resistivity measurements were used to derive an equivalent soil structure model. This multilayer soil model is representative of the changing soil characteristics as a function of depth. The inductive coupling interference modeling uses the bottom-most soil resistivity layer from the multilayer model. The complete multilayer soil characteristics are used to calculate the conductive and total AC interference effects. Touch voltage, coating stress voltage, and touch & step safety limits all use the complete multilayer soil model.

Table 2-3: Soil Resistivity Values Derived Using Previous Measurements

Bottom Layer Resistivity (Ω-m)	Resistivity at Pipeline Depth (Ω-m)
6.8	9.8

3. MODELING DETAILS

3.1 Steady State Conditions

The proposed construction details of the UG circuit have been considered as part of this analysis. These include, among other details, the arrangement of the conductors and the grounding of the metallic sheaths at the vaults. The projected future maximum load current, provided by NV5, was used to compute the maximum steady state inductive AC interference effects on the seven (7) metallic pipelines.

Although the UG circuit may not be loaded to this level, the data provided by NV5 constitutes a realistic scenario if other critical circuits are out of service and the load must be redirected through this transmission circuit. Therefore, under normal conditions, the steady state AC interference levels should be significantly less than those reported in this study.

Table 3-1 indicates the projected future maximum load current used for this AC interference analysis.

Table 3-1: Transmission Circuit Maximum Current Rating

Power Company	Circuit Name	Maximum Load Current (A)
San Diego Gas & Electric	Sycamore Canyon to Peñasquitos	2,290

3.2 Fault Conditions

To determine the maximum AC interference effects of the faulted circuit on the existing pipelines, the model included single phase-to-ground fault branch currents on the UG circuit.

Fault conditions were simulated on the UG circuit in the areas of parallelism with the existing pipelines. Single phase-to-ground branch current values, provided by NV5, were used to calculate fault currents on grounded structures along the proposed circuit.

Reference Appendix C for all fault data used in this analysis.

3.3 Modeled Interference Levels

ARK Engineering performed this AC interference analysis using the CDEGS software package. The output file plots for the steady state and simulated fault conditions on the UG circuit are included in Appendix B.

3.3.1 Steady State Conditions

The induced AC pipeline potentials were computed with the UG circuit operating at projected future maximum load conditions. These results are summarized in Appendix B.

The computed induced AC pipeline potentials were below the maximum allowable design limit of fifteen (15) Volts for the seven (7) metallic pipelines.

For the pipelines under study, a maximum induced AC pipeline potential of approximately three (3) Volts, with respect to remote earth, was computed for the 4” gas pipeline at approximate GPS location 32.905195°N, 117.084795°W. At this location, the 4” pipeline will exit a region of parallelism with the UG circuit at Avenida Magnifica.

Table 3-2 outlines the computed maximum induced AC pipeline potentials at projected future maximum load conditions on the UG circuit.

Table 3-2: Maximum Induced Potentials at Projected Future Peak Load Conditions

Pipeline Diameter (in.)	Maximum Induced Potential (V)	Design Limit (V)
4	1.7	15
4	0.31	15
4	0.24	15
6	0.49	15
4	0.62	15
4	2.6	15
8	1.5	15

See Appendix B for plots of the computed induced AC pipeline potentials.

3.3.2 Fault Conditions

As outlined in Chapter 1 of this report, when an electric transmission circuit fault occurs at a grounded structure (transmission vault) in proximity to a pipeline, the induced AC pipeline potential is essentially out of phase with the earth potentials developed by conduction near the faulted structure. Therefore, inductive and conductive interference effects reinforce each other in terms of coating stress voltages and touch voltages.

3.3.2.1 Inductive Interference – Inductive AC interference effects to the pipelines were computed and analyzed during simulated fault conditions on the UG circuit. This was undertaken to determine the maximum induced AC pipeline potentials at all points along the pipelines.

3.3.2.2 Conductive Interference – The configuration of the UG circuit grounding systems was used to determine earth surface potentials in proximity to the structures and the pipelines during simulated single phase-to-ground fault conditions.

3.3.2.3 Total Fault Current Interference – The maximum total pipeline coating stress voltage was computed for each point along the existing pipelines. This is the sum of the inductive and conductive AC interference effects.

The maximum pipeline coating stress voltage was calculated at one hundred nineteen (119) Volts. This maximum value was computed on the 8” pipeline at approximate GPS location 32.916581°N, 117.068783°W. At this location, the existing pipeline will be located approximately thirty (30) feet from a UG circuit vault.

This maximum total coating stress voltage is outlined below in Table 3-3.

Table 3-3: Maximum Coating Stress Voltage under Simulated Fault Conditions

Pipeline Diameter (in.)	Pipeline GPS Location	Maximum Coating Stress Voltage (V)	Design Limit (V)
8	32.916581°N, 117.068783°W	119	2,500

Appendix B includes a plot of the maximum coating stress voltage on the pipeline during simulated fault conditions on the UG circuit.

3.3.3 AC Touch and Step Voltage

Pursuant to MM Hazards-7, aboveground and buried metallic objects which may present a shock hazard due to induced AC voltages or currents resulting from the operation of the UG circuit have been identified. These conductive objects with shock potential include eight (8) pipeline regulator stations within proximity of the UG circuit. These objects have been analyzed during steady state conditions to determine if induced AC voltages will exceed 15 Volts and during fault conditions to determine if AC touch and step potentials will exceed the ANSI/IEEE Standards 80 thresholds.

The shock potential of these objects was modeled with a simulated fault at the closest project vault location to determine the worst-case scenario for AC touch and step potentials. The maximum touch and step potentials calculated for the 8 pipeline regulator stations were computed at the pipeline regulator station located at the intersection of Pomerado Road and Elliot Field Access Drive. The maximum touch and step potentials calculated at this station are outlined in Table 3-4.

Table 3-4: Maximum Touch & Step Voltage Results

	Calculated Without Mitigation	IEEE Standard 80 Safety Limit
Touch Voltage (Volts AC)	43.1 V	346.6 V
Step Voltage (Volts AC)	0.003 V	918.0 V

The touch and step voltages computed at the Pomerado Road/Elliot Field Access Drive pipeline regulator station, as well as at the remaining seven (7) regulator stations, are below the ANSI/IEEE Standard 80 design limits.

3.4 AC Corrosion Analysis Results

Pursuant to Mitigation Measure Utilities-4, AC corrosion effects have been modeled on parallel metallic pipelines within 100-ft of the UG circuit. ARK Engineering has coordinated these efforts with SDG&E, which has been determined to be the only utility affected by the UG circuit.

To analyze the possible AC corrosion effects to the identified metallic pipelines, calculations were completed to determine the AC density based upon induced AC pipeline voltages, assuming a one (1) cm^2 circular coating holiday, along the pipelines. The computed induced pipeline voltages are shown in Appendix B.

A peak AC density of fifty-nine (59) A/m^2 was calculated for the 4” gas pipeline at approximate GPS location 32.905195°N, 117.084795°W. This is the same location where the maximum induced AC pipeline potential was computed, as referenced in Section 3.3.1.

Table 3-5 outlines the computed maximum AC density at projected future maximum load conditions on the UG circuit.

Table 3-5: Maximum Coating Holiday Pipeline AC Current Density

Pipeline Diameter (in.)	Maximum Current Density (A/m²)	Design Limit (A/m²)
4	39.6	100
4	7.0	100
4	5.4	100
6	11.3	100
4	13.9	100
4	59.2	100
8	33.1	100

Since the maximum current density of the pipelines within 100-ft of the UG circuit were within appropriate AC corrosion limits, further study of metallic pipelines beyond 100-ft was not warranted. Appendix B includes plots of the computed AC density on the pipelines.

4. CONCLUSIONS

4.1 Conclusions

An AC interference and induced current touch study has been completed by modeling and analyzing the proposed San Diego Gas & Electric 230 kV "Sycamore to Peñasquitos" underground electric transmission circuit, the seven (7) metallic pipelines, and the eight (8) pipeline regulator stations as described in this report.

Computer modeling and analysis, using projected future maximum steady state load conditions and single phase-to-ground fault current conditions on the UG circuit, indicate the following:

- ➢ AC Interference Study (Mitigation Measure Utilities-4):
  - Steady state induced AC pipeline voltages will not exceed the design limit of fifteen (15) Volts under the maximum load condition on the UG circuit.
  - Pipeline coating stress voltages will not exceed the two thousand five hundred (2,500) Volt design limit for a single phase-to-ground fault on the UG circuit.
  - Pipeline AC density across a 1 cm^2 coating holiday will not exceed the one hundred (100) A/m^2 design limit.
- ➢ Induced Current Touch Study (Mitigation Measure Hazards-7):
  - Touch and step voltages at the identified conductive objects (pipeline regulator stations) will not exceed the ANSI/IEEE Standard 80 design limits during single phase-to-ground fault conditions or the 15 Volt touch voltage limit during steady state conditions.

This analysis results in AC interference levels, including AC touch and step potentials, that are conservative. Under normal operating conditions, the AC interference levels on the existing pipelines and metallic objects should be less than reported in this study.

4.2 Assumptions

During the modeling and analysis of the AC interference effects, various assumptions were required. These assumptions are outlined below in no particular order:

- ➢ Conservative coating resistance values were used for the pipeline segments, as explained in section 2.1.
- ➢ A coating holiday size of 1 cm^2 was used in the calculation of AC current density.
- ➢ Specific soil resistivity measurements were not recorded along the UG circuit right-of-way, therefore an equivalent multilayer soil resistivity model was derived from measurements recorded previously by ARK Engineering in the area of this study.

5. RECOMMENDATIONS

5.1 Recommendations

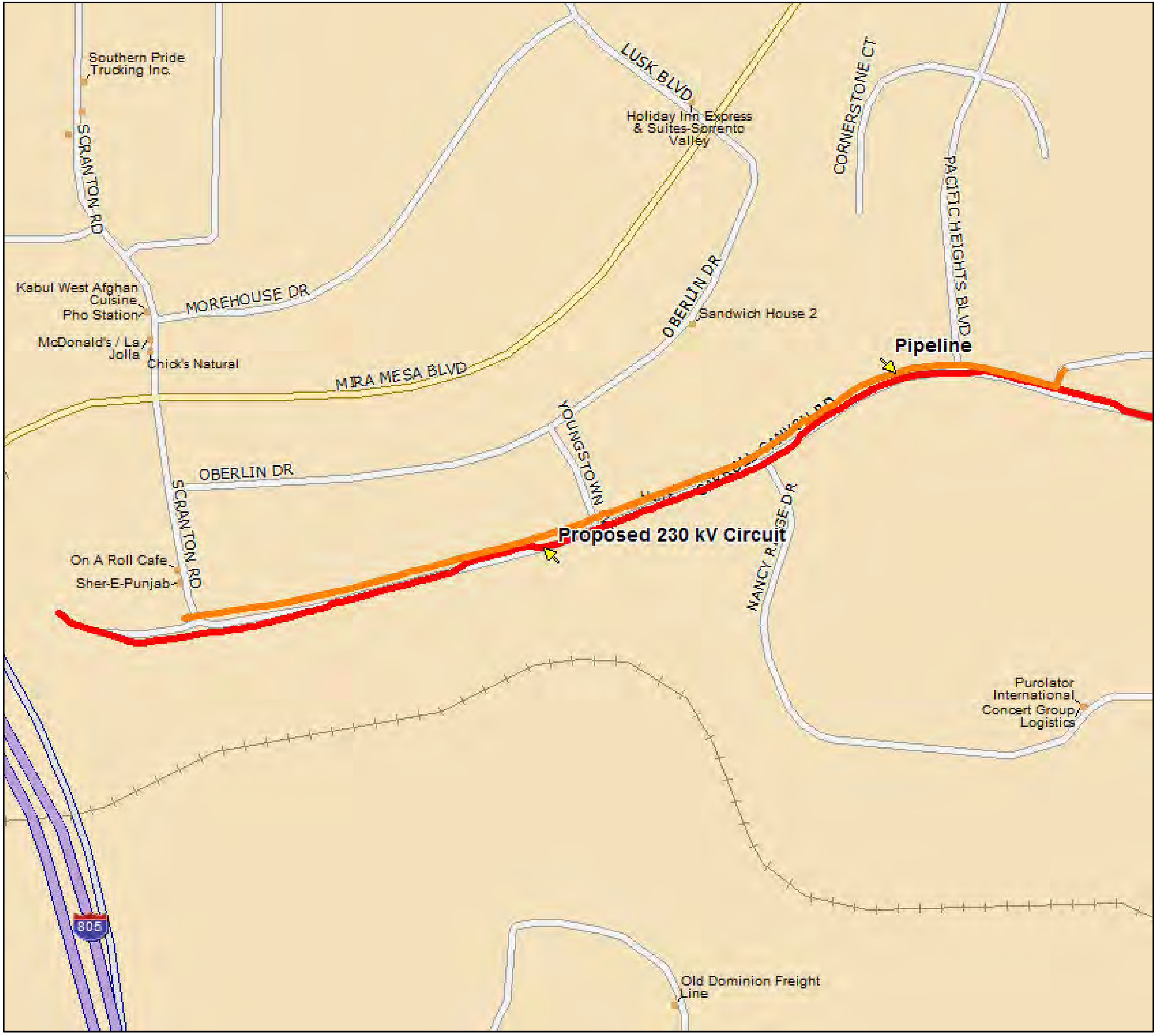
As outlined in the previous sections of this report, induced AC interference levels were calculated at values below the design limits detailed in Table 1-1, for the existing metallic pipelines during projected future maximum steady state load conditions and single phase-to-ground fault conditions on the UG circuit. In addition, touch and step voltages at nearby conductive objects were calculated at values below 15 Volts during steady state conditions and below ANSI/IEEE Standard 80 thresholds during fault conditions.

Based upon the results of this analysis, AC interference levels on above and below ground metallic objects will not present a threat to the integrity of these objects (i.e. corrosion) or public safety (i.e. induced current and shock hazard).

No additional AC mitigation is recommended for these nearby pipelines or other metallic objects as a result of the operation of the underground segment of the UG circuit.

Please call the author if you have questions or require additional information regarding this report.

APPENDIX A –
AREAS OF CONCERN MAPS



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TN
MN (11.7°E)

0 200 400 600 800 1000 ft
0 80 160 240 320 400 m

Data Zoom 14-3

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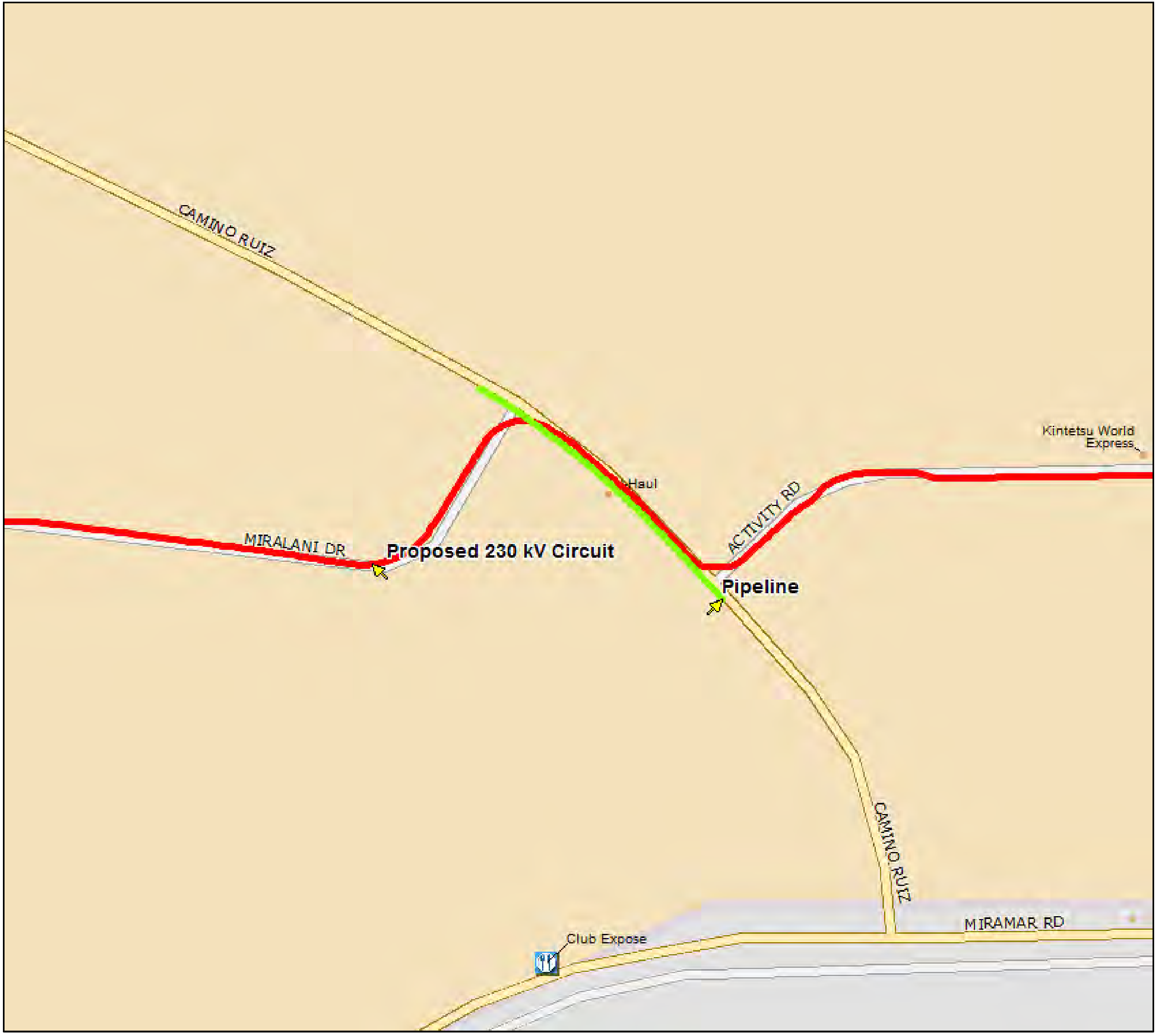
TN

MN (11.7°E)

0	200	400	600	800	1000	ft
0	80	160	240	320	400	m

Data Zoom 14-2



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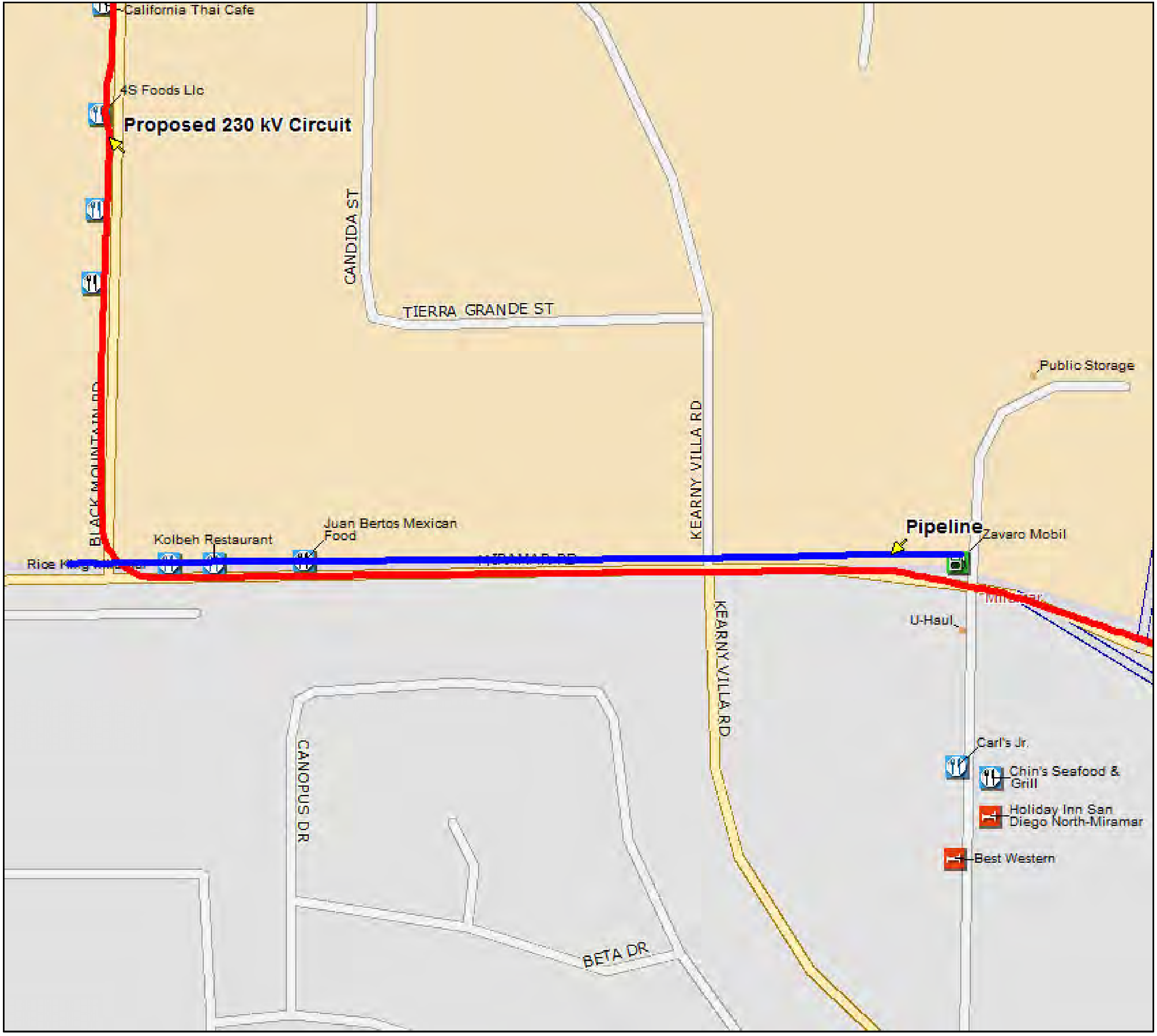

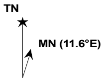

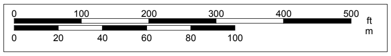

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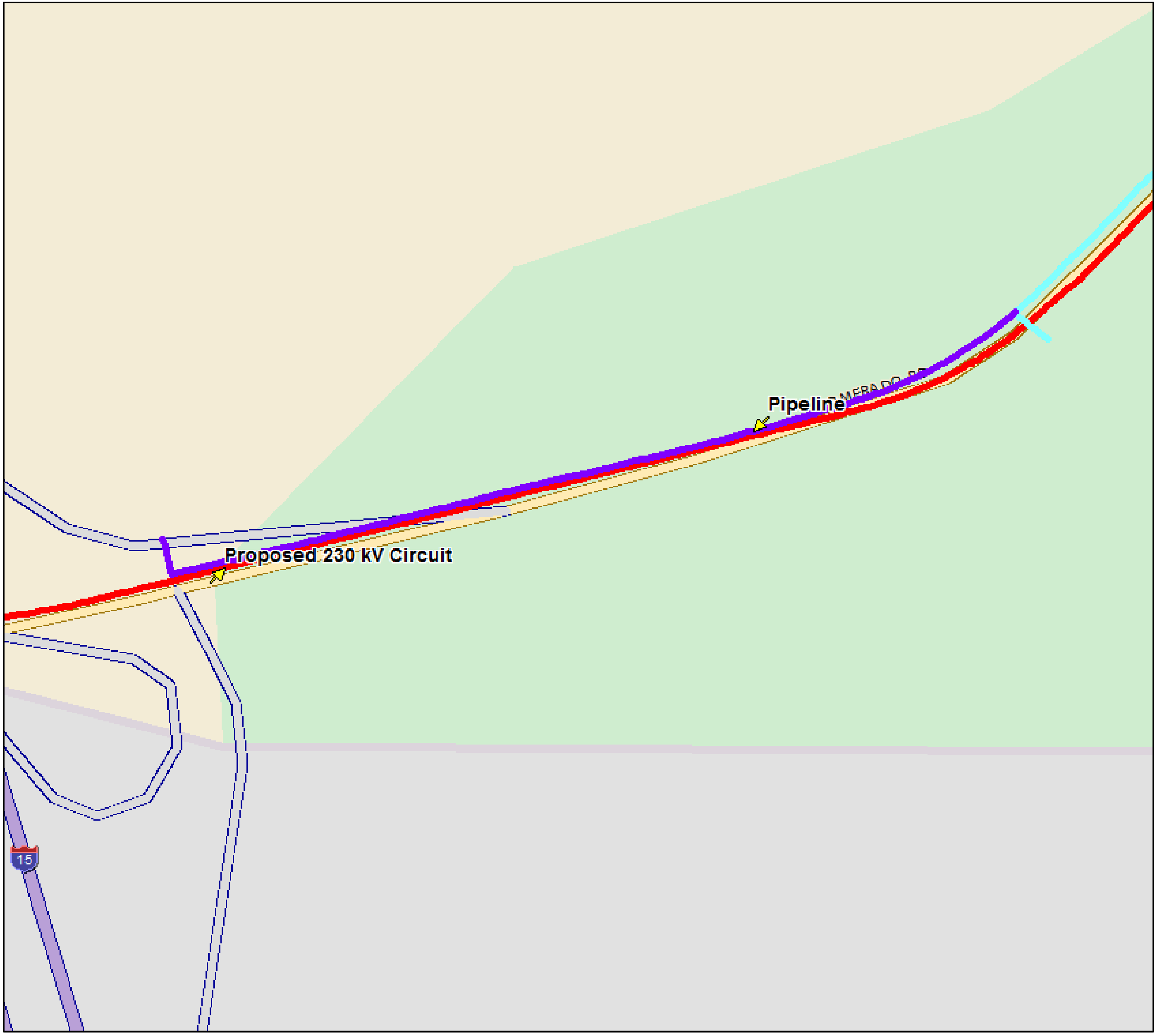

TN
MN (11.6°E)

0 100 200 300 400 500 ft
0 20 40 60 80 100 m

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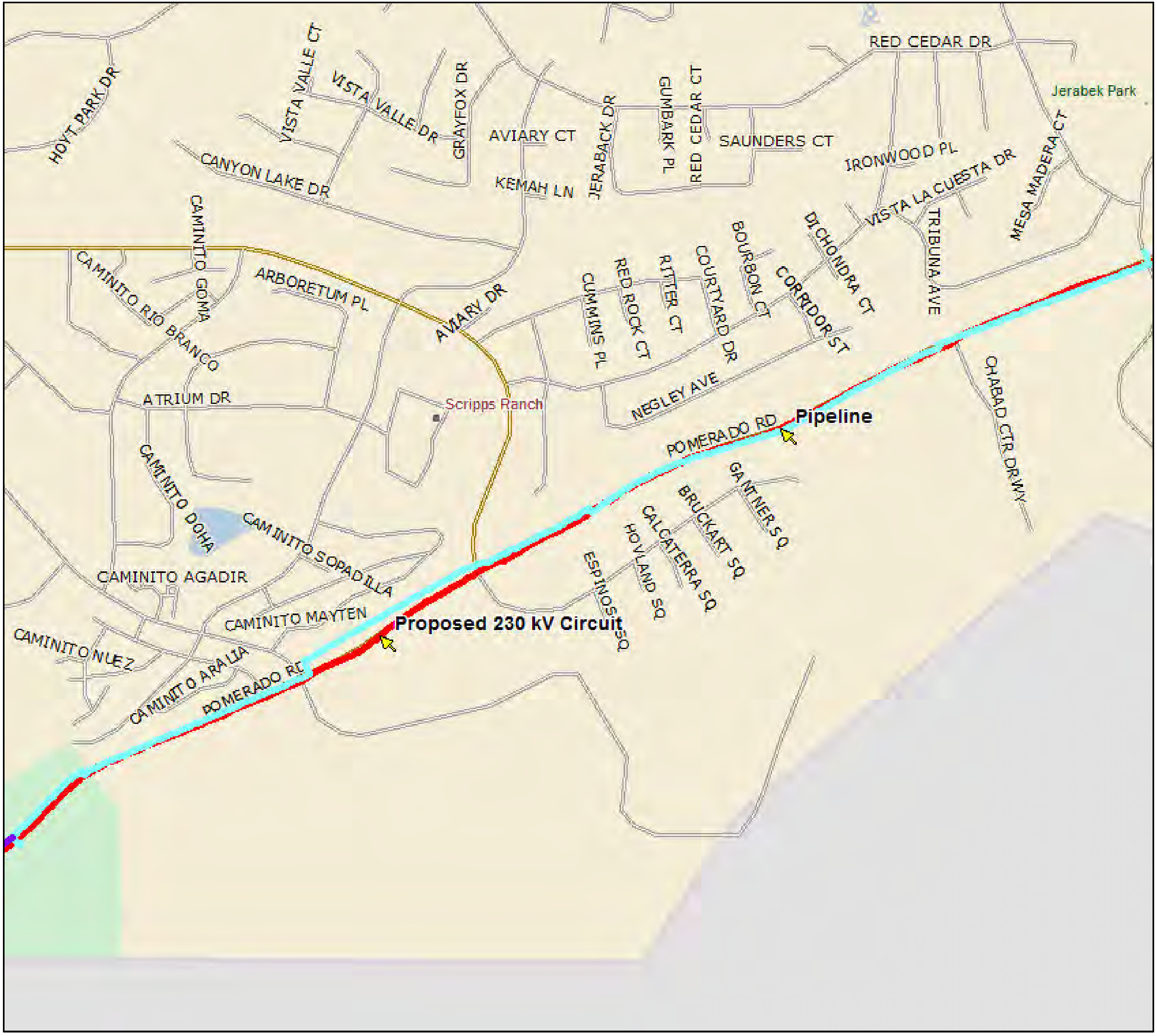

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Data Zoom 13-7

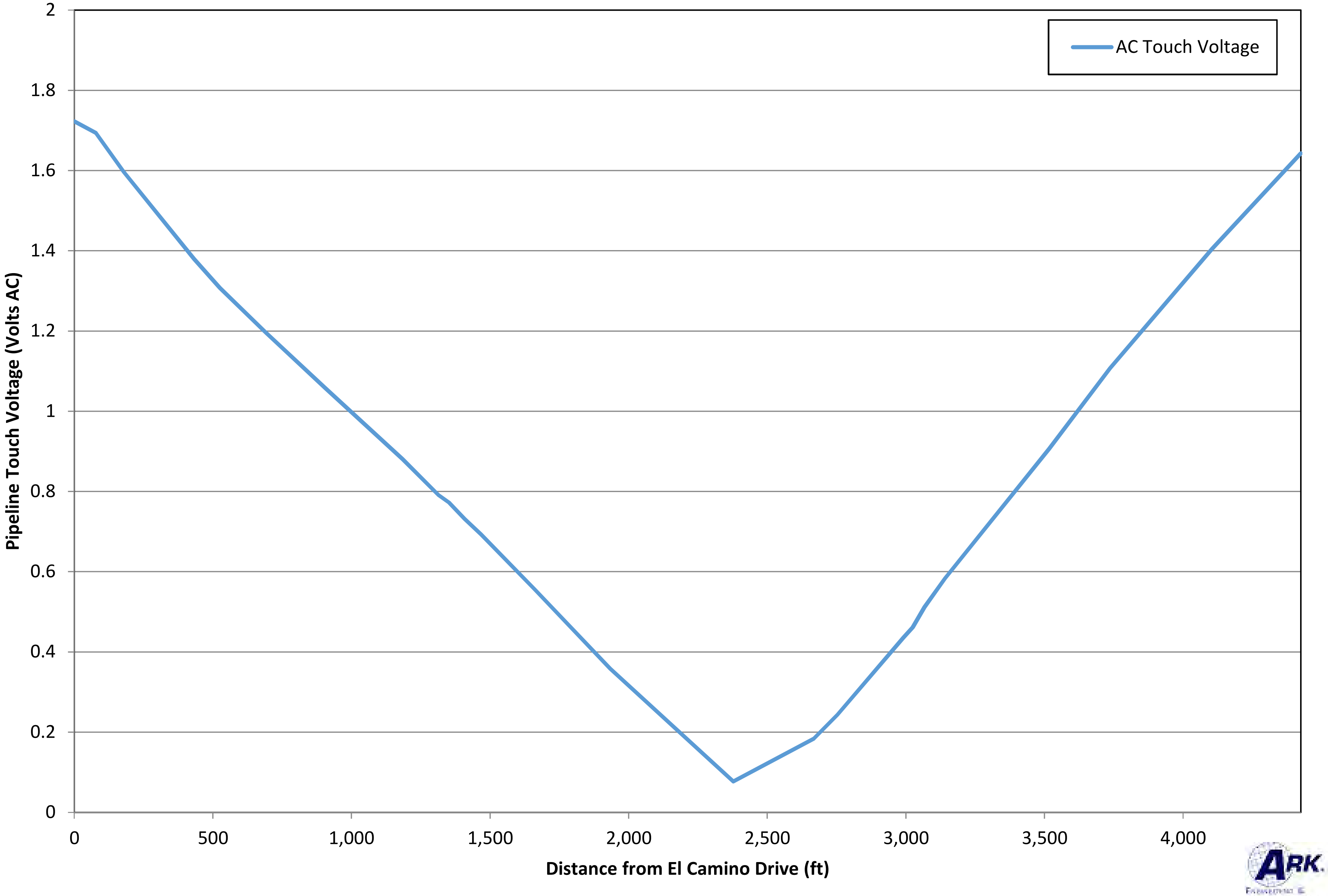
Data Zoom 14-6

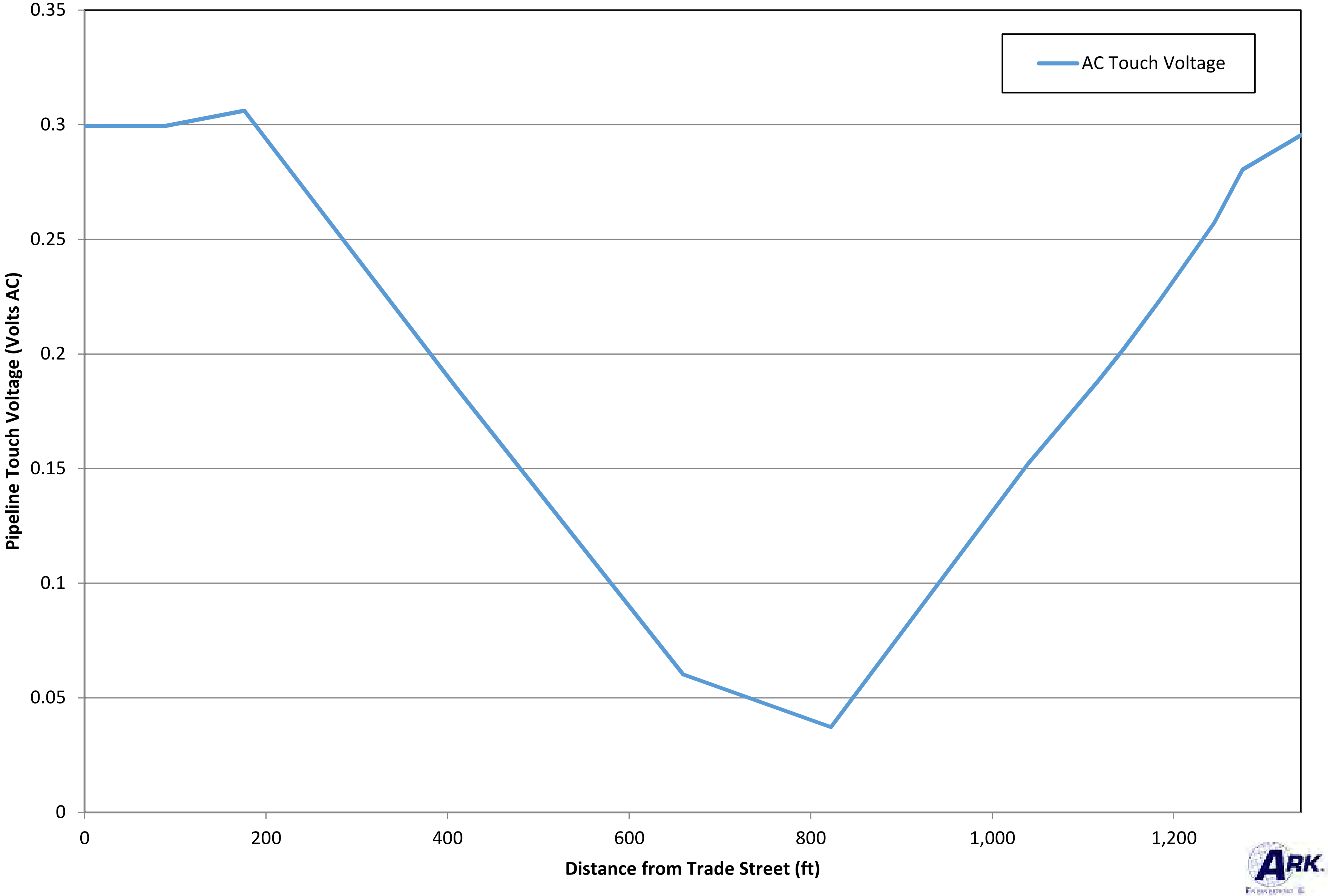
APPENDIX B –

PIPELINE STEADY STATE, AC CURRENT DENSITY & FAULT PLOTS

STEADY STATE INDUCED

4" Pipeline Parallelism Between Scranton Road and El Camino Drive
Modeled AC Touch Voltage

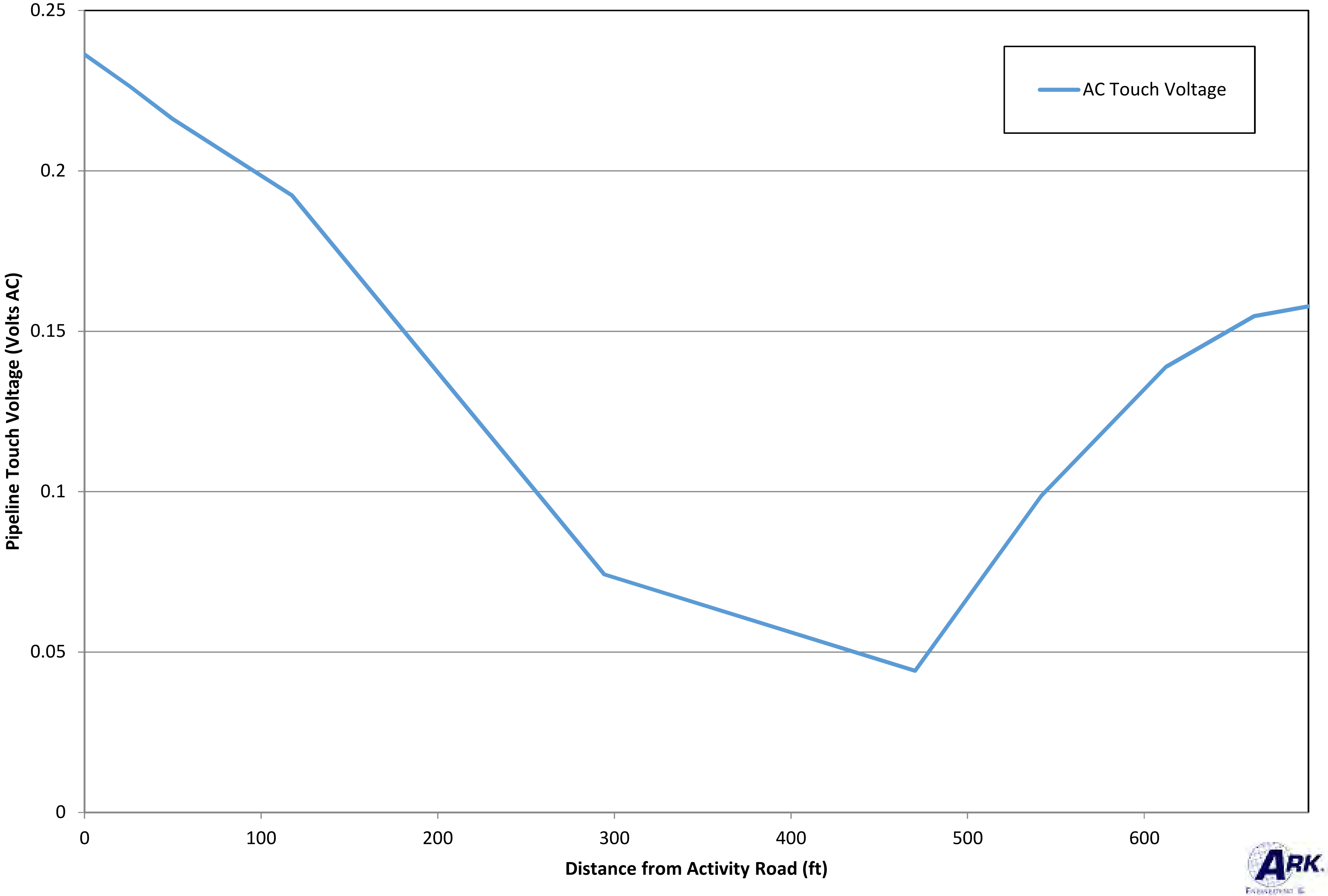




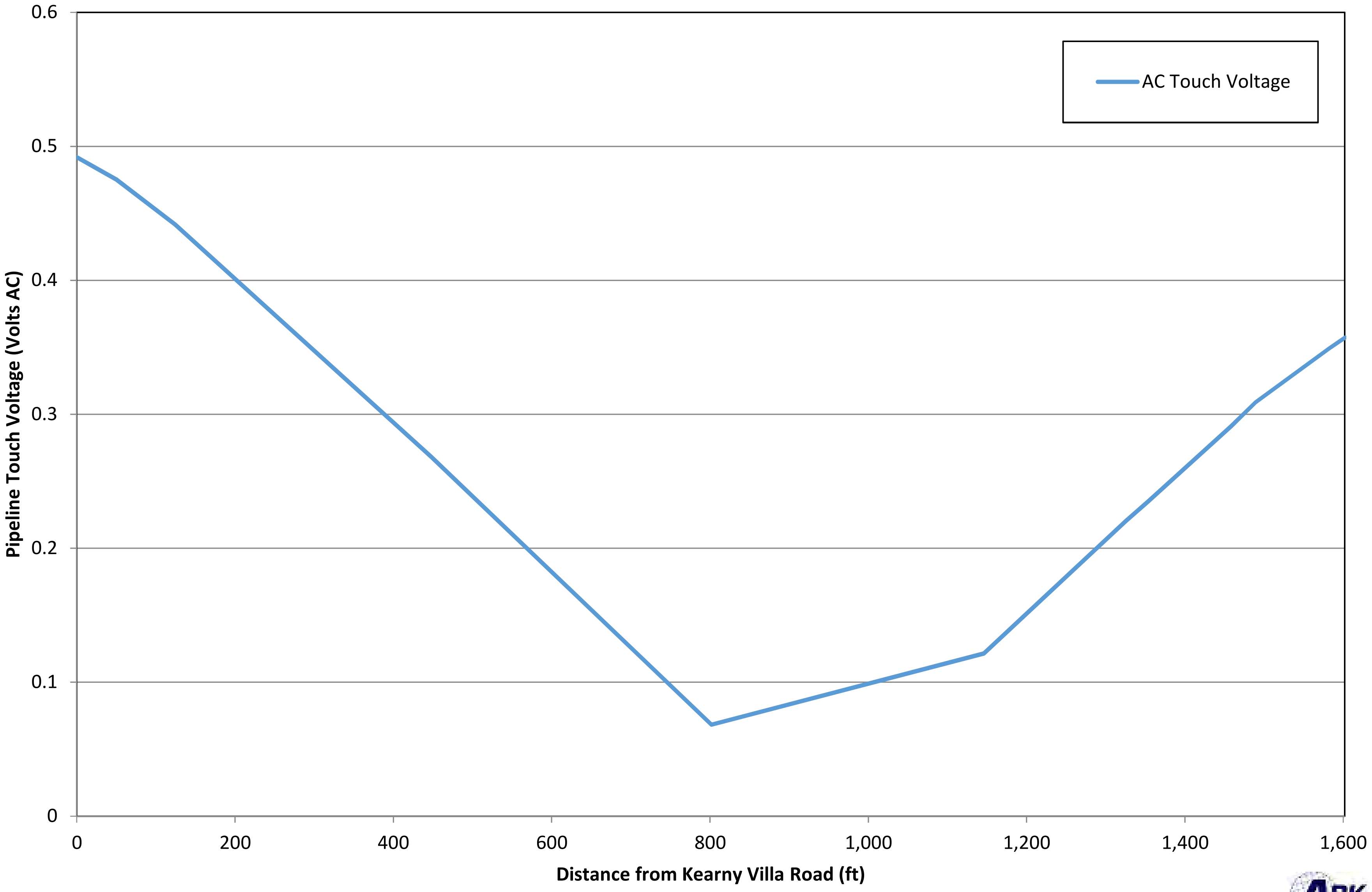
4" Pipeline Parallelism Between Carroll Road and Trade Street
Modeled AC Touch Voltage

ARK.

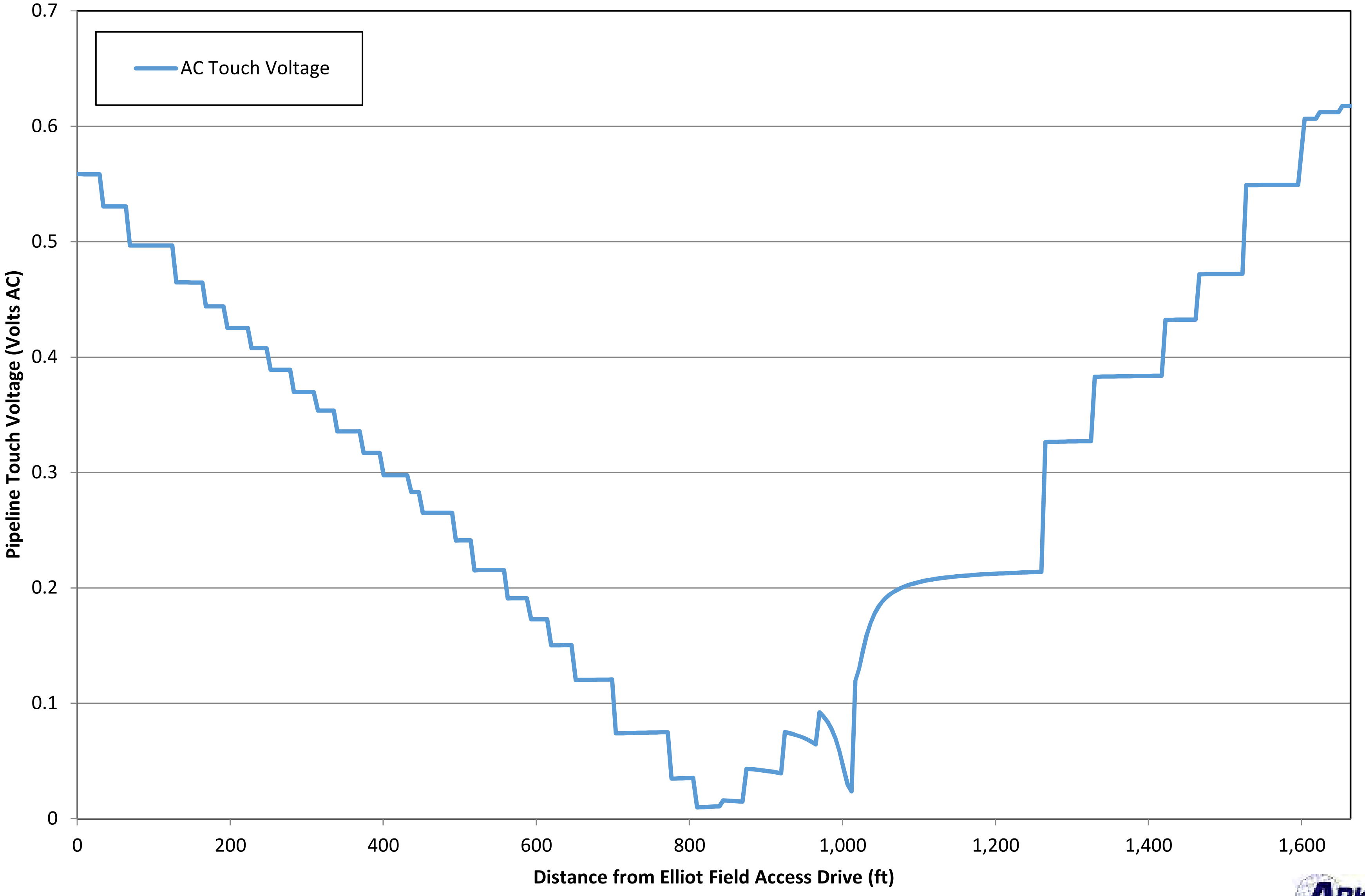
4" Pipeline Parallelism Between Miralani Drive and Activity Road
Modeled AC Touch Voltage



6" Pipeline Parallelism Between Black Mountain Road and Kearny Villa Road
Modeled AC Touch Voltage



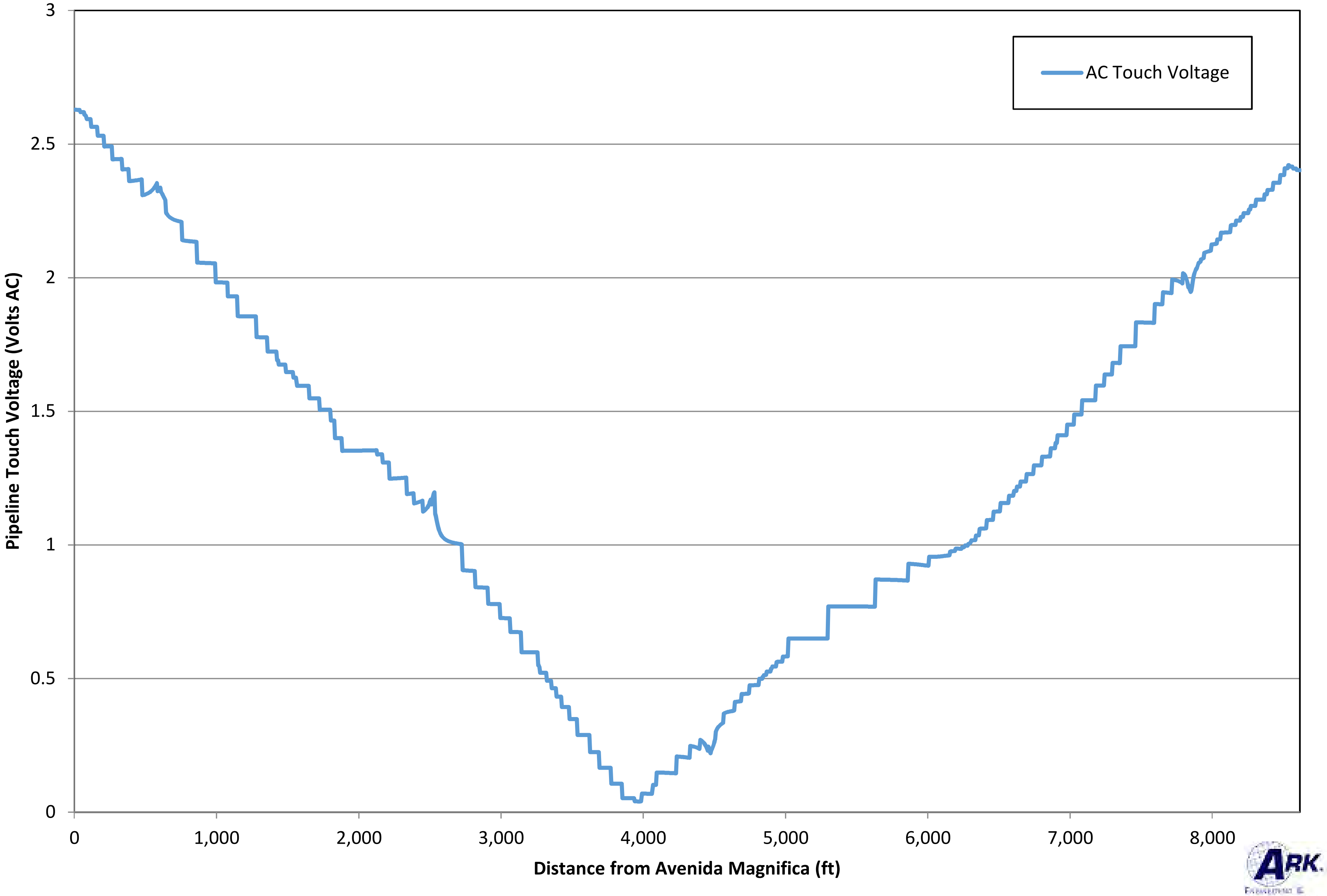
ARK.



4" Pipeline Parallelism Between I-15 Northbound On Ramp and Elliot Field Access Drive
Modeled AC Touch Voltage

ARK.

4" Pipeline Parallelism Between Elliot Field Access Drive and Avenida Magnifica
Modeled AC Touch Voltage



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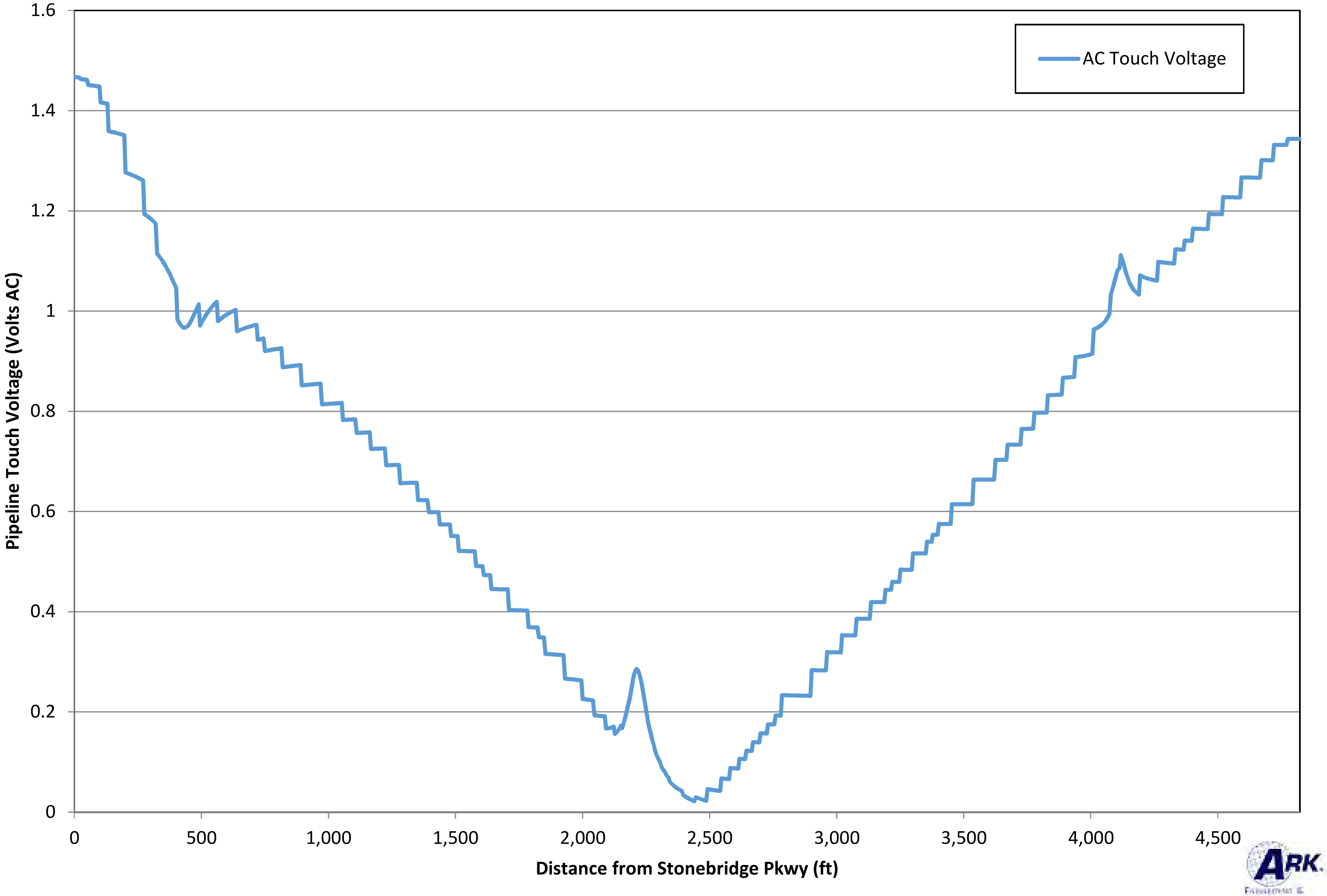
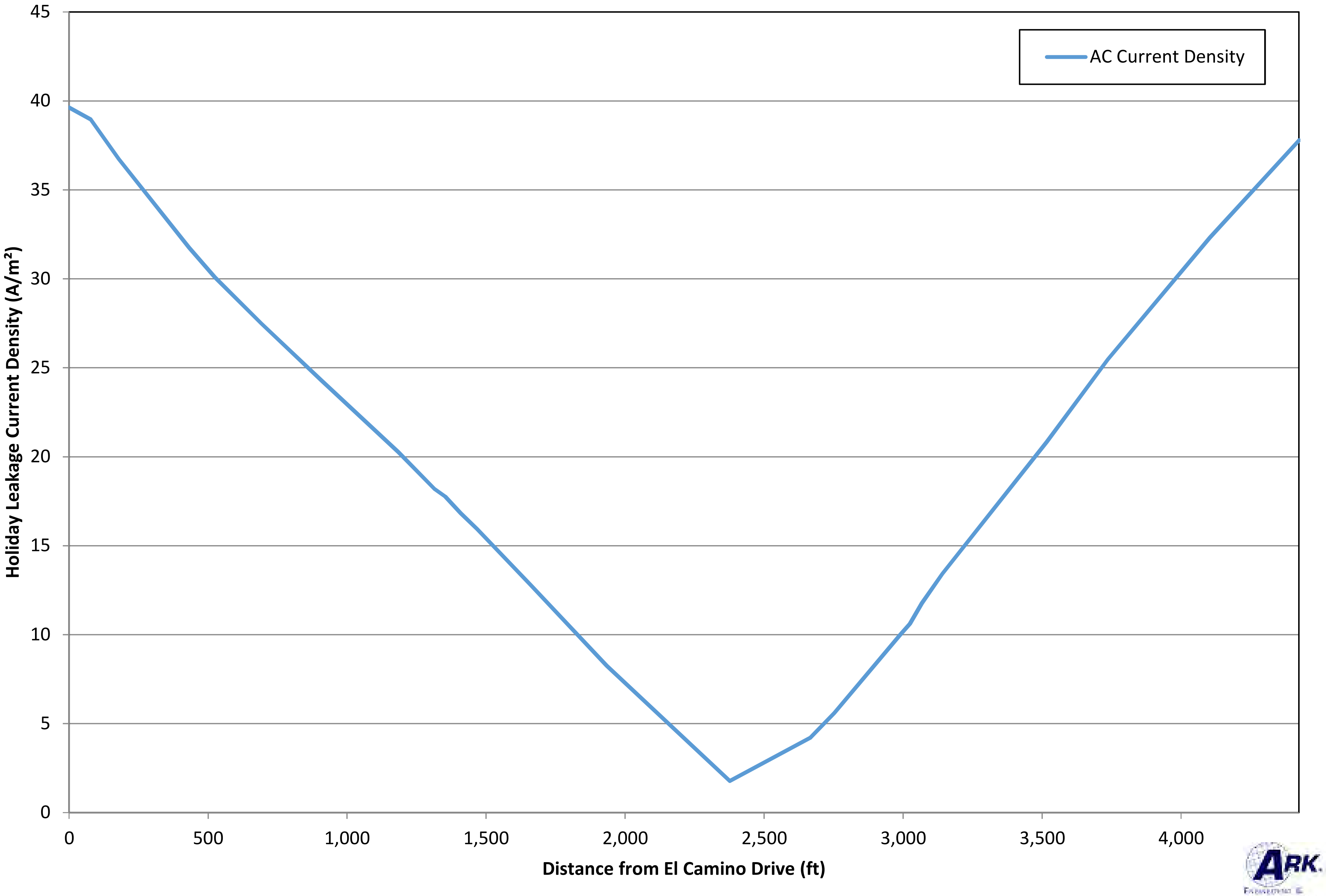
8" Pipeline Parallelism Between Semillon Blvd and Stonebridge Pkwy
Modeled AC Touch Voltage

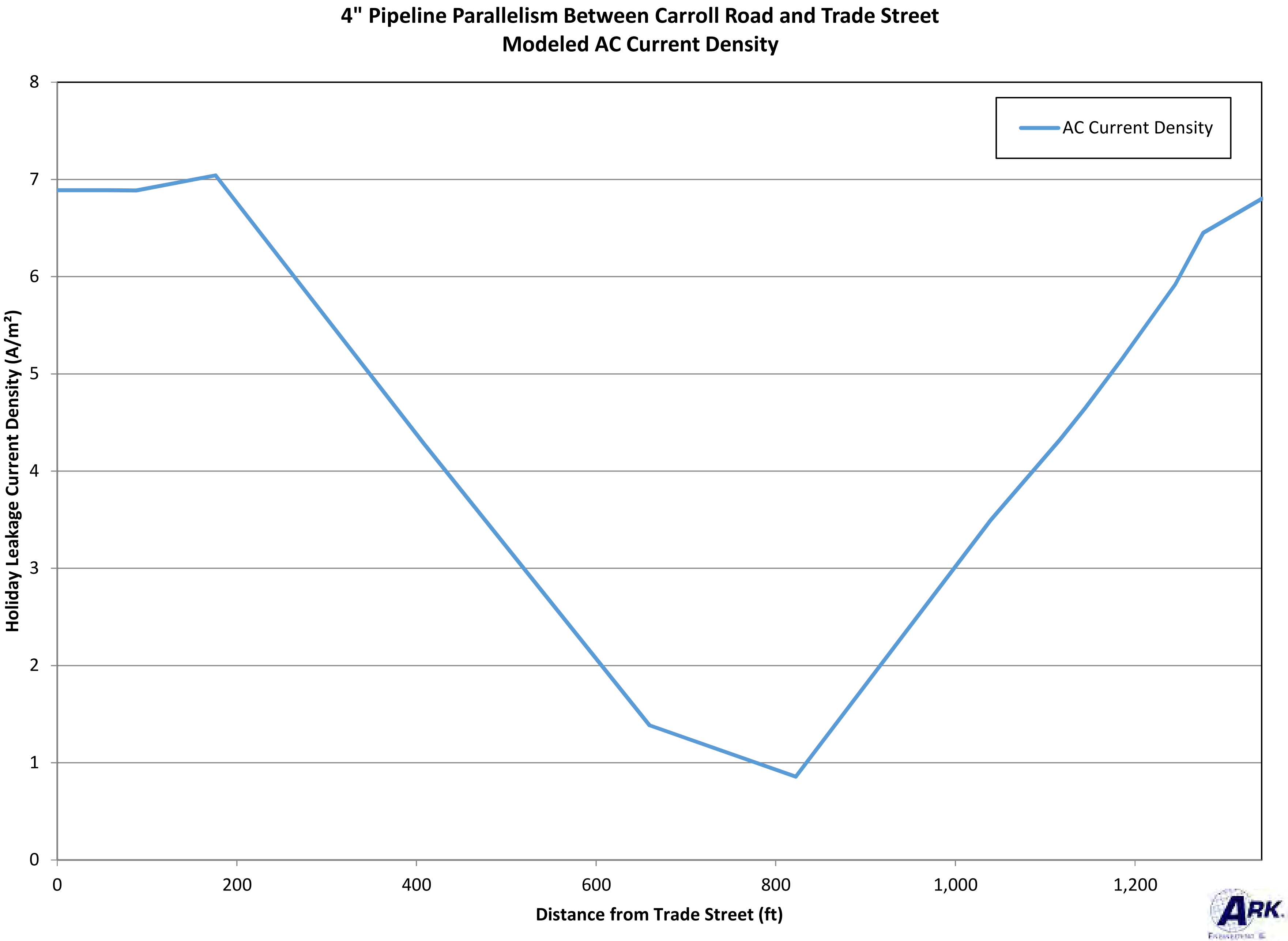


ARK.

AC CURRENT DENSITY



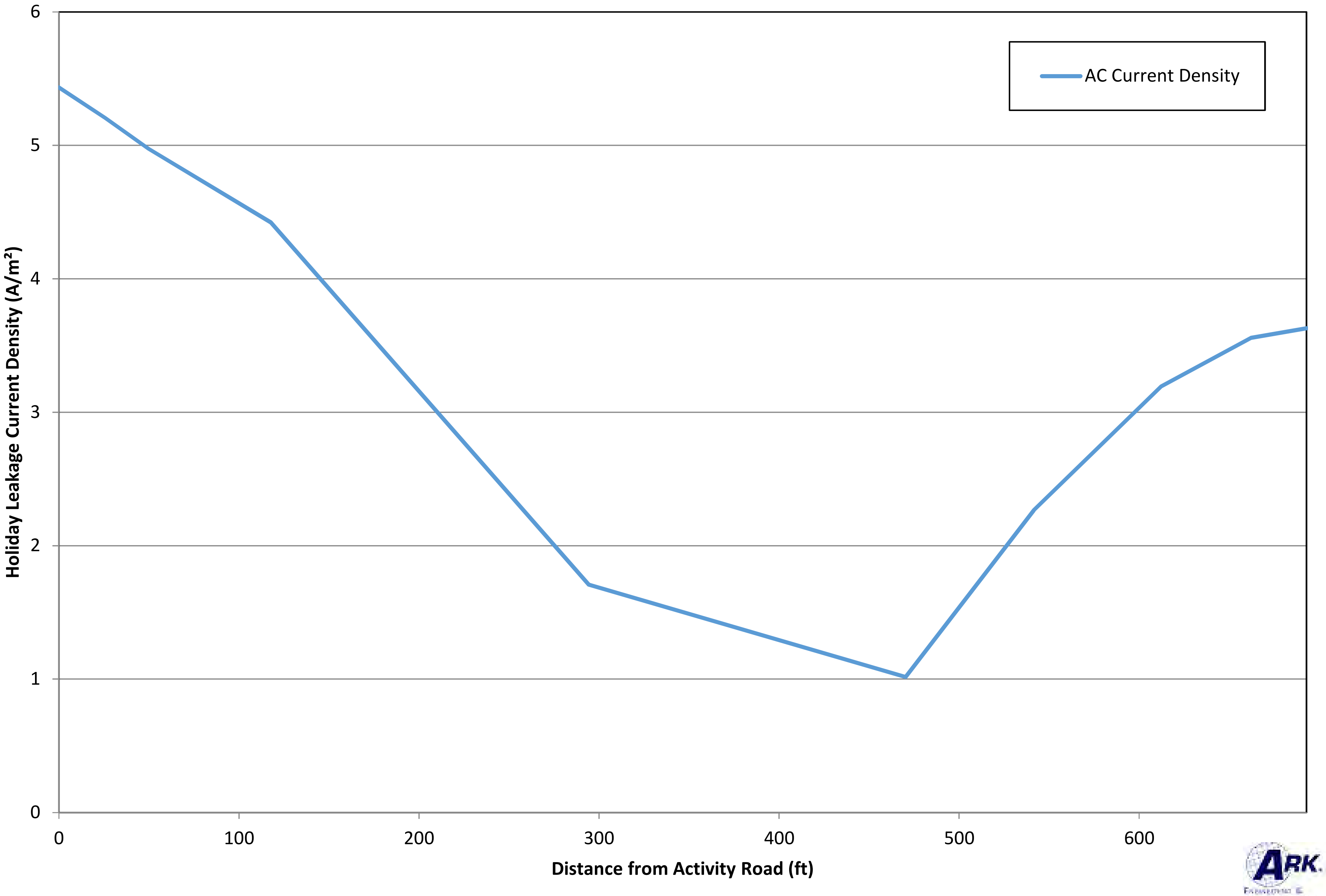
4" Pipeline Parallelism Between Scranton Road and El Camino Drive
Modeled AC Current Density



4" Pipeline Parallelism Between Carroll Road and Trade Street
Modeled AC Current Density

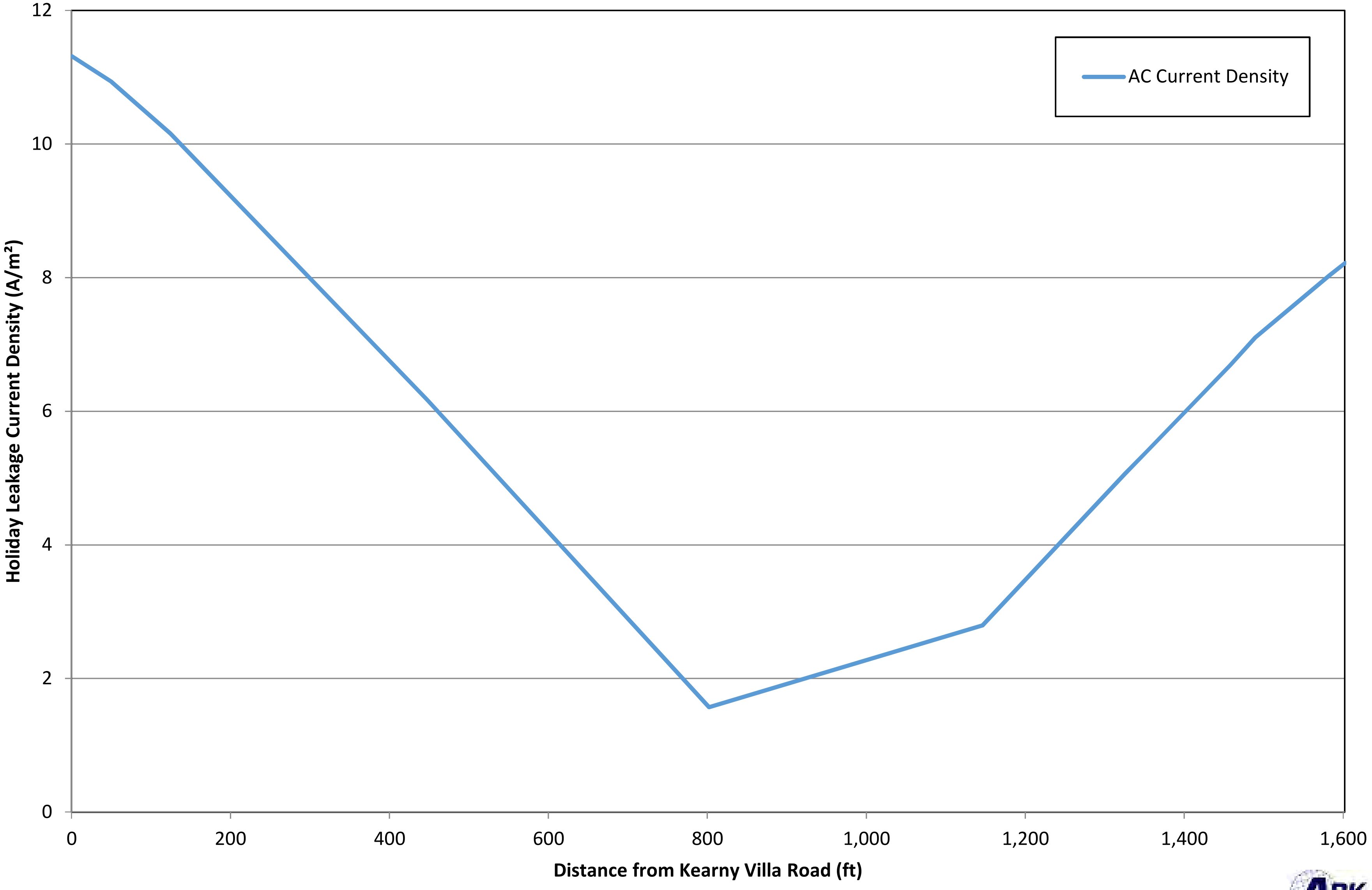
ARK.

4" Pipeline Parallelism Between Miralani Drive and Activity Road
Modeled AC Current Density



ARK
Engineering & Technical Services, Inc.

6" Pipeline Parallelism Between Black Mountain Road and Kearny Villa Road
Modeled AC Current Density



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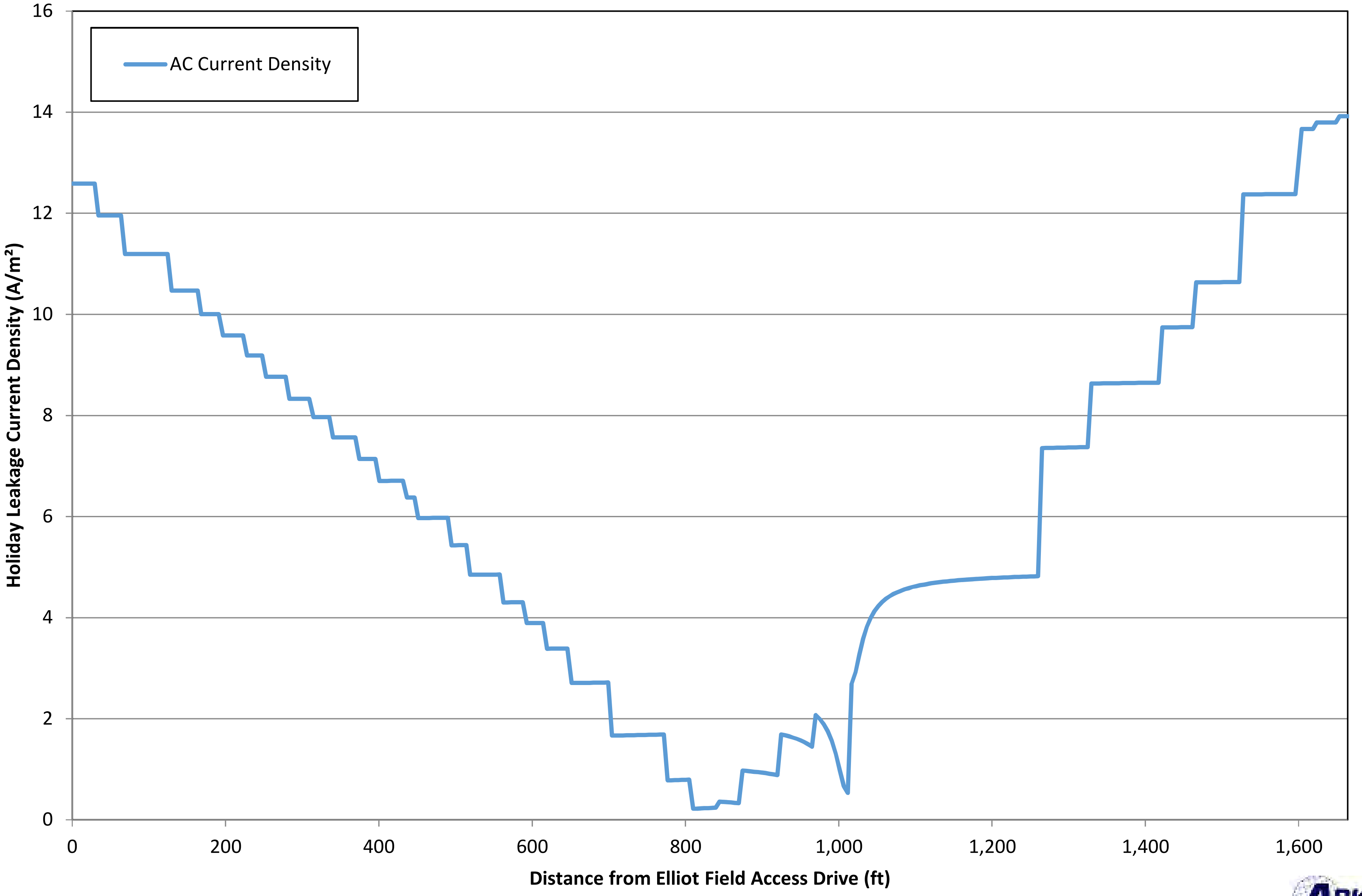
4" Pipeline Parallelism Between I-15 Northbound On Ramp and Elliot Field Access Drive
Modeled AC Current Density



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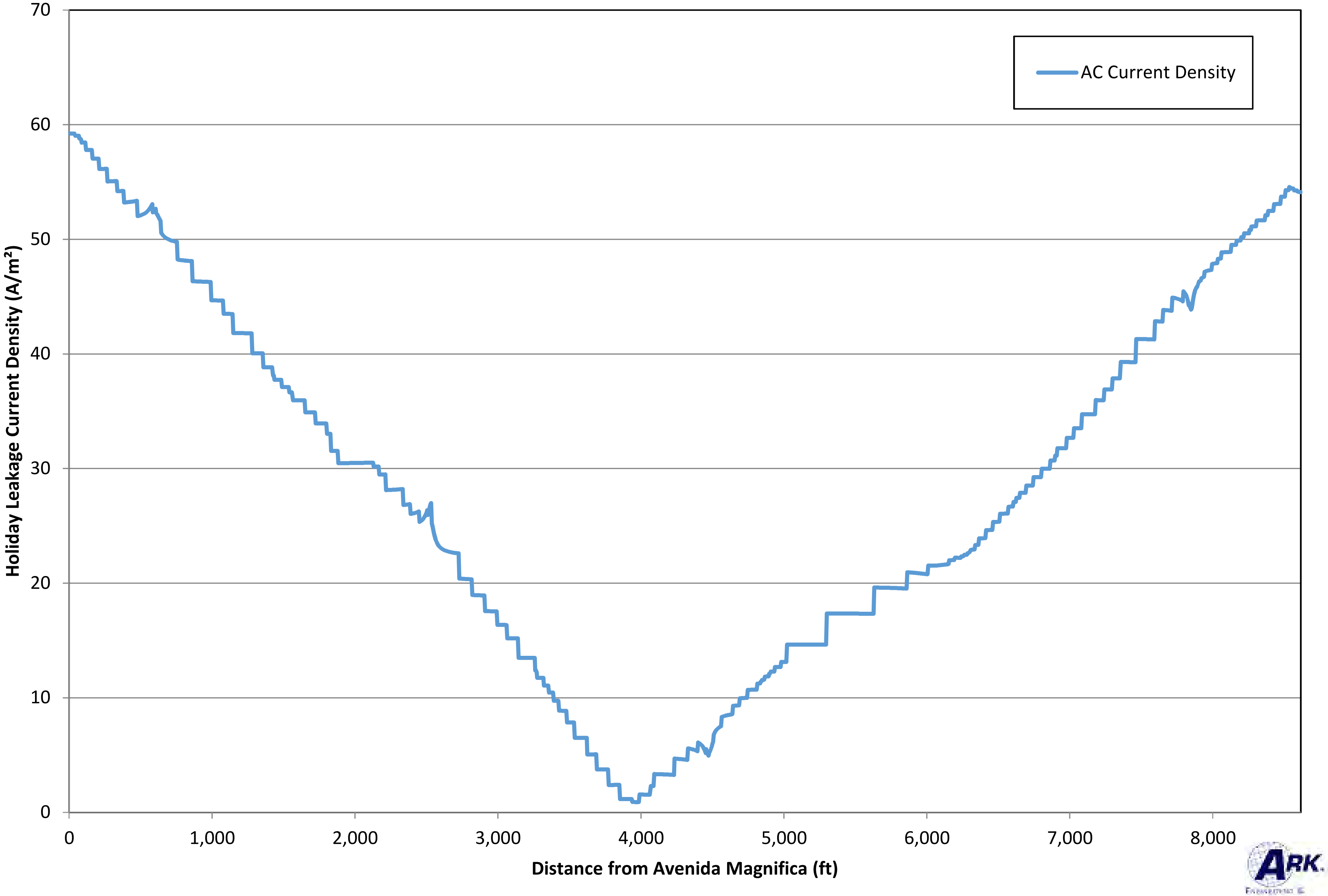
4" Pipeline Parallelism Between Elliot Field Access Drive and Avenida Magnifica
Modeled AC Current Density



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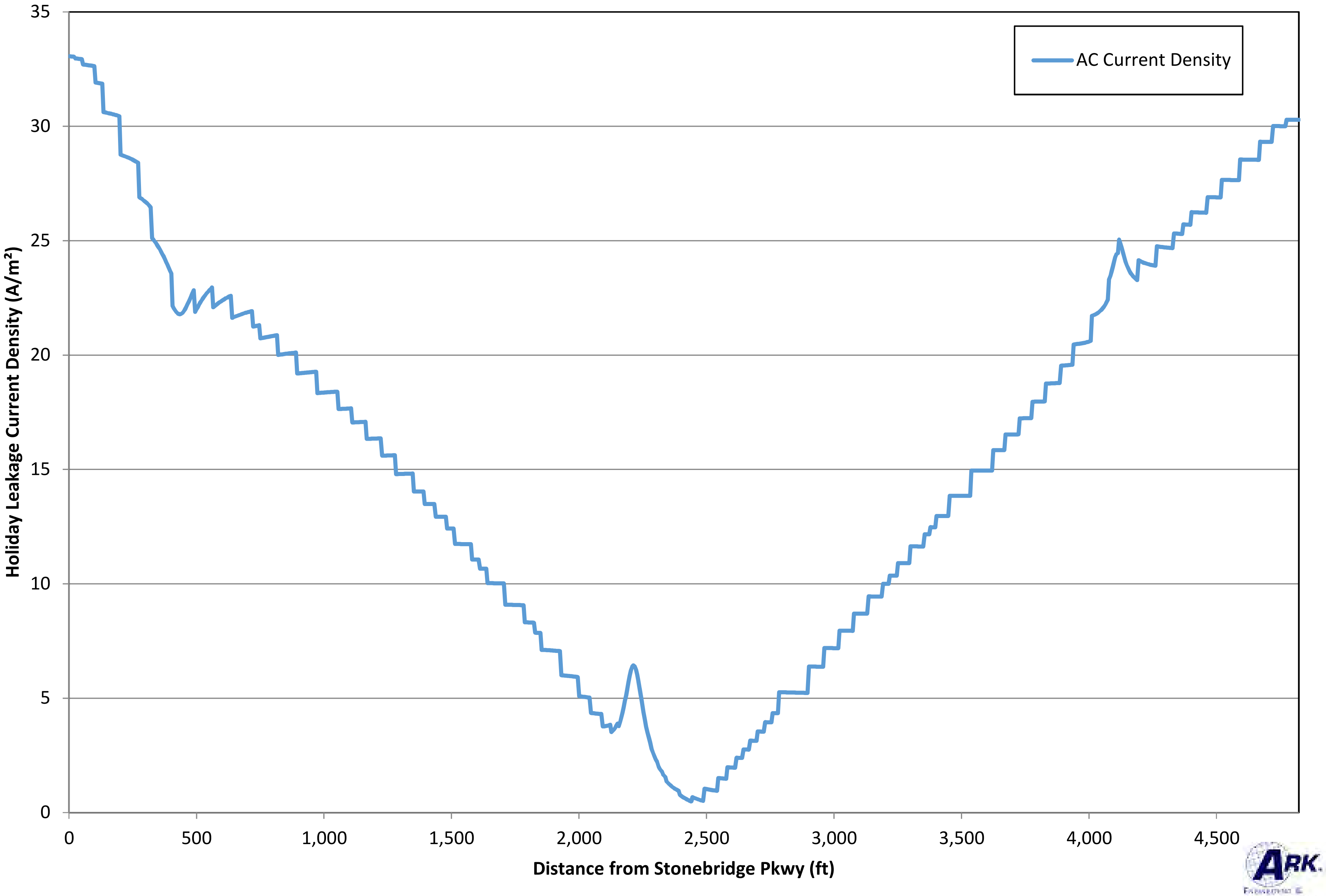
8" Pipeline Parallelism Between Semillon Blvd and Stonebridge Pkwy
Modeled AC Current Density



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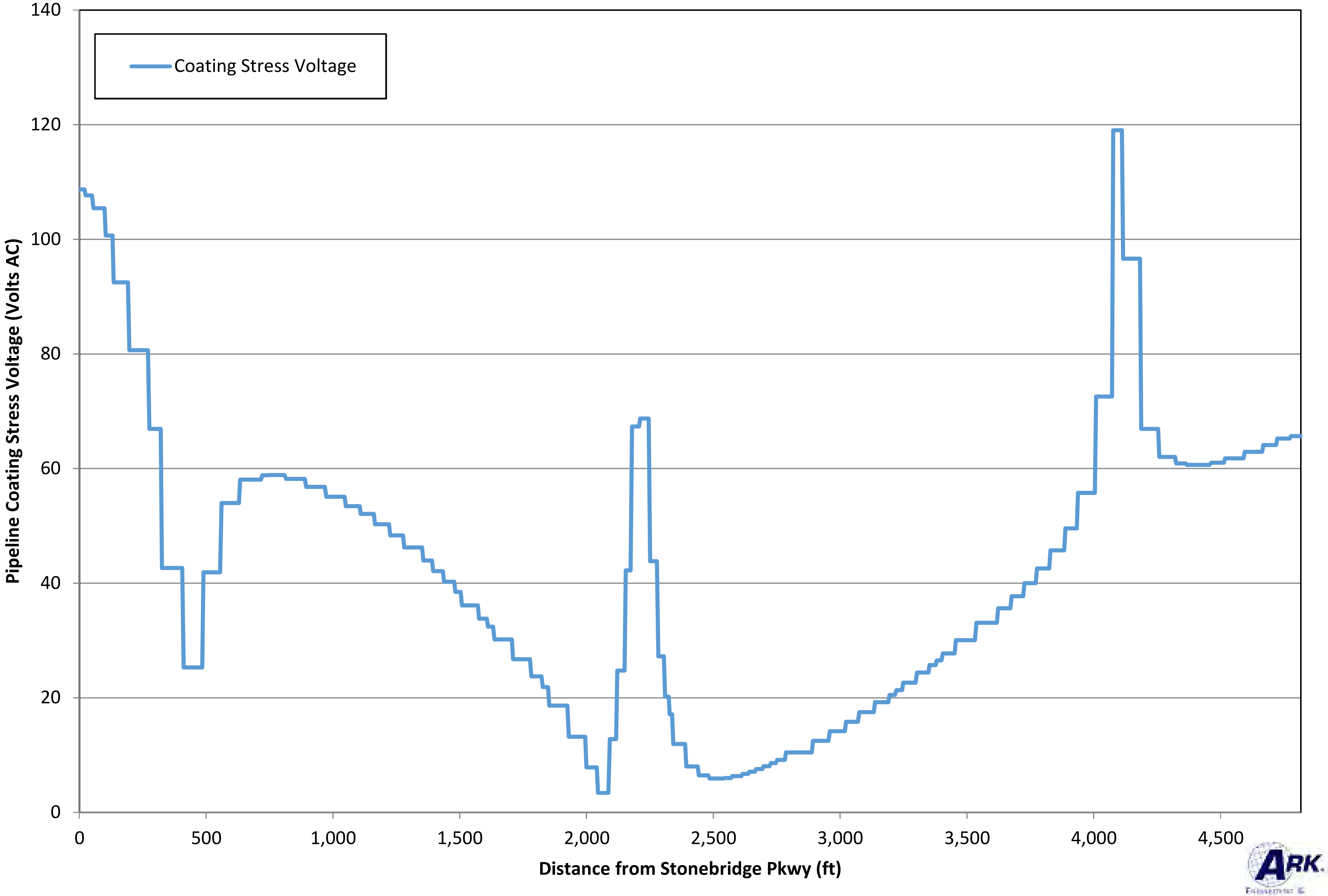
FAULT – COATING STRESS VOLTAGE

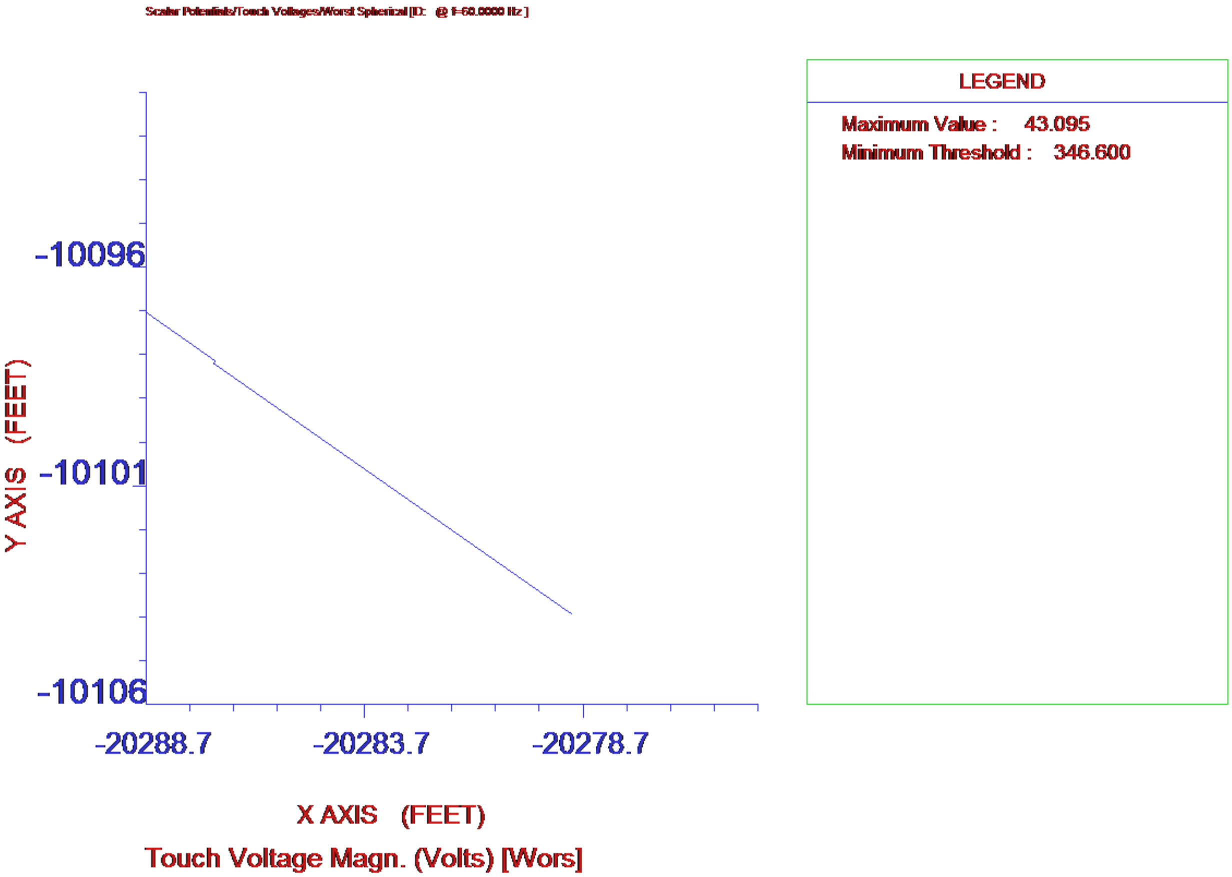
8" Pipeline Parallelism Between Semillon Blvd and Stonebridge Pkwy
Modeled Coating Stress Voltage During Simulated Fault Conditions



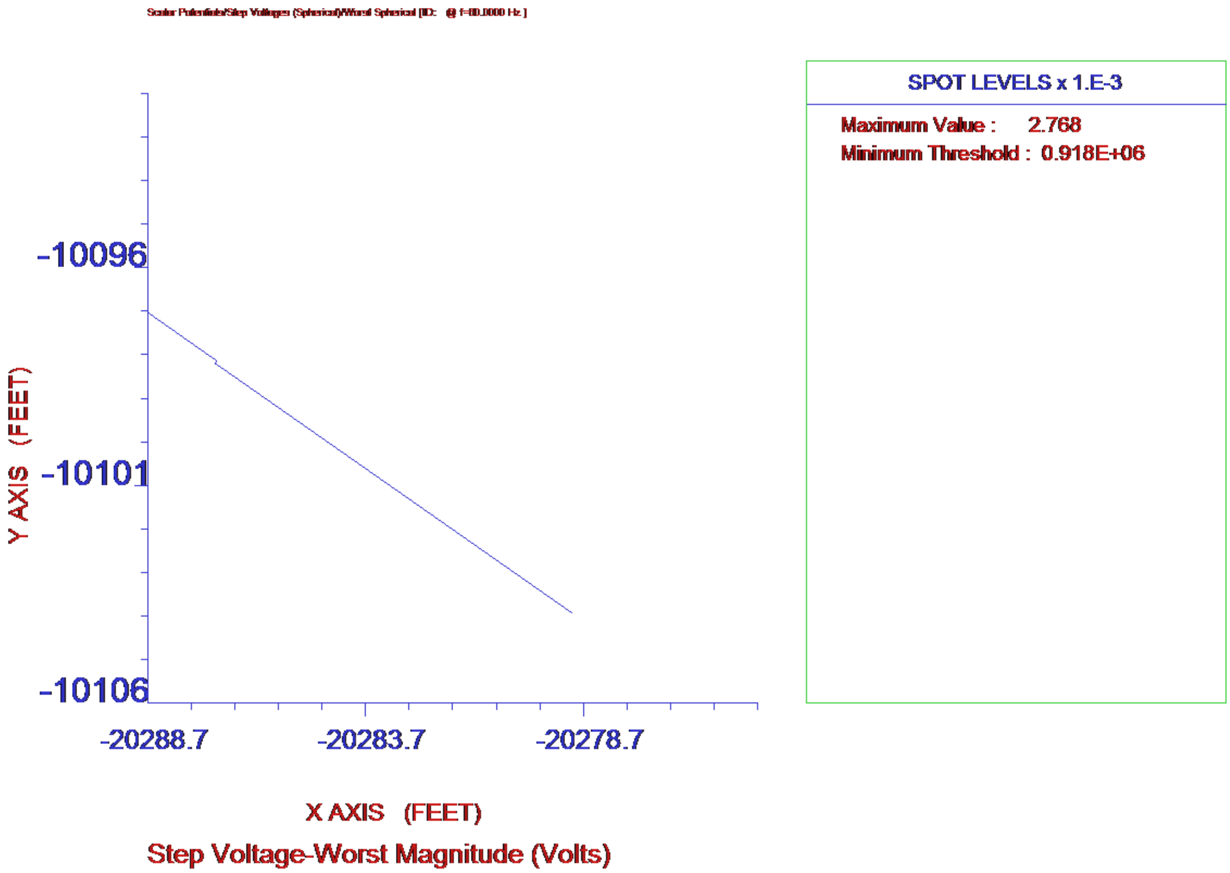
ARK.

FAULT – TOUCH & STEP VOLTAGE

Pipeline Regulator Station
At the Intersection of Pomerado Road and Elliot Field Access Drive
Touch Voltage - Safety Limit 346.6 Volts



Pipeline Regulator Station
At the Intersection of Pomerado Road and Elliot Field Access Drive
Step Voltage - Safety Limit 918 Volts

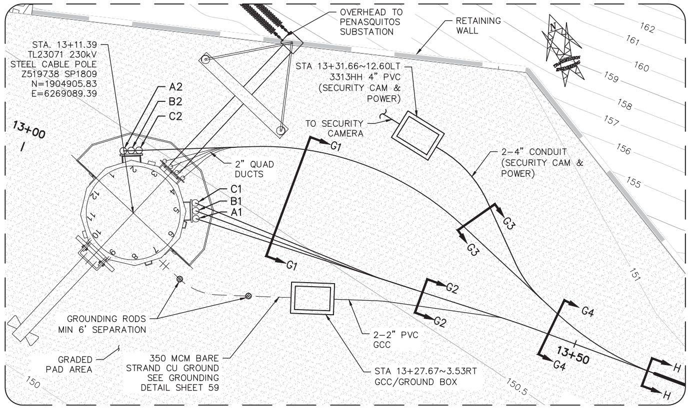


APPENDIX C –
POWER COMPANY DATA

ARK Data Request

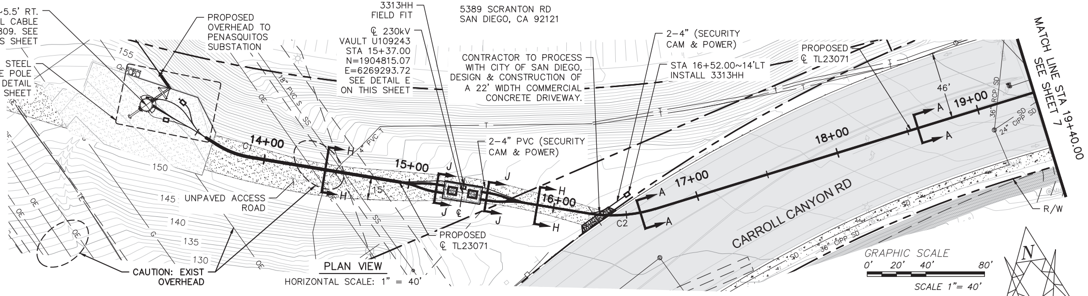
Electrical Characteristics

Circuit Information			Current Load (A)				Fault Current @ Collocation(A)														
Transmission Line	Circuit #	Voltage (kv)	Avg Summer	Avg Winter	Peak	Emergency	Pole Z519738					Mid-point					End				
							Total	Coontributed from SX	SX angle	Contributed from PQ	PQ angle	Total	Coontributed from SX	SX angle	Contributed from PQ	PQ angle	Total	Coontributed from SX	SX angle	Contributed from PQ	PQ angle
23071	SX-PQ	230kV	1603	1400	2290	2950	35667	27238	-87	8459	-81	30623	15830	-84	14793	-84	34482	9351	-81	25170	-87

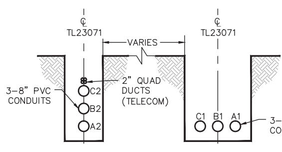


STEEL CABLE POLE LAYOUT DETAIL 1

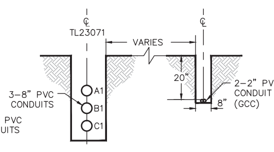
230kV STEEL CABLE POLE
SCALE: 1"=5'



PLAN VIEW
HORIZONTAL SCALE: 1" = 40'



SECTION "G1–G1"
(REF. DETAILS 12 & 20 SHEET 55 & 56)



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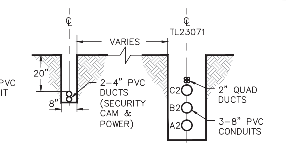

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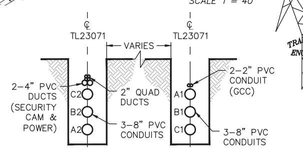

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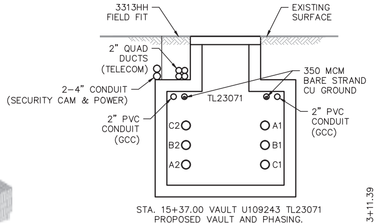
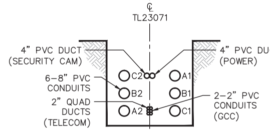
PHASING TO BE FIELD VERIFIED

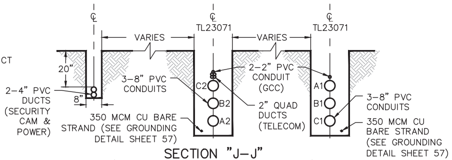


STA. 15+37.00 VAULT U109243 TL23071
PROPOSED VAULT AND PHASING.
REF US CONCRETE PRECAST GROUP DWG XXXXXX
LOOKING UP STATION

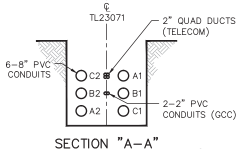
DETAIL "E"



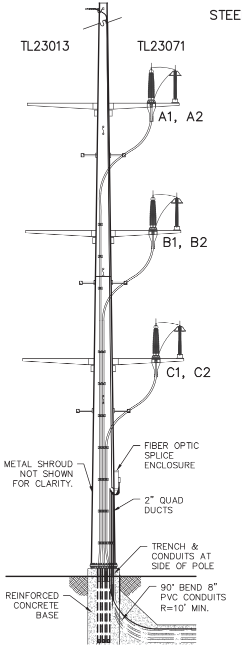
SECTION "H–H"
(REF. DETAIL 9 SHEET 55)



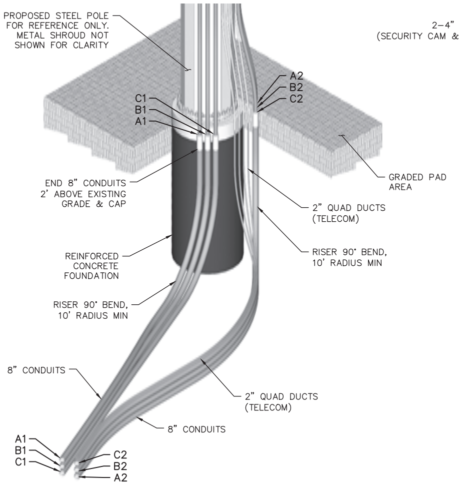
SECTION "J–J"
(REF. DETAILS 16, 10 & 11, SHEETS 55–56)



SECTION "A–A"
(REF. DETAILS 1–2 & 7 SHEET 55)



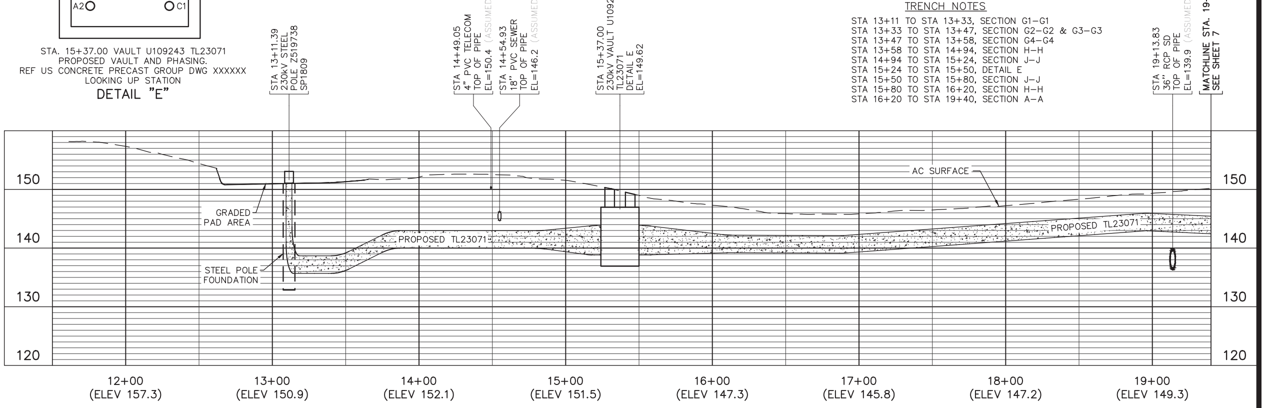
ELEVATION VIEW DETAIL 3
230KV STEEL CABLE POLE Z519738 SP1809
FOR REFERENCE ONLY.
LOOKING WEST
NO SCALE



ISOMETRIC VIEW
RISERS & QUAD DUCTS TO STEEL POLE
DETAIL 2
LOOKING WESTERLY
NO SCALE

TRENCH NOTES

STA 13+11 TO STA 13+33, SECTION G1–G1
STA 13+33 TO STA 13+47, SECTION G2–G2 & G3–G3
STA 13+47 TO STA 13+58, SECTION G4–G4
STA 13+58 TO STA 14+94, SECTION H–H
STA 14+94 TO STA 15+24, SECTION J–J
STA 15+24 TO STA 15+50, DETAIL E
STA 15+50 TO STA 15+80, SECTION J–J
STA 15+80 TO STA 16+20, SECTION H–H
STA 16+20 TO STA 19+40, SECTION A–A



PROFILE VIEW
HORIZONTAL SCALE: 1" = 40'
VERTICAL SCALE: 1" = 10'

SCALE IS ACCURATE FOR 24"X36" SHEET PLOT. REPRODUCTIONS ON ANY OTHER SIZE SHEET DOES NOT REPRESENT TRUE SCALE.

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DATE:	2016/07/26
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PROJ. NO.	--
CONST. NO.	2650975

PLAN & PROFILE
HORIZONTAL: 1"=40'
VERTICAL: 1'=10'

REV	BUDGET	CONST ORDER	CHANGE	DWN	CHKD	APPV	DATE
A	---	---					
-	---	2650975	TRENCH & SUBSTRUCTURES - BID SET ONLY	NV5			7/5/16

SDGE
SAN DIEGO GAS & ELECTRIC
TRANSMISSION ENGINEERING

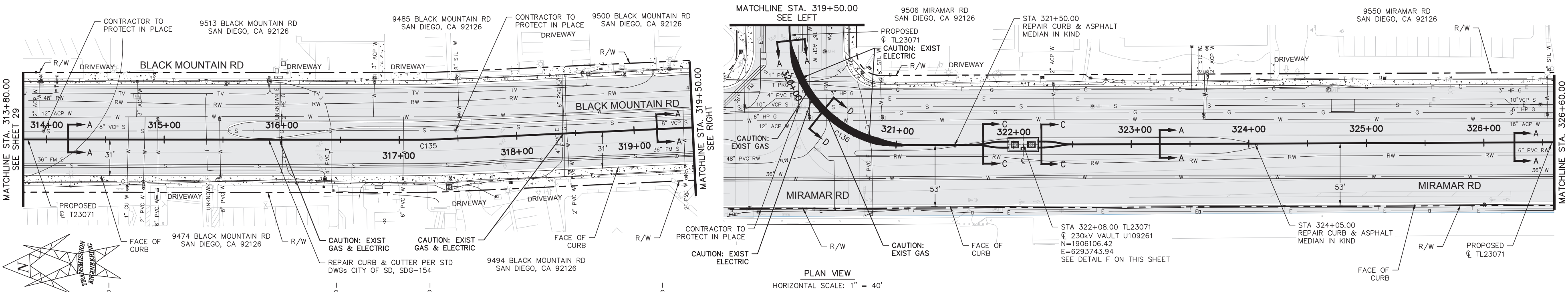
PLAN & PROFILE
TL23071

TL23071
SYCAMORE CANYON SUBSTATION
TO PENASQUITOS SUBSTATION
230kV UNDERGROUND SEGMENT

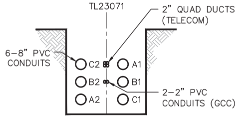
SCALE: H 1"=40' V 1"=10' SHEET 6 OF 65

DRAWING NUMBER
NV5–006

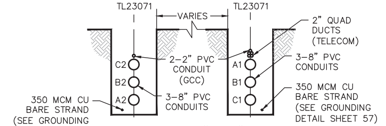
N:\SDB090102.01\CADD\POWER\SXPQ_ALT5_P&P_05–18.DWG 7/26/2016 9:29 AM



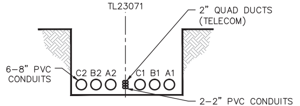
PLAN VIEW
HORIZONTAL SCALE: 1" = 40'



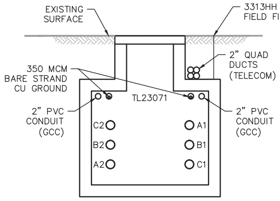
SECTION "A-A"
(REF. DETAILS 1-2 & 7 SHEET 55)



SECTION "C-C"
(REF. DETAILS 3-4 & 8 SHEET 55)

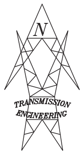


SECTION "D-D"
(REF. DETAIL 14 SHEET 56)



STA. 322+08.00 VAULT U109261 TL23071
PROPOSED VAULT AND PHASING.
REF US CONCRETE PRECAST GROUP DWG XXXXXX
LOOKING UP STATION

DETAIL "F"

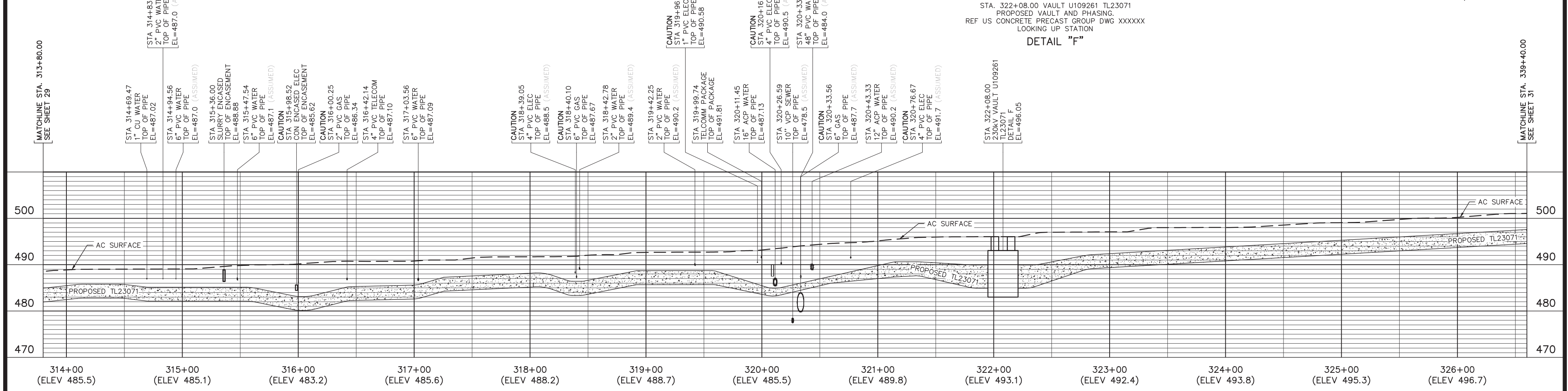


GRAPHIC SCALE
0' 20' 40' 80'
SCALE 1"= 40'

SCALE IS ACCURATE FOR 24"X36" SHEET PLOT. REPRODUCTIONS ON ANY OTHER SIZE SHEET DOES NOT REPRESENT TRUE SCALE.

TRENCH NOTES

STA 313+80 TO STA 319+60, SECTION A-A
STA 319+60 TO STA 321+15, SECTION D-D
STA 321+15 TO STA 321+65, SECTION A-A
STA 321+65 TO STA 321+95, SECTION C-C
STA 321+95 TO STA 322+21, DETAIL F
STA 322+21 TO STA 322+51, SECTION C-C
STA 322+51 TO STA 326+60, SECTION A-A



PROFILE VIEW
HORIZONTAL SCALE: 1" = 40'
VERTICAL SCALE: 1" = 10'

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DATE:	2016/07/26
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PROJ. NO.	--
CONST. NO.	2650975

PLAN & PROFILE
HORIZONTAL: 1"=40'
VERTICAL: 1'=10'

REV	BUDGET	CONST ORDER	CHANGE	DWN	CHKD	APPV	DATE
A	---	---					
-	---	2650975	TRENCH & SUBSTRUCTURES - BID SET ONLY	NV5			7/5/16

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SAN DIEGO GAS & ELECTRIC
TRANSMISSION ENGINEERING

PLAN & PROFILE
TL23071

SCALE: H:1"=40' V:1"=10'
SHEET 30 OF 65

TL23071
SYCAMORE CANYON SUBSTATION
TO PENASQUITOS SUBSTATION
230kV UNDERGROUND SEGMENT

DRAWING NUMBER
NV5-030

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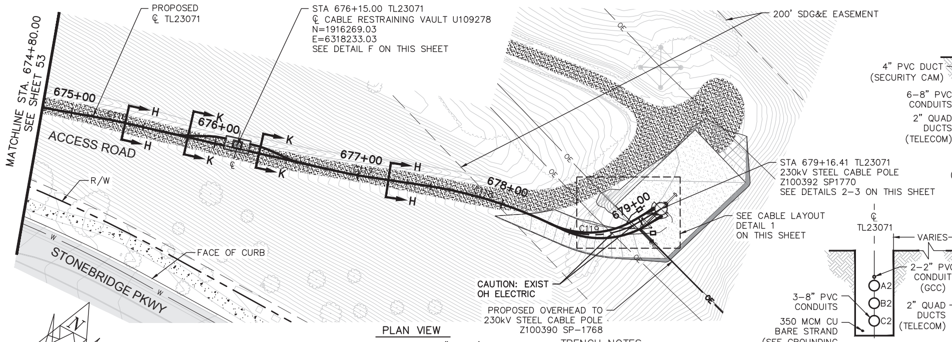
N:\SDB090102.01\CADD\POWER\SXPQ_ALT5_P&P_19-31.DWG 7/26/2016 9:42 AM



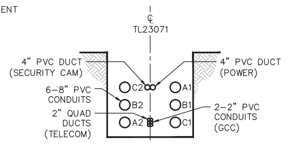
PLAN VIEW
HORIZONTAL SCALE: 1" = 40'

SCALE IS ACCURATE FOR 24"X36" SHEET PLOT. REPRODUCTIONS ON ANY OTHER SIZE SHEET DOES NOT REPRESENT TRUE SCALE.

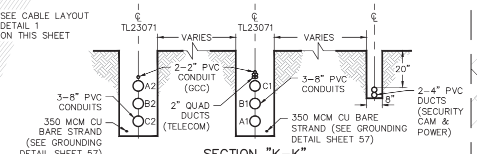
GRAPHIC SCALE
0' 20' 40' 80'
SCALE 1"= 40'

TRENCH NOTES

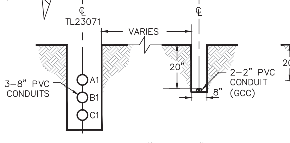
STA 674+80 TO STA 675+70, SECTION H–H
STA 675+70 TO STA 676+06, SECTION K–K
STA 676+06 TO STA 676+24, DETAIL F
STA 676+24 TO STA 676+62, SECTION K–K
STA 676+62 TO STA 678+37, SECTION H–H
STA 678+37 TO STA 678+89, SECTION G4–G4
STA 678+89 TO STA 679+02, SECTION G2–G2 & G3–G3
STA 679+02 TO STA 679+08, SECTION G5–G5
STA 679+08 TO STA 679+14, SECTION G6–G6



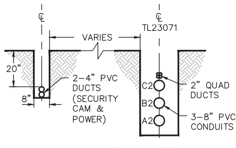
SECTION "H–H"
(REF. DETAIL 9 SHEET 55)



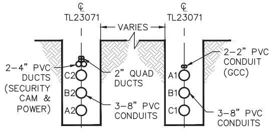
SECTION "K–K"
(REF. DETAILS 16, 10, & 11 SHEETS 55–56)



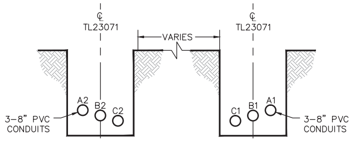
SECTION "G2–G2"
(REF. DETAILS 18 & 17 SHEET 56)



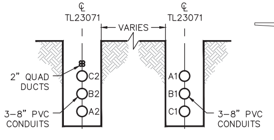
SECTION "G3–G3"
(REF. DETAILS 16 & 20 SHEET 56)



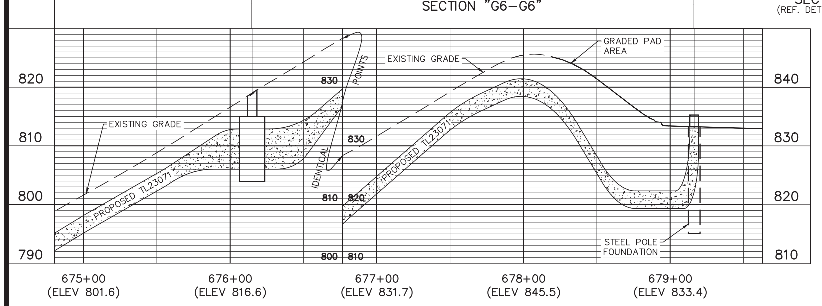
SECTION "G4–G4"
(REF. DETAILS 19 & 13 SHEET 56)



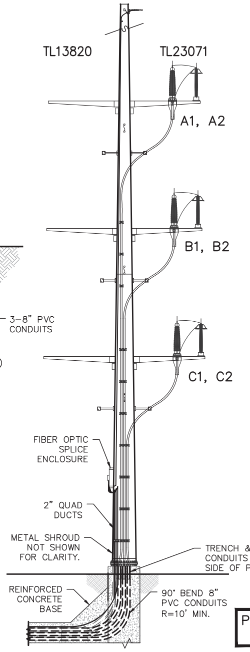
SECTION "G6–G6"



SECTION "G5–G5"
(REF. DETAIL 20 & 18 SHEET 56)

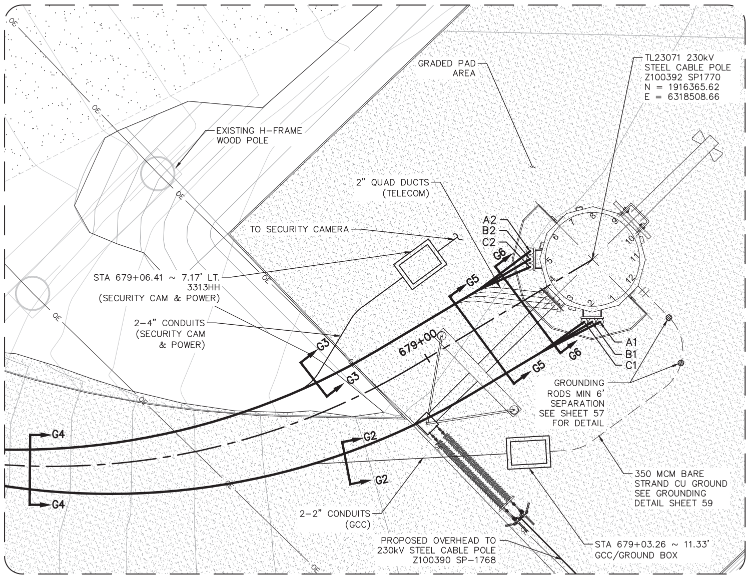


PROFILE VIEW
HORIZONTAL SCALE: 1" = 40'
VERTICAL SCALE: 1" = 10'

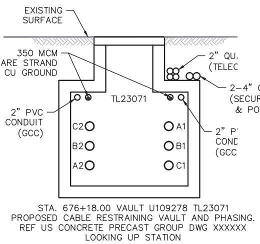


ELEVATION VIEW DETAIL 3
230KV STEEL CABLE POLE Z519738 SP1809
LOOKING WEST
NO SCALE

PHASING TO BE FIELD VERIFIED

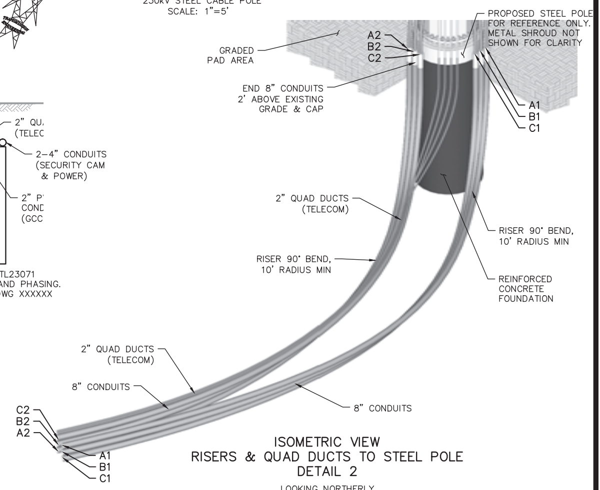


STEEL CABLE POLE LAYOUT DETAIL 1
230kV STEEL CABLE POLE
SCALE: 1"=5'



STA. 676+18.00 VAULT U109278 TL23071
PROPOSED CABLE RESTRAINING VAULT AND PHASING.
REF US CONCRETE PRECAST GROUP DWG XXXXXX
LOOKING UP STATION

DETAIL "F"



ISOMETRIC VIEW
RISERS & QUAD DUCTS TO STEEL POLE
DETAIL 2
LOOKING NORTHERLY
NO SCALE

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CONST. NO.	2650975

PLAN & PROFILE
HORIZONTAL: 1"=40'
VERTICAL: 1"=10'

REV	BUDGET	CONST ORDER	CHANGE	DWN	CHKD	APPV	DATE
A	---	---					
-	---	2650975	TRENCH & SUBSTRUCTURES - BID SET ONLY	NV5			7/5/16

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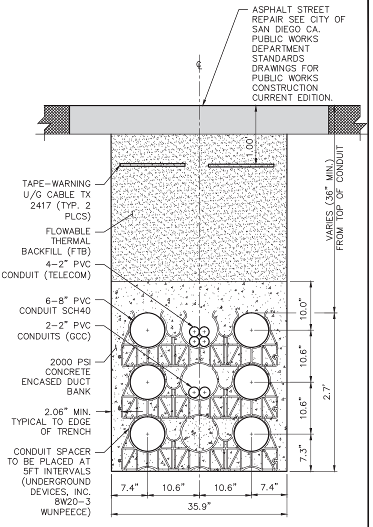
PLAN & PROFILE
TL23071

TL23071
SYCAMORE CANYON SUBSTATION
TO PENASQUITOS SUBSTATION
230kV UNDERGROUND SEGMENT

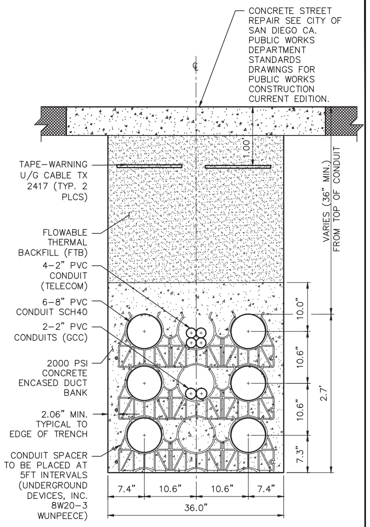
SCALE: H:1"=40' V:1"=10'
SHEET 54 OF 65

DRAWING NUMBER
NV5–054

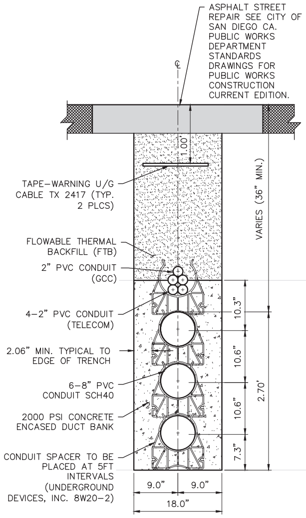
N:\SDB090102.01\CADD\POWER\SXPQ_ALT5_P&P_43–53.DWG 7/26/2016 10:04 AM



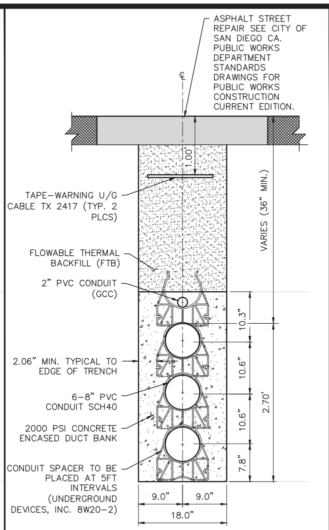
DETAIL 1
DUCT BANK 6–8" CONDUITS, 2" QUAD DUCTS, 2–2" DUCTS GCC, ASPHALT SURFACE
NOT TO SCALE



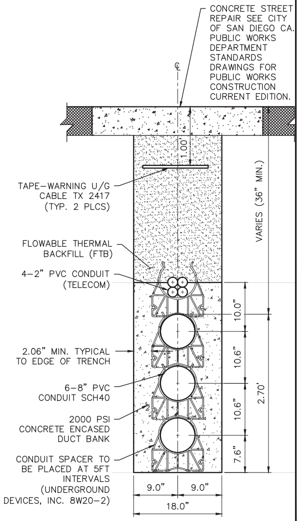
DETAIL 2
DUCT BANK 6–8" CONDUITS, 2" QUAD DUCTS, 2–2" DUCTS GCC, CONCRETE SURFACE
NOT TO SCALE



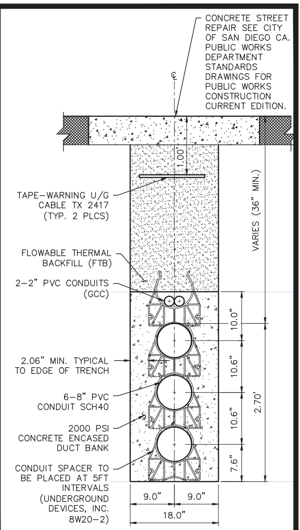
DETAIL 3
DUCT BANK 3–8" CONDUITS & 2" QUAD DUCTS, ASPAHALT SURFACE
NOT TO SCALE



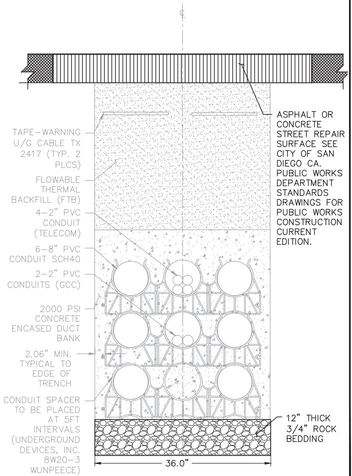
DETAIL 4
DUCT BANK 3–8" CONDUITS & 2–2" DUCT GCC, ASPHALT SURFACE
NOT TO SCALE



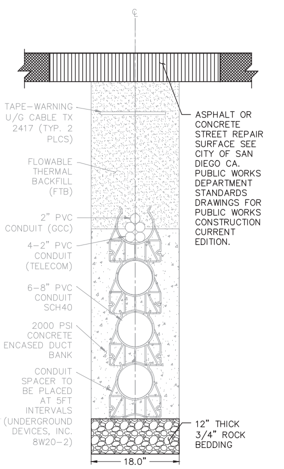
DETAIL 5
DUCT BANK 3–8" CONDUITS & 2" QUAD DUCTS CONCRETE SURFACE
NOT TO SCALE



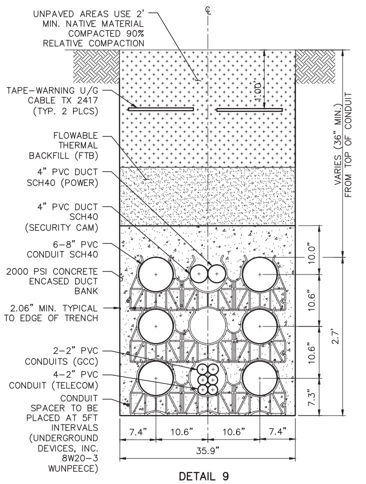
DETAIL 6
DUCT BANK 3–8" CONDUITS & 2–2" DUCT GCC, CONCRETE SURFACE
NOT TO SCALE



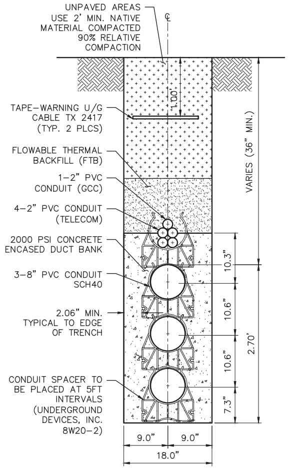
DETAIL 7
DUCT BANK FOR WET BOTTOM TRENCH CONDITION
NOT TO SCALE



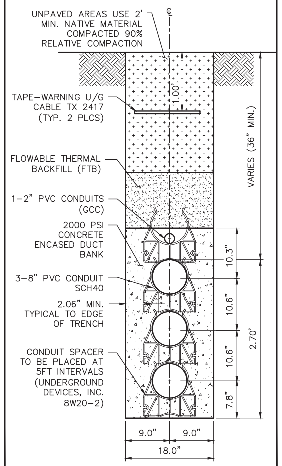
DETAIL 8
DUCT BANK FOR WET BOTTOM TRENCH CONDITION
NOT TO SCALE



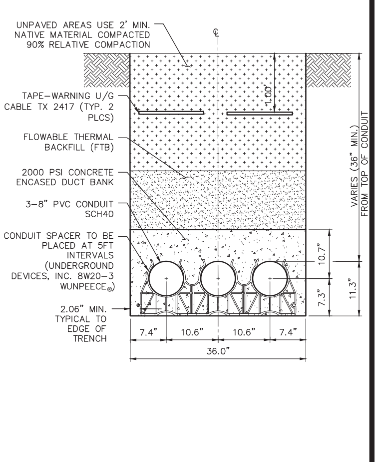
DETAIL 9
DUCT BANK 6–8" CONDUITS, 2" QUAD DUCTS, 2–2" DUCTS GCC & 2–4" DUCT, DIRT SURFACE
NOT TO SCALE



DETAIL 10
DUCT BANK 3–8"CONDUITS & 2" QUAD DUCTS DIRT SURFACE
NOT TO SCALE



DETAIL 11
DUCT BANK 3–8" CONDUITS & 2–2" DUCT GCC, DIRT SURFACE
NOT TO SCALE



DETAIL 12
HORIZONTAL DUCT BANK
3–8" CONDUITS, DIRT SURFACE
NOT TO SCALE

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DRAWN BY:	NV5
DATE:	2016/07/26
THO. BROS.	1208, E7 – 1210, E2
PROJ. NO.	--
CONST. NO.	2650975

DETAILS
HORIZONTAL: N/A
VERTICAL: N/A

REV	BUDGET	CONST ORDER	CHANGE	DWN	CHKD	APPV	DATE
A	---	---					
–	---	2650975	TRENCH & SUBSTRUCTURES – BID SET ONLY	NV5			7/5/16

SAN DIEGO GAS & ELECTRIC
TRANSMISSION ENGINEERING

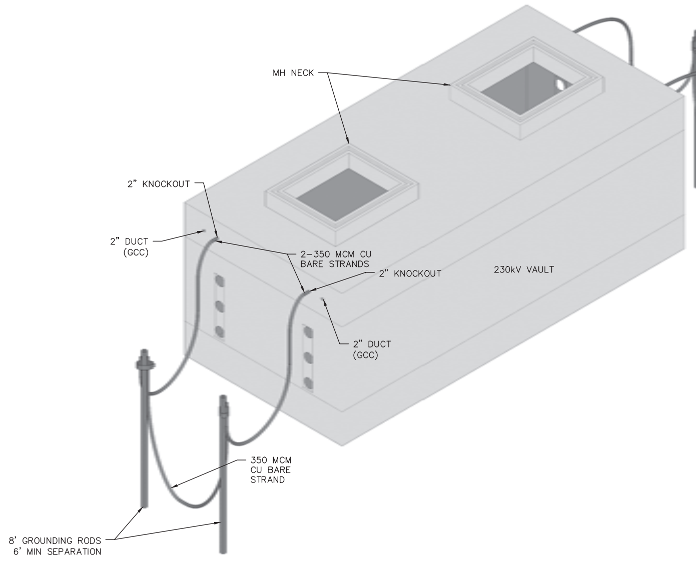
SECTION DETAILS
TL23071

SCALE: N/A
SHEET 55 OF 65

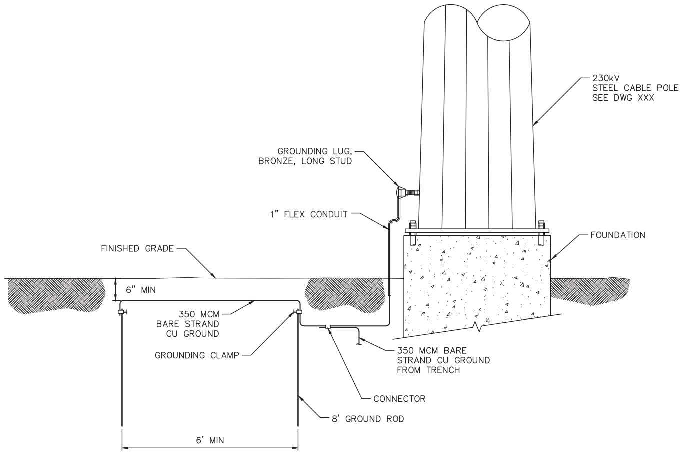
TL23071
SYCAMORE CANYON SUBSTATION
TO PENASQUITOS SUBSTATION
230kV UNDERGROUND SEGMENT

DRAWING NUMBER
NV5–055

N:\SDB090102.01\CADD\POWER\SXPQ_ALT5_P&P_54–58.DWG 7/26/2016 9:34 AM



VAULT GROUNDING DETAL
NOT TO SCALE



CABLE POLE GROUNDING
NOT TO SCALE

BID SET ONLY

PRELIMINARY DESIGN ONLY NOT FOR CONSTRUCTION

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DRAWN BY: NV5
DATE: 2016/07/26
THO. BROS. 1208, E7 – 1210, E2
PROJ. NO. --
CONST. NO. 2650975
DETAILS
HORIZONTAL: N/A
VERTICAL: N/A

REV	BUDGET	CONST ORDER	CHANGE	DWN	CHKD	APPV	DATE
A	---	---					
-	---	2650975	TRENCH & SUBSTRUCTURES – BID SET ONLY	NV5			7/5/16

SAN DIEGO GAS & ELECTRIC
TRANSMISSION ENGINEERING
GROUNDING
DETAILS
TL23071

SCALE: N/A
SHEET 57 OF 65

TL23071
SYCAMORE CANYON SUBSTATION
TO PENASQUITOS SUBSTATION
230kV UNDERGROUND SEGMENT

DRAWING NUMBER
NV5–057