AC INTERFERENCE ANALYSIS & MITIGATION SYSTEM DESIGN

Prepared for:

Burns & McDonnell
San Diego Gas & Electric
Sycamore-Peñasquitos 230 Kilovolt
Transmission Line Project
Segments A & C

Prepared By:

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ARK Engineering & Technical Services, Inc.
639 Granite Street, Suite 200
Braintree, MA 02184
Phone: 781-849-3800
Fax: 781-849-3810

For information, please contact:
Mr. Robert Allen, Project Engineer

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EXECUTIVE SUMMARY

ARK Engineering & Technical Services, Inc. was contracted by Burns & McDonnell to investigate potential alternating current (AC) electrical interference effects, including corrosion, on nearby 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 (Project), in accordance with Mitigation Measure Utilities-4 and Mitigation Measure Hazards-7 of the Project's Final Environmental Impact Report (FEIR).

This analysis and report pertains specifically to the approximately one mile long overhead section from Sycamore Substation to Stonebridge Parkway – Segment A and the two (2) mile long overhead addition from Carroll Canyon Road to Peñasquitos Substation along Segment C. This proposed overhead 230 kV circuit will be located in San Diego, California.

ARK Engineering did not identify any metallic pipelines within one thousand (1,000) feet of the overhead section from Sycamore Substation to Stonebridge Parkway - Segment A.

ARK Engineering and Burns & McDonnell identified one (1) SDG&E and two (2) Kinder Morgan coated metallic pipelines that parallel and cross the proposed 230 kV circuit within one thousand (1,000) feet of Segment C and are therefore subject to alternating current (AC) electrical interference effects. One (1) of the identified Kinder Morgan pipelines has been abandoned. Although corrosion effects to this pipeline are permissible, AC touch potentials must remain at acceptable levels for personnel and public safety. Other pipelines within a 1,000 foot radius of the proposed 230 kV circuit 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. Underground uncoated pipelines are essentially continuously grounded through their direct contact with the local soil and non-metallic pipelines do not exhibit AC touch or corrosion potentials. Due to the distance from the 230 kV circuit conductors, all pipelines located outside of the 1,000-foot radius will be subject to significantly lower AC interference levels than the worst-case scenarios included in this analysis; therefore, no further investigation was necessary outside of this radius.

This report identifies potential AC electrical interference effects on the n coated metallic pipelines and presents the predicted AC interference pipeline potentials during projected future maximum load conditions on the twelve (12) existing and one (1) proposed electric transmission circuits, as provided by SDG&E. Fault conditions on the circuits were also modeled to determine AC inductive and conductive coupling effects to these existing pipelines.

Neither SDG&E nor Kinder Morgan were able to provide information on existing AC mitigation systems for the pipelines under study, therefore this analysis was completed under the assumption, as approved by Burns & McDonnell in conjunction with SDG&E and Kinder Morgan, that there are no existing AC mitigation systems installed for these pipelines in the area under study. This assumption has been made to ensure that the completed analysis presents the worst-case AC electrical interference scenario, as the existence of AC mitigation systems for these pipelines would significantly reduce the computed AC potentials. SDG&E has contacted Kinder Morgan and SDG&E gas operations personnel to confirm that no protection systems are currently in place along these potentially affected pipeline segments.

Construction details, including circuit conductor arrangement, were considered as part of the modeling effort.

The results of this study indicate a potential for AC corrosion on the operational SDG&E and Kinder Morgan pipelines, as well as induced AC touch potentials on the operational Kinder Morgan pipeline which present a threat to personnel and public safety, as a result of AC interference effects from the proposed and existing electric transmission circuits.

For the pipelines under study, a maximum induced AC pipeline potential of approximately twenty-one (21) Volts, with respect to remote earth, was computed for the 16" Kinder Morgan pipeline at approximate GPS location 32.914326°N, 117.217772°W. At this location, the pipeline will begin to cross the proposed 230 kV circuit approximately two hundred forty-five (245) feet north of East Ocean Air Drive.

In addition, AC current density calculations associated with AC corrosion mechanisms were completed for the pipelines. A maximum AC density of four hundred sixty-nine (469) Amps per square meter (A/m^2) was calculated for the 16" Kinder Morgan pipeline at approximate GPS location 32.914326°N, 117.217772°W. This is the same location where the maximum induced AC pipeline potential was computed, as referenced above.

With the proposed AC mitigation systems connected to the pipelines, a maximum induced AC pipeline potential of approximately four (4) Volts, with respect to remote earth, was computed for the 30" SDG&E pipeline at approximate GPS location 32.907372°N, 117.214168°W. At this location, the pipeline will begin to cross the proposed 230 kV circuit approximately four hundred fifty (450) feet northwest of Sorrento Valley Boulevard. At this location, a maximum AC density of ninety-nine (99) A/m^2 was also computed for the 30" SDG&E pipeline.

During simulated single phase-to-ground fault conditions on the circuits, 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.

With the proposed AC mitigation systems connected to the pipelines, the maximum pipeline coating stress voltage was calculated at two thousand five hundred seventy-four (2,574) Volts. This maximum value was computed on the 16" Kinder Morgan pipeline at approximate GPS location 32.897120°N, 117.207610°W. At this location, the existing pipeline will be located approximately twenty-five (25) feet from one of the 230 kV circuit towers.

Based upon the results of the analysis completed, with the proposed AC mitigation systems connected to the pipelines, induced AC touch voltages and corrosion potentials on the metallic pipelines which parallel and cross the proposed 230 kV circuit will not present a threat to public safety or pipeline integrity.

In addition, a survey along the 230 kV circuit was performed to identify all aboveground pipeline appurtenances in compliance with Mitigation Measure Hazards-7 of the FEIR. Maximum AC touch and step voltages occur on aboveground metallic objects located within close proximity to electric transmission circuit towers. No aboveground pipeline appurtenances were identified within the specified 1,000 foot radius, therefore no AC touch and step analysis was necessary. All other existing above ground metallic objects located within the ROW are subject to the grounding requirements described in SDG&E's Encroachment Guideline (April 2009). The proposed 230kV line will not affect how these existing metal objects are grounded, nor will it increase the area of influence that requires grounding.

In conclusion, assuming AC mitigation systems are not currently installed for the 16” Kinder Morgan and 30” SDG&E pipelines, AC mitigation is recommended for these pipelines as a result of the operation of the proposed Sycamore to Peñasquitos 230 kV circuit. Kinder Morgan has reviewed the proposed mitigation plan and has agreed it is acceptable, with the understanding that once the proposed transmission line is constructed and energized additional interference testing will be completed to validate the influence of the power line.

Induced AC interference levels will be below the limits for personnel safety and pipeline integrity for all other metallic pipelines located within proximity to the proposed circuit. No aboveground facilities were identified that could present a shock hazard to the public.

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1. INTRODUCTION

1.0 Introduction

ARK Engineering & Technical Services, Inc. was contracted by Burns & McDonnell to investigate potential alternating current (AC) electrical interference effects on nearby 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 (Project), in accordance with MM Utilities-4 and MM Hazards-7 of the Project's FEIR.

This analysis and report pertains specifically to the approximately three (3) mile long overhead addition along Alternative Route 5 – Segments A and C, located in San Diego, California.

ARK Engineering and Burns & McDonnell identified one (1) SDG&E and two (2) Kinder Morgan metallic pipelines that parallel the proposed 230 kV circuit and have the potential to experience AC electrical interference effects. One (1) of the identified Kinder Morgan pipelines has been abandoned. Although corrosion effects on this pipeline are permissible, AC touch potentials must remain at acceptable levels for personnel and public safety. No other pipeline parallelisms susceptible to high induced AC touch or corrosion potentials were identified within a one thousand (1,000) foot radius of the proposed 230kV circuit because the pipelines are either non-metallic or uncoated.

Induced AC touch and corrosion potentials were analyzed for these pipelines during projected future maximum load conditions on the twelve (12) existing and one (1) proposed electric transmission circuits, as provided by SDG&E.

In addition, a survey along the 230 kV circuit was performed to identify all aboveground pipeline appurtenances in compliance with Mitigation Measure Hazards-7 of the FEIR. Maximum AC touch and step voltages occur on aboveground metallic objects located within close proximity to electric transmission circuit towers. No aboveground pipeline appurtenances were identified within the specified 1,000 foot radius, therefore no AC touch and step analysis was necessary. All other existing above ground metallic objects located within the ROW are subject to the grounding requirements described in SDG&E's Encroachment Guideline (April 2009). The proposed 230kV line will not affect how these existing metal objects are grounded, nor will it increase the area of influence that requires grounding.

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 one thousand (1,000) foot radius from the proposed 230 kV circuit route was established as the baseline for determining AC interference effects to pipelines along the route. Due to their significant distance from the 230 kV circuit conductors, all pipelines located outside of this 1,000-foot radius will be subject to significantly lower AC interference levels than the worst-case scenarios included in this analysis; therefore, no further investigation was necessary outside of this radius.

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.

This report presents the computed steady state induced AC pipeline potentials for the three (3) existing pipelines located along the proposed circuit route. Simulated fault conditions on the circuits were also modeled using the Current Distribution, Electromagnetic Fields, Ground and Soil Structure Analysis (CDEGS) software package[1] to determine pipeline coating stress voltages. Projected future maximum load conditions and single phase-to-ground fault current values, provided by SDG&E, were used to predict worst-case scenarios caused by inductive and conductive AC electrical interference effects to the existing pipelines.

Neither SDG&E nor Kinder Morgan were able to provide information on existing AC mitigation systems for the pipelines under study, therefore this analysis was completed under the assumption, as approved by Burns & McDonnell in conjunction with Kinder Morgan and SDG&E, that there are no existing AC mitigation systems installed for these pipelines in the area under study. This assumption has been made to ensure that the completed analysis presents the worst-case AC electrical interference scenario, as the existence of AC mitigation systems for these pipelines would significantly reduce the computed AC potentials. SDG&E has contacted Kinder Morgan and SDG&E gas operations personnel to confirm that no protection systems are currently in place along these potentially affected pipeline segments.

AC interference simulation programs within the CDEGS software package were used to model the proposed 230 kV circuit and estimate the levels of induced and conductive AC voltage on the existing pipelines. The CDEGS programs were also used to evaluate the effectiveness of the proposed mitigation designs.

This report summarizes the analysis completed and outlines ARK Engineering's recommendations for the mitigation of AC electrical interference effects on the existing pipelines. The proposed AC mitigation system designs, as outlined in this report, will reduce the AC electrical interference effects on the pipelines to acceptable levels. This report also discusses the survey results and conclusions associated with the lack of potential aboveground metallic objects that could present a shock hazard to the public in compliance with MM Hazards-7.

The conclusions in this report are based upon pipeline data provided by Kinder Morgan and pipeline and power line data provided by SDG&E.

1.1 Joint Facility Corridor Overview

The areas of concern, where the proposed 230 kV circuit will parallel and cross the Kinder Morgan and SDG&E pipelines, are outlined below:

- For approximately two (2) miles, from approximate pipeline GPS location 32.916511°N, 117.219078°W to 32.889504°N, 117.203038°W, the 16" Kinder Morgan pipeline will parallel the proposed circuit.
- At the following approximate pipeline GPS locations, the 16" Kinder Morgan pipeline will cross the proposed circuit:
    - 32.913658°N, 117.217370°W (approximate crossing angle of 12°)

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

- 32.897727°N, 117.207837°W (approximate crossing angle of 16°)
- 32.895749°N, 117.206650°W (approximate crossing angle of 27°)
- 32.893629°N, 117.205365°W (approximate crossing angle of 23°)
- 32.890962°N, 117.203728°W (approximate crossing angle of 37°)

➢ For approximately two (2) miles, from approximate pipeline GPS location 32.916587°N, 117.219734°W to 32.889436°N, 117.203023°W, the 30" SDG&E pipeline will parallel the proposed circuit.

➢ At the following approximate pipeline GPS locations, the 30" SDG&E pipeline will cross the proposed circuit:

- 32.905419°N, 117.212568°W (approximate crossing angle of 2°)
- 32.897823°N, 117.207892°W (approximate crossing angle of 38°)
- 32.895694°N, 117.206616°W (approximate crossing angle of 24°)
- 32.893929°N, 117.205546°W (approximate crossing angle of 86°)

➢ For approximately two (2) miles, from approximate pipeline GPS location 32.916492°N, 117.219092°W to 32.889521°N, 117.202790°W, the 10" Kinder Morgan pipeline will parallel the proposed circuit.

➢ At the following approximate pipeline GPS locations, the 10" Kinder Morgan pipeline will cross the proposed circuit:

- 32.913524°N, 117.217328°W (approximate crossing angle of 12°)
- 32.894997°N, 117.206200°W (approximate crossing angle of 68°)
- 32.893744°N, 117.205432°W (approximate crossing angle of 11°)
- 32.891250°N, 117.203907°W (approximate crossing angle of 2°)

Appendix A includes a map detailing the areas of concern.

These areas of concern have been determined by ARK Engineering using pipeline information provided by Burns & McDonnell 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 cross the 230 kV circuit or parallel it within 1,000 feet for extended distances were included in the completed analysis, therefore the results presented in this report represent the worst-case AC interference effects. Uncoated metallic pipelines and coated metallic pipelines which parallel the 230 kV circuit outside of the 1,000-foot radius will be subject to significantly lower AC interference levels than the worst-case scenarios included in this report.

Similarly, aboveground pipeline appurtenances located within 1,000 feet of the 230 kV circuit towers would be subject to worst-case AC touch and step voltages associated with a shock hazard, as described in MM Hazards-7.

1.2 Objectives & Project Tasks

The primary objectives of this study were as follows:

- Identify underground metallic pipelines which may be subject to AC electrical interference effects as a result of the operation of the 230 kV circuit

- Determine the AC electrical interference effects to underground metallic utility facilities with corrosion potential during steady state and fault conditions on the electric transmission circuits in accordance with MM Utilities-4.

- Assess the induced 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, recommend AC mitigation methods to reduce or eliminate the likelihood of AC corrosion effects.

- 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 coal tar enamel coated pipelines to less than 2,500 Volts and on epoxy coated pipelines to less than 5,000 Volts, for protection of the pipeline coating.

- Identify aboveground pipeline appurtenances and evaluate the conductive and inductive interference effects of the 230 kV circuit on them in accordance with MM Hazards-7.

- If required, recommend AC mitigation methods, such as grounding features, to reduce touch and step voltages at aboveground pipeline appurtenances.

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

- <u>Inductive Interference Analysis</u> - Circuit models for the existing pipelines and the existing and proposed electric transmission circuits were developed and used to determine magnetically induced pipeline potentials during steady state and fault conditions on the electric transmission circuits. This task is described in Section 3, and detailed results are presented in Appendix B.

- <u>Conductive Interference Analysis</u> - The effects of single phase-to-ground faults of the proposed 230 kV electric transmission circuit on the pipelines identified in Section 1.1 were studied. These results were used to calculate coating-stress voltages along the pipelines. AC touch and step voltages at aboveground pipeline appurtenances were not analyzed because no appurtenances were identified within the 1,000 foot radius of concern. This task is described in Section 3, and detailed results are presented in Appendix B.

1.3 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 electric transmission circuits, including the distance between the phase and shield conductors and the arrangement of the phase conductors. 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 thousand (1,000) foot radius of the proposed 230 kV circuit were included in this analysis.

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.

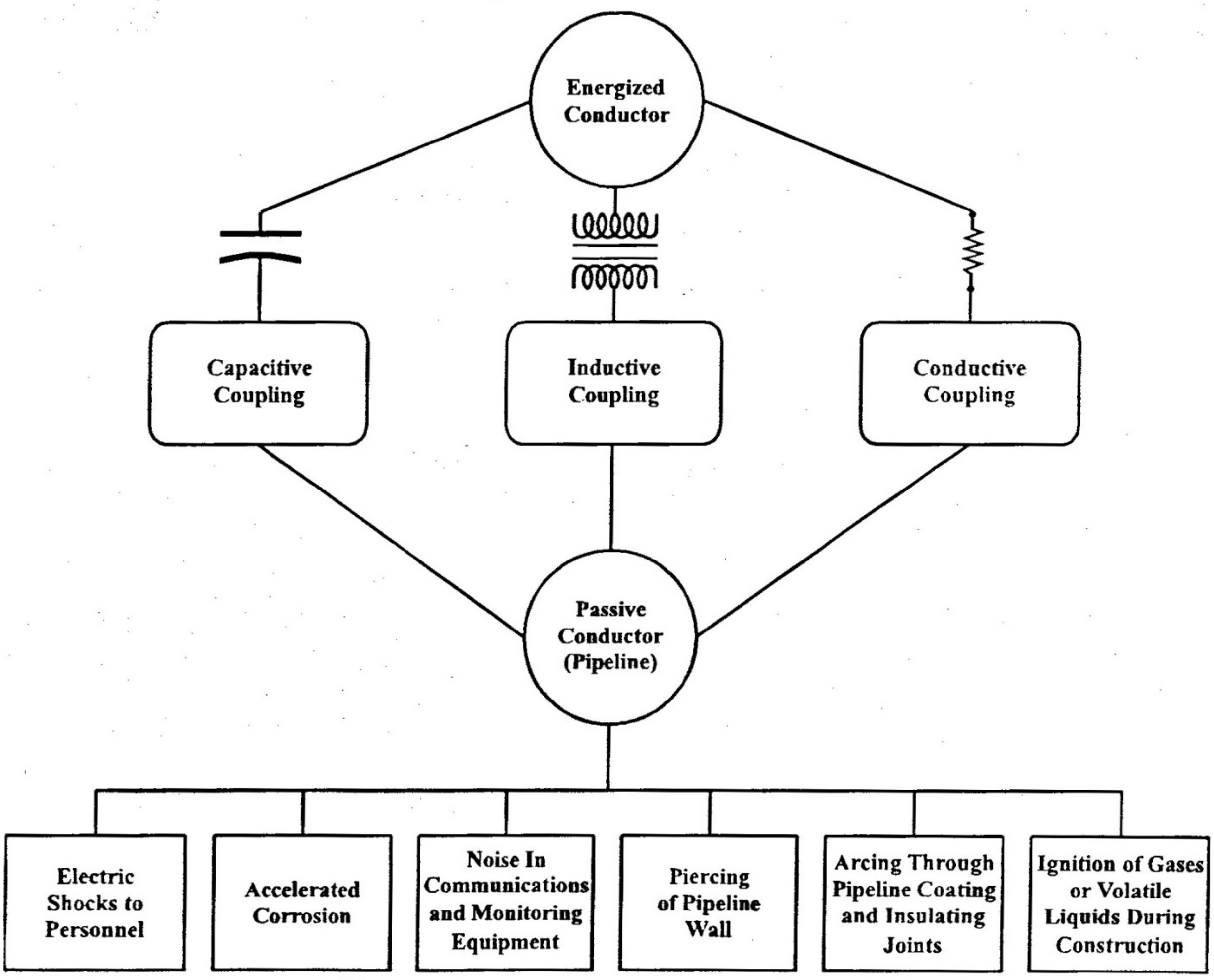


Figure 1-1: Interference Mechanisms and Effects on Pipeline

1.3.1 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 of personnel.

Protection Practices:

Buried pipelines are relatively immune to 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 towers during a fault.

1.3.2 Inductive Coupling

Mechanism:

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. 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.

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 - 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 mitigation 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 practices 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.

1.3.3 Conductive Coupling

Mechanism:

When a single phase-to-ground fault occurs at a power line structure, 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. Conductive interference can involve long sections of a pipeline if several towers adjacent to the faulted tower discharge a significant portion of the fault current, or if a ground conductor connected to the pipeline (anode) and located near a faulted tower, picks up current from the soil.

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

- <u>GPR of Transmission Circuit Structure</u>. 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.

Protection Practices:

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.

1.4 A Brief Perspective on AC Corrosion Mechanisms

1.4.1 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 small holiday in low resistance soil conditions.

1.4.2 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

AC voltage induced on a pipeline as a result of nearby electric transmission circuits 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.

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

<u>Where</u>:

i = Current Density (A/m^2)

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

ρ = Soil Resistivity (ohm-meters)

d = Holiday diameter (meters)

1.4.3 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 mitigation) 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.

1.5 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.

1.6 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.

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 Kinder Morgan and 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	-----	2,500/5,000

[1] With respect to "Local Earth"

2. FIELD DATA

2.0 Physical Layout

The proposed overhead 230 kV circuit addition under study will be approximately three (3) miles long, located in San Diego, California. One (1) SDG&E and two (2) Kinder Morgan pipelines will parallel and cross 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
Kinder Morgan	16	Parallelism from 32.916511°N, 117.219078°W to 32.889504°N, 117.203038°W (Approx. 2 miles) Crossings at 32.913658°N, 117.217370°W; 32.897727°N, 117.207837°W; 32.895749°N, 117.206650°W; 32.893629°N, 117.205365°W; 32.890962°N, 117.203728°W
	10	Parallelism from 32.916492°N, 117.219092°W to 32.889521°N, 117.202790°W (Approx. 2 miles) Crossings at 32.913524°N, 117.217328°W; 32.894997°N, 117.206200°W; 32.893744°N, 117.205432°W; 32.891250°N, 117.203907°W
San Diego Gas & Electric	30	Parallelism from 32.916587°N, 117.219734°W to 32.889436°N, 117.203023°W (Approx. 2 miles) Crossings at 32.905419°N, 117.212568°W; 32.897823°N, 117.207892°W; 32.895694°N, 117.206616°W; 32.893929°N, 117.205546°W

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

Coating Resistance of Pritec-coated pipelines:	750,000 ohm-ft^2
Coating Resistance of Coal Tar Enamel-coated pipelines:	400,000-500,000 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 Kinder Morgan and Burns & McDonnell, are identified in table 2-2.

Table 2-2: Pipeline Characteristics

Pipeline Company	Pipeline Diameter (in.)	Minimum Depth of Cover (ft.)	Pipeline Wall Thickness (in.)	Pipeline Coating Type
Kinder Morgan	16	3	0.281	Pritec
Kinder Morgan	10	3	0.219	Coal Tar Enamel
SDG&E	30	3	0.344	Coal Tar Enamel

2.1 Soil Resistivity Measurements

This AC electrical interference analysis was based on soil resistivity measurements recorded by ARK Engineering personnel in the vicinity of Poway Road and Pomerado Road using equipment and procedures developed especially for this type of AC interference study.

Although the soil resistivity was measured approximately seven (7) miles from the area of computed AC pipeline corrosion concern, the measured resistivity values are acceptable for this analysis. Based upon previous work done in the San Diego area, ARK Engineering would expect the measured soil resistivity in the vicinity of the Peñasquitos Substation to indicate a highly corrosive soil. Soil resistivity on the order of ten (10) to thirty (30) ohm-m is considered highly corrosive, while soil resistivity below ten (10) ohm-m is considered extremely corrosive. The proposed AC mitigation system is conservative, as a higher resistivity soil would reduce the induced AC current density, while a lower resistivity soil would increase the AC density while also increasing the effectiveness of the deepwell mitigation.

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 nearby faulted overhead 230 kV circuit structures. 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 mitigation designs.

2.2.1 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.

2.2.2 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: Derived Soil Resistivity Values

Measurement Location	Bottom Layer Resistivity (Ω-m)	Resistivity at Pipeline Depth (Ω-m)
1	6.8	9.8
2	10.4	13.8
3	5.3	9.5
4	4.8	4.8

3. MODELING DETAILS

3.0 Steady State Conditions

The proposed construction details of the 230 kV circuit have been considered as part of this analysis. Most notably, reverse phasing has been assumed, based upon discussions with Burns & McDonnell and SDG&E, for all instances where two (2) electric transmission circuits are located on the same structure. This phase configuration results in significant attenuation of circulating currents within one phase by similar currents in other phases.

Projected future maximum load currents were used to compute the maximum steady state inductive AC interference effects on the Kinder Morgan and SDG&E pipelines.

Although these circuits may not be loaded to this level, the data provided by SDG&E constitutes a realistic scenario if other critical circuits are out of service and the load must be redirected through these transmission circuits. 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 currents used for the twelve (12) existing and one (1) proposed electric transmission circuits included in this AC interference analysis.

Table 3-1: Transmission Circuit Maximum Current Rating

Power Company	Transmission Line	Circuit Size (kV)	Peak Load Current (A)	Reverse Phasing
San Diego Gas & Electric	PQ-DM	69	253	N/A
San Diego Gas & Electric	PQ-EG	69	344	With PQ-MRGT Tap
San Diego Gas & Electric	PQ-MTO	69	509	With PQ-FR Tap
San Diego Gas & Electric	PQ-TP	69	599	With PQ-GE
San Diego Gas & Electric	PQ-DM	69	305	N/A
San Diego Gas & Electric	PQ-MRGT Tap	69	372	With PQ-EG
San Diego Gas & Electric	PQ-GE	69	467	With PQ-TP
San Diego Gas & Electric	PQ-NCW	69	522	N/A
San Diego Gas & Electric	PQ-FR Tap	138	464	With PQ-MTO
San Diego Gas & Electric	PQ-EA	230	545	With PQ-EA
San Diego Gas & Electric	PQ-OT	230	1,177	With PQ-SX
San Diego Gas & Electric	PQ-EA	230	548	With PQ-EA
San Diego Gas & Electric	PQ-SX	230	1,600	With PQ-OT

3.1 Fault Conditions

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

Fault conditions were simulated on the circuits in the areas of parallelism and crossings with the existing pipelines. Single phase-to-ground branch current values were used to calculate fault currents on grounded tower structures along the circuits.

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

3.2 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 are included in Appendix B.

3.2.1 Steady State Conditions

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

The computed induced AC pipeline potentials were above the maximum allowable design limit of fifteen (15) Volts at various locations along the 16” Kinder Morgan pipeline.

For the pipelines under study, a maximum induced AC pipeline potential of approximately twenty-one (21) Volts, with respect to remote earth, was computed for the 16” Kinder Morgan pipeline at approximate GPS location 32.914326°N, 117.217772°W. At this location, the pipeline will begin to cross the proposed 230 kV circuit approximately two hundred forty-five (245) feet north of East Ocean Air Drive.

With the proposed AC mitigation systems connected to the pipelines, a maximum induced AC pipeline potential of approximately four point four (4.4) Volts, with respect to remote earth, was computed for the 30” SDG&E pipeline at approximate GPS location 32.907372°N, 117.214168°W. At this location, the pipeline will begin to cross the proposed 230 kV circuit approximately four hundred fifty (450) feet northwest of Sorrento Valley Boulevard.

Table 3-2 outlines the computed maximum induced AC pipeline potentials at projected future maximum load conditions on the 230 kV circuit.

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

Pipeline Company	Pipeline Diameter (in.)	Conditions	Pipeline GPS Location	Maximum Induced Potential (V)	Design Limit (V)
Kinder Morgan	16	Without AC Mitigation	32.914326°N, 117.217772°W	20.79	15
		With Zinc Ribbon AC Mitigation	32.891028°N, 117.203715°W	4.33	15
		With Deepwell AC Mitigation	32.890168°N, 117.203440°W	4.34	15
	10	Without AC Mitigation	32.889213°N, 117.202591°W	13.31	15

Pipeline Company	Pipeline Diameter (in.)	Conditions	Pipeline GPS Location	Maximum Induced Potential (V)	Design Limit (V)
San Diego Gas & Electric	30	Without AC Mitigation	32.906786°N, 117.213679°W	11.35	15
		With Zinc Ribbon AC Mitigation	32.906238°N, 117.213222°W	3.41	15
		With Zinc Ribbon & Alternate Deepwell AC Mitigation	32.907372°N, 117.214168°W	3.98	15
		With Deepwell AC Mitigation	32.907372°N, 117.214168°W	4.40	15

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

3.2.2 Fault Conditions

As outlined in Chapter 1 of this report, when an electric transmission circuit fault occurs at a grounded structure (transmission tower) 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.

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

3.2.2.2 Conductive Interference – The configuration of the circuit towers and their 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.

3.2.2.3 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.

With the proposed AC mitigation systems connected to the pipelines, the maximum pipeline coating stress voltage was calculated at two thousand five hundred seventy-four (2,574) Volts. This maximum value was computed on the 16” Kinder Morgan pipeline at approximate GPS location 32.897120°N, 117.207610°W. At this location, the existing pipeline will be located approximately twenty-five (25) feet from one of the 230 kV electric transmission circuit towers.

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

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

Pipeline Company	Pipeline Diameter (in.)	Conditions	Pipeline GPS Location	Maximum Coating Stress Voltage (V)	Design Limit (V)
Kinder Morgan	16	With Zinc Ribbon AC Mitigation	32.897120°N, 117.207610°W	2,574	5,000
		With Deepwell AC Mitigation	32.897108°N, 117.207602°W	2,571	5,000
San Diego Gas & Electric	30	With Zinc Ribbon AC Mitigation	32.901866°N, 117.210302°W	2,065	2,500
		With Zinc Ribbon & Alternate Deepwell AC Mitigation	32.901866°N, 117.210302°W	2,070	2,500
		With Deepwell AC Mitigation	32.901866°N, 117.210302°W	2,154	2,500

Appendix B includes plots of the coating stress voltage levels on the pipelines during simulated fault conditions on the circuits.

3.3 AC Corrosion Analysis Results

Pursuant to Mitigation Measure Utilities-4, AC corrosion effects have been modeled on nearby metallic pipelines. ARK Engineering has coordinated these efforts with Kinder Morgan and SDG&E, which are believed to be the only utilities affected by the proposed 230 kV circuit.

To analyze the possible AC corrosion effects to the Kinder Morgan and SDG&E 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.

For the pipelines under study, a maximum AC density of four hundred sixty-nine (469) A/m^2 was calculated for the 16” Kinder Morgan pipeline at approximate GPS location 32.914326°N, 117.217772°W. This is the same location where the maximum induced AC pipeline potential was computed, as discussed in Section 3.2.1.

With the proposed AC mitigation systems connected to the pipelines, a maximum AC density of ninety-nine (99) A/m^2 was computed for the 30” SDG&E pipeline at approximate GPS location 32.907372°N, 117.214168°W. At this location, the pipeline will begin to cross the proposed 230 kV circuit approximately four hundred fifty (450) feet northwest of Sorrento Valley Boulevard.

Although the AC current density design limit of one hundred (100) A/m^2 indicates a medium likelihood of AC corrosion occurring on the pipeline, the conservative nature of the analysis completed makes this an acceptable computed design limit. Based upon industry experience, an AC mitigation system designed to reduce AC current density levels below 100 A/m^2 typically results in field-monitored AC density levels below 30 A/m^2. Although designing a mitigation system to reduce the AC density below 30 A/m^2 would ensure that no AC corrosion effects will occur on the pipelines, the significant amount of mitigation necessary to reach this limit within a highly corrosive, low soil resistivity area is likely to result in additional load losses for the overhead transmission lines, as well as constructability concerns. As a result, it is preferable to design an AC mitigation system to reduce the AC density below 100 A/m^2 and then to monitor the AC density levels on the pipeline.

Table 3-4 outlines the computed maximum AC density at projected future maximum load conditions on the 230 kV circuit.

Table 3-4: Maximum Coating Holiday Pipeline AC Current Density

Pipeline Company	Pipeline Diameter (in.)	Conditions	Pipeline GPS Location	Maximum Current Density (A/m²)	Design Limit (A/m²)
Kinder Morgan	16	Without AC Mitigation	32.914326°N, 117.217772°W	468.6	100
		With Zinc Ribbon AC Mitigation	32.891028°N, 117.203715°W	97.5	100
		With Deepwell AC Mitigation	32.890168°N, 117.203440°W	97.7	100
San Diego Gas & Electric	30	Without AC Mitigation	32.906786°N, 117.213679°W	255.7	100
		With Zinc Ribbon AC Mitigation	32.906238°N, 117.213222°W	76.8	100
		With Zinc Ribbon & Alternate Deepwell AC Mitigation	32.907372°N, 117.214168°W	89.6	100
		With Deepwell AC Mitigation	32.907372°N, 117.214168°W	99.1	100

Appendix B includes plots of the computed AC density.

3.4 AC Mitigation System

The AC mitigation systems designed and recommended by ARK Engineering for the Kinder Morgan and SDG&E pipelines reduce the AC interference effects to acceptable levels during projected future maximum load conditions and single phase-to-ground fault conditions on the twelve (12) existing and one (1) proposed SDG&E electric transmission circuits.

The proposed AC mitigation system designs include the installation of gradient control wires (zinc ribbon anode or equivalent) and/or vertical deepwells in the areas of computed high pipeline AC potentials. When feasible, gradient control wires should be installed using horizontal directional drilling. These AC mitigation systems will reduce the induced steady state AC touch voltage and AC current density on the pipelines.

Once the transmission line is constructed and energized, interference testing in coordination with the pipeline owners will be completed to validate the influence of the transmission line. This testing involves recording AC voltage induced on the pipelines from the operating of the electric circuit and calculating the AC density using the equation above. If the testing reveals that the AC density values on these pipelines is within the 100 A/m^2 design limit or meets (or is less than) the modeled values, then no further testing or on-going monitoring of the AC density values on the pipeline by SDG&E would be warranted as the AC mitigation system would continue to operate as designed. SDG&E will submit the results of this testing to the CPUC for its administrative record.

In the event that testing reveals values are above the design limit or modeled values, then additional modeling or system troubleshooting may be required to determine the cause of the discrepancy between the modeling results and actual field conditions. This may result in additional AC mitigation methods to reduce the current density values to below the design limits. The actual mitigation requirements will be determined at that time, if needed, but could include additional deepwell systems or horizontal grounding conductors. SDG&E would work with the pipeline owners to design and implement the additional AC mitigation methods and would provide a summary report of the additional mitigation to the CPUC for review and approval. If the implementation of the mitigation requires any additional approvals by the CPUC or other agencies (i.e. California Coastal Commission), such as a Minor Project Refinement (MPR), SDG&E would submit those requests for the agency's approval prior to implementation as well. Similarly, once the additional mitigation is implemented and testing confirms the AC density is within threshold limits, no on-going monitoring by SDG&E would be needed.

A survey along the 230 kV circuit was performed to identify all aboveground pipeline appurtenances in compliance with Mitigation Measure Hazards-7 of the FEIR. Maximum AC touch and step voltages occur on aboveground metallic objects located within close proximity to electric transmission circuit towers. No aboveground pipeline appurtenances were identified within the specified 1,000-foot radius, therefore no AC touch and step analysis was necessary. All other existing above ground metallic objects located within the ROW are subject to the grounding requirements described in SDG&E's Encroachment Guideline (April 2009). The proposed 230kV line will not affect how these existing metal objects are grounded, nor will it increase the area of influence that requires grounding.

4. CONCLUSIONS

4.0 Conclusions

An AC interference and induced current touch study has been completed by modeling and analyzing the proposed San Diego Gas & Electric 230 kV electric transmission circuit, the twelve (12) existing SDG&E electric transmission circuits, the one (1) SDG&E and two (2) Kinder Morgan pipelines 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 electric transmission circuits, indicate the following:

- AC Interference Study (Mitigation Measure Utilities-4):
    - Steady state induced AC pipeline voltages will exceed the design limit of fifteen (15) Volts under maximum load conditions on the electric transmission circuits.
    - Pipeline coating stress voltages will not exceed the design limits for a single phase-to-ground fault on the proposed circuit.
    - Pipeline AC density across a 1 cm^2 coating holiday may exceed the one hundred (100) A/m^2 design limit.
- Induced Current Touch Study (Mitigation Measure Hazards-7):
    - Based upon the completed survey, no aboveground metallic objects were identified which would require analysis and/or mitigation (i.e. grounding).

AC mitigation systems were designed to effectively reduce the induced AC interference effects and AC corrosion effects on the Kinder Morgan and SDG&E pipelines to acceptable levels. ARK Engineering did not identify any metallic pipelines within one thousand (1,000) feet of the overhead section from Sycamore Substation to Stonebridge Parkway - Segment A.

This analysis results in AC interference levels that are conservative. Under normal operating conditions, the AC interference levels on the existing pipelines should be less than reported in this study.

4.1 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 pipelines, as explained in section 2.1.
- A coating holiday size of 1 cm^2 was used in the calculation of AC current density.
- Existing AC mitigation system details were not made available for the Kinder Morgan and SDG&E pipelines at the time this analysis was completed; therefore, ARK Engineering assumed that no AC mitigation systems were in place for these pipelines.

- ARK Engineering has assumed, based upon discussions with SDG&E and Burns & McDonnell, reverse phasing will be applied for all instances where two (2) electric transmission circuits are located on the same structure.

5. RECOMMENDATIONS

5.0 Recommendations

As outlined in the previous sections of this report, induced AC touch voltage and current density levels were calculated at values greater than the design limits detailed in Table 1-1 for the Kinder Morgan and SDG&E pipelines in the vicinity of Segment C during projected future maximum steady state load conditions and single phase-to-ground fault conditions on the electric transmission circuits.

Pipeline AC voltage mitigation is accomplished by the installation of gradient control wires (zinc ribbon anode or equivalent) and/or vertical deepwells along the pipeline in the areas of computed high AC touch voltage and current density values. When feasible, gradient control wires should be installed using horizontal directional drilling. This method also reduces AC coating stress voltages during fault conditions on the electric transmission circuits. The gradient control wires and deepwells will be connected to the pipeline at various locations through a solid-state decoupling (SSD) device. The deepwell mitigation design will be utilized in place of the 2 other options because of the reduced environmental impact.

DC isolation is recommended between pipelines and grounding conductors through the use of a solid-state decoupling (SSD) device. These devices allow AC current to flow from the pipeline to the grounding system while blocking any DC cathodic protection current from flowing off the pipeline.

The modeling and analysis results of this study have been confirmed with Kinder Morgan and SDG&E will coordinate the implementation of the proposed AC mitigation system.

5.1 Proposed Safety and Mitigation System Requirements

Having performed the modeling and analysis of the AC interference effects on these pipelines, ARK Engineering designed deepwell AC mitigation systems that will reduce the AC interference effects to safe levels for pipeline integrity and public and personnel safety.

5.1.1 AC Mitigation System Design

The AC mitigation system design proposed includes the installation of four (4) deepwell grounding systems for the 16” Kinder Morgan pipeline and two (2) deepwell grounding systems for the SDG&E 30” pipeline. ARK Engineering recommends installation of deepwell systems in the following areas:

Table 5-6: 16" Kinder Morgan Pipeline AC Mitigation System - Deepwell

Deepwell Location No.	GPS Location	Deepwell Depth (Ft)
1	32.916143°N, 117.218857°W	100
2	32.913765°N, 117.217435°W	100
3	32.890950°N, 117.203732°W	125
4	32.889571°N, 117.203080°W	100

Table 5-7: 30" SDG&E Pipeline AC Mitigation System - Deepwell

Deepwell Location No.	GPS Location	Deepwell Depth (Ft)
1	32.919216°N, 117.221099°W	100
2	32.906378°N, 117.213335°W	150

Reference ARK Engineering design drawing package number: 16008-100 in Appendix D for AC mitigation system installation details.

16008-100 Burns & McDonnell
San Diego Gas & Electric
Sycamore to Peñasquitos – Alternate Route 5 – Segment C
AC Mitigation System Design
Installation Drawings
San Diego County, California

Reference Appendix E for aerial overviews of the proposed AC mitigation system design options.

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

Approved by:

Robert Allen

Vice President

ARK Engineering & Technical Services, Inc.

6/21/2017

APPENDIX A –
AREAS OF CONCERN MAP

TN
MN (11.7°E)

Scale 1 : 34,375

0 1000 2000 3000 4000 5000 ft
0 200 400 600 800 1000 m

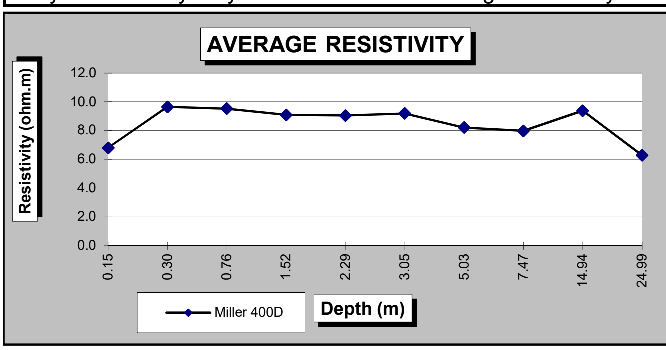
1" = 2,864.6 ft Data Zoom 12-5

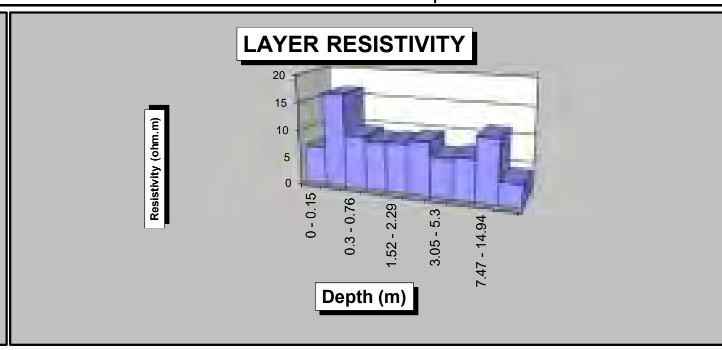
SOIL RESISTIVITY DATA

Project Name:	Burns & McDonnell - Pensaquitos Alternate Rt 5
	16008-E-01
Date:	11/17/2014
Location:	32.92909° N, 117.05599° W
	Off Pomerado Rd
Testers:	SP & DB
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Miller 400D
Weather:	
Soil Description	

4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	ohm.m
0.50	0.15	7.100	1	6.8	0.14085	n/a	n/a	n/a	0 - 0.15	7
1.00	0.30	5.040	2	9.7	0.19841	0.05757	17.371	1	0.15 - 0.3	17
2.50	0.76	1.990	5	9.5	0.50251	0.30410	3.288	3	0.3 - 0.76	9
5.00	1.52	0.950	10	9.1	1.05263	0.55012	1.818	5	0.76 - 1.52	9
7.50	2.29	0.630	14	9.0	1.58730	0.53467	1.870	5	1.52 - 2.29	9
10.00	3.05	0.480	19	9.2	2.08333	0.49603	2.016	5	2.29 - 3.05	10
16.50	5.03	0.260	32	8.2	3.84615	1.76282	0.567	12	3.05 - 5.3	7
24.50	7.47	0.170	47	8.0	5.88235	2.03620	0.491	15	5.03 - 7.47	8
49.00	14.94	0.100	94	9.4	10.00000	4.11765	0.243	47	7.47 - 14.94	11
82.00	24.99	0.040	157	6.3	25.00000	15.00000	0.067	63	14.94 - 25.0	4

* Layer Resistivity may not correlate with Average Resistivity because of soil characteristic variations with depth





Derived Multilayer Soil Model		
Layer Number	Resistivity ohm-m	Thickness ft
1	8.23	2.89
2	9.81	10.73
3	6.77	Infinite

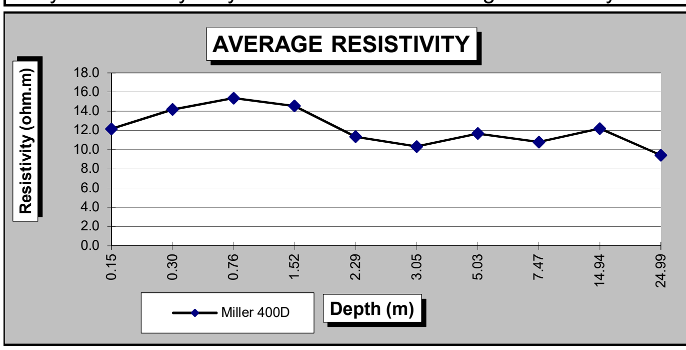
SOIL RESISTIVITY DATA

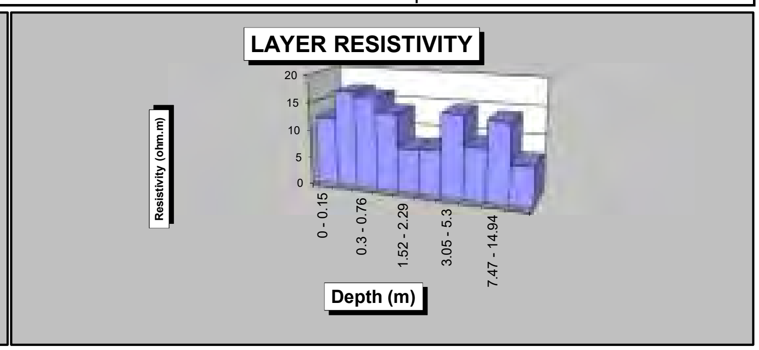
Project Name:	Burns & McDonnell - Pensaquitos Alternate Rt 5
	16008-E-02
Date:	11/17/2014
Location:	32.94549° N, 117.10681° W
	Off Interstate 15
Testers:	SP & DB
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Miller 400D
Weather:	
Soil Description	

ARK. ENGINEERING & TECHNICAL SERVICES, INC.

4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	Layer Resistivity* ohm.m
0.50	0.15	12.700	1	12.2	0.07874	n/a	n/a	n/a	0 - 0.15	12
1.00	0.30	7.410	2	14.2	0.13495	0.05621	17.790	1	0.15 - 0.3	17
2.50	0.76	3.210	5	15.4	0.31153	0.17657	5.663	3	0.3 - 0.76	16
5.00	1.52	1.520	10	14.6	0.65789	0.34637	2.887	5	0.76 - 1.52	14
7.50	2.29	0.790	14	11.3	1.26582	0.60793	1.645	5	1.52 - 2.29	8
10.00	3.05	0.540	19	10.3	1.85185	0.58603	1.706	5	2.29 - 3.05	8
16.50	5.03	0.370	32	11.7	2.70270	0.85085	1.175	12	3.05 - 5.3	15
24.50	7.47	0.230	47	10.8	4.34783	1.64512	0.608	15	5.03 - 7.47	9
49.00	14.94	0.130	94	12.2	7.69231	3.34448	0.299	47	7.47 - 14.94	14
82.00	24.99	0.060	157	9.4	16.66667	8.97436	0.111	63	14.94 - 25.0	7

* Layer Resistivity may not correlate with Average Resistivity because of soil characteristic variations with depth





Derived Multilayer Soil Model		
Layer Number	Resistivity ohm-m	Thickness ft
1	13.78	3.81
2	10.5	9.88
3	10.41	Infinite

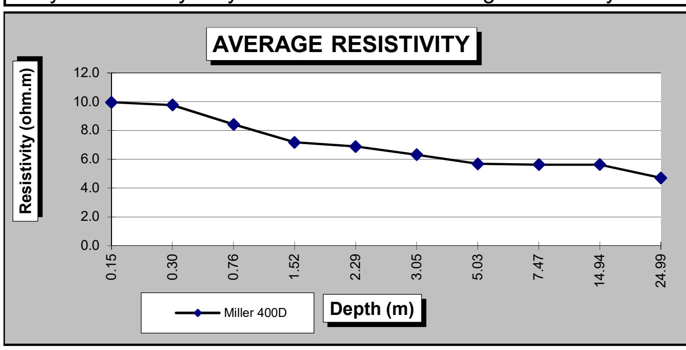
SOIL RESISTIVITY DATA

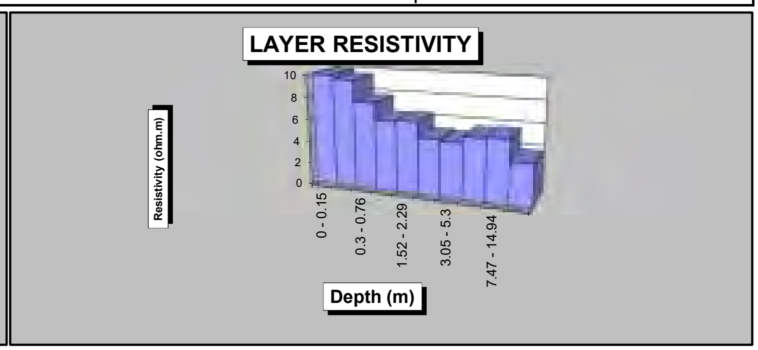
Project Name:	Burns & McDonnell - Pensaquitos Alternate Rt 5
	16008-E-03
Date:	11/17/2014
Location:	32.95149° N, 117.10556° W
	Off Paseo Montril
Testers:	SP & DB
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Miller 400D
Weather:	
Soil Description	

ARK. Engineering & Technical Services, Inc.

4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	ohm.m
0.50	0.15	10.400	1	10.0	0.09615	n/a	n/a	n/a	0 - 0.15	10
1.00	0.30	5.100	2	9.8	0.19608	0.09992	10.008	1	0.15 - 0.3	10
2.50	0.76	1.760	5	8.4	0.56818	0.37210	2.687	3	0.3 - 0.76	8
5.00	1.52	0.750	10	7.2	1.33333	0.76515	1.307	5	0.76 - 1.52	6
7.50	2.29	0.480	14	6.9	2.08333	0.75000	1.333	5	1.52 - 2.29	6
10.00	3.05	0.330	19	6.3	3.03030	0.94697	1.056	5	2.29 - 3.05	5
16.50	5.03	0.180	32	5.7	5.55556	2.52525	0.396	12	3.05 - 5.3	5
24.50	7.47	0.120	47	5.6	8.33333	2.77778	0.360	15	5.03 - 7.47	6
49.00	14.94	0.060	94	5.6	16.66667	8.33333	0.120	47	7.47 - 14.94	6
82.00	24.99	0.030	157	4.7	33.33333	16.66667	0.060	63	14.94 - 25.0	4

* Layer Resistivity may not correlate with Average Resistivity because of soil characteristic variations with depth





Derived Multilayer Soil Model		
Layer Number	Resistivity ohm-m	Thickness ft
1	9.54	3.2
2	5.29	Infinite

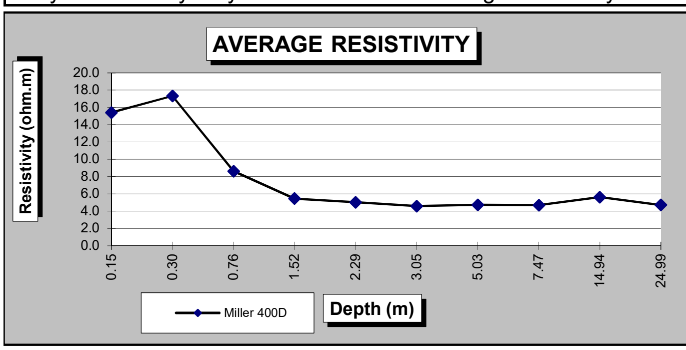
SOIL RESISTIVITY DATA

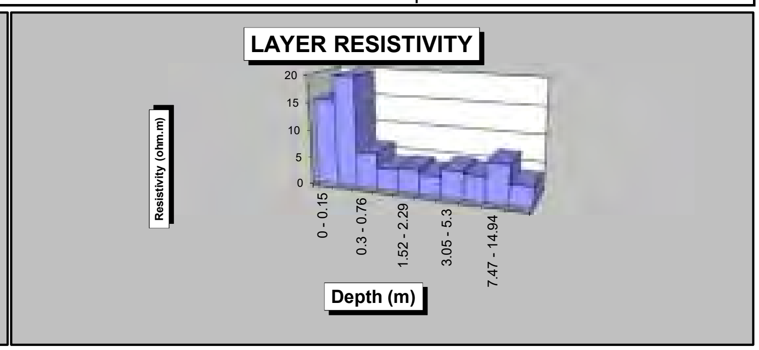
Project Name: Burns & McDonnell - Pensaquitos Alternate Rt 5
16008-E-04
Date: 11/17/2014
Location: 32.95699° N, 117.10903° W
Off Rancho Penasquitos Blvd
Testers: SP & DB
Methodology: $\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation: Miller 400D
Weather:
Soil Description

ARK. Engineering & Technical Services, Inc.

4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	1/(Δ 1/R) ohms	Spacing Factor	Layer Resistivity* Layer (m)	ohm.m
0.50	0.15	16.100	1	15.4	0.06211	n/a	n/a	n/a	0 - 0.15	15
1.00	0.30	9.050	2	17.3	0.11050	0.04839	20.667	1	0.15 - 0.3	20
2.50	0.76	1.800	5	8.6	0.55556	0.44506	2.247	3	0.3 - 0.76	6
5.00	1.52	0.570	10	5.5	1.75439	1.19883	0.834	5	0.76 - 1.52	4
7.50	2.29	0.350	14	5.0	2.85714	1.10276	0.907	5	1.52 - 2.29	4
10.00	3.05	0.240	19	4.6	4.16667	1.30952	0.764	5	2.29 - 3.05	4
16.50	5.03	0.150	32	4.7	6.66667	2.50000	0.400	12	3.05 - 5.3	5
24.50	7.47	0.100	47	4.7	10.00000	3.33333	0.300	15	5.03 - 7.47	5
49.00	14.94	0.060	94	5.6	16.66667	6.66667	0.150	47	7.47 - 14.94	7
82.00	24.99	0.030	157	4.7	33.33333	16.66667	0.060	63	14.94 - 25.0	4

* Layer Resistivity may not correlate with Average Resistivity because of soil characteristic variations with depth



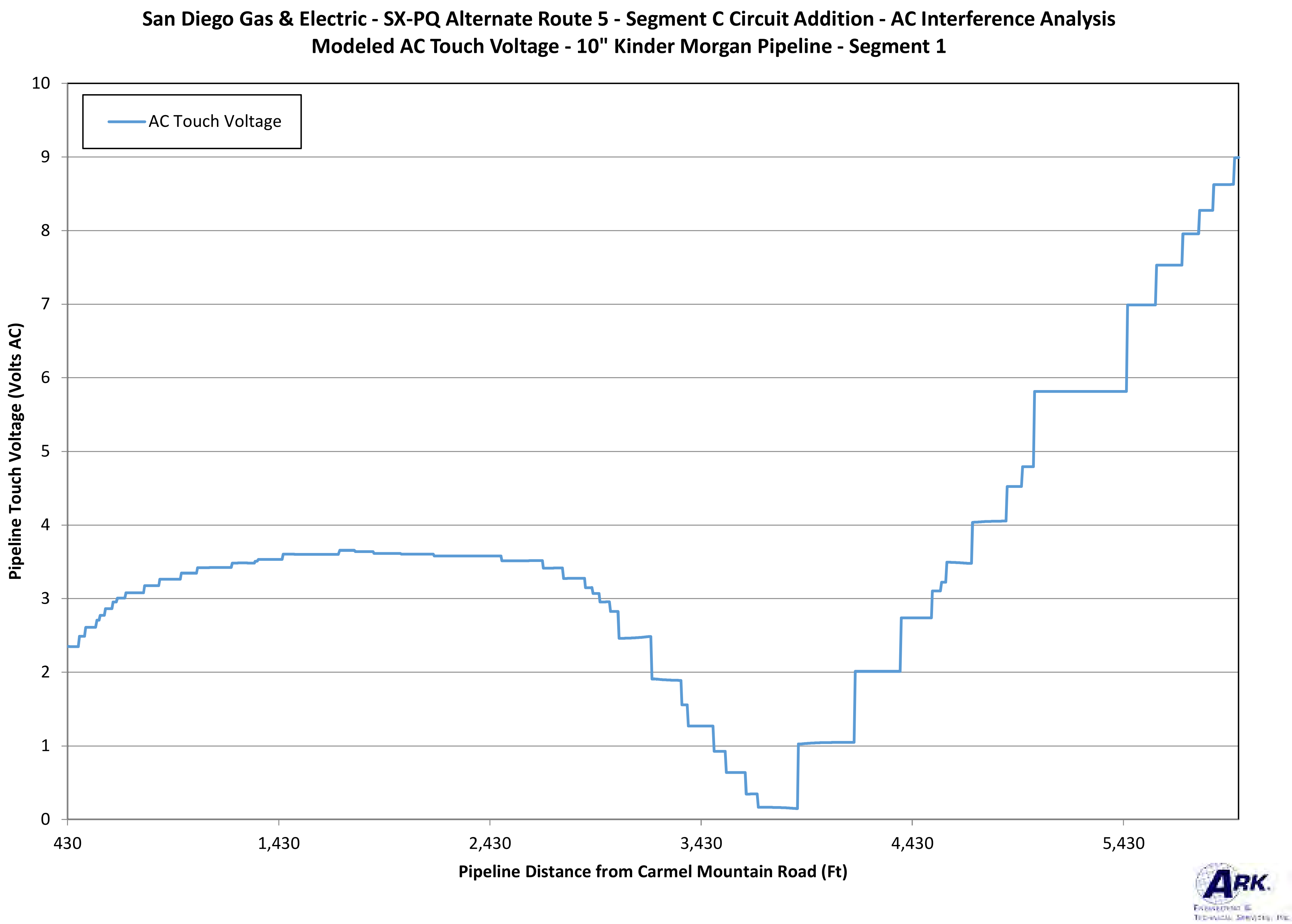


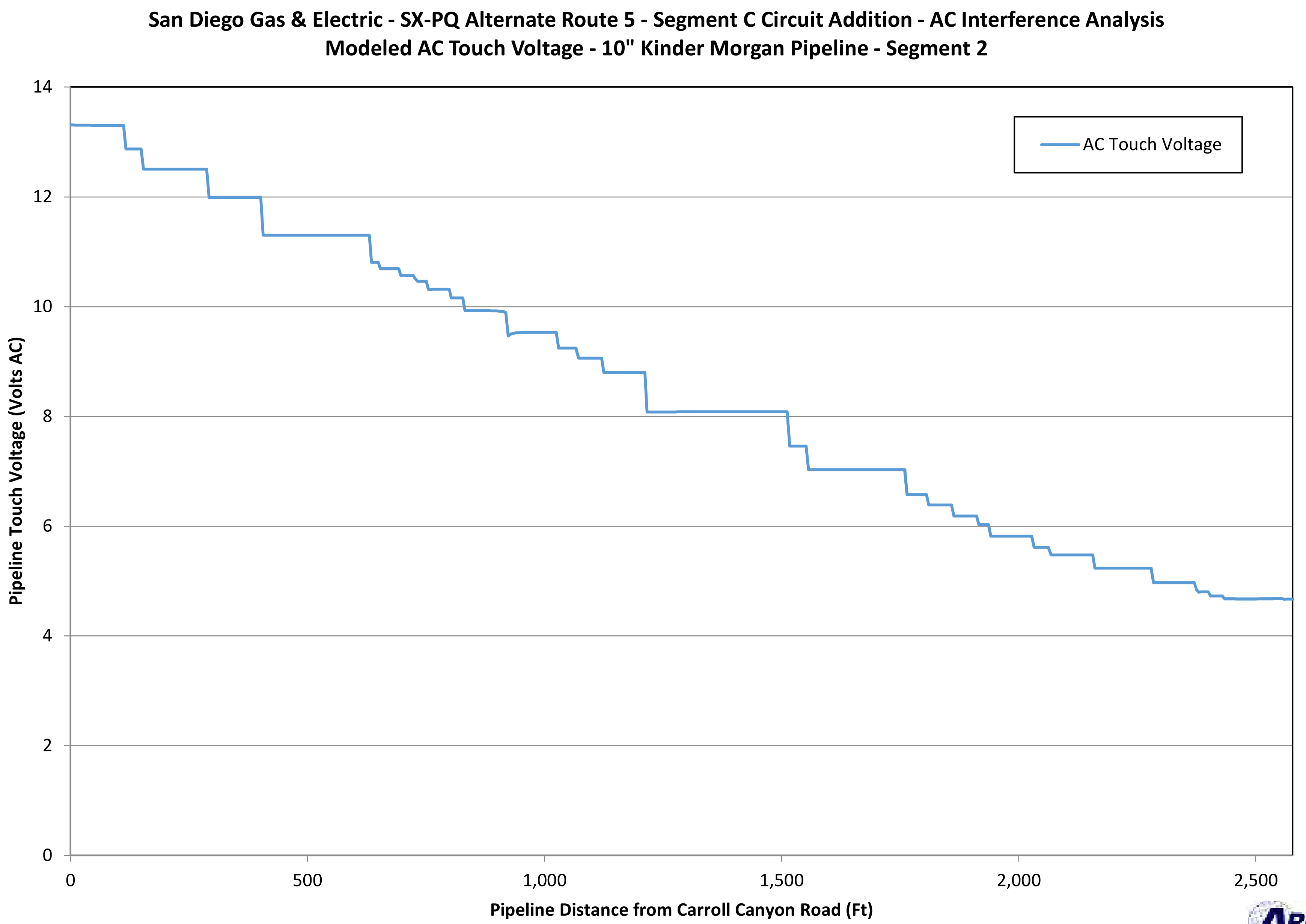
Derived Multilayer Soil Model		
Layer Number	Resistivity ohm-m	Thickness ft
1	17.12	1.26
3	4.76	Infinite

APPENDIX B –

PIPELINE STEADY STATE, AC CURRENT DENSITY & FAULT PLOTS

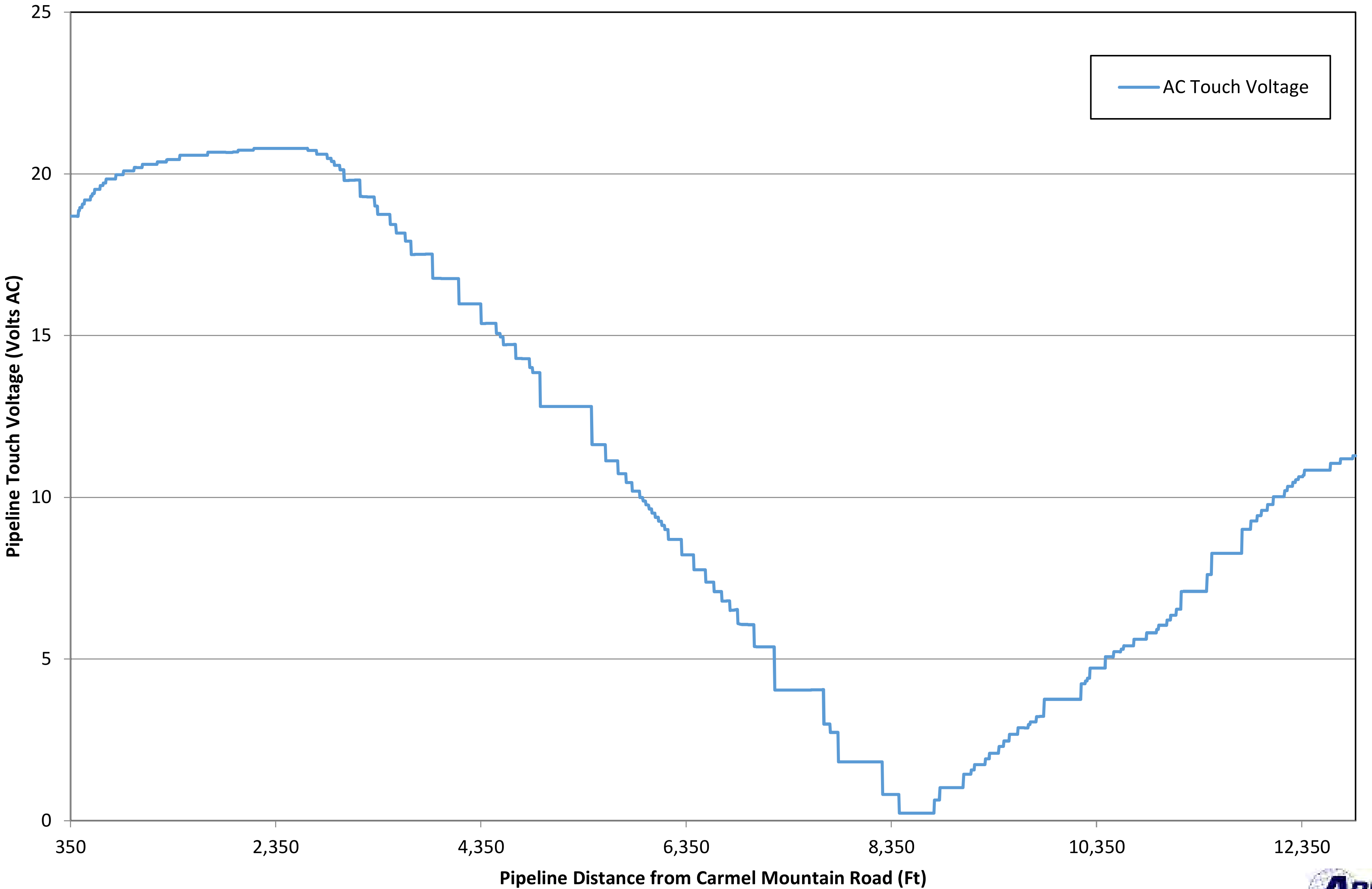
STEADY STATE INDUCED


San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Touch Voltage - 10" Kinder Morgan Pipeline - Segment 1
AC Touch Voltage
Pipeline Touch Voltage (Volts AC)
0
1
2
3
4
5
6
7
8
9
10
430
1,430
2,430
3,430
4,430
5,430
Pipeline Distance from Carmel Mountain Road (Ft)

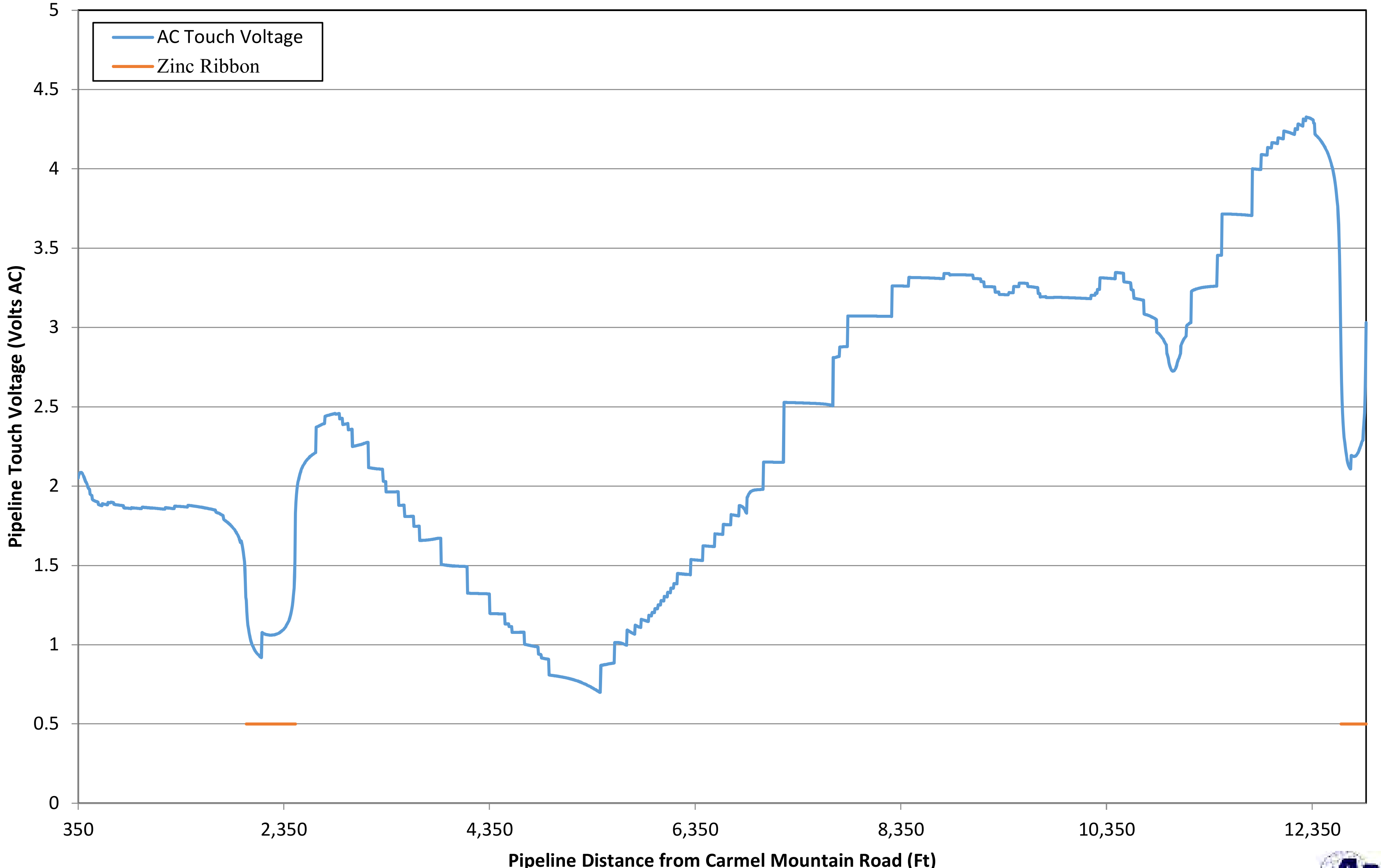


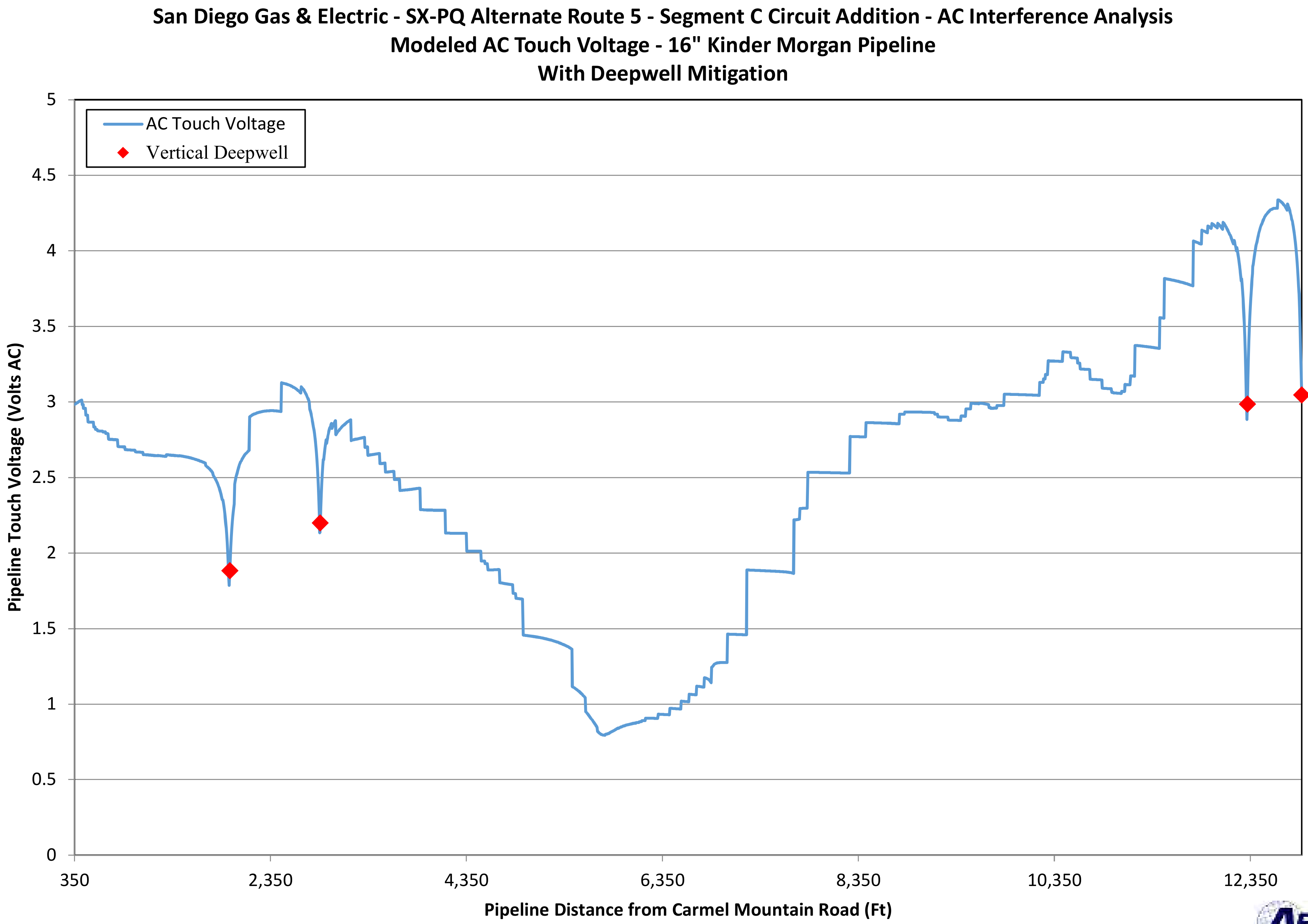
San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Touch Voltage - 10" Kinder Morgan Pipeline - Segment 2
AC Touch Voltage
Pipeline Touch Voltage (Volts AC)
14
12
10
8
6
4
2
0
500
1,000
1,500
2,000
2,500
Pipeline Distance from Carroll Canyon Road (Ft)

San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Touch Voltage - 16" Kinder Morgan Pipeline

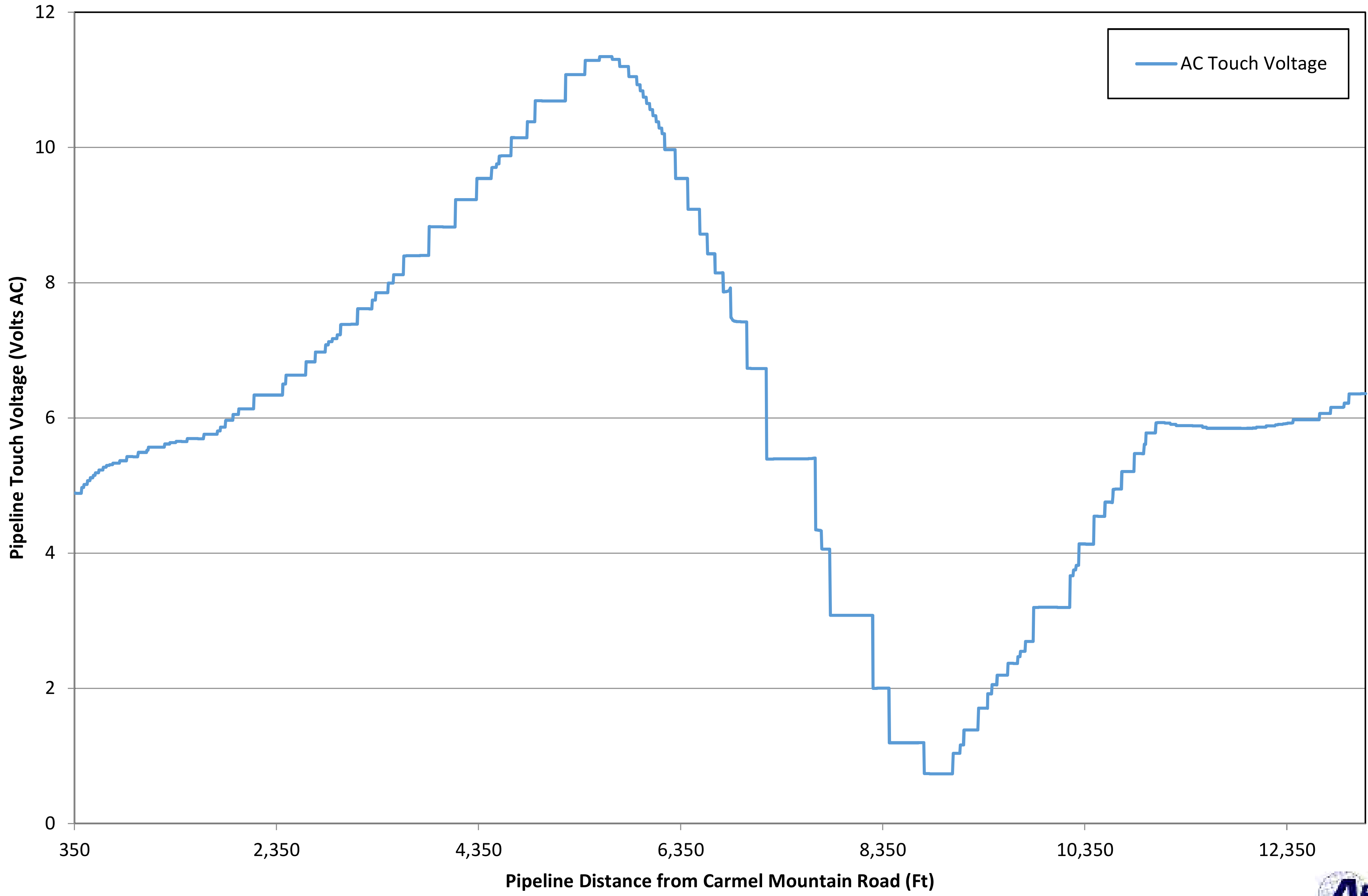


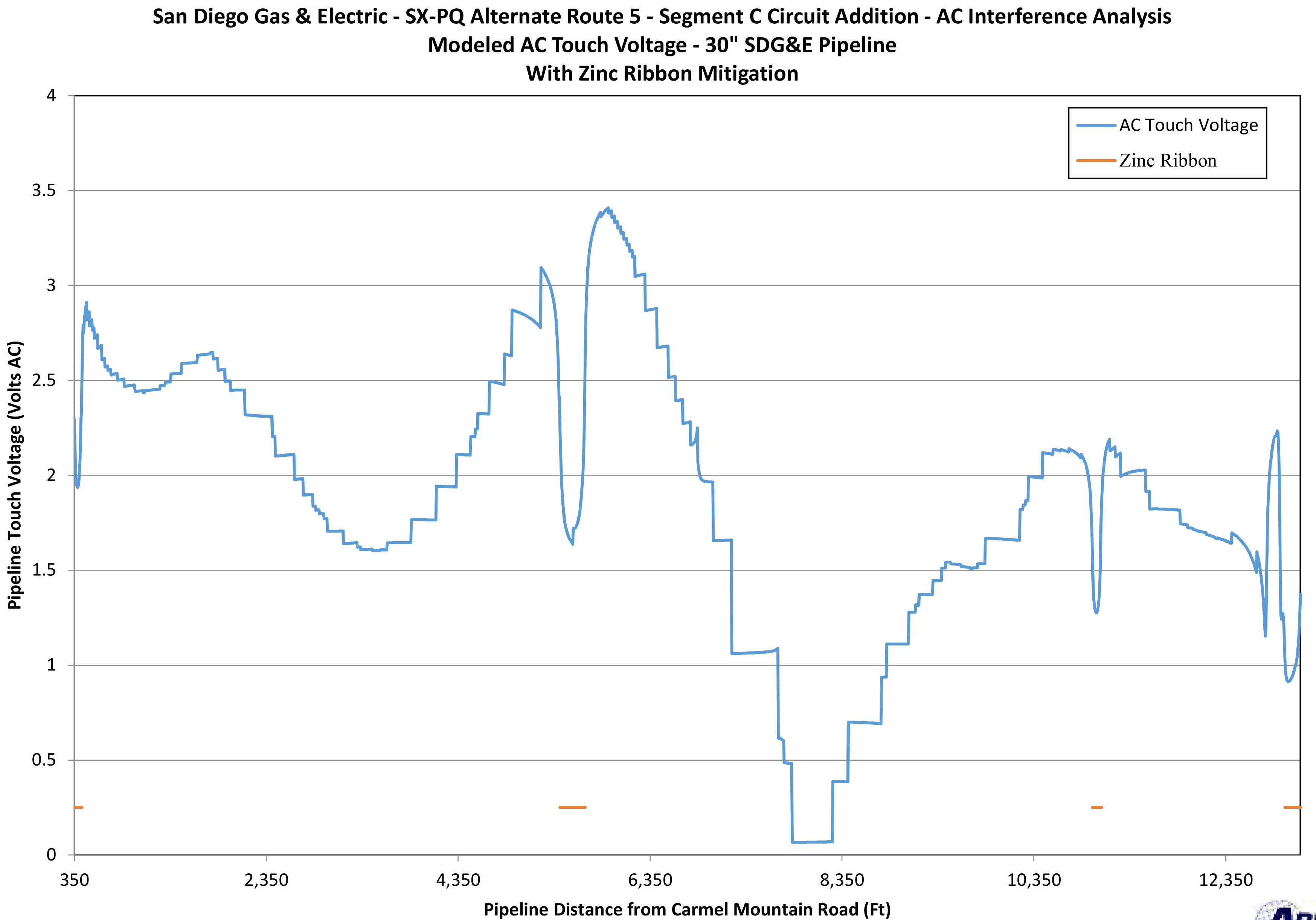
San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Touch Voltage - 16" Kinder Morgan Pipeline
With Zinc Ribbon Mitigation




San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Touch Voltage - 16" Kinder Morgan Pipeline
With Deepwell Mitigation
AC Touch Voltage
Vertical Deepwell
Pipeline Touch Voltage (Volts AC)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
350
2,350
4,350
6,350
8,350
10,350
12,350
Pipeline Distance from Carmel Mountain Road (Ft)

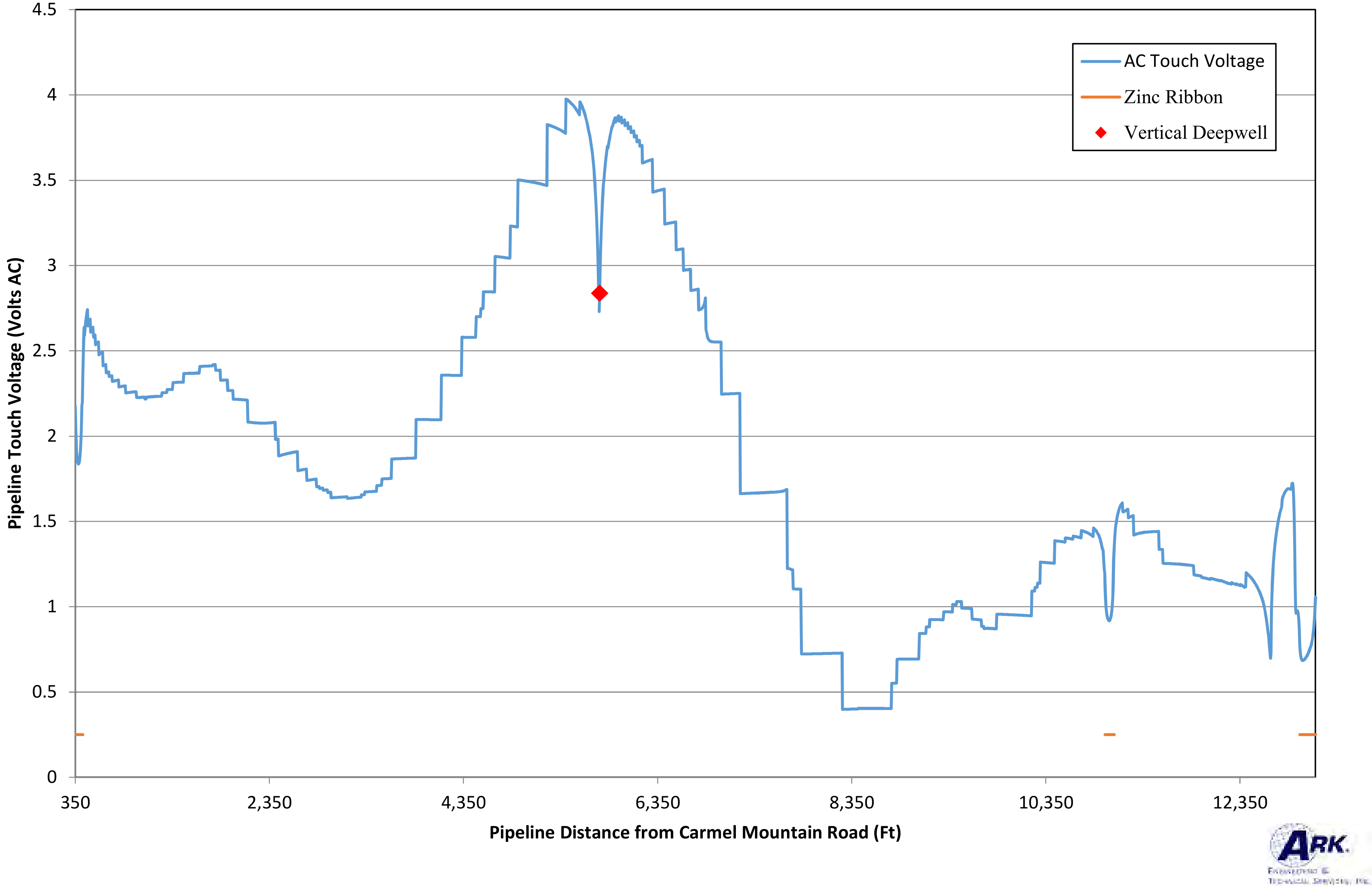
San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Touch Voltage - 30" SDG&E Pipeline



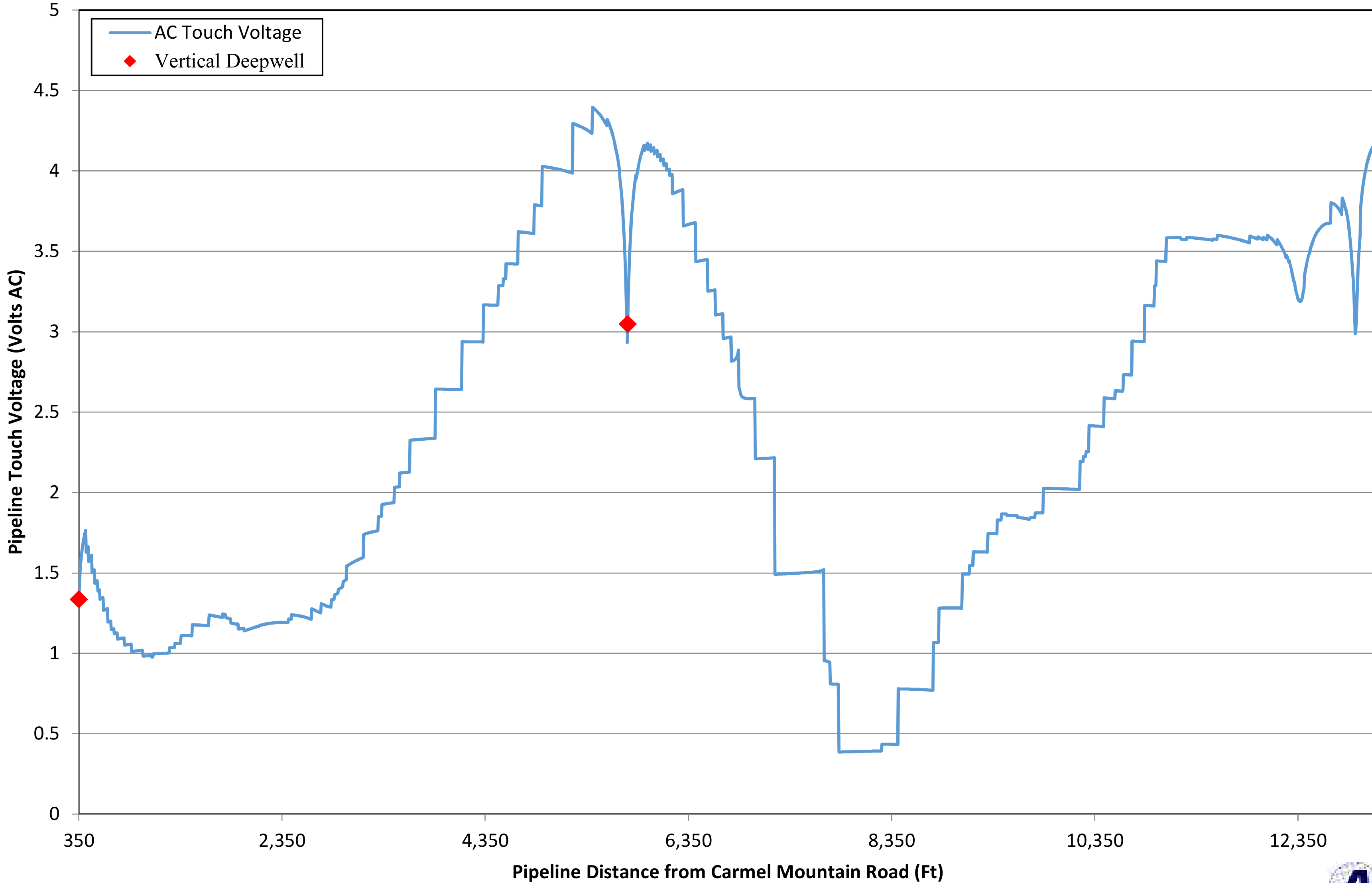


San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Touch Voltage - 30" SDG&E Pipeline
With Zinc Ribbon Mitigation
AC Touch Voltage
Zinc Ribbon
Pipeline Touch Voltage (Volts AC)
4
3.5
3
2.5
2
1.5
1
0.5
0
350
2,350
4,350
6,350
8,350
10,350
12,350
Pipeline Distance from Carmel Mountain Road (Ft)

San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Touch Voltage - 30" SDG&E Pipeline
With Zinc Ribbon & Deepwell Mitigation

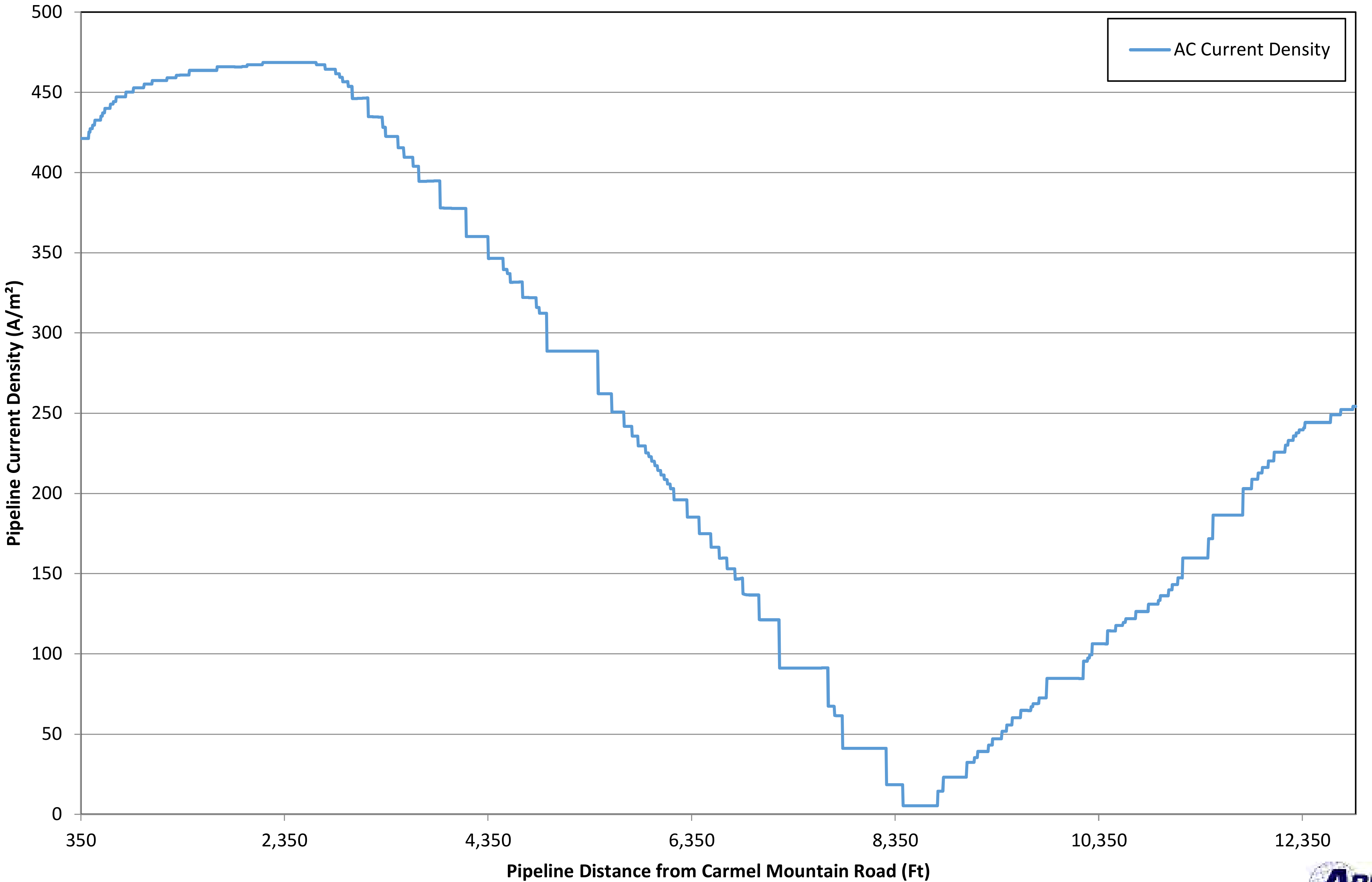


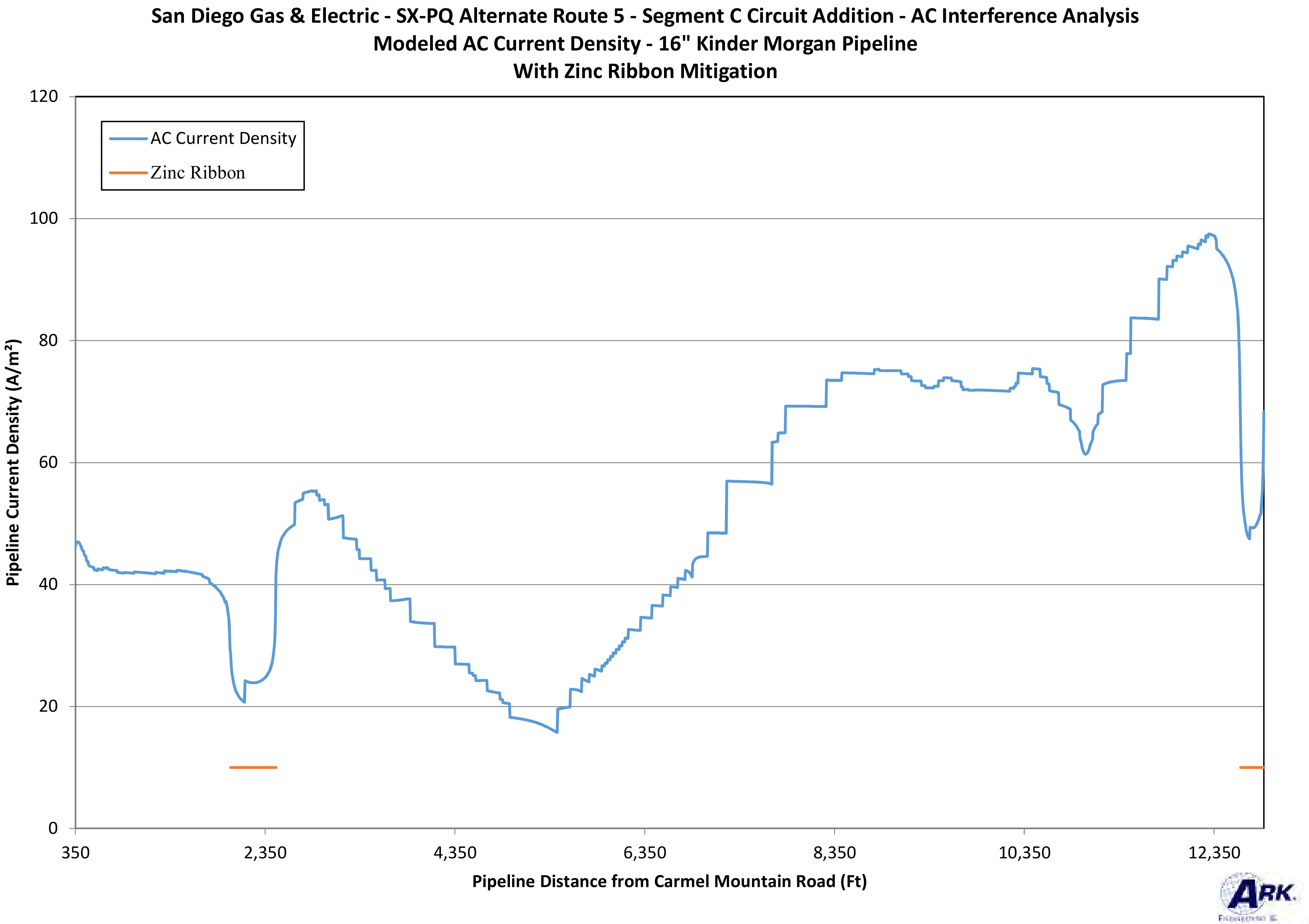
San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Touch Voltage - 30" SDG&E Pipeline
With Deepwell Mitigation



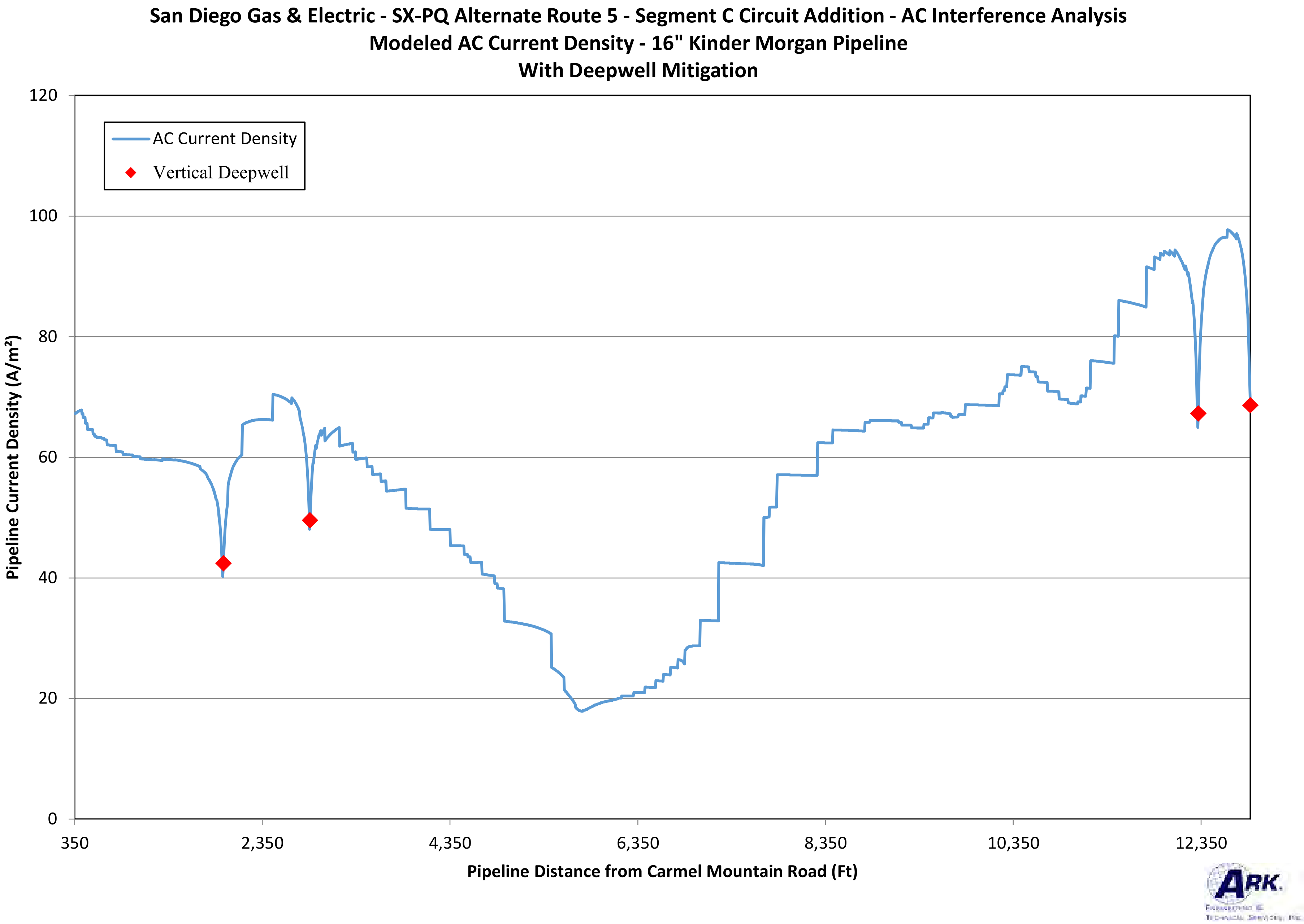
AC CURRENT DENSITY

San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Current Density - 16" Kinder Morgan Pipeline



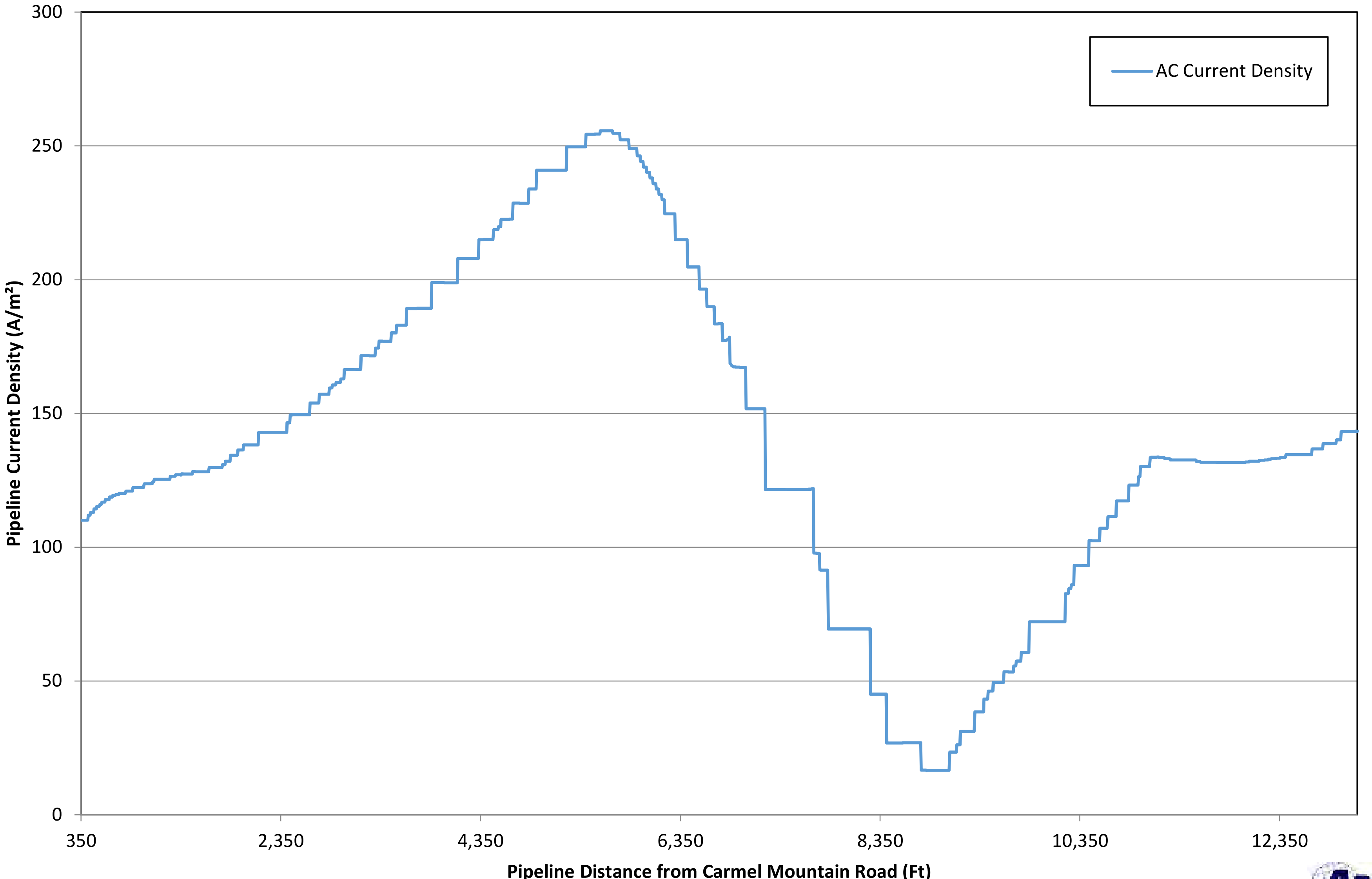


San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Current Density - 16" Kinder Morgan Pipeline
With Zinc Ribbon Mitigation
AC Current Density
Zinc Ribbon
Pipeline Current Density (A/m²)
120
100
80
60
40
20
0
350
2,350
4,350
6,350
8,350
10,350
12,350
Pipeline Distance from Carmel Mountain Road (Ft)
ARK

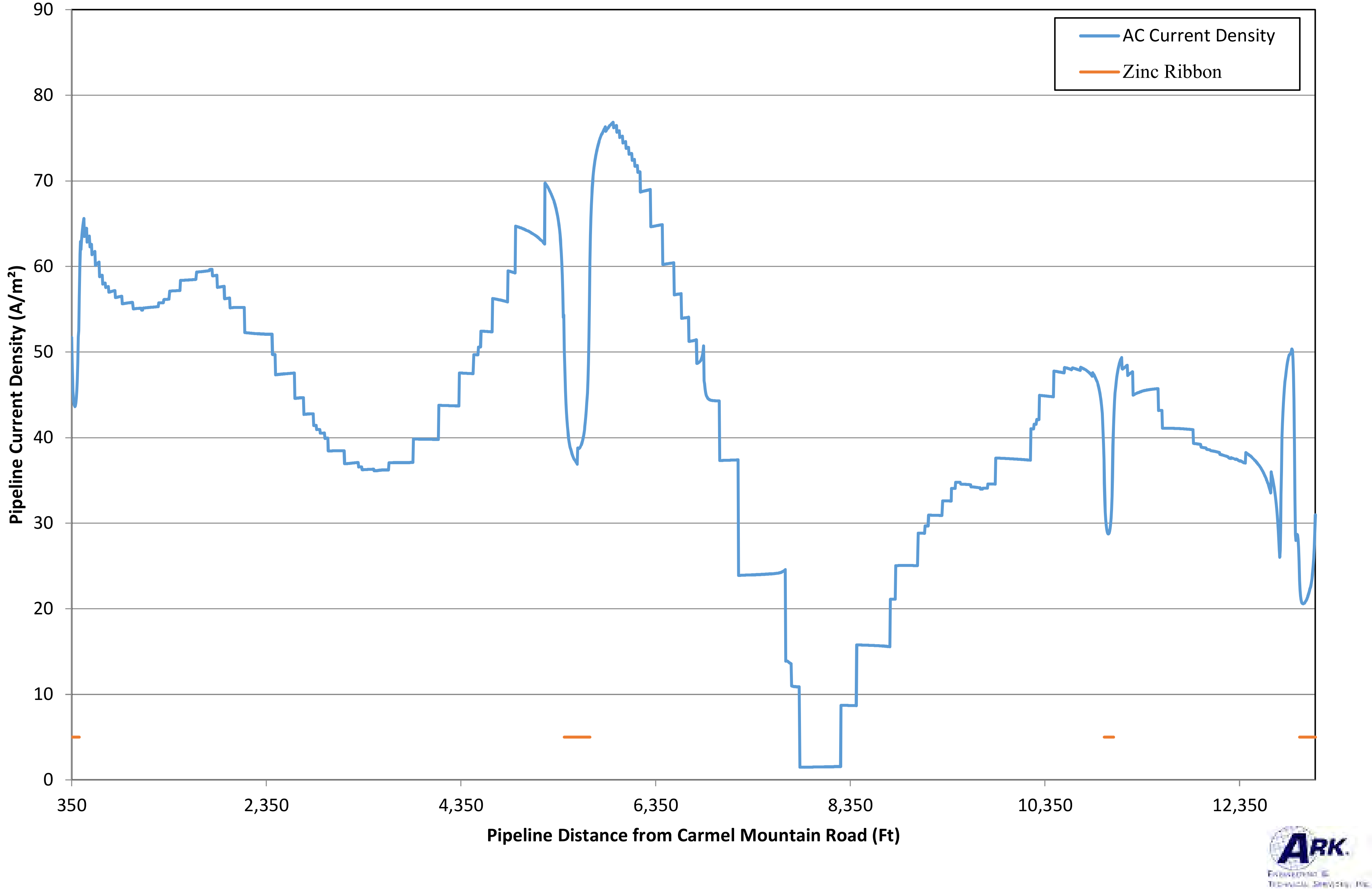


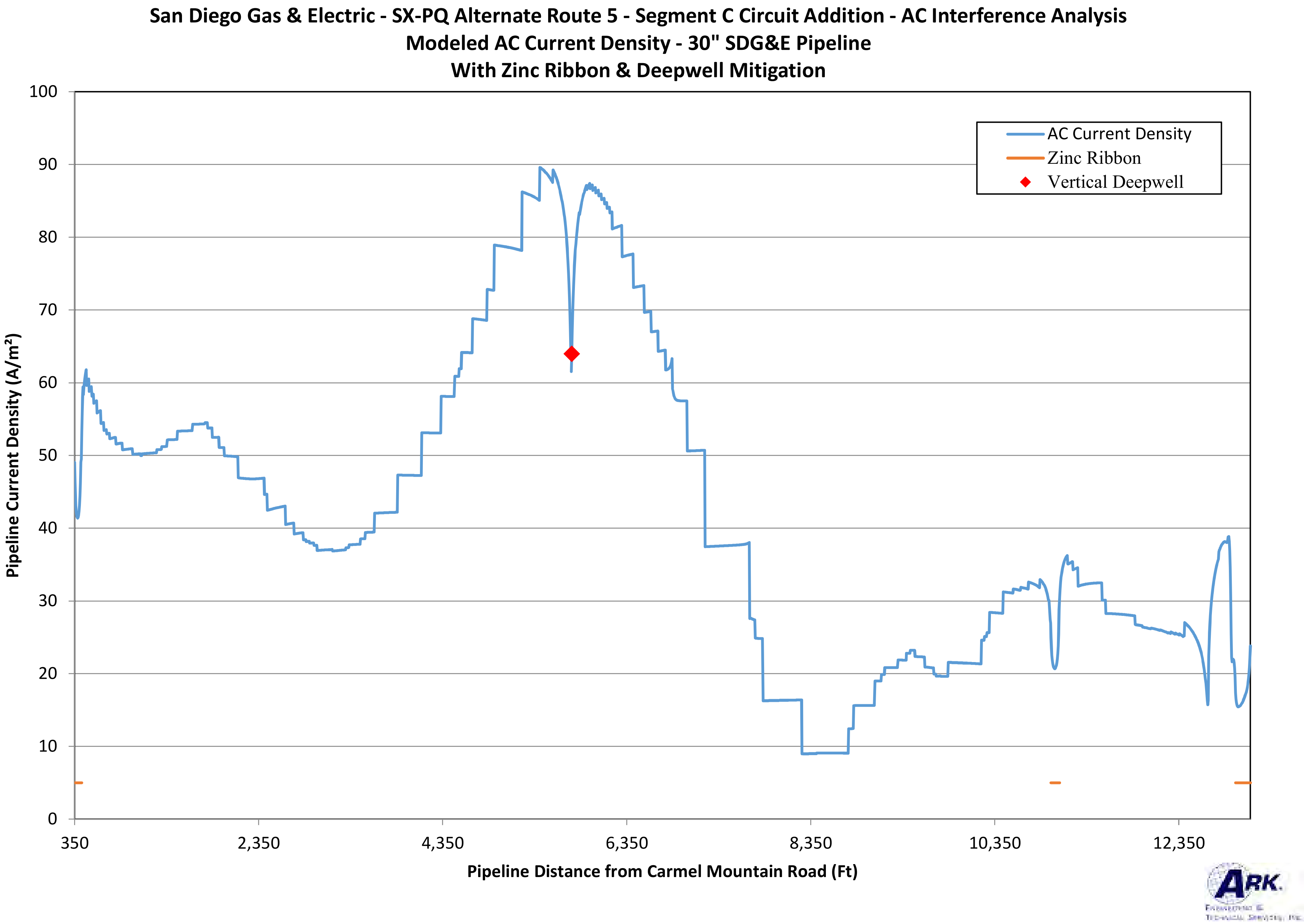
San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Current Density - 16" Kinder Morgan Pipeline
With Deepwell Mitigation
AC Current Density
Vertical Deepwell
Pipeline Current Density (A/m²)
Pipeline Distance from Carmel Mountain Road (Ft)
0
20
40
60
80
100
120
350
2,350
4,350
6,350
8,350
10,350
12,350
ARK

San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Current Density - 30" SDG&E Pipeline



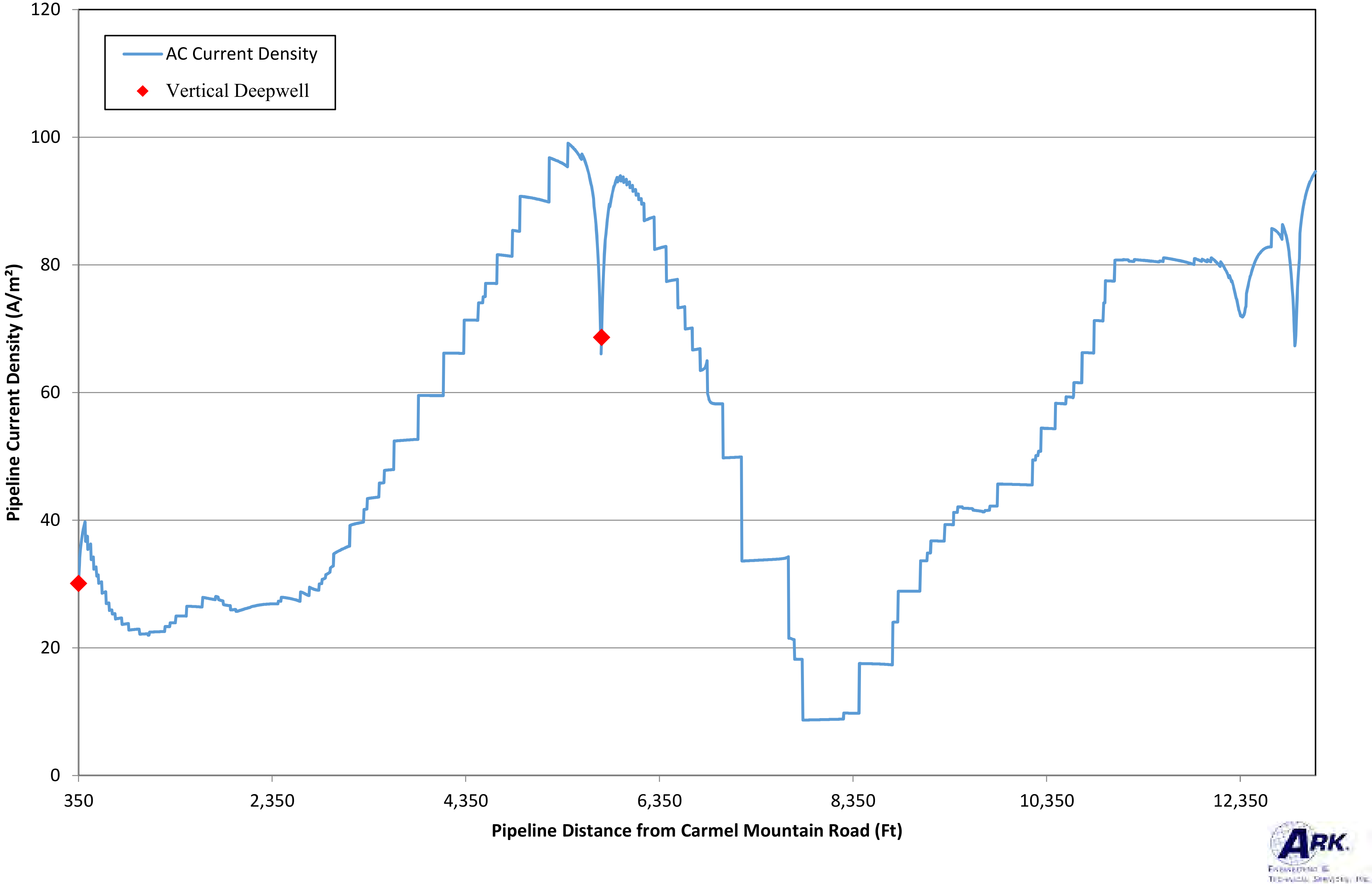
San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Current Density - 30" SDG&E Pipeline
With Zinc Ribbon Mitigation



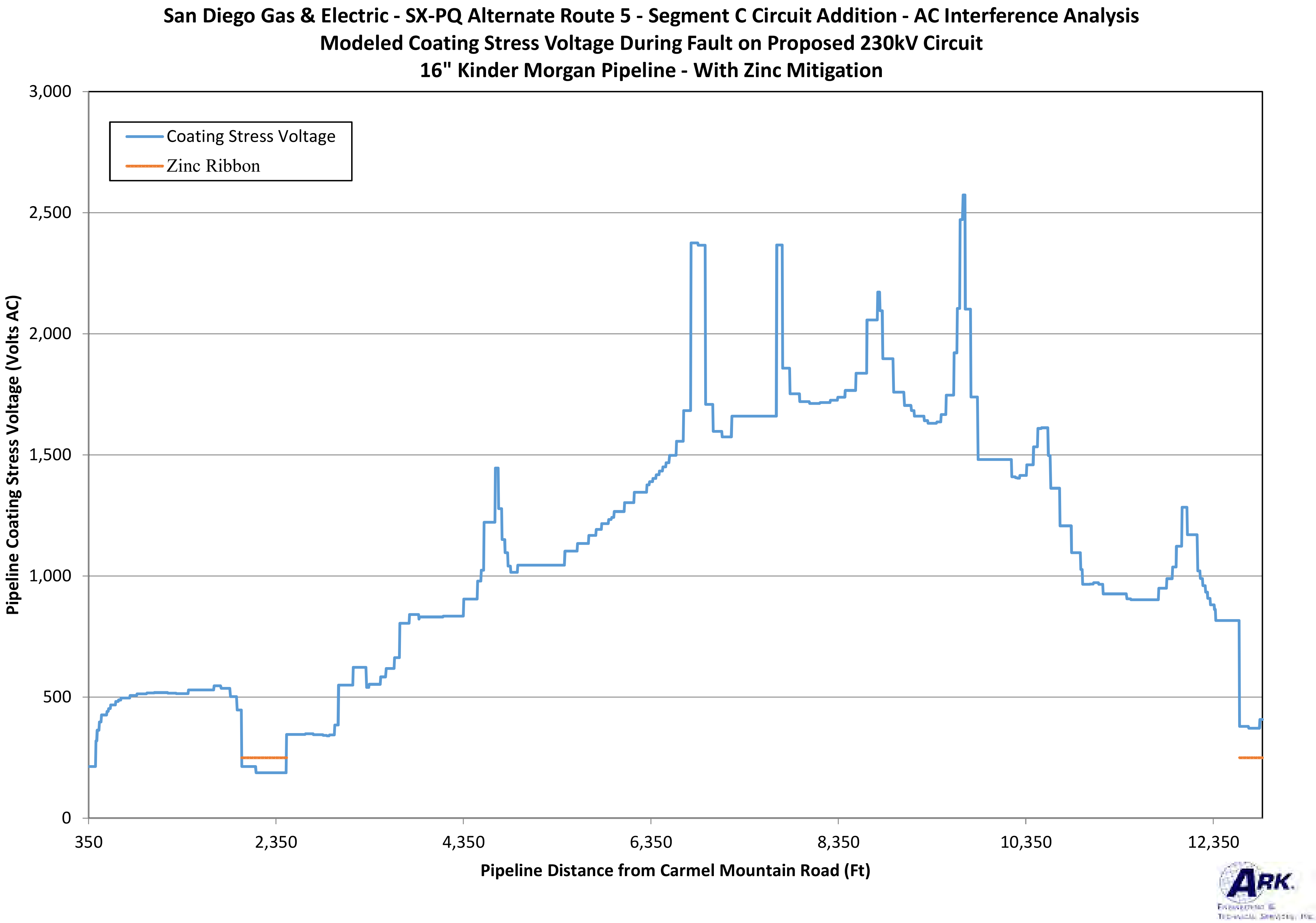


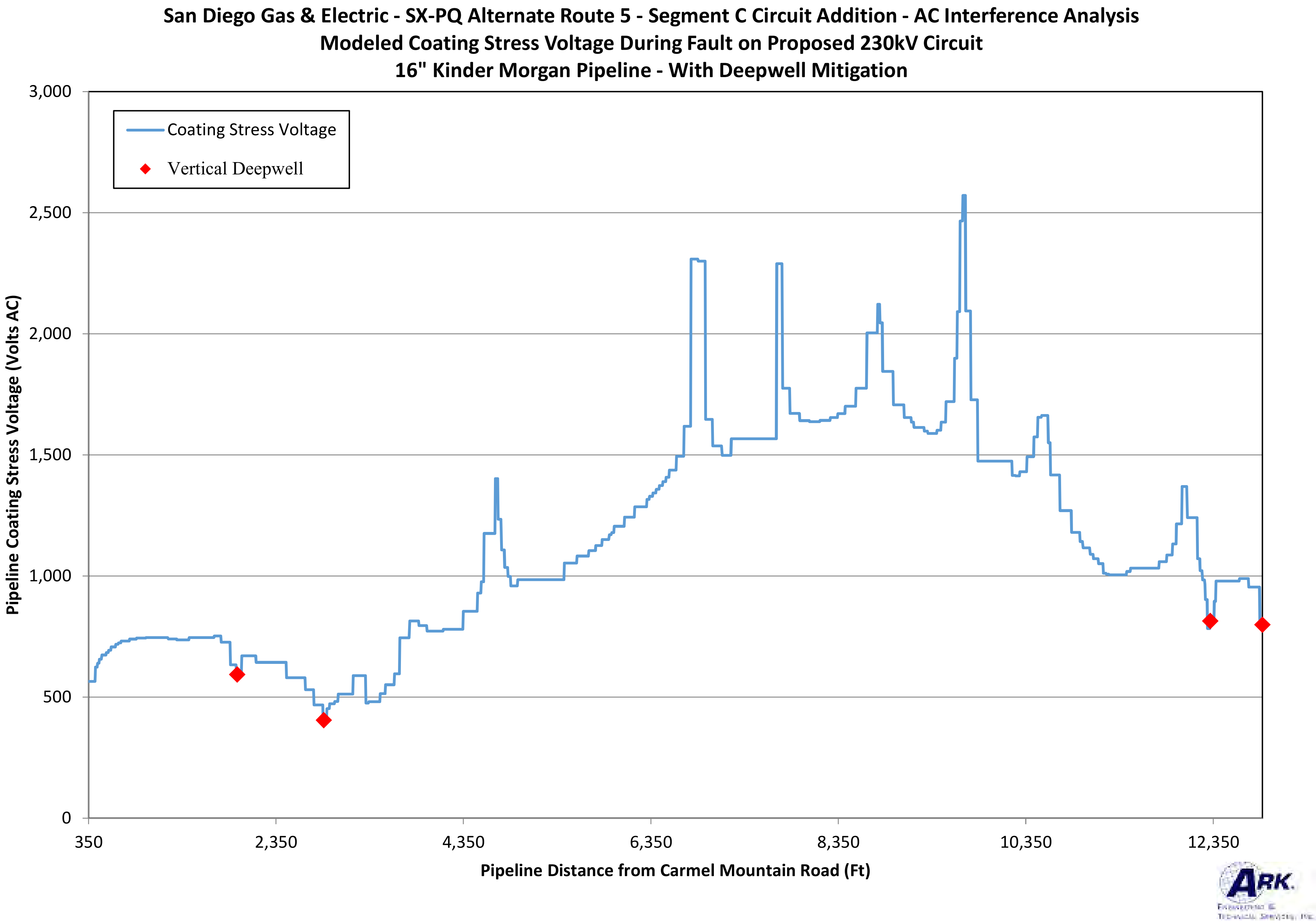
San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Current Density - 30" SDG&E Pipeline
With Zinc Ribbon & Deepwell Mitigation
AC Current Density
Zinc Ribbon
Vertical Deepwell
Pipeline Current Density (A/m²)
Pipeline Distance from Carmel Mountain Road (Ft)
100
90
80
70
60
50
40
30
20
10
0
350
2,350
4,350
6,350
8,350
10,350
12,350
ARK

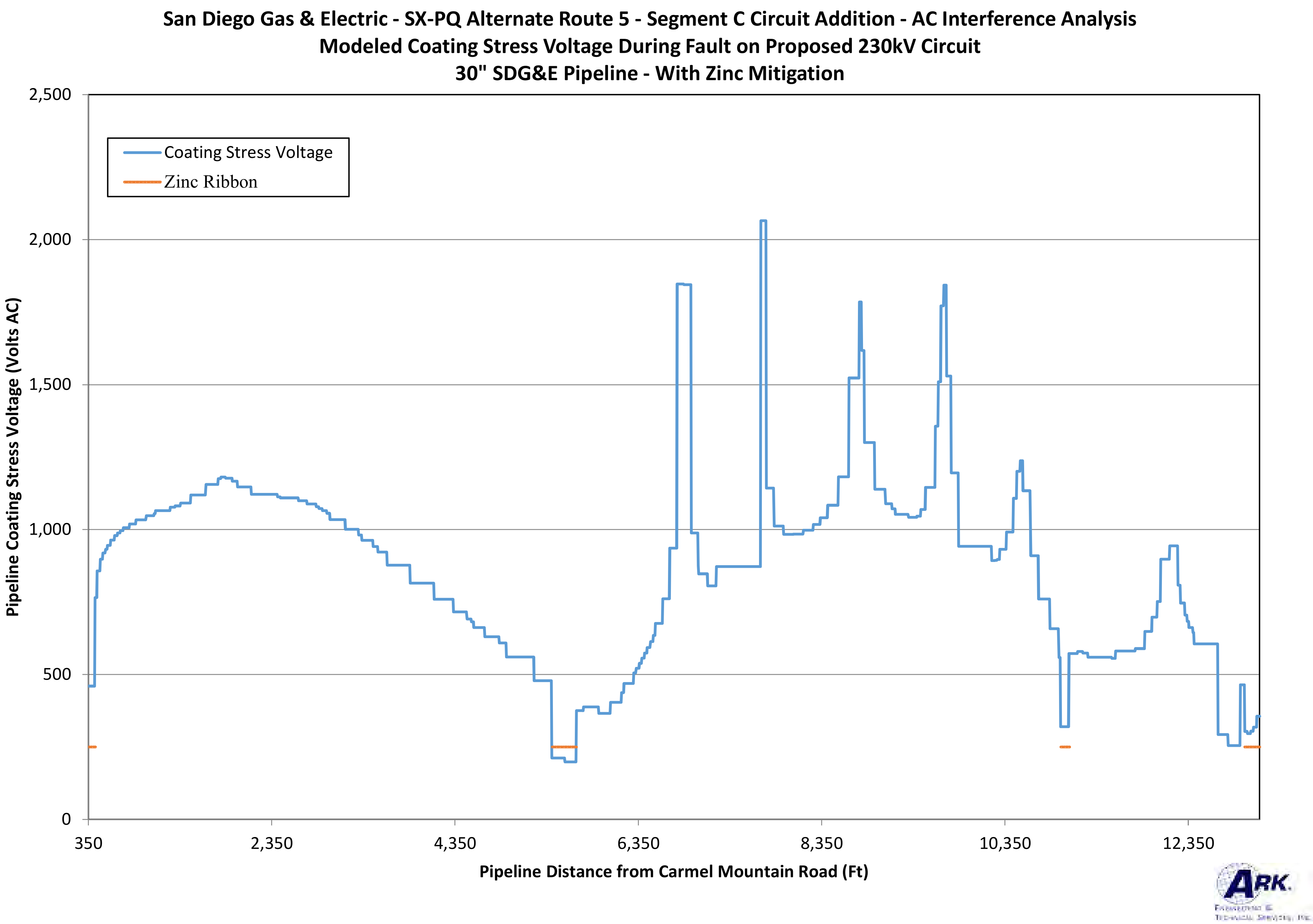
San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled AC Current Density - 30" SDG&E Pipeline
With Deepwell Mitigation



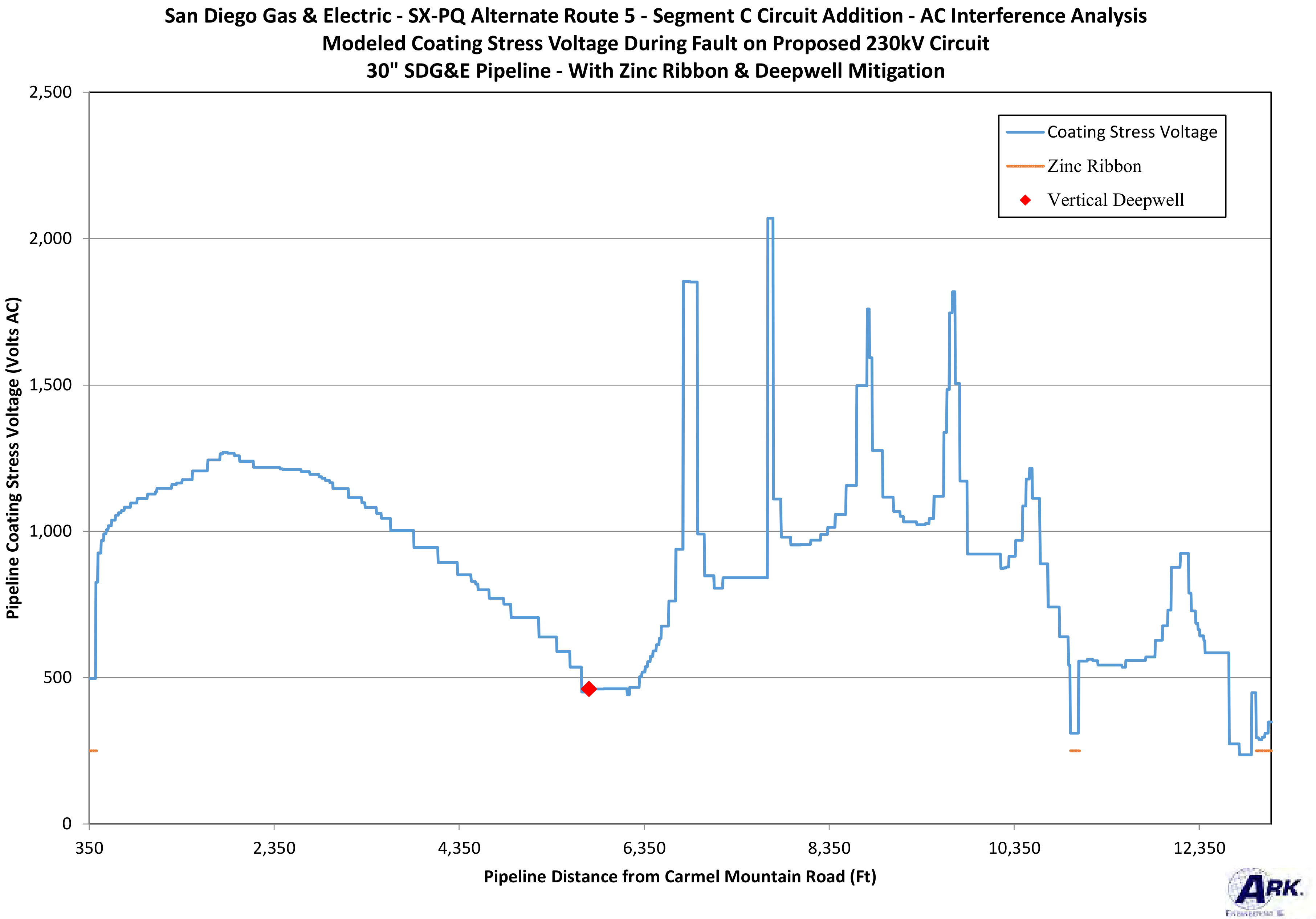
FAULT – COATING STRESS VOLTAGE


San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled Coating Stress Voltage During Fault on Proposed 230kV Circuit
16" Kinder Morgan Pipeline - With Zinc Mitigation
Coating Stress Voltage
Zinc Ribbon
Pipeline Coating Stress Voltage (Volts AC)
3,000
2,500
2,000
1,500
1,000
500
0
350
2,350
4,350
6,350
8,350
10,350
12,350
Pipeline Distance from Carmel Mountain Road (Ft)


San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled Coating Stress Voltage During Fault on Proposed 230kV Circuit
16" Kinder Morgan Pipeline - With Deepwell Mitigation
Coating Stress Voltage
Vertical Deepwell
Pipeline Coating Stress Voltage (Volts AC)
3,000
2,500
2,000
1,500
1,000
500
0
350
2,350
4,350
6,350
8,350
10,350
12,350
Pipeline Distance from Carmel Mountain Road (Ft)
ARK

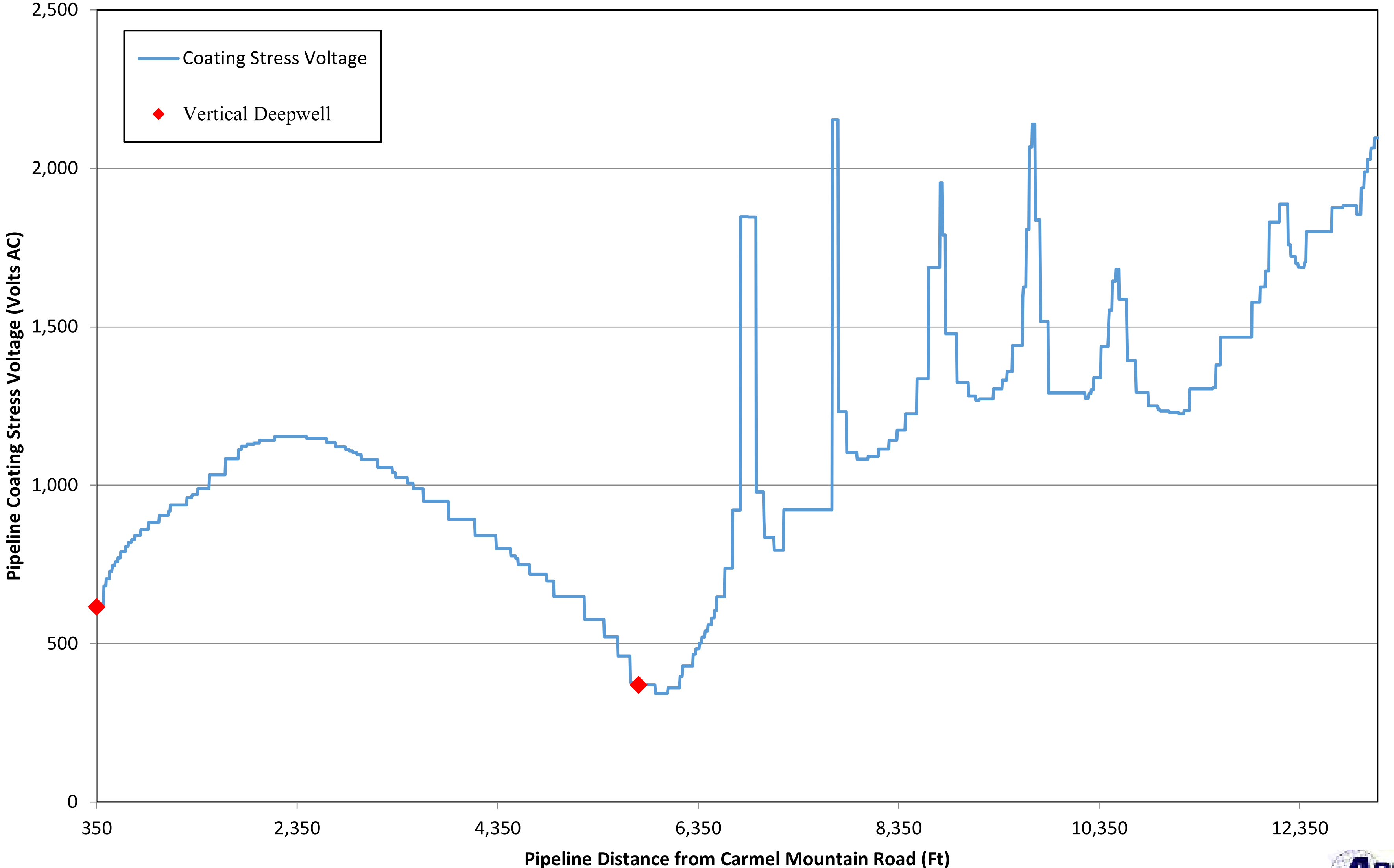


San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled Coating Stress Voltage During Fault on Proposed 230kV Circuit
30" SDG&E Pipeline - With Zinc Mitigation
Coating Stress Voltage
Zinc Ribbon
Pipeline Coating Stress Voltage (Volts AC)
2,500
2,000
1,500
1,000
500
0
350
2,350
4,350
6,350
8,350
10,350
12,350
Pipeline Distance from Carmel Mountain Road (Ft)
ARK



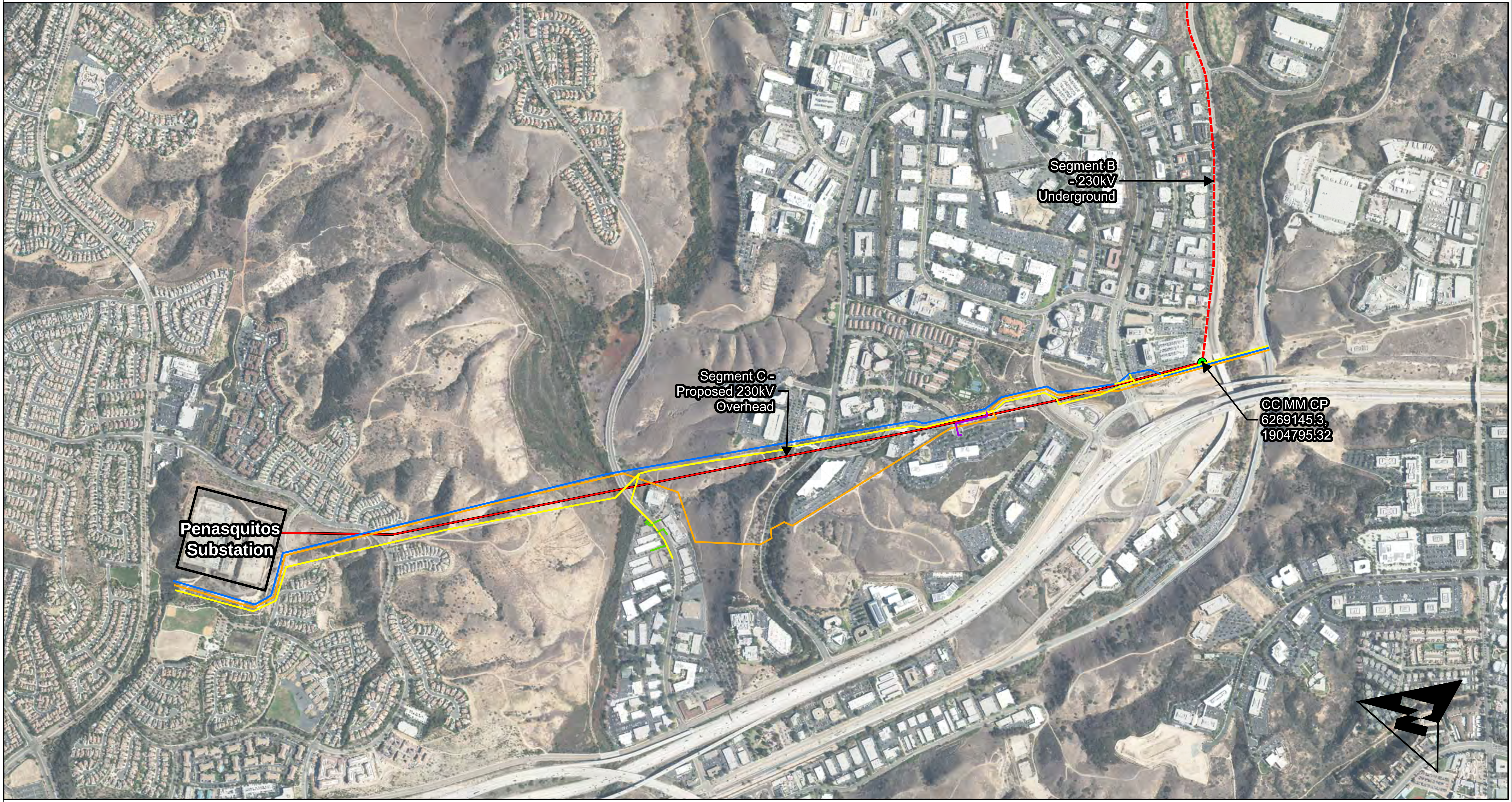
San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled Coating Stress Voltage During Fault on Proposed 230kV Circuit
30" SDG&E Pipeline - With Zinc Ribbon & Deepwell Mitigation
Coating Stress Voltage
Zinc Ribbon
Vertical Deepwell
Pipeline Coating Stress Voltage (Volts AC)
2,500
2,000
1,500
1,000
500
0
350
2,350
4,350
6,350
8,350
10,350
12,350
Pipeline Distance from Carmel Mountain Road (Ft)
ARK

San Diego Gas & Electric - SX-PQ Alternate Route 5 - Segment C Circuit Addition - AC Interference Analysis
Modeled Coating Stress Voltage During Fault on Proposed 230kV Circuit
30" SDG&E Pipeline - With Deepwell Mitigation



APPENDIX C –
POWER DATA

SYCAMORE TO PENASQUITOS 230kV TRANSMISSION LINE PROJECT



NV5

1 inch = 1,047 feet @ 11 x 17

0 500 1,000 2,000 Feet

The data displayed has been collected from various sources including and may change over time without notice. These data may be generalized and not parcel based nor of a licensed survey based level of accuracy.

Legend

- Cable_Pole_Locations
- Segment C 230kV Proposed Overhead (Existing TL23013)
- Segment B 230kV Proposed Underground
- SDG&E Steel HP Gas Pipe 10inch
- SDG&E Steel HP Gas Pipe .75 inch
- SDG&E Steel HP Gas Pipe 30 inch
- Kinder Morgan Steel Petrolium Pipe 10 inch
- Kinder Morgan Steel Petrolium Pipe 16 inch

ALTERNATIVE ROUTE 5
SEGMENT C - 230kV PROPOSED OVERHEAD AND BURIED STEEL PIPES IN THE CORRIDOR

12/9/2015

Document Path: N:\SDB090102.01\GIS\MXD\ALT 5_SEGMENT C MAPBOOK_GAS.mxd

ARK Data Request

Circuit Information			Shield Conductors						Phase Wires					Circuit	Current Load (A)			
Transmission Line	Circuit #	Voltage (kv)	# of Conductors	Type	Height above ground (ft)	Horizontal distance from center (ft)	Resistance (Ω/mi) @ 25C	GMR (ft)	# of Conductors	Type	Avg height a/b/c (ft)	Horizontal Distance a/b/c (ft)	Phasing a/b/c (degrees)	Circuit Type on Tower (ex. Steel Tower)	Avg Summer	Avg Winter	Peak	Emergency
610	PQ-DM	69kV	0	NA	NA	NA	NA	NA	3	636 ACSR/AW	50/55/60	4.5/4.5/4.5	0/120/240	Wood Poles	153	132	253	854
661	PQ-EG	69kV	0	NA	NA	NA	NA	NA	3	1033.5 ACSR/AW	50/55/60	6/6/6	0/120/240	Wood Poles	113	74	344	1145
6959	PQ-MTO	69kV	1	7#10	120	0	3.88	0.00166	6	336.4 ACSR/AW	60/80/100	15/15/15	0/120/240	Steel Towers	307	231	509	1142
675	PQ-MRM	69kV	0	NA	NA	NA	NA	NA	3	1033.5 ACSR/AW	60/60/60	15/0/15	0/120/240	Wood H-Frames	232	231	572	1145
662	PQ-TP	69kV	0	NA	NA	NA	NA	NA	3	1033.5 ACSR/AW	50/59/68	6/6/6	0/120/240	Wood Poles	276	214	599	1145
666	PQ-PQ tap	69kV	0	NA	NA	NA	NA	NA	3	1750 KCMIL/AL	-3/-4/-5	.5/.5/.5	0/120/240	Underground Duct	91	317	490	800
667	PQ-DM	69kV	0	NA	NA	NA	NA	NA	3	1033.5 ACSR/AW	50/55/60	6/6/6	0/120/240	Wood Poles	186	164	305	1145
664	PQ-MRGT tap	69kV	0	NA	NA	NA	NA	NA	3	1033.5 ACSR/AW	50/55/60	6/6/6	0/120/240	Wood Poles	115	89	372	1145
6905	PQ-GE	69kV	0	NA	NA	NA	NA	NA	3	1033.5 ACSR/AW	60/66/72	6/6/6	0/120/240	Wood Poles	264	202	467	1145
6906	PQ-MR	69kV	1	7#10	120	0	3.88	0.00166	3	1033.5 ACSR/AW	60/80/100	15/15/15	0/120/240	Steel Towers	74	56	333	1145
6952	PQ-NCW	69kV	0	NA	NA	NA	NA	NA	3	900 ACSS/AW	60/60/60	15/0/15	0/120/240	Wood H-Frames	266	203	522	1436
13810	PQ-FR tap	138kV	1	7#10	120	0	3.88	0.00166	3	636 ACSR/AW	60/80/100	15/15/15	0/120/240	Steel Towers	221	200	464	854
13804	PQ-BQ tap	138kV	1	7#10	130	0	3.88	0.00166	6	1033.5 ACSR/AW	70/90/110	15/15/15	0/120/240	Steel Towers	115	66	587	2290
23012	PQ-EA	230kV	1	7#10	140	0	3.88	0.00166	6	1033.5 ACSR/AW	80/100/120	10/10/10	0/120/240	Steel Poles	131	130	545	2290
23013	PQ-OT	230kV	1	7#10	140	0	3.88	0.00166	6	1033.5 ACSR/AW	80/100/120	10/10/10	0/120/240	Steel Poles	736	670	1177	2290
23053	PQ-EA	230kV	1	7#10	140	0	3.88	0.00166	6	1033.5 ACSR/AW	80/100/120	10/10/10	0/120/240	Steel Poles	132	131	548	2290
23071	SX-PQ	230kV	1	7#10	140	0	3.88	0.00166	6	900 ACSS/AW	120/100/80	10/10/2010	0/120/240	Steel Poles	1603	1400	2290	2950

ARK Data Request

Fault Current Parameter			Fault Current @ Collocation(A)														
Avg lower resistance to remote (Ω)	Avg dist. btwn towers (ft)	Primary fault clearing times OR breaker failure clearing times (each line)	Start (Sycamore Substation)					Mid-point					End (Peñasquitos Substation)				
			Total	From Sycamore	Sycamore angle	From Peñasquitos	Peñasquitos angle	Total	From Sycamore	Sycamore angle	From Peñasquitos	Peñasquitos angle	Total	From Sycamore	Sycamore angle	From Peñasquitos	Peñasquitos angle
20	460	<20 Cycles	35748	35673	-116	76	55	11632	8139	-112	3493	-111	11630	4046	-112	7584	-112
20	332	<20 Cycles	35673	34110	-117	568	-112	15504	12679	-114	2826	-112	11349	7710	-113	3639	-113
20	407	<20 Cycles	35673	34321	-116	1351	-116	19759	14537	-113	5223	-115	16712	8514	-112	8202	-115
20	320	<20 Cycles	35673	34577	-117	1098	-113	10853	7596	-113	3257	-113	8711	4384	-113	4327	-113
20	364	<20 Cycles	35673	35534	-116	139	-117	16998	11425	-114	5574	-114	17067	5941	-114	11126	-114
20	350	<20 Cycles	35673	35398	-116	275	-115	27426	24446	-115	2981	-115	23210	18345	-115	4866	-115
20	290	<20 Cycles	35673	35483	-116	190	-114	11053	7057	-113	3997	-112	11630	3282	-113	8349	-112
20	320	<20 Cycles	35673	32859	-117	2822	-112	17723	12420	-114	5303	-113	15211	7308	-113	7903	-113
20	320	<20 Cycles	35673	35397	-116	276	-116	14854	9052	-113	5803	-113	17716	4012	-113	13704	-114
20	509	<20 Cycles	35673	34484	-117	1194	-111	9338	5348	-112	3990	-113	12893	2356	-112	10538	-113
20	753	<20 Cycles	35673	34453	-117	1223	-113	15177	13105	-114	2074	-111	10980	8358	-114	2624	-111
20	789	<20 Cycles	27589	25480	-87	2125	-80	25434	23055	-86	2391	-80	23659	21042	-86	2627	-81
20	663	<20 Cycles	27589	25782	-87	1815	-81	12448	4983	-83	7465	-83	23199	2470	-83	20729	-85
20	1002	<20 Cycles	25741	23619	-86	2135	-79	16696	8266	-84	8432	-82	35580	33781	-86	1804	-82
20	907	<20 Cycles	25741	20335	-87	5453	-79	21450	10456	-84	10996	-82	29092	5398	-81	23706	-85
20	1002	<20 Cycles	25741	23482	-86	2273	-79	16696	8266	-84	8432	-82	35580	1804	-86	33665	-86
20	907	<20 cycles	35667	27238	-87	8459	-81	30623	15830	-84	14793	-84	34482	9351	-81	25170	-87

APPENDIX D –
ARK ENGINEERING DESIGN DRAWINGS

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION	5/12/17	RFA

BURNS & MCDONNELL
SAN DIEGO GAS & ELECTRIC

SYCAMORE TO PEÑASQUITOS - ALTERNATE ROUTE 5 - SEGMENT C

AC MITIGATION SYSTEM DESIGN
DEEPWELL INSTALLATION DRAWINGS
SAN DIEGO COUNTY, CALIFORNIA

PROJECT DRAWING LISTING

DRAWING NO.	SHEETS	REV	TITLE
16008-100	1	A	COVER SHEET
16008-200	1	A	DEEPWELL INSTALLATION LOCATIONS AND REQUIRED MATERIALS
16008-201	1	A	SSD LOCATIONS
16008-300	1	A	CABLE TO PIPELINE CONNECTION DETAILS
16008-301	1	A	SOLID STATE DECOUPLER (SSD) DEVICE CONNECTION DETAILS
16008-302	1	A	DEEPWELL INSTALLATION DETAILS
16008-303	1	A	EXOTHERMIC WELD CONNECTION DETAILS
16008-400	1	A	MATERIALS LIST

ISSUED FOR CONSTRUCTION

CLIENT
BURNS & MCDONNELL
SAN DIEGO GAS & ELECTRIC

SITE
SYCAMORE TO PEÑASQUITOS
ALTERNATE ROUTE 5 - SEGMENT C

PROJECT NO. 16-E-008-AC

ARK ENGINEERING & TECHNICAL SERVICES, INC.
ARK ENGINEERING &
TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

TITLE
COVER SHEET

DRAWN BY SRM | DATE 8/24/16 | SIZE B
APPROVED BY RFA | DATE 5/12/17 | SCALE NTS

DWG. NO. 16008-100 | REV A
CAD FILE NAME 16008-100-1-RA | SHEET 1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION	5/12/17	RFA

CONSTRUCTION NOTES:

1. ALL PIPELINE CONNECTION WORK TO BE COMPLETED BY KINDER MORGAN.
2. ALL WORK NOT INVOLVING PIPELINE CONNECTIONS (ZINC RIBBON, ETC.) TO BE COMPLETED BY SDG&E.

30" SAN DIEGO GAS & ELECTRIC PIPELINE DEEPWELL INSTALLATION LOCATIONS AND REQUIRED MATERIALS

DEEPWELL NO.	GPS LOCATION	DEEPWELL DEPTH (FT)	NUMBER OF DEEPWELLS	NUMBER OF SSD'S	2/0 COPPER (FT)	#6 AWG COPPER CABLE SSD TO PIPE (FT)	#6 AWG COPPER CABLE TO PIPELINE EXOTHERMIC WELD CONNECTIONS	30'x8" I.D. PVC CASING, TYPE 80	CONDUCRETE BACKFILL (BAGS)	#2 COPPER CABLE TO 2/0 COPPER EXOTHERMIC WELD CONNECTIONS	SSD PEDESTALS	#2 AWG COPPER CABLE SSD TO 2/0 COPPER (FT)	3/4" X 10' GROUND RODS
1	32.919216°N, 117.221099°W	100	1	1	100	100	2	1	13	1	1	50	1
2	32.906378°N, 117.213335°W	150	1	1	150	100	2	1	20	1	1	50	1
TOTAL:			2	2	250	200	4	2	33	2	2	100	2

16" KINDER MORGAN PIPELINE DEEPWELL INSTALLATION LOCATIONS AND REQUIRED MATERIALS

DEEPWELL NO.	GPS LOCATION	DEEPWELL DEPTH (FT)	NUMBER OF DEEPWELLS	NUMBER OF SSD'S	2/0 COPPER (FT)	#6 AWG COPPER CABLE SSD TO PIPE (FT)	#6 AWG COPPER CABLE TO PIPELINE EXOTHERMIC WELD CONNECTIONS	30'x8" I.D. PVC CASING, TYPE 80	CONDUCRETE BACKFILL (BAGS)	#2 COPPER CABLE TO 2/0 COPPER EXOTHERMIC WELD CONNECTIONS	SSD PEDESTALS	#2 AWG COPPER CABLE SSD TO 2/0 COPPER (FT)	3/4" X 10' GROUND RODS
1	32.916143°N, 117.218857°W	100	1	1	100	100	2	1	13	1	1	50	1
2	32.913765°N, 117.217435°W	100	1	1	100	100	2	1	13	1	1	50	1
3	32.890950°N, 117.203732°W	125	1	1	125	100	2	1	17	1	1	50	1
4	32.889571°N, 117.203080°W	100	1	1	100	100	2	1	13	1	1	50	1
TOTAL:			4	4	425	400	8	4	56	4	4	200	4

ISSUED FOR CONSTRUCTION

CLIENT
BURNS & MCDONNELL
SAN DIEGO GAS & ELECTRIC

SITE
SYCAMORE TO PEÑASQUITOS
ALTERNATE ROUTE 5 - SEGMENT C

ARK ENGINEERING & TECHNICAL SERVICES, INC.

ARK ENGINEERING & TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

TITLE
DEEPWELL INSTALLATION LOCATIONS AND REQUIRED MATERIALS

DRAWN BY: SRM | DATE: 8/24/16 | SIZE: B

DWG. NO. 16008-200 | REV A

PROJECT NO. 16-E-008-AC | APPROVED BY: RFA | DATE: 5/12/17 | SCALE: NTS | CAD FILE NAME: 16008-200-1-RA | SHEET 1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION	5/12/17	RFA

CONSTRUCTION NOTES:

1. ALL PIPELINE CONNECTION WORK TO BE COMPLETED BY KINDER MORGAN.

2. ALL WORK NOT INVOLVING PIPELINE CONNECTIONS (ZINC RIBBON, ETC.) TO BE COMPLETED BY SDG&E.

30" SAN DIEGO GAS & ELECTRIC PIPELINE SSD LOCATIONS

DEEPWELL NO.	SSD COORDINATES
1	32.919216°N, 117.221099°W
2	32.906378°N, 117.213335°W

16" KINDER MORGAN PIPELINE SSD LOCATIONS

DEEPWELL NO.	SSD COORDINATES
1	32.916143°N, 117.218857°W
2	32.913765°N, 117.217435°W
3	32.890950°N, 117.203732°W
4	32.889571°N, 117.203080°W

ISSUED FOR CONSTRUCTION

CLIENT
BURNS & MCDONNELL
SAN DIEGO GAS & ELECTRIC

SITE
SYCAMORE TO PEÑASQUITOS
ALTERNATE ROUTE 5 - SEGMENT C

ARK ENGINEERING & TECHNICAL SERVICES, INC.

ARK ENGINEERING & TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

TITLE
SSD LOCATIONS

DRAWN BY	DATE	SIZE		DWG. NO.	REV
SRM	8/24/16	B	The information contained on this drawing is confidential and is the sole property of ARK Engineering. Transferring this information to a third party or reproducing in part or in full without a written consent from ARK Engineering is prohibited.	16008-201	A

PROJECT NO.	APPROVED BY	DATE	SCALE	CAD FILE NAME	SHEET
16-E-008-AC	RFA	5/12/17	NTS	16008-201-1-RA	1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION	5/12/17	RFA

EXOTHERMIC WELD INSTRUCTIONS:

1. FIRST DETERMINE IF THE PIPELINE IS SUITABLE FOR EXOTHERMIC WELDING BY CONDUCTING THE FOLLOWING TESTS:

   A) DETERMINE THAT THE PIPELINE SMYS (SPECIFIED MINIMUM YIELD STRENGTH) IS <80,000 PSI.
   B) DETERMINE THAT PIPELINE WALL THICKNESS IS 1/8" (0.125") OR GREATER.
   C) PERFORM ULTRASONIC TESTING TO PIPELINE TO DETERMINE THAT NO SURFACE OR INTERNAL DEFECTS EXIST.

2. FOR EACH CABLE TO PIPELINE CONNECTION (EXOTHERMIC WELD), REMOVE A 3"X3" MAX AREA OF PIPELINE COATING AT THE 12:00 O'CLOCK POSITION ON THE PIPELINE AND BRUSH UNTIL SHINY. ANY ADJACENT CABLE CONNECTIONS SHALL BE NO CLOSER THAN 9" AND NO FURTHER THAN 18".

3. PREPARE PIPELINE SURFACE AS SPECIFIED BY PIPELINE COATING MANUFACTURER.

4. DETAIL "A" SHOWS POSSIBLE METHOD OF CABLE STRAIN RELIEF FOR NEW PIPE INSTALLATIONS. THIS METHOD IS NOT A REQUIREMENT. OTHER MEANS OF STRAIN RELIEF MAY BE USED.

5. STRIP BACK ANY CABLE INSULATION 1"-2" AND TAPE CABLE TO PIPE.

6. ENSURE THAT THE PIPELINE WELD AREA AND CABLE ARE CLEAN AND DRY PRIOR TO WELDING.

7. USE SPECIFIC WELD MOLD AND WELD METAL AS INDICATED IN DRAWING MATERIALS LIST.

8. IF INDICATED, USE COPPER HEAT SLEEVE ON CABLE END TO BE WELDED.

9. USE ONLY A 15 GRAM WELDING CHARGE. DO NOT EXCEED.

10. PLACE THE METAL RETAINER DISK IN THE SPECIFIED WELD MOLD AND DUMP (DO NOT POUR) WELD METAL POWDER ONTO THE DISK. MAKE SURE THAT ALL OF THE FINE STARTING POWDER IS IN THE MOLD. IF ANY POWDER REMAINS IN THE CARTRIDGE BOTTOM, SQUEEZE OUT INTO MOLD AND BREAK UP.

11. CLOSE MOLD LID.

12. REPLACE CAP ON EMPTY WELD METAL CARTRIDGE AND PLACE BACK INTO CARTRIDGE PACK BOX UPSIDE DOWN TO KEEP THE REMAINING CARTRIDGES UPRIGHT.

13. LAY THE CABLE END ON THE PREPARED PIPE SURFACE USING A SPRING LOADED CHAIN CLAMP TO HOLD CRUCIBLE TIGHT TO PIPELINE.

14. USING EYE AND HAND PROTECTION, STAND ON THE OPPOSITE SIDE OF THE CRUCIBLE FROM THE TOUCH HOLE AND IGNITE POWDER WITH SPARK FROM FLINT GUN. *CAUTION: POWDER WILL FLASH WHEN IGNITED*

15. WHEN WELD HAS SET, REMOVE WELD MOLD AND TEST CONNECTION BY RAPPING SHARPLY WITH A SLAG HAMMER. IF THERE IS ANY INDICATION THAT A COMPLETE WELD HAS NOT BEEN ACHIEVED, REMOVE THE WELD AND RE-APPLY.

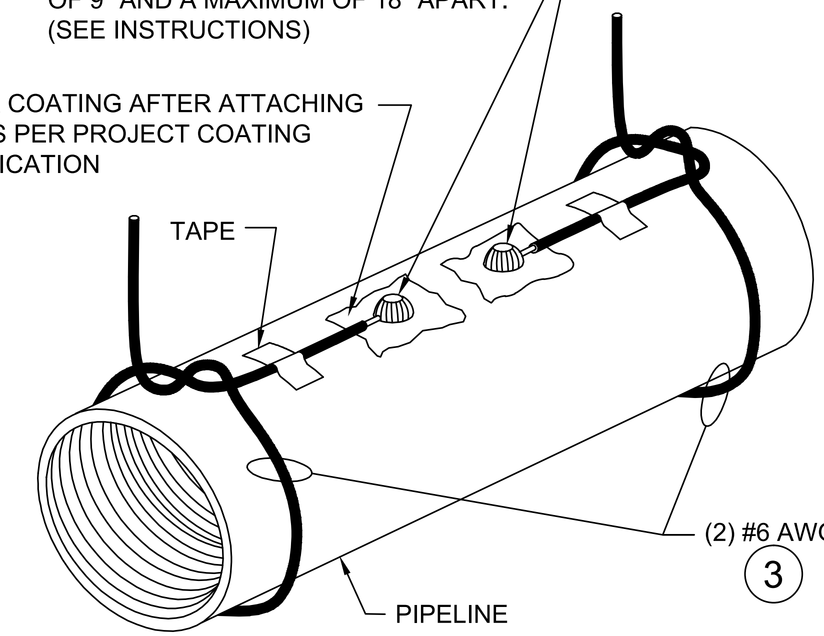
16. IF WELD IS GOOD, REMOVE ANY SLAG WITH HAMMER AND CLEAN USING A WIRE BRUSH.

17. AFTER COMPLETING THE EXOTHERMIC WELD CONNECTION TO THE PIPELINE, ALL COATING DAMAGE IS TO BE CLEANED AND COATED WITH 20 MILS MINIMUM OF SPC SP-2888, TWO PART EPOXY COATING OR SAN DIEGO GAS & ELECTRIC APPROVED EQUAL.

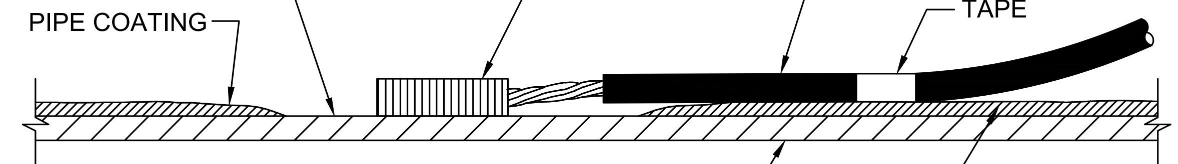
18. REFER TO SAN DIEGO GAS & ELECTRIC REPAIR SPECIFICATIONS AND PRODUCT DATA SHEET TO DETERMINE IF REPAIR IS ACCEPTABLE.

19. AFTER REPAIR COATING HAS CURED ACCORDING TO MANUFACTURER'S SPECIFICATIONS, HOLIDAY DETECTION MUST BE PERFORMED.

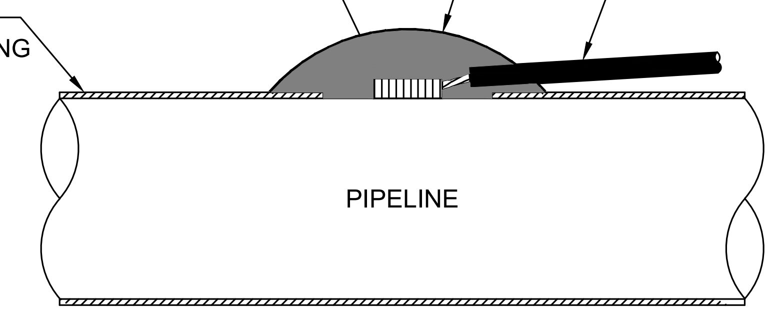
ALL CONNECTIONS TO PIPELINE TO BE COMPLETED BY KINDER MORGAN.



DETAIL 'A'
CABLE TO PIPELINE ATTACHMENT DETAIL



DETAIL 'B'
EXOTHERMIC WELD CONNECTION



DETAIL 'C'
CORROSION PROTECTION SEAL

ISSUED FOR CONSTRUCTION

CLIENT: BURNS & MCDONNELL, SAN DIEGO GAS & ELECTRIC SITE: SYCAMORE TO PEÑASQUITOS ALTERNATE ROUTE 5 - SEGMENT C	ARK ENGINEERING & TECHNICAL SERVICES, INC. ARK ENGINEERING & TECH. SERVICES, INC. 639 GRANITE STREET SUITE 200 BRAINTREE, MA 02184 U.S.A.	TITLE: CABLE TO PIPELINE CONNECTION DETAILS	
	DRAWN BY: SRM	DATE: 8/24/16	SIZE: B
PROJECT NO.: 16-E-008-AC	APPROVED BY: RFA	DATE: 5/12/17	SCALE: NTS

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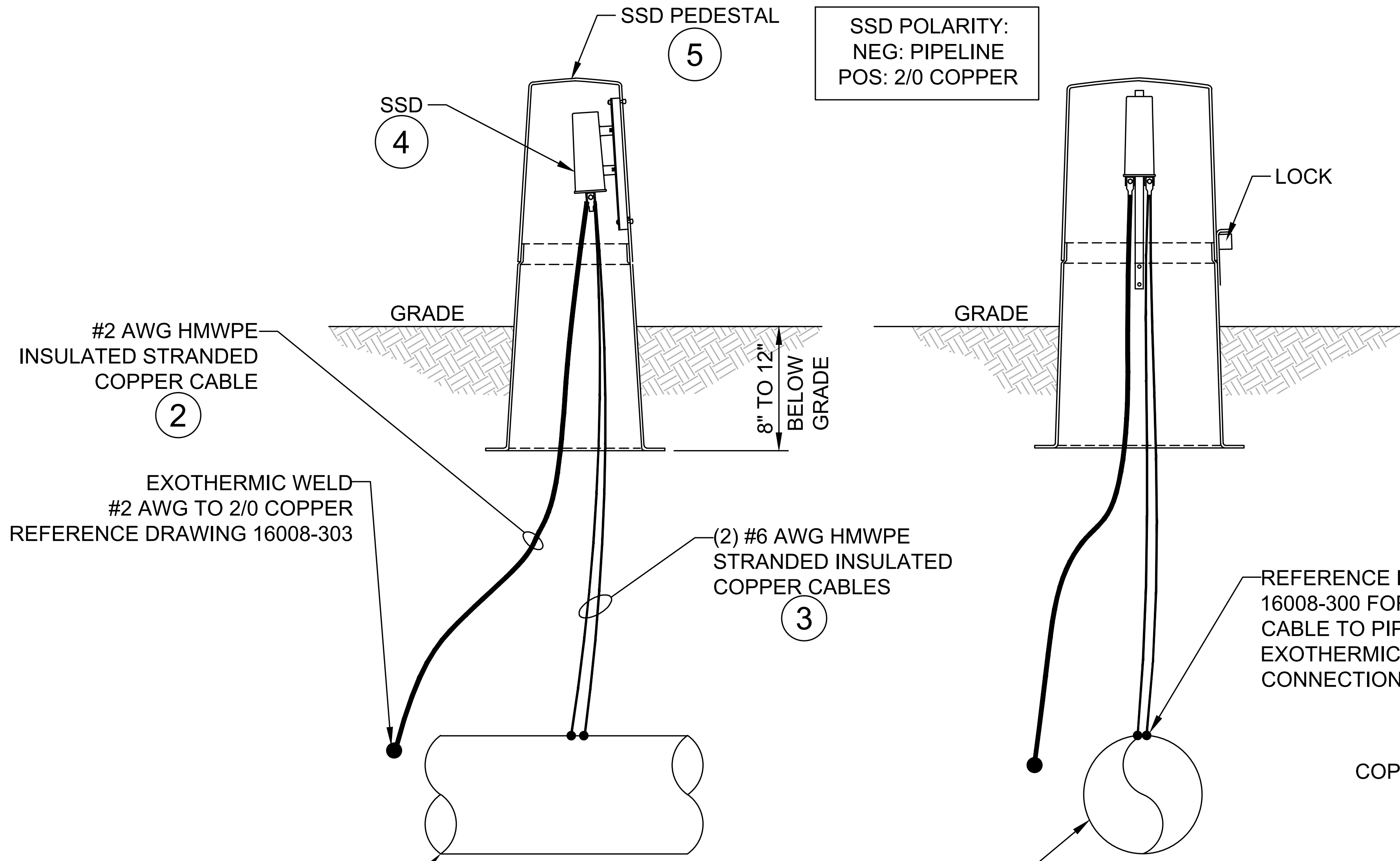
DWG. NO.	REV	CAD FILE NAME	SHEET
16008-300	A	16008-300-1-RA	1 OF 1

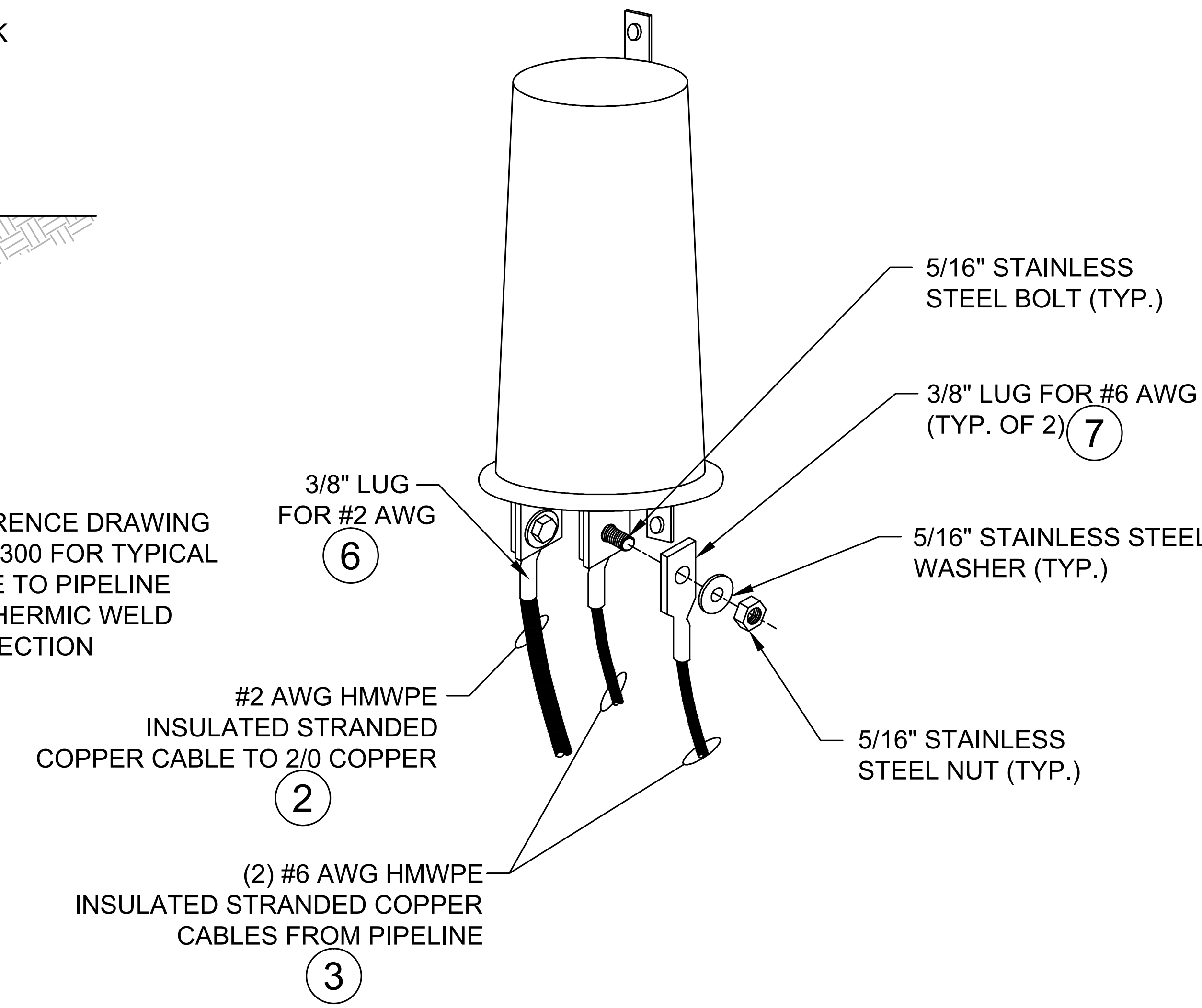
REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION	5/12/17	RFA



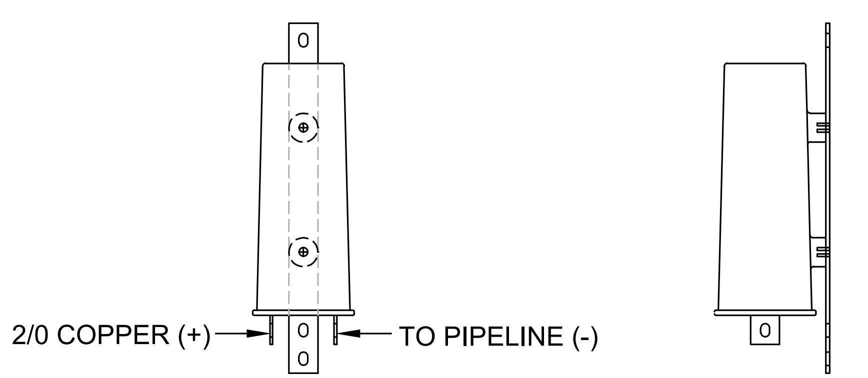
DETAIL A
SIDE VIEW

DETAIL B
FRONT VIEW

SSD INSTALLATION DETAILS



CABLE TO SSD TERMINAL CONNECTION DETAIL



FRONT VIEW

SIDE VIEW

SOLID STATE DECOUPLER DEVICE (SSD)

NOTES:

1. SSD IS TO BE MOUNTED INSIDE THE FIBERGLASS PEDESTAL. ALL COPPER CABLES ARE TO PASS THROUGH BOTTOM OF PEDESTAL.
2. INSTALL PEDESTAL AS CLOSE AS POSSIBLE TO PIPING CONNECTIONS TO REDUCE LEAD LENGTHS.

ISSUED FOR CONSTRUCTION

CLIENT
BURNS & MCDONNELL
SAN DIEGO GAS & ELECTRIC

SITE
SYCAMORE TO PEÑASQUITOS
ALTERNATE ROUTE 5 - SEGMENT C

PROJECT NO. 16-E-008-AC

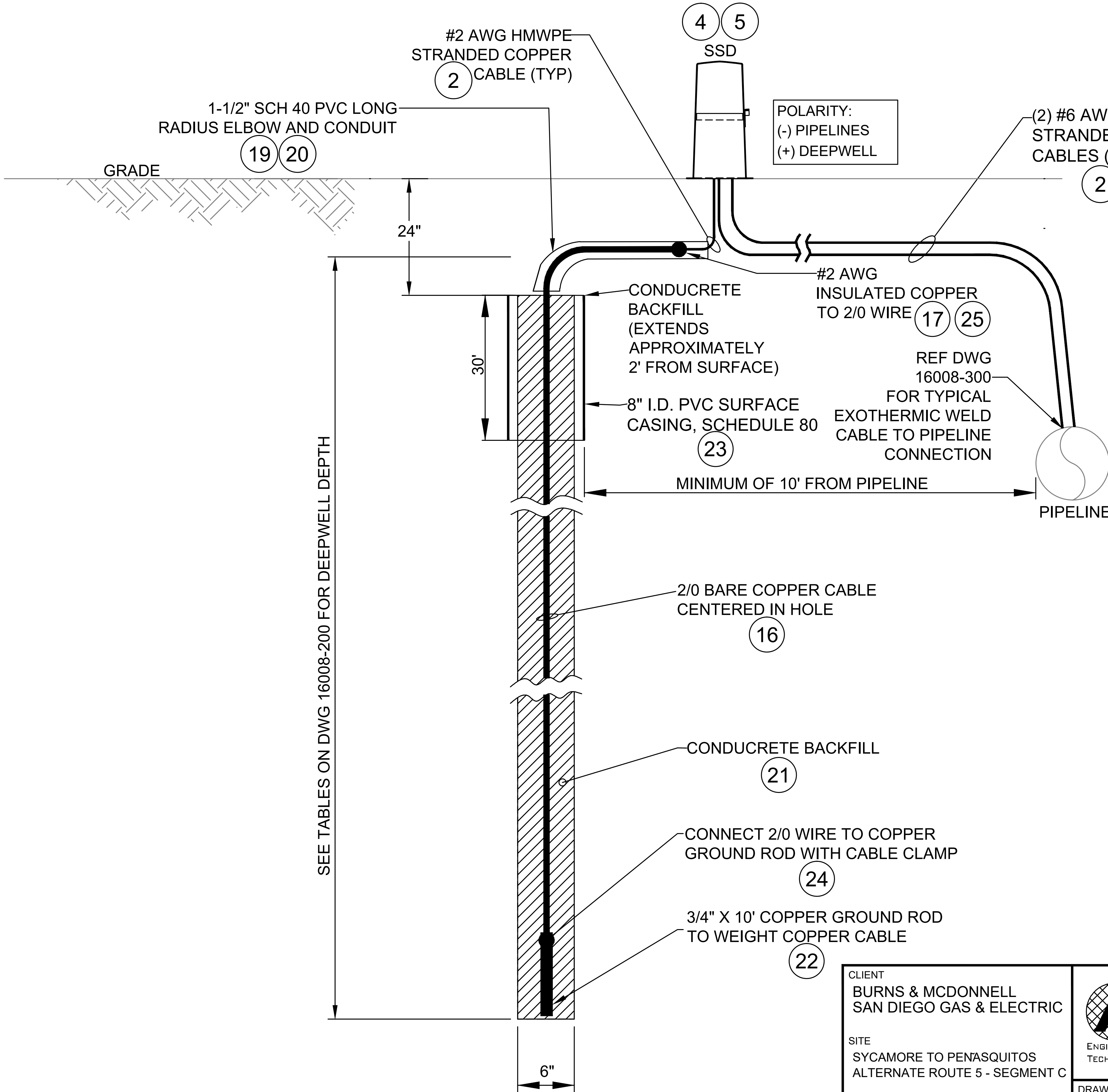
ARK ENGINEERING & TECHNICAL SERVICES, INC.

ARK ENGINEERING & TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

TITLE
SOLID STATE DECOUPLER (SSD)
DEVICE CONNECTION DETAILS

DRAWN BY	DATE	SIZE		DWG. NO.	REV
SRM	8/24/16	B	The information contained on this drawing is confidential and is the sole property of ARK Engineering. Transferring this information to a third party or reproducing in part or in full without a written consent from ARK Engineering is prohibited.	16008-301	A
APPROVED BY: RFA	DATE: 5/12/17	SCALE: NTS	CAD FILE NAME: 16008-301-1-RA		SHEET 1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION	5/12/17	RFA



DEEPWELL ANODE INSTALLATION

NOTES:

1. SURFACE CASING WITH MINIMUM 8" I.D. SHOULD BE INSTALLED TO A DEPTH OF 32'. THE HOLE FOR THE DEEP ANODE SYSTEM CAN THEN BE DRILLED THROUGH THE OPENING OF THE SURFACE CASING.
2. DRILL HOLE TO DESIGNED DEPTH AND DIAMETER.
3. PLACE WEIGHTED, 2/0 BARE COPPER CABLE IN CENTER OF HOLE, LEAVING A MINIMUM OF 10' OF CABLE EXTENDING OUT OF THE TOP OF THE HOLE FOR CONNECTION TO #2 WIRE.
4. MIX CONDUCRETE (ITEM 21) INTO A SLURRY AT A RATIO OF 4.2 GALLONS OF WATER TO EACH 55 POUND BAG OF CONDUCRETE.
5. PUMP SLURRIED CONDUCRETE INTO THE HOLE FROM THE BOTTOM OF THE HOLE TO THE TOP OF THE PVC PIPE USING A TREMMY TUBE OR EQUIVALENT.

ISSUED FOR CONSTRUCTION

CLIENT
BURNS & MCDONNELL
SAN DIEGO GAS & ELECTRIC

SITE
SYCAMORE TO PEÑASQUITOS
ALTERNATE ROUTE 5 - SEGMENT C

ARK ENGINEERING & TECHNICAL SERVICES, INC.

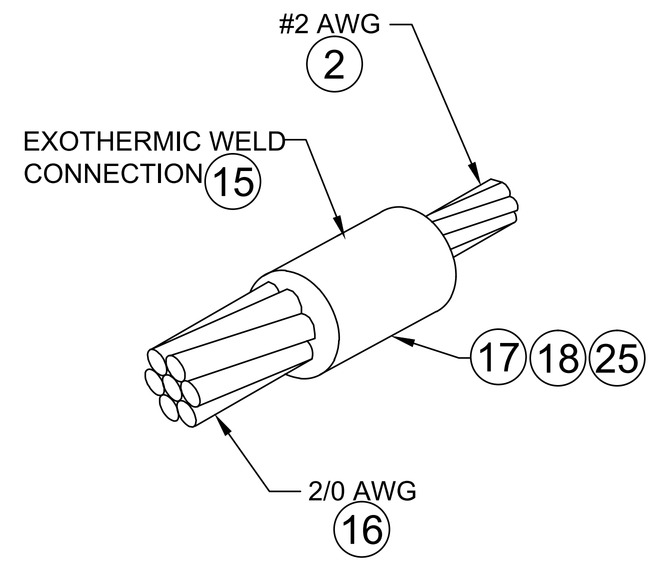
ARK ENGINEERING & TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

TITLE
DEEPWELL
INSTALLATION DETAILS

DRAWN BY	DATE	SIZE		DWG. NO.	REV
SRM	8/24/16	B		16008-302	A

PROJECT NO.	APPROVED BY	DATE	SCALE	CAD FILE NAME	SHEET
16-E-008-AC	RFA	5/12/17	NTS	16008-302-1-RA	1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION	5/12/17	RFA



DETAIL 'A'

2/0 AWG COPPER CABLE TO #2 AWG COPPER CABLE
IN-LINE EXOTHERMIC WELD INSTALLATION

DETAIL	MOLD	WELD METAL
'A'	M-5166	#45CP

ISSUED FOR CONSTRUCTION

NOTES:

1. ALL EXOTHERMIC WELD CONNECTIONS ARE TO BE SEALED WITH ROYSTON "SPLICE RIGHT" SPLICE KIT (ITEM 15), OR SAN DIEGO GAS & ELECTRIC APPROVED ALTERNATIVE.

CLIENT
BURNS & MCDONNELL
SAN DIEGO GAS & ELECTRIC

SITE
SYCAMORE TO PEÑASQUITOS
ALTERNATE ROUTE 5 - SEGMENT C

PROJECT NO. 16-E-008-AC

ARK ENGINEERING & TECHNICAL SERVICES, INC.

ARK ENGINEERING & TECH. SERVICES, INC.
639 GRANITE STREET
SUITE 200
BRAINTREE, MA
02184 U.S.A.

DRAWN BY SRM | DATE 8/24/16 | SIZE B
APPROVED BY RFA | DATE 5/12/17 | SCALE NTS

TITLE
EXOTHERMIC WELD
CONNECTION DETAILS

DWG. NO. 16008-303 | REV A
CAD FILE NAME 16008-303-1-RA | SHEET 1 OF 1

REV	DESCRIPTION	DATE	APPROVED
A	ISSUED FOR CONSTRUCTION	5/12/17	RFA

ITEM	16" KINDER MORGAN PIPELINE QUANTITY	30" SDG&E PIPELINE QUANTITY	DESCRIPTION
2	200'	100'	COPPER CABLE, #2 AWG HMWPE (BLACK) INSULATED, STRANDED, SOFT-DRAWN, COMMERCIALLY PURE COPPER, ASTM B8, CLASS B STD. USED FOR CONNECTIONS OF 2/0 COPPER CABLE TO SOLID-STATE DECOUPLING DEVICES.
3	400'	200'	COPPER CABLE, #6 AWG (BLACK) HMWPE INSULATED, STRANDED, SOFT-DRAWN, COMMERCIALLY PURE COPPER, ASTM B8, CLASS B STD. USED FOR CONNECTIONS OF SOLID-STATE DECOUPLING DEVICES TO PIPE.
4	4	2	SOLID-STATE DECOUPLING DEVICE (SSD), DAIRYLAND ELECTRICAL INDUSTRIES P/N SSD-2/2-5.0-100-R. EQUIPPED WITH STANDARD CONNECTORS. -2V/+2V BLOCKING VOLTAGE. 100KA LIGHTNING SURGE CURRENT RATING (4 X 10 WAVEFORM). 45 AMP STEADY-STATE CURRENT RATING AT 50/60 HZ. 5KA FAULT CURRENT RATING AT 30 CYCLES.
5	4	2	SSD PEDESTAL, DAIRYLAND ELECTRICAL INDUSTRIES P/N MTP-36. FIBERGLASS CASE: 9" X 14" X 36" HIGH, 22-1/2" BASE, 13-1/2" TOP WITH 2 FLANGES STAINLESS STEEL BACK-PLATES FOR MOUNTING THE SOLID-STATE DECOUPLING DEVICE.
6	4	2	TWO HOLE, LONG BARREL COMPRESSION LUG, 3/8" HOLE, BURNDY P/N YAZ2C-2TC38. USED WITH #2 AWG STRANDED COPPER CABLE. FOR 2/0 COPPER TO SSD CONNECTIONS
7	8	4	TWO HOLE, LONG BARREL COMPRESSION LUG, 3/8" HOLE, BURNDY P/N YAZ6C-2TC38. USED WITH #6 AWG STRANDED COPPER CABLE. FOR SSD CONNECTION TO PIPE.
8	1	1	EXOTHERMIC WELD MOLD, THERMOWELD P/N M-0102. HANDLE CLAMP AND FLINT IGNITOR ARE INCLUDED. USED FOR EXOTHERMIC WELD CONNECTION OF #6 AWG COPPER CABLE TO PIPE. USE #15CP WELD METAL.
11	1 BOX	1 BOX	EXOTHERMIC WELD METAL, THERMOWELD P/N #15CP. BONDS #6 AWG CABLE TO PIPELINE. 20 SHOTS PER BOX.
14	4 CARTRIDGES	2 CARTRIDGES	TWO PART EPOXY: SPECIALTY POLYMER COATINGS, INC SP-2888, TWO PART EPOXY. FOR REPAIRING PIPE COATING AT #6 AWG CONNECTIONS TO PIPE. APPLY 20 MILS THICK MIN., 50 ML CARTRIDGE WILL REPAIR TWO EXOTHERMIC CONNECTIONS TO PIPELINE. INCLUDES TWO MINI STATIC MIXING TIPS PER 50ML CARTRIDGE.
15	4	2	ROYSTON SPLICERIGHT KIT (OR APPROVED EQUAL). INSULATION KIT FOR EXOTHERMIC WELD SPLICE CONNECTIONS.
16	425'	250'	2/0 STRANDED, BARE, SOFT-DRAWN COPPER CABLE. TO RUN DEEPWELLS.
17	1	1	EXOTHERMIC WELD MOLD, THERMOWELD P/N M-5166. USED FOR IN-LINE SPLICE OF 2/0 COPPER TO #2 AWG CABLE. USE #45CP WELD METAL.
18	1	1	HANDLE CLAMP AND FLINT IGNITOR, THERMOWELD P/N 40-0106-00. USED FOR 2/0 COPPER TO TO #2 AWG CABLE IN-LINE SPLICE CONNECTIONS.
19	4	2	1-1/2" SCHEDULE 40 PVC CONDUIT. CUT TO PROPER LENGTH IN FIELD. CONTAINS 2/0 COPPER AND #2 AWG CABLE FROM DEEPWELL TO SSD.
20	4	2	1-1/2" SCHEDULE 40 PVC ELBOW. CONTAINS 2/0 COPPER FROM DEEPWELL TO SSD.
21	56 BAGS	33 BAGS	DM100 CONDUCRETE, CONDUCTIVE CONCRETE BACKFILL. 55 POUND BAGS. SAE, INC.
22	4	2	3/4" DIAMETER, 10 FOOT LONG COPPER COATED GROUND ROD, GALVAN INDUSTRIES P/N 7510. USED TO WEIGHT 2/0 COPPER IN DEEPWELL.
23	4	2	30' X 8" ID. PIPE FOR DEEPWELL CASING (SCHEDULE 80).
24	4	2	GROUND ROD CLAMP, GALVAN INDUSTRIES P/N SRC.
25	N/A	1	EXOTHERMIC WELD METAL, THERMOWELD P/N #45CP. USED FOR #2 AWG CABLE TO 2/0 COPPER CABLE CONNECTIONS. 10 SHOTS PER BOX.

NOTE:

ARK ENGINEERING CAN PROVIDE ALL MATERIALS LISTED ABOVE AND INSTALLATION SERVICES. PLEASE CALL 1-800-469-3436 FOR A MATERIAL OR INSTALLATION QUOTATION.

ISSUED FOR CONSTRUCTION

CLIENT
BURNS & MCDONNELL
SAN DIEGO GAS & ELECTRIC

SITE
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ALTERNATE ROUTE 5 - SEGMENT C

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639 GRANITE STREET
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02184 U.S.A.

TITLE
MATERIALS LIST

DRAWN BY	DATE	SIZE		DWG. NO.	REV
SRM	8/24/16	B	The information contained on this drawing is confidential and is the sole property of ARK Engineering. Transferring this information to a third party or reproducing in part or in full without a written consent from ARK Engineering is prohibited.	16008-400	A

PROJECT NO.	APPROVED BY	DATE	SCALE	CAD FILE NAME	SHEET
16-E-008-AC	RFA	5/12/17	NTS	16008-400-1-RA	1 OF 1

APPENDIX E –
AC MITIGATION SYSTEM MAPS

AC Mitigation System Design Option 3 – 16" Kinder Morgan Pipeline AC Mitigation System

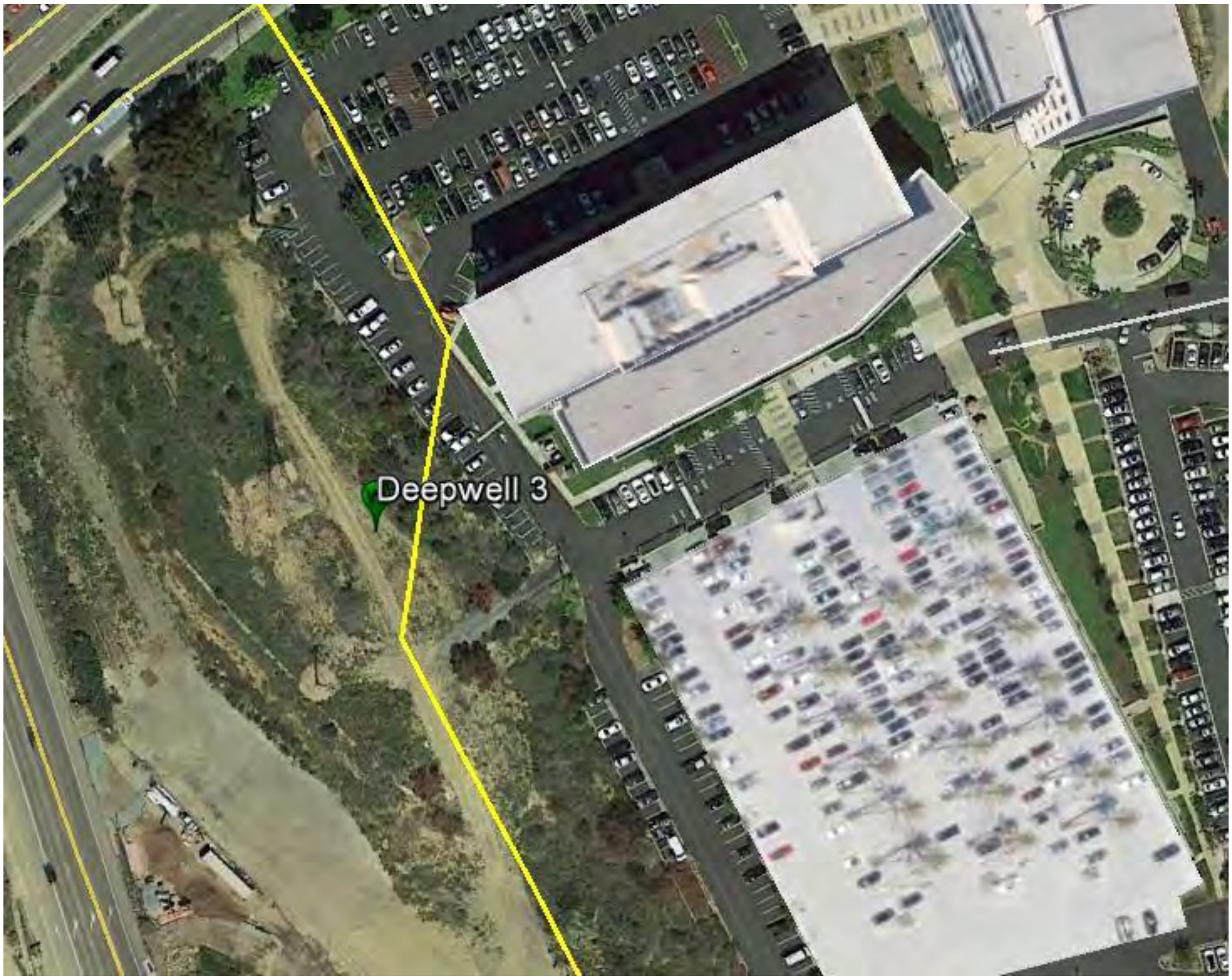
Deepwell Section #1

AC Mitigation System Design Option 3 – 16" Kinder Morgan Pipeline AC Mitigation System

Deepwell Section #2

AC Mitigation System Design Option 3 – 16" Kinder Morgan Pipeline AC Mitigation System

Deepwell Section #3

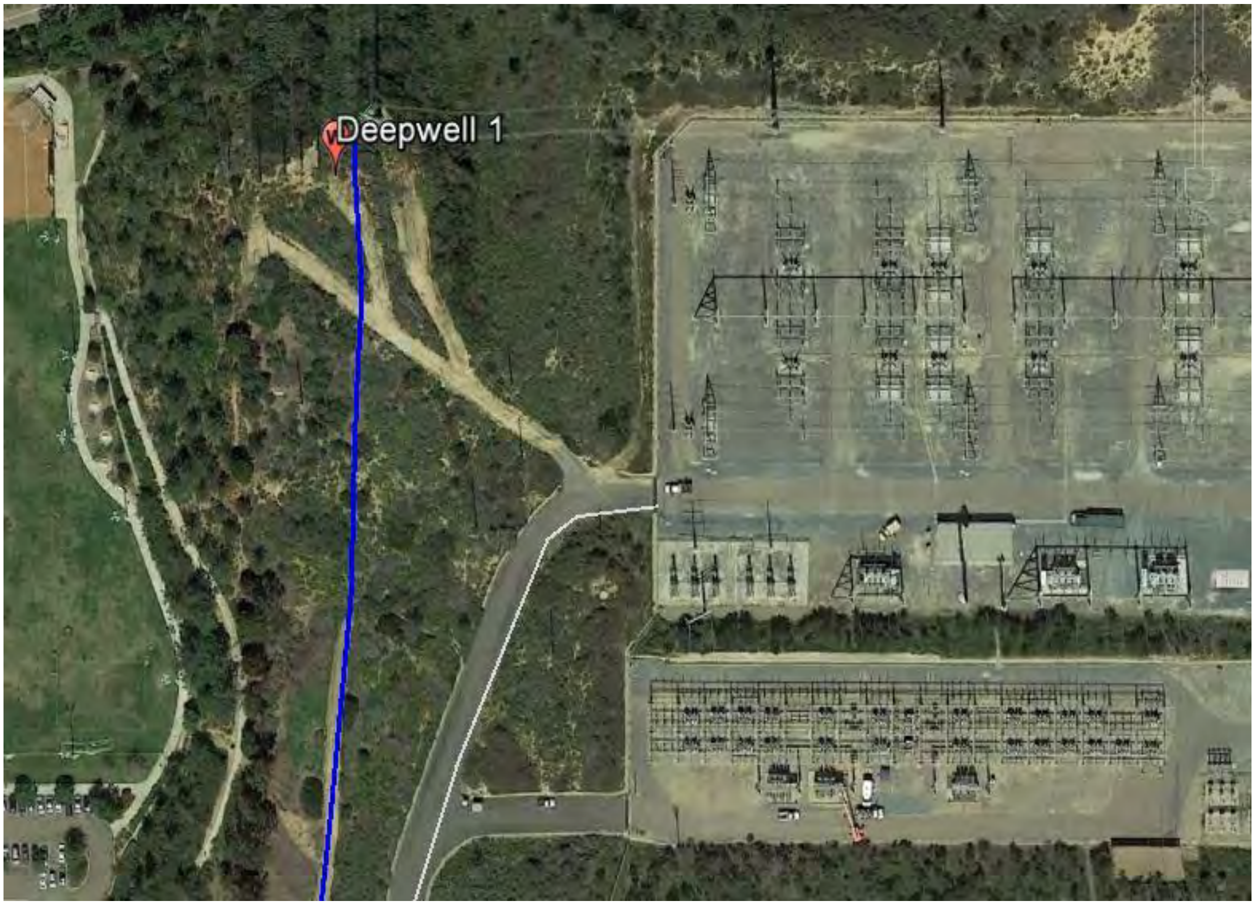


AC Mitigation System Design Option 3 – 16" Kinder Morgan Pipeline AC Mitigation System

Deepwell Section #4

AC Mitigation System Design Option 3 – 30" SDG&E Pipeline AC Mitigation System

Deepwell Location #1



AC Mitigation System Design Option 3 – 30" SDG&E Pipeline AC Mitigation System

<u>Deepwell Location #2</u>