CATHODIC PROTECTION
SURVEY REPORT
MCB - CAMP LEJEUNE, N.C.

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INTRODUCTION

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DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA

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CATHODIC PROTECTION SURVEY

at the

MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

FINAL SUBMITTAL
January 14, 1985

prepared by

MENENDEZ-DONNELL & ASSOCIATES, INC.
Houston, Texas

in association with

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SUMMARY

MENENDEZ-DONNELL & ASSOCIATES, INC., in association with its consultant, GENERAL CATHODIC PROTECTION SERVICES, INC., conducted a corrosion control survey of underground POL systems, water distribution system, elevated water tanks, and underground fuel tanks at the U.S. Marine Corps Base, Camp Lejeune, North Carolina, during October and November, 1984.

The corrosion survey included inspection and evaluation of existing elevated water tanks' cathodic protection systems; inspection and testing of underground steel structures, and recommendations for cathodic protection systems for proposed new construction.

None of the POL and fuel storage facilities has cathodic protection.

The underground water distribution system has no cathodic protection, and would be the most difficult and expensive of all base piping systems to protect since it consists primarily of bare or poorly coated cast iron pipe and is not electrically continuous.

The fourteen elevated water tanks were found to be under complete cathodic protection and with the internal coating in very good condition.

The soil resistivity tests showed a wide variation ranging from a low of 1,400 ohm-cm at Bldg. M622 in the Montford Camp area, up to 1,150,000 ohm-cm, on Snead's Road between Marine Road and Amphibian Road. Low resistivity corrosive soils below 5,000 ohm-cm constitute about 8% and moderately corrosive soils between 5,000 and 10,000 ohm-cm constitute about 21% of the totals. Laboratory tests of soil samples showed the pH to be essentially neutral, and both chloride and sulfate contents are moderate.

A new impressed current cathodic protection system should be provided for the fifteen underground steel, tanks and existing steel piping at the Fuel Farm.

New impressed current cathodic protection systems should be provided for the underground fuel storage tanks located at the Main Exchange gas station; at Bldg. No. 1885; at Bldg. No. 1775; at the Courthouse Bay area gasoline station and diesel fuel storage area; and at Bldg. FC-202, French Creek area.

New sacrificial cathodic protection systems should be provided for the underground fuel Storage Tanks located at the Rifle Range area, at the Beach area, and at the New Naval Hospital.

Cathodic protection of the underground water piping system with sacrificial type, galvanic anodes is recommended for piping in soils with resistivities of 5000 ohm-cm or less.

Cost estimates for the recommended work are:

1. Install a new rectifier and groundbed on tanks and piping at the Fuel Farm; $30,710.00

2. Install 5 new rectifiers and groundbeds on various fuel tanks throughout the base as previously referenced; $36,667.00

3. Install a new rectifier and groundbed on tanks at the Main Exchange: $9,640.00

4. Install magnesium anodes on underground Fuel Storage Tanks at the Rifle Range, New Naval Hospital and the Beach area:

   $6,553. + $ 20,610. = $27,163.00

1.0 INTRODUCTION AND PURPOSE

This report contains all data acquired and conclusions reached as a result of the corrosion survey of underground POL system, utility systems, water distribution systems, elevated water tanks and underground fuel storage tanks at the Marine Corps Base, Camp Lejeune, North Carolina.

Field work was started on November 5, 1984, and was completed by November 14, 1984. It consisted of collecting data and studying all existing cathodic protection systems, obtaining soil resistivity measurements, obtaining soil and water samples at selective locations, conducting continuity tests, obtaining structure-to-electrolyte potential measurements, and performing current requirement tests on line sections and selected underground storage tanks.

There are fourteen existing impressed current cathodic protection systems on the elevated water tanks. No cathodic protection exists for the following facilities:

1. The underground water distribution system.
2. Tanks and piping at the Fuel Farm.
3. Various underground fuel storage tanks throughout the Base.

All data obtained during this survey is included in the Tables of Appendix B. Results and analysis of the data are included in Sections 2.1.3 and 2.2.3. The test procedures used during this survey are described in Section 2.1.2 and 2.2.2 of this report. The layouts of recommended cathodic protection systems and test points used during this survey are shown on Drawings enclosed in Appendix H of this report.

Photographs were taken of underground piping systems, elevated water storage tanks, rectifiers and various miscellaneous structures. These may be found in Appendix G.

The purpose of this survey was to evaluate the effectiveness of the existing cathodic protection systems; to determine any additional corrosion control requirements and to establish the most feasible type of additional cathodic protection systems, when required. In addition, supportive information, such as drawings, photographs, cost estimates and appropriate recommendations are supplied.

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SURVEY

2.0 CORROSION CONTROL SURVEY

2.1 POL System

2.1.1 System Description

The POL System consists of tank car unloading facilities located north of the Fuel Farm in the Industrial Area, a truck loading station, storage tanks, refueling facilities and the connecting underground piping.

MOGAS fuel is received at the Fuel Farm and stored in ten underground steel tanks of varying capacities. The total storage capacity of MOGAS Fuel is 141,000 gallons.

Diesel fuel is received at the Fuel Farm and stored in two 12,000 gallon and in two 15,000 gallon underground steel tanks.

Number 6 fuel is received at the Fuel Farm and stored in a 600,000 gallon aboveground steel tank.

Two other aboveground steel tanks No. S-1701 and S-1735, store 420,000 gallons and 172,000 gallons of No. 6 fuel respectively. In addition to the Fuel Farm storage facilities, MOGAS, Diesel, Kerosene, number 2 and number 6

fuels are stored for local use throughout the Base in tanks with capacities ranging from 2,000 gallons to 30,000 gallons. For detailed breakdown of these fuel storage facilities at each area, please refer to Inventory, Appendix A.

2.1.2 Test Procedures

Test procedures on the POL Systems included taking soil resistivity and structure-to-electrolyte potential measurements, conducting current requirement tests to determine design criteria for unprotected structures, and collecting soil and water samples for laboratory analysis.

2.1.2.1 Soil Resistivity Survey

Soil resistivity measurements were acquired at approximately 1000 ft. intervals along underground piping systems throughout the camp to 5-foot average depths, using a Nilsson Model 400 soil resistivity meter and the "Wenner" four pin method. Measurements were also acquired to 10 ft., 15 ft., and 20 ft. depths near and around all underground tanks within the POL system. The location of individual resistivity measurements are shown in Drawings No. 5000 through 5020, of Appendix H, and the soil resistivity data are presented in Table I, Appendix B.

2.1.2.2 Structure-to-Electrolyte Potential Survey

Structure-to-electrolyte potential measurements were taken on the POL system facilities, using a high impedance digital Beckman Model 3010 volt-ohm meter with reference to a saturated copper-copper sulfate half cell.

Potential measurements were taken at representative locations including piping at pumphouses, and around storage tanks. For each measurement the reference electrode was placed directly over or as near as possible to the structure subject to test. All acquired potential measurement data are presented in Table III, Appendix B. Test point locations are shown in Drawings No. 5019 & 5020

2.1.2.3 Current Requirement Tests

Current requirement tests were conducted on various underground tanks to aid in determining the Cathodic Protection design criteria for POL structures. This procedure consisted of applying direct current to the structure under test using a 12-volt automobile battery as a temporary power source and 5/8-inch diameter by 5 ft. long steel rods driven into the ground for anodes. Whenever it was necessary, abandoned lines and metal post

fences were used as temporary groundbeds to satisfy the high current demand.

Structure-to-electrolyte potential measurements were taken both before and during the application of the test current. The current output was determined by measuring the voltage drop across a calibrated 100mV-100A shunt. The current requirement was determined by the magnitude of potential shift between the native potential and the measured potential with current applied.

Generally accepted criteria for cathodic protection (NACE and DOT) used for this project, is a structure to electrolyte potential of minus 0.85 volts referred to a copper-copper sulphate half cell at all test points on the structure under test, or to achieve a minimum 300 millivolt negative potential shift with protective current applied. Current requirements test data are shown in Tables III, Appendix B.

2.1.2.4 Soil and Water Analysis

Soil samples were gathered from nine distributed locations along the POL and water distribution systems. These samples were taken at depths from 18-inches to approximately 3 ft.

Water samples were gathered from six representative elevated water tanks around the base.

The soil samples were sealed in sterile Zip Lock plastic bags and the water samples were stored in sterile glass jars. They were submitted to SGS Control Services, Inc., Houston, Texas, for chemical analysis. Specific tests were made for:

1. Electrical conductance
2. pH
3. Chlorides
4. Sulfates
5. Sodium
6. Phosphate
7. Carbonate

The locations from which the samples were acquired are shown on drawing No. 5000 and the chemical analysis data are presented in Appendix C.

2.1.3 Results and Analysis

2.1.3.1 Soil Resistivity Measurements

Soil resistivity is the reciprocal of soil conductance, and is usually expressed in ohm-cm. It is the most commonly used criterion for estimating the corrosivity of a given soil. The resistivity of a given soil is one of the primary factors affecting the flow of electrical currents associated with corrosion. A scale often used by corrosion engineers to classify the corrosivity of soil is as follows:

Soil Resistivity	Classification
Below 1000 ohm-cm	Extremely corrosive
1000 to 5000 ohm-cm	Very corrosive
5000 to 10,000 ohm-cm	Mildly corrosive
Above 10,000 ohm-cm	Progressively less corrosive

As shown on the data sheets in Table I, Appendix B, soil resistivity measurements at or near the POL facilities range from a low of 2,600 ohm-cm near the New Navy Hospital, up to 66,000 ohm-cm at the French Creek Area. With the exception of the New Navy Hospital Area, all soils measured were 10,000 ohm-cm or higher.

Serious corrosion can occur in higher resistivity soils where large variations in soil resistivity exist. These diverse resistivities indicate the existance of varying soil compositions, and such variations are conducive to concentration cell corrosion activity on the underground pipeline as it extends through the boundaries of the dissimilar soils. Corrosion is often encountered at such boundaries in the lower resistivity soils.

2.1.3.2 Structure to Electrolyte Potential Measurements

The level of cathodic protection of a given structure is evaluated by structure-to-electrolyte potential measurements. The most generally accepted criterion for cathodic protection of steel and cast iron structures buried or submerged in an electrolyte is a structure to electrolyte potential measurement of at least 0.85 volt negative to a saturated copper-copper sulfate half-cell, with DC current applied. Another widely accepted criterion for cathodic protection is a negative potential shift of 300 mv with protective current applied to the structure.

These are also two of the criteria established by NACE in its Recommended Practice R.P 01-69 (1983 REV); and also two of the criteria specified by the U.S. Department of

Transportation Office of Pipeline Safety Regulations for natural gas and hazardous liquid pipelines.

Native state structure to soil potentials are also useful in evaluating the level of corrosion occuring on an underground steel structures and therefore helpful in determining if that structure should be cathodically protected. In a given homogeneous electrolyte, anodic and cathodic areas would not develop on a steel structures if potential differences did not exist. Since the soil is not a homogeneous electrolyte, anodes and cathodes do develop with the areas with more negative potentials being the anode. The severity of corrosion is directly proportional to the difference in potential of the anodic and cathodic ares of an electrically continuous steel structures.

An analysis of the native state structure to soil potential data acquired on the POL system and presented in Table III, Appendix B, shows a wide variation in potential differences between anodes and cathodes on individual structures or systems. These range from -0.062 volts at the 10,000 bbl. tank in the Beach Area, up to -0.216 volts at the three 6,000 bbl. tanks in the Court House Bay Area. Greater potential differences probably would have been found had more potential measurements been taken.

These potential differences are large enough that moderately severe to severe corrosion can occur on the underground POL systems even in many of the higher resistivity soils unless they are cathodically protected.

A summary of known structures that should be cathodically protected is as follows:

1. Underground steel tanks and associated piping in the Fuel Farm.
2. Four fuel tanks at Main Exchange Gas station.
3. Four fuel tanks at Bldg. 1855, Industrial area.
4. Two fuel tanks at Bldg. 1755, Industrial area.
5. One fuel tanks at Rifle Range gas station.
6. Three fuel tanks at Court House Bay gas station.
7. One additional 30,000 gallon diesel fuel tank in the Court House Bay Area.
8. One No.2 fuel tank near Steam Plant in Beach Area.
9. One No. 2 fuel tank at Bldg. FC-202 in the French Creek Area.
10. Six fuel tanks in the New Navy Hospital Area.
11. Other miscellaneous tanks not specifically included above.

2.1.3.3 Current Requirement Tests

Current requirement test data are presented in Tables III, Appendix B. A total of six current requirements test were conducted on various underground fuel storage tanks located throughout the Base. Due to the high current demand and the high soil resistivity at the Fuel Farm Area, attempts to set up a temporary groundbed and power source were not successful. As a result, current requirements at the Fuel Farm were calculated based on .00148 ampere per square foot current density as determined by actual test previously made for Cherry Point Air Station's Fuel Farm, since the two installations are similar.

Impressed current testing of the gas station fuel tank located in the Rifle Range area and of the fuel tank located in the New Navy Hospital indicated that current drains of 0.25 amperes and 0.235 amperes, or current densities of 0.000326 amperes and 0.00033 amperes per square foot, respectively, were required to provide cathodic protection. Two other impressed current tests were conducted. One, on the three fuel tanks at the gas station located in the Courthouse Bay area, which required a current drain of 0.40 amperes, or a current density of 0.00026 amperes per square foot for cathodic protection. The other, on the four fuel tanks located at the Main

Exchange gas station in which 0.4 amperes and 0.6 amperes of current were impressed on the tanks. The data were extrapolated and 0.9 amperes of current was estimated for cathodic protection of the tanks.

Impressed current testing of fuel tank FC-202 located in the French Creek Area indicated that 0.1 ampere was not enough to achieve protective potentials. Due to the high soil resistivity (66,000 ohm-cm) the current drain obtained from a temporary groundbed was limited to 0.1 amperes. Therefore, in figuring the current requirement, current densitites calculated for other areas were considered.

Impressed current testing of the fuel tank located near the steam plant in the Beach Area indicated that the tank is shorted through the piping to the steam plant. The current requirement was therefore based on current density calculated for other areas with allowances made for the very low (1000 ohm-cm) soil resistivity measured in this area.

Calculations of tank surface areas and current densities can be found in Appendix D of this report. These calculations are based on tank dimensions and sizes provided us by base personnel.

These current density values should be used for design calculations to estimate current requirements for other underground steel tanks of similar type and environment.

2.1.3.4 Soil and Water Analysis

The nine soil samples analysis appear to be normal for this area. The soil conductivity varies from a high of 371 micro mhos/cm for sample S-18 to a low of 47 micro mhos/cm for sample S-11. Sample S-11 was obtained from the north side of the Fuel Farm. Sample S-12 was obtained from the soil backfill on top of the Fuel Farm; which is indicative by the side variation in their conductivities.

The pH values of the soil samples range from a low of 6.1, which is slightly acidic, to a high of 9.5 for Sample S-18. A pH of 9.5 is moderately basic or alkaline, but presents no problems for steel pipe or tanks.

For water sample analysis, refer to Section 2.2.3.5.

2.2 Water Distribution System

2.2.1 System Description

The water distribution system consists of facilities for

the treatment and filtration of raw water for domestic and industrial use and fire protection; and underground distribution piping. Water wells scattered throughout the base constitute the primary source of raw water.

Raw water is piped to the water reservoirs located at the filtration plants. The water is treated and filtered before being discharged to fourteen elevated water tanks. The water is then piped from the individual storage facilities to basewide facilities.

2.2.2 Test Procedures

Test procedures on the water distribution system included soil resistivity measurements, pipe-to-soil potential measurements, electrical continuity tests, internal investigation of elevated water tanks, rectifier and anode inspection, and electrolyte chemical analysis.

2.2.2.1 Soil Resistivity Survey

Soil resistivity measurements were obtained at approximately 1000 foot intervals along the right-of-way to 5 foot average depths. A Nilsson Model 400 soil resistivity meter and the Wenner four-pin method were utilized to obtain the measurements.

This procedure involved driving four steel pins into the earth in a straight line, equally spaced with the pin spacing equal to the depth to which the average soil resistivity was desired. The average soil resistivity measurement is a function of the voltage drop between the center pair of pins with current flowing between the two outside pins.

Soil resistivity measurements obtained in the vicinity of the water distribution system are listed in Table I, of Appendix B.

All test locations are shown on drawings No. 5000 to 5019, Appendix H.

2.2.2.2 Structure-to-Soil Potential Survey

Structure-to-soil potential measurements were obtained on the fire hydrants at representative locations throughout the station including the residential areas.
All potential measurements were obtained using a high input impedance voltmeter Beckman Model 3010 in conjunction with a copper-copper sulfate reference electrode placed directly over or as near as possible to the structure subject to test.

Potential measurements obtained on the water distribution system are listed in Table II of Appendix B.

All test point locations and their respective reference numbers are shown on Drawings No. 5001 to 5019, in Appendix H of this report.

2.2.2.3 Continuity Tests

Continuity tests were conducted at various locations throughout the Base. A temporary groundbed consisting of four 5 ft. long ground rods and an automobile battery were utilized. The test was performed by measuring pipe-to-soil potentials at one test point, then moving the negative connection to the next test point location with the reference electrode kept stationary. Electrical continuity between test points is indicated when both potential measurements are of the same magnitude. Electrical discontinuity between test points is indicated when potential measurements are of different magnitude. Continuity test results are shown in Table IV, Appendix B, and on Drawings No. 5001 thru 5019.

2.2.2.4 Elevated Water Storage Tank Inspection

Visual inspection of anode array, handhole inspection

plates, conduits, wiring, rectifier unit and coating integrity was performed at fourteen elevated water tanks. All observations were recorded in the field. Please refer to section 2.2.3 for Results and Analysis of this report.

2.2.2.5 Elevated Water Storage Tanks Potential Profile Survey

A potential profile of the submerged portion of each tank was conducted utilizing a standard copper-copper sulfate reference electrode in conjunction with a high impedance Beckman voltmeter (Model 3010). The reference electrode was lowered to the bottom of each tank, and tank to water potentials were measured and recorded at 3 ft. intervals to the top, along the tank wall. Data acquired are presented in Table V, Appendix B of this report.

2.2.2.6 Tank Rectifiers and Anode Strings Investigations

Each rectifier was visually inspected and adjusted to provide optimum output in accordance with potential measurements taken inside the tank.

All rectifier meters were checked and calibrated as needed, using accurate portaole test meters. All meters were left

operating properly with no further repairs needed.

Voltage measurements were taken directly off the DC stacks.. Direct current outputs were determined by connecting the Beckman Voltmeter across the calibrated shunts. The meters were then adjusted to reflect the findings as accurately as possible.

Individual anode strings were inspected at each tank. Anode string current drains were measured and recorded using an SWAIN Model CP-3/4 inductive clip meter. This data is presented in Table V, Appendix B.

2.2.2.7 Water and Soil Analysis

Water samples were taken from six elevated water tanks at Camp Lejuene. These samples were placed in sterile glass jars and submitted to SGS Control Services, Inc., Houston, Texas for analysis. Results are discussed in Section 2.2.3.5. Procedures for soil analysis are discussed in Section 2.1.3.4. Results of the analysis are presented in Appendix C.

2.2.3 Results and Analysis

2.2.3.1 Soil Resistivity Measurements

Soil resistivity is the reciprocal of soil conductance, and is usually expressed in ohm-cm. It is the most commonly used criterion for estimating the corrosivity of a given soil. The resistivity of a given soil is one of the primary factors affecting the flow of electrical currents associated with corrosion. Since the corrosion rate or severity is dependent on the relatioship of the potential difference between anode and cathode and the corrosion cell circuit resistance as expressed by Ohm's Law, I=E/R, and considering that soil resistivity accounts for essentially all circuit resistance; it can be stated that the corrosion rate is inversely proportional to the soil resistivity. For example, if other conditions are equal, the corrosion rate will be three times as great in 1000 ohm-cm soil as in 3000 ohm-cm soil. A scale often used by corrosion engineers to classify the corrosivity of soil is as follows:

Soil Resistivity	Classification
Below 1000 ohm-cm	Extremely corrosive
1000 to 5000 ohm-cm	Very corrosive
5000 to 10,000 ohm-cm	Mildly corrosive
Above 10,000 ohm-cm	Progressively less corrosive

As shown on the data sheets in Table I, Appendix B, soil resistivity measurements are generally above 10,000 ohm-cm, with only 8% below 5,000 ohm-cm and 21% between 5,000 and 10,000 ohm-cm.

Serious corrosion can occur in higher resistivity soils where large variations in soil resistivity exist. These diverse resistivities indicate the existance of varying soil compositions, and such variations are conducive to concentration cell corrosion activity on the underground pipeline as it extends through the boundaries of the dissimilar soils. Corrosion is often encountered at such boundaries in the lower resistivity soils.

2.2.3.2 Structure to Soil Potential Measurements

The discussion of cathodic protection criteria presented in Section 2.1.3.2 is also applicable to the water distribution system.

Water line potential measurements obtained throughout the Camp were, with one exception, well below the negative 0.85 volt criterion, showing a lack of cathodic protection. The exception is a single potential measurement of -0.85 volt on a water spigot at the campsite in the Beach Area, Reference No. 311, Drawing No. 5017. This measurement is higher than the oxidation potential of steel and is indicative of galvanized piping, or may simply be an invalid reading and should be disregarded.

Structure to soil potentials taken along a bare underground pipeline undergoing active corrosion can range from a low of -0.1 to -0.3 volts in the most cathodic areas to a high approaching -0.8 volts in the most anodic areas.

Generally speaking, older pipelines that have developed a uniform rust film will have lower average potentials than newer lines that have not developed as much rust film and consequently have more bare steel in contact with the electrolyte. Potentials measured along the water system ranged from a low of -0.200 volts to a high of -0.687 volts indicating the probability of corrosion activity in some areas.

2.2.3.3 Continuity Tests

The data acquired from continuity tests at eighteen locations (Table IV, Appendix B) show a lack of electrical continuity between joints on these sections of the water distribution system. This is typical of mechanically coupled piping, and each joint must be electrically bonded before the system can be cathodically protected with an impressed current system. Sacrificial anodes could be installed on each joint without bonding.

2.2.3.4 Elevated Water Tanks

Normally a standard inspection of a cathodic protection system installed in a water tank encompasses an electrical potential profile on three foot intervals, a visual inspection of the anodes and associated hardware, and a calibration of the rectifier to provide optimum levels of protection to the interior submerged portions of the tank. In some cases where provisions have been made by providing access covers at designated cardinal points, additional electrical potential profiles are taken to correlate readings in order to assure proper current distribution.

Visual inspection of the coating is usually noted as an aid in the overall analysis of the performance of the corrosion mitigation measures. Assuming anode array integrity, the qualitv of the coating will be the single greatest factor determining current distribution to the tank surfaces.

Analysis of current drain data from individual anode strings is helpful in verifying a functional anode array and, to some extent, coating integrity. Since the anodes are wired in a series-parallel configuration with the same number and size of anodes in each string of a specific "ring"; current drains should be essentially uniform if all anodes are intact and coating quality is uniform.

The findings of this report as they relate to the total current requirement to obtain effective protective levels of cathodic protection correlate coating integrity better than any other measurement used. Since in almost all cases we found that very little current was required to achieve adequate protective levels on the tank interiors, one can be reasonably assured that very little metal is exposed and the coatings are in fairly good condition.

It should be noted that the rectifier ouput data listed in the Tables under "Rectifier Data" were measured with rectifier panel meters which had been calibrated with accurate portable test meters as closely as possible, and the current drain data listed under "Anode String Current Drains" were taken with the SWAIN clamp-on meter. The total current drains do not always agree, in which case the rectifier meter is not accurate.

Data acquired on elevated water tanks are presented in Table V, Appendix B. Results and analysis on each tank are discussed in the following paragraphs.

<u>Tank No. S-1000</u>

Rectifier No. 4107 rated at 40 volts and 20 amperes was left operating on a transformer tap setting of A-3 providing 0.75 ampere of current to the bowl and 0.2 amperes to the riser at 4.0 volts. The potential profile data indicated that adequate protection is being achieved and individual anode string current drains confirmed anode array integrity. The anodes themselves appeared in good condition and can be expected to perform for approximately 6 to 8 more years. The associated hardware was in fair condition, however there were a few condulet covers missing on the balcony.

These should be replaced since water accumulating on the balcony can enter the conduit and make its way to the rectifier cabinet. The interior coating looked good. Structurally, the roof manway is detached, rusted and represents a hazard which should be repaired as soon as possible.

Tank No. S-29

Rectifier No. 4106 rated at 18 volts and 16 amperes was found to be operating on a tap setting of B-1. Potential measurements indicated over-protection and the transformer taps were changed to A-1. The potential profile indicated adequate levels of protection and individual anode string current drains confirmed anode array integrity. The coating system appeared to be good and the anodes themselves should last approximately 6 to 8 more years. The associated hardware such as conduit, wiring, and handhole covers were all in good condition. Structurally the tank appeared to be in fairly good condition.

Tank No. S-FC-314

Rectifier No. 7238 rated at 20 volts and 24 amperes was found to be operating on a transformer tap setting of B-2.

Measurements taken from the stacks and thru the SWAIN meter indicated errors in the rectifier meters which were calibrated to reflect actual voltage and current. The voltage was set from an indicated 4.5 volts to 7.0 volts. The bowl current meter was approximately correct and so was the riser meter. The roof ladder obstructed access to the manways therefore a potential profile could not be obtained. The anode string current drains confirmed anode array integrity, however, on the inner array one string was found to be missing. The coating appeared to be in good condition. The air vent on the top of the tank is completely rusted off and was lying on the top of the tank, secured only by the riser anode string. The vent was placed back in position but should be repaired as soon as possible. All obstruction lighting is missing. The condulet at the top of the tank is cracked and the cover is missing. Most likely the ladder hit and damaged it. The anodes themselves appeared to be in fairly good condition and should last at least five more years.

Tank No. S-BA-108

Rectifier No. 760043 rated at 40 volts and 10 amperes was found to be operating at a tap setting of 1C-4F providing 1.08 amperes to the bowl and 0.6 amperes to the riser at 8.0 volts.

The manway on top of the tank was rusted shut and could not be opened. Individual anode string current drains on the bowl anodes confirmed anode array integrity, however, the anodes could not be removed for inspection since they are too close to the insulator for clearance thru the 5-inch handhole access. The handhole covers are rusted badly and need to be replaced. The coating on the outside of the tank is peeling badly, particularly on the very top. The interior lighting system does not work and should be repaired so that the tank can be climbed safely.

Tank No. S-BB-25

Rectifier No. 4109 rated at 18 volts and 10 amperes was found to be operating on transformer tap setting A-1. The potential profile indicated adequate levels of protection and anode current drains confirmed anode array integrity. The anodes looked good and should last at least five more years, however, all of the bowl anodes are attached to the inlet pipe via a rope. The strings could not be freed. In addition there is a shovel lying on the bottom of the tank. The coating looked good as did all associated hardware.

Tank No. S-RR-44

Rectifier No. 80C-2835 rated at 40 volts and 20 amperes

was found operating on tap setting B-1. The potential profile indicated over-protection and the tap setting was changed to A-3. Adequate levels of protection were achieved at this setting. Readings were taken from the stack and thru the shunts to determine meter accuracy and calibrated as necessary. Anode string current drains confirmed anode array integrity, however, no reading could be taken on the riser since it was covered with wasps. All associated hardware looked good as did the coating.

<u>Tank No. S-TC-1070</u>

Rectifier No. 81C215 rated at 60 volts and 28 amperes was found to be operating on a tap setting of A-1 providing 0.24 amperes to the bowl and 0.13 amperes to the riser at 2.06 volts. The potential profile indicated less than adequate protection and the taps were changed to A-3 providing 4.38 amperes to the bowl and 1.72 amps to the riser at 8.02 volts. Anode string current drains confirmed anode array integrity and the coating appeared to be in good condition. There was one condulet cover missing on the balcony. The exterior of the riser needs painting. The anodes should last about 5-7 more years.

Tank No. S-TC-606

Rectifier No. 7236 rated at 40 volts and 12 amperes was found to be operating on transformer tap A-2 providing 0.455 amps to the bowl and 0.10 amps to the riser at 2.44 volts. The potential profile indicated less than adequate protection and the taps were changed to B-1 providing 3.0 amps to the bowl and 1.80 amps to the riser at 8.8 volts. All anodes looked good and should be expected to last approximately 5-7 more years. The anode current drains confirmed anode array integrity and the coating looked good.

Tank No. S-M-624

Rectifier No. 12210 rated at 18 volts and 10 amps was operating on a tap setting of A-4 providing 0.35 amps to the bowl and 0.050 amps to the riser at 3.53 volts. The potential profile indicated less than adequate protection and the taps were changed to B-3 providing 1.00 amps to the bowl and 0.6 amps to the riser at 6.72 volts. The individual anode current drains confirmed anode array integrity, however, life expectancy of the anodes should not be expected to exceed 2-3 more years. Some of the bowl wiring was under water but should be allright. The tank coating and hardware were in good condition.

Tank No. S-MP-4004

Rectifier No. 80C2834 rated at 40 volts and 16 amperes was found to be operating on transformer tap setting A-3 providing 0.58 amps to the bowl and 0.18 amps to the riser at 4.62 volts. The potential profile indicated adequate protective levels and the individual anode string current drains confirmed anode array integrity. All associated wiring as well as interior coating looked good. Anodes also looked good and should last 5-7 more years, however, rectifier does not function properly on lower tap settings, and it should be repaired.

Tank No. S-TT-40

Rectifier No. 5630 rated at 18 volts and 16 amperes was found to be operating on transformer tap setting A-3 providing 0.40 amps to the bowl and 0.06 amps to the riser at 3.0 volts. The potential profile indicated adequate protective levels and the individual anode string current drains confirmed anode array integrity. All associated wiring as well as the interior coating looked good.

Tank No. S-830

Rectifier No. 5201 rated at 36 volts and 16 amperes was found to be operating on transformer taps A-3 providing 1.0 amps to the bowl and 0.20 amps to the riser at 5.4 volts. The potential profile indicated adequate levels of protection and anode string current drains confirmed anode array integrity. The anodes looked good and should last 5-7 more years. All associated hardware as well as the interior coating looked good.

Tank No. S-2323

Rectifier No. 80C2833 rated at 40 volts and 20 amperes was found to be operating on transformer taps A-3 providing 0.45 amps to the bowl and 0.20 amps to the riser at 4.0 volts. The potential profile indicated adequate levels of protection and anode current drains confirmed anode array integrity. The anodes should last 5-7 more years and all associated hardware was in good condition. The interior coating also appeared to be in good condition.

Tank No. S-5

Rectifier No. 4103 rated at 18 volts and 10 amperes was found operating on transformer taps A-1 providing 0.6 amps to the bowl and 0.12 amps to the riser at 3.96 volts. The potential profile indicated adequate levels of protection and the anode string current drains confirmed anode array integrity. The inner anode array had only four functioning string, with the fifth string missing. All associated hardware looked good as did the interior coating. The anodes themselves appeared to be in good condition and should last 5-7 more years.

2.2.3.5 Water Samples Analysis

The analysis of the treated water samples may be found in Appendix C, with the analysis of all other samples tested.

The calculated resistivities of samples number W-12, W-13, W-14, W-15, W-16, and W-17 are 1355 ohm-cm, 5347 ohm-cm, 5882 ohm-cm, 2695 ohm-cm, 2817 ohm-cm, and 2777 ohm-cm, respectively. Sample W-12 has a low resistivity, a moderate chloride and low sulfate content, a slightly basic (alkaline) pH of 8.6; and should be considered very corrosive.

The remaining samples have moderate resistivities, low chloride and sulfate contents and should be considered corrosive.

Based on this analysis, cathodic protection for the internal surfaces of the water storage tanks is needed to mitigate corrosion.

2.3 Evaluation of Activity Corrosion Control Program

2.3.1 Operating and Maintenance Practices

As part of the corrosion study, existing corrosion control maintenance practices were investigated. Information gathered from camp personnel indicated limited maintenance of the cathodic protection systems had been conducted.

A monthly inspection of the elevated water tank rectifiers is being performed by the Maintenance Department. It consists of a visual inspection, and reading and recording the DC output levels of each rectifier.

We believe that the present camp personnel are very capable of incorporating a successful corrosion control maintenance program with the aid of corrosion control short courses, in-field supervised training and proper cathodic protection testing equipment.

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RECOMMENDATIONS

3.0 RECOMMENDATIONS

3.1 POL System

Based on the results of this survey, we recommend that cathodic protection systems be installed on all underground steel tanks and POL piping. A combination of sacrificial galvanic anodes in low resistivity soils and impressed current systems in higher resistivity soils should provide the most cost effective approach.

The sacrificial anodes should be elongated, high potential magnesium anodes, prepacked in prepared backfill, such as DOW Galvomag-Galvopak, or equal.

Anodes for impressed current cathodic protection systems should be 3-inch diameter by 60 inches long specially treated graphite anodes, meeting MIL. SPEC. MIL-A-18279C. Impressed current anode backfill should be calcined fluid petroleum coke.

Specific recommendations are:

1. Install a rectifier rated at 120 volts and 40 amperes output in conjunction with a distributed groundbed containing a minimum of thirty graphite

anodes and fourteen test stations for protection of the underground tanks and piping at the Fuel Farm.

2. Install a rectifier rated at 10 volts and 5 amperes, eight graphite and four test stations anodes to protect the four underground fuel storage tanks at the Main Exchange Gas Station.

3. Install a rectifier rated at 10 volts and 5 amperes with eight graphite anodes and four test stations to protect the four underground fuel storage tanks at Building No. 1855 in the Industrial area.

4. Install a rectifier rated at 10 volts and 5 amperes, six graphite anodes and two test stations, to protect the two underground fuel storage tanks at Building No. 1775.

5. Install twelve 20 lb. elongated high potential magnesium anodes, DOW Galvomag 20-D2, or equal, and one test station on the underground fuel storage tank at the Rifle Range Area Gas Station.

6. Install one 10 volt, 5 ampere rectifier, six graphite anodes and three test stations to protect the three underground fuel storage tanks at the Courthouse Bay Gas Station.

7. Install one 10 volt, 5 ampere rectifier six graphite anodes and one test station to protect the 30,000 gallon diesel fuel storage tank located in the Courthouse Bay area.

8. Install one 20 volt, 5 ampere rectifier, six graphite anodes and one test station to protect the underground fuel tank at Building FC-202 located in the French Creek area.

9. Install six 20-D2 magnesium anodes and one test station on the underground fuel tank located near the New Naval Hospital.

10. Install twenty 40-D3 magnesium anodes and four test stations on the five underground fuel tanks located near the New Naval Hospital.

11. Install nine 40-D3 magnesium anodes and one test station on the fuel tank located near the steam plant in the Beach area.

12. Install insulating flanges on the lines located at the above fuel tank in order to isolate it from above ground piping and the steam plant.

13. Install cathodic protection systems on any additional underground fuel tanks not specifically referenced above. Design criteria in Appendix D should be followed.

3.2 Water Distribution System

Recommendations for the water distribution system are as follows:

1. Inspect elevated water tanks and rectifiers on a monthly basis in order to insure uninterrupted protection. Maintain current outputs as listed in Table V, Appendix B unless a change in current requirements is indicated by subsequent cathodic protection surveys.

2. Replace missing or depleted anode strings in elevated water tanks as follows:

   a. Tank S-FC-314: Replace one missing string in inner array.

b. Tank S-5: Replace one missing string in inner array.

3. Repair or replace tank hardware as follows:

   a. Tank S-1000: Replace 3/4-inch conduit covers on the balcony.

   b. Tank S-FC-314: Repair the roof ladder and the air vent on top of tank, and replace the damaged condulet on top of tank.

   c. Tank S-BA-108: Repair manway cover on top tank so it can be opened, replace the handhole covers on top of the tank, and repair the interior lighting system.

   d. Tank S-1070: Replace one condulet cover on the balcony.

   e. Tank S-TT-40: Replace the missing bolt and bar on the riser cover assembly.

   f. Tank S-MP-4004: Repair existing rectifier to achieve proper operation at all tap settings.

4. Install sacrificial high potential magnesium anodes on individual underground pipe joints in all areas where soil resistivities are below 5000 ohm-cm as described in Appendix D.

   As an alternate, all pipe joints falling within, and adjacent to, areas with soils below 5000 ohm-cm could be electrically bonded and cathodically protected with impressed current systems. However, both initial costs and maintenance costs will exceed the cost of sacrificial anode systems and changes of stray current corrosion will be greatly increased.

5. In areas where cathodic protection is to be considered, electrically bond all cast iron pipe joints exposed by maintenance or construction activities. Bonds should be minimum No. 8 AWG copper wire or equivalent copper straps. Electrical continuity of underground piping cathodically protected with sacrificial anodes is desirable since it equalizes structure-to-soil potentials and permits monitoring the effectiveness of the system without the need to contact each pipe joint.

6. Install two-wire potential test stations at preselected locations to monitor the level of cathodic protection and anode outputs.

3.3 Activity Corrosion Control Program

3.3.1 Recommendations for Maintenance Practices

The following recommendations are aimed towards aiding Camp personnel in developing a total corrosion control preventive maintenance program.

It is recommended that the responsibility for monitoring and maintenance of cathodic protection systems, once they are installed, be assigned to competent permanent personnel with either experience in cathodic protection or with technical backgrounds to facilitate their training as described in Section 3.3.2.

The present policy of monthly rectifier inspections should be continued. These inspections should include as a minimum, reading and recording the D.C. output levels as indicated by the panel meters, and a visual inspection of all major rectifier components. Output levels should be promptly compared with those recorded from previous inspections and any significant changes investigated.

In addition, other system components should be observed and repairs effected whenever needed.

It is further recommended that a comprehensive system-wide corrosion control survey be conducted on an annual basis by an experienced corrosion engineer. The corrosion engineer accomplishing this survey should be accompanied by the station personnel responsible for corrosion control monitoring since this would constitute valuable field experience.

Drawings provided in this report showing the location of structure-to-electrolyte potential measurements should be used as a guide in the annual survey.

It is recommended that all data pertaining to the corrosion control program be recorded for future reference. The corrosion control records program should include investigating and recording all leaks that occur. Bell hole inspections should be made and a leak report form completed, detailing the type of leak, repairs made, and their locations.

For further details in establishing a corrosion control program and for additional information on maintenance programs, refer to NAVFAC INST 11014.51 of 19 October 1983 and MO-307 of May 1981; "Cathodic Protection Systems Maintenance".

Additional assistance in establishing a corrosion control program may be obtained from the Atlantic Division, Naval Facilities Engineering Command corrosion engineer.

3.3.2 Recommendations for Training Program

The routine monitoring of cathodic protection systems is essential to maintaining adequate protection against corrosion attack in soil and water electrolytes. It is recommended that a training program involving Camp personnel be instituted. This program would involve the training of personnel, in both theory of cathodic protection and field training.

The following corrosion control courses are recommended for Camp personnel.

National Association of Corrosion Engineers (NACE) Courses:

a. "Basic Corrosion Course".

b. "Corrosion Prevention by Cathodic Protection".

c. "Corrosion Prevention by Coatings".

We recommend these courses for learning the basic theory of corrosion and methods and practices used in cathodic protection. These courses can be taken by "Home Study" with personnel working at their own pace. The courses are designed for people with no prior knowledge of cathodic protection. Further information can be obtained by writing to NACE Education Department, P. O. Box 218340, Houston, Texas 77218; or by telephoning (713) 492-0535.

Another excellent training course is the "Cathodic Protection Rectifier School" offered by Good-All Electric, Inc.

This short three day course is designed to familiarize students with cathodic protection rectifiers. Basic theory is discussed as well as field troubleshooting. Additional information can be obtained by writing to GOOD-ALL Electric, Inc., 3725 Canal Drive, Fort Collin, Colorado 80524, attention to Mr. Don Olson, or by calling (303) 484-3080.

A number of corrosion control short courses are offered every year by several universities and sections of NACE throughout the United States.

One of the better ones is held each May in Morgantown, West Virginia; and another excellent course is offered each September at the University of Oklahoma, Norman, Oklahoma. These three-day seminars are taught by professional instructors and include practical field demonstrations. Details of these courses can be obtaind by contacting the University of West Virginia or the University of Oklahoma, respectively.

It is also recommended that an experienced corrosion engineer accredited by NACE as a Corrosion Specialist conduct an on-site training seminar with Camp personnel. By this seminar, Camp personnel can obtain practical training on the testing procedures used for conducting routine maintenance of cathodic protection systems. This training would include taking structure-to-electrolyte potentials, soil resistivity measurements and the basics of rectifier inspection techniques.

Additional details on training courses offered by the Atlantic Division, Naval Facilities Engineering Command, the Naval Civil Engineering Laboratory, the U.S. Air Force Institute of Technology and commercial firms may be obtained by contacting the Atlantic Division, Naval Facilities Engineering Command corrosion engineer.

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ESTIMATES

4.0 ECONOMIC EVALUATIONS

4.1 Fuel Farm

1. Based on the detailed Cost Estimates included in Appendix E, the initial cathodic protection investment is = \$30,710.

2. Investment = Initial Cost x Capital Recovery Factor thus on the basis of 12% for 20 years, the annual cost to own becomes:

   \$30,710 x 0.1175 = \$3,608.

   Maximum Power Cost:

   $$\text{AC Watts} = \frac{\text{DC Watts}}{\text{conversion efficiency (.68)}}$$

   Recommended Rectifier (120V-40A)

   $$\text{AC KW} = \frac{120 \times 40}{.68} \times \frac{1\text{KW}}{1000\text{W}} = 7.06\text{KW}$$

   Annual Power Cost:

   $$7.06 \text{ KW} \times \frac{8760 \text{ hr}}{\text{yr}} \times \frac{\$0.06}{\text{KW-hr}} = \$3710.$$

   Estimated Annual Cosc=3608 + 3710 = \$ 7,318.

3. Repairs and replacements on the POL system have been made in the past, but exact costs were not available.

4. The investment involved in the tanks and associated equipment, along with their importance to operations, justify the recommended cathodic protection system.

5. DOT Standards require all underground fuel gas storage and piping to be provided with cathodic protection.

4.2 Fuel Storage Tank at Rifle Range Area

Field data indicates that two cathodic protection alternatives can be used to protect the fuel tank at the Rifle Range area.

A. Impressed Current System

1. Based on the detailed Cost Estimates included in Appendix E, the initial cathodic protection investment is

= $6,928.

2. Investment = Initial Cost x Capital Recovery Factor thus on the basis of 12% for 20 years, the annual cost to own becomes:

$6,928. x .1175 = $ 814.

Maximum Power Cost:

AC Watts = DC Watts/conversion efficiency

Recommended Rectifier = 10V - 4A

$$AC\ KW = \frac{10x4}{.68} \times \frac{1\text{-}KW}{1000\ Watts} = 0.06\ KW$$

Annual Power Cost:

$$0.06\ KW \times \frac{8760\ hr}{1\ yr.} \times \frac{\$0.06}{KW\text{-}hr} = 32.$$

Estimated Annual Cost = 814. + 32. = $846.

B. <u>Sacrificial Anode System</u>

1. Initial Cathodic Protection Investment as estimated in Appendix E of this report

$ 6,553.

2. Investment = Initial Cost x Capital Recovery Factor thus on the basis of 12% for 20 years, the annual cost to own becomes:

$ 6,553 x .1175 = $ 770.

C- Based on the above estimated annual costs we recommend that the sacrificial anode system be installed.

D. Annual maintenance costs of the fuel tank were not available, however if the investment involved in the tank justifies the $770. annual cost, we recommend that a cathodic protection system be installed.

4.3 Fuel Storage Tanks in New Naval Hospital and Onslow Beach Areas

1. Based on detailed Cost Estimates included in Appendix E, the initial investment for the sacrificial cathodi protection in the two areas is = $ 20,610.

2. Investment = Initial Cost x Capital Recovery Factor thus on the basis of 12% for 20 years, the annual cost to own becomes:

$ 20,610 x .1175 = $ 2,422.

3. Costs of repairs and replacements on the POL system were not available. The investment in the tanks and associated equipment, along with their importance to operations, justify the recommended cathodic protection system.

4. DOT Standards require all underground fuel gas storage and piping to be provided with cathodic protection.

4.4 Fuel Storage Tanks at Main Exchange

1. Based on detailed Cost Estimates included in Appendix E, the initial investmenc for the sacrificial cathodic protection of these tanks is = $ 9,640.

2. Investment = Initial Cost x Capital Recovery Factor thus on the basis of 12% for 20 years, the annual to cost to own becomes:

$ 9,640. x .1175 = $ 1,133.

Maximum Power Cost:

AC Watts=DC Watts/conversion efficiency

Recommended Rectifier = 10V - 4A

$$AC\ KW = \frac{10x4}{.68} \times \frac{1\text{-}KW}{1000\ Watts} = 0.06KW$$

Annual Power Cost:

$$0.06\ KW \times \frac{8760\ hr}{1\ yr.} \times \frac{\$0.06}{KW\text{-}hr} = \$\ 32./yr$$

Estimated Annual Cost: = 1133 + 32 = $ 1,165.

3. Repairs and replacements of the tanks have been made in the past, but exact cost were not available.

4. The investment involved to protect these tanks and associated equipment, justify the recommended cathodic protection system.

5. DOT Standards require all underground fuel gas storage and piping to be provided with cathodic protection

4.5 Remaining Fuel Storage Tanks

1. Based on the detailed Cost Estimates included in Appendix E, the initial cathodic protection investment is = $36,667.

2. Investment = Initial Cost x Capital Recovery Factor thus on the basis of 12% for 20 years, the annual cost to own becomes:

   $36,667.00 x .1175 = $4,308.

   Maximum Power Cost:

   AC Watts = DC Watts/conversion efficiency.

Recommended Rectifiers = 4 each 10V-4A

1 each 20V-4A

$$\text{AC KW} = \frac{4(10x4) + (20x4)}{.68} \times \frac{1KW}{1000 \text{ Watt}} = 0.353 \text{ KW}$$

Annual Power Bill:

0.353 KW x 8760 hr/yr x $0.06/KW-hr = $185.

Estimated Annual Cost= $4,308 + $185 = $4,493.00

3. Leaks and repairs have been reported at several locations. Some underground fuel tanks are scheduled to be replaced with aboveground tanks or with underground fiberglass tanks. Only existing metal tanks not scheduled for replacement were considered for cathodic protection.

4. Annual replacements and maintenance costs were not available. However, if the investment involved justifies the annual cost of $4,493. we recommend that cathodic protection systems be installed.

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APPENDIX A

INVENTORY

APPENDIX A

CAMP LEJUENE, NORTH CAROLINA

POL SYSTEM INVENTORY OF MAJOR PRODUCT STORAGE FACILITIES

Area	Ref. No.	Capacity (Gallons)	Products	AG: Aboveground UG: Underground
Industrial	S-1009	600,000	#6 Fuel	AG-Steel
Industrial	S-1023	12,000	MOGAS	UG-Steel
Industrial	S-1024	15,000	MOGAS	UG-Steel
Industrial	S-1025	12,000	MOGAS	UG-Steel
Industrial	S-1026	15,000	MOGAS	UG-Steel
Industrial	S-1027	15,000	MOGAS	UG-Steel
Industrial	S-1028	15,000	MOGAS	UG-Steel
Industrial	S-1029	15,000	MOGAS	UG-Steel
Industrial	S-1030	12,000	MOGAS	UG-Steel
Industrial	S-1031	15,000	MOGAS	UG-Steel
Industrial	S-1032	15,000	MOGAS	UG-Steel
Industrial	S-1033	12,000	Diesel	UG-Steel
IndustriaL	S-1034	12,000	Diesel	UG-Steel
Industrial	S-1035	15,000	Diesel	UG-Steel
Industrial	S-1036	15,000	Diesel	UG-Steel
Industrial	S-1037	(2) 3,500	Kerosene	N/A
Industrial	Main Exchange	30,000	MOGAS	UG-Steel
Industrial	Main Exchange	30,000	MOGAS	UG-Steel
Industrial	Main Exchange	(2) 10,000	MOGAS	UG-Steel
Industrial	Bldg. 1855	(2) 6,000	Diesel	UG-Steel
Industrial	Bldg. 1855	(2) 6,000	MOGAS	UG-Steel
Industrial	Bldg. 1775	6,000	Diesel	UG-Steel
Industrial	Bldg. 1775	6,000	MOGAS	UG-Steel
Industrial	S-1701	420,000	# 6 Fuel	AG-Steel
Industrial	S-1735	172,000	# 6 Fuel	AG-Steel
Old Hospital	(Not in use)	10,000	Diesel	UG-Steel
Old Hospital	(Not in use)	10,000	Diesel	UG-Steel
Berkley Manor	Exchange # 2	(3) 10,000	MOGAS	UG-Steel
Berkely Manor	Exchange # 2	10,000	Diesel	UG-Steel
Paradise Pt.	Bldg. 2615	8,000	# 6 Fuel	UG-Steel
Paradise Pt.	Bldg. 2615	8,000	# 6 Fuel	UG-Steel
Montford Pt.	M-625	30,000	# 6 Fuel	UG-Steel
Montford Pt.	M-625	20,000	# 6 Fuel	UG-Steel
Montford Pt.	M-230	15,000	Diesel	UG-Steel
Montford Pt.	M-230	15,000	Diesel	UG-Steel
Geiger Camp		(2) 15,000	Diesel	AG-Steel
Geiger Camp		(2) 15,000	Unlead MOGAS	AG-Steel
Geiger Camp		15,000	Kerosene	AG-Steel
Rifle Range	Gas Station	10,000	Unlead MOGAS	UG-Steel
Rifle Range	RR-15	10,000	# 6 Fuel	UG-Steel
Rifle Range	RR-15	10,000	# 6 Fuel	UG-Steel

Area	Ref. No.	Capacity (Gallons)	Products	AG: Aboveground UG: Underground
Courthouse Bay	BB-9	(3)10,000	# 6 Fuel	UG-Steel
Courthouse Bay	BB-9	30,000	Diesel	UG-Steel
Courthouse Bay	BB-9	(3) 6,000	MOGAS	UG-Steel
Onslow Beach	BA-106	10,000	Diesel	UG-Steel
French Creek	FC-202	10,000	Diesel	UG-Steel
New Hospital	M7-1	(2)20,000	# 6 Fuel	UG-Steel
New Hospital	M7-1	(2)20,000	Diesel	UG-Steel
New Hospital	M7-1	10,000	MOGAS	UG-Steel
New Hospital	M7-1	2,000	Diesel	UG-Steel

WATER DISTRIBUTION INVENTORY OF STORAGE FACILITIES

Description	Capacity	Type
Tank S-1000	300,000 gal.	Elevated Steel
Tank S-29	300,000 gal.	Elevated Steel
Tank S-FC-314	300,000 gal.	Elevated Steel
Tank S-BA-108	100,000 gal.	Elevated Steel
Tank S-BB-125	100,000 gal.	Elevated Steel
Tank S-RR-44	100,000 gal.	Elevated Steel
Tank S-TC-1070	100,000 gal.	Elevated Steel
Tank S-TC-606	100,000 gal.	Elevated Steel
Tank S-M-624	150,000 gal.	Elevated Steel
Tank S-TT-40	250,000 gal.	Elevated Steel
Tank S-MP-4004	200,000 gal.	Elevated Steel
Tank S-830	300,000 gal.	Elevated Steel
Tank S-2323	200,000 gal.	Elevated Steel
Tank S-5	300,000 gal.	Elevated Steel

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APPENDIX B

DATA SHEETS

M D A MENENDEZ-DONNELL & ASSOCIATES, INC. HOUSTON, TEXAS

GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: INDUSTRIAL AREA 2

DATE 11/6/84 **ENGINEER** CM/JH **TABLE** I **PAGE** 1 **OF** 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	* FACTOR	OHM-CM
1	HOLCOMB & SNEADS FERRY	5'3"	8.40	10.0	1000	84,000
2	SNEADS & MICHAEL		2.70			27,000
3	LOUIS & MULBERRY ST.		1.30			13,000
4	DUNCAN ST. @ BLDG. 1012		4.35			43,500
5	BIRCH & LOUIS ROAD		1.25			12,500
6	ASH @ BLDG. 1114		2.10			21,000
7	ASH & HOLCOMB BLVD		3.95			39,500
8	OFF HOLCOMB (BLDG. 601)		8.00	1.0		8,000
9	DOGWOOD ST. @ BLDG 1400		9.30	1.0		9,300
10	DOGWOOD ST. & HAMMOND RD.		3.50	10.0		35,000
11	"O" ST. & DOGWOOD		3.50			35,000
12	LOUIS ROAD & GUM ST		1.20			12,000
13	GUM ST. @ BLDG. 1705		9.60	1.0		9,600
14	GUM ST. & HALCOMB BLVD		1.20	10.0		12,000
15	MOLLY PITCHER DRIVE @ BLDG 59		2.00	10.0		20,000

NOTES : Nilsson 400 meter & the 4Pin method were used to obtain soil resistivity measurements.

* The "K" factor is the Average depth or pin spacing in feet X a meter constant of .191.5

M D A MENENDEZ-DONNELL & ASSOCIATES, INC. HOUSTON, TEXAS

GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: HADNOT POINT 2, AREA 3

DATE 11/6/84 ENGINEER NE/GG TABLE I PAGE 2 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
20	HOLCOMB BLVD	5'-3"	4.1	1.0	1000	4,100
		10'-6"	2.8		2000	5,600
21	FIELD @ BLDG. 1725	5'-3"	8.3		1000	8,300
		10'-6"	4.3		2000	8,600
		15'-9"	2.9		3000	8,700
		21'-0"	2.3		4000	9,200
22	FIELD @ BLDG 751	5'-3"	1.2	10.0	1000	12,000
		10'-6"	4.4	1.0	2000	8,800
		15'-9"	2.3		3000	6,900
		21'-0"	1.2		4000	4,800
23	MAIN SERVICE ROAD	5'-3"	1.0	10.0	1000	10,000
24			1.6			16,000
25	LOUIS ROAD		1.6			16,000
26	@ BLDG. 1820		3.6			36,000
27	MAIN SERVICE ROAD		1.1			11,000
28			4.9	1.0		4,900
29	"O" STREET		5.1			5,100
30			5.6			5,600
31	"O" STREET & RIVER ROAD		6.2			6,200
32	"N" STREET		9.7			9,700
33	BLDG. 540		5.7			5,700
34	"N" STREET		7.1			7,100

M D A MENENDEZ-DONNELL & ASSOCIATES, INC. HOUSTON, TEXAS

GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: HADNOT POINT 2, AREA 3

DATE 11/6/84 ENGINEER NE/GG TABLE I PAGE 3 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
35	"M" STREET	5'-3"	3.3	10.0	1000	33,000
36	"L" STREET		1.3			13,000
37	"L" STREET @ BLDG 417		1.2			12,000
38	"K" STREET		8.7	1.0		8,700
39			2.0	10.0		20,000
40	RIVER ROAD & "I" STREET		1.6			16,000
41	"I" STREET		9.2	1.0		9,200
42	"I" STREET & "H" STREET		3.6			3,600
		10'-6"	3.8		2000	7,600
		15'-9"	2.6		3000	7,800
		21'-0"	2.4		4000	9,600
43	"H" STREET	5'-3"	1.1	10.0	1000	11,000
44	RIVER ROAD		1.4			14,000
		10'-6"	6.8	1.0	2000	13,600
45	HOLCOMB BLVD	5'-3"	1.9	10.0	1000	19,000
46			9.1	1.0		9,100
		10'-6"	4.0		2000	8,000
		15'-9"	2.1		3000	6,300
		21'-0"	1.3		4000	5,200

M D A MENENDEZ-DONNELL & ASSOCIATES, INC. HOUSTON, TEXAS

GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: HADNOT POINT 1, AREA 4

DATE 11/7/84 ENGINEER NE/GG TABLE I PAGE 4 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
50	RIVER ROAD	5'-3"	8.0	1.0	1000	8,000
51	"G" STREET		4.1			4,100
52	MAIN SERVICE RD & "G" ST.		6.5			6,500
53	"F" STREET		8.3			8,300
54	"E" STREET		1.9	10.0		19,000
55			1.1			11,000
56	RIVER ROAD		4.0	1.0		4,000
		10'-6"	3.7		2000	7,400
		15'-9"	2.9		3000	8,700
		21'-0"	2.3		4000	9,200
57	"D" STREET	5'3"	1.5	10.0	1000	15,000
58			1.2			12,000
59	POST LANE		6.1	1.0		6,100
60			3.4			3,400
61	LUCY BREWER AVE.		7.4			7,400
62	MOLLY PITCHER DR.		6.9			6,900
63	VIRGINIA DARE DR.		6.6			6,600
64	MAIN SERVICE ROAD		1.5	10.0		15,000
65	"C" STREET		6.8	1.0		6,800
66	"B" STREET		7.3			7,300
67			9.1			9,100
68	"A" STREET		7.2			7,200

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: HADNOT POINT 1, AREA 4

DATE 11/7/84 ENGINEER NE/GG TABLE I

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
69	"A" STREET	5'3"	3.0	1.0	1000	3,000
70	RIVER ROAD		4.7			4,700
71	NEAR WALLACE CREEK		6.5			6,500
72	CROSS STREET		2.1	10.0		21,000
73	MAIN SERVICE ROAD		2.5			25,000
		10'-6"	1.0		2000	20,000
		15'-9"	4.9	1.0	3000	14,700
		21'-0"	3.4		4000	13,600
74		5'3"	6.8		1000	6,800
		10'-6"	4.9		2000	9,800
		15'9"	3.1		3000	9,300
		21'-0"	2.2		4000	8,800

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: OLD NAVAL HOSPITAL AREA 5

DATE 11/7/84 ENGINEER NE/GG TABLE I PAGE 6 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
80	RIVER ROAD	5'3"	1.2	10.0	1000	12,000
81	RIVER ROAD @ BLDG 15	↓	3.5	1.0	↓	3,500
	↓	10'6"	2.1	↓	2000	4,200
		15'9"	1.9		3000	5,700
		21'-0"	1.6		4000	6,400
82	RIVER ROAD	5'3"	2.0	10.0	1000	20,000
83	↓	↓	2.3	↓	↓	23,000
84	SURGEONS ROW		2.2			22,000
85	RIVER ROAD		2.4			24,000
86	↓		3.4			34,000
87	CUTLER STREET		1.2			12,000
88	↓		5.3			53,000
89	BLACKWOOD ROAD		2.0			20,000
90	↓		2.6			26,000

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: OFFICER'S QUARTERS AREA 6

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
100	SETH WILLIAMS BLVD	5'-3"	6.2	1.0	1000	6,200
101	ONSLOW DRIVE	↓	3.2	10.0	↓	32,000
102	↓	↓	4.1	↓	↓	41,000
103	↓	↓	2.8	↓	↓	28,000
104	STONE STREET	↓	8.2	1.0	↓	8,200
105	TIMMERMAN PLACE	↓	4.7	10.0	↓	47,000
106	SETH WILLIAMS BLVD	↓	9.8	1.0	↓	9,800
107	EDEN STREET	↓	1.4	10.0	↓	14,000
108	BEVIN STREET	↓	2.1	↓	↓	21,000
109	↓	↓	3.6	↓	↓	36,000
110	HILL STREET	↓	1.8	↓	↓	18,000
111	BEVIN STREET	↓	5.7	↓	↓	57,000
112	EDEN STREET	↓	10.2	1.0	↓	10,200
113	SETH WILLIAMS BLVD	↓	3.6	10.0	↓	36,000
114	CUKELA CIRCLE	↓	2.6	↓	↓	26,000
115	CUKELA STREET	↓	3.1	↓	↓	31,000
116	↓	↓	3.4	↓	↓	34,000
117	SETH WILLIAMS BLVD	↓	3.6	↓	↓	36,000
118	↓	↓	4.5	↓	↓	45,000
119	JEWEL & EDEN	↓	2.1	100.0	↓	210,000
	↓	10'-6"	5.8	10.0	2000	116,000
	↓	15'-9"	2.5	↓	3000	75,000
	↓	21'-0"	1.6	↓	4000	64,000

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: OFFICER'S QUARTERS AREA 6

DATE 11/7/84 ENGINEER NE/GG TABLE I

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
120	EDEN STREET	5'-3"	5.3	10.0	1000	53,000
121	↓	↓	3.0	↓	↓	30,000
122	SETH WILLIAMS BLVD	↓	8.9	1.0	↓	8,900
	↓	10'-6"	8.0	↓	↓	8,000
	↓	15'-9"	5.2	↓	↓	5,200
	↓	21'-0"	4.1	↓	↓	4,100
123	↓	5'-3"	1.3	10.0	↓	13,000
124	WINSTON ROAD	↓	1.6	↓	↓	16,000

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: PARADISE POINT AREA 7

DATE 11/7/84 **ENGINEER** NE/GG **TABLE** I **PAGE** 9 **OF** 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
130	SETH WILLIAMS @ BLDG 2702	5'-3"	5.2	1.0	1000	5200
131	WAVEL ST. @ BLDG. 2616		5.6	10.0		56,000
132	SETH WILLIAMS BLVD		3.6	1.0		3,600
133	SETH WILLIAMS & CHARLES ST.		2.9			2,900
134	SETH WILLIAMS & HOWARD ST.		4.5			4,500
135	SETH WILLIAMS & BEACH		8.2			8,200
		10'-6"	2.5		2000	5,000
		15'-9"	1.3		3000	3,900
		21'-0"	1.1		4000	4,400
136	SETH WILLIAMS BLVD	5'-3"	1.2	10.0	1000	12,000
137			2.3			23,000
138	KENT ROAD		3.3			33,000
139			4.8			48,000
140	BREWSTER BLVD @ GOLF CRSE		2.9			29,000
141			10.5	1.0		10,500
		10'-6"	6.5		2000	13,000
		15'-9"	5.1		3000	15,300
		21'-0"	3.7		4000	14,800
142		5'-3"	9.1		1000	9,100
143	ST. MARY'S DRIVE		1.5			1,500
144			1.5	10.0		15,000
145			9.1	1.0		9,100
146			1.1	10.0		11,000
147			7.0	1.0		7,000

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: BERKELEY MANOR & WATKINS VILLAGE AREAS 8 & 8A

DATE 11/7/84 **ENGINEER** CM/JH **TABLE** I **PAGE** 10 **OF** 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
150	BREWSTER & STONE	5'-3"	1.8	10.0	1000	18,000
151	ALABAMA AVE & MICHIGAN CT	↓	5.5	1.0	↓	5,500
152	ALABAMA AVE & FLORIDA AVE	↓	10.5	↓	↓	10,500
153	ALABAMA AVE & VERMONT CT	↓	3.7	10.0	↓	37,000
154	ALABAMA AVE @ BLDG. 5261	↓	3.0	↓	↓	30,000
155	COLORADO AVE & DELAWARE AVE	↓	2.7	↓	↓	27,000
156	MICHIGAN AVE & COLORADO AVE	↓	1.75	↓	↓	17,500
157	MICHIGAN AVE & FLORIDA AVE	↓	3.85	↓	↓	38,500
158	MARYLAND AVE & VIRGINIA ST	↓	8.05	↓	↓	80,500
159	STONE ST @ HIGH SCHOOL	↓	1.70	↓	↓	17,000
160	VIRGINIA ST & LOUISIANA ST	↓	5.0	↓	↓	50,000
161	OREGON ST & FLORIDA AVE	↓	2.5	↓	↓	25,000
162	DELAWARE AVE & MARYLAND AVE	↓	1.85	↓	↓	18,500
163	DELAWARE AVE & FLORIDA AVE	↓	9.50	↓	↓	95,000
164	STONE ST. @ MARINE CORPS EXCHANGE	↓	4.7	↓	↓	47,000
165	VIRGINIA ST & BICENTENNIAL AVE	↓	1.9	↓	↓	19,000
166	BICENTENNIAL AVE & FLORIDA AVE	↓	4.9	↓	↓	49,000
167	HAWAII ST & NEBRASKA CT	↓	4.1	↓	↓	41,000

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: MIDWAY PARK AREA 9

DATE 11/8/84 ENGINEER CM/JH TABLE I PAGE 11 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
170	BUTLER DR. SOUTH & BUTLER CT	5'-3"	1.9	10.0	1000	19,000
171	BUTLER DR. NORTH	↓	5.65	↓	↓	56,500
172	↓		2.9			29,000
173	↓		2.25			22,500
174	BUTLER DR. NORTH @ WATER TWR		6.1			61,000
175	SECOND ST		2.55			25,500
176	BUTLER DR. NORTH		1.1	100.0		110,000
177	BUTLER DR. SOUTH		10.5	1.0		10,500
178	BUTLER DR. SOUTH @ FIRE STA.		1.7	10.0		17,000
179	BUTLER DR. SOUTH @ BLDG 1054		5.7	↓		57,000
180	BUTLER DR. SOUTH @ BLDG 1500	↓	6.4	↓	↓	64,000

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: TARAWA TERRACE I, AREA 10

DATE 11/8/84 ENGINEER NE/GG TABLE I PAGE 12 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
190	TARAWA TERRACE ENTRANCE No. 1	5'-3"	5.3	10.0	1000	53,000
191	NORTH-WEST END OF ATHLETIC FIELD		5.8			58,000
192	TARAWA TERRACE ENTRANCE No. 1		7.4	1.0		7,400
		10'-6"	4.9		2000	9,800
		15'-9"	4.5		3000	13,500
		21'-0"	4.0		4000	16,000
193	EAST PELELIU @ BLDG 960	5'-3"	3.4	10.0	1000	34,000
194	OROTE PL. @ BLDG 1628		2.7			27,000
195	OROTE PL. @ CIRCLE		4.4			44,000
196	EAST PELELIU @ BLDG. 1026		2.8			28,000
197	WEST PELELIU @ BLDG. 1058		2.4			24,000
198	WEST PELELIU @ BLDG 1108		2.7			27,000
199	SURIBACHI PL. @ BLDG 1127		1.2	100.0		120,000
200	TARAWA BLVD. @ BLDG 21		2.2	10.0		22,000
		10'-6"	10.8	1.0	2000	21,600
		15'-9"	5.5		3000	16,500
		21'-0"	4.9		4000	19,600
201	WEST PELELIU @ BLDG. 599	5'-3"	3.4	10.0	1000	34,000
202	WEST PELELIU @ BLDG. 481		4.8			48,000
203	WEST PELELIU @ BLDG. 369		1.9			19,000
204	TARAWA BLVD & EAST PELELIU		1.6			16,000
205	COURT @ BLDG 1261		3.1			31,000

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SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: TARAWA TERRACE I, AREA 10

DATE 11/8/84 ENGINEER NE/GG TABLE I PAGE 13 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
206	INCHON ST @ BLDG 1294	5'-3"	1.5	10.0	1000	15,000
207	INCHON ST @ BLDG 1367	↓	2.4	↓	↓	24,000
208	TINIAN ROAD		3.9			39,000
209	INCHON ST @ BLDG 830		3.6			36,000
210	NAHA DR @ BLDG 709		2.3	100.0		230,000
211	MATANIKAU @ BLDG 1522		3.6	10.0		36,000

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SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: TARAWA TERRACE II, AREA 11

DATE 11/8/84 ENGINEER NE/GG TABLE I PAGE 14 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
220	IWO JIMA @ ENTRANCE	5'3"	7.5	10.0	1000	75,000
221	IWO JIMA BLVD	↓	2.2		↓	22,000
		10'-6"	1.3	↓	2000	26,000
		15'-9"	10.2	1.0	3000	30,600
		21'-0"	8.9		4000	35,600
222	↓	5'3"	8.3		1000	8,300
223	IWO JIMA BLVD & INCHON ST		8.4			8,400
224	↓ & TARAWA		6.4			6,400
225	TARAWA BLVD		9.2	↓		9,200
226	ROAD TO SEWAGE DISPOSAL	↓	4.3	10.0	↓	43,000
		10'-6"	2.4		2000	48,000
		15'-9"	2.5		3000	75,000
	↓	21'-0"	1.4		4000	56,000
227	HAGARU DR @ BLDG 3385	5'3"	2.2		1000	22,000
228	CHOSIN CIRCLE @ BLDG 3544		2.0	↓		20,000
229	GUAM AVE & AGANA PL.		8.1	1.0		8,100
230	BOUGAINVILLE DR	↓	1.3	10.0	↓	13,000
		10'-6"	4.9	1.0	2000	9,800
		15'-9"	4.1		3000	12,300
	↓	21'-0"	3.0	↓	4000	12,000
231	BOUGAINVILLE @ BLDG. 3140	5'3"	1.5	10.0	1000	15,000
232	BOUGAINVILLE & TARAWA BLVD	↓	1.6	↓	↓	16,000

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SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: TARAWA TERRACE II, AREA II

DATE 11/8/84 **ENGINEER** NE/GG **TABLE** I **PAGE** 15 **OF** 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
233	BOUGAINVILLE DR @ BLDG 2631	5'-3"	5.2	10.0	1000	52,000
234	BOUGAINVILLE DR & SAIPAN DR		7.1	1.0		7,100
235	BOUGAINVILLE DR @ WATER TANK		6.7	↓		6,700
236	BOUGAINVILLE DR @ BLDG 2811		2.0	10.0		20,000
237	OPEN FIELD @ TARAWA & SCHOOL		2.1			21,000
238	TARAWA BLVD @ BLDG 2202		1.4			14,000
239	SAIPAN DR @ BLDG 3019	↓	2.0	↓	↓	20,000

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: TRAILER PARK AREA 12

DATE 11/8/84 ENGINEER CM/JH TABLE I

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
250	CAMP KNOX RD	5'-3"	2.8	10.0	1000	28,000
251			1.7			17,000
252	RICHMOND RD		8.3	1.0		8,300
253	TOLEDO RD		1.4	10.0		14,000
254	BALTIMORE RD		9.6	1.0		9,600
255	BOSTON & NORFOLK CT		7.4			7,400
256	FLORENCE & DETROIT CT		7.1			7,100
257	BUFFALO CT		7.0			7,000
258	CAMP KNOX & FLORENCE RD		1.2	10.0		12,000
259	BOSTON RD		5.2	1.0		5,200

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: CAMP KNOX AREA 13

DATE 11/8/84 ENGINEER CM/JH TABLE I

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
260	RALEIGH RD	5'-3"	1.1	10.0	1000	11,000
261	AUSTIN DR	↓	7.5	1.0	↓	7,500
262	LEXINGTON CT	↓	1.1	10.0	↓	11,000
263	RALEIGH RD & DENVER CT	↓	4.7	1.0	↓	4,700
264	SACREMENTO RD	↓	4.8	↓	↓	4,800

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: MONTFORD POINT AREA 14

DATE 11/9/84 ENGINEER CM/JH TABLE I

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
270	MONTFORD LANDING RD	5'-3"	1.6	10.0	1000	16,000
271	NEW CONSTRUCTION @ BLDG 131	↓	1.7	↓	↓	17,000
272	HARLEM DR @ BLDG 415		10.9	↓		109,000
273	CO. ST. 'D' @ BLDG 622		1.4	1.0		1,400
274	CO. ST 'E' @ BLDG 518		7.6	↓		7,600
275	FLORENCE RD @ BLDG E-1		3.5			3,500
276	NEUSE RD @ BLDG 105		2.5	↓		2,500
277	MONTFORD LANDING RD @ BLDG 142		1.1	10.0		11,000
278	WASTE TREATMENT PLANT		1.5	1.0		1,500
279	WILSON @ TENNIS COURTS		2.3	10.0		23,000
280	HOOVER RD @ BLDG 203		6.9	10.0		69,000
281	END OF HAYES ST	↓	6.5	1.0	↓	6,500

M D A MENENDEZ-DONNELL & ASSOCIATES, INC. HOUSTON, TEXAS

GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: CAMP GEIGER AREA 15

DATE 11/9/84 ENGINEER CM/JH TABLE I PAGE 19 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
290	ELEVENTH & 'A' ST	5'-3"	2.7	10.0	1000	27,000
291	BLDG TC 1063		8.5	1.0		8,500
292	9TH ST @ BLDG TC 853		9.7			9,700
293	'C' ST @ BLDG TC 1021		7.3			7,300
294	'C' ST @ BLDG TC 821		5.0	↓		5,000
295	'A' ST @ BLDG TC 910		3.5	10.0		35,000
296	7TH ST @ BLDG TC 704		8.0			80,000
297	6TH ST @ BLDG G 551		1.1			11,000
298	'A' ST & 3RD ST		1.2	↓		12,000
299	'C' ST & 1ST ST		9.7	1.0		9,700
300	'G' ST @ BLDG TC 474		1.9			1,900
301	BRINSON CREEK		8.4			8,400
302	'G' ST @ BLDG TC 609		4.9	↓		4,900
303	CURTISS RD @ SUBSTATION		1.5	10.0		15,000
304	↓	↓	8.0	1.0	↓	8,000

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: GEIGER TRAILER PARK AREA 16

DATE 11/9/84 ENGINEER CM/JH TABLE I PAGE 20 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
310	R.L. WILSON BLVD & BORDELON ST	5'-3"	4.5	1.0	1000	4,500
311	BORDELON ST	↓	2.5	10.0	↓	25,000
312	AGERHOLM ST	↓	1.2	↓	↓	12,000
313	R.L WILSON BLVD & EPPERSON ST	↓	3.8	1.0	↓	3,800
314	EPPERSON ST & HAWKINS BLVD	↓	1.5	10.0	↓	15,000
315	HAWKINS BLVD	↓	1.7	↓	↓	17,000
316	R.L. WILSON BLVD	↓	1.5	↓	↓	15,000
317	↓	↓	6.3	1.0	↓	6,300

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: RIFLE RANGE AREA 17

DATE 11/6/84 ENGINEER NE/GG TABLE I PAGE 21 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
320	RANGE RD	5'-3"	4.4	10.0	1000	44,000
	↓	10'-6"	1.6	↓	2000	32,000
	↓	15'-9"	10.4	1.0	3000	31,200
	↓	21'-0"	1.2	10.0	4000	48,000
321	POWDER LN	5'-3"	4.1	↓	1000	41,000
322	POWDER LN @ BLDG 72	↓	4.3	↓	↓	43,000
	↓	10'-6"	1.3	↓	2000	26,000
323	POWDER LN @ BLDG 15	5'-3"	30.0	↓	1000	300,000
324	ROAD OFF RANGE RD	↓	2.4	↓	↓	24,000
	↓	10'-6"	1.5	↓	2000	30,000
	↓	15'-9"	1.1	↓	3000	33,000
	↓	21'-0"	9.5	1.0	4000	38,000
325	RANGE RD	5'-3"	19.0	10.0	1000	190,000
326	↓	↓	23.0	↓	↓	230,000
327	↓	↓	7.5	1.0	↓	7,500
328	↓ @ BLDG 69	↓	1.0	10.0	↓	10,000
329	BOOKER T. WASHINGTON BLVD	↓	1.0	↓	↓	10,000
330	↓	↓	2.9	↓	↓	29,000
331	G.W. CARVER ST. @ BLDG 212	↓	1.1	↓	↓	11,000
332	ROAD OFF RANGE RD	↓	9.2	↓	↓	92,000
	↓	10'-6"	5.0	1.0	2000	10,000
	↓	15'-9"	2.7	↓	3000	8,100
	↓	21'-0"	1.8	↓	4000	7,200

M D A MENENDEZ-DONNELL & ASSOCIATES, INC. HOUSTON, TEXAS

GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: COURT HOUSE BAY AREA 18

DATE 11/6/84 ENGINEER NE/GG TABLE I PAGE 22 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
340	COURTHOUSE RD	5'-3"	9.4	1.0	1000	9,400
		10'-6"	4.6			4,600
		15'-9"	3.1			3,100
		21'-0"	2.7			2,700
341	COURTHOUSE RD @ U.G. FUEL TANKS	5'-3"	9.1			9,100
		10'-6"	4.7			4,700
		15'-9"	3.2			3,200
		21'-0"	2.8			2,800
342	COURTHOUSE RD	5'-3"	2.5			2,500
343	SNEADS FERRY RD		2.9			2,900
344			2.2	100.0		220,000
345	MARINES RD		6.5	1.0		6,500
346	POE RD @ BLDG 71		7.5			7,500
		10'-6"	4.0		2000	8,000
		15'-9"	2.4		3000	7,200
		21'-0"	1.5		4000	6,000
347	ROAD @ BLDG 50	5'-3"	1.9	10.0	1000	19,000
348	POE RD		1.8			18,000
349	MARINES RD		3.4			34,000
350			7.9			79,000
351	PEACH ST.		3.5			35,000
352	ELLEN PATH		1.4			14,000

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TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: COURT HOUSE BAY AREA !8

DATE 11/6/84 ENGINEER NE/GG TABLE I PAGE 23 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
353	FRONT ST	5'-3"	1.2	10.0	1000	12,000
354	↓	↓	2.3	1.0	↓	2,300
355	CLINTON ST		1.3	10.0		13,000
356	MARINES RD		1.4	↓		14,000
357	MARINES RD @ GAS STATION		3.1			31,000
	↓	10'-6"	1.6		2000	32,000
		15'-9"	8.4	1.0	3000	25,200
		21'-0"	6.0	↓	4000	24,000
358	GRACE LN @ BLDG 80	5'-3	2.1	10.0	1000	21,000
359	SNEADS FERRY & MARINE RD	↓	3.15	100.0	↓	315,000
	↓	10'-6"	1.1	↓	2000	220,000
		15'-9"	5.65	10.0	3000	169,500
		21'-0"	3.35	↓	4000	134,000

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: ONSLOW BEACH AREA 19

DATE 11/9/84 ENGINEER CM TABLE I PAGE 24 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
370	ACCESS RD. AT TURNAROUND	5'-3	3.10	10	1000	31,000
	↓	10'-6"	1.30	10	2000	26,000
		15'-9"	8.10	1	3000	24,300
		21'-0"	7.10	1	4000	28,400
371	BEACH AVE. AT BEACH RD.	5'-3"	1.15	100	1000	115,000
	↓	10'-6"	2.60	10	2000	52,000
		15'-9"	6.5	1	3000	19,500
		21'-0"	1.20	1	4000	4,800
372	BEACH AREA FRONT BA-115	5'-3"	4.85	10	1000	48,500
	↓	10'-6"	1.95	10	2000	39,000
		15'-9"	1.40	10	3000	42,000
		21'-0"	1.90	10	4000	76,000
373	BEACH AREA AT WATER TANK	5'-3"	1.70	10	1000	17,000
	↓	10'-6"	7.0	1	2000	14,000
		15'-9"	9.0	1	3000	27,000
		21'-0"	5.1	1	4000	20,400
374	BEACH AREA AT BA-105	5'-3"	2.60	10	1000	26,000
	↓	10'-6"	1.20	10	2000	24,000
		15'-9"	1.05	10	3000	31,500
		21'-0"	6.60	1	4000	26,400
375	FUEL TANK AT BLDG. BA-106	5'-3"	4.3	1	1000	4,300
	↓	10'-6"	1.4	1	2000	2,800
376	FUEL TANK AT BLDG BA-106	5'-3"	1.0	1	1000	1,000
	↓	10'-6"	1.1	1	2000	2,200

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N. C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: FRENCH CREEK AREA 20

DATE 11/9/84 ENGINEER CM TABLE I

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
390	MAIN SERVICE RD AT COGDELS CREEK	5'-3"	6.90	1	1000	6,900
391	" " AT DALY ST.	↓	1.35	10	↓	13,500
392	" " AT BLDG. ES-200		6.40	10		64,000
393	AT WATER TOWER		1.20	100		120,000
394	BLDG. FC-566		2.50	10		25,000
395	GONZALEZ BLVD. AT REASONER ST.		3.50	10		35,000
396	" " " ANDERSON ST		4.90	10		49,000
397	ANDERSON ST. AT BARKER RD.		1.90	10		19,000
398	AT BLDG. FC-202	↓	5.4	10	↓	54,000
	(UNDERGROUND TANK)	10'-6"	3.3	10	2000	66,000

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SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: NEW NAVAL HOSPITAL AREA 21

DATE 11/9/84 ENGINEER CM TABLE I PAGE 26 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
410	"A" STREET	5'-3"	1.30	10	1000	13,000
411	'A" STREET	↓	7.30	1	↓	7,300
412	NORTH-WEST OF HOSPITAL		9.20			9,200
413	NORTH OF HOSPITAL		5.2			5,200
414	NORTH-EAST OF HOSPITAL		8.7	↓		8,700
415	AT PUBLIC WORKS BLDG.	↓	1.1	10	↓	11,000
416	UNDERGROUND FUEL TANK, NORTH	5'-3"	1.3	1	1000	1,300
	↓	10'-6"	1.0		2000	2,000
417	, EAST	5'-3"	4.4		1000	4,400
	↓	10'-6"	1.3		2000	2,600
418	, WEST	5'-3"	3.85		1000	3,850
	↓ ↓	10'-6"	1.6		2000	3,200
419	UNDERGROUND FUEL TANK AT	5'-3"	4.0		1000	4,000
420	PUBLIC WORKS BLDG. GAS STATION	5'-3"	2.9	↓	1000	2,900

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: SITE PLAN

DATE 11/9/84 ENGINEER CM/JM TABLE I

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
430	BREWSTER BLVD.	5'-3"	3.9	10	1000	39,000
431	STONE ST. AT STABLES	↓	1.45	↓	↓	14,500
432	HOLCOMB & BREWSTER BLVD.		2.3			23,000
433	HOLCOMB BLVD. AT WATER WELL		1.9			19,000
434	↓ & WALLACE CREEK		3.5	1		3,500
435	& BEAR HEAD CREEK		1.8	10		18,000
436	LYMAN & SNEADS FERRY RD.		2.2	↓		22,000
437	↓		4.0			40,000
438	& COWHEAD CREEK		2.5			25,000
439	& OBSERVATION POST #3		5.15			51,500
440			2.6			26,000
441	LYMAN & DUCK CREEK STARLING RD.	5'-3"	3.1		1000	31,000
	↓	10'-6"	1.9		2000	38,000
		15'-9"	1.4		3000	42,000
		21'-0"	1.05		4000	42,000
442	DUCK CREEK STARLING & SPRING BRANCH	5'-3"	9.75		1000	97,500
	↓	10'-6"	2.8		2000	56,000
		15'-9"	1.85		3000	55,500
		21'-0"	1.4	↓	4000	56,000
443	DUCK CREEK STARLING RD.	5'-3"	1.15	100	1000	115,000
	↓	10'-6"	6.75	10	2000	135,000
		15'-9"	4.75	10	3000	142,500
		21'-0"	3.3	10	4000	132,000

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SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: SITE PLAN

DATE 11/9/84 ENGINEER CM/JM TABLE I

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
444	DUCK CREEK STARLING RD.	5'-3"	3.95	10	1000	39,500
	↓	10'-6"	2.15	↓	2000	43,000
	↓	15'-9"	1.6	↓	3000	48,000
	↓	21'-0"	1.35	↓	4000	54,000
445	DUCK CREEK STARLING RD.	5'-3"	1.4	100	1000	140,000
	↓	10'-6"	4.65	10	2000	93,000
	↓	15'-9"	2.5	↓	3000	75,000
	↓	21'-0"	1.9	↓	4000	7,640
446	DUCK CREEK STARLING RD.	5'-3"	1.5	↓	1000	15,000
	& FREEMANS CREEK	10'-6"	3.6	1	2000	7,200
	↓	15'-9"	1.8	↓	3000	5,400
	↓	21'-0"	5.0	↓	4000	20,000
447	SNEADS FERRY RD. & BEACH RD.	5'-3"	2.9	10	1000	29,000
448	BEACH RD.	5'-3"	5.25	↓	1000	52,500
449	SNEADS FERRY RD. & ACCESS RD.	5'-3"	8.5	↓	1000	85,000
	↓	10'-6"	3.5	↓	2000	70,000
	↓	15'-9"	1.95	↓	3000	58,500
	↓	21'-0"	1.2	↓	4000	48,000
450	SNEADS FERRY RD &	5'-3"	1.9	↓	1000	19,000
	HOLOVER CREEK	10'-6"	7.0	1	2000	14,000
	↓	15'-9"	3.7	↓	3000	11,100
	↓	21'-0"	2.8	↓	4000	11,200
451	SNEADS FERRY RD &	5'-3"	3.55	10	1000	35,500
	AMPHIBIAN RD.	10'-6"	2.4	10	2000	48,000

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SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: SITE PLAN

DATE 11/9/84 ENGINEER CM/JM TABLE I PAGE 29 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
451	SNEADS FERRY RD. &	15'-9"	1.85	10	3000	55,500
	AMPHIBIAN RD.	21'-0"	1.45	↓	4000	58,000
452	AMPHIBIAN RD.	5'-3"	7.2		1000	72,000
	↓	10'-6"	4.3		2000	86,000
		15'-9"	2.7		3000	81,000
	↓	21'-0"	1.85		4000	74,000
453	SNEADS FERRY RD.	5'-3"	6.15		1000	61,500
	↓	10'-6"	3.15		2000	63,000
		15'-9"	2.1		3000	63,000
		21'-0"	1.6	↓	4000	64,000
454		5'-3"	1.15	1000	1000	1,150,000
		10'-6"	3.2	100	2000	640,000
		15'-9"	2.65	100	3000	795,000
		21'-0"	7.4	10	4000	296,000
455	↓	5'-3"	5.1	↓	1000	51,000
456	SNEADS FERRY RD & FRENCH CREEK	↓	4.45		↓	44,500
457	& MARINE RD		1.7			17,000
458	& COWHEAD CREEK		1.95			19,500
459	↓		3.7			37,000
460	MARINES RD		3.6			36,000
461	↓		3.0			30,000
462			1.1			11,000
463			2.0			20,000
464	↓	↓	1.8	↓	↓	18,000

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SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: SITE PLAN

DATE 11/9/84 ENGINEER CM/JM TABLE I PAGE 30 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
465	MARINES RD.	5'-3"	3.8	10	1000	38,000
466	↓		1.1			11,000
467	SNEADS FERRY RD		2.9			29,000
468			1.6			16,000
469	↓ & RANGE RD.		4.2			42,000
470	GREY POINT RD.		3.9			39,000
471			4.85			48,500
472			3.55			35,500
473	↓		2.5			25,000
474	VERONA RD.		1.3			13,000
475			4.6			46,000
476			1.3			13,000
477	↓		4.4			44,000
478	VERONA AT U.S. 17	↓	4.0		↓	40,000
479	CURTIS RD. AT GUARD HOUSE	5'-3"	7.6		1000	76,000
	(GEIGER)	10'-6"	9.3		2000	186,000
	↓	15'-9"	1.7		3000	51,000
480	CURTIS RD.	5'-3"	1.1		1000	11,000
481	AT MC EXCHANGE		1.4			14,000
482	↓ AT ELEM. SCHOOL	↓	3.0	↓	↓	30,000

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

SOIL RESISTIVITY MEASUREMENTS

STRUCTURE: TANK FARM & MAIN EXCH. GAS STATION

DATE 11/6/84 ENGINEER ____ TABLE I PAGE 31 OF 31

TEST NO.	TEST LOCATION	AVERAGE DEPTH	READING	MULTI.	FACTOR	OHM-CM
490	WEST OF TANK FARM	5'-3"	2.5	10	1000	25,000
	↓	10'-6"	1.9	10	2000	38,000
	↓	15'-9"	10.1	1	3000	30,300
	↓	21'-0"	7.6	1	4000	30,400
491	NORTH OF TANK FARM	5'-3"	2.2	10	1000	22,000
	↓	10'-6"	1.1	10	2000	22,000
	↓	15'-9"	8.5	1	3000	25,500
	↓	21'-0"	4.5	1	4000	18,000
492	TANK FARM BETWEEN TANK 12&13	5'-3"	4.8	10	1000	48,000
	↓	10'-6"	1.6	10	2000	32,000
	↓	15'-9"	1.8	10	3000	54,000
	↓	21'-0"	6.0	1	4000	24,000
493	SOUTH OF TANK FARM	5'-3	2.4	10	1000	24,000
	↓	10'-6	1.2	10	2000	24,000
	↓	15'-9	8.5	1	3000	25,500
	↓	21'-0"	6.5	1	4000	26,000
494	MAIN EXCH. GAS STATION	5'-3"	1.1	10	1000	11,000
	↓	10'-6"	4.3	1	2000	8,600
495	↓	5'-3"	9.8	1	1000	9,800
	↓	10'-6"	6.7	1	2000	13,400

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: TANK FARM, INDUSTRIAL AREA 2

DATE 11/8/84 ENGINEER N.E. TABLE III-A

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
350	TANK #1	-.421			DUE TO THE HIGH CUR-
351	↓	-.446			RENT DEMAND AND HIGH
352	↓	-.346			SOIL RESISTIVITY, ATTEM-
353	TANK #2	-.437			PTS TO SET UP A TEMPO-
354	↓	-.507			RARY GROUNBED AND
355	↓	-.491			POWER SOURCE WERE
356	TANK #3	-.515			NOT SUCCESSFUL,
357	↓	-.516			THEREFORE NO IMPRESSED
358	↓	-.477			CURRENT MEASUREMENTS
359	TANK #4	-.510			WERE TAKEN.
360	↓	-.378			
361	↓	-.510			
362	↓	-.501			
363	TANK #5	-.437			
364	↓	-.514			
365	↓	-.447			
366	TANK #6	-.445			
367	↓	-.458			
368	↓	-.501			
369	↓	-.452			
370	TANK #7	-.515			
371	↓	-.534			
372	↓	-.448			
373	TANK #8	-.518			

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: TANK FARM, INDUSTRIAL AREA

DATE 11/8/84 ENGINEER N.E. TABLE III-A PAGE 2 OF 2

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
374	TANK #8	-.528			
375	↓	-.477			
376	↓	-.547			
377	TANK #15	-.494			
378	↓	-.488			
379	↓	-.478			
380	↓	-.402			
381	TANK #14	-.520			
382	↓	-.507			
383	↓	-.508			
384	TANK #13	-.508			
385	↓	-.536			
386	TANK #12	-.538			
387	↓	-.501			
388	↓	-.536			
389	TANK #11	-.498			
390	↓	-.554			
391	TANK #9	-.481			
392	↓	-.494			
393	↓	-.486			
394	TANK #10	-.402			
395	(600,000 GAL.)	-.418			
396	↓	-.429			
397	↓	-.409			

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: MAIN EXCHANGE, GAS STATION

DATE 11/8/84 ENGINEER C.M. / J.H. TABLE III-B PAGE 1 OF 1

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
		0 AMPS	0.4 AMPS	0.6 AMPS	
400	30,000 GAL.	-.453	-1.20	-1.66	
401	WEST TANK	-.477	-2.15	-2.43	
402	↓	-.469	-2.32	-2.64	DRAIN POINT
403		-.475	-.848	-.956	
404	↓	-.464	-.659	-.748	
405	30,000 GAL.	-.494	-.694	-.786	
406	CENTER TANK	-.469	-.731	-.847	
407	↓	-.451	-1.02	-1.23	
408	↓	-.477	-.819	-.939	
409	10,000 GAL.	-.497	-.684	-.772	
410	EAST TANK	-.474	-.711	-.807	
411	↓	-.450	-.805	-.916	
412	↓	-.480	-.690	-.784	
413	10,000 GAL.	-.431	-.582	-.667	
414	NORTH TANK	-.439	-.582	-.668	
415	↓	-.384	-.583	-.680	
416		-.427	-.619	-.703	
417	↓	-.541	-.709	-.791	

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: 10,000 GALLON TANK, RIFLE RANGE AREA 17

DATE 11/6/84 ENGINEER N.E./G.G. TABLE III-6 PAGE 1 OF 1

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
		0 AMPS	800 mA	250 mA	
420	NORTH SIDE	-.436	-1.70	-.944	
421	EAST SIDE	-.420	-3.21	-1.46	
422	SOUTH SIDE	-.413	-3.14	-1.38	
423	WEST SIDE	-.424	-3.06	-1.27	
224	TOP OF TANK	-.335	-1.98	-1.001	
225	AT VENT PIPE	-.469	-6.50	-1.98	DRAIN POINT

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: THREE FUEL TANKS AT GAS STATION, COURTHOUSE BAY AREA 18

DATE 11/6/84 ENGINEER N.E./G.G. TABLE III-D PAGE 1 OF 1

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
		0 AMPS	.40 AMPS		
430	NORTH TANK	-.363	-1.743		CONTINUITY BETWEEN
	↓				THE THREE TANKS
431		-.477	-2.08		WAS ESTABLISHED
					AT THE VENT PIPES
432	↓	-.439	-.803		(6000 GAL.)
433	CENTER TANK	-.470	-2.75		
434	↓	-.396	-.713		
435	↓	-.277	-.648		
436	SOUTH TANK	-.261	-.962		
437	↓	-.447	-2.70		

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: 10,000 GALLON TANK, #2 FUEL, ONSLOW BEACH AREA 19

DATE 11/6/84 ENGINEER C.M./ J.H. TABLE III-E PAGE 1 OF 1

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS STATIC VOLTS	CURRENT VOLTS	APPLIED VOLTS	REMARKS
		0 AMPS	9.8 AMPS		
440	WEST SIDE	-.510	-.902		
441	NORTH SIDE	-.449	-.729		
442	EAST SIDE	-.511	-.963		
443	SOUTH SIDE	-.508	-.713		

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: 10,000 GALLON TANK, #2 FUEL, FRENCH CREEK AREA 20

DATE 11/7/84 ENGINEER G.M./J.H. TABLE III-F PAGE 1 OF 1

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
		0 AMPS	100 mA		
450	SOUTH SIDE	-.483	-.646		DRAIN POINT
451	EAST SIDE	-.466	-1.160		
452	NORTH SIDE	-.459	-.563		
453	WEST SIDE	-.473	-.580		
454	TOP CENTER	-.502	-.647		
	TANK LOCATED SOUTH-EAST OF BLDG. FC-202				

M D A MENENDEZ-DONNELL & ASSOCIATES, INC. HOUSTON, TEXAS

GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CURRENT REQUIREMENT TEST

STRUCTURE: 10,000 GALLON TANK, GAS STATION AT PUBLIC WORKS, AREA 21

DATE 11/8/84 ENGINEER C.M./J.H. TABLE III-G PAGE 1 OF 1

REF. NO.	LOCATION	POTENTIAL MEASUREMENTS			REMARKS
		STATIC	CURRENT APPLIED		
		VOLTS	VOLTS	VOLTS	
		0 AMPS	235 mA		
460	NORTH SIDE	-.621	-1.07		
461	EAST SIDE	-.565	-1.01		
462	SOUTH SIDE	-.601	-1.22		DRAIN POINT
463	WEST SIDE	-.543	-.990		
464	TOP CENTER	-.576	-.970		

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CONTINUITY TEST DATA

STRUCTURE: FIRE WATER LINES

DATE 11/7/84 ENGINEER N.E./G.G. TABLE IV PAGE 1 OF 4

TEST NO.	SECTION OF LINE TESTED	STRUCT.-TO-SOIL POTENTIAL (VOLTS) CLOSE I-ON	CLOSE I-OFF	REMOTE I-ON	REMOTE I-OFF	REF. LOCAT.	REMARKS
	HADNOT POINT 1, AREA 4						
500A	FIRE HYDRANT ON	-1.006	-.542			AT 'A'	
	RIVER RD. AT BLDG.						
	123						
500B	FIRE HYDRANT ON	-.468	-.468			AT 'B'	
	'B' STREET & RIVER	-.936		-.426		AT 'B'	NO CONTINUITY
	RD.						
	OLD HOSPITAL, AREA 5						
501A	FIRE HYDRANT ON	-1.162	-.433			AT 'A'	
	RIVER RD. AT BLDG.						
	45						
501B	FIRE HYDRANT ON	-.492	-.492			AT 'B'	
	RIVER RD. AT BLDG.	-1.162		-.492		AT 'B'	NO CONTINUITY
	5						

NOTES: SEE DWG. NO. SK-6148-A FOR TEST PROCEDURE

M D A MENENDEZ-DONNELL & ASSOCIATES, INC. HOUSTON, TEXAS

GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CONTINUITY TEST DATA

STRUCTURE: FIRE WATER LINES

DATE 11/7/84 ENGINEER N.E./G.G. TABLE IV PAGE 2 OF 4

TEST NO.	SECTION OF LINE TESTED	STRUCT.-TO-SOIL POTENTIAL (VOLTS) CLOSE		REMOTE		REF. LOCAT.	REMARKS
		I-ON	I-OFF	I-ON	I-OFF		
	PARADISE POINT, AREA 7						
502A	FIRE HYDRANT ON	-1.361	-.460			AT 'A'	
	SETH WILLIAMS						
	BLVD., AT BLDG. 08						
502B	FIRE HYDRANT ON	-.489	-.487			AT 'B'	
	SETH WILLIAMS	-.489		-1.116		AT 'B'	NO CONTINUITY
	BLVD., AT BLDG. 04						
	TARAWA TERRACE II, AREA 11						
503A	FIRE HYDRANT ON	-2.44	-.497			AT 'A'	
	TARAWA BLVD. AT						
	BLDG. 2012						
503B	FIRE HYDRANT ON	-.477	-.477			AT 'B'	
	TARAWA BLVD. AT	-.477		-2.91		AT 'B'	NO CONTINUITY
	BLDG. 2072						

NOTES:

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CONTINUITY TEST DATA

STRUCTURE: FIRE WATER LINES

DATE 11/8/84 ENGINEER N.E./G.G. TABLE IV PAGE 3 OF 4

TEST NO.	SECTION OF LINE TESTED	STRUCT.-TO-SOIL POTENTIAL (VOLTS)				REF. LOCAT.	REMARKS
		CLOSE		REMOTE			
		I-ON	I-OFF	I-ON	I-OFF		
	MONTFORD POINT, AREA 14						
504A	FIRE HYDRANT ON	-.790	-.404			AT 'A'	
	MONTFORD RD. AT						
	BLDG. M-142						
504B	FIRE HYDRANT ON	-.470	-.470			AT 'B'	
	MONTFORD RD. AT	-.920		-.477		AT 'B'	NO CONTINUITY
	BLDG. M-128						
	CAMP GEIGER, AREA 15						
505A	FIRE HYDRANT ON	-.760	-.491			AT 'A'	
	'A' ST. & 9TH ST.						
505B	FYRE HYDRANT ON	-.468	-.468			AT 'B'	
	'A' ST. & 10TH ST.	-.870		-.468		AT 'B'	NO CONTINUITY

NOTES:

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GCPS GENERAL CATHODIC PROTECTION SERVICES INC.

TITLE: CATHODIC PROTECTION SURVEY, MARINE CORPS BASE, CAMP LEJEUNE, N.C.

CONTINUITY TEST DATA

STRUCTURE: FIRE WATER LINES

DATE 11/9/84 ENGINEER C.M./J.H. TABLE IV PAGE 4 OF 4

TEST NO.	SECTION OF LINE TESTED	STRUCT.-TO-SOIL POTENTIAL (VOLTS) CLOSE I-ON	CLOSE I-OFF	REMOTE I-ON	REMOTE I-OFF	REF. LOCAT.	REMARKS
	ONSLOW BEACH, AREA 19						
506A	WATER SPIGOT ON	-6.90	-.850			AT 'A'	
	CAMPING AREA						
506B	FIRE HYDRANT ON	-.220	-.220			AT 'B'	
	ACCESS RD.	-.220		-.167		AT 'B'	NO CONTINUITY
507A	FIRE HYDRANT AT	-.709	-.532			AT 'A'	
	BLDG. BA-103						
507B	FIRE HYDRANT AT	-.510	-.510			AT 'B'	
	BLDG. BA-102	-.510		-.575		AT 'B'	NO CONTINUITY
	FRENCH CREEK, AREA 20						
508A	FIRE HYDRANT AT	-.554	-.325			AT 'A'	
	BLDG. FC-200						
500B	FIRE HYDRANT AT	-.264	-.264			AT 'B'	
	BLDG. FC-100	-.264		-.767		AT 'B'	NO CONTINUITY

NOTES:

RECTIFIER DATA

MFGR. HARCO SERIAL NO. 4107

DC RATING 40 VOLTS. 20 AMPS.

SHUNT RATING: ______ mV. ______ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	A	A
	FINE	3	3
DC OUTPUT		4 V	4 V
BOWL CURRENT		1 A	.75A
RISER CURRENT		.4A	.2A.

COMMENTS:

ROOF MAN-WAY IS DETACHED (RUSTED OFF)

CONDULET COVERS ON BALCONY ARE MISSING

HARDWARE O.K. INTERIOR COATING LOOKED GOOD

ANODES ~ 6 TO 8 YEARS LIFE

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY 75% FULL TANK

BOTTOM	1.49V.	+15	1.62V.	+30	1.46V. SURFACE
+3	1.52V.	+18	1.60V.	+33	
+6	1.57V.	+21	1.57V.	+36	
+9	1.61V.	+24	1.53V.	+39	
+12	1.62V.	+27	1.48V.		

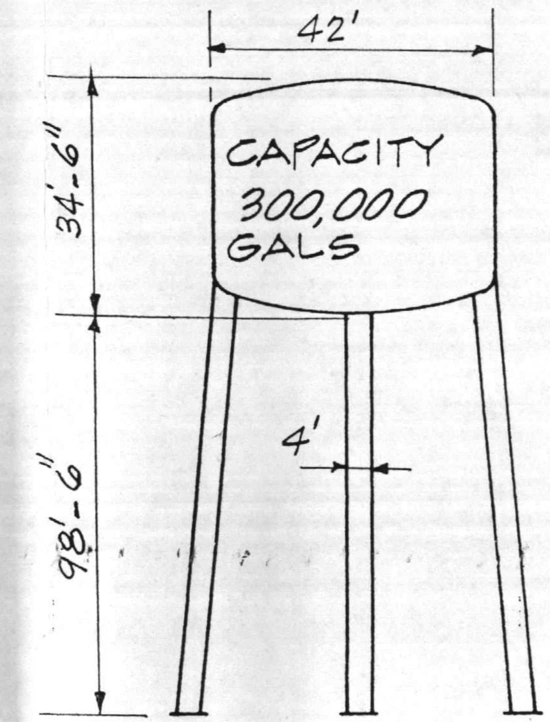
OFF POTENTIAL 1.04 V I.R. DROP 250 MV

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	0.050A.	1	.010A.
2	0.065A.	2	.015A.
3	0.050A	3	.010A.
4	0.055A.	4	.015A.
5	0.055A	5	.010A
6	0.055A.		
7	0.060A		
8	0.060A	RISER	.18A
9	0.060A		
10	0.060A		

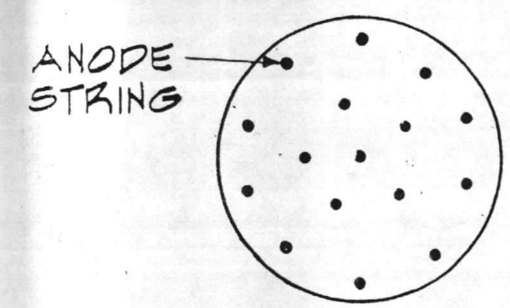
DATE OF SURVEY - NOV. 7, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK CATHODIC PROTECTION DATA (TANK S-1000) AREA 2

DES. C.R.M. DR. R.F.V. SCALE NONE	CK. R.S. APP. DATE 1-14-85	DWG. NO. REV. TABLE V-A

RECTIFIER DATA

MFGR. HARCO SERIAL NO. 4106

DC RATING 18 VOLTS. 16 AMPS.

SHUNT RATING: ______ mV. ______ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	B	A
	FINE	1	1
DC OUTPUT		6.2 V	2.3V
BOWL CURRENT		1.3A	.65A
RISER CURRENT		.30A	.015A

COMMENTS:

ANODES 6 TO 8 YEARS LIFE

HARDWARE O.K.-

INTERIOR COATING LOOKED GOOD

SURVEY DATA

POTENTIAL PROFILE

WET AREA AT SURVEY 50% FULL TANK

BOTTOM	1.26 V.	+15	1.25 V.	+30	
+3	1.24 V.	+18	1.22 V.	+33	
+6	1.28 V.	+21	1.20 V.	+36	
+9	1.25 V.	+24	1.21 V.	+39	
+12	1.26 V	+27	1.19 V. SURFACE		

OFF POTENTIAL 1.03 V. I.R. DROP 200 MV.

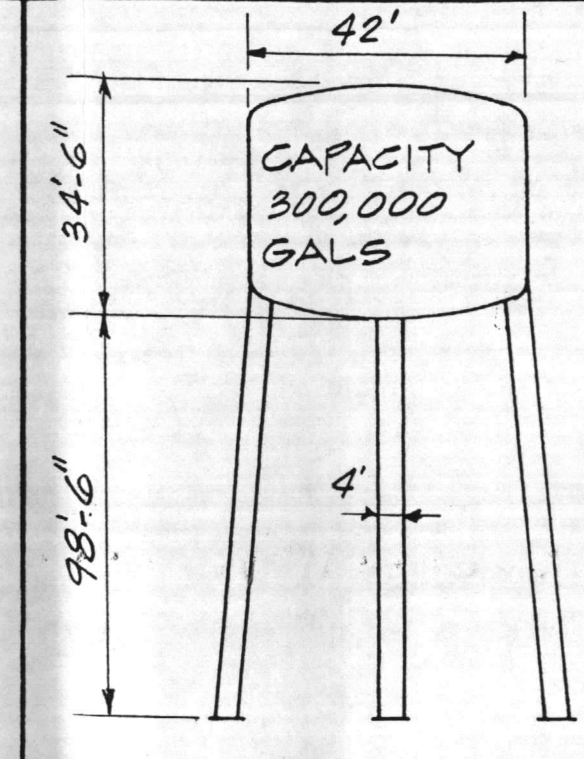
ANODE STRING CURRENT DRAINS

(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	.020A.	1	.05A.
2	.020A.	2	.05A.
3	.015A.	3	.08A.
4	.015A.	4	.08A.
5	.015A.	5	.08A.
6	.015A.		
7	.015A.		
8	.020A.	RISER	.013A
9	.020A.		
10	.020A.		

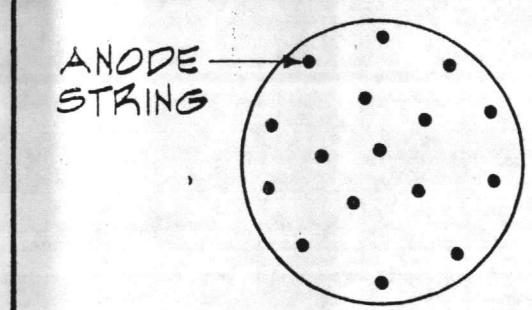
DATE OF SURVEY - NOV. 7, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK CATHODIC PROTECTION DATA (TANK S-29) AREA 3

DES. C.R.M.	CK. R.S.	DWG. NO. / REV
DR. R.F.V.	APP.	TABLE V-B
SCALE NONE	DATE 1-14-85	

RECTIFIER DATA

MFGR. HARCO SERIAL NO. 4103

DC RATING 18 VOLTS. 10 AMPS.

SHUNT RATING: ____ mV. ____ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	A	A
	FINE	1	1
DC OUTPUT		3.96 V.	3.96V.
BOWL CURRENT		.60A.	.60A.
RISER CURRENT		.12A.	.12A.

COMMENTS:

INNER ARRAY MISSING ONE STRING,

ANODES ~ 5 TO 7 YRS LIFE

HARDWARE O.K.

INTERIOR COATING LOOKED GOOD

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY FULL TANK.

BOTTOM	1.36V.	+15	1.61V.	+30	1.53V.
+3	1.50V.	+18	1.60V.	+33	1.54V.
+6	1.55V.	+21	1.57V.	+36	1.52V.
+9	1.59V.	+24	1.54V.	+39	1.48V. SURFACE
+12	1.61V.	+27	1.51V.		

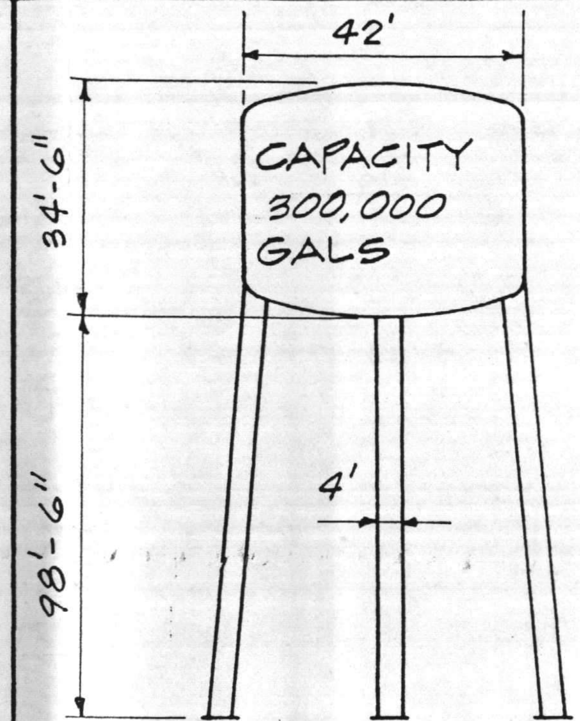
OFF POTENTIAL 1.07V. I.R. DROP 250MV.

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	.045A.	1	.008A.
2	.048A.	2	.010A.
3	.046A.	3	MISSING
4	.050A.	4	.011A.
5	.048A.	5	.009A.
6	.045A.		
7	.046A.		
8	.050A.	RISER	.14A.
9	.045A.		
10	.045A		

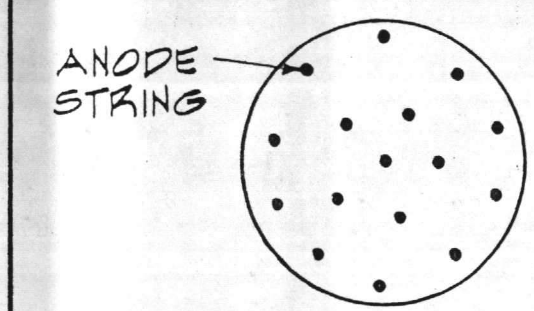
DATE OF SURVEY.- NOV. 11, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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ELEVATED WATER STORAGE TANK
CATHODIC PROTECTION DATA
(TANK S-5) AREA 4

DES. C.R.M. DR. R.F.V. SCALE NONE	CK. R.S. APP. DATE 1-14-85	DWG. NO. REV TABLE V-C

RECTIFIER DATA

MFGR. GOOD-ALL SERIAL NO. 80C 2833

DC RATING 40 VOLTS. 20 AMPS.

SHUNT RATING (Bowl) .0014 mV. .70 AMPS.
(Riser) .0022 mV. .22 AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	A	A
	FINE	3	3
DC OUTPUT		4 V.	4 V.
BOWL CURRENT		.45A.	.45A.
RISER CURRENT		.20A.	.20A.

COMMENTS:

ANODES ~ 5 TO 7 YRS LIFE

HARDWARE O.K

INTERIOR COATING LOOKED GOOD.

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY 50% FULL TANK

BOTTOM	1.32V.	+15	1.56V.	+30	
+3	1.43V.	+18	1.53V.	+33	
+6	1.53V.	+21	1.48V.	+36	
+9	1.57V.	+24	1.44V. SURFACE	+39	
+12	1.58V.	+27			

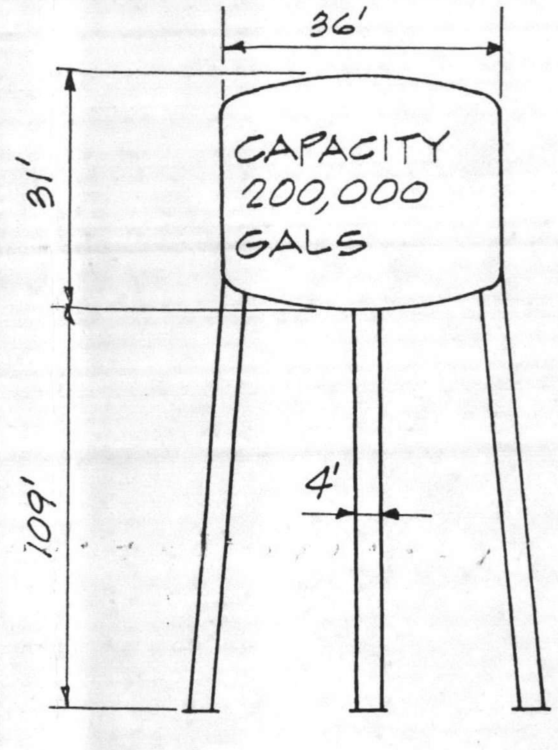
OFF POTENTIAL 1.07V. I.R. DROP 200MV.

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	.065A.	1	.025A.
2	.050A.	2	.012A.
3	.060A.	3	.010A.
4	.060A.	4	.025A
5	.060A.	5	
6	.055A.		
7	.055A.		
8	.060A.	RISER	.20A.
9			
10			

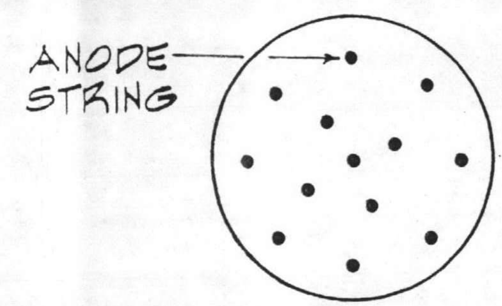
DATE OF SURVEY.- NOV. 7, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



MDA MENENDEZ · DONNELL & ASSOCIATES, INC.
GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK
CATHODIC PROTECTION DATA
(TANK S-2323) AREA 7

DES. C.R.M. DR. R.F.V. SCALE NONE	CK R.S. APP DATE 1-14-85	DWG NO REV TABLE V-D

RECTIFIER DATA

MFGR. HARCO SERIAL NO. 5201

DC RATING 36 VOLTS. 16 AMPS.

SHUNT RATING: ______ mV. ______ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	A	A
	FINE	3	3
DC OUTPUT		5.4V	5.4V
BOWL CURRENT		1A	1A
RISER CURRENT		.20A	.20A

COMMENTS:

ANODES ~ 5 TO 7 YRS LIFE

HARDWARE O.K.

INTERIOR COATING LOOKED GOOD.

SURVEY DATA

POTENTIAL PROFILE

WET AREA AT SURVEY 60% FULL TANK.

BOTTOM	1.45V.	+15	1.54V.	+30	
+3	1.49V.	+18	1.52V.	+33	
+6	1.50V.	+21	1.49V	+36	
+9	1.54V.	+24	1.48V.	+39	
+12	1.54V.	+27	SURFACE		

OFF POTENTIAL 1.07 V. I.R. DROP 250 MV.

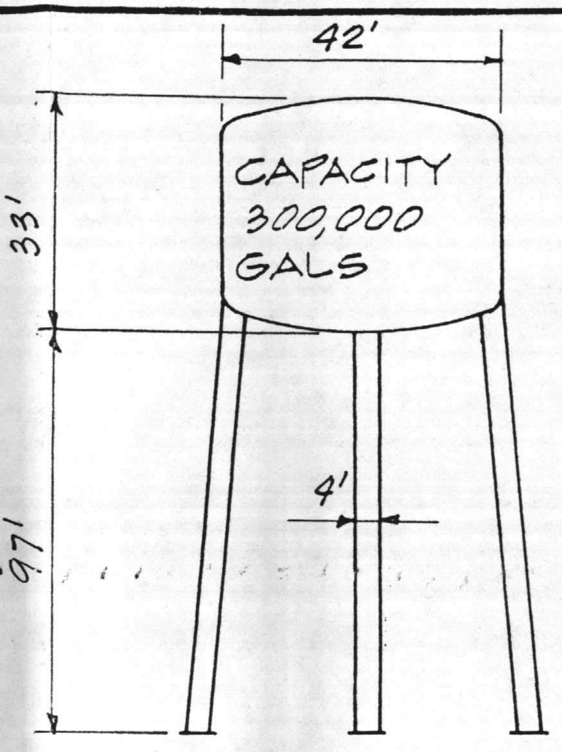
ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	.090A.	1	.035A
2	.120A.	2	.025A.
3	.120A.	3	.045A.
4	.100A.	4	
5	.095A.	5	
6	.100A.		
7			
8			
9			
10			

RISER 0.17A

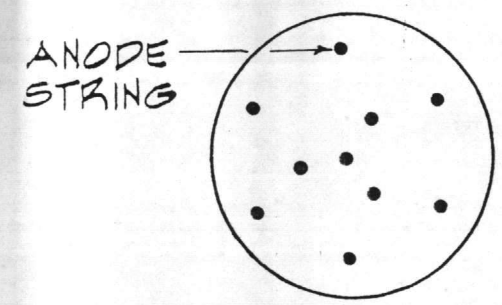
DATE OF SURVEY - NOV. 8, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



MDA MENENDEZ · DONNELL & ASSOCIATES, INC.

GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK
CATHODIC PROTECTION DATA
(TANK S-830) AREA 8

DES. C.R.M.	CK. R.S.	DWG. NO	REV
DR. R.F.V.	APP.	TABLE V-E	
SCALE NONE	DATE 1-14-85		

RECTIFIER DATA

MFGR. GOOD-ALL SERIAL NO. 80C2834

DC RATING 40 VOLTS. 20 AMPS.

SHUNT RATING (Bowl) .0015 mV. .75 AMPS.
(Riser) .0018 mV. .18 AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	A	A
	FINE	3	3
DC OUTPUT		4.62V.	4.62V
BOWL CURRENT		.58A	.58A.
RISER CURRENT		.18A.	.18A

COMMENTS:

ANODES ~ 5 TO 7 YRS LIFE

HARDWARE O.K.

INTERIOR COATING LOOKED GOOD.

RECTIFIER DOES NOT FUNCTION PROPERLY ON LOWER TAP SETTING

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY 50% FULL TANK

BOTTOM	1.38V.	+15	1.66V.	+30	
+3	1.54V.	+18	1.61V.	+33	
+6	1.64V.	+21	1.58V.	+36	
+9	1.67V.	+24	SURFACE	+39	
+12	1.68V.	+27			

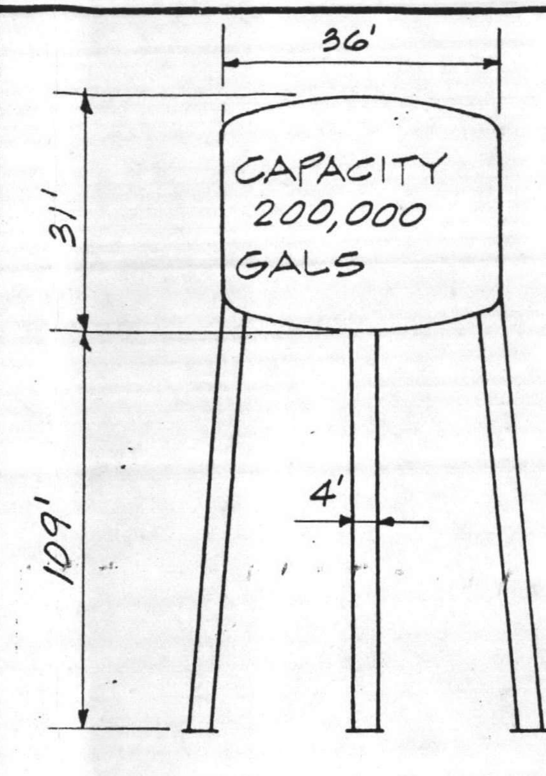
OFF POTENTIAL .90V I.R. DROP 50 MV.

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	.080A.	1	.012A.
2	.080A.	2	.005A.
3	.070A.	3	.012A.
4	.070A.	4	.020A.
5	.075A.	5	
6	.070A		
7	.075A.		
8	.065A.	RISER	.16A
9			
10			

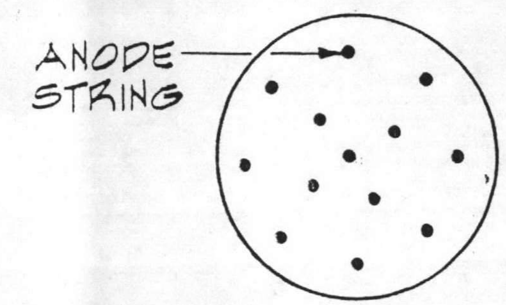
DATE OF SURVEY- NOV. 8, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK
CATHODIC PROTECTION DATA
(TANK S-MP-4004) AREA 9

DES. C.R.M.	CK. R.S.	DWG. NO.	REV
DR. R.F.V.	APP.	TABLE V-F	
SCALE NONE	DATE 1-14-85		

RECTIFIER DATA

MFGR. HARCO SERIAL NO. 5630

DC RATING 18 VOLTS. 16 AMPS.

SHUNT RATING: ____ mV. ____ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	A	A
	FINE	3	3
DC OUTPUT		3V	3V
BOWL CURRENT		.4A	.4A
RISER CURRENT		.06A	.06A

COMMENTS:

RISER HANDHOLE COVER MISSING BAR & BOLT.

ANODES 5 TO 7 YRS LIFE

HARDWARE O.K.

INTERIOR COATING LOOKED GOOD

SURVEY DATA

POTENTIAL PROFILE

WET AREA AT SURVEY TANK FULL

BOTTOM	1.43V.	+15	1.49V.	+30	1.54V. SURFACE
+3	1.45V.	+18	1.49V.	+33	
+6	1.46V.	+21	1.50V.	+36	
+9	1.46V.	+24	1.52V.	+39	
+12	1.48V.	+27	1.53V.		

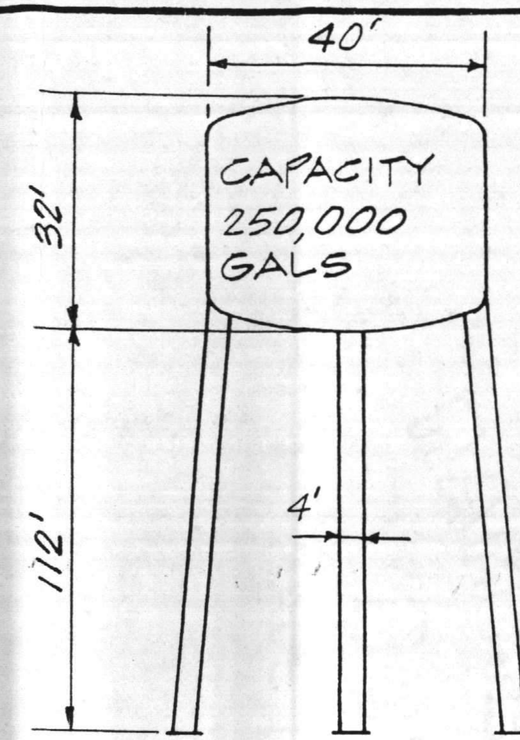
OFF POTENTIAL 1.02V. I.R. DROP 300MV.

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

	OUTER RING		INNER RING
1	.050A.	1	.025A.
2	.040A.	2	.015A.
3	.045A.	3	.020A.
4	.050A.	4	.020A.
5	.040A.	5	
6	.050A.		
7	.045A.		
8	.040A.	RISER	.090A
9			
10			

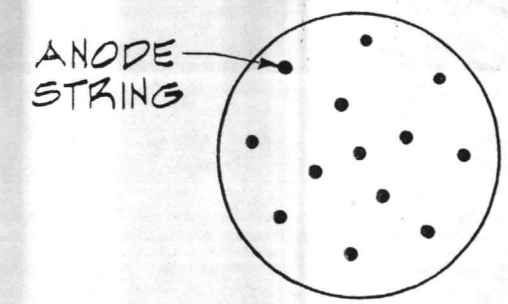
DATE OF SURVEY - NOV. 8, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK CATHODIC PROTECTION DATA (TANK S-TT-40) AREA II

DES. C.R.M.	CK. R.S.	DWG. NO
DR. R.F.V.	APP.	TABLE V-G
SCALE NONE	DATE 1-14-85	

RECTIFIER DATA

MFGR. HARCO SERIAL NO. 12210

DC RATING 18 VOLTS. 10 AMPS.

SHUNT RATING: ______ mV. ______ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	A	B
	FINE	4	3
DC OUTPUT		3.53V	6.72V
BOWL CURRENT		.35A.	1.0 A
RISER CURRENT		.050A	.60A

COMMENTS:

SOME WIRING UNDERWATER. BUT SHOULD BE O.K.

ANODES 2 TO 3 YRS LIFE

HARDWARE O.K.

INTERIOR COATING LOOKED GOOD.

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY TANK FULL

BOTTOM	1.00V.	+15	1.07V.	+30	
+3	1.04V.	+18	1.07V.	+33	
+6	1.08V.	+21	1.07V. SURFACE	+36	
+9	1.10V.	+24		+39	
+12	1.09V.	+27			

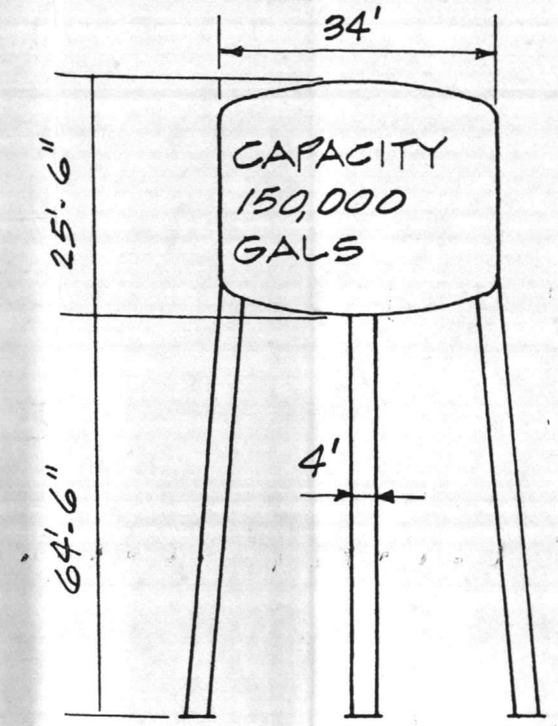
OFF POTENTIAL .950V I.R. DROP 50 MV.

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	.095A.	1	
2	.10A.	2	
3	.10A.	3	
4	.075A.	4	
5	.10A.	5	
6			
7			
8		RISER	.55A
9			
10			

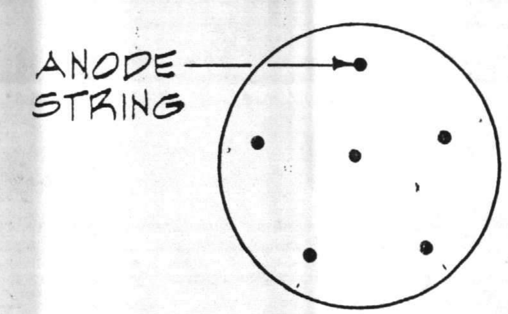
DATE OF SURVEY - NOV. 13, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK
CATHODIC PROTECTION DATA
(TANK S-M-624) AREA 14

DES. C.R.M. DR. R.F.V. SCALE NONE	CK R.S. APP DATE 1-14-85	DWG. NO. TABLE V-H REV

RECTIFIER DATA

MFGR. HARCO SERIAL NO. 7236

DC RATING 40 VOLTS. 12 AMPS.

SHUNT RATING: ______ mV. ______ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	A	B
	FINE	2	1
DC OUTPUT		2.44V.	8.8V.
BOWL CURRENT		.455A.	3A.
RISER CURRENT		.10A.	1.8A.

COMMENTS:

ANODES ~ 5 TO 7 YRS LIFE

HARDWARE O.K.

INTERIOR COATING LOOKED GOOD.

SURVEY DATA

POTENTIAL PROFILE

WET AREA AT SURVEY 70% FULL TANK.

BOTTOM	1.20V.	+15		+30	
+3	1.33V.	+18		+33	
+6	1.38V.	+21		+36	
+9	1.43V.	+24		+39	
+12	1.65V. SURFACE	+27			

OFF POTENTIAL .64V. I.R. DROP 300MV.

ANODE STRING CURRENT DRAINS

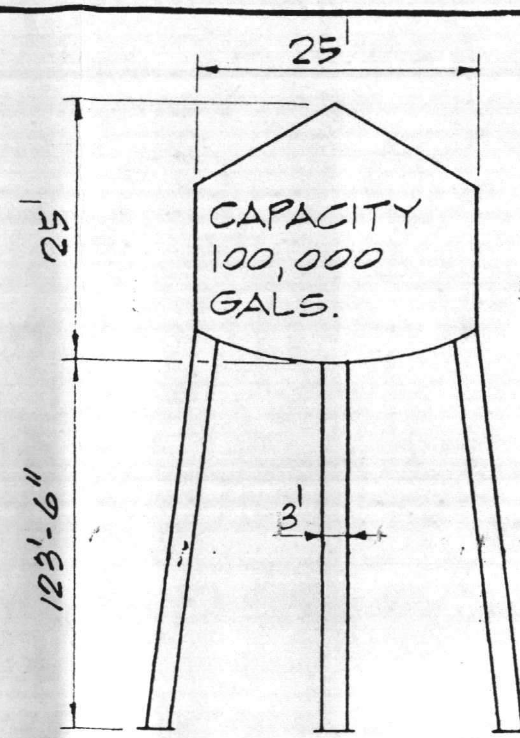
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	.50A.	1	
2	.50A.	2	
3	.50A.	3	
4	.50A.	4	
5	.55A.	5	
6			
7			
8			
9			
10			

RISER 1.75A

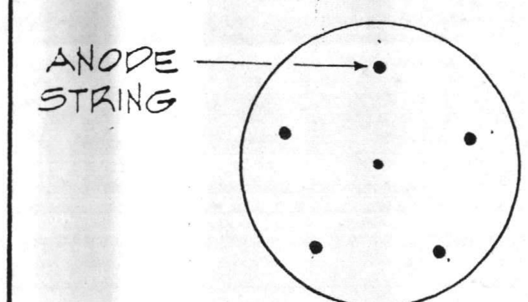
DATE OF SURVEY.- NOV. 12, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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ELEVATED WATER STORAGE TANK
CATHODIC PROTECTION DATA
(TANK S-TC-606) AREA 15

DES C.R.M.	CK R.S.	DWG NO / REV
DR R.F.V.	APP	TABLE V-I
SCALE NONE	DATE 1-14-85	

RECTIFIER DATA

MFGR. *GOOD-ALL* SERIAL NO. *81C1215*

DC RATING *60* VOLTS. *28* AMPS.

SHUNT RATING: ______ mV. ______ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	*A*	*A*
	FINE	*1*	*3*
DC OUTPUT		*2.06 V.*	*8.02 V.*
BOWL CURRENT		*.24 A.*	*4.38 A.*
RISER CURRENT		*.13 A.*	*1.72 A*

COMMENTS:

CONDULET COVER MISSING ON BALCONY.
EXTERIOR OF RISER NEEDS PAINTING.
ANODES ~ 5 TO 7 YRS LIFE.
HARDWARE O.K.
INTERIOR COATING LOOKED GOOD.

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY *75% FULL TANK.*

BOTTOM	*1.15 V.*	+15	*1.51 V.*	+30	
+3	*1.08 V.*	+18	*SURFACE*	+33	
+6	*1.10 V.*	+21		+36	
+9	*1.22 V.*	+24		+39	
+12	*1.36 V.*	+27			

OFF POTENTIAL *.68 V.* I.R. DROP *300 MV.*

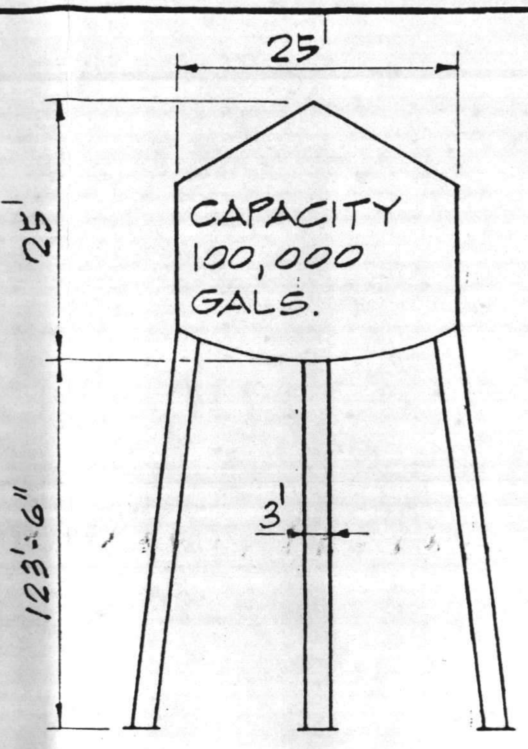
ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	*.50 A.*	1	
2	*.45 A.*	2	
3	*.45 A.*	3	
4	*.45 A.*	4	
5	*.45 A.*	5	
6			
7			
8			
9			
10			

RISER *1.72 A*

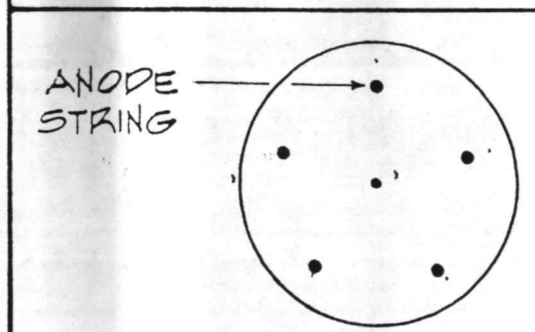
DATE OF SURVEY.- NOV. 12, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK
CATHODIC PROTECTION DATA
(TANK S-TC-1070) AREA 15

DES. C.R.M.	CK. R.S.	DWG. NO.
DR. R.F.V.	APP.	TABLE V-J
SCALE NONE	DATE 1-14-85	REV.

RECTIFIER DATA

MFGR. GOOD-ALL SERIAL NO. 80C2835

DC RATING 40 VOLTS. 20 AMPS.

SHUNT RATING	(Bowl) .0072 mV.	3.6	AMPS.
	(Riser) .013 mV	1.3	AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	B	A
	FINE	1	3
DC OUTPUT		10.1 V.	4.09 V.
BOWL CURRENT		3.6 A.	.80 A.
RISER CURRENT		1.3 A	.32 A.

COMMENTS:

WASP NEST INSIDE TANK ON SPIDER RODS
ANODES ~ 5 YRS LIFE
HARDWARE O.K.
INTERIOR COATING LOOKED GOOD

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY FULL TANK

BOTTOM	1.24 V.	+15	1.31 V.	+30	
+3	1.26 V.	+18	1.31 V. SURFACE	+33	
+6	1.27 V.	+21		+36	
+9	1.29 V.	+24		+39	
+12	1.31 V.	+27			

OFF POTENTIAL 1.12 V. I.R. DROP 100 MV.

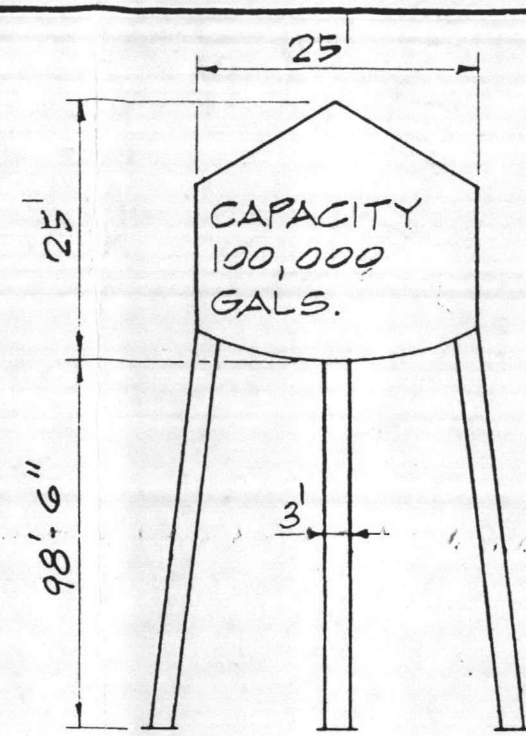
ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	.12 A.	1	
2	.12 A.	2	
3	.14 A.	3	
4	.17 A.	4	
5	.18 A.	5	
6			
7			
8			
9			
10			

RISER NO READING COVERED W/ WASPS

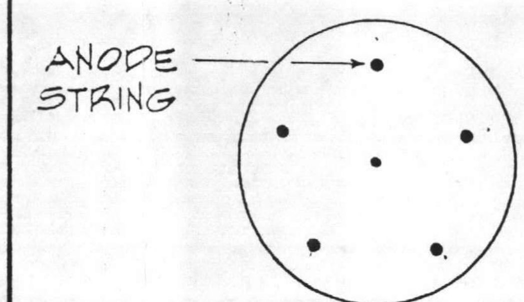
DATE OF SURVEY - NOV. 11, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK
CATHODIC PROTECTION DATA
(TANK S-RR-44) AREA 17

DES. C.R.M.	CK. R.S.	DWG. NO.
DR. R.F.V.	APP.	TABLE V-K
SCALE NONE	DATE 1-14-85	

RECTIFIER DATA		
MFGR. HARCO	SERIAL NO. 4109	
DC RATING 18 VOLTS. 10 AMPS.		
SHUNT RATING: ____ mV. ____ AMPS.		
	AS FOUND	AS LEFT
TAP SETTINGS — COURSE	A	A
TAP SETTINGS — FINE	1	1
DC OUTPUT	4.8V.	4.8V.
BOWL CURRENT	.75A.	.75A.
RISER CURRENT	.30A.	.30A.

COMMENTS:

ALL ANODE STRING TIED TO INLET PIPE
SHOVEL ON BOTTOM
ANODES ~ 5 YRS LIFE
HARDWARE O.K.
INTERIOR COATING LOOKED GOOD.

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY 75% FULL TANK.

BOTTOM	1.41 V.	+15	1.35 V.	+30	
+3	1.36 V.	+18	1.36 V. SURFACE	+33	
+6	1.33 V.	+21		+36	
+9	1.34 V.	+24		+39	
+12	1.34 V.	+27			

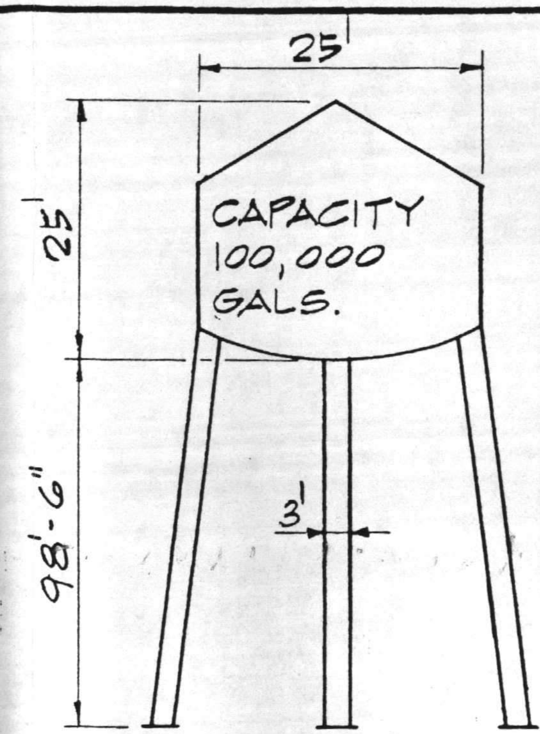
OFF POTENTIAL 1.13 V. I.R. DROP 200 MV.

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	.15A.	1	
2	.15A.	2	
3	.15A.	3	
4	.15A.	4	
5	.15A	5	
6			
7			
8		RISER	.25A.
9			
10			

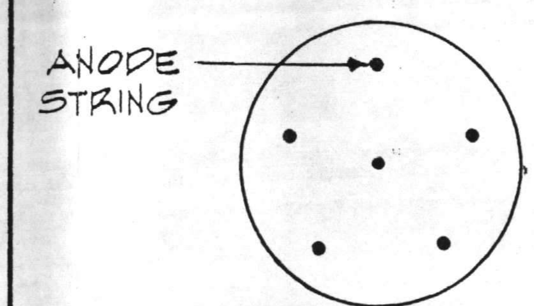
DATE OF SURVEY - NOV. 12, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK
CATHODIC PROTECTION DATA
(TANK S-BB-25) AREA 18

DES. C.R.M. DR. R.F.V. SCALE NONE	CK. R.S. APP. DATE 1-14-85	DWG. NO. REV. TABLE V-L

RECTIFIER DATA

MFGR. RIO SERIAL NO. 760043

DC RATING 40 VOLTS. 15 AMPS.

SHUNT RATING: ______ mV. ______ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	1	1
	FINE	4	4
DC OUTPUT		8V	8V
BOWL CURRENT		1.08A	1.08A
RISER CURRENT		.6A	.6A

COMMENTS:

MANWAY RUSTED CLOSED & COULD NOT BE OPENED

ANODES COULD NOT BE REMOVED THROUGH ACCESS HOLE.- TOO CLOSE TO INSULATOR.

ALL WIRING APPEARED O.K., HOWEVER HANDHOLES NEED REPLACEMENT.

EXTERIOR PAINT PEELING BADLY

INTERIOR LIGHTING SYSTEM NON-FUNCTIONAL

SURVEY DATA

POTENTIAL PROFILE
WET AREA AT SURVEY SEE COMMENTS.

BOTTOM		+15		+30	
+3		+18		+33	
+6		+21		+36	
+9		+24		+39	
+12		+27			

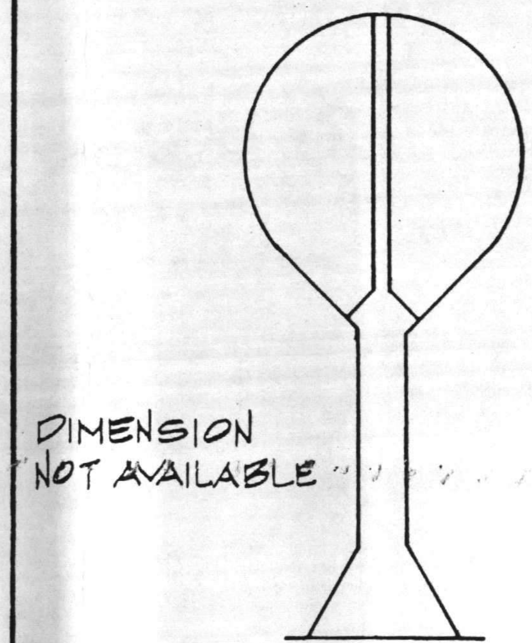
OFF POTENTIAL ______ I.R. DROP ______

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	.35A.	1	
2	.35A.	2	
3	.35A.	3	
4	.35A.	4	
5		5	
6			
7			
8		RISER	
9			
10			

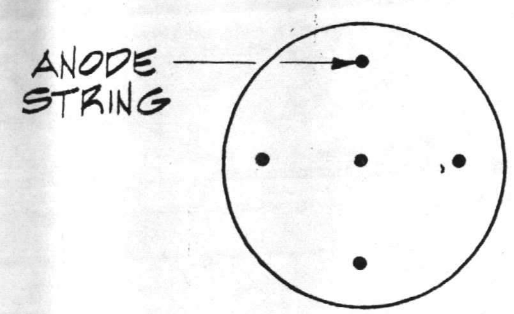
DATE OF SURVEY.- NOV. 11, 1984

TANK DATA



ELEVATION

ANODE GEOMETRY



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ELEVATED WATER STORAGE TANK CATHODIC PROTECTION DATA (TANK S-BA-108) AREA 19

DES. C.R.M.	CK. R.S.	DWG. NO.
DR. R.F.V.	APP.	TABLE V-M
SCALE NONE	DATE 1-14-85	REV.

RECTIFIER DATA

MFGR. *HARCO* SERIAL NO. *7238*

DC RATING *20* VOLTS. *24* AMPS.

SHUNT RATING: ______ mV. ______ AMPS.

		AS FOUND	AS LEFT
TAP SETTINGS	COURSE	*B*	*B*
	FINE	*2*	*2*
DC OUTPUT		*7 V.*	*7 V.*
BOWL CURRENT		*.75A.*	*.75A.*
RISER CURRENT		*.35A*	*.35A.*

COMMENTS:

ROOF LADDER CAN NOT BE MOVED & OBSTRUCTS ACCESS TO MANWAY.

AIR VENT COMPLETELY RUSTED OFF

ALL OBSTRUCTION LIGHTS ARE MISSING

3/4" CONDULET ON TOP OF TANK IS CRACKED AND MISSING ITS COVER.

ANODES ~ 5 YRS LIFE

HARDWARE O.K.

INTERIOR COATING LOOKED GOOD.

SURVEY DATA

POTENTIAL PROFILE

WET AREA AT SURVEY *SEE COMMENTS*

BOTTOM		+15		+30	
+3		+18		+33	
+6		+21		+36	
+9		+24		+39	
+12		+27			

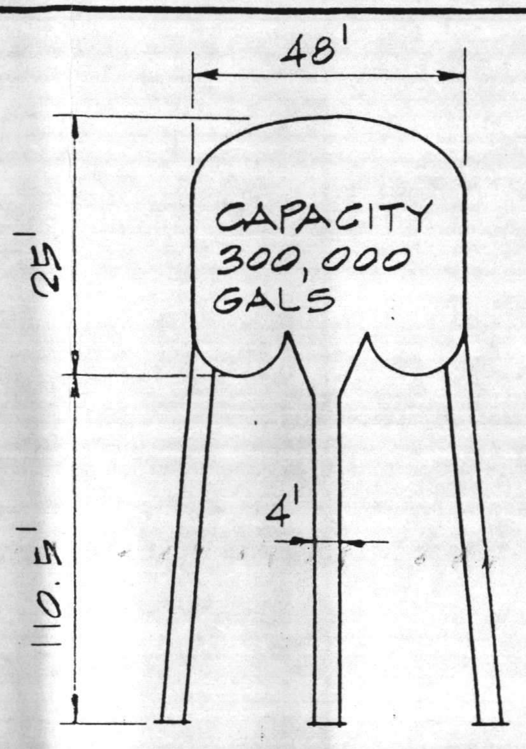
OFF POTENTIAL ______ I.R. DROP ______

ANODE STRING CURRENT DRAINS
(going counterclockwise from ladder)

OUTER RING		INNER RING	
1	*.075A.*	1	*.015A.*
2	*.060A.*	2	*.015A.*
3	*.058A.*	3	*.015A.*
4	*.065A.*	4	
5	*.065A.*	5	
6	*.065A.*		
7	*.070A.*		
8	*.072A.*	RISER	*.250A*
9	*.070A.*		
10	*.072A.*		

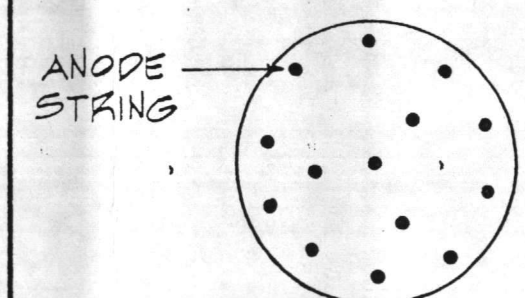
DATE OF SURVEY.- NOV. 8, 1984.

TANK DATA



ELEVATION

ANODE GEOMETRY



MDA MENENDEZ · DONNELL & ASSOCIATES, INC.

GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELEVATED WATER STORAGE TANK
CATHODIC PROTECTION DATA
(TANK S-FC-314) AREA 20

DES. C.R.M.	CK. R.S.	DWG. NO	REV
DR. R.F.V.	APP.	TABLE V-N	
SCALE NONE	DATE 1-14-85		

TAB PLACEMENT HERE

DESCRIPTION:

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C

APPENDIX C

SOIL AND WATER ANALYSIS

LOCATION OF SAMPLES

SOIL SAMPLES

"S-11" Industrial Area 2, from top of tank berm at Fuel Farm.

"S-12" Industrial Area 2, from vicinity of piping at North end of Fuel Farm.

"S-13" Hadnot Point 2, Area 3, from pipeline construction trench at "I" Street.

"S-14" French Creek Area 20, at Reasoner Street.

"S-15" Montford Point Area 14, from ongoing construction excavation at Montford Road.

"S-16" Old Naval Hospital Area 5, near Building No. 16.

"S-17" Berkeley Manor Area 8, from ditch at Stone Street near Marine Corps Exchange # 2.

"S-18" Courthouse Bay Area 18, at Sneads Ferry Road.

"S-19" Onslow Beach Area 19, near intersection of Sneads Ferry Road and Access Road.

WATER SAMPLES

"W-12" Camp Geiger Area 15, from Tank No. S-TC-606.

"W-13" Midway Park Area 9, from Tank No. S-MP-4004.

"W-14" Industrial Area 2, from Tank No. S-1000.

"W-15" Rifle Range Area 17, from Tank No. S-RR-44.

"W-16" Onslow Beach Area 19, from Tank No. S-BA-108.

"W-17" Courthouse Bay Area 18, from Tank No. S-BB-25.

SGS Control Services Inc.

1201 W. 8th Street
P.O. Box 550
Deer Park, Texas 77536
Tel: (713) 479-7170
TWX: 910 881 1681
TLX: 795065 SUPERCO DERK

December 15, 1984

MENENDEZ-DONNELL & ASSOCIATES
11999 Katy Freeway, #355
Houston, TX 77079
ATTN: Joe Meszaros

Analytical Report No. #97414-2

LAB REFERENCE NO.: L/3445/84 SAMPLE DESCRIPTION: Soil / Water

SAMPLE MARKED: SUBMITTED SAMPLES AS MARKED BELOW / RECEIVED 12-4-84

SUBMITTED BY: Menendez-Donnell & Associates

RESULTS OF ANALYSIS

Based upon samples submitted to us, tested in our laboratory, reported to you as follows:

"WATER SAMPLES"

[Standard Methods 15th Edition]

Method	Tests	"W-12"	"W-13"	"W-14"
423	Total Dissolved Solids, mg/L	397	127	108
209C	pH	8.6	8.1	8.3
426B	Sulfate, mg/L	21.8	10.3	14.8
407C	Chlorides, mg/L	82	13	11
205	Conductivity, μmhos/cm	738	187	170

	"W-15"	"W-16"	"W-17"
Total Dissolved Solids, mg/L	226	210	202
pH	8.1	7.9	8.4
Sulfate, mg/L	11.5	11.5	7.4
Chlorides, mg/L	19	18	15
Conductivity, μmhos/cm	371	355	360

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SAMPLE MARKED: SUBMITTED SAMPLES AS MARKED BELOW / RECEIVED 12-4-84

SUBMITTED BY: Menendez-Donnell & Associates

RESULTS OF ANALYSIS

Based upon samples, submitted to us, tested in our laboratory, reported to you as follows:

"SOIL SAMPLES"

Method	Tests	"S-11"	"S-12"	"S-13"	"S-14"
ASTM D-2976*	pH	7.4	6.6	8.6	7.8
Gravimetric	Sulfate, Wt. %	0.001	0.001	0.002	0.002
Potentiometer	Chlorides, Wt. %	<0.001	<0.001	<0.001	<0.001
Conductimeter**	Conductivity, μmhos/cm	47	205	130	254
A. A. S.	Sodium, ppm	19.5	16.6	25.3	22.2
U. V.	Phosphate, Wt.%	0.013	0.009	0.039	0.005
Carbon Dioxide Apparatus	Carbonate, Wt. %	0.76	0.39	7.02	2.50

	"S-15"	"S-16"	"S-17"	"S-18"	"S-19"
pH	9.3	6.1	7.3	9.5	6.3
Sulfate, Wt. %	0.002	0.001	<0.001	0.002	0.001
Chlorides, Wt. %	<0.001	<0.001	<0.001	<0.001	<0.001
Conductivity, μmhos/cm	224	59	111	371	87
Sodium, ppm	177	19.1	18.7	106	22.2
Phosphate, Wt. %	0.345	0.049	0.015	0.056	0.006
Carbonate, Wt. %	19.89	5.67	7.00	3.80	2.32

* Dilution Ratio 1:10
** Dilution Ratio 1:1

SGS CONTROL SERVICES INC.

By: Hugh L. Mayo

Hugh L. Mayo,
Laboratory Manager

HLM/bj

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APPENDIX D

DESIGN CALCULATIONS

I. POL SYSTEM-INDUSTRIAL AREA

A. Fuel Farm

1. The 15 underground tanks at the fuel farm have an exposed surface area of 18376 square feet. Based on a current density of 0.00148 amperes per square foot as calculated for Tank Farm A at Cherry Point Station. Total Current requirement will be 27.2 amperes.

2. A rectifier and distributed groundbed are recommended for proper current distribution.

3. Weight of anode materials:

Fully treated graphite anodes with calcined fluid petroleum coke backfill are recommended having a deterioration rate of 1-lb per ampere year and a 75% utilization factor.

Design life = 20 years

Weight = 20 years x 1-lb/amp-yr x 27.2 amperes
= 544 lbs of anode materials

4. Number of Anodes required for 20 years life:

a. Use fully treated graphite anodes 3-inches diameter x 60 inces long fitted with epoxy and heat shrink cap.

b. Quantity = 540 lbs x 1 anode/27-lbs x 1/.75
= 27 anodes

.75 is the utilization factor, meaning when the anode is 75% consumed it will require replacement.

Use 30 anodes.

5. Groundbed design

a. Resistance of groundbed to earth:

$$R = \frac{.00521\rho}{NL}\left[\ln \frac{8L}{D} - 1 + 2\frac{L}{S}\ln .656(N)\right]$$

L = Length of anode and coke column = 7'
D = Diameter in ft. = 1'
S = Spacing in ft. = 25
ρ = Soil resistivity in ohm-cm = 24,000 ohm-cm
N = No. of anodes = 30

$$R = \frac{.00521(24,000)}{7(30)}\left[\ln \frac{8(7)}{1} - 1 + \frac{2(7)}{25}\ln .656(30)\right]$$

= 2.8 ohms

b. Anode Resistance to Backfill:

$$R = \frac{0.00521\rho}{L}\left(\ln\frac{8L}{D} - 1\right)$$

L = Length of anode = 5'
D = Diameter of anode = 0.25'
= Resistivity of Backfill

$$R = \frac{.00521(50)}{5}\left(\ln\frac{8(5)}{.25} - 1\right)$$

= 0.212 ohm for 1 anode

$$R \text{ for 30 anodes} = \frac{.212}{30} = 0.007 \text{ ohm.}$$

Total Groundbed resistance=2.8 + 0.007 = 2.807 ohms.

c. Cable resistance

Maximum conductor length for this installation should not exceed 1500 ft.

Use # 1/0 AWG, resistance = .102 ohms/1000 ft.
Cable resistance = 1500 x .102/1000 = 0.153 ohms
Total Groundbed Resistance:
2.807 + 0.153 = 2.96 ohms

d. Rectifier Voltage

$$\text{Rectifier Voltage } V_r = \frac{IR + 2V \text{ (Back EMF)}}{.8 \text{ reserve factor}}$$

Design current output = 30 amperes

$$V_r = \frac{30(2.96) + 2V}{.8} = 113.5 \text{volts}$$

Use the next larger rating = 120 volts

B. Four Fuel Storage Tanks-Main Exchange Gas Station

1. Current requirement test data indicated that a current 0.6 ampere was sufficient for protection at most test points. Protective potentials will be acheived with better current distribution and an additional 50% of direct current, say 1.0 ampere.

2. Since the soil resistivity is reasonably high (11000 ohm-cm) and current distribution is very important, a single rectifier and 8 anodes are recommended for installation.

3. The weight of anode materials is not a factor due to the small current drain required. Type 3" x 60"

specially treated graphite anodes with calcined petroleum coke backfill are recommended.

4. Groundbed design:

Soil Resistivity = 11000 ohm-cm

$$R = \frac{.00521(11000)}{7} \left(\ln\frac{8(7)}{1} - 1\right)$$

Resistance of 1 single anode= 24.8+ 0.212 = 25.ohms

Groundbed Resistance = 25/8 anodes = 3.125 ohms say 3.0 ohms.

5. Rectifier Rating:

$$\text{Rectifier Voltage } V_r = \frac{IR+2V \text{ (Back EMF)}}{.8 \text{ reserve factor}}$$

Maximum current drain = 1 ampere

$$V_r = \frac{(1)(3.125)+2V}{.8} = 6.4 \text{ volts}$$

In order to reduce the stock of spare parts and rectifier maintenance a 10 volt 5 ampere rectifier is recommended for installation.

C. <u>Fuel Storage Tanks at Building 1855</u>

1. The 4-6000 gallons underground steel tanks near building 1855 have an exposed surface area of 2,060 square feet. Based on a current density of 0.326 ma/sq.ft. as calculated for a similar type tank in the Rifle Range area, these tanks will require:

2060 sq.ft. x .326 ma/sq.ft. = 671.5 miliampers
= 0.671 amperes.

2. Since the soil resistivity is high (16,000 ohm-cm) an impressed current system is recommended for installation.

3. Following the same procedure outlined previously, a 10 Volt-5 ampere rectifier in conjunction with 8 each 3 x 60 treated graphite anodes are recommended for installation.

D. <u>Fuel Storage Tanks at Bldg. 1775</u>

1. The two 16,000 gallons underground steel tanks near building 1785 have an exposed surface area of 1030 square feet. Based on a current density of 0.326 ma. /sq.ft. as calculated for similar type tank in the Rifle Range area, these tanks will require:

1030 sq.ft. x .326 ma = 335.8 ma = 0.336 amperes

2. Since the soil resistivity is high (16,000 ohm-cm) an impressed current system is recommended for installation.

3. Following the same procedure outlined previously, a 10 volt, 5 amperes rectifier in conjunction with 6 each 3 x 60 treated graphite anodes are recommended for installation.

II. <u>POL SYSTEM- RIFLE RANGE AREA</u>

A. <u>Fuel Storage Tank at Gas Station</u>

1. Current requirements test data indicated that a current of 0.250 ampere will be required to achieve protective potentials on the 10,000 gallon underground tank in the Rifle Range area.

Tank Dimensions: 8' diameter x 26.5' long
Tank Surface area = 767 sq. ft.

$$\text{Current density} = \frac{0.25 \text{ amps}}{767 \text{ sq. ft.}} = 0.000326 \text{ Amp/sq.ft.}$$

$$= 0.326 \text{ ma/sq.ft.}$$

2. Average Soil Resistivity at 10' depths is 10,000 ohm-cm for economic evaluation purposes, consider 2 alternates:

Alternate A- Sacrificial sytem
Alternate B- Impressed system

Alternate A- Sacrificial Anodes System

1. Weight of anode materials required:
Prepackaged magnesium anodes will be used having an estimated deterioration rate of 1-lb per 500 Amp-hr. and an estimated life of 20 years

$$\text{Weight} = 20 \text{ yrs} \times \frac{1\text{-lb}}{\text{amp-yr}} \times \frac{8760\text{hr}}{1 \text{ yr}} \times 0.25 \text{ amp}$$

$$= 87.5 \text{ lbs of anode materials}$$

2. Number of anodes required for 20 years life:

a. Use prepackaged 20 lb elongated magnesium anode.

b. Number = 87.5 lbs x 1 anode/20lb = 4.37 anodes

4.37 x 1/.75 = 5.83 anodes; Use 6 anodes.

.75 is the utilization factor meaning when the anode is 75% consumed it will require replacement.

c. Calculated current drain for a 20-D2 Galvomag Galvopack, high potential magnesium anode with a driving potential of 0.9 volt:

$$R = \frac{.00521\rho}{L}\left(\ln\frac{8(L)}{D} - 1\right)$$

P = Soil Resistivity = 10,000 ohm-cm
L = Anode Length = 5'
D = Anode Diameter = 0.266'

$$R = \frac{.00521\ (1000)}{5}\left(\ln\frac{8(5)}{0.266} - 1\right) = 41.8 \text{ ohms}$$

I = E/R   E = driving potential
I = 0.9volt/41.8 ohms = 0.0215 amper/anode

$$\text{Number} = 0.250 \text{ amp} \times \frac{1\text{-anode}}{.0216 \text{ amp}} = 11.57 \text{ anodes.}$$

d. To achieve the desired current drain and a minimum of 20 years life for the system, twelve (12) 20-D2 Galvopack magnesium anodes will be scheduled for installation.

Alternate B.   Impressed Current System

1. Weight of anode material required

Specially trated graphite anodes will be used having an estimated deterioration rate of 1-lb per ampere year for an estimated life of 20 years.

Weight = 20 years x 1-lb/amp-yr x 0.25 amps = 5 lbs

2. Number of anodes required

a. The weight of anode materials is not a factor due to the small current drain required; 3" x 60" specially treated graphite anodes with calcined petroleum coke backfill will be utilized.

b. For good current distribution and low groundbed resistance, four (4) anodes are recommended for this installation.

3. Groundbed design

$$R = \frac{.00521\rho}{L}\left(\ln\frac{8(L)}{D} - 1\right)$$

$$R = \frac{.00521\ (10,000)}{7}\left(\ln\frac{8(7)}{1} - 1\right)$$

Resistance of 1 single anode = 20 ohms.

Groundbed resistance = 20.0 + 0.212 = 20.212/4 anodes = 5.05 ohms

4. Rectifier Rating:

$$\text{Rectifier Voltage } V_r = \frac{IR + 2V \text{ (Back EMF)}}{.8 \text{ reserve factor}}$$

Allow 1 ampere for current drain

$$V_r = \frac{(1)(5.05) + 2V}{.8} = 8.8\text{volts}$$

Use the nearest standard size, 10V-5 amps, air cooled, single phase unit.

III. POL SYSTEM - COURT HOUSE BAY AREA

A. Fuel Storage Tanks at Gas Station

1. Current requirement test data indicated that a current of 0.4 amperes will be required to achieve protective potentials on the 3-6000 gallons underground fuel tanks. Current density required for cathodic protection is 0.4 amp/1545 sq.ft. = 0.000259 ampere = 0.26 ma.

2. Since the soil resistivity is high (25000 ohm-cm) and current distribution is important a single rectifier and six (6) anodes are recommended for installation.

3. The weight of anode materials is not a factor due to the small current drain required. Type 3" x 60" specially treated graphite anodes with calcined petroleum coke backfill will be utilized.

4. Groundbed Design:

Soil Resistivity = 25000 ohm-cm

$$R = \frac{.00521\ (25000)}{7} \left(\ln\frac{8(7)}{1} - 1\right)$$

Resistance of 1 single anode= 56.2 + .212 = 56.4ohms

Groundbed Resistance = 56.4/6 anodes = 9.4 ohms

Rectifier Rating:

$$\text{Rectifier Voltage } V_r = \frac{IR + 2V \text{ (Back EMF)}}{.8 \text{ reserve factor}}$$

$$V_r = \frac{(0.4)(9.4) + 2V}{.8} = 7.2 \text{ volts}$$

In order to reduce the stock of spare parts and rectifier maintenance a 10 Volt 5 amperes rectifier is recommended for installation

B. Diesel Fuel Storage Tank

1. The 30,000 gallon underground diesel tank has a calculated area of approximately 1690 square feet. Based on a current density of 0.326 as calculated for similar type tank, the tank will require:

   1690 x 0.326 = 550 milliampers = 0.55 amperes

2. Since the soil resistivity is high (25000 ohm-cm) an impressed current system is recommended for installation.

3. Following the same procedure outlined previously a 10 volt 5 ampere rectifier in conjunction with 6-3 x 60 specially trated graphite anodes are recommended for installation.

IV. POL-SYSTEM - BEACH AREA

A. # 2 Fuel Tank at the Steam Plant.

1. Current requirement test data indicated that 9.8 amperes were applied to the # 2 fuel tank. Protective potentials were not achieved due to the electrical continuity between the tank and the steam plan. As a result, design calculations are based on previous current requirement tests conducted with consideration for the low soil resistivity.

2. Based on a current density of 1.0 ma per square foot and an exposed tank surface area of 767 square feet, the tank will require:

   767 sq. ft. x 1.0 ma/sq.ft. = 0.767 amps.

3. The low soil resistivity (2500 ohm-cm) is suitable for a sacrificial magnesium anode installation.

4. Groundbed design:

   a. Design life = 20 years

   b. Weight of anode materials:

Weight=20 years x 1-lb/500 amp.yr. x 8760hr/yr x 0.76 amp = 268 lbs.

268 x 1/.75 = 357 lbs of anode materials, .75 is the utilization factor

c. Minimum number of anodes
Assume use of 40-D3 (40 lbs) magnesium anodes:

Number = 357 lbs x 1 anode/40 lbs = 9 anodes.

d. Calculated Current drain for a 40-D3 Galvomag Galvopack high potential magnesium anode with a driving potential of 0.9 V.

$$R=\frac{.00521(2500)}{5}\left(\ln\frac{8(5)}{.3125}-1\right) = 10 \text{ ohms}$$

I = E/R   E = driving potential
I = 0.9/10 = 0.09 ampere/anode.

e. To achieve desired current drain and a 20 years life for the system, nine (9) 40-D3 Galvopack magnesium anodes will be scheduled for installation. Combined current ouput of all anodes should be restricted to 0.81 amperes.

V. POL SYSTEM - FRENCH CREEK AREA

A. # 2 Fuel Tank at Bldg. FC-202

1. Current requirement test data indicated that 100 ma. were not adequate to acheive protective potentials on the 10,000 gallon tank. Due to the high soil resistivity in the tank area (66000 ohm-cm) the maximum current drain from the temporary groundbed was 100 ma

   The exposed surface area of the tank if 767 sq. ft. Based on a current density of 0.326 ma/sq.ft. as calculated at other similar underground tanks, total current requirement will be 0.25 amperes.

2. Since the soil resistivity is high a single rectifier and 6 anodes are recommended for installation.

3. The weight of anode materials is not a factor due to the small current drain required. Type 3" x 60" specially treated graphite anodes with calcined fluid petrolelum coke backfill will be utilized.

4. Groundbed design

   Soil resistivity = 66000 ohm-cm

$$R = \frac{.00521(66000)}{7}\left(\ln\frac{8(7)}{1} - 1\right)$$

Resistance of 1 single anode=148 + 0.212 = 148.2 ohms

Groundbed resistance = 148.2/6 anodes = 24.8 ohms.

5. Rectifier Rating =

$$\text{Rectifier Voltage } V_r = \frac{IR+2V \text{ (Back EMF)}}{.8 \text{ reserve factor}}$$

$$V_r = \frac{(0.25)(24.8) + 2V}{.8} = 10.3 \text{ volts}$$

Use the next larger rating of 20V-5 amps.

VI. POL SYSTEM- NEW NAVAL HOSPITAL

A. Fuel Storage Tank - New Navy Hospital

1. Current requirement test data indicated that a current of 0.235 amperes will be required to acheive protective potentials on the 10,000 gallons underground tank.

Tank Dimensions; 10' diameter x 17'-8" long.
Tank Surface Area= 712 sq. ft.

$$\text{Current density} = \frac{.235 \text{ amp.}}{712 \text{ sq.ft.}} = 0.00033 \text{ amp/sq.ft.}$$

$$= .33 \text{ ma/sq.ft.}$$

2. Weight of anode materials: Because of the low current requirement and the reasonably low soil resistivity of 4000 ohm-cm near the tank, sacrificial magnesium anodes will be used having an estimated deterioration rate of 1-lb per 500 amp-hr and an estimated life of 20 years.

Weight=20yrs. x 1-lb/500 amp-yr x 8760hr x 0.235 amps
= 82.3 lbs of anode materials

3. Number of anodes required for 20 year life:

a. Use prepackaged 20-D2 high potential magnesium anodes

b. Number=82.3lbs x 1-anode/20-lb = 4.1 anodes

4.1 x 1/.75 = 5.46 anodes

.75 is the utilization factor.

Use 6 anodes.

c. Calculated current drain for a 20-D2 Galvopack anodes with a driving potential of 0.9 volt:

$$R = \frac{.00521(4000)}{5}\left(\ln\frac{8(5)}{.266} - 1\right) = 16.7 \text{ ohms.}$$

$I = \frac{E}{R}$ E = Driving potential

I = 0.9 volt/16.7ohm = 0.054 amp/anode

Number of anodes required for 0.235 amperes:

$$0.235 \text{ amp} \times \frac{1\text{-anode}}{.054} = 4.35 \text{ anodes}$$

d. To achieve the desired current drain and a minimum of 20 years life for the system, six (6) 20-D2 Galvopack magnesium anodes will be scheduled for installation. Combined current output of all anodes should be restricted to a maximum of 0.350 amperes.

B. Heating Oil Storage Tanks - New Naval Hospital

1. The 5 heating oil underground steel tanks at the New Naval Hospital have an exposed surface area of 5030 square feet. Based on a current density of 0.00033 ampere per square foot as calculated for the 10,000 gallon MOGAS tank in the same area, these tanks will require:

5030 x .00033 = 1.66 amperes.

2. The low soil resistivity (2600 ohm-cm) is suitable for a sacrificial magnesium anode installation.

3. Groundbed design

a. Design life = 20 years.

b. Weight of anode materials:

Weight=20yrs x 1.66 amp x 1-lb/500amp-yr x 8760 hr/yr= 580 lbs of anode material

580 x 1/.75 = 770-lbs of anode material 0.75 is the utilization factor.

c. Minimum number of anodes required:

Assume use of 40-D3 (40 pounds) magnesium anodes:

Number = 770 lbs x 1-anode/40 lb = 19.25 say 20 anodes.

d. Calculated current drain of a 40-D3 Galvomag, Galvopack high potential magnesium anode with a driving potential of 0.9 volt.

Average soil resistivity at 10' depth = 2600 ohm-cm.

$$R = \frac{.00521(2600)}{5} \left(\ln\frac{8(5)}{.3125} - 1\right)$$

$$= 10.4 \text{ ohms}$$

$$I = \frac{E}{R} \qquad E = \text{driving potential}$$

I = 0.9/10.4 = 0.086 amperes/anode.

e. To achieve desired current drain and a 20 years life for the system, twenty four (24) 32-D3 Galvopack magnesium anodes will be scheduled for installation. Combined current output of all anodes should be restricted to a maximum of 2.30 amperes.

VII. WATER DISTRIBUTION SYSTEM

1. Based on a current density of 0.0015 ampere per square foot, current requirement for different standard pipe joints will be as follows:

Dimension	Current requirement
4" x 20'	0.032 A
6" x 20'	0.047 A
8" x 20'	0.063 A
10" x 20'	0.078 A
12" x 20'	0.094 A
14" x 20'	0.109 A
20" x 20'	0.157 A

2. Because of soil resistivity variations and the lack of electrical continuity, anodes are sized for each individual joint.

3. Weight of anode materials required for a 6" x 20' joint.

a. Anode life = 20 years

$$\text{weight} = 20 \text{ yrs} \times \frac{8760 \text{ hr}}{\text{yr}} \times \frac{1 \text{lb}}{500 \text{ amp-hr}} \times .047\text{A} \times \frac{1}{.85} = 19.37 \text{lbs}$$

b. Select (1) 20-D2 Valvopack magnesium anode for installation on each 6" x 20' joint

c. Anode Resistance:

$$R = \frac{.00521(\ )}{L} \left(\ln \frac{8}{D} - 1\right)$$

$$= \frac{.00521(\ )}{5} \left(\ln \frac{8(5)}{.266} - 1\right) = 0.004$$

Maximum current drain depends on soil resistivity.

$$I = \frac{\text{Driving Potential}}{R} = \frac{0.09\text{V}}{.004}$$

For = 1000 ohm-cm
I = .225 amperes

Therefore (1) 20-D2 anode can be used on 1 joint of 6" x 20'pipe in soil resistivities up to 5000 ohm/cm.

4. Following the above procedure the following tables were prepared:

4" x 20'

Maximum Soil Resistivity ohm-cm	No. of magnesium Anodes Re.	Maximum Current Ouput "Amperes"
1000	1-20D2	0.215
2000	1-20D2	0.1076
3000	1-20D2	0.072
4000	1-20D2	0.054
5000	1-20D2	0.043

6" x 20'

1000	1-20D2	0.215
2000	1-20D2	0.1076
3000	1-20D2	0.072
4000	1-20D2	0.054
5000	1-20D2	0.043

8" x 20'

1000	1-32-D3	0.192
2000	1-32-D3	0.096
3000	2-20D2	0.144
4000	2-20D2	0.108
5000	2-20D2	0.086

10" x 20'

1000	1-40D3	0.2432
2000	1-40D3	0.122
3000	1-40D3	0.081
4000	2-20D2	0.108
5000	2-20D2	0.086

12" x 20'

1000	1-48D5	0.152
2000	2-20D2	0.215
3000	2-20D2	0.143
4000	2-20D2	0.1076
5000	2-20D2	0.086

14" x 20'

1000	1-48D5	0.152
2000	1-40D3	0.121
3000	2-20D2	0.224
4000	2-20D2	0.168
5000	2-20D2	0.135

20" x 20'

1000	2-40D3	0.484
2000	2-40D3	0.242
3000	2-40D3	0.161
4000	2-40D3	0.112
5000	2-40D3	0.090

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APPENDIX E

COST ESTIMATES

NAVFAC 11013/7 (1-78)
Supersedes NAVDOCKS 2417 and 2417A

COST ESTIMATE

DATE PREPARED: JAN 15, 1985

SHEET 1 OF 6

ACTIVITY AND LOCATION: MCB, CAMP LEJEUNE, N.C.

CONSTRUCTION CONTRACT NO.:

IDENTIFICATION NUMBER:

PROJECT TITLE: CATHODIC PROTECTION SURVEY

ESTIMATED BY: MENENDEZ-DONNELL & ASSOC.

CATEGORY CODE NUMBER:

STATUS OF DESIGN: ☐ PED ☐ 30% ☐ 100% ☐ FINAL ☒ Other (Specify) STUDY

JOB ORDER NUMBER:

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NUMBER	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
FUEL FARM-INDUSTRIAL AREA								
1 - 120V.-40A OIL IMMERSED RECT.	1	EA	3050	3050	950	950		4000
2 - 3"x60" TREATED GRAPHITE ANODES W/5'-#8 HMWPE LEADWIRE	30	EA	76	2280	180	5400		7680
3 - CALCINED FLUID PETROLEUM COKE	11,500	LB	0.32	3680		1200		4880
4 - #1/0 HMWPE HEADER CABLE	1,500	FT	0.95	1425	1.25	1875		3300
5 - EPOXY RESIN SPLICE KITS & PRESSURE CONNECTION	30	EA	14	420	22	660		1080
6 - A/C POWER CONNECTION	1	LOT	250	250	550	550		800
7 - TEST STATION	14	EA	65	910	180	2520		3430
8 - MISCELLANEOUS	1	LOT	300	300	800	800		1100
9 - FIELD ENGINEERING & SUPERV								2440
10 - OFFICE ENGINEERING & REPORT								1200
11 - DRAFTING & SECRETARIAL								800
TOTALS				12,315		13,955		30,710

NAVFAC 11013/7 (1-78)
Supersedes NAVDOCKS 2417 and 2417A

COST ESTIMATE

DATE PREPARED: JAN 15, 1985

SHEET 2 OF 6

ACTIVITY AND LOCATION: MCB, CAMP LEJEUNE, N.C.

CONSTRUCTION CONTRACT NO.

IDENTIFICATION NUMBER

PROJECT TITLE: CATHODIC PROTECTION SURVEY

ESTIMATED BY: MENENDEZ-DONNELL & ASSOC.

CATEGORY CODE NUMBER

STATUS OF DESIGN: ☐ PED ☐ 30% ☐ 100% ☐ FINAL ☒ Other (Specify) STUDY

JOB ORDER NUMBER

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NUMBER	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
RIFLE RANGE - FUEL TANK @								
GAS STATION, SACRIFICIAL SYSTEM								
1- 20-02 PREPACKAGED MAGNESIUM								
ANODES W/ 10'- #12 TW LEADWIRES	12	EA	66	792	165	1980		2772
2- #10 AWG HEADER CABLE	150	FT	0.15	23	1.25	188		211
3- CRIMP CONNECTIONS & SPLICE	12	EA	0.50	6	12	144		150
4- TEST STATION	1	EA	65	65	180	180		245
5- MISCELLANEOUS	1	LOT	150	150	400	400		550
6- ENGINEERING & SUPERVISION								1025
7- OFFICE ENGINEERING & SUPERVISION								1000
8- DRAFTING & SECRETARIAL								600
TOTALS				1036		2892		6553

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COST ESTIMATE

DATE PREPARED: JAN 15 1985

SHEET 3 OF 6

ACTIVITY AND LOCATION: MCB, CAMP LEJEUNE, N.C.

CONSTRUCTION CONTRACT NO.

IDENTIFICATION NUMBER

PROJECT TITLE: CATHODIC PROTECTION SURVEY

ESTIMATED BY: MENENDEZ-DONNELL & ASSOC.

CATEGORY CODE NUMBER

STATUS OF DESIGN: ☐ PED ☐ 30% ☐ 100% ☐ FINAL ☒ Other (Specify) STUDY

JOB ORDER NUMBER

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NUMBER	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
RIFLE RANGE - FUEL TANK IMPRESSED CURRENT SYSTEM								
1- 10V-5A AIR COOLED RECTIFIER	1	EA	510	510	575	575		1085
2- 3"x60" TREATED GRAPHITE ANODES W/10'-#8 HMWPE LEAD WIRE	4	EA	76	304	180	720		1024
3- CALCINED FLUID PETROLEUM COKE	1,600	LB	0.32	512		160		672
4- #4 HMWPE HEADER CABLE	200	FT	0.49	98	1.25	250		348
5- EPOXY RESIN SPLICE KIT & CRIMP CONNECTION	4	EA	14	56	22	88		144
6- POWER CONNECTION	1	EA	200	200	85	85		285
7- TEST STATION	1	EA	65	65	180	180		245
8- MISCELLANEOUS	1	LOT	200	200	300	300		500
9- FIELD ENGINEERING & SUPERV.								1025
10- OFFICE ENGINEERING & REPORT								1000
11- DRAFTING & SECRETARIAL								600
TOTALS				1,945		2,358		6,928

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COST ESTIMATE

DATE PREPARED: JAN 15, 1985

SHEET 4 OF 6

ACTIVITY AND LOCATION: MCB, CAMP LEJEUNE, N.C.

CONSTRUCTION CONTRACT NO.

IDENTIFICATION NUMBER

PROJECT TITLE: CATHODIC PROTECTION SURVEY

ESTIMATED BY: MENENDEZ-DONNELL & ASSOC.

CATEGORY CODE NUMBER

STATUS OF DESIGN: ☐ PED ☐ 30% ☐ 100% ☐ FINAL ☒ Other (Specify) STUDY

JOB ORDER NUMBER

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NUMBER	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
NEW NAVAL HOSPITAL & BEACH AREA								
1- 20-D2 PREPACKAGED MAGNESIUM ANODES W/10'-#12 TW LEAD WIRES	6	EA	66	396	165	990		1386
2- 40-D3 PREPACKAGED MAGNESIUM ANODES W/10'-#12 TW LEAD WIRES	29	EA	126	3654	180	5220		8,874
3- #10 TW HEADER CABLE	800	FT	0.15	120	1.25	1000		1,120
4- TEST STATION	5	EA	65	325	180	900		1,225
5- CRIMP CONNECTIONS & SPLICE	35	EA	1.00	35	12	420		455
6- MISCELLANEOUS	1	LOT	600	600	1100	1100		1,700
7- FIELD ENGINEERING & SUPERVISION								2,850
8- OFFICE ENGINEERING & REPORT								1,800
9- DRAFTING & SECRETARIAL								1,200
TOTALS				5130		9630		20,610

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COST ESTIMATE

DATE PREPARED: JAN 15 1985

SHEET 5 OF 6

ACTIVITY AND LOCATION: MCB, CAMP LEJEUNE, N.C.

CONSTRUCTION CONTRACT NO.:

IDENTIFICATION NUMBER:

PROJECT TITLE: CATHODIC PROTECTION SURVEY

ESTIMATED BY: MENENDEZ-DONNELL & ASSOC.

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STATUS OF DESIGN: ☐ PED ☐ 30% ☐ 100% ☐ FINAL ☒ Other (Specify) STUDY

JOB ORDER NUMBER:

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NUMBER	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
REMAINING FUEL STORAGE TANKS								
1- 10V.-5A AIR COOLED RECTIFIER	4	EA	510	2040	575	2300		4,340
2- 20V-5A AIR COOLED RECTIFIER	1	EA	510	510	575	575		1,085
3- 3"x60" TREATED GRAPHITE ANODES								
W/10'-#8 HMWPE LEAD WIRE	32	EA	76	2432	180	5760		8,192
4- CALCINED FLUID PETROLEUM COKE	10,500	LB	0.32	3360		1400		4,760
5- #4 HMWPE HEADER CABLE	1,200	FT	0.49	588	1.25	1500		2088
6- EPOXY RESIN KITS & SPLICE CONNECTION	32	EA	14	448	22	704		1,192
7- POWER CONNECTION	5	EA	200	1000	85	425		1,425
8- TEST STATION	5	EA	65	325	180	900		1,225
9- MISCELLANEOUS	5	LOT	150	750	250	1250		2,000
10- FIELD ENGINEERING & SUPERV.								5,000
11- OFFICE ENGINEERING & REPORT								3,500
12- DRAFTING & SECRETARIAL								1900
TOTALS				11,453		14,814		36,667

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COST ESTIMATE

DATE PREPARED: JAN. 15, 1985 | SHEET 6 OF 6

ACTIVITY AND LOCATION: MCB, CAMP LEJEUNE, N.C.

CONSTRUCTION CONTRACT NO.

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JOB ORDER NUMBER

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NUMBER	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
MAIN EXCHANGE FUEL TANKS								
1- 10V. - 5A, AIR COOLED RECTIFIER	1	EA.	510	510	575	575		1,085
2- 3"x60" TREATED GRAPHITE ANODES W/10'- #8 HMWPE LEAD WIRE	8	EA.	76	608	180	1440		2,048
3- CALCINED FLUID PETROLEUM	2,600	Lb.	0.32	832	—	400		1,232
4- #4 HMWPE HEADER CABLE	300	FT.	0.49	147	1.25	375		522
5- EPOXY RESIN KITS & SPLICE CONNECTION	8	EA.	14	112	22	176		288
6- POWER CONNECTION	1	EA.	200	200	85	85		285
7- TEST STATION	4	EA.	65	260	180	720		980
8- MISCELLANEOUS	1	LOT	150	150	250	250		400
9- FIELD ENGINEERING & SUPERVISION								1,200
10- OFFICE ENGINEERING & REPORT								1,000
11- DRAFTING & SECRETARIAL								600
TOTALS				2,819		4,021		9,640

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★ U.S. Government Printing Office: 1982—606-106/6011 2-1

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APPENDIX F

CORROSION AND CATHODIC PROTECTION

CORROSION AND CATHODIC PROTECTION THEORY

Corrosion is an electro-chemical process or transformation of energy resulting in the metal of a structure in contact with an electrolyte going into solution, or reverting to its natural status as an oxide form. There is a great deal of stored energy in a piece of metal and it is not at all in accordance with the laws of nature for that piece of metal to remain intact--in fact, it cannot exist without some type or degree of maintenance by man.

There are, generally speaking, two main forms of corrosion--electrolytic and galvanic. Electrolysis is usually construed to mean the process of a stray electrical current being impressed upon a buried structure from an external and metallically unconnected source such as an electric railway (Figure 1). The current, usually relatively great in magnitude, supposedly confined to the rail as a return encounters high resistant joints, takes the path of least resistance to nearby piping, follows the pipe line back to the proximity of the source, at which point the current is discharged from the line carrying iron particles into solution with it. Due to the quantity of current usually involved, this type of corrosion is usually manifested in severe metal loss in the area of current discharge. Any uncontrolled current from a D.C. current source can result in detrimental interference effects on foreign structures within the area of influence of the D.C. source.

Galvanic corrosion is the result of the formation of galvanic cells upon the structure itself and independent of external power sources. Basic forms of galvanic cells exist as: (a) dissimilar connected metals in a common electrolyte, (b) a continuous metal structure exposed to dissimilar electrolytes, and (c) a combination of the above conditions. It is this form of corrosion which plays the major role in deterioration of underground structures in most areas.

The galvanic cell involving dissimilar metals can perhaps best be illustrated by referring to these examples taken from the Electromotive Force Series of Metals Table (Figure 2). This table is a comparative index of the solution potential or activity level of various metals ranging from potassium which has the highest relative potential to the noble metals of silver and gold which are very stable and thus reflect the lowest solution potentials. For practical purposes, the most common metals for underground construction and cathodic protection are shown. Magnesium, with a potential of -2.34, is anodic to zinc, with a

potential of -0.762. Zinc, in turn is anodic to iron, with a potential of -0.044. Iron, with a potential of -0.044, is anodic to copper, with a potential of +0.345. The term anodic is of Greek derivation meaning "up way" and indicates that the metal which has the higher potential will give up current (thus dissipating itself) to the lower potential metal which is termed cathodic or the cathode.

The common flashlight battery is a galvanic cell composed of a zinc outer case, an electrolyte, a carbon rod, and an external circuit (Fig. 3). In this case, the zinc has the higher potential and acts as the anode with the carbon rod being the cathode. When the external circuit is closed through the metallic case of a flashlight, current flows from the zinc outer case, through the electrolyte to the carbon rod, and thence through the light bulb filament. As the metallic ions go into solution, water in the electrolyte is disassociated, the zinc combining with the hydroxyl ion to form an oxide, and the atomic hydrogen released to migrate to the cathode.

Common examples of this type of galvanic cell encountered in everyday construction of underground structures are a brass fitting between steel section (Fig. 4), steel connected to cast iron, steel pipe in contact with cinders (Fig. 5), bright metal from wrench or tong from scratches (Fig. 6), mill scale patches on pipe (Fig. 7), and new pipe installed as replacement between old sections of pipe.

The other basic galvanic cell is one consisting of a common metal in dissimilar electrolytes (Fig. 8). In this case, the electrolyte surrounding the metal determines which portion of the metal is anodic and which is cathodic. The current flow is from the metal in contact with the lower resistivity electrolyte to the portion of metal in a higher resistivity environment. This case is, of course, similar to our underground pipe lines composed of the same metal, but traversing a heterogeneous mixture of soils such as sand, sandy loam, clay, loam, rock, gypsum beds, salt beds, etc. The oxygen content and moisture conditions will also vary radically for different soil types encountered. Each change of soil characteristic such as the frequency, and the degree of change of resistivity, has a great role in determining the severity and extent of corrosion.

Examples of these conditions are dramatized in Figure 9, which illustrates a continuous metal pipe in contact with a moisture retentative (thus relatively low resistivity), clay electrolyte, and also a well-drained (thus higher resistivity) sandy loam electrolyte. Current discharge is

initiated in the lower resistivity soil area with the adjacent pipe surfaces receiving the current, and the pipe wall serving as the external circuit back to the source of the galvanic cell at the corroding area. Figures 10 and 11 illustrate the dissimilarity of soil conditions which can result from normal excavation and backfill procedures of buried structures; also, the dissimilarity of electrolyte conditions encountered due to oxygen availability and presence as a result of normal construction practices.

A typical example of numerical soil resistivity value relationships over an extent of pipe line right-of-way is shown in Figure 12. Although a large percentage of detrimetnal corrosion is normally associated with the low soil resistivity ranges, severe corrosion does occur in the medium and high range categories. Thus, the frequency and magnitude of electrolyte change must be considered rather than relying solely on categorized numerical ranges.

Corrosion results are apparent in several forms--the most common being scaling, pitting, patching, graphitization, and oxide films. Some less common forms are failure within the crystaline structure itself and stress corrosion. Uniform scaling, or exfoliation, is usually associated with some of the older laminated types of pipe construction. The severity of metal loss depends essentially on the ratio of anodic area to cathodic area. In other words, if there is a small anodic area between two large cathodic areas, the small anodic area will be discharging current in quantities large enough to protect the two large cathodic areas. Since the area of current discharge is small, it follows that the metal will be removed in this area at an accelerated rate. However, if the anodic area was relatively large in comparison with the cathodic area, the penetration process would proceed much slower as it would be taking place over a much larger area. When it is realized that one ampere of D.C. current flowing continuously for a period of one year can drive 20 pounds of steel into solution, it can be ascertained that very small quantities of uncontrolled current discharge can cause failure of a thin wall metallic structure within a relatively short time.

Corrosion prevention is normally accomplished by the following procedures:

1. Judicious choice of construction materials and procedures with respect to corrosion mitigation for new construction.

2. Protective coatings.

3. Cathodic protection.

On new construction, many corrosion problems of the future can be prevented during the design stage of proposed faciliites. The type of metal most suitable for handling a given product, the type of surface treatment for the metallic structure, provisions for electrical isolation of new systems from old or foreign systems, and minimizing or avoiding coupling of dissimilar metals are but a few of the decisions which merit consideration during the project planning phase.

Protective coatings are recognized as a basic weapon in the battle against underground corrosion. It is known that if the metal of a structure does not contact an electrolyte, no corrosion will take place. Thus, the use of coatings is widespread, the desire being a coating material which is an impervious, inert substance, unaffected by temperature variance, mechanically sturdy enough to withstand soil and cyclic stress to which it is subjected underground, as well as potential damage from handling during transportation and construction. Commonly used coating materials consist of asphalt and coal tar enamels, asphalt and coal tar mastics, polyethylene and polyvinyl chloride tape applications, micro-crytaline wax compounds, and extruded plastic jackets or sleeves. Coating efficiences of the pipe line coatings in place are dependent not only on the material used, but also the care with which it was applied and the care exercised during structure installation. It is virtually a physical impossibility for any coated structure in place and backfilled to be without minute faults or "holidays", with small bare metal surfaces thus exposed and in direct contact with the surrounding soil or electrolyte. This situation is a classic example of the condition previously discussed concerning ratios of anodic and cathodic areas. Since the exposed metallic area at any coating fault will be relatively small compared to coated or cathodic areas surrounding it, corrosion activity will be concentrated on the small bare metallic area and early metal loss and penetration may be reasonably anticipated unless further protective steps are taken. In addition, all coating materials are subject to deterioration with time, thus exposing more metal surface to the corrosion process.

The accepted supplement to coating procedures is that of applying cathodic protection to the coated structure. In general, cathodic protection is a process whereby adequate quantities of D.C. current are impressed upon a given

structure to overcome the quantities of galvanic current generated and being discharged from the structure. This procedure is accomplished through the use of external current sources; either, galvanic anodes or impresssed current systems. Galvanic anodes normally consist of zinc or magnesium alloys of varying shapes and weights to accommodate differing soil resistivity values, current outputs, and design life. In both cases, the anode metal is more active or higher in the electromotive series than the steel structure to which it is attached. Thus, (Fig. 13) a large galvanic cell has been deliberately created with the metal from the sacrificial galvanic anode being dissipated to prolong the life of the structure to which it is attached. The current flow, electrically speaking, is from the sacrificial anode through the earth onto the structure and is returned to the source through the leadwire connected to the structure and the anode.

The same principle holds true for impressed current systems (Fig. 14), except that in this case power is being derived from some external source such as rectifier units which convert A.C. electrical power to D.C. current, or possibly thermoeletric units which convert heat to electric power. The D.C. current is then routed through a groundbed composed of graphite rods, cast iron rods, or junk steel, and thence through the earth to the structure to be protected. Once again, a low resistant return path is provided between the structure and the power source to complete the circuit and to provide controlled current drainage from the structure.

Cathodic protection in various forms and to varying degrees can be applied to old existing structures as well as new construction.

Naturally, the cost of providing complete overall protection to bare structures involves a much greater expenditure than for similar coated structures due to the greater exposed surface area involved on the bare structures. Thus, partial or spot protection at areas subject to deterioration, as indicated by past history or investigative procedures, is often the course followed to reduce maintenance cost and commodity loss, and to prolong useful life of the structure or system.

In any case, whether on new construction or existing facilities, the use of cathodic protection must be justified economically. Since both the initial investment and projected operating costs of cathodic protection are directly dependent upon the design and effectiveness of the installation, it is of great importance that the type of

protective system utilized, amount of current required, and location of the protective current systems must be determined by thorough preliminary field investigation conducted by experienced personnel. Many survey techniques, interpretation standards, and an array of specialized instrumentation are utilized in determining the most economical and practical protective design for providing cathodic protection to a given system or structure. Upon completion of any protective installation, the system must be adjusted and a thorough checkout conducted to determine that adequate protection is being realized over the entirety of the pertinent structure; further, that any detrimental interference effects on foreign or isolated structures are detected and removed.

In as much as electrical grounding systems frequently complicate cathodic protection efforts and contribute to corrosion of other underground structures, possible improvement of grounding procedures and effect of stray current on underground electrical structures merit the following brief discussion.

In general, electrical grounding systems must be comprised of materials that are good electrical conductors with sufficient area in contact with the soil to provide resistance of the current path within the allowable limits, and to be resistant to the corrosion process. The major material utilized for grounding systems in the past has been copper due to its excellent conductance characteristics, reasonable cost, and corrosion resistant properties. As long as overhead power transimission lines utilizing wooden supports were used, very little corrosion damage was apparent from this procedure. However, with the advent of lead sheath cable, armored cable, and galvanized conduit for underground installation, this situation has changed considerably. Potential differences, due to galvanic couples of some of the most commonly used metals for underground electrical construction, are presented in Figure 15. As indicated, the commonly used metals are all anodic to copper, i.e., when coupled with copper in a common electrolyte, the metals will be dissipated to provide current to the copper to which they are attached. Probably the most serious situation here is the couple between lead and copper where even though the potential difference is not as great as indicated for the other couples, the dissipation rate of lead, approximately 75 pounds per ampere year of current, becomes an important factor.

Conditions being what they are today, considerable thought for grounding procedures should be given to utilization of

other metals for grounding materials, the two most common substitutes being zinc and high silicon cast iron anodes. Zinc anodes are generally considered more attractive because they not only provide a degree of protection to metals to which they are attached due to being higher on the electromotive series of metals, but also they exhibit relatively long effective life in most environments. Of interest is a comparison of grounding rod resistance values between standard copper and zinc grounding rods in varying soil resistivity ranges. This comparison, as presented in Figure 16, indicates the effectivness of the zinc anode, particularly when surrounded by a prepared backfill material. Number, spacing, and configuration of grounding rods to provide a specified resistance can be readily determined in most cases when the resistivity of an electrolyte has been acquired through measurements, based upon design data for zinc anodes. High silicon content cast iron anodes are less attractive due to the galvanic couple between the cast iron alloy and steel. Although the potential difference between the two is not great, being in the neighborhood of 0.10 volt, the steel pipe is nevertheless anodic to the cast iron anode.

Another important aspect of choice of grounding system materials involves the application of cathodic protection to underground facilities within the area. In case of a copper grounding system in contact with piping or conduit to be cathodically protected, it is not uncommon to encounter current requirements 40 to 50 times as great to provide protection for both the copper grounding system and the piping as would be required to protect the piping alone if the copper grounding system was not connected to it. On the other hand, zinc grounding system under the same circumstances would actually supplement the cathodic protection system. In many areas, involving both plant piping and grounding systems, the proper choice of grounding materials thus becomes a decision of major economical importance.

Often a piping system also serves as part of a grounding system. Once again, the coupling of a copper grounding system with steel piping results in dissipation of the steel and should be avoided. In addition, today's standard acceptance of high resistance coatings for pipe line construction actually provides, in many cases, a very poor grounding device.

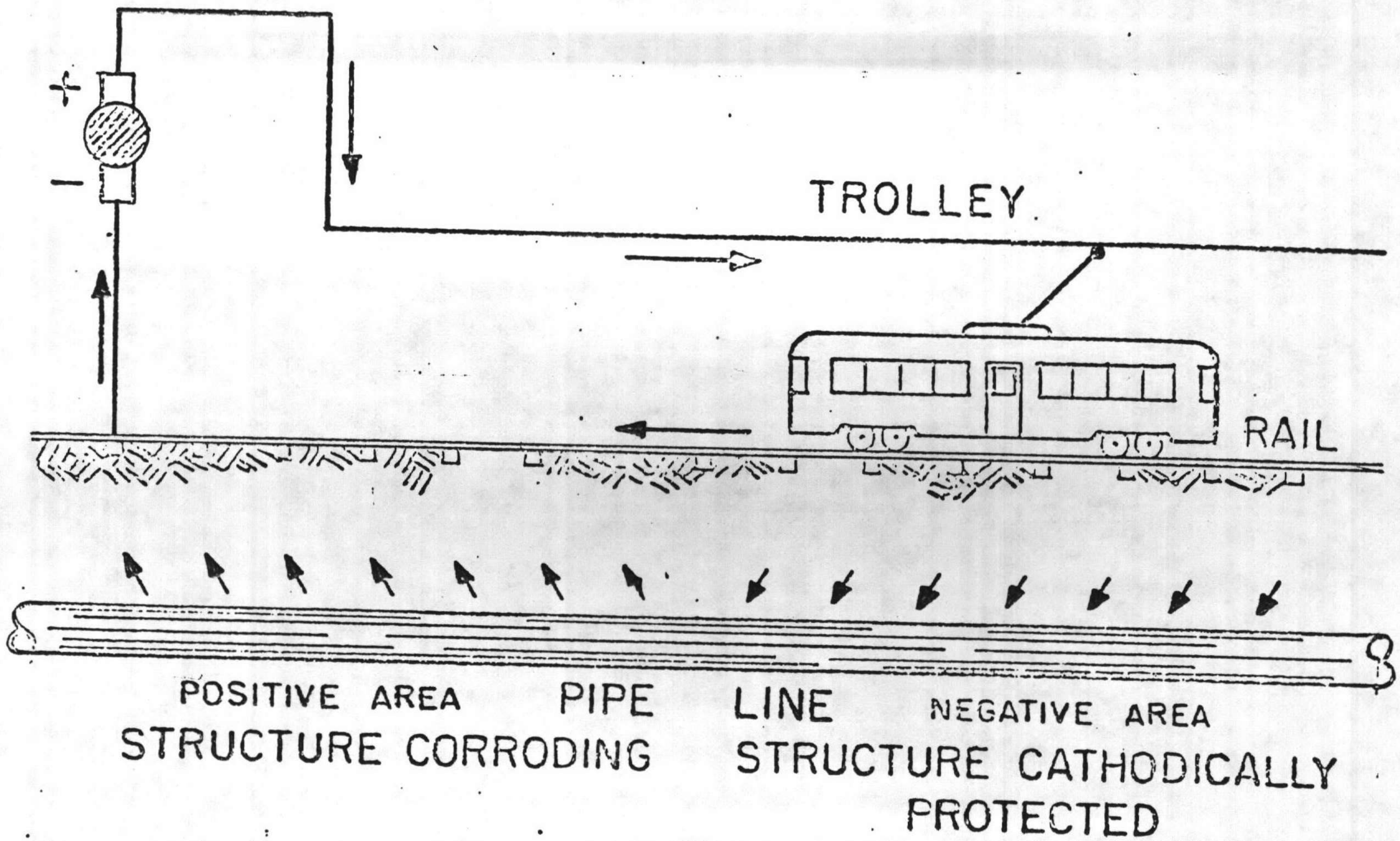
Neutral conductors for underground electrical distribution systems often consist of bare copper cables with the neutrals of transformers and electrical apparatus housings frequently grounded to the neutral conductor. Water piping

for water-cooled transformers and lead-sheath cables is also often grounded to the neutral conductor cable. Once again, the galvanic couples and resulting potential differences between copper and steel and copper and lead is encountered and deterioration of both the steel water piping and lead sheath cable may be reasonably anticipated. The answer to this problem appears to be a neutral conductor provided with a polyethylene or polyvinyl direct burial jacket which will provide insulation between the copper conductor and the earth, and also provide additional self-contained grounding rods.

Any underground power cable equipped with an adequate polyvinyl or plyethylene jacket will not be influenced by stray current from cathodic protection systems or other stray current sources. Certainly, the lead sheath cable, which parallels a cathodically-protected structure or lays within the area of influence of cathodic protection installations, is receptive to pickup and uncontrolled discharge of stray current resulting in metal deterioration. Interference testing and adequate bonding procedures are the answers to this problem. Lead sheath cable installed in metallic or non-metallic duct systems is not subject to stray current influence, but may be subject to galvanic corrosion action at points within the ducts at which moisture may collect.

Any metallic objects such as pole anchors, grounding rods, cables, or grids which fall within the area of influence of a D.C. current source are exposed to varying degrees of deterioration depending largely upon the metals involved, size of structure, and their proximity to the D.C. current source. In cathodic protection installations, judicious placement of current sources, consistent with design requirements of the structure or system to be protected, is taken into consideration to minimize the possibility of interference on foreign structures. Prior to adjustment and checkout of a protective system, native state potential values on all foreign structures within the area of influence of the current source should be acquired. Upon energizing and adjusting the protective system, potential measurements on the foreign structures involved are again acquired to determine any effects being experience from stray current. In the event that detrimental interference effects on a foreign structure are detected, the situation is relieved by either providing a controlled resistance bond from the affected structure to the current source or providing the affected structure with a small protetive system of its own, normally in the form of self-contained sacrificial anodes. The problems involved, particularly in congested areas involving a number of utilities with the

effects of stray current or interference can be complex in nature and costly in results, unless corrected. As in the case of design, installation, and checkout of protective systems, the detection and correction of interference problems can best be solved by personnel experienced in the specialized field of corrosion mitigation.



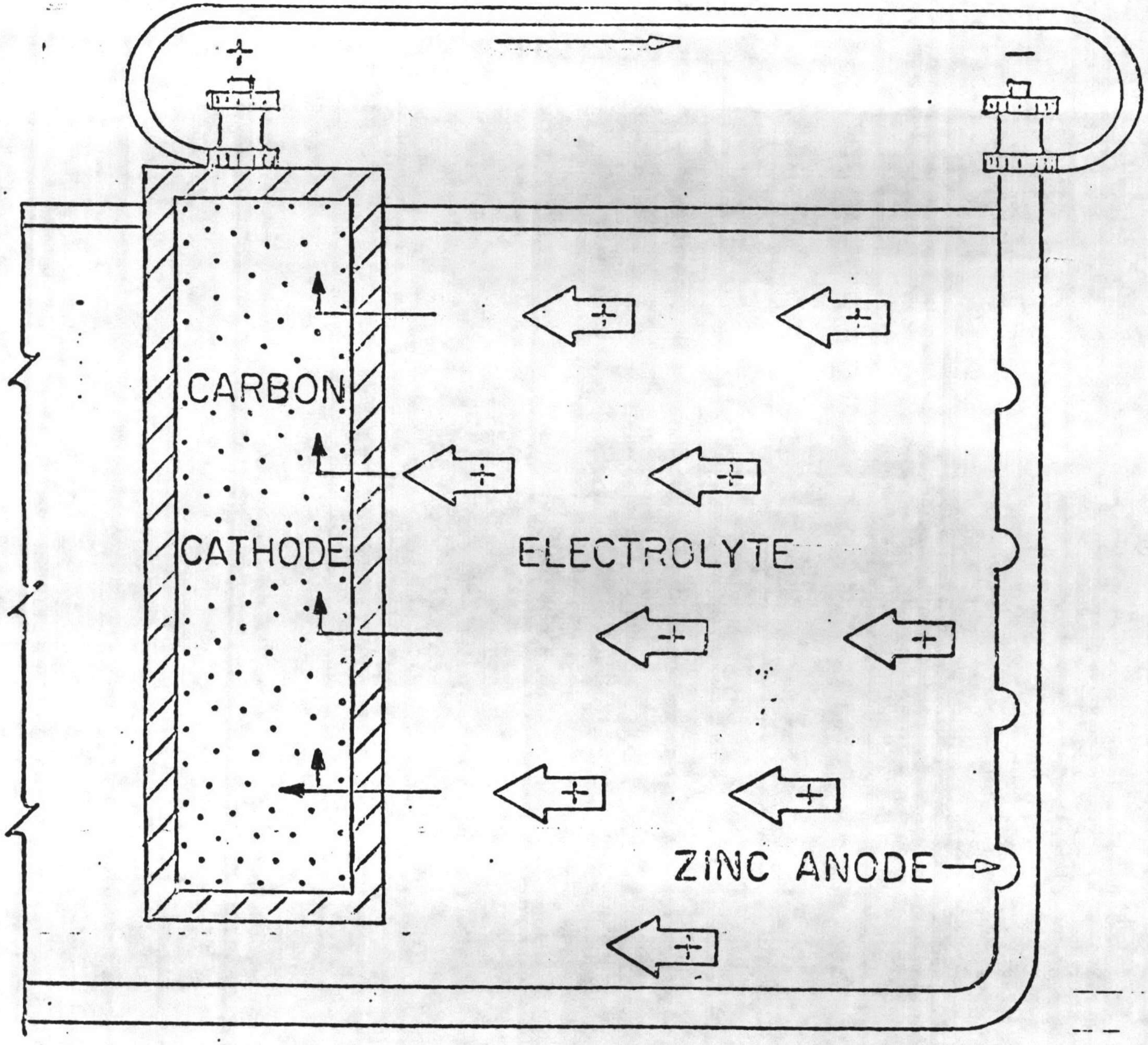
ELECTROLYSIS CORROSION

FIGURE 1

ELECTROMOTIVE FORCE SERIES

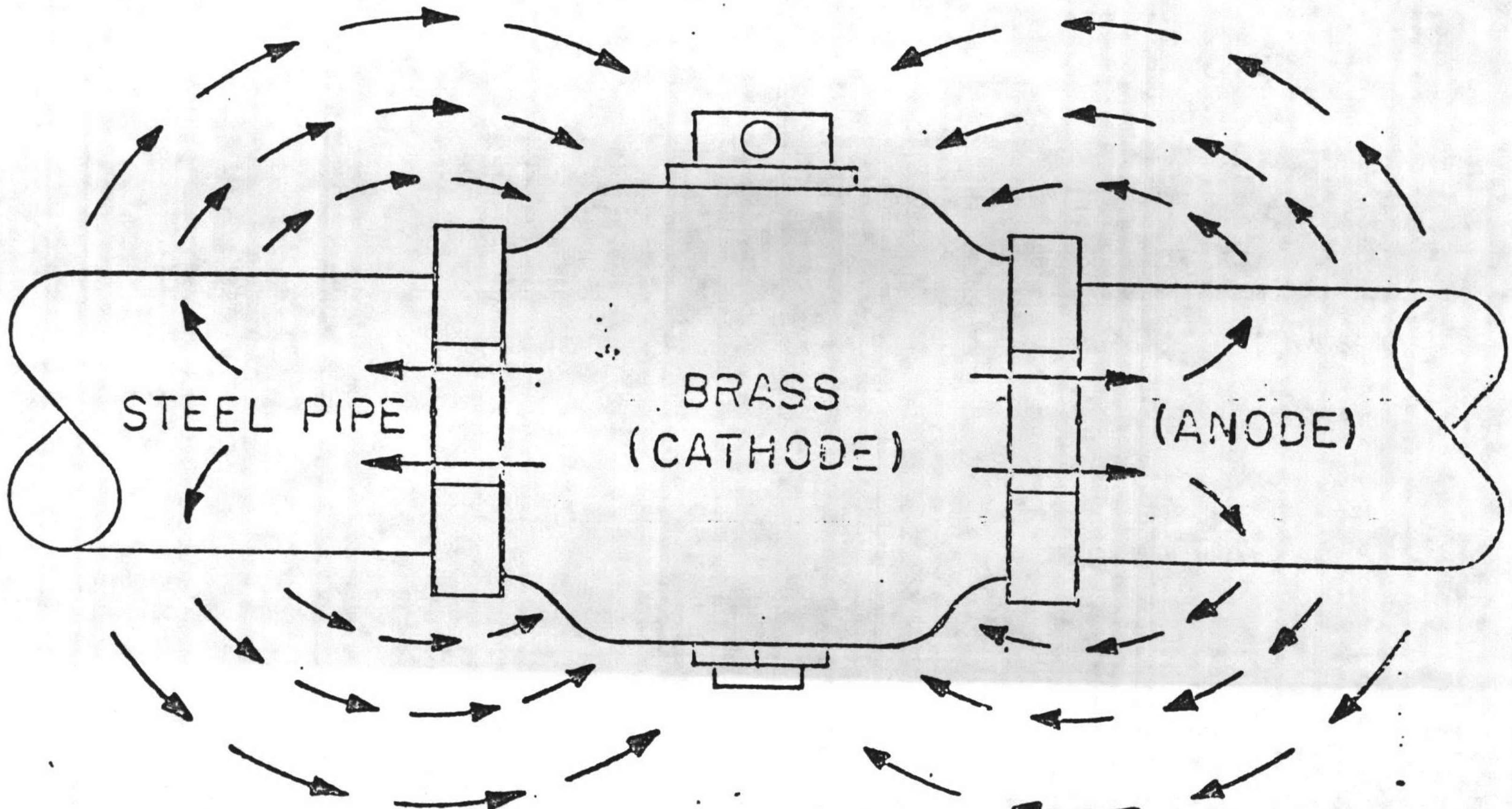
Electrode Reaction		Standard Electrode Potential E^0 (Volts), 25° C
Magnesium -	Mg^{++} +2e⁻	-2.34
Zinc	Zn^{++} +2e⁻	-0.762
Iron	Fe^{++} +2e⁻	-0.440
Lead	Pb^{++} +2e⁻	-0.126
Hydrogen	$2H^{+}$ +2e⁻	-0.00
Copper	Cu^{+} _e⁻	+0.522

FIGURE 2



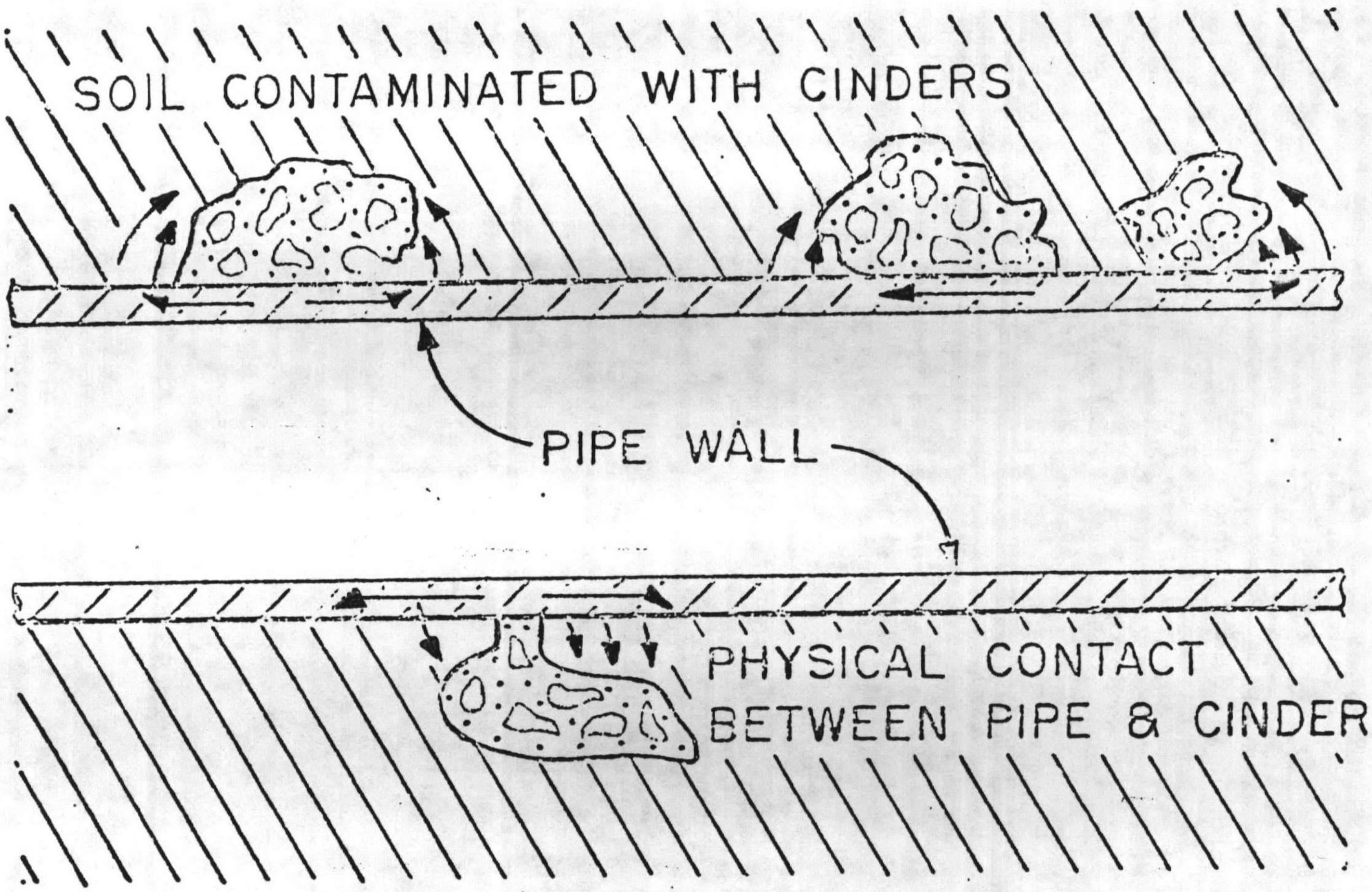
GALVANIC CELL - DISSIMILAR METALS

FIGURE 3



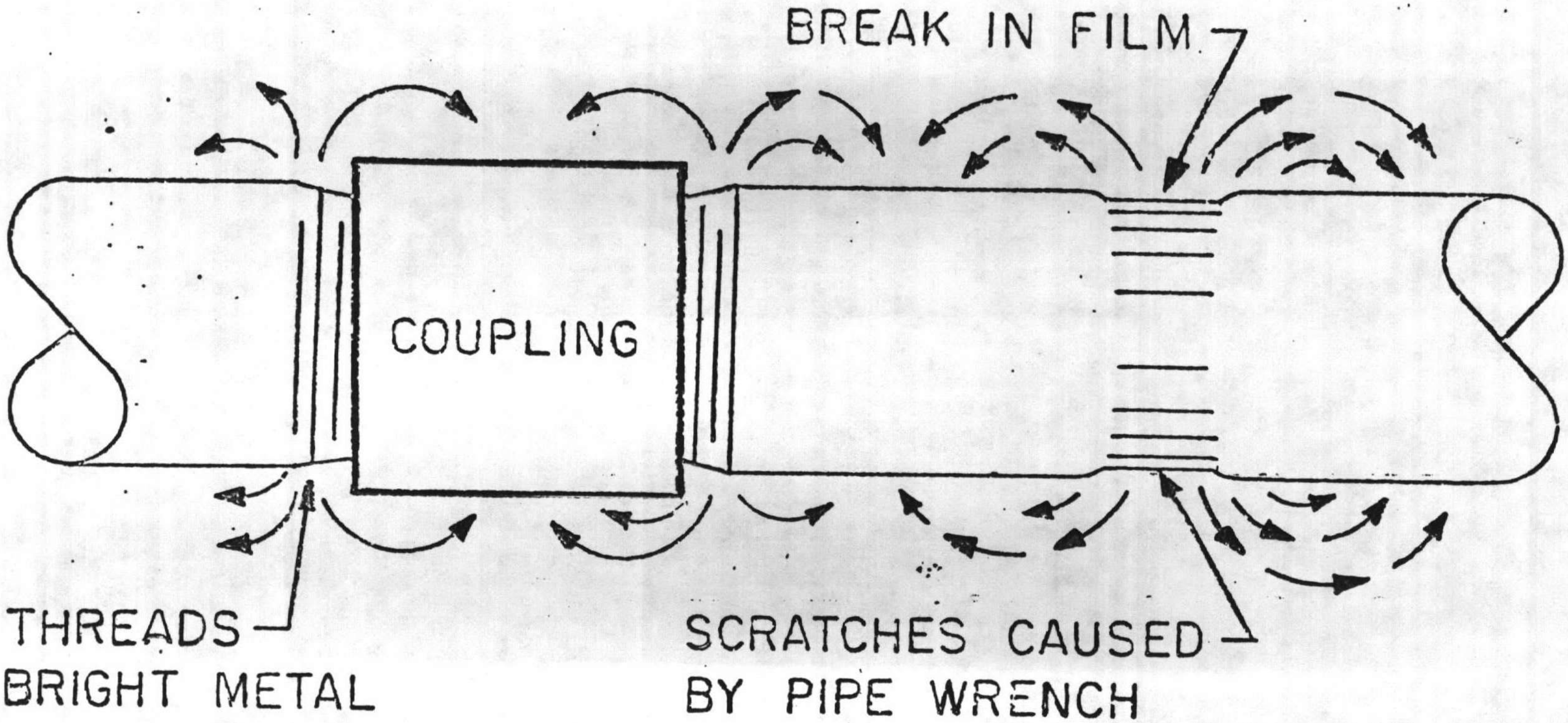
CORROSION CAUSED BY DISSIMILAR METALS

FIGURE 4



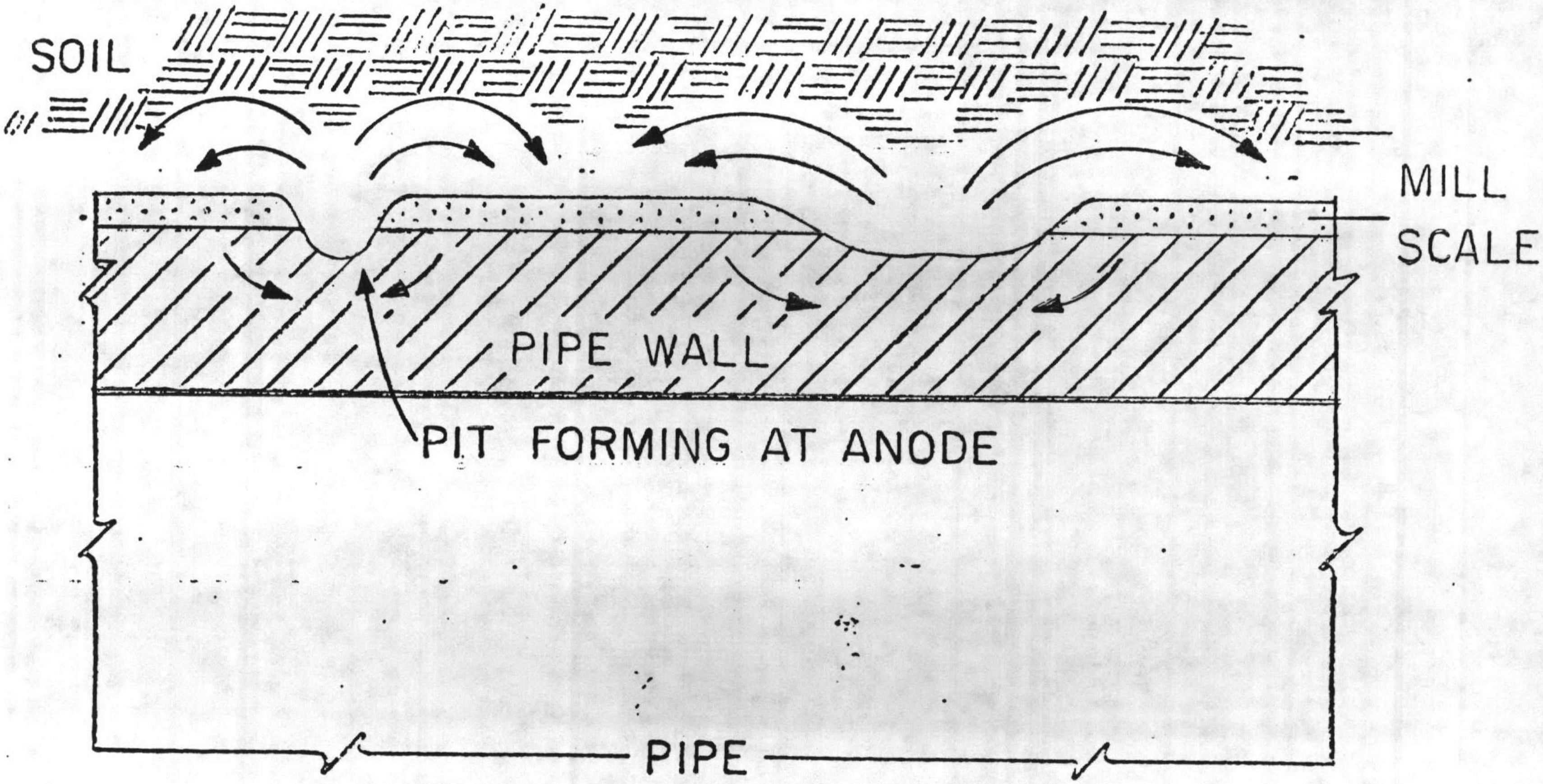
CORROSION DUE TO CINDERS

FIGURE 5



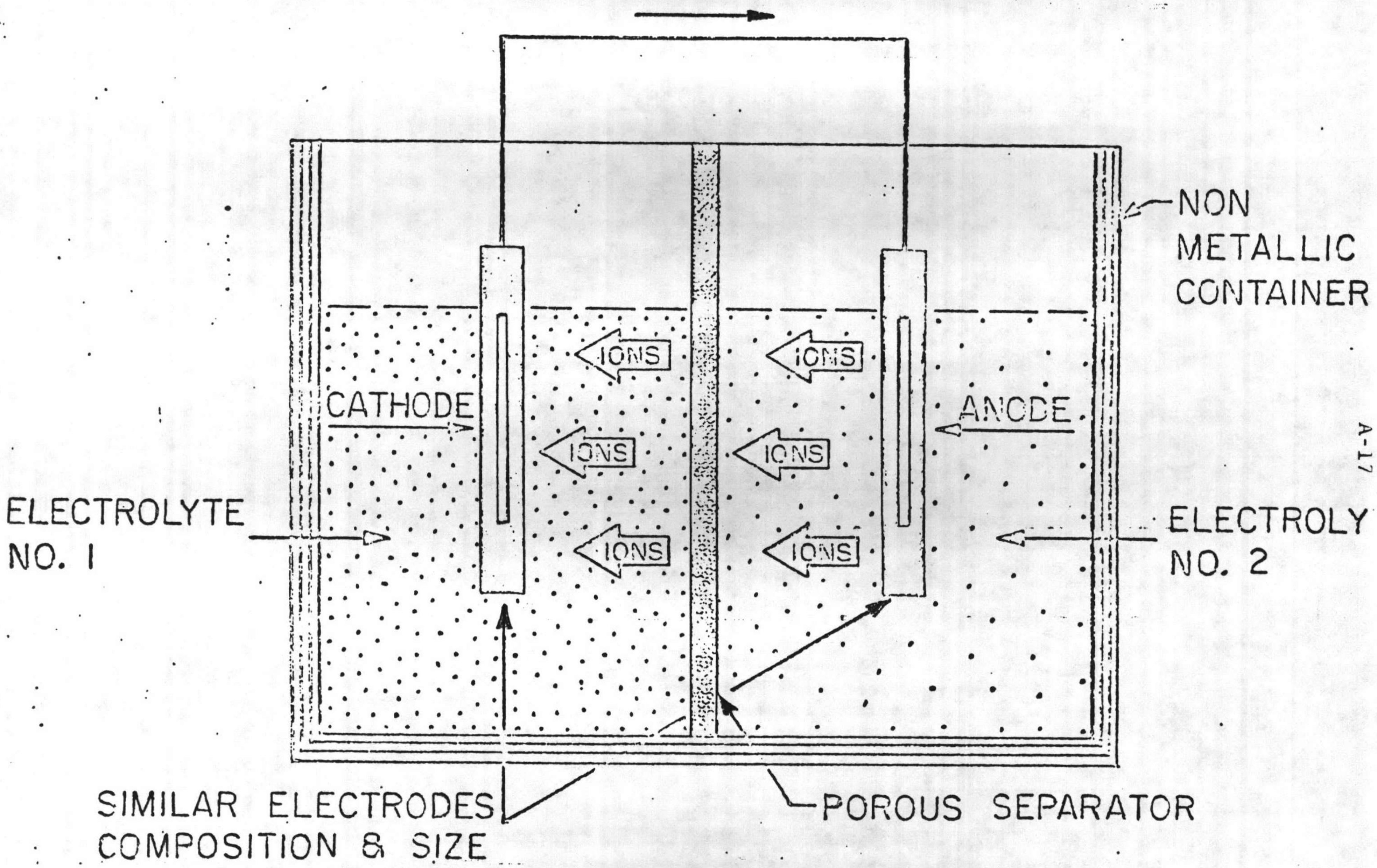
CORROSION CAUSED BY DISSIMILARITY OF SUR-
FACE CONDITIONS

FIGURE 6



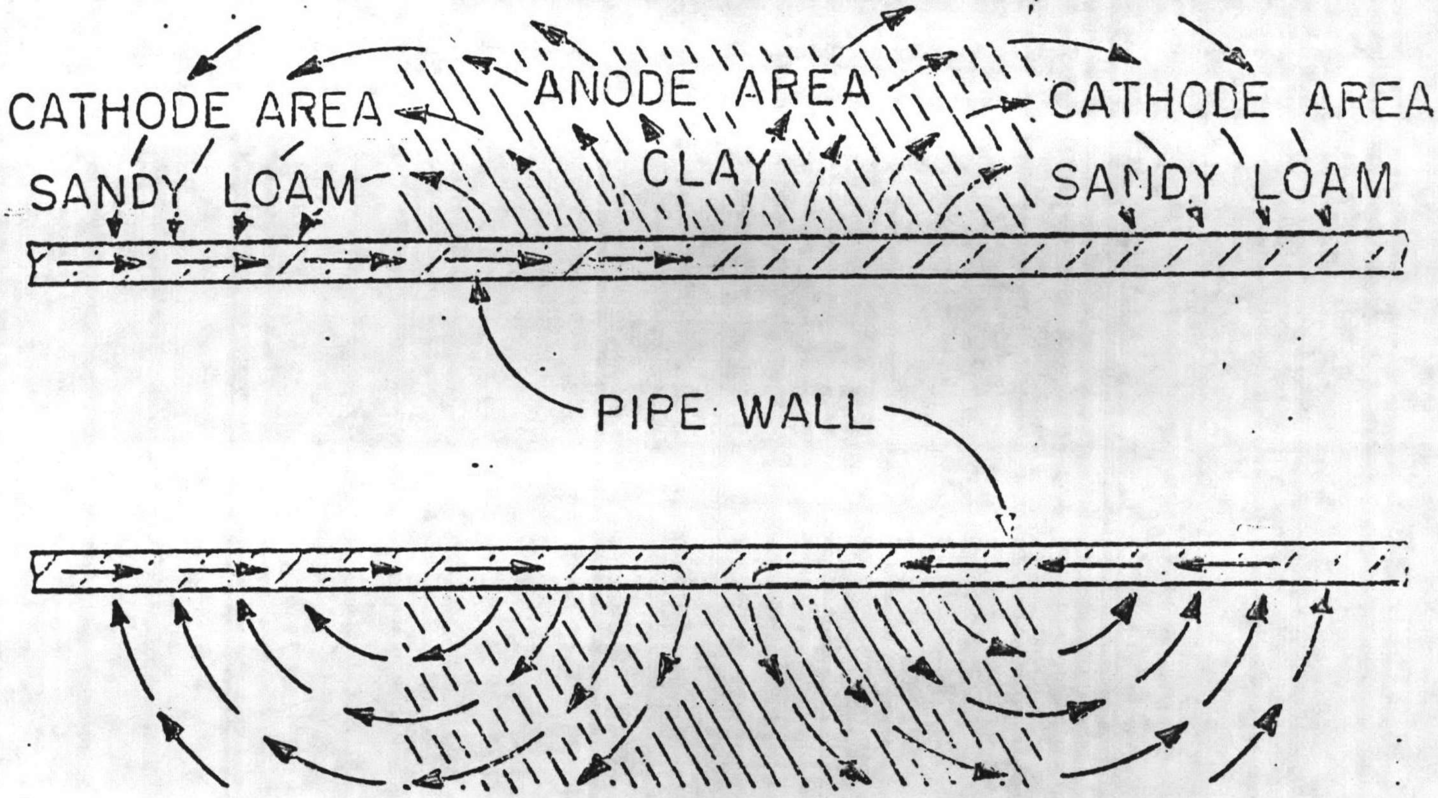
PITTING DUE TO MILL SCALE

FIGURE 7



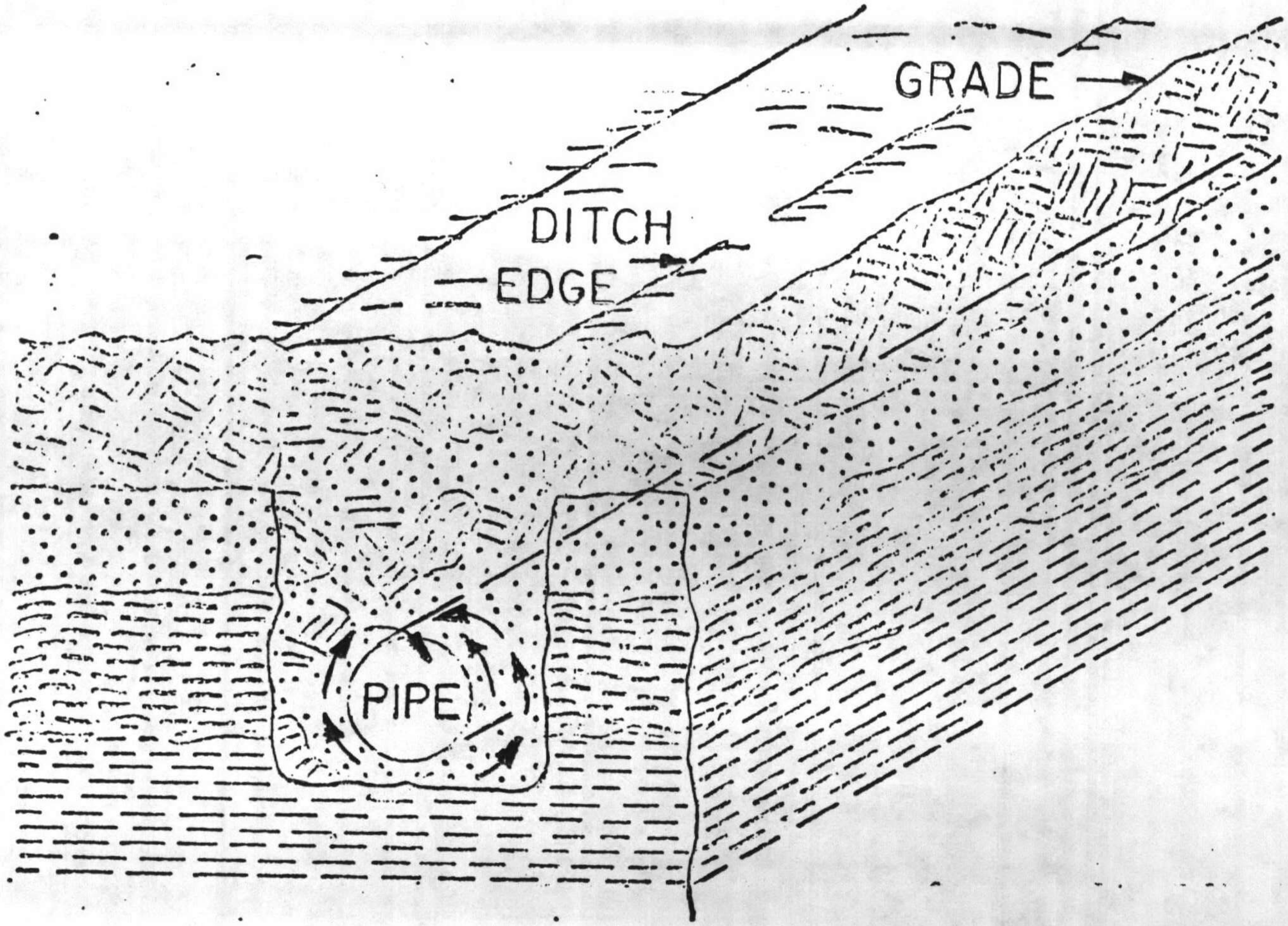
GALVANIC CELL - DISSIMILAR ELECTROLYTE

FIGURE 8



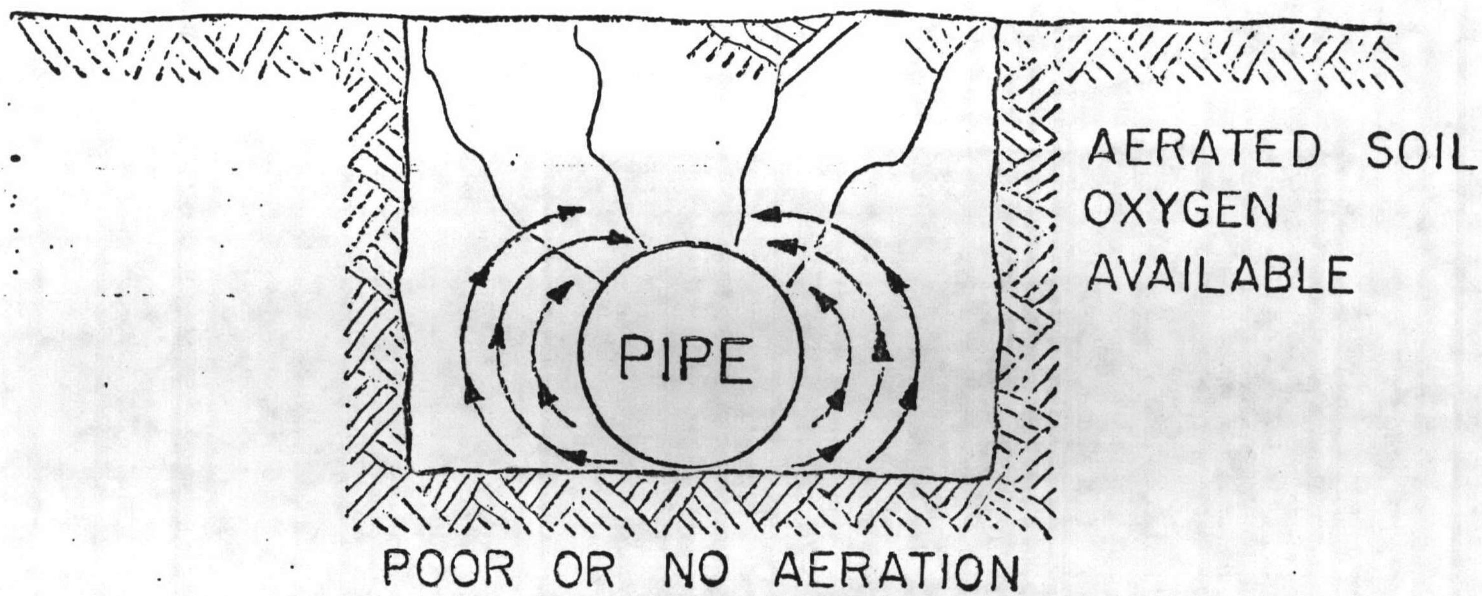
CORROSION CAUSED BY DISSIMILAR SOILS

FIGURE 9



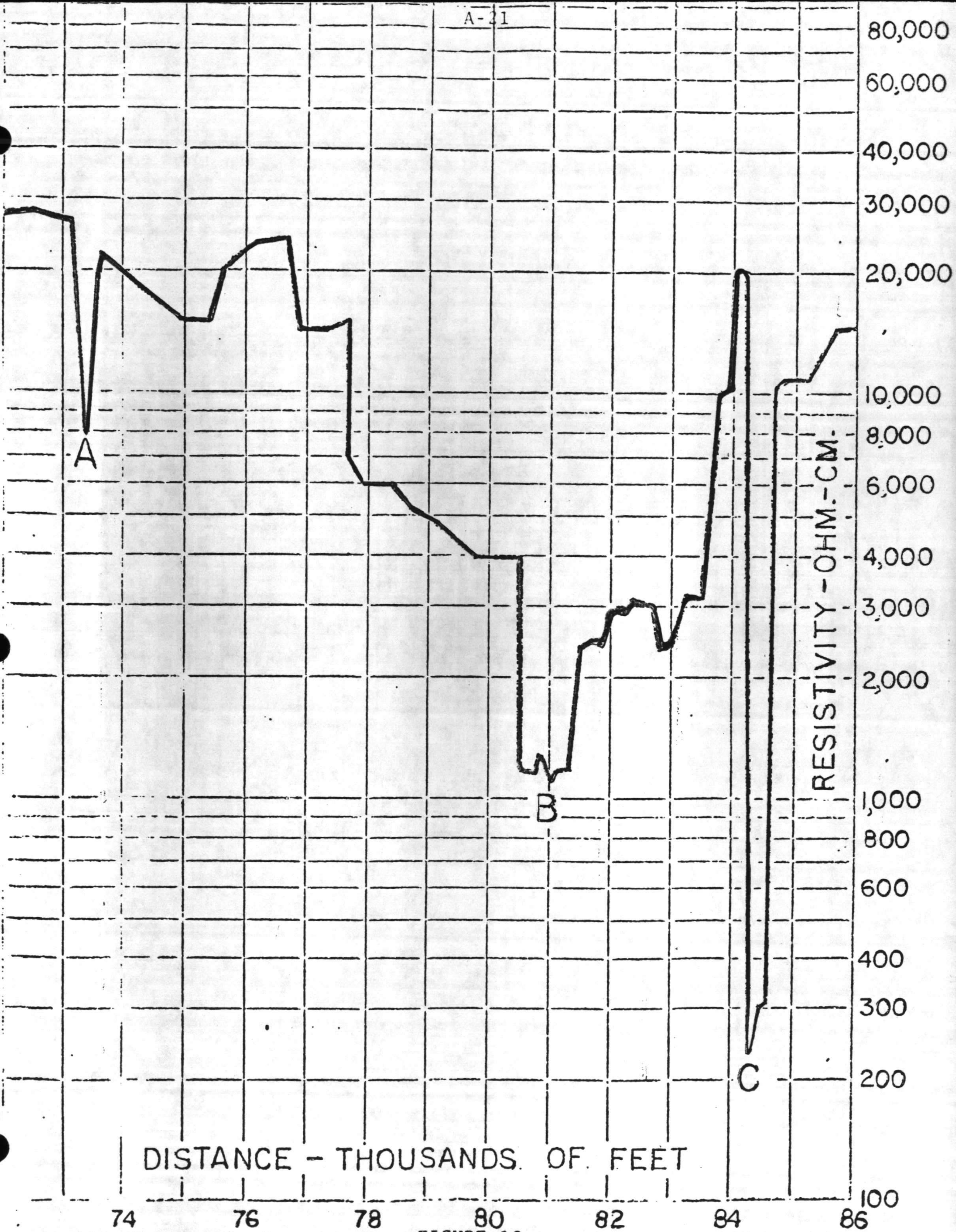
CORROSION CAUSED BY MIXTURE OF
DIFFERENT SOILS

FIGURE 10



CORROSION CAUSED BY DIFFERENTIAL
AERATION OF SOIL

FIGURE 11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60,000
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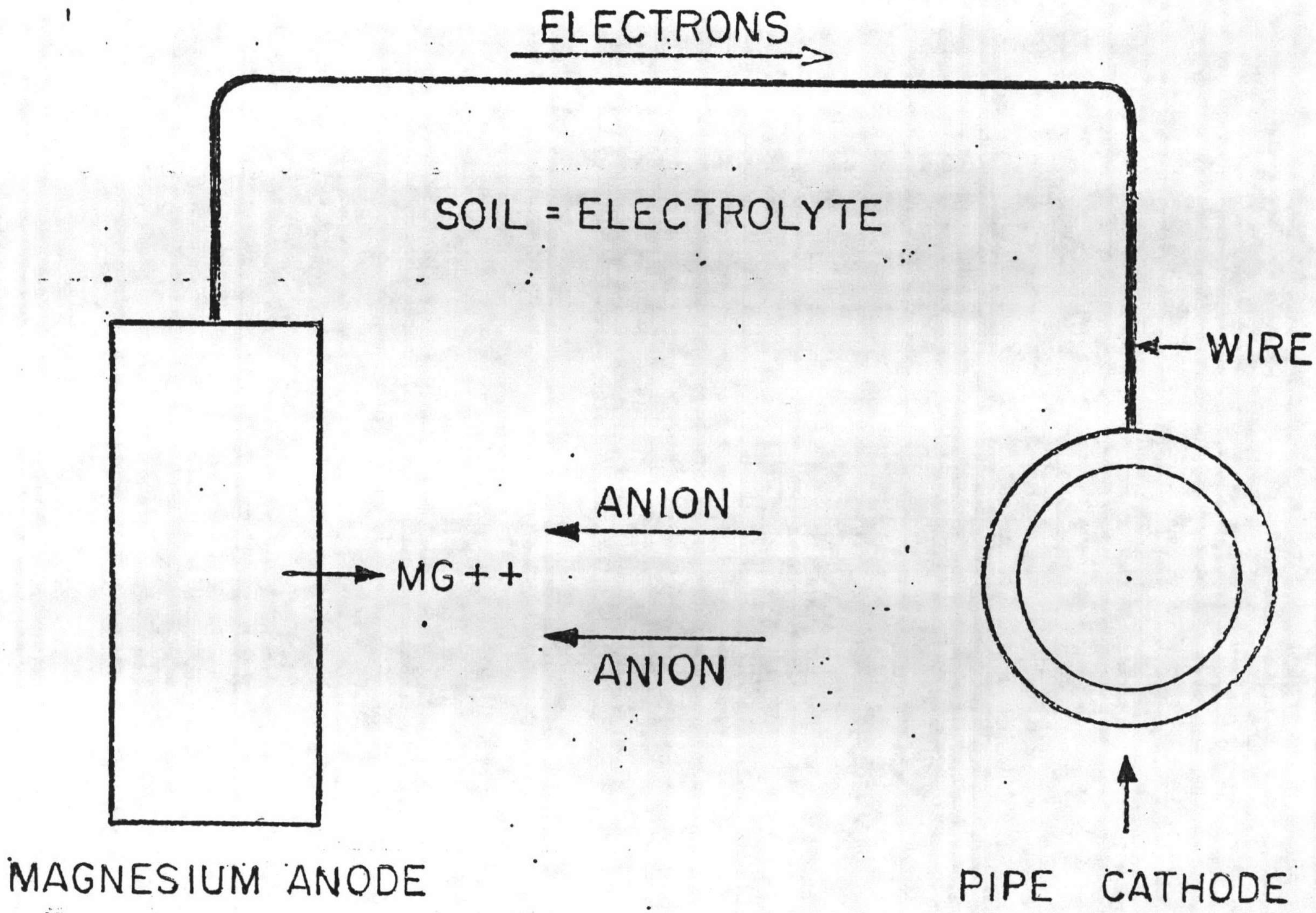
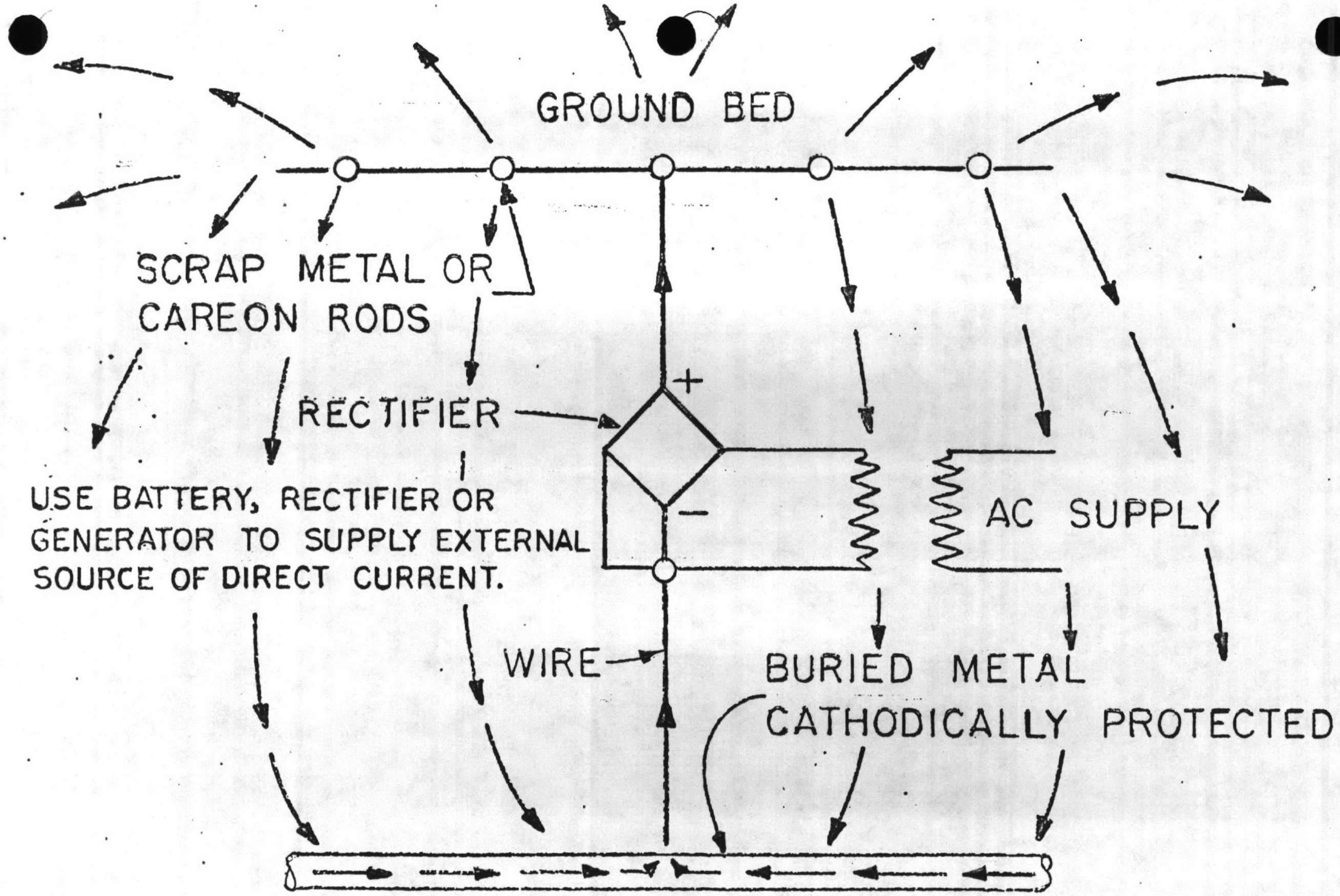
30,000
20,000
10,000
8,000
6,000
4,000
3,000
2,000
1,000
800
600
400
300
200
100
RESISTIVITY-OHM.-CM.
A
B
C
DISTANCE - THOUSANDS OF FEET
74
76
78
80
82
84
86

FIGURE 12



THE CATHODIC PROTECTION BATTERY

FIGURE 13



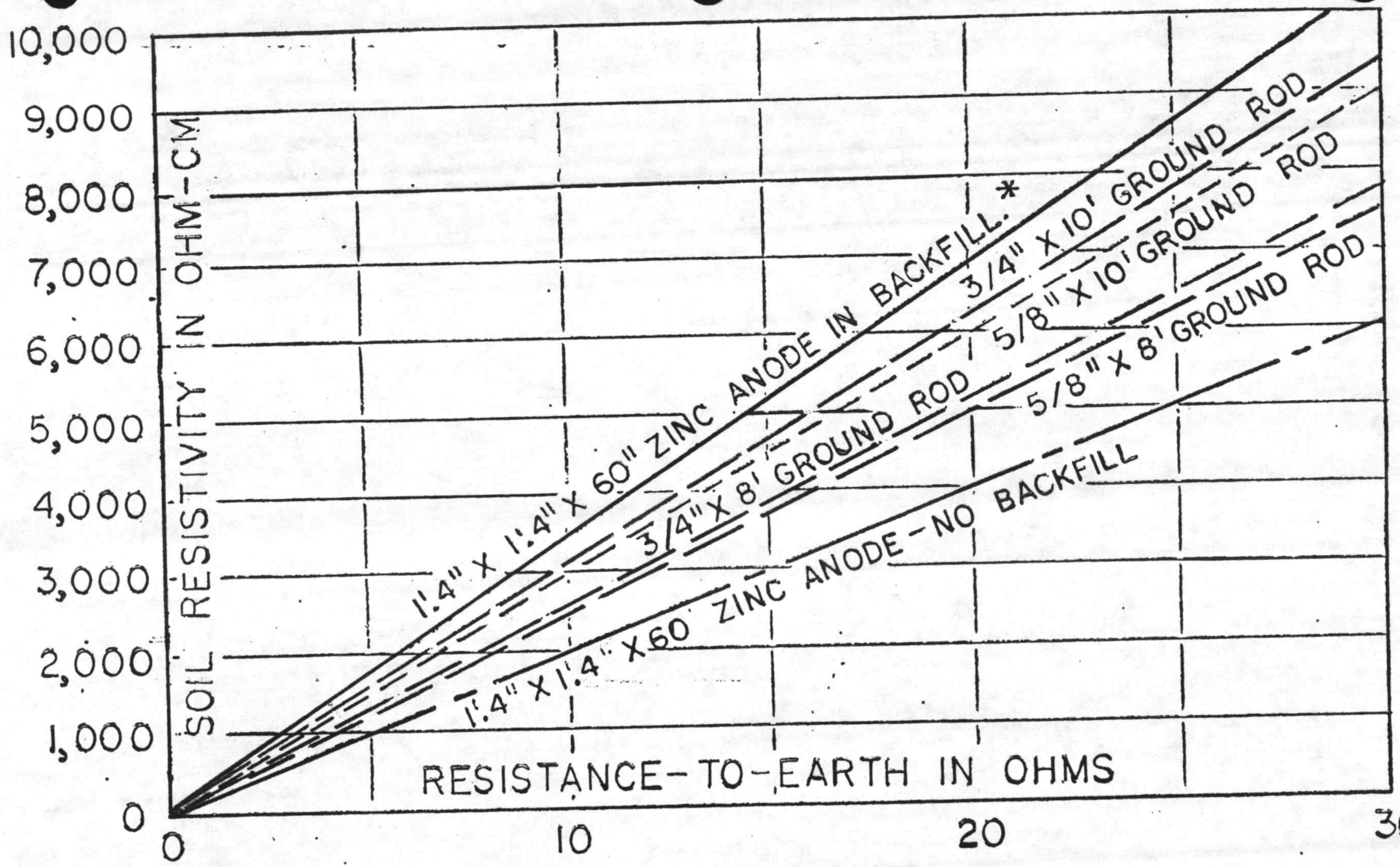
SCHEMATIC DIAGRAM OF CATHODIC PROTECTION
OF BURIED METALS

FIGURE 14

GALVANIC COUPLE POTENTIALS

Galvanic Couple	Voltage Difference Volt
Iron-copper	0.55
Aluminum-copper	1.55
Lead-copper	0.45
Zinc (galvanizing)-copper	0.99

FIGURE 15



RESISTANCE OF ZINC ANODE VS COPPER CLAD GROUND RODS

FIGURE 16

TAB PLACEMENT HERE

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APPENDIX G

PHOTOGRAPHS

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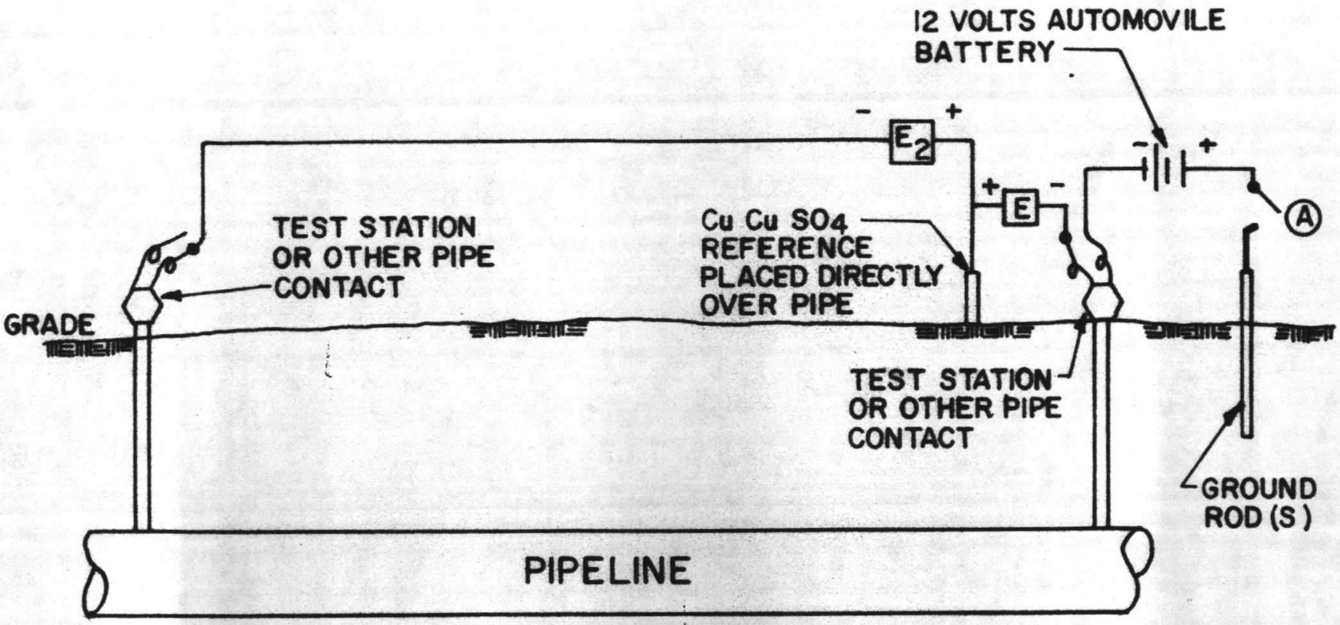
APPENDIX H

DRAWINGS



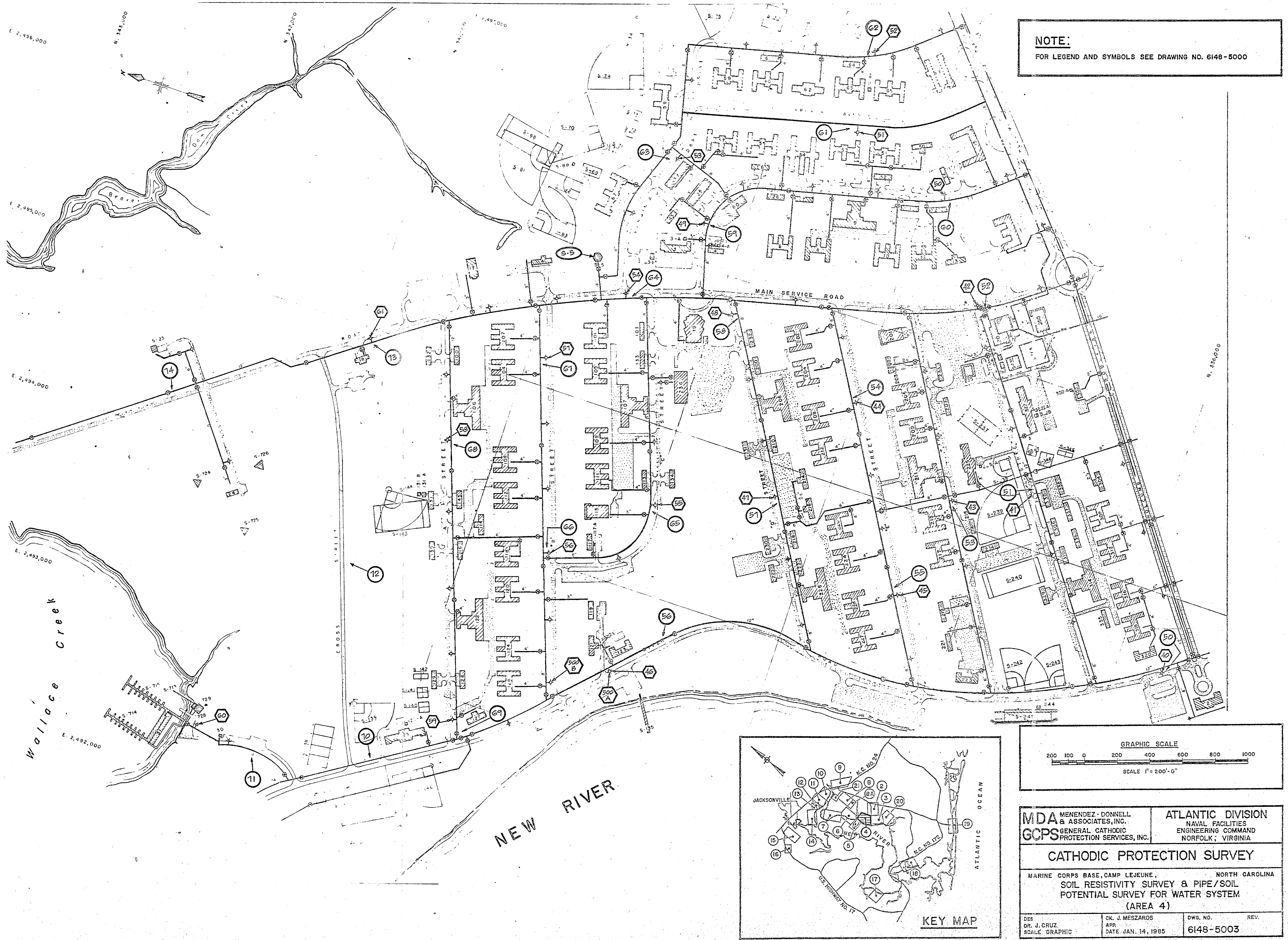
TEST PROCEDURE

1. ESTABLISH POSITIVE ELECTRICAL CONTACT TO THE PIPE AT EACH EXTREMITY OF SECTION TO BE TESTED.
2. WITH THE SWITCH AT (A) OPEN AND CLOSED, ELECTRICAL CONTINUITY FROM TEST STATION IS INDICATED WHEN E_1 AND E_2 ARE THE SAME MAGNITUDES.
3. WITH THE SWITCH AT (A) OPEN AND CLOSED, ELECTRICAL DISCONTINUITY FROM TEST STATION TO TEST STATION IS INDICATED WHEN E_1 AND E_2 ARE DIFFERENT MAGNITUDES.

MDA MENENDEZ-DONNELL & ASSOCIATES, INC.
GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ELECTRICAL CONTINUITY TEST
UNDERGROUND PIPELINE

NO.	REVISION	DATE	DES DR H.D.V. SCALE NONE	CK APP DATE 10-15-84	DWG NO. SK-6148-A	REV



NOTE:
FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000

GRAPHIC SCALE
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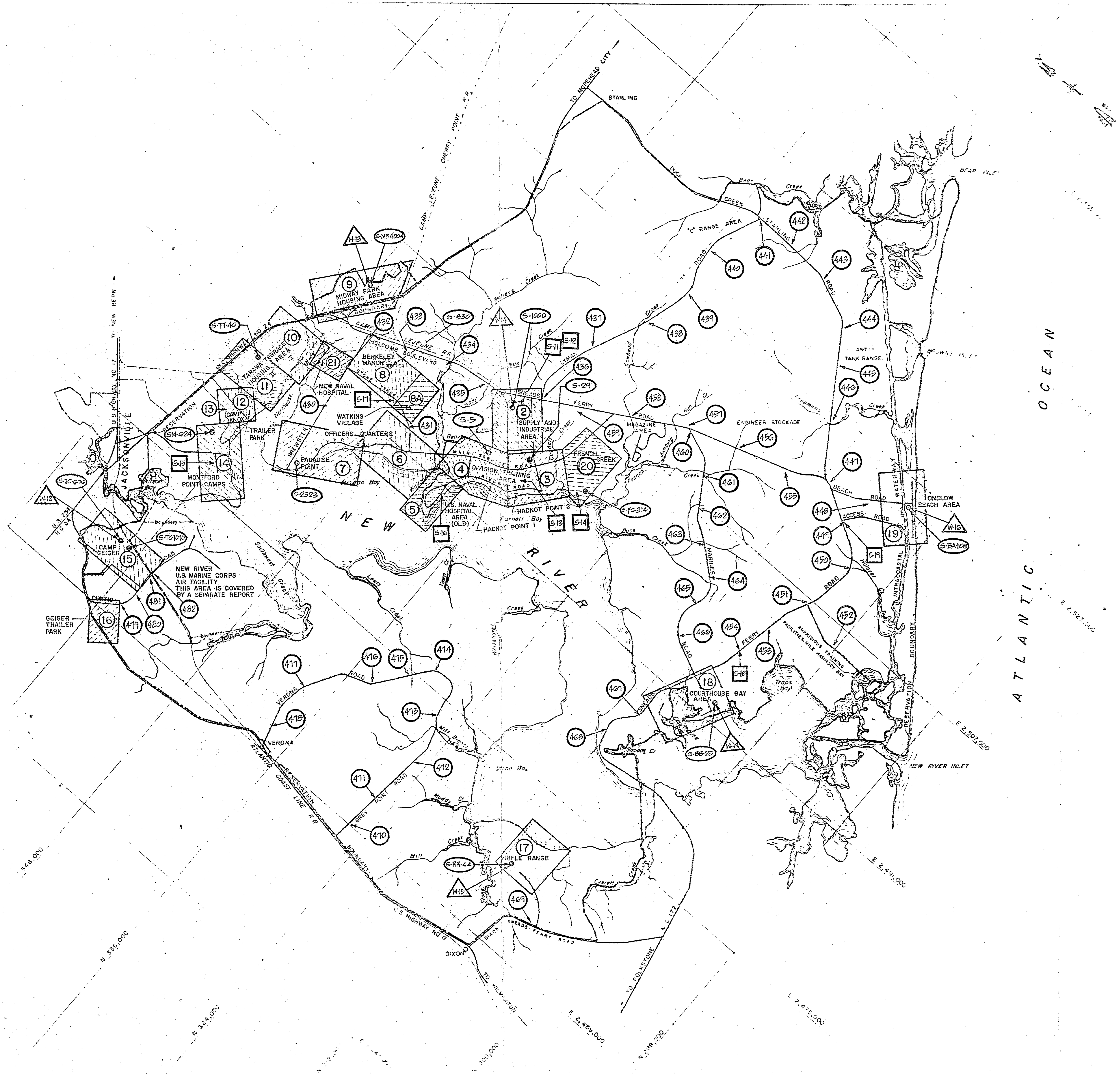
SCALE 1" = 200'-0"

MDA MENENDEZ-DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA
SOIL RESISTIVITY SURVEY & PIPE/SOIL
POTENTIAL SURVEY FOR WATER SYSTEM
(AREA 4)

DES DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5003	REV.



LEGEND

- ○ SOIL RESISTIVITY TEST POINT
- ⬡ PIPE/SOIL POTENTIAL MEASUREMENT
- □ SOIL SAMPLE LOCATION
- △ WATER SAMPLE LOCATION
- R- EXISTING RECTIFIER
- GB- EXISTING GROUNDBED
- R- PROPOSED RECTIFIER
- GB- PROPOSED GROUNDBED
- ⬭ EXISTING ELEVATED WATER TANK
- — EXISTING WATER LINE
- EXISTING FIRE HYDRANT
- EXISTING GATE VALVE

AREA REFERENCE

AREA NO.	NAME
2	INDUSTRIAL AREA
3	HADNOT POINT 2
4	HADNOT POINT 1
5	OLD NAVAL HOSPITAL
6	OFFICER'S QUARTERS
7	PARADISE POINT
8	BERKELEY MANOR
8A	WATKINS VILLAGE
9	MIDWAY PARK
10	TARAWA TERRACE I
11	TARAWA TERRACE II
12	TRAILER PARK
13	CAMP KNOX
14	MONTFORD POINT
15	CAMP GEIGER
16	GEIGER TRAILER PARK
17	RIFLE RANGE
18	COURTHOUSE BAY
19	ONSLOW BEACH
20	FRENCH CREEK
21	NEW NAVAL HOSPITAL

GRAPHIC SCALE

4,000 0' 4,000 8,000 12,000 16,000 20,000

SCALE 1" = 4,000'-0"

MDA MENENDEZ · DONNELL & ASSOCIATES, INC.
GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

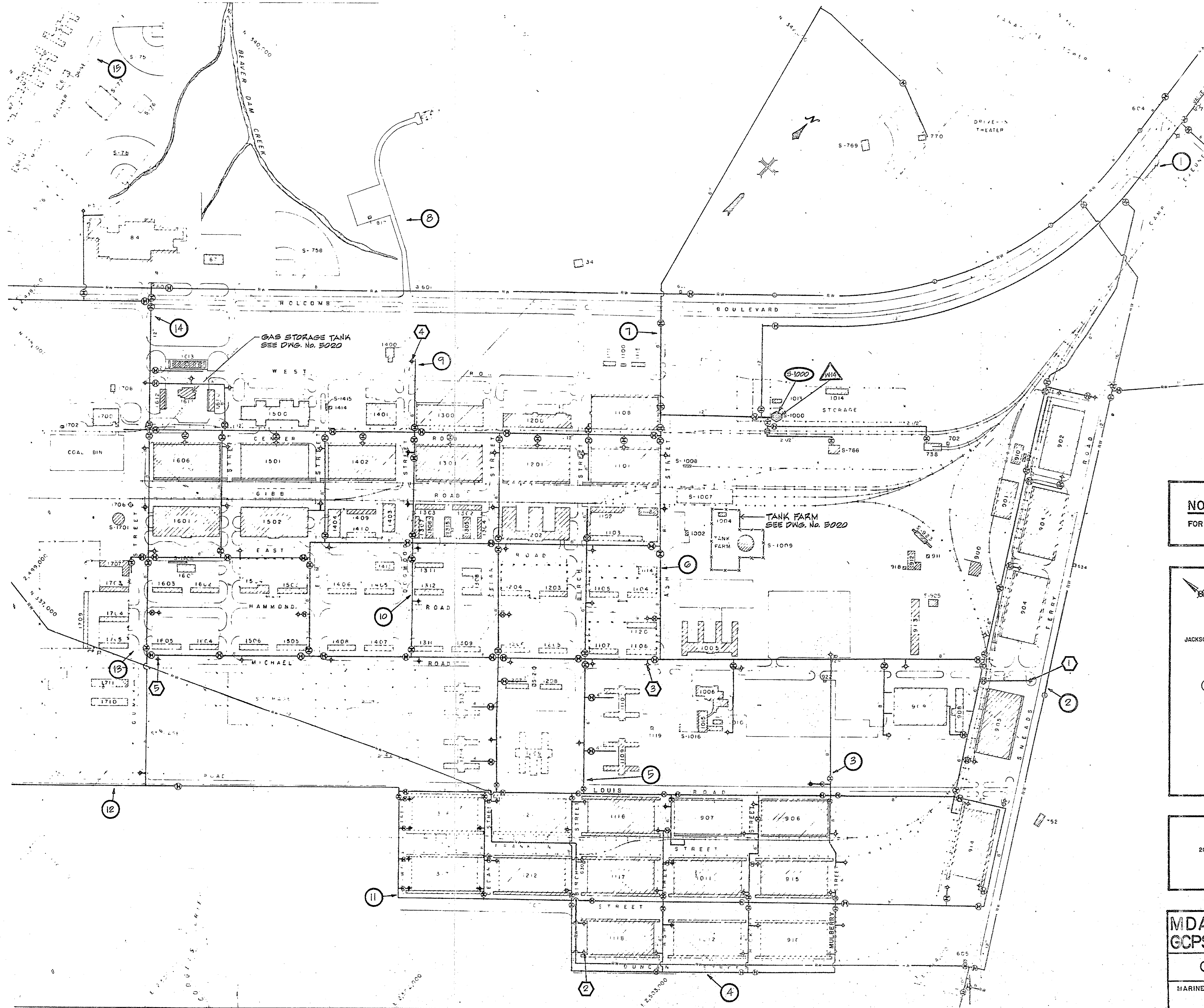
ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

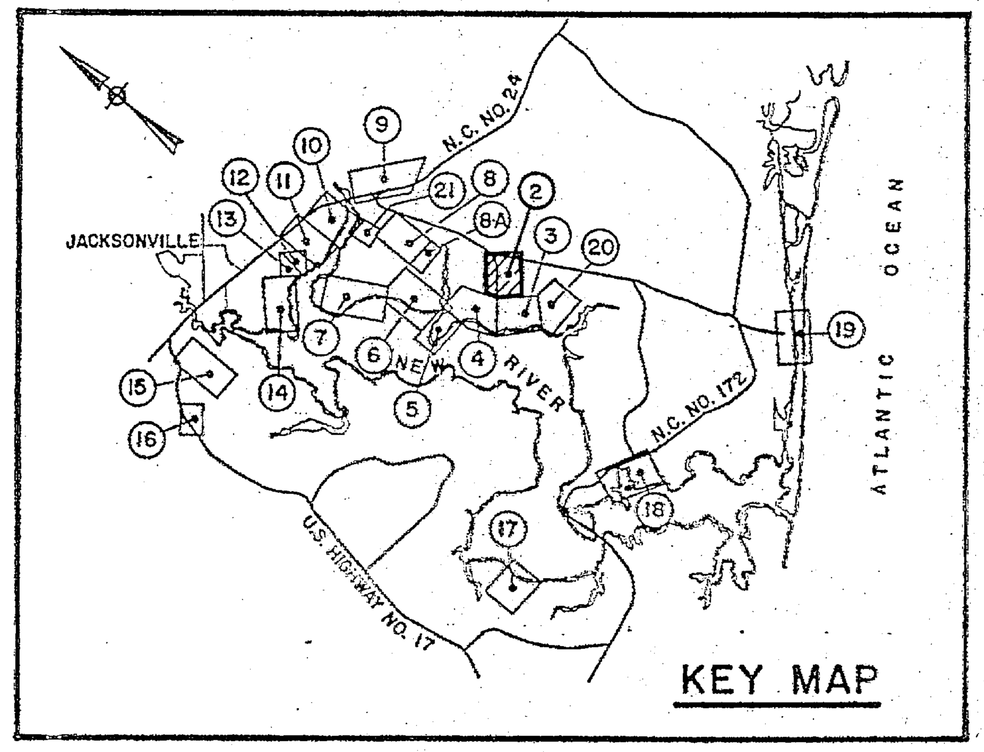
STATION MAP

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APR. DATE JAN. 14, 1985	DWG. NO. 6148-5000	REV.



NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000



KEY MAP

GRAPHIC SCALE

200 100 0 200 400 600 800 1000

SCALE 1" = 200'-0"

MDA MENENDEZ-DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

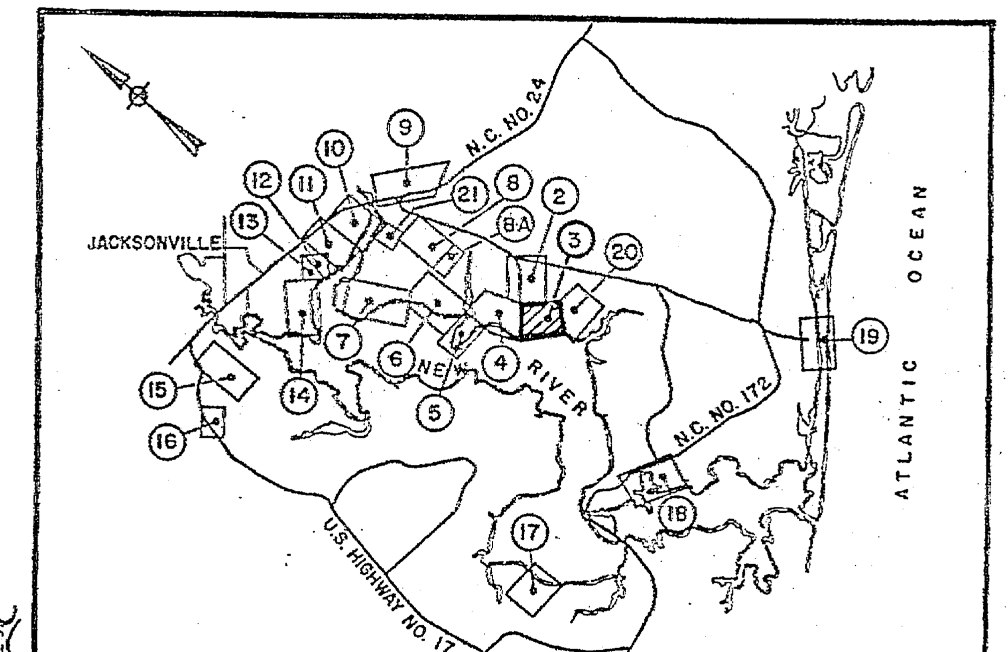
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 2)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5001	REV.

NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000



KEY MAP

GRAPHIC SCALE

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SCALE 1" = 200'-0"

MDA MENENDEZ · DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

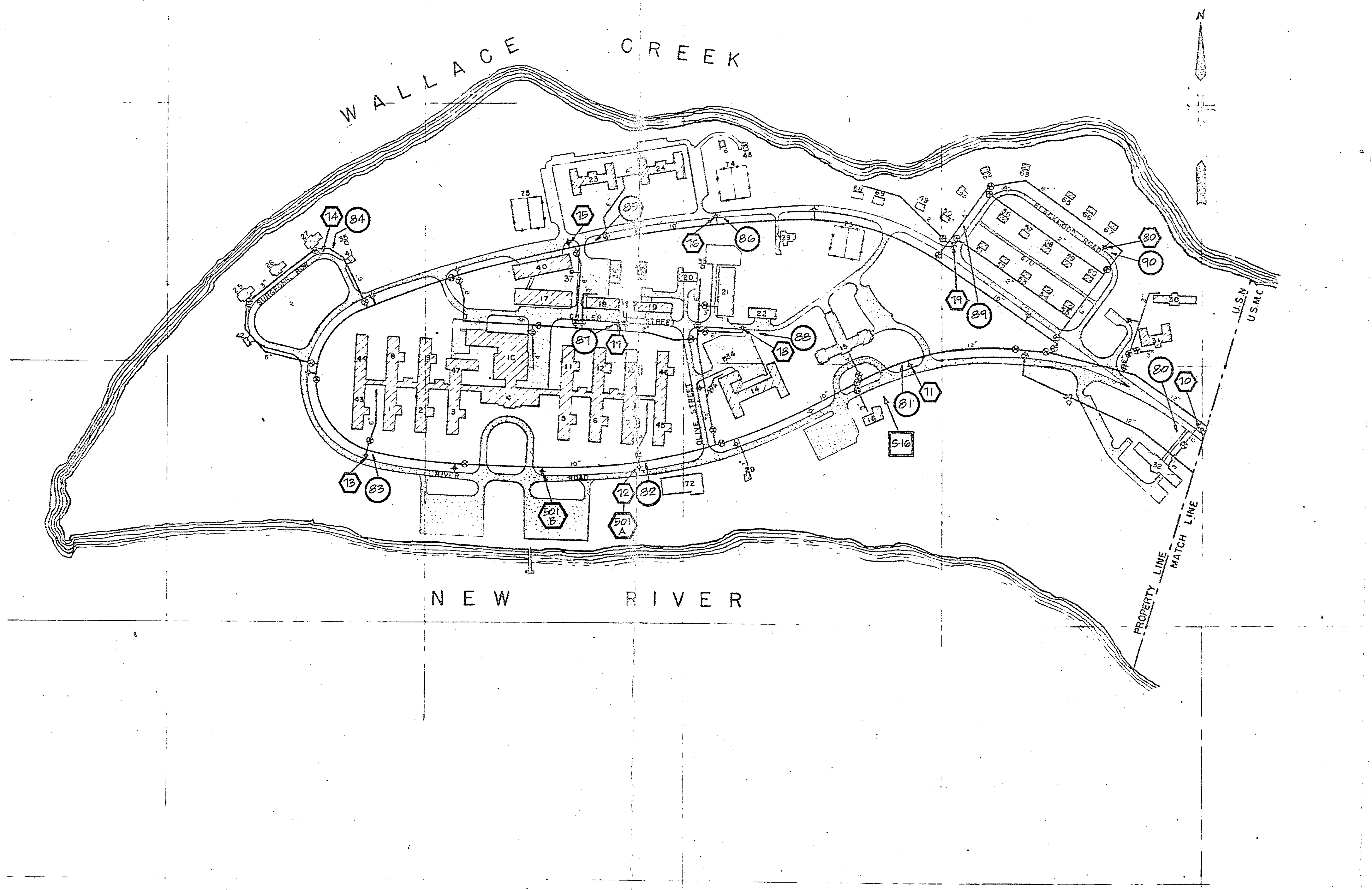
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

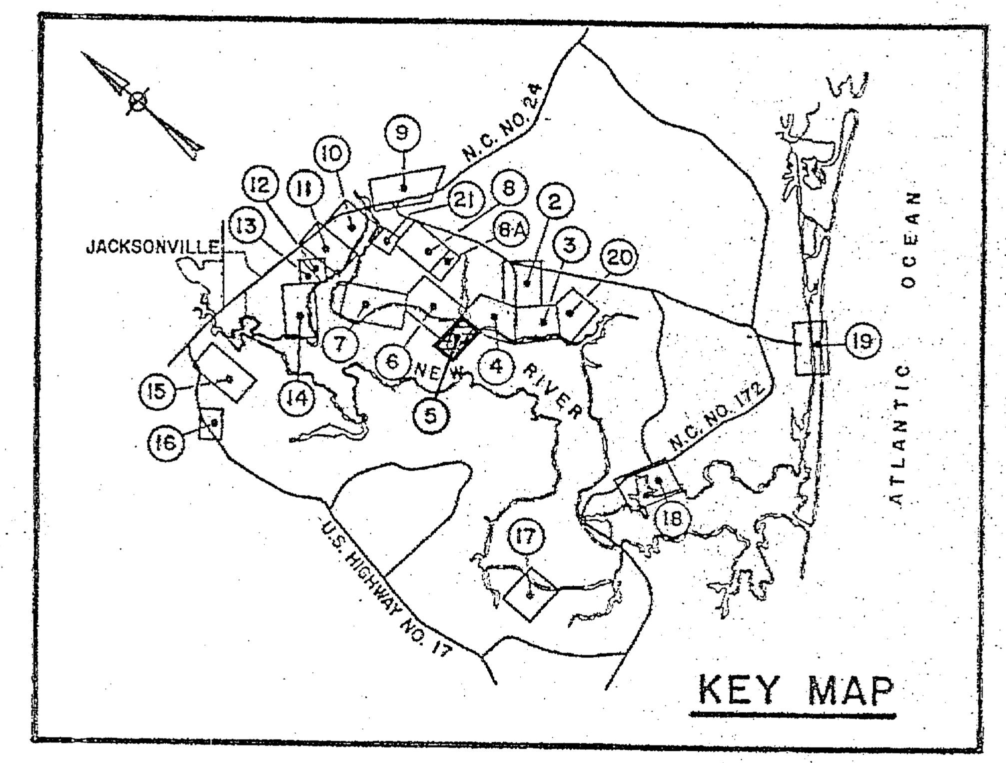
SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 3)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5002	REV.

NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000





GRAPHIC SCALE

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SCALE 1" = 200'-0"

MDA MENENDEZ · DONNELL & ASSOCIATES, INC.

GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

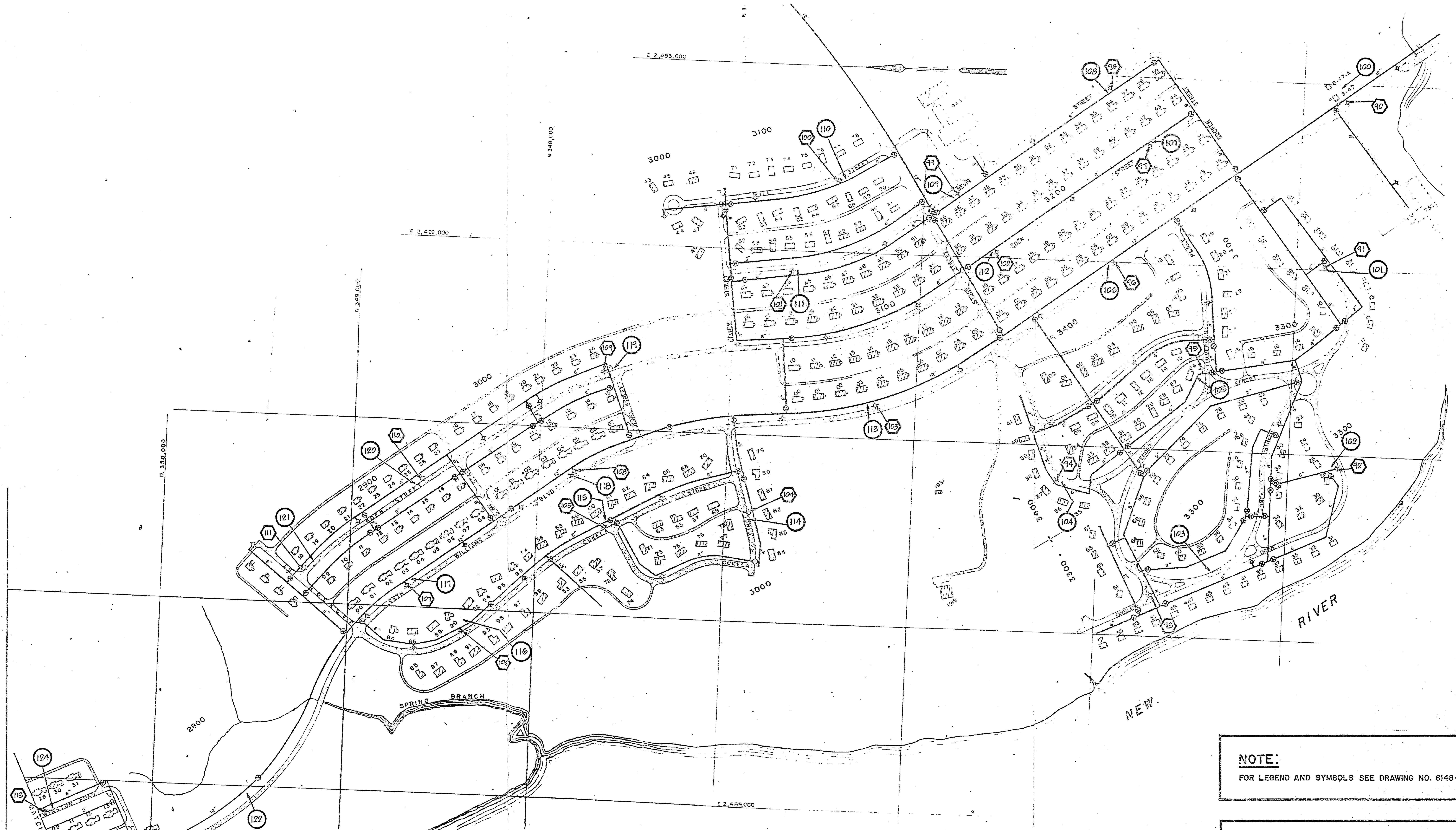
ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 5)

DES DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5004 REV.



NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000

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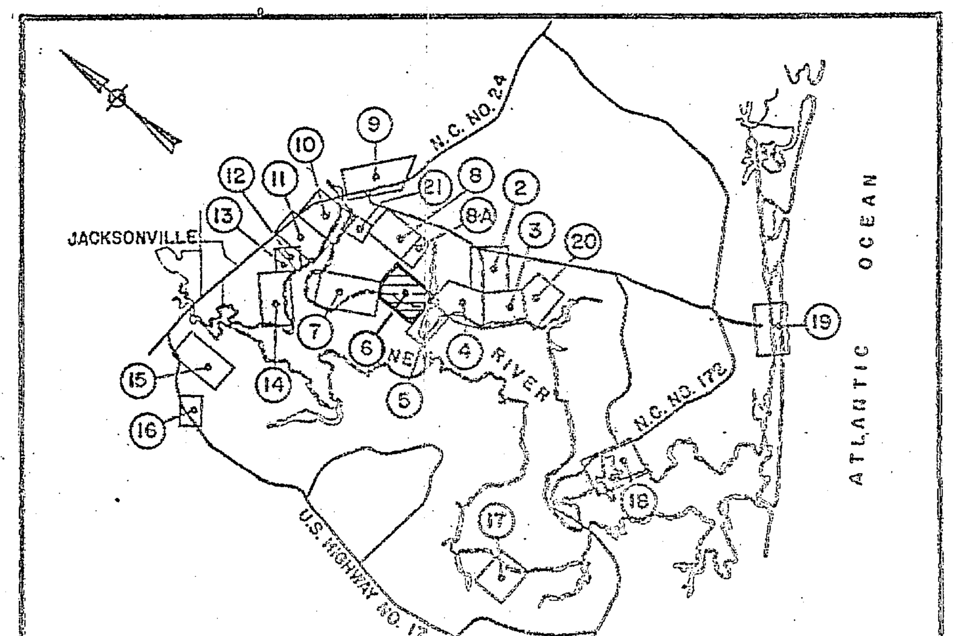
SCALE 1" = 200'-0"



KEY MAP

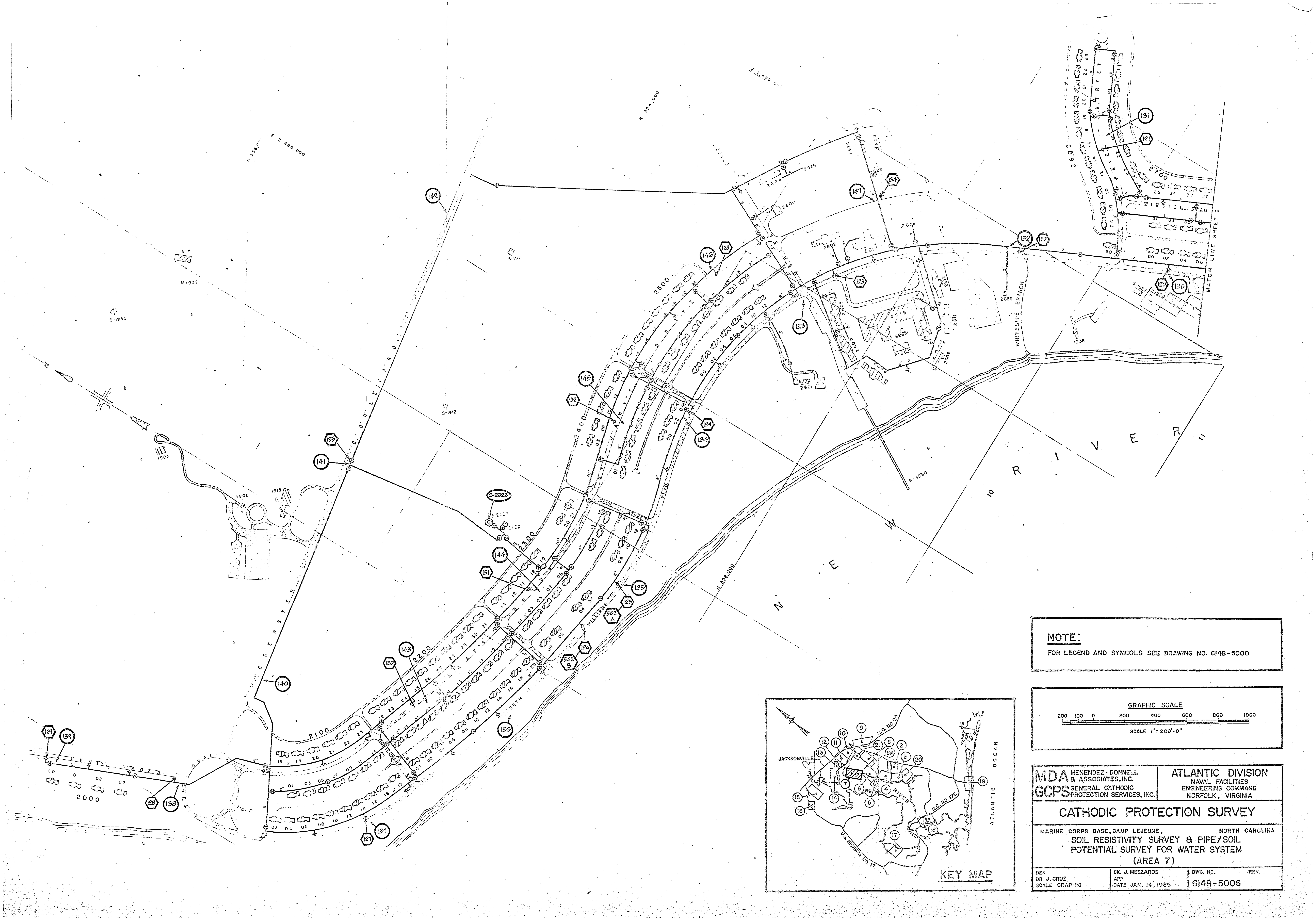
MDA MENENDEZ-DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA.

CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 6)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5005	REV.



NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000

GRAPHIC SCALE

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SCALE 1" = 200'-0"

MDA MENENDEZ · DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

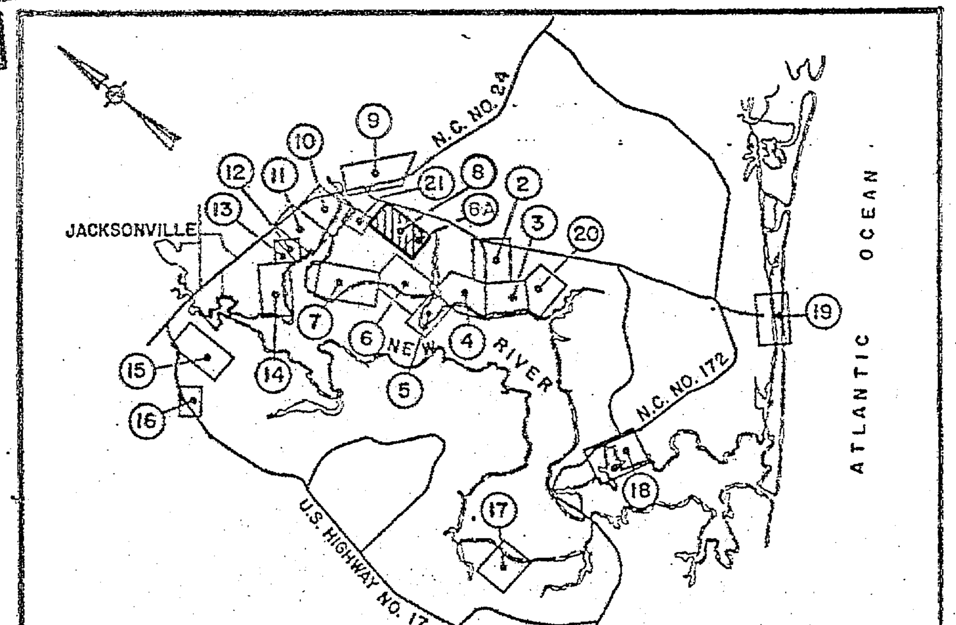
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 7)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5006 REV.

NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000



KEY MAP

GRAPHIC SCALE

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SCALE 1" = 200'-0"

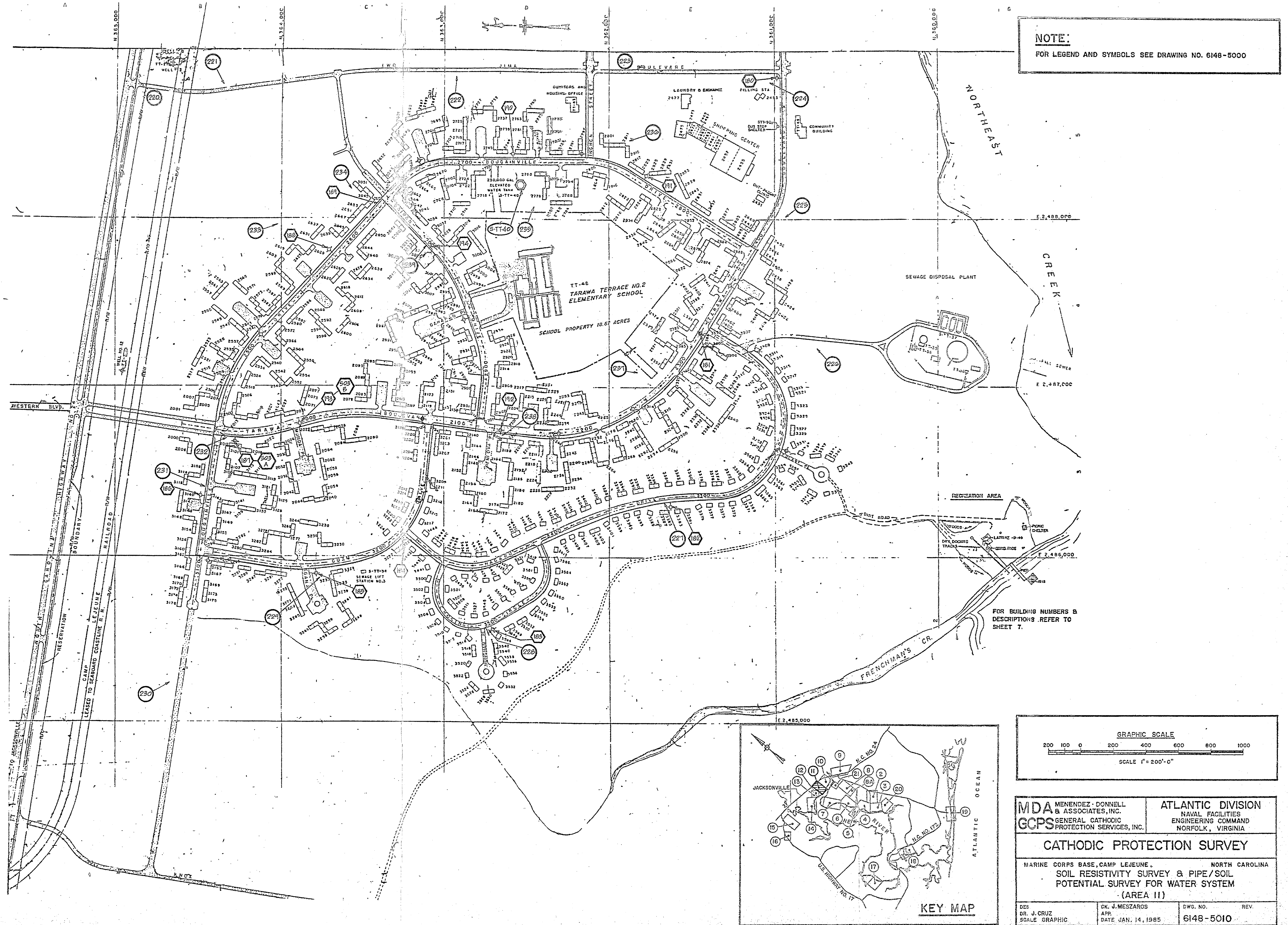
MDA MENENDEZ · DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 8 AND 8A)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5007	REV.


NOTE:
FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000
TARAWA TERRACE NO.2 ELEMENTARY SCHOOL
SCHOOL PROPERTY 10.67 ACRES
SEWAGE DISPOSAL PLANT
NORTHEAST CREEK
RECREATION AREA
FRENCHMAN'S CR.
WESTERN BLVD.
CAMP LEJEUNE RESERVATION BOUNDARY
LEASED TO SEABOARD COASTLINE R.R.
FOR BUILDING NUMBERS & DESCRIPTIONS REFER TO SHEET 7.
GRAPHIC SCALE
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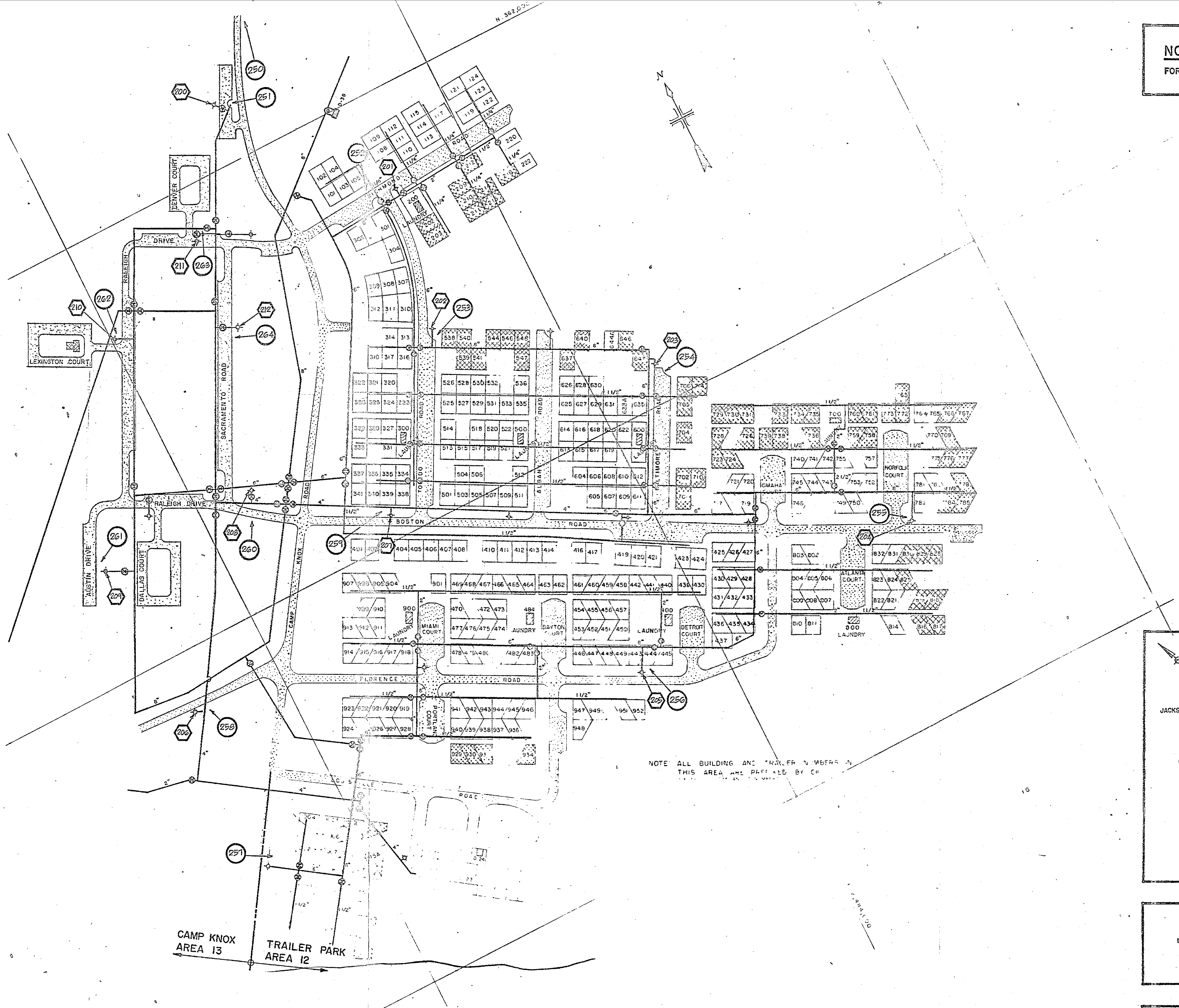
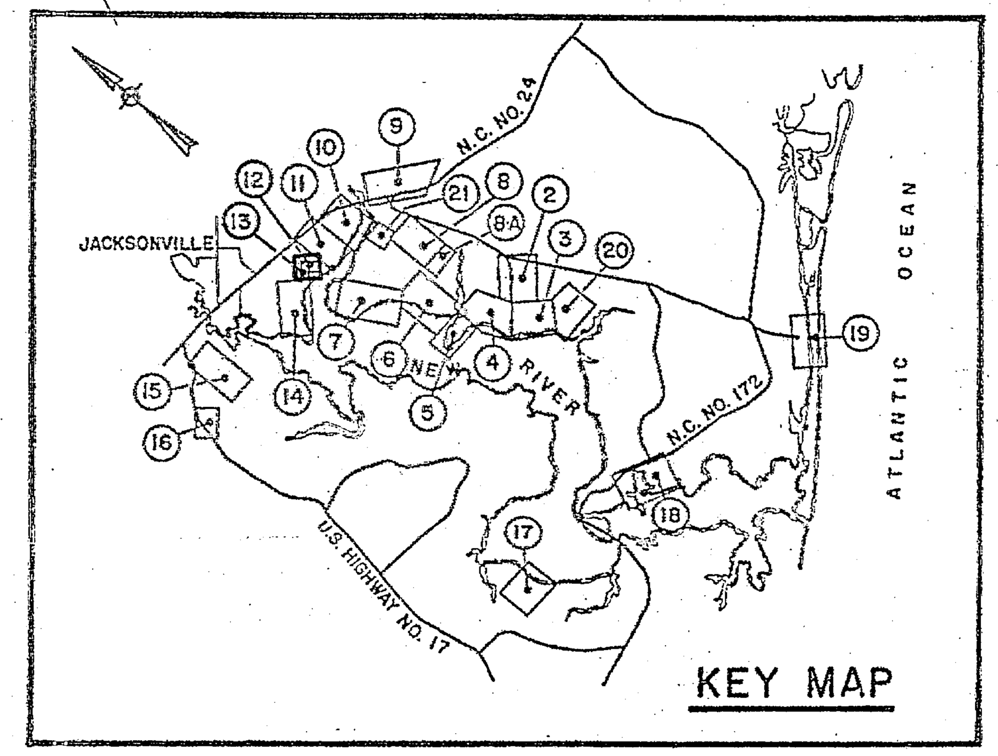
SCALE 1" = 200'-0"
KEY MAP
JACKSONVILLE
NEW RIVER
ATLANTIC OCEAN
MDA MENENDEZ-DONNELL & ASSOCIATES, INC.
GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.
ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA
CATHODIC PROTECTION SURVEY
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA
SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM
(AREA II)
DES DR. J. CRUZ
SCALE GRAPHIC
CK. J. MESZAROS
APP.
DATE JAN. 14, 1985
DWG. NO. 6148-5010
REV.

NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000





GRAPHIC SCALE

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SCALE 1" = 100'-0"

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CATHODIC PROTECTION SURVEY

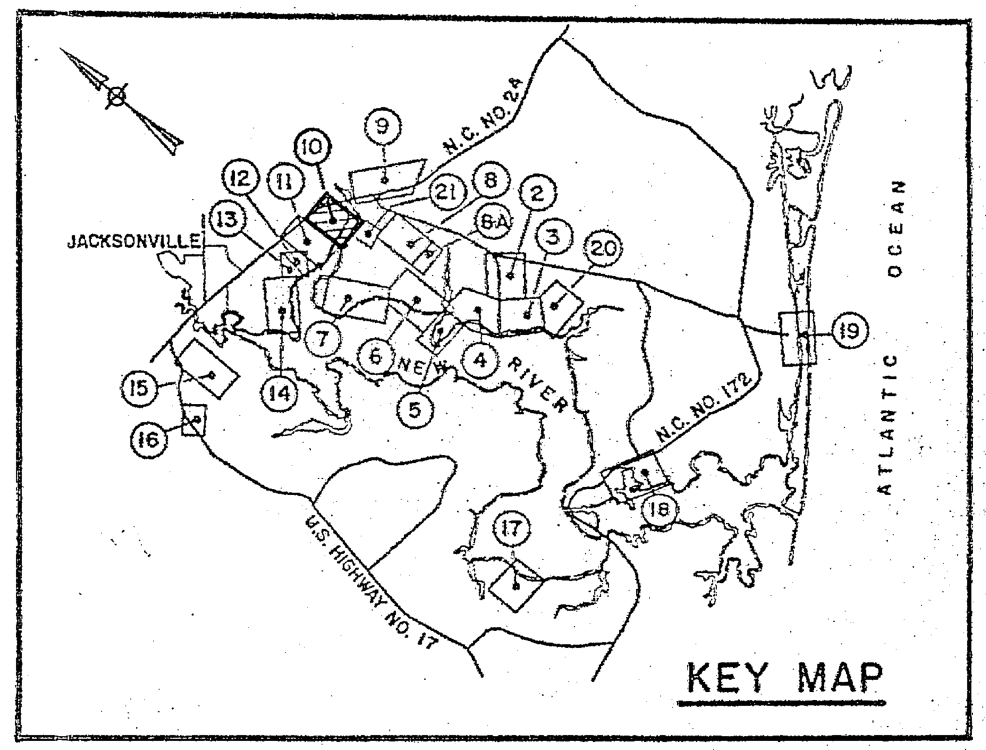
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 12 AND 13)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5011 REV.

NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000



GRAPHIC SCALE

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SCALE 1" = 200'-0"

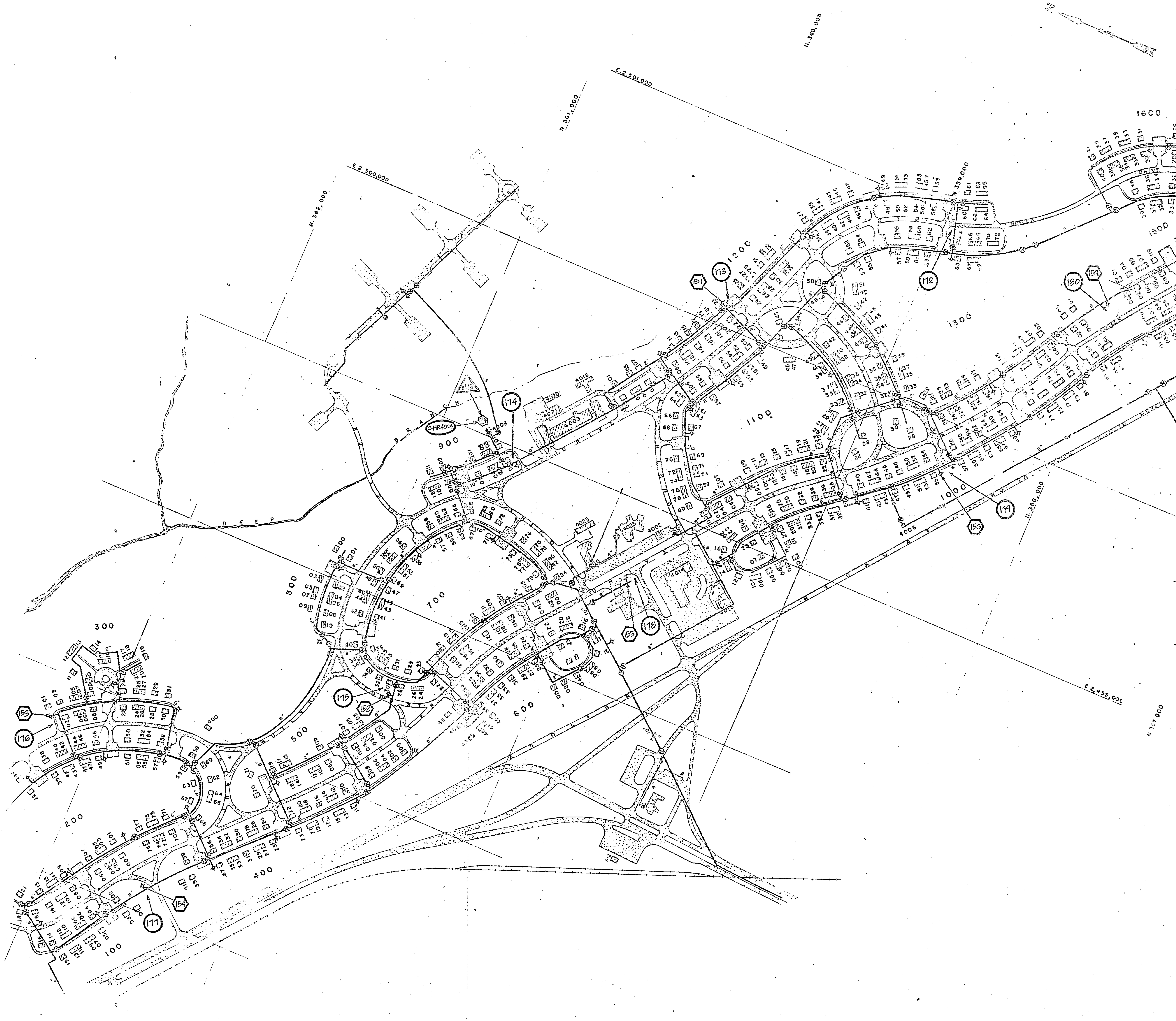
MDA MENENDEZ · DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

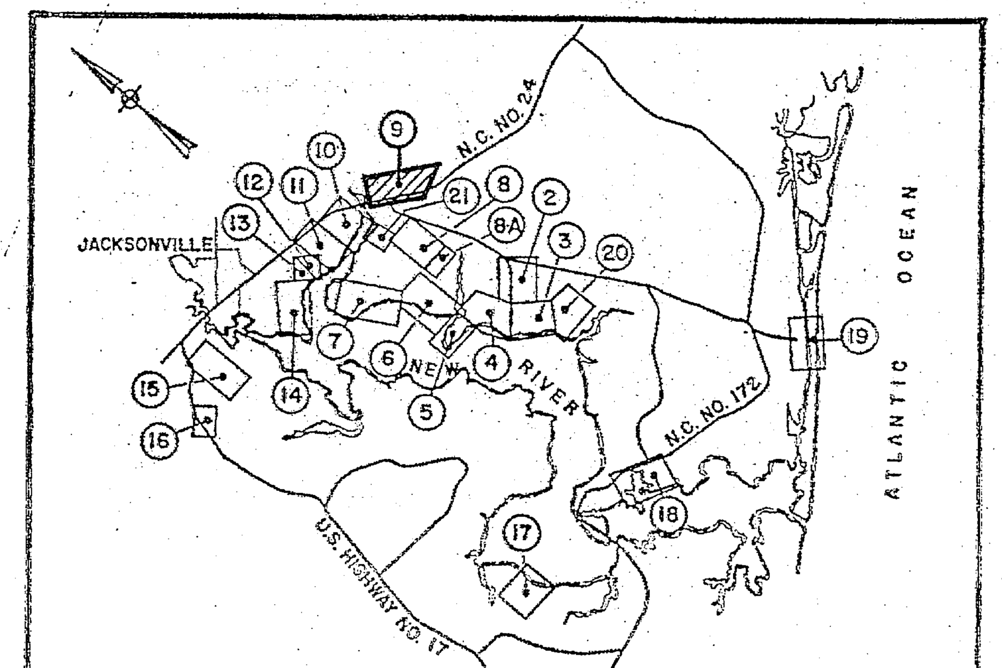
SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 10)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5009	REV.



NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000



KEY MAP

GRAPHIC SCALE

200 100 0 200 400 600 800 1000

SCALE 1" = 200'-0"

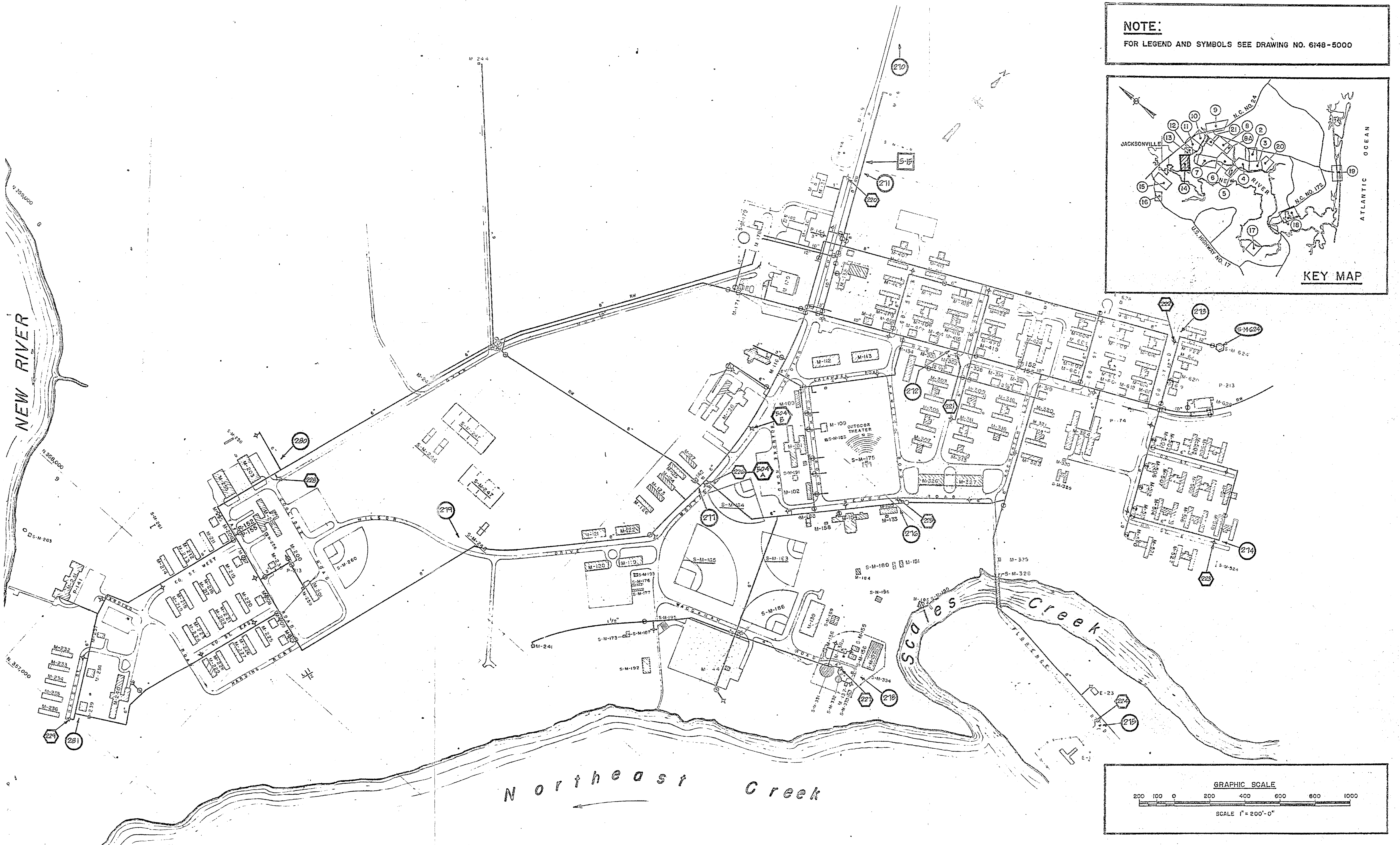
MDA MENENDEZ-DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 9)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5008 REV.



MDA MENENDEZ-DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

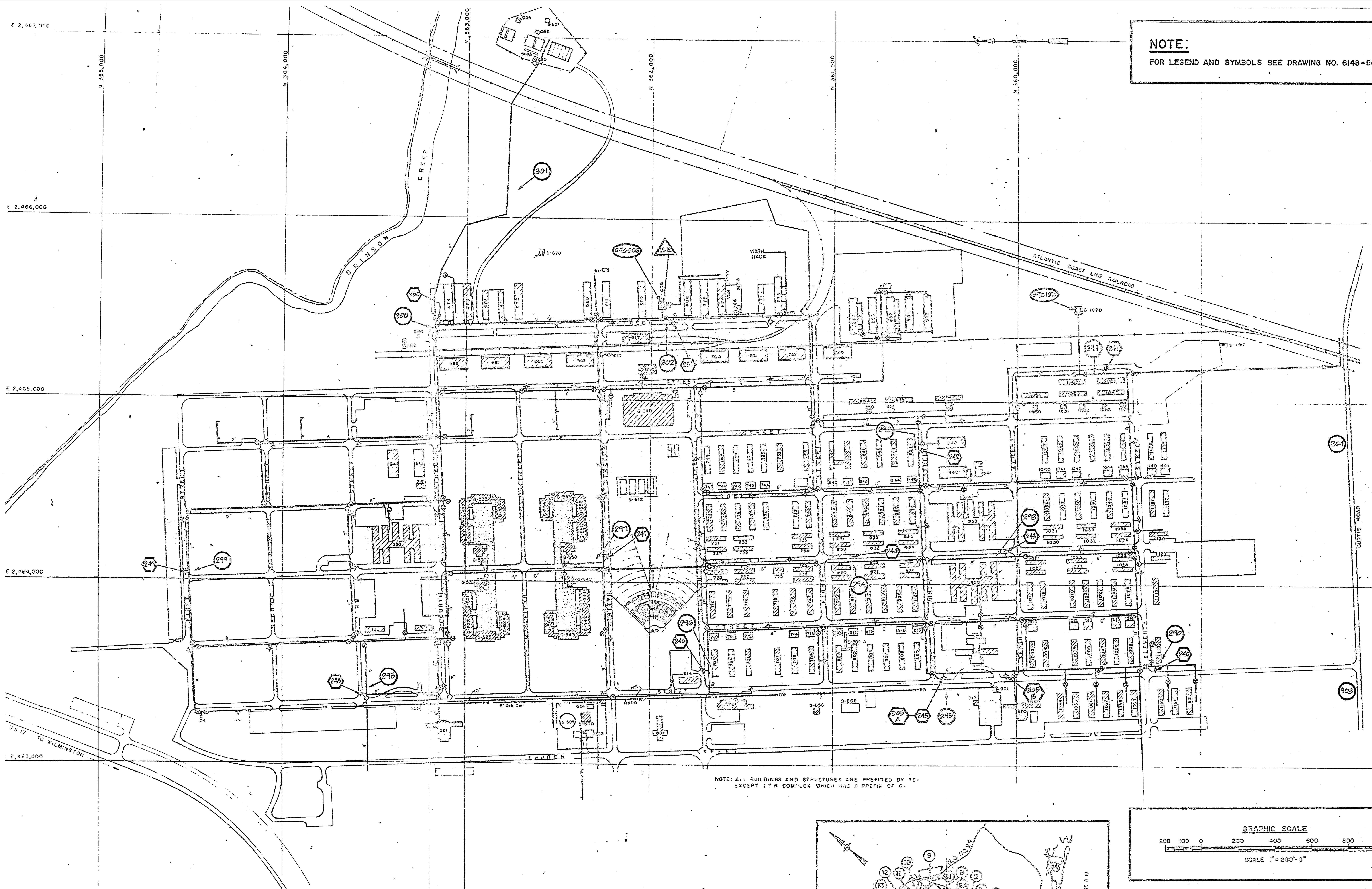
CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

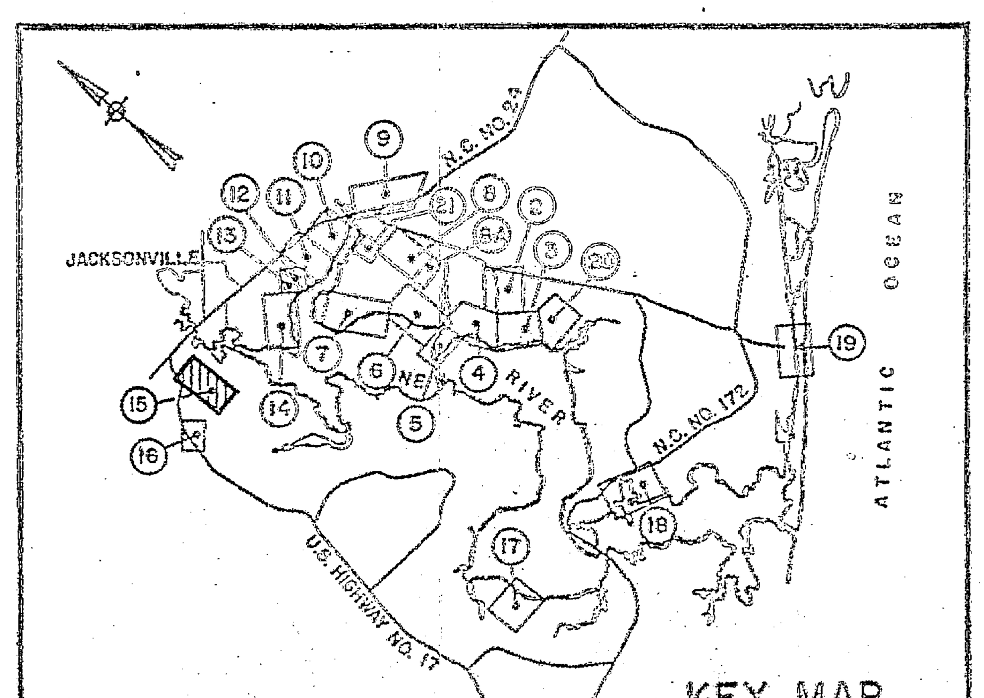
SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 14)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5012	REV.

NOTE:
FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000



NOTE: ALL BUILDINGS AND STRUCTURES ARE PREFIXED BY TC-
EXCEPT I T R COMPLEX WHICH HAS A PREFIX OF G-



KEY MAP

GRAPHIC SCALE

200 100 0 200 400 600 800 1000

SCALE 1" = 200'-0"

MDA MENENDEZ · DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 15)

DES DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5013 REV.

NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000

GRAPHIC SCALE

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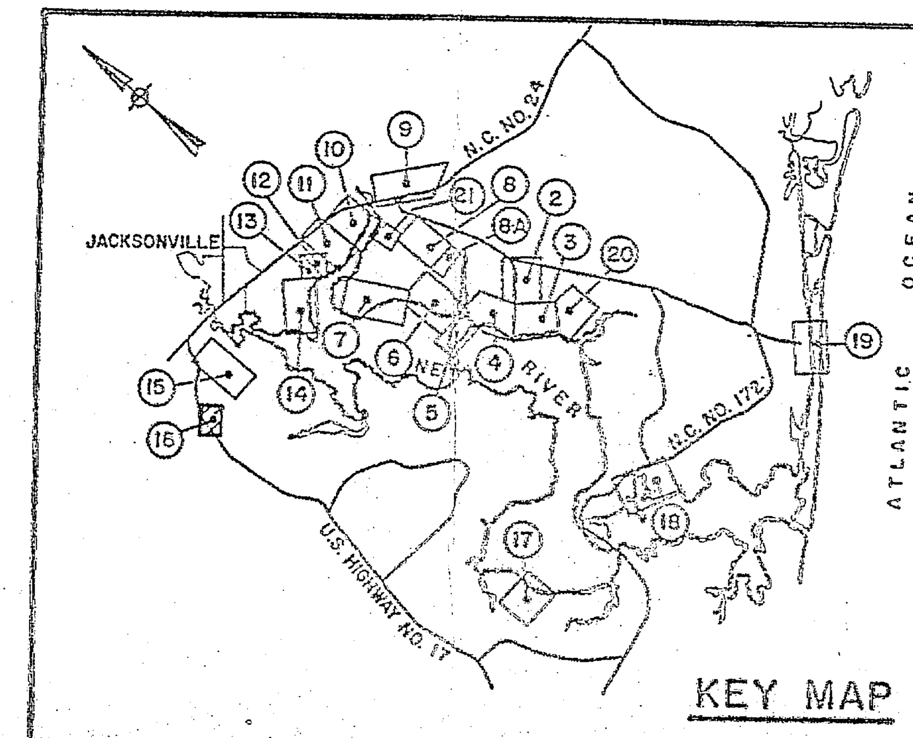
SCALE 1" = 200'-0"



MDA MENENDEZ-DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

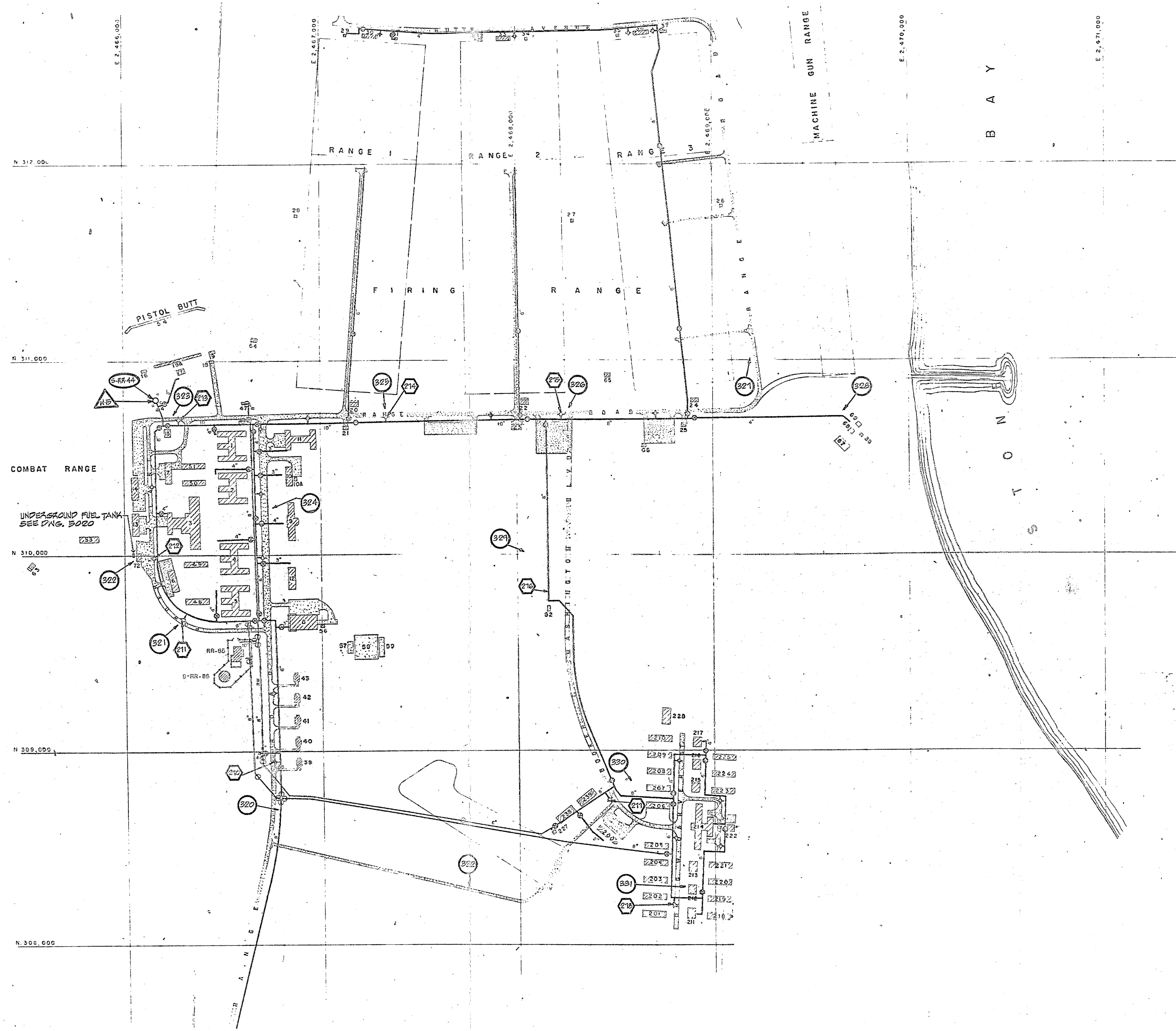
CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

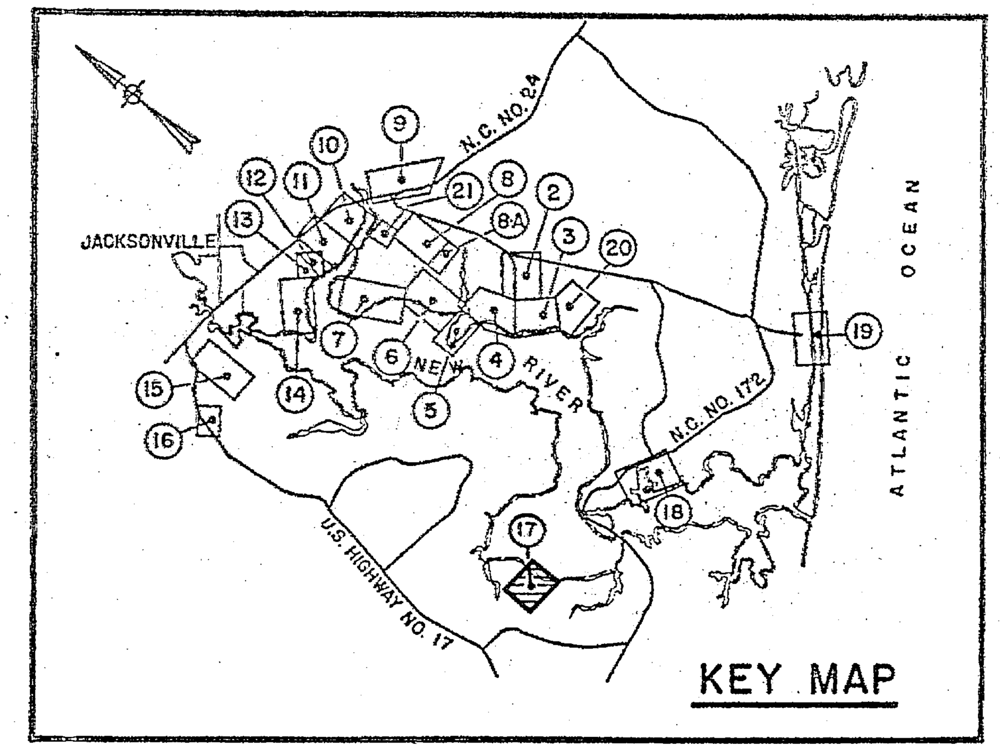
SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM

(AREA 16)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5014 REV.



NOTE:
FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000



GRAPHIC SCALE
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SCALE 1" = 200'-0"

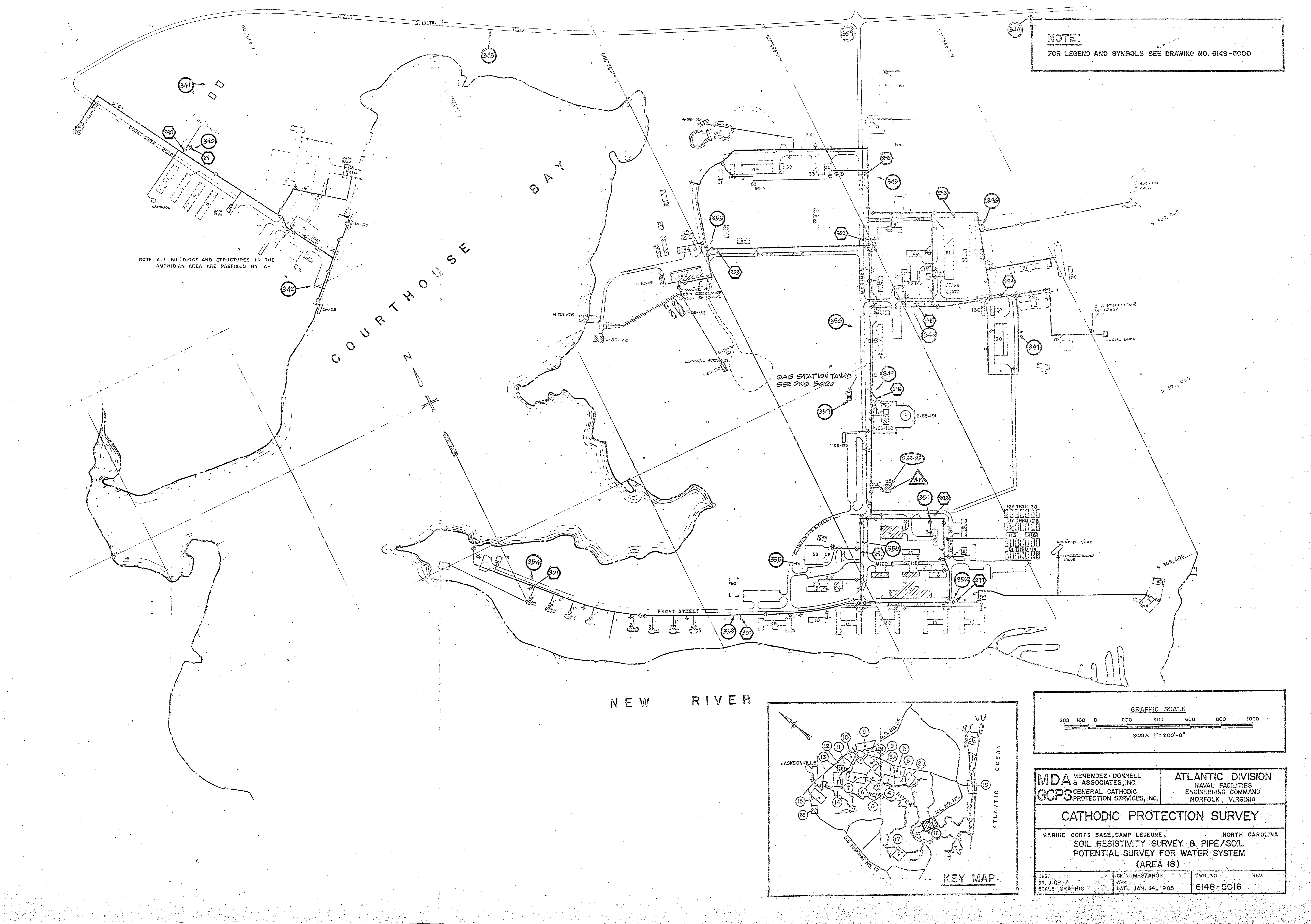
MDA MENENDEZ-DONNELL & ASSOCIATES, INC.
GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.

ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

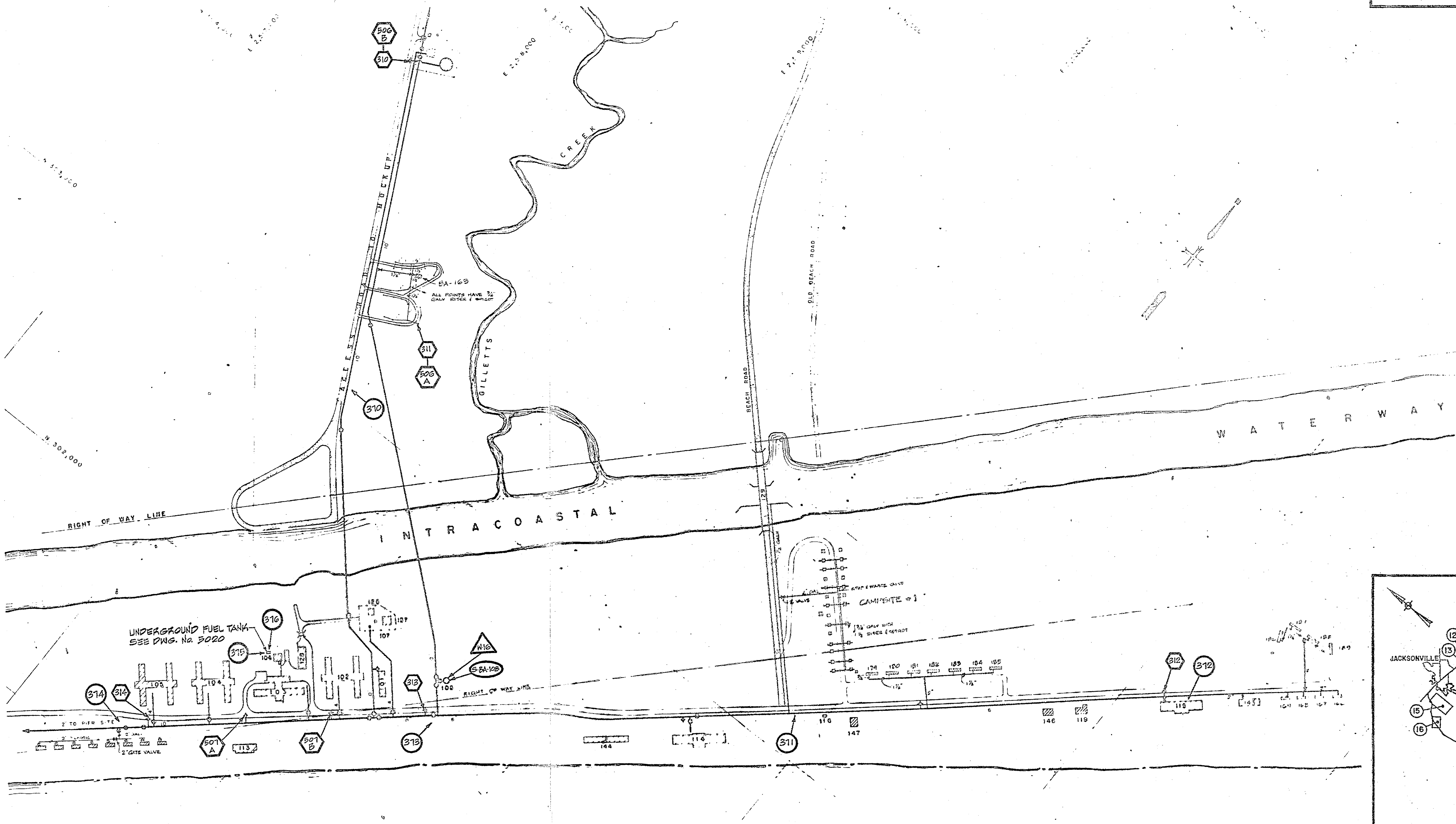
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA
SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 17)

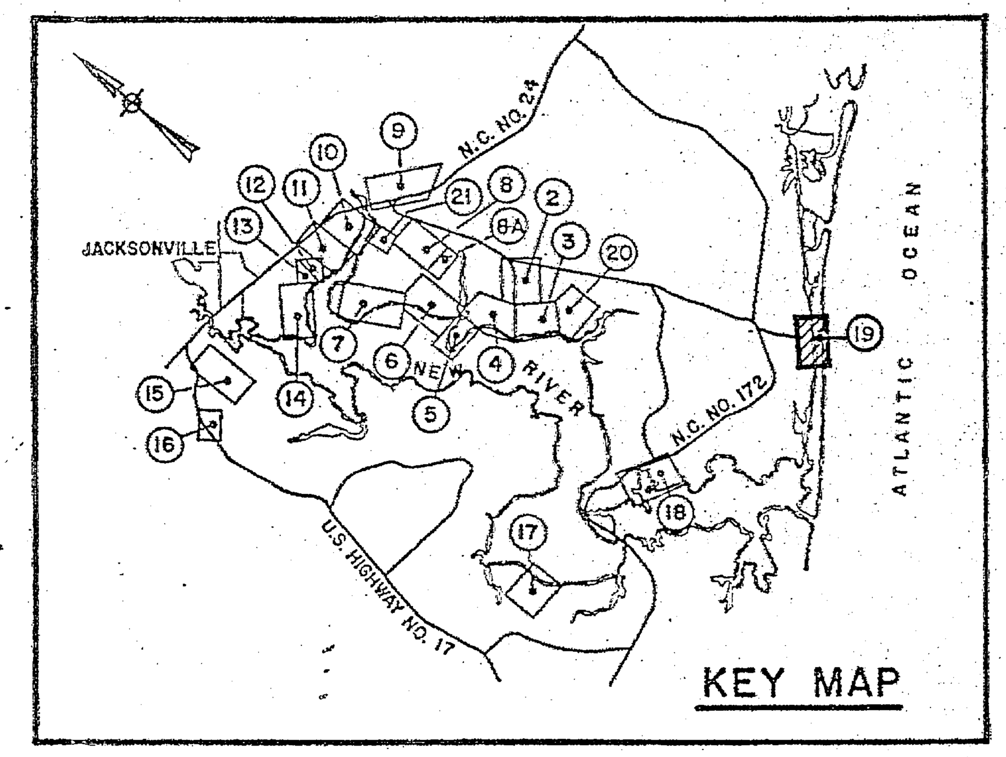
DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5015 REV.


NOTE:
FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000
NOTE: ALL BUILDINGS AND STRUCTURES IN THE AMPHIBIAN AREA ARE PREFIXED BY A-
COURTHOUSE BAY
NEW RIVER
GAS STATION TANKS SEE DWG. 5020
FRONT STREET
CLINTON STREET
MIDDLE STREET
CONCRETE SLAB
GRAPHIC SCALE
200 100 0 200 400 600 800 1000
SCALE 1" = 200'-0"
KEY MAP
JACKSONVILLE
ATLANTIC OCEAN
MDA MENENDEZ · DONNELL & ASSOCIATES, INC.
GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.
ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA
CATHODIC PROTECTION SURVEY
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA
SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM
(AREA 18)
DES.
DR. J. CRUZ
SCALE GRAPHIC
CK. J. MESZAROS
APP.
DATE JAN. 14, 1985
DWG. NO.
6148-5016
REV.

NOTE:

FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000





GRAPHIC SCALE

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SCALE 1" = 200'-0"

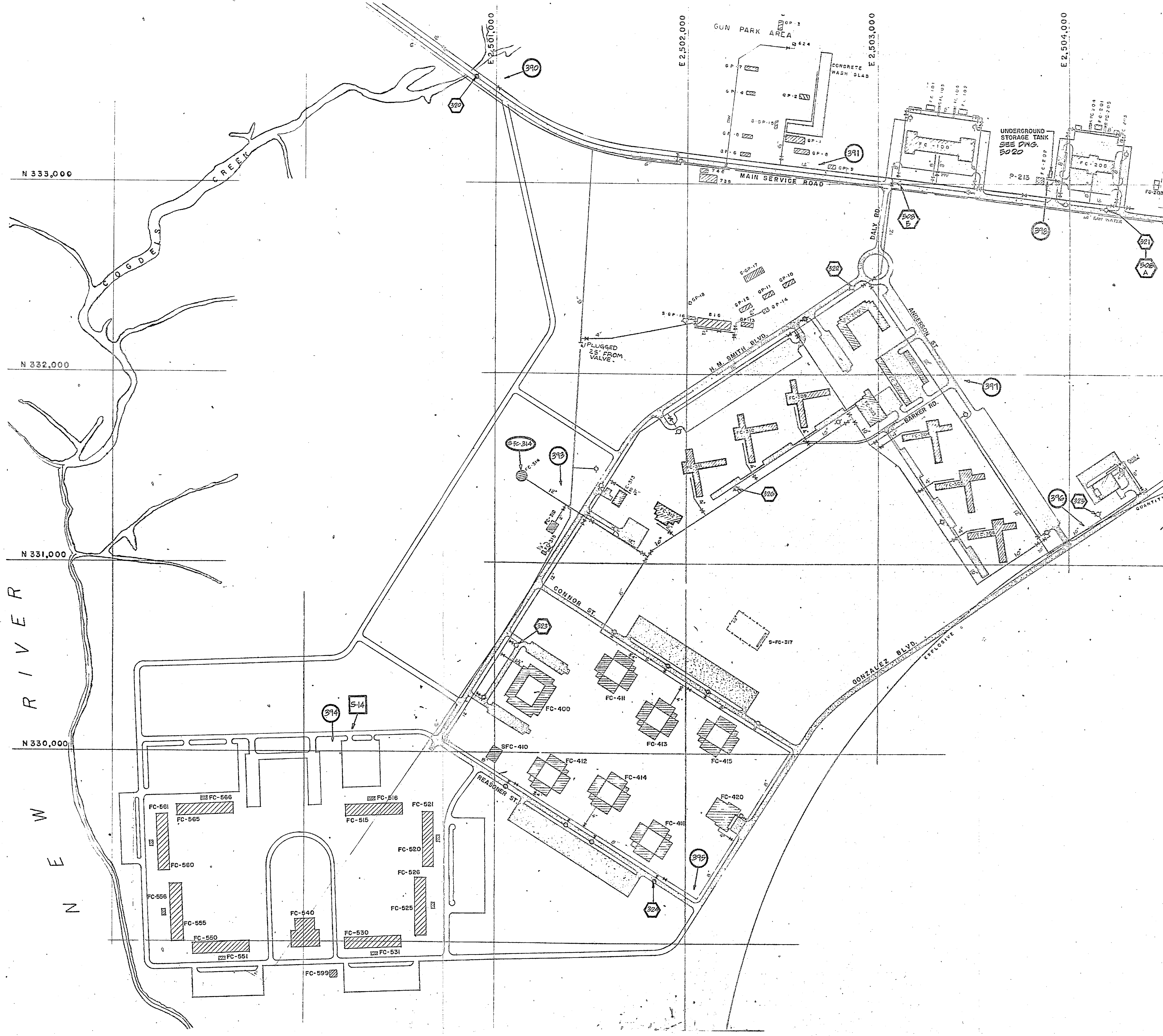
MDA MENENDEZ · DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

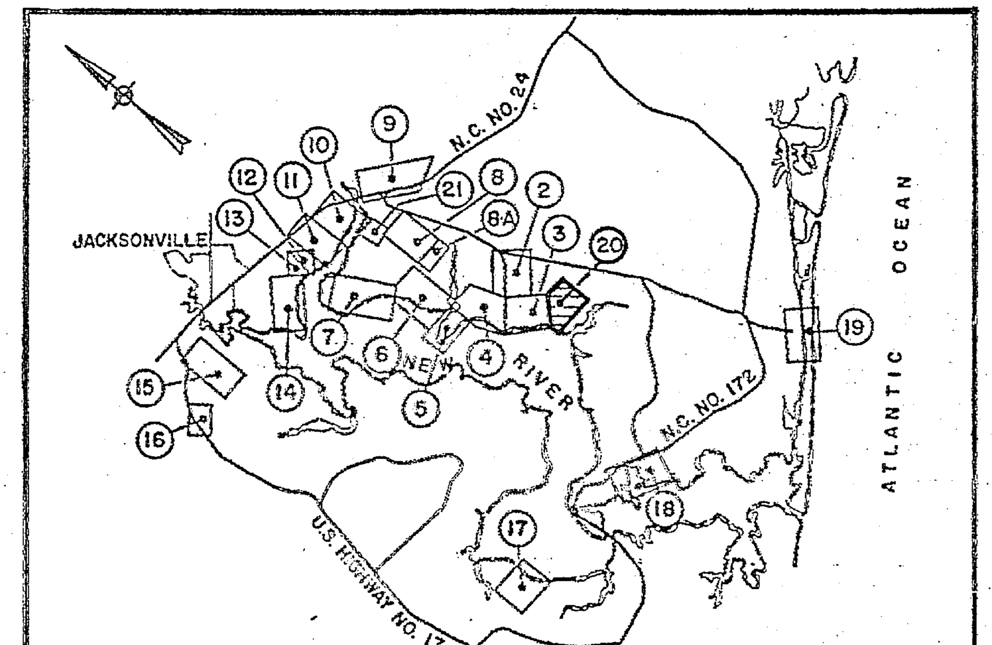
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM (AREA 19)

DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5017 REV.



NOTE:
FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000



KEY MAP

GRAPHIC SCALE
200 100 0 200 400 600 800 1000
SCALE 1" = 200'-0"

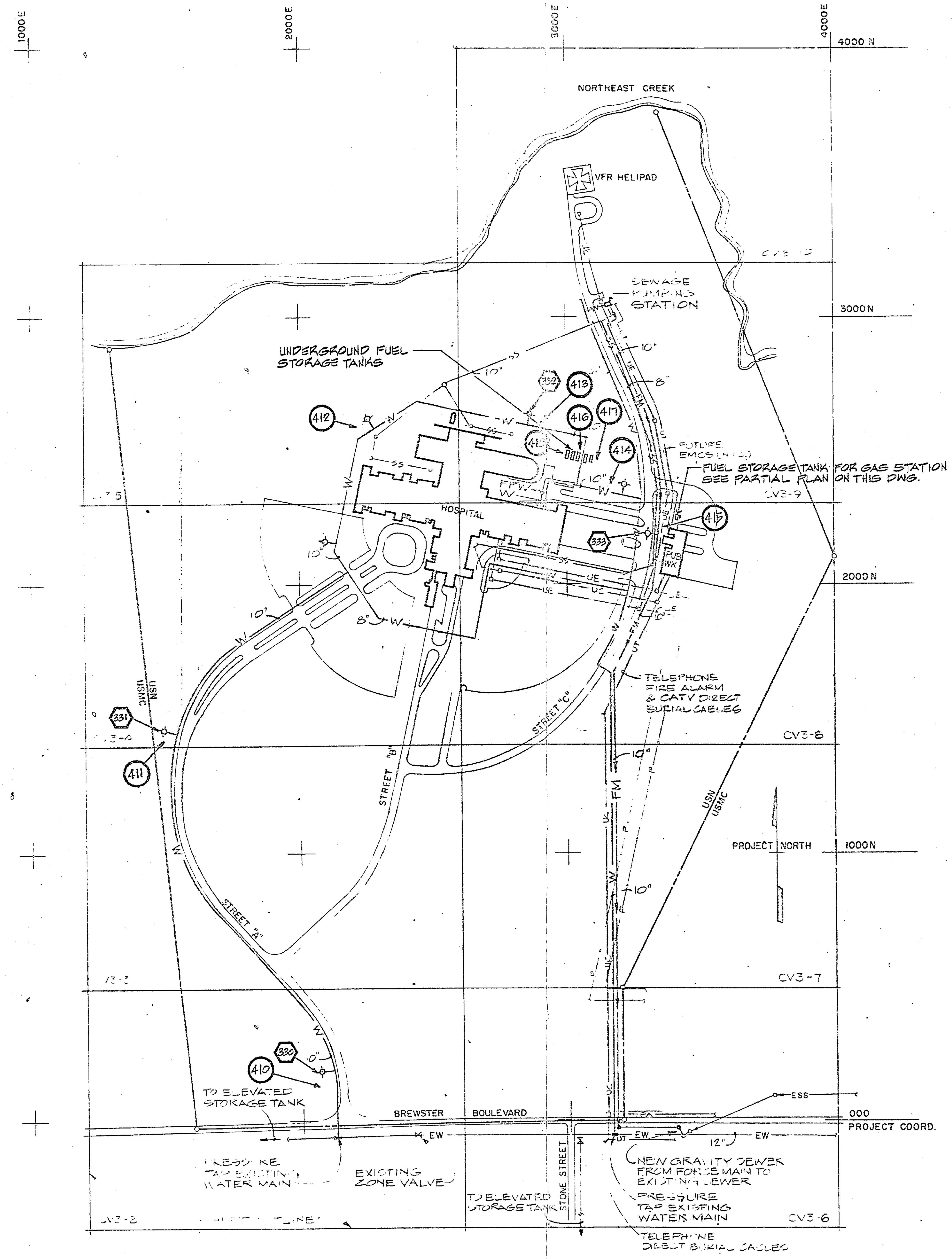
MDA MENENDEZ · DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

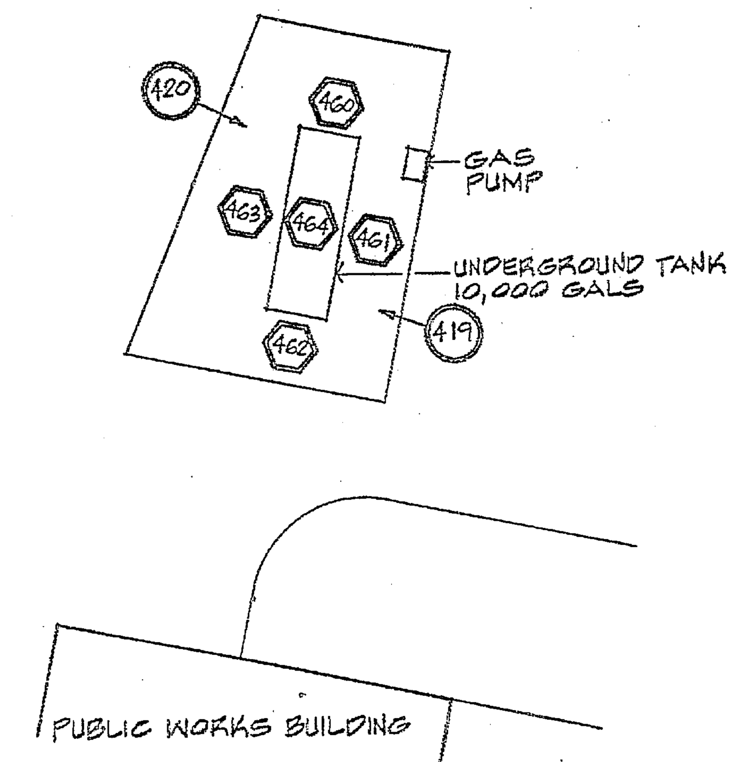
CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA
SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM
(AREA 20)

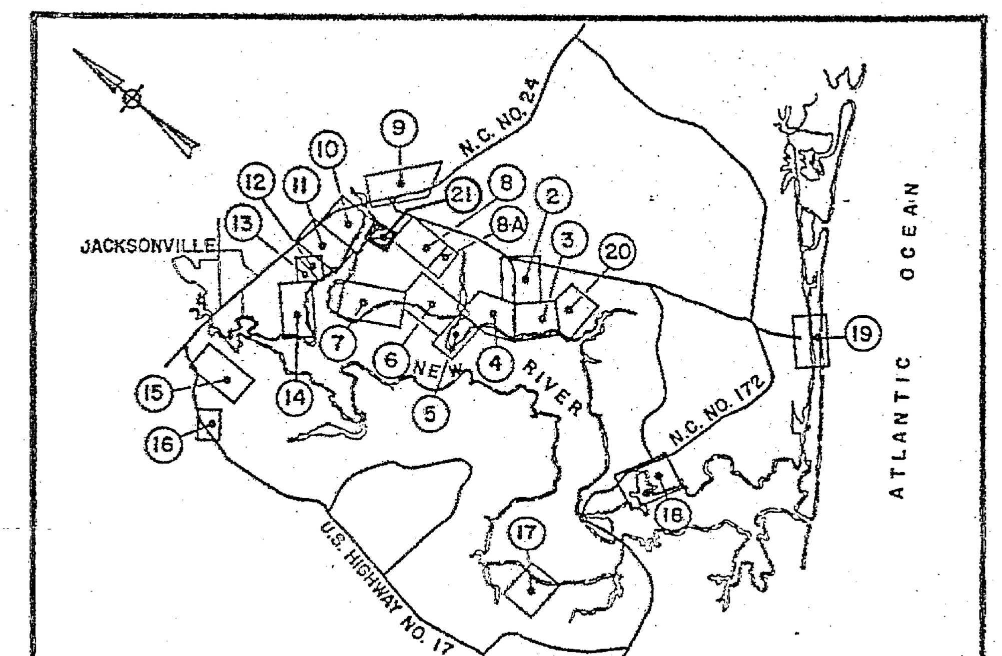
DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5018 REV.

NOTE:
FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000

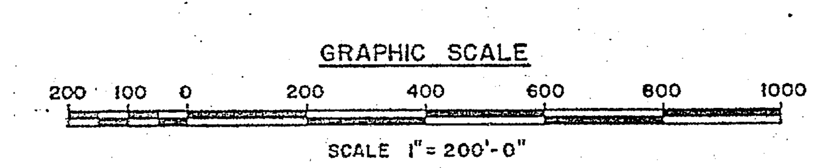




FUEL TANK AT GAS STATION
NOT TO SCALE



KEY MAP



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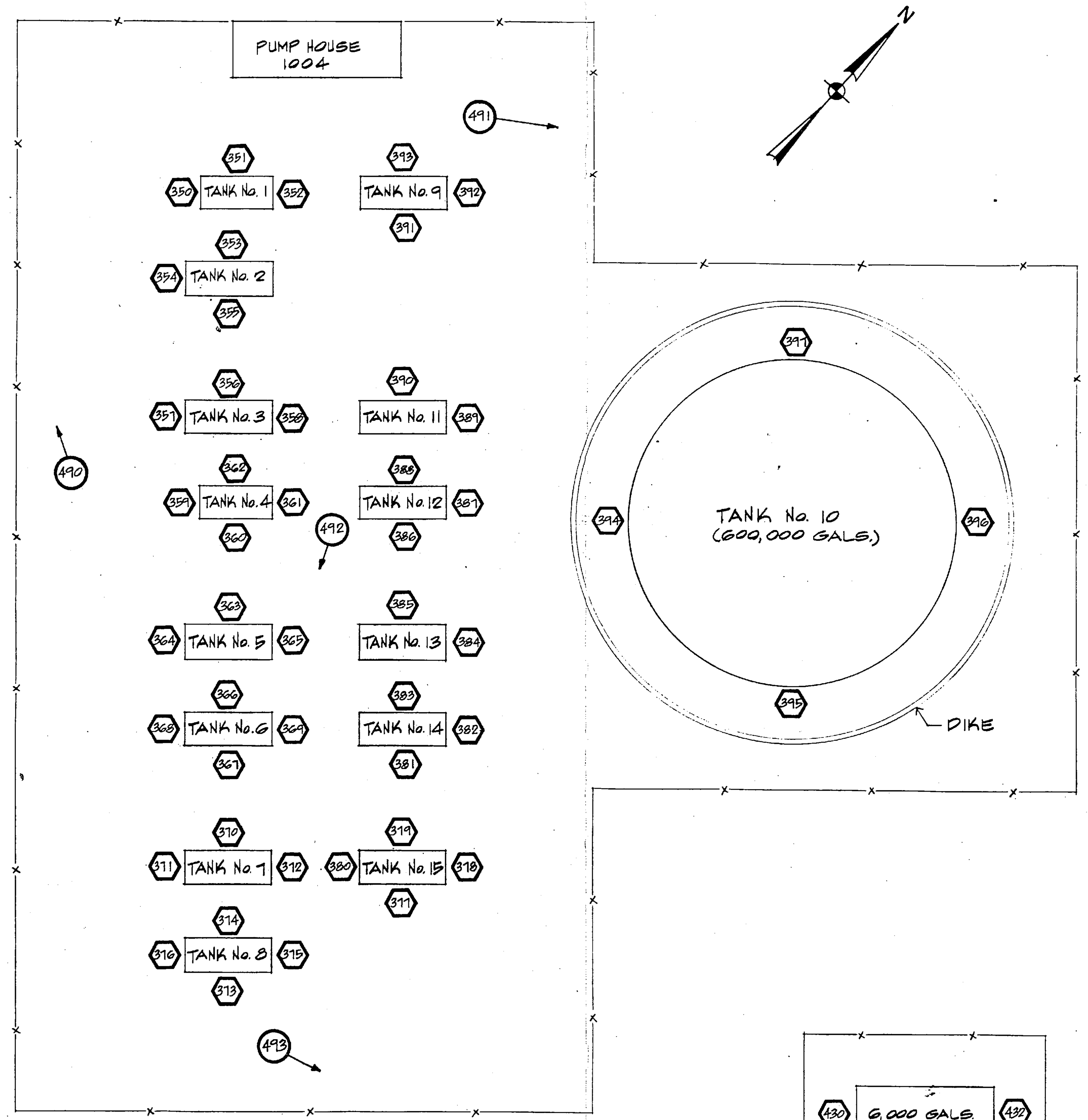
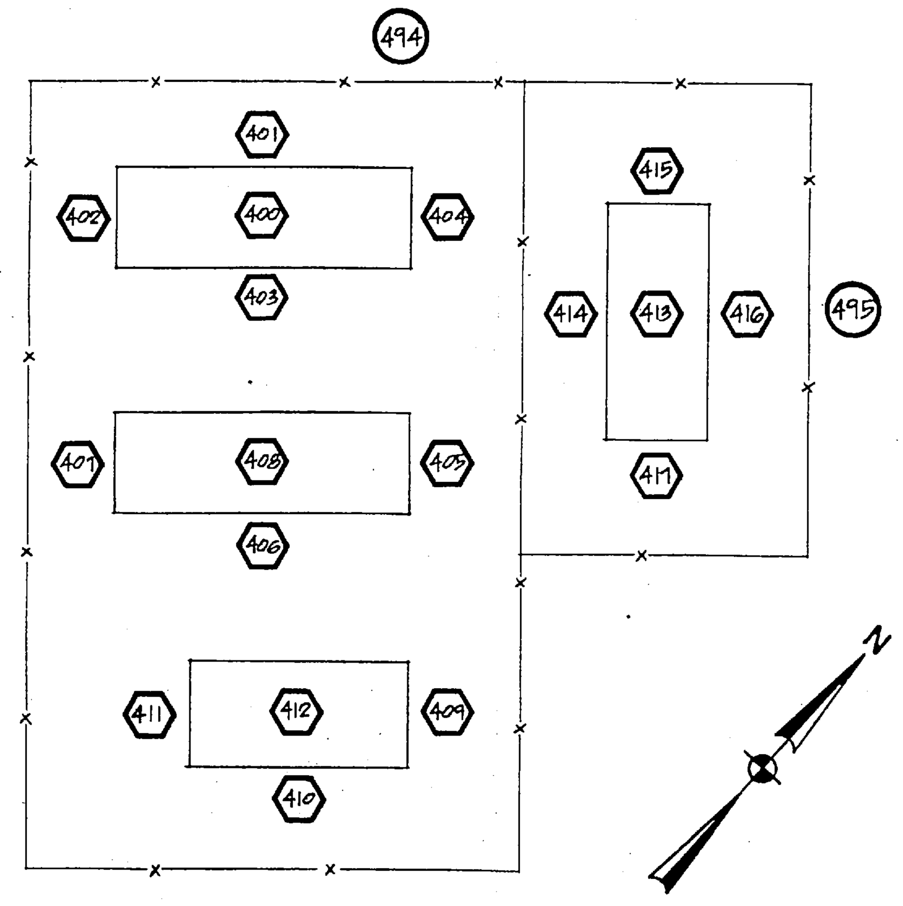
CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA
SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR WATER SYSTEM
(AREA 21)

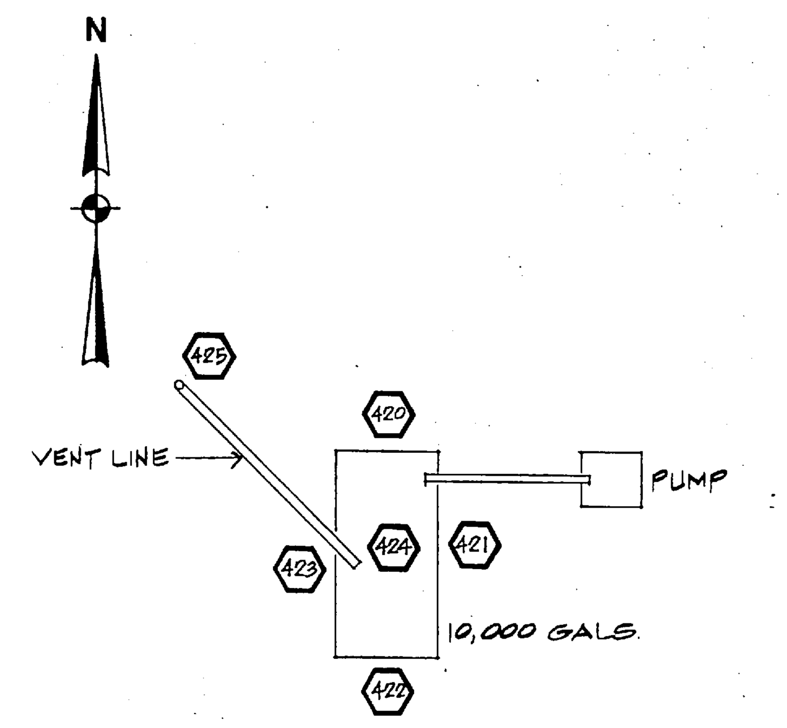
DES. DR. J. CRUZ SCALE GRAPHIC	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5019	REV.



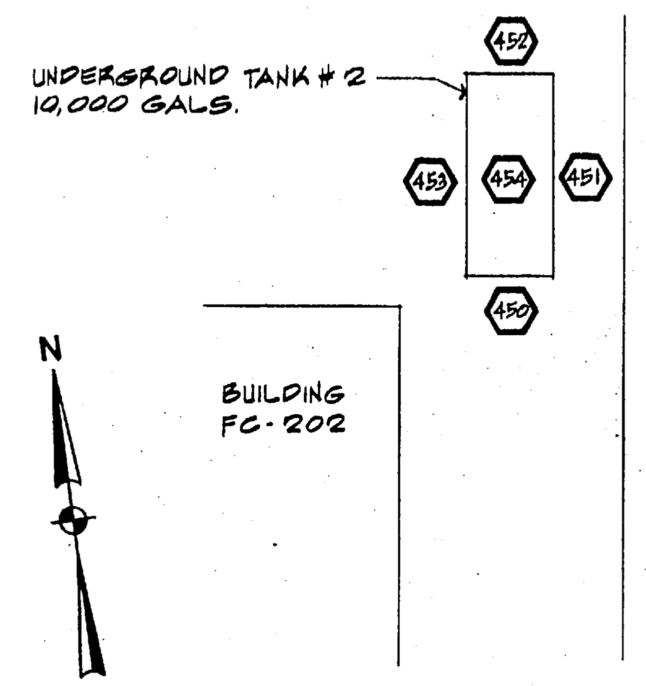
TANK FARM AT INDUSTRIAL AREA
NOT TO SCALE



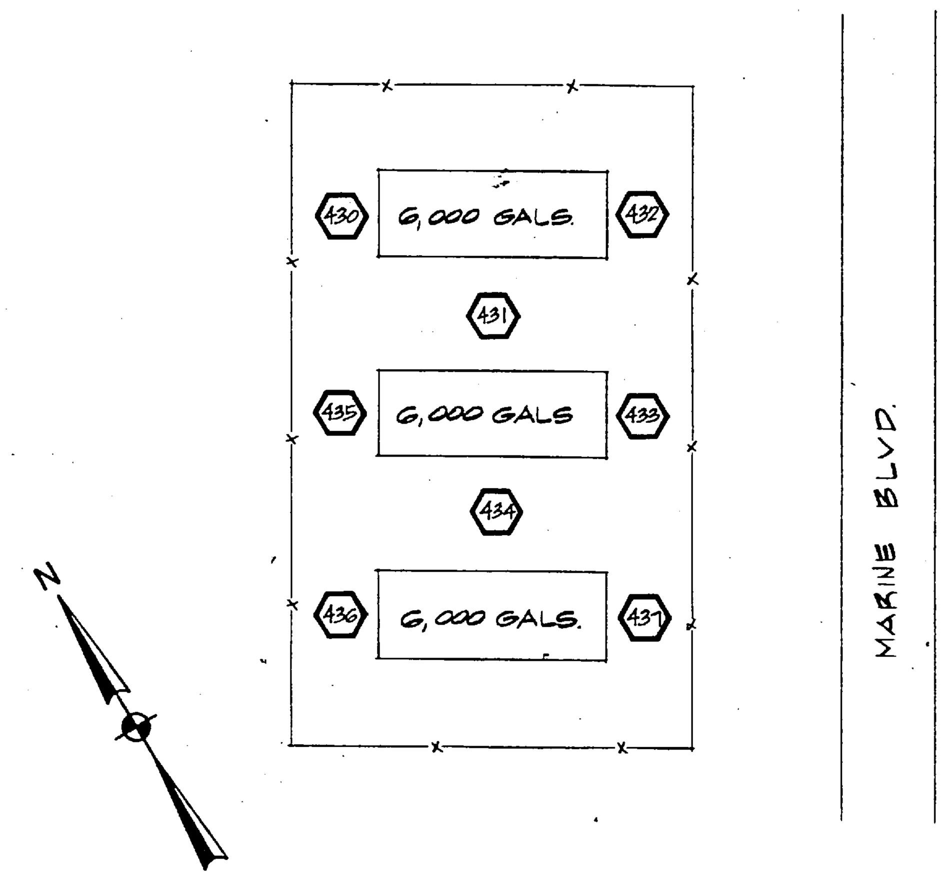
MAIN EXCHANGE GAS STORAGE TANK
NOT TO SCALE



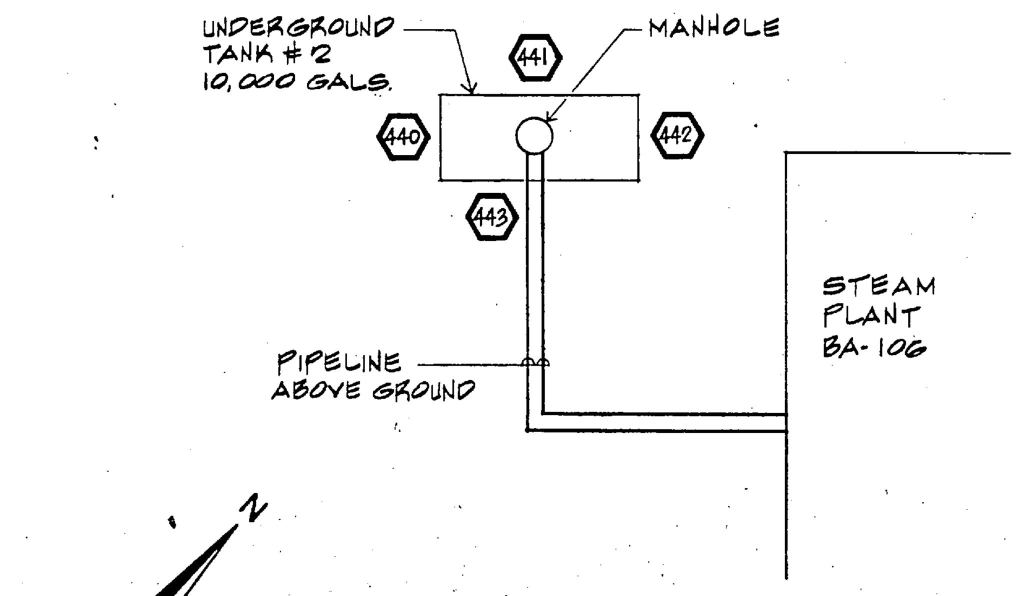
GAS TANK AT RIFLE RANGE AREA
NOT TO SCALE



FUEL TANK AT FRENCH CREEK AREA
NOT TO SCALE



GAS TANK AT COURTHOUSE BAY AREA
NOT TO SCALE



FUEL TANK AT ONSLOW BEACH AREA
NOT TO SCALE

NOTE:
FOR LEGEND AND SYMBOLS SEE DRAWING NO. 6148-5000

MDA MENENDEZ-DONNELL & ASSOCIATES, INC. GCPS GENERAL CATHODIC PROTECTION SERVICES, INC.	ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND NORFOLK, VIRGINIA

CATHODIC PROTECTION SURVEY

MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

SOIL RESISTIVITY SURVEY & PIPE/SOIL POTENTIAL SURVEY FOR UNDERGROUND FUEL TANKS

DES DR. J. CRUZ SCALE NOT TO SCALE	CK. J. MESZAROS APP. DATE JAN. 14, 1985	DWG. NO. 6148-5020	REV.