

**" Corrosion Rates and the Time to Cracking of  
Chloride Contaminated Reinforced Concrete Bridge Components "**

by:

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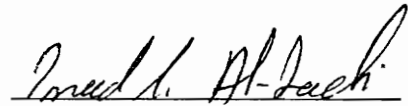
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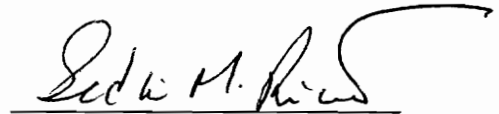
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(Abstract)

In order to predict the future needs of existing bridges, Bridge Management Systems use models to predict the time when damage will reach a level to cause repair, rehabilitation, or replacement of the structure. One such model is the deterioration model, which has three distinct phases. The second phase of the model, the corrosion phase, is the focus of this study.

During the corrosion phase, chloride ion concentration reaches a threshold level at the depth of the reinforcing steel which initiates corrosion. The corrosion continues until sufficient pressure is exerted on the surrounding concrete to cause cracking.

This study is a continuation of a study implemented in the Materials Division at Va Tech. The study includes the monitoring of the corrosion rate of steel reinforcing bars placed in simulated bridge decks. The corrosion rates were varied by placing between 0 - 9.6 lbs/yd<sup>3</sup> of chloride ions in the concrete to produce six different series. Also, the depth of concrete cover, bar spacing, bar size, and exposure conditions were varied.

The specimens were monitored until the time that the cracking of the concrete was observed. At that time, samples of the steel reinforcing bars were removed and

the actual amount of corrosion which had occurred was determined as the weight loss of the steel. The actual weight loss of the steel reinforcing bars was then compared to the predicted weight loss from the corrosion rate measurement devices.

The time to cracking and the mode of cracking was compared to Bazant's equations for cracking which are the basis for the corrosion phase of the deterioration model. Although only one series cracked during the study, corrections in the use of Bazant's equations were proposed.



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## **1.0 Introduction**

### **1.1 Problem Statement**

When a substance deteriorates because of a reaction with its environment, it is said to have undergone corrosion. Either directly or indirectly, most engineers face problems associated with corrosion. Currently in the United States, it is estimated that 40 percent of the steel that is produced every year will be used to replace corroded steel. It is also estimated that this problem causes over \$15 billion a year of damage in the United States(1).

The bridges that make up the United States Highway System are not immune to this problem. Of the 576,665 bridges receiving federal aid, the United States Department of Transportation (USDOT) estimates that nearly 40 percent of these bridges are structurally deficient or functionally obsolete(2). It is also estimated that, of the bridges which are structurally deficient or functionally obsolete, corrosion of the steel reinforcement causes the problem in 40 percent of the bridges(2).

Bridges are a key element in any transportation system. Not only do bridges generally control the traffic volume of a system, but they also have the highest unit cost of the elements in the system. If a bridge fails, the entire system will fail(4). Therefore, bridges need to be kept in service for as long as possible in order to minimize the costs of delay. However, when repair, rehabilitation, or replacement is necessary, it must be performed cost-effectively, minimizing life-cycle costs.

## 1.2 Bridge Management Systems

One way in which government agencies are striving to increase the life of bridges while minimizing the life-cycle costs is by establishing bridge management systems. The systems are designed to determine the current needs as well as to predict future needs. In many instances, because of inadequate planning procedures, once a need is discovered, there are insufficient funds to address the deficiency. However, by using appropriate prediction models, bridge management systems can predict future needs and estimate funding levels.

One model which can be used to estimate the remaining life of concrete bridge components in corrosive environments is the deterioration model developed by Cady and Weyers(3). The model predicts deck deterioration as measured in an area percentage of the entire deck. The total area of spalls, delaminations, asphalt patches, and crack lengths multiplied by a tributary width combine to produce the total damage. The model, as shown in Figure 1, has three distinct phases. These phases are: 1 - diffusion, 2 - corrosion, and 3 - deterioration(3).

Included in the diffusion stage is an almost immediate percent damage which occurs following the placement of the deck. This damage is primarily due to construction irregularities such as inadequate cover depths which result in subsidence cracking. A cover depth survey is used to determine the percent damage a deck may encounter due to subsidence cracking. The damage due to the subsidence cracking accounts for nearly all of the damage that occurs during this early phase. The actual

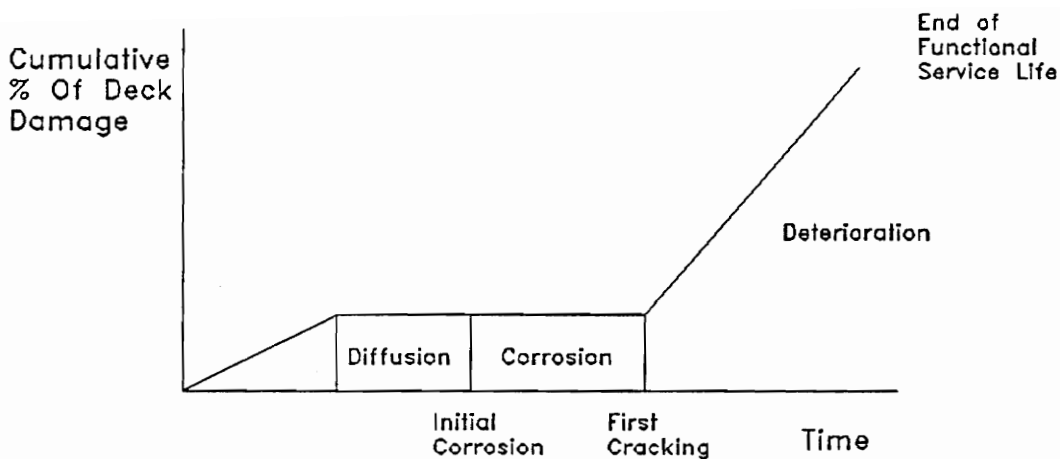


Figure 1 – Deterioration Model

diffusion of the chloride ions does not cause any appreciable damage. However, it does take a certain amount of time for the chloride ions to diffuse through the concrete to the level of the reinforcing steel. The rate at which the ions diffuse through the deck can be determined empirically using Fick's Second Law. Once the corrosion threshold of chloride ions is present at the observable damage level at 2.5% of the reinforcing steel(3), the protective layer of gamma iron oxide on the reinforcing steel will break down and corrosion will begin.

During the second phase of the model, corrosion will occur and produce expansive corrosion products on the surface of the reinforcing steel. These products will eventually cause enough pressure on the surrounding concrete to cause cracking of the concrete. The cracks will either connect to adjacent bars as delamination cracks or

surface as inclined cracks.

Once corrosion has occurred and initiates cracking at 2.5% of the reinforcing steel, the deck enters the final phase of the model. During this phase, it has been shown empirically that the deck will continue to deteriorate at a relatively uniform rate. Upon reaching a certain level of percent damage, repair, rehabilitation, or replacement becomes necessary. By predicting the time to repair, rehabilitation, or replacement, adequate funding levels can be allocated.

### **1.3 Scope of Study**

The corrosion phase, or time to cracking, is based primarily on equations developed by Bazant which address the theory and application of modeling steel corrosion in concrete sea structures(4). The equations use a corrosion rate and mechanical properties of the concrete and the steel to determine a time to cracking. This research will focus on the current equations and their dependence on corrosion rate measurements. Studies will be performed which will either support Bazant's model, recommend adjustments to Bazant's model, or development a new time to cracking model.

In August of 1991, the specimen testing phase of a thesis designed to study the time to cracking model used in the corrosion phase of the deterioration model was implemented(5). This study included the construction of 56 simulated bridge decks, each with five reinforcing bars running parallel to each other. During the construction

of the simulated decks, different amounts of chlorides were mixed into the concrete. This was done in order to ensure a known, uniform amount of chloride ions present in the different slabs and to vary the corrosion rate. Forty of the simulated decks were placed outdoors while the remaining 16 were placed inside the laboratory. Study variables in addition to the amount of chloride ions were spacing between the reinforcing bars, size of the reinforcing bars, and concrete cover of the reinforcing bars(5).

Since the construction of the simulated bridge decks, a corrosion assessment of the reinforcing steel has been performed on a monthly basis. The assessment includes determining the corrosion rates of the reinforcing steel by using two different corrosion rate measuring devices. One of the devices is a Kenneth Clear Inc. 3-LP device, a linear polarization device. It first measures the potential difference between the steel reinforcing and a reference electrode. The device then changes the potential difference by a known amount by sending a current through the concrete and polarizing the reinforcing steel(6). The measurements are then used along with the Tafel slopes to determine the rate of the corrosion of the steel reinforcing. The second device is the Gecor device manufactured by Geocisa Inc. It uses the same principal as the 3-LP device, except that it uses a guard ring electrode to confine the current so it will not spread out over an area larger than the counter electrode during the polarization of the steel reinforcing.

During the preliminary phase of the study, a sensitivity analysis of the time to

cracking equations was performed(5). By assuming the materials and the physical dimensions that are typically used in a reinforced concrete bridge deck, the analysis indicated that the corrosion rate dominates the time to cracking equations(5).

Therefore, since the time to cracking is dominated by the rate of corrosion, the accuracy and precision of the corrosion rates must be considered.

It has been observed that corrosion rates of steel in concrete are influenced by temperature, moisture content, and the resistivity of the surrounding concrete. However, exactly how these factors interact and influence the corrosion rate has not been thoroughly investigated.

Once cracking occurs, sections of the bars will be removed and the actual amount of corrosion will be determined by the weight loss of the steel reinforcement. The weight loss can then be converted to an average corrosion rate. The corrosion rates will be investigated to determine how well the measured corrosion rates compare to the observed corrosion rate. Finally, the theoretical equations which predict the time to cracking will be evaluated. If necessary, the theoretical equations will be adjusted or different equations will be proposed.

## **2.0 Background**

### 2.1 Concrete

#### **2.1.1 Reinforced Concrete**

The Portland Cement Association states that "portland cement concrete is a simple material in appearance with a complex internal nature..." and that "...concrete's versatility, durability, and economy have made it the world's most used construction material"(7). Concrete is used in highways, bridges, buildings, dams, sidewalks, and even in works of art. Mehta states that the future of concrete is promising because it "...offers suitable engineering properties at low costs, combined with energy savings and ecological benefits"(8).

Concrete is a mixture of aggregates , cement and water. The aggregates are natural or crushed rocks and are classified as either course aggregate (C.A.) or fine aggregate (F.A.) depending on their size. The cement is a fine powder which hydrates in the presence of water to form a solid mass. As concrete cures, a void system in addition to the solid aggregate and hydrated cement paste (hcp) phases is created. The ranges of ingredients for cement rich and lean mixtures of air-entrained (AE) concrete are in Table 1.

The aggregates, which account for 59-75% of the concrete, must have sufficient strength and environmental resistance. Also, the aggregates must not react with the cement paste.



Table 1-Percentage by Absolute Volume of AE Concrete(7)

|      | Cement | Water | Air | F.A. | C.A. |
|------|--------|-------|-----|------|------|
| Rich | 15     | 18    | 8   | 28   | 31   |
| Lean | 7      | 14    | 4   | 24   | 51   |

The gradation of the aggregates must be monitored to ensure that the paste adequately coats the aggregates. However, there should not be excess paste since it is the most expensive material in the mix(4).

The cement is a fine powder composed primarily of calcium and aluminum silicates. The materials used to produce the cement are lime (CaO) from limestone, silica (SiO<sub>2</sub>) from clay, and alumina (Al<sub>2</sub>O<sub>3</sub>) also from clay. Small percentages of magnesia (MgO), alkalis, and iron oxide are present and gypsum is also included(9). In the presence of water, the cement hydrates to form three types of solid particles: calcium silicate hydrate (C-S-H), calcium hydroxide (Ca(OH)<sub>2</sub>), and calcium sulfoaluminates. Unhydrated grains are also present(8).

By nature, the hydrated cement paste (hcp) is not a static material. In fact, the word "concrete" comes from the Latin term *concretus* meaning to grow(8). Therefore, it is best to consider the hcp as in a condition of chemical equilibrium instead of in a static condition.

Concrete has a tensile strength of about one tenth its compressive strength and

is also subject to shrinkage due to temperature and moisture changes. For these reasons, steel reinforcing is often used in tensile regions and in regions subject to shrinkage in order to control cracking. The steel reinforcing also helps the concrete perform under service loads and provides reserve strength for ultimate load conditions(9).

### **2.1.2 Pore Structure**

The size and distribution of the capillary void system influence the likelihood of corrosion occurring and rate of corrosion of steel reinforcement in concrete. The capillary void system is created during the hydration of the cement. A unit volume of cement paste will hydrate with water to produce hydration products comprising about twice the original volume of the cement(8). For example, if 1 ft<sup>3</sup> (0.028 m<sup>3</sup>) of a normal portland cement with a specific gravity of 3.15 (which corresponds to a unit weight of 3.15 X 62.4 lbs/ft<sup>3</sup> (999.6 kg/m<sup>3</sup>) = 196.6 lbs/ft<sup>3</sup> (3149.2 kg/m<sup>3</sup>) is mixed with 1 ft<sup>3</sup> (0.028 m<sup>3</sup>) of water weighing 62.4 lbs(999.6 kg/m<sup>3</sup>), hydration products totaling 2 ft<sup>3</sup> (0.056 m<sup>3</sup>) will result provided that complete hydration occurs. The hardened paste would have a water to cement ratio (w/c) by weight equal to the weight of 1 ft<sup>3</sup> (0.028 m<sup>3</sup>) of water divided by the weight of 1 ft<sup>3</sup> (0.028 m<sup>3</sup>) of cement paste, or 62.4 lbs(28.3 kg)/196.6lbs(89.2 kg) = 0.32.

Therefore, in normal concrete, any mix which has a w/c ratio above 0.32 will have excess water in the mix. When the cement paste is mixed with the water, the

unhydrated grains are dispersed in the water. As the grains hydrate, the space originally filled with the unhydrated grains and water are filled with hydration products. If excess water is present (w/c above 0.32), than the space not filled by the hydration products becomes the capillary voids(8). It follows that the higher the w/c ratio, the higher the excess water, and thus the larger the capillary void system. Most concrete mixtures used for bridge decks require a specified w/c ratio between 0.4 and 0.5. Therefore, a capillary void system does exist in concrete used for bridge decks. Relative to corrosion, the larger the volume and more continuous the capillary void system is, the easier it is for oxygen, water, and chloride ions to travel through the concrete and cause corrosion of the embedded steel. Also, the size distribution of the void system influences how the capillary pore water acts as an electrolyte.

As an electrolyte, the concrete pore water influences the flow of ions through the concrete. The ions, which are charged particles created by the addition or removal of an electron to an atom, are the basis of the conversion of metals to corroded forms. The flow of current in an electrolyte requires the presence of ions. The ability of an electrolyte to oppose the flow of electrons is the resistivity of the electrolyte. As the resistivity of the electrolyte increases, the tenancy for electrons to flow decreases. Likewise, as the resistivity of the electrolyte decreases, the tenancy for electrons to flow increases(1).

The resistivity of the concrete depends on many factors including the water to cement ratio of the original mix, chloride ion content, permeability, temperature, and

relative humidity inside the concrete. Generally, as the resistivity of the concrete decreases, the likelihood of current to flow, or for corrosion to occur, increases. A completely dry concrete is generally considered to have a resistivity of  $1 \times 10^9 \Omega\text{-cm}$  which is too high to allow corrosion to occur because ions can not flow. A completely saturated concrete has a resistivity of  $1 \times 10^4 \Omega\text{-cm}$  which is low enough to allow corrosion to occur; however, it does not allow enough oxygen to enter the concrete, thus starving the reaction(10).

The amount of moisture in the concrete also influences the electrolytic properties of the concrete. The internal relative humidity of the concrete is used as a measure of the amount of moisture inside the concrete. No clear range of internal relative humidity which will support the corrosion process has been established. One reason that no range has been established is that different pore structures may contain the same amount of water, but have different equilibrium vapor pressures, which account for different internal relative humidities(11). This is shown in Figure 2, where different pore structures create different internal equilibrium vapor pressures for the same quantity of water.

The ability of the concrete to allow reactants such as oxygen, chloride ions, and water to the cathode and anode areas also influences the corrosion process. Reactants must be present to allow the corrosion of steel in concrete to occur. Also, the quantity of reactants present influences the rate of the corrosion process. Free oxygen has a significant influence on the rate of corrosion whereas the presence of

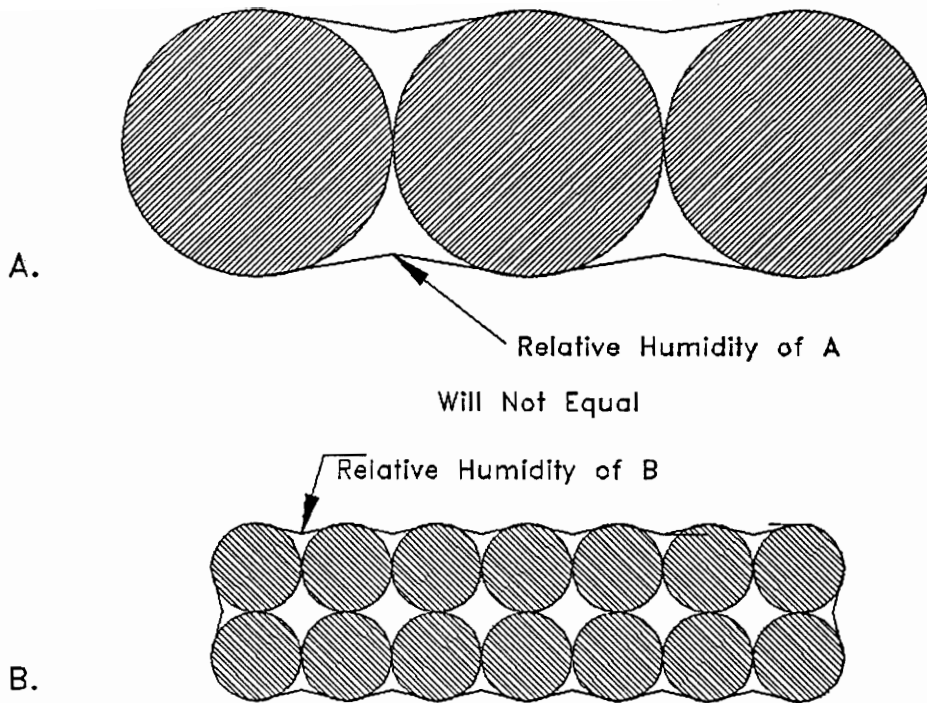


Figure 2 – Relative Humidities in Pore Structure

chloride ions appears to influence the location of active corrosion more than the rate of the corrosion(12).

Also, the manner in which the concrete is placed influences the chance of corrosion of the steel reinforcement occurring in the concrete. Improper placement techniques may cause excessive bleeding, segregation, or poor consolidation. These conditions may result in differences in the permeability of the concrete at different locations. The different permeabilities allow different concentrations of chloride ions,

free oxygen, and water to enter the concrete. These different concentrations establish potential differences which activate the corrosion cells. Also, they may cause differences in concentrations between reinforcing steel mats, which may allow for corrosion to occur(13).

### **2.1.3 Pore Solution Chemistry**

Water will remain in the void system of the hydrated cement paste even after complete hydration has occurred. The amount of water depends largely on the size and distribution of the void system as well as the relative humidity of the environment. There are four states that water may exist in the void system of the hydrated cement paste. Capillary water is found in voids larger than  $50\text{\AA}$  ( $50(10^{-7})$  mm) and is not subject to attractive forces from the hcp. Adsorbed water is attached to the solid surfaces in the hcp in layers up to 6 molecules or  $15\text{\AA}$  ( $15(10^{-7})$  mm) thick. Removal of the adsorbed water is mainly responsible for the shrinkage of the hcp. Interlayer water is located between the layers of the calcium silicate hydrate sheets and is held with strong hydrogen bonds. Chemically combined water is water which has combined with cement hydration products or latencies(8).

Water is known to dissolve more substances than any other liquid(8). This property enables the water in the pore solution of concrete to dissolve and carry many different ions. Considering corrosion of the steel reinforcement in concrete, the two most important ions that water will dissolve are the hydroxyl ion and the chloride ion.

The hydroxyl ion is responsible for the high pH of the pore solution which protects the steel from corrosion while the chloride ion is responsible for the disruption of the protective layer on the steel reinforcement. Therefore, the properties of the pore solution are important in determining the likelihood of corrosion of the steel reinforcement initiating in a concrete environment. Also, the amount of ions present in the pore solution will be important in determining the electrolytic properties of the concrete, as previously presented.

Chloride ions may be present in the cement paste, certain aggregates (primarily limestone from the seacoast), and the mix water(14). Chloride ions introduced into the mix at the time of batching will increase the chance of corrosion occurring by entering the pore solution and acting to break down the protective layer and to improve the concrete's ability to transfer ions. But, it is unlikely that chloride ions introduced in the batching process will be as harmful to concrete as chloride ions introduced after the concrete has cured because of chloride binding.

Chloride binding occurs when chloride ions in the mixture react with the tricalcium aluminates in the cement paste to create insoluble chloroaluminate products which can not act to break down the passive layer or transfer ions(15). The amount of chloride ions that a cement is capable of binding is a function of the tricalcium aluminate content of the cement paste(15). However, recently, studies have shown that as the pH of the mixture increases, the capacity of the mix to bind chlorides decreases(16).

## 2.2 Corrosion

Corrosion is said to occur when a substance deteriorates because of a reaction with its environment. The two types of corrosion which generally occur are dry and wet corrosion. Dry corrosion occurs when a metal reacts with vapors or gases at high temperatures. Wet corrosion occurs when a metal reacts with an aqueous solution or electrolyte. Dry corrosion seldom occurs in reinforced concrete; however, wet corrosion causes a great deal of damage to reinforced concrete(1).

In the corrosion process, metals attempt to revert back to their native compounds releasing electrical energy(1). In order for the current to flow, an electrochemical cell containing balanced oxidation and reduction reactions is established. The corrosion cell contains four parts: an anode, a cathode, a conductor, and an electrolyte. The two types of electrochemical cells are galvanic and electrolytic. Galvanic cells react spontaneously producing a flow of electrons while electrolytic cells require an external source of electrical energy to operate(17). A concentration cell is the type of galvanic cell in which the corrosion process of the majority of steel reinforcing in concrete occurs(1).

At the anode, metal atoms are oxidized by losing electrons. The positively charged metal ions then pass into solution as positively charged hydrated ions and the electrons flow through the metal to the cathode where hydrogen ions or dissolved



oxygen accept the electrons in a reduction process. These reduced ions then migrate through the electrolyte to the anode site where they combine with the positively charged metal ions to produce corrosion products(18).

The reaction can only continue as long as conditions favor both the oxidation and the reduction reactions allowing for the flow of electrons. Adequate amounts of reactants must be present at the cathode and the electrolyte must allow for the flow of ions. The cell must follow Ohm's Law which states "... the amount of flowing current (corrosion loss) decreases as the resistance of the circuit increases and current flow increases as the potential difference between the anode and the cathode increases. Thus, the amount of corrosion experienced is proportional to the electrolytes ability to react, the potential difference between the cathode and the anode, and the amount of resistance in the external metal circuit(1)."

A potential difference must exist between the metal and the solution in order for the flow of electrons to occur, see Figure 3. The potential at the metal's cathode ( $Pot_{M,C}$ ) must be more positive than the potential at the metal's anode ( $Pot_{M,A}$ ). Also the potential at the solution's anode ( $Pot_{S,A}$ ) must be more positive than the potential at the solution's cathode ( $Pot_{S,C}$ ). The following relationships must exist in order for the electrons to flow:

$$Pot_{M,C} > Pot_{M,A} \quad \text{eq.1}$$

$$Pot_{S,A} > Pot_{S,C} \quad \text{eq.2}$$

It follows from equation 1 and equation 2 that:

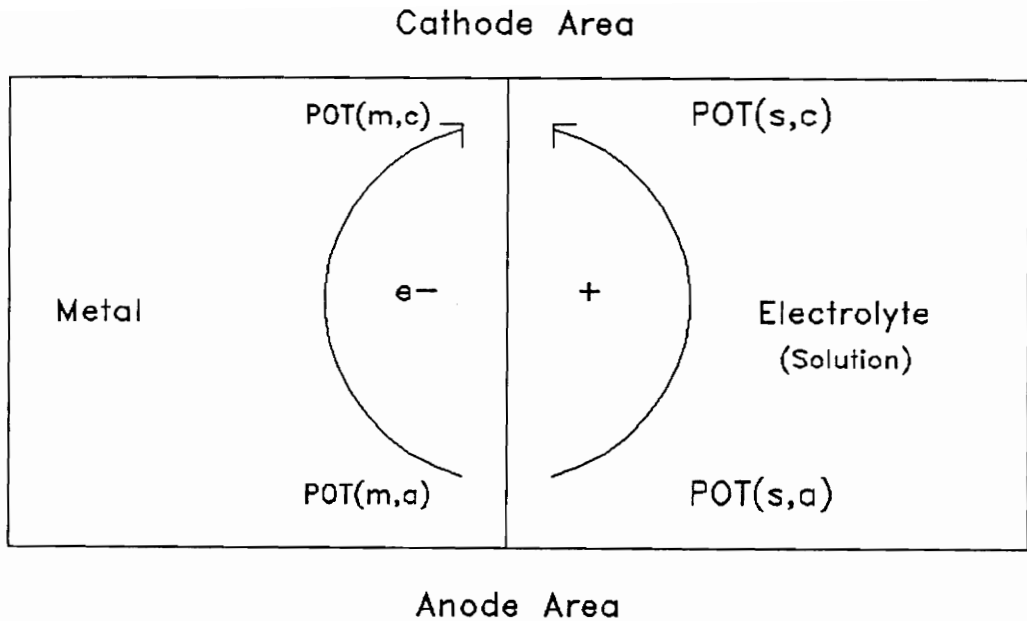


Figure 3 – Potentials at Anode and Cathode Areas

$$(\text{Pot}_{MA} - \text{Pot}_{s,A}) < (\text{Pot}_{MC} - \text{Pot}_{s,C}) \quad \text{eq.3}$$

Both of the quantities  $(\text{Pot}_{MA} - \text{Pot}_{s,A})$  and  $(\text{Pot}_{MC} - \text{Pot}_{s,C})$  in equation 3 are the potential drop across the electrical double layer of the metal/solution interface and are termed the electrode potentials,  $E_A$  and  $E_C$  (18). It can be seen that the potential at the anode is lower than the potential at the cathode. The potential difference can be low and still allow electrons to flow if the cell contains a good electrolyte, but it must be higher if the cell contains a poor electrolyte.

## 2.3 Corrosion of Steel in Concrete

### **2.3.1 Mechanisms of Corrosion of Steel in Concrete**

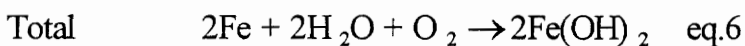
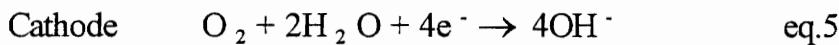
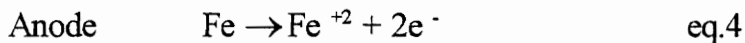
Steel reinforcement placed in concrete undergoes an electrochemical reaction in the presence of moisture, oxygen, and water soluble alkaline products to create a gamma iron oxide ( $\gamma\text{Fe}_2\text{O}_3$ ) layer on the surface of the steel. This layer acts to protect the steel, or passivate it, from undergoing further corrosion(13). Locke states "corrosion of steel in concrete is not a problem unless an external agent upsets the normal passive state of the steel in this alkaline environment"(10). Since iron exists in the oxidized form in nature, it has a strong tenancy to rust or reoxidize once it has been refined into a metallic state(10). Nonetheless, the protective gamma iron oxide layer in the presence of the high pH environment of the concrete will prevent the steel from oxidizing or undergoing corrosion as long as the gamma iron oxide layer is not disturbed.

There are many agents which act to disrupt the iron oxide layer and the pH of the concrete. The two most common are carbonation and halide intrusion(19). Carbonation occurs when carbon dioxide from the environment enters the concrete and reacts with the calcium hydroxide to produce calcium carbonate. The reduction of the calcium hydroxide lowers the pH of the concrete, allowing for the breakdown of the gamma iron oxide layer(14). Due to differences in construction practices and materials, carbonation is generally considered more of a problem in Europe than it is

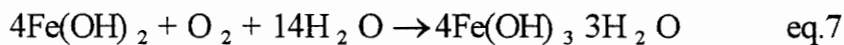
in the United States.

The intrusion of halides, specifically chlorides from road salts (NaCl, CaCl<sub>2</sub>), acts as a unique destroyer of the gamma iron oxide layer. Once a threshold layer of chloride ions (Cl<sup>-</sup>) reaches the surface of the gamma iron oxide layer, the ions act to breakdown the layer allowing for corrosion to commence(12).

Upon disruption of the gamma iron oxide layer, an autogenous corrosion cell is formed. At the anode of the cell, iron will lose electrons in an oxidation process which creates Fe<sup>+2</sup> and two free electrons. The two free electrons will travel through the steel reinforcing, the conductor, to the anode site where they will reduce free oxygen in the presence of water to create hydroxide ions. The hydroxide ions then may travel through the electrolyte (concrete pore water) to the anode site where they react with the free iron ions to create corrosion products or rust(20). The anode, cathode, and total reactions follow:



The rust (Fe(OH)<sub>2</sub>) is about four times more expansive than iron. It can then react with water and free oxygen to produce red rust (Fe(OH)<sub>3</sub>·3H<sub>2</sub>O) which is about six times more expansive than iron(8). This reaction follows:



In order for the reactions to continue, there must be water and oxygen at the

cathode site and the resistivity of the concrete must be low enough to allow ions to flow between the anode and the cathode because of the low potential difference between the two sites(19).

The corrosion state of steel reinforcement in concrete may be described in many different conditions. The three most common states of corrosion of steel reinforcement in concrete are passive, pitting, and general corrosion. Steel reinforcement in the passive state is not undergoing appreciable corrosion. This state exists if the protective gamma iron oxide layer has not been destroyed or if conditions do not allow the cathodic reaction to occur(18).

Pitting corrosion occurs when a small area of steel is depassivated due to high concentrations of Cl<sup>-</sup> ions. The cell has a large cathode area and a small anode area. Accelerated corrosion occurs at the anode area because a large cathode area is available to allow the reduction reaction to occur rapidly(18).

The condition of general corrosion is approached as the anode area increases and the cathode area decreases. This allows for corrosion products to be formed in larger areas; however, the corrosion does not occur as rapid as it does in pitting corrosion because of the decreased cathode to anode ratio(18).

A small potential difference between the anode site and the cathode site requires that the two sites be in close proximity to each other. This type of corrosion is called microcell corrosion. If the anode and cathode sites are further apart, the corrosion process is called macrocell corrosion. A large potential difference is

required for macrocell corrosion to occur. This potential difference may be established by different concentrations of materials in the concrete such as chloride ions or free oxygen. Also, differences in the properties of the concrete or the properties of the steel reinforcement may cause large potential differences. The concept of macrocell corrosion seems well supported by the action of accelerated corrosion of uncoated steel when it is placed in concrete with coated steel(19).

Steel reinforcement can undergo a certain amount of corrosion before damaging the concrete. However, once a certain amount of corrosion products are formed on the surface of the steel reinforcement, pressure is exerted on the concrete. The pressure eventually causes cracking and section loss of the concrete(13). An example is the unwanted pot holes which are common on many older bridge decks.

### **2.3.2 Corrosion Products**

Similar to the hydrated cement paste, the corrosion products are not necessarily always in a state of equilibrium. Depending on the amount of available oxygen and water, the corrosion products may react creating different types of corrosion products. The amount of expansion that the corrosion products are capable of producing are shown in Figure 4(8 ).

In the high pH range (11-13) normal for pore solution in concrete, iron tends to have an extremely low solubility of  $\sim 1$  mM/l(millimoles/liter)(21). As a result of the low solubility for iron, many have assumed that the corrosion products would also

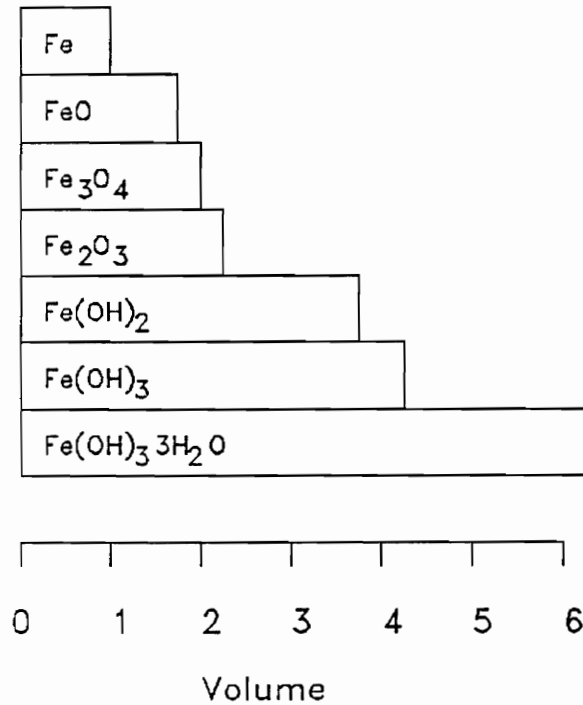


Figure 4 – Relative Volumes of Corrosion Products

have a low solubility(4). However, the introduction of a low concentration of chloride ions, ~15 mM/l, causes the iron solubility to increase to ~175 mM/l(21).

As a result of the increased iron solubility, iron ions ( $Fe^{2+}$  and  $Fe^{3+}$ ) from corrosion products are capable of complexing with the chloride ions to produce a chlorocomplex referred to as "green rust" because of its greenish appearance. The green rust is a layered structure which is soluble in typical pore solutions. Green rust will most readily form in neutral or slightly alkaline environments; but, its presence has been documented in reinforced concrete environments which have more alkaline environments(~12.6). Once exposed to free oxygen, green rust will also oxidize to form

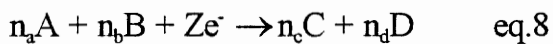
akagenite ( $\beta$ -FeOOH) and released chloride ions. The chloride ions are then free to migrate back to the anodic site where they may once again complex(76).

The presence of green rust explains the observations of corrosion products which have migrated through the concrete and oxidize at a remote location, thus producing expansion away from the anodic site or producing harmless expansion in voids.

### 2.3.3 Passivity of Steel in Concrete

In understanding the corrosion process, it is important to discuss why some conditions allow steel reinforcement to remain passive in concrete for decades while other conditions allow steel reinforcement to corrode enough to produce damage in less than a year. One way to better understand this is by understanding the thermodynamics of the corrosion process.

Considering a reaction involving the transfer of electrons:



where  $n$  is the number of moles and  $Z$  is the number of electrons. The condition of equilibrium for the reaction at constant temperature and pressure is determined by the following equation where  $E^\ominus$  is the standard electrode potential for

the reaction,  $R$  is the universal gas constant,  $T$  is the absolute temperature, and  $F$  is



$$E_{eq} = E^{\circ} + \frac{RT}{ZF} \ln \frac{[A]^{n_a}[B]^{n_b}}{[C]^{n_c}[D]^{n_d}} \quad eq.9$$

Faraday's constant. The reaction will proceed only if the electrode potential is less than  $E_{eq}$ (18).

For steel reinforcement in concrete, an Equilibrium Potential/pH diagram, also called a Pourbaix diagram, for iron in water at 25 °C shows the thermodynamically possible reactions for potentials at different pH values, see Figure 5. In the regions where the soluble ions  $Fe^{2+}$  and  $FeOOH$  are stable, corrosion will occur. Where the oxides  $Fe_3O_4$  and  $Fe_2O_3$  are stable, corrosion will not occur because these oxides create and support the gamma iron oxide layer which promotes passivity of the iron. In the region where iron (Fe) is stable no corrosion will occur because the iron is thermodynamically stable(18).

The Pourbaix diagram is an idealized case. Many variables such as temperature changes and the changing influences of the concrete on the aqueous phase surrounding the steel are not considered. A more specific diagram, shown in Figure 6 has been proposed by Escalante and Ito which shows how the chloride ion content, the oxygen content, and the pH of the concrete interact to define a region of corrosion and no corrosion. If the steel reinforcing is within the no corrosion region, it is expected that the steel would not undergo corrosion. But, if it is outside of this corrosion

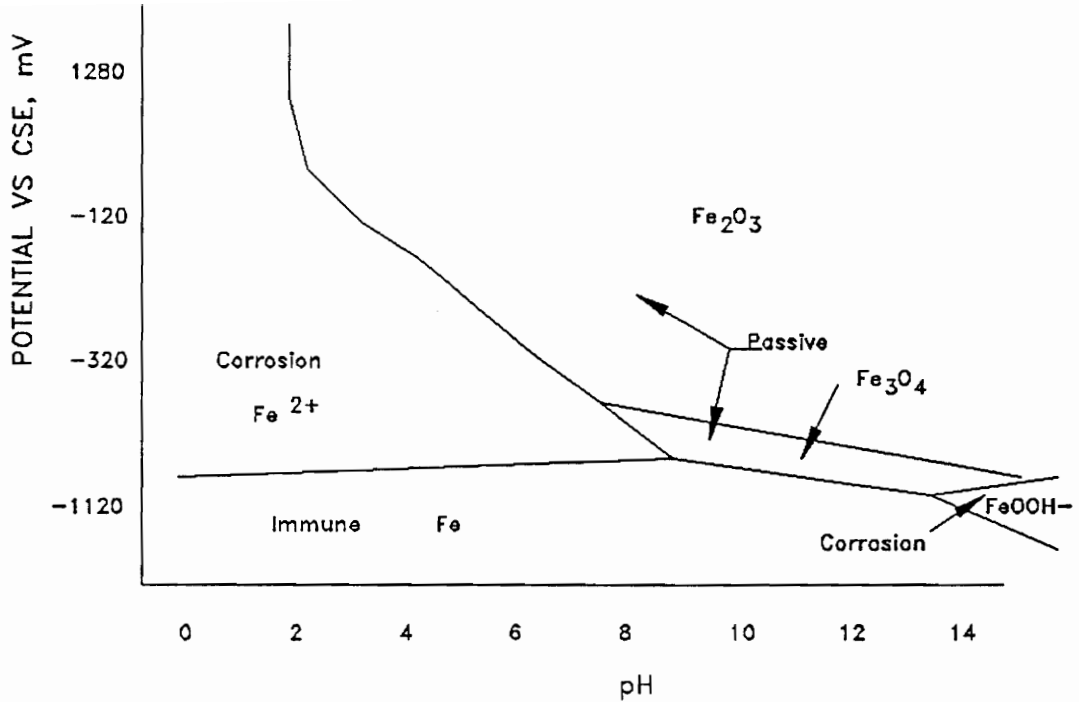


Figure 5 – Pourbaix Diagram for Steel in an Aqueous Environment

region, it would be expected to undergo autogenous corrosion(12).

### 2.3.4 Initiation of Corrosion

Steel reinforcement is generally considered to be kept passive in the highly alkaline environment of the concrete by the protective gamma iron oxide layer which is formed on the surface of the reinforcement in the presence of oxygen and moisture(19). Recently, studies have proposed that there are actually two layers which

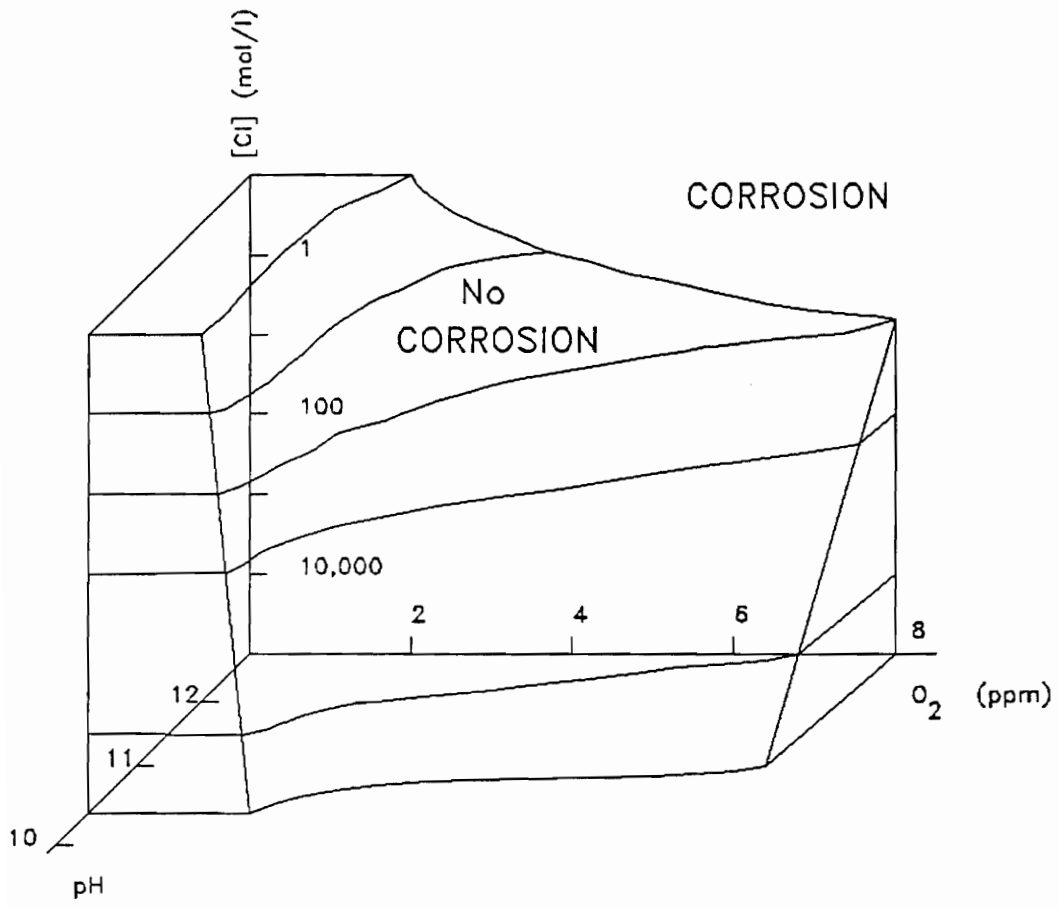


Figure 6 - Three Dimensional Corrosion Envelope

help to passivate the steel. The first layer is the gamma iron oxide layer which has been recognized for some time. The second layer is a portlandite layer which contains calcium-silicate-hydrate inclusions. This layer is believed to be discontinuous in sections around steel reinforcing. As a result, it only provides imperfect protection of the steel reinforcement. The gamma iron oxide layer provides the most protection(22).

The exact manner in which the chloride ions disrupt the gamma iron oxide layer is unknown as of today. Much research is being performed in this area in the hopes that by understanding the mechanisms that the protective layer is broken down, conditions can be altered to prevent its disruption. One recent study proposes that the chloride ions actually migrate through the gamma iron oxide layer and destroy the bond between the protective layer and the steel reinforcing(22). Once the bond is broken, the passive layer is unable to prevent the steel from undergoing corrosion.

In order for the chloride ions to breakdown the protective layer, a threshold level of chloride ions must be present at the steel reinforcement/concrete interface. The threshold concentration level is somewhat dependent on the concrete type. Concentrations ranging from 0.3 to 4.7 lbs/yd<sup>3</sup> (0.18 to 2.79 kg/m<sup>3</sup>) of concrete have been suggested for the threshold level (23). A level of 1.2 lbs/yd<sup>3</sup> (0.71 kg/m<sup>3</sup>) is usually considered the threshold level for steel reinforcement in a reinforced bridge deck. AASHTO recommends that Cl<sup>-</sup> ion concentrations less than 2.4 lbs/yd<sup>3</sup> (1.42 kg/m<sup>3</sup>) are acceptable for bridge decks. Concentrations above 4.7 lbs/yd<sup>3</sup> (2.79 kg/m<sup>3</sup>)

<sup>3</sup>) require that the bridge deck should be replaced(24).

A second theory states that it is not the level of the chloride ions alone that determine the threshold level. Instead, it is the ratio of the concentration of chloride ions to the concentration of hydroxide ions that determines the threshold level.

Hausmann recommends that the ratio of 0.6 be used as the threshold(13). Ratios above 0.6 would indicate that it is likely for protective layer to be destroyed.

Considering the ratio, it can be concluded that either an increase in chloride ion concentration or a decrease in hydroxide ion concentration (which is equivalent to a decrease in the pH of the surrounding solution) would cause the ratio to increase.

Once the gamma iron oxide layer has been broken down, conditions must then favor the oxidation and reduction reactions for autogenous corrosion. Free oxygen and water must be present at the cathode in order for the reduction reaction to occur.

Mather states that once the relative humidity (RH) of the concrete drops below 80%, no chemical reactions can take place(14). Experiments performed in aerated solutions also show that free oxygen and water are necessary for the reduction reaction to take place(19). Also, a potential difference must exist between the cathode and the anode area in order for corrosion to initiate. This difference may be caused by differences in the properties of the steel or the concrete or by differences in the exposure conditions of the two sites (i.e. the  $\text{Cl}^-$  ion concentrations)(13).

Several theories have been suggested as to how the corrosion cell first establishes after the breakdown of the protective layer. One theory proposes that once

a threshold level of chloride ions is reached, microcell corrosion begins. Upon drying of the concrete, the chloride ions in voids surrounding the steel/concrete interface crystallize on the walls of the voids, causing a reduction in the pH at the interface. Upon subsequent wetting, the reduced pH allows for corrosion to occur more easily(19). A second theory proposes that as chloride ions migrate through the concrete, the concentration at the upper mat of steel is higher than the concentration at the lower mat of steel. This difference in concentrations causes a potential difference to be established, and macrocell corrosion begins with the top mat of steel being the anode and the lower mat of steel being the cathode(10). Clearly, the initiation of corrosion is a complex issue which is not the same in all circumstances.

### **2.3.5 Corrosion State of Steel in Concrete**

Corrosion of steel in a concrete environment may eventually cause several different types of damage to occur. One of the first indications of corrosion may be the appearance of rust staining on the surface of the concrete due to the migration of rust products to the surface. However, in some cases the rust products will not migrate to the surface prior to the build up of sufficient pressure to cause the concrete to crack. The cracking may take the form of delamination cracking where the cracks run horizontally from one bar to another. Or, the cracks may propagate to the surface at an approximately 45° angle in the form of inclined cracking. The inclined cracking in turn accounts for much of the section loss or pot holes often seen in bridge decks.

A visual survey is conducted to locate these indications of corrosion. In order to locate delaminations, a sounding method is often used. This may entail a simple striking of the concrete with a hammer and noticing the differences in vibrations either by feel or by sound. Also, a drag chain may be used to drag over the surface of the concrete in order to produce differences in vibrations which indicate the presence of a delamination. Ultrasonic reflective methods are also being used to locate delaminations(19).

Potential readings and chloride contents are two methods which indicate the likelihood of corrosion to occur. Unlike corrosion rate methods and visual methods, the potential readings and chloride contents do not identify corrosion activity or the results of corrosion activity. Instead, these methods indicate that conditions favor the corrosion process to occur.

The method for taking and interpreting potential readings is prescribed in ASTM C 876-80, Standard Test Method for Half Cell Potentials of Reinforcing Steel in Concrete. The method describes how a half-cell (the reference electrode) is connected to a voltmeter which is then connected to the reinforcing steel (the working electrode). The half-cell is then placed on the concrete above the steel and the potential of the steel/concrete interface is determined. The more negative the reading, the greater the chance of corrosion to occur. ASTM C-876 presents the following guidelines for the interpretation of the potential readings taken with a copper-copper sulfate half cell (CSE)(25):

|                  |                                     |
|------------------|-------------------------------------|
| > -0.20 v        | 90% probability of no corrosion     |
| -0.35 to -0.20 V | uncertain                           |
| < -0.35 V        | 90% probability of active corrosion |

Potential readings must be used with care for several reasons. First, the shift in a more negative direction may not always indicate an increase chance of corrosion to occur. For instance, a shift in the negative direction may indicate that the anodic reaction is being made more likely to occur which would increase the corrosion rate. But, the same shift may also indicate that the cathodic reaction is being impeded, which would result in a decrease in the corrosion rate(18).

Chloride contents are often taken in a corrosion condition survey along with the potential readings and the corrosion rate readings. The chloride contents are used to determine if a site has a high enough level of chloride ions to initiate corrosion. Clear has recommended the actions in Table 2 to be taken for the given chloride ion contents(26).

Table 2 - Recommendations for Chloride Content Studies

| lbs Cl <sup>-</sup> /yd <sup>3</sup> | Action   |
|--------------------------------------|--|
| < 1.0                                | leave intact   |
| 1.0 - 2.0                            | questionable area                                      |
| > 2.0                                | remove concrete below bar level or replace entire deck |



Chloride contents must also be used with care since the threshold level to initiate corrosion seems to be different for different types of concrete. In fact, the chloride ion to hydroxyl ion ratio may be a much better indicator of the danger of corrosion occurring(27).

Techniques have been developed to directly measure the rate of corrosion of the steel reinforcement in the concrete. Electrochemical noise, impedance and harmonic analysis, and linear polarization techniques can be used to determine a corrosion rate(28). For an active system such as a bridge deck where closing a lane has an inherent cost to the public, linear polarization techniques have proven to be the best suited because of the time and the size of the equipment needed to perform a measurement.

The term linear polarization refers to the linear regions of the polarization curve, see Figure 7. A popular linear polarization technique is the three electrode linear polarization technique. This technique uses a counter electrode to apply a cathodic current to the steel reinforcement, called the working electrode. A third electrode, the reference electrode, monitors the corresponding change in potential of the steel/concrete interface. By knowing the slopes of the Tafel Slopes (shown in Figure 6) and using the Stern-Geary relationship, a corrosion current can be determined. This current can then be converted to a corrosion current density by knowing the area of the steel which is polarized. Faraday's Law can then be used to determine the section loss of the steel reinforcement in mills per year from the

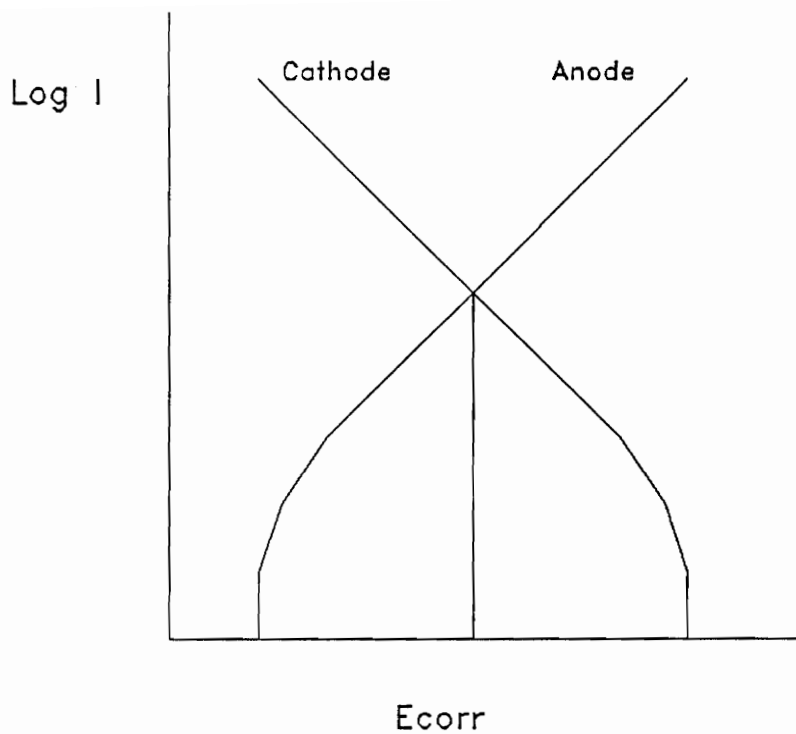


Figure 7 – Tafel Slopes for Corrosion of Steel

corrosion rate.

The 3LP device is currently used in the United States to determine corrosion rates using the linear polarization technique. In order to determine a corrosion rate with the device, the steel reinforcement, or working electrode, must first be connected to the instrument, called the counter electrode. A probe containing the reference electrode is then placed on the concrete above the steel which will be investigated. The counter electrode is then used to apply a cathodic current and the changes in

potential are monitored. Assume that the following currents produce the corresponding changes in current:

|                           |       |       |       |       |
|---------------------------|-------|-------|-------|-------|
| Potential ( $-10^3$ V)    | 0     | 4     | 8     | 12    |
| Current ( $10^{-3}$ Amps) | .0002 | .0289 | .0535 | .0688 |

The Stern-Geary relationship follows:

$$I_{corr} = \frac{\Delta I_{appl} (\beta_a \beta_c)}{2.3 \Delta \phi (\beta_a + \beta_c)} \quad eq.10$$

Assuming that the anodic Tafel slope ( $\beta_a$ ) is 150 mV/decade and that the cathodic Tafel slope ( $\beta_c$ ) is 250 mV/decade, the Stern-Geary equation reduces to equation 11.

$$I_{corr} = 40.76 \frac{\Delta I_{appl}}{\Delta \phi} = 40.76 \frac{1}{R_p} \quad eq.11$$

Performing a simple linear regression on the data in Table determines the  $R_p$  value.

The slope of the relationship (0.00576) is equal to the value of  $\Delta I_{appl} / \Delta \phi$ . Using the slope in Equation 3 provides an  $I_{corr} = 40.76 \times 0.00576 = 0.2348$  mA. By knowing that the steel bar is a number five bar, 5/8" (1.59 cm) in diameter, and that the length which is polarized is 7.25 inches (18.42 cm), the surface area of the

polarized bar can be determined to be  $\text{area} = \pi D L$ , or  $\text{area} = \pi (5/8") (7.25") / (144 \text{ in}^2 / \text{ft}^2) = 0.0989 \text{ ft}^2 (91.9 \text{ cm}^2)$ . Therefore, the current density ( $i_{\text{corr}}$ ) would be  $I_{\text{corr}} / \text{area} = 0.2348 / 0.0989 (0.2348 / 91.9) = 2.37 \text{ mA/ft}^2 (2.56 \mu\text{A/cm}^2)$  (26).

The constant  $k$  used to convert from  $\text{mA/ft}^2$  to mills/year can be determined as in equation 12.

$$k = \frac{\text{mA}}{\text{ft}^2} \frac{0.001 \text{ Columb/sec}}{1 \text{ mA}} \frac{1 e^-}{1.6(10^{-19}) \text{ Columb}} \frac{1 \text{ Fe atom}}{2 e^-} \frac{1 \text{ mol Fe}}{(6.02(10^{23}) \text{ Fe atoms})} \frac{55.59 \text{ g Fe}}{1 \text{ mol Fe}} \frac{1 \text{ cm}^3 \text{ Fe}}{7.87 \text{ g Fe}} \frac{1 \text{ in}^3}{2.54^3 \text{ cm}^3} \frac{1 \text{ ft}^2}{144 \text{ in}^2} \frac{100 \text{ mills}}{\text{in}} \frac{31557600 \text{ sec}}{\text{year}} = 0.4927 \frac{\text{mills ft}^2}{\text{mA year}} \quad \text{eq.12}$$

Therefore, assuming that the corrosion rate density remains constant throughout the year, it ( $2.406 \text{ mA/ft}^2$ ) can be multiplied by  $k$  to obtain a value of  $\text{MPY} = 2.406 \times 0.4927 = 1.185 \text{ mills/year}$  of metal loss.

A second corrosion rate meter which, according to the Strategic Highway Research Program, best approximates the true corrosion rate by confining the polarization current with a guard ring electrode is the Gecor device(29). This device uses the same linear polarization technique, with the addition of a guard ring electrode. This fourth electrode monitors the polarization current and does not allow it to drift horizontally in the concrete as it travels from the surface of the concrete to the

working electrode.

The corrosion current density is then used to predict when the corrosion process will build up sufficient pressure to cause cracking of the concrete. In a reinforced concrete bridge deck having a normal cover depth (about 1.5 to 2.5 inches (3.8-6.4 cm) for older decks), the following guidelines have been proposed by Clear for the evaluation of the corrosion current density(26):

Table 3 - Recommendations for Corrosion Rate Studies

| $i_{corr}$ (mA/ft <sup>2</sup> ) | Expectation               |
|----------------------------------|---------------------------|
| < 0.2                            | No damage expected        |
| 0.2 - 1.0                        | Damage possible 10-15 yrs |
| 1.0 -10                          | Damage possible 2-10 yrs  |
| >10                              | Damage possible < 2yrs    |

## 2.4 Corrosion Deterioration in Models

### **2.4.1 Corrosion Rates in Models**

Models which attempt to predict the time at which damage will occur in a structure usually consider the corrosion process as a two phase process. Beeby and Goni and Andrade consider the time to initiate the corrosion process as the first stage and the time to build up sufficient pressure as to cause cracking as the second stage(20,30). The Cady-Weyers deterioration model also considers the corrosion process as a two phase process; however, the names of the two stages are different.

In the Cady- Weyers model, the initiation period is the time necessary for the chloride ions to diffuse through the concrete to a threshold level at the steel reinforcing. It is called the Diffusion period in this model. A statistical approach is used to determine the percentage of the total deck area of steel reinforcement that will be contaminated with chloride ions at a given time. The second period is called the Corrosion period in the Cady-Weyers Deterioration model. In this stage, the corrosion of the steel continues until cracking occurs(3). The criteria which determines how much corrosion is necessary to produce corrosion is described by work performed by Bazant. Bazant's work describes two states of cracking, inclined cracking and fracture cracking (delamination cracking). The size of the steel bar, the spacing of the steel bars, and the cover of concrete above the steel bars influence which state of cracking will occur(4).

The third phase of the Cady-Weyers model is the Deterioration phase. In this phase, the surface of the bridge deck continues to deteriorate at a constant rate until repairs, rehabilitation, or replacement becomes necessary. The criteria for deck damage includes the total area as a percent which has spalling, delaminations, and asphalt patches. A recent Strategic Highway Research Program report, Concrete Bridge Protection and Rehabilitation: Chemical and Physical Techniques - Service Life Estimates, presents levels of damage which define the end of the service life of bridge decks. The report determined that 9.3% - 13.6% damage of the worst traffic lane would indicate the end of service life according to today's recommended practices.

But, current practices indicate that damage from 5.8% to 10.0 % indicates that the bridge deck has reached the end of its service life(31).

#### 2.4.2 Time to Cracking Criteria

Bazant assumes a steady-state of corrosion producing expansive black rust in his steady-state corrosion cracking criteria. Once the protective nature of the protective ferric oxide layer is destroyed, the steel reinforcement will undergo corrosion at a steady rate for a time  $t_{cor}$ . At the end of this time, cracking will occur. The time of corrosion until cracking is produced,  $t_{cor}$ , follows:

$$t_{cor} = \rho_{cor} \frac{D \Delta D}{s j_r} \quad eq.13$$

where  $s$  is the bar spacing,  $D$  is the diameter of the bar,  $\Delta D$  is the change in diameter of the bar,  $j_r$  is the corrosion rate, and  $\rho_{cor}$  is a function of the mass densities of steel and rust(4). The three variables  $D$ ,  $s$ , and  $\rho_{cor}$  can be determined nondestructively by finding the steel and determining its size and spacing by using a commercially available device. The rate of corrosion,  $j_r$ , can be estimated by a corrosion rate measuring device. The last variable,  $\Delta D$ , depends on the cover depth of the reinforcement.

If the spacing,  $s$ , is less than  $6D$ , then the following formula governs  $\Delta D$ :

$$\Delta D = 2f_t \frac{L}{D} \delta_{pp} \quad eq.14$$

where  $f_t$  is the tensile strength of the concrete and  $\delta_{pp}$  is the bar hole flexibility. The bar hole flexibility is taken as the average of the following bar hole flexibilities, the first being for the case of concrete acting as a thick-walled cylinder and the second being for the case of the concrete acting as an infinite medium:

$$\delta^o_{pp} = \frac{D}{E_{ef}} (1 + \nu) + \frac{2 D^3}{s^2 E_{ef}} \quad eq.15$$

$$\delta'_{pp} = \frac{D}{E_{ef}} \left[ 1 + \nu + \frac{D^2}{2 L (L+D)} \right] + \frac{2 D^3}{s^2 E_{ef}} \quad eq.16$$

The average of the above two equations, the bar hole flexibility,  $\delta_{pp}$ , becomes:

$$\delta_{pp} = \left[ \frac{D(1+\phi_{cr})}{E} \right] \left[ (1+\nu) + D^2 \left[ \frac{2}{s^2} + \frac{1}{4L(L+D)} \right] \right] \quad eq.17$$

where  $\phi_{cr}$  is the creep coefficient of the concrete,  $\nu$  is the poisson's ratio of the concrete, and E is the elastic modulus of the concrete. For this condition, the expected mode of failure is inclined cracking.

If the cover depth, L, is greater than  $(s-D)/2$ , then the following formula



governs  $\Delta D$ :

$$\Delta D = f_t \left( \frac{S}{D} - 1 \right) \delta_{pp} \quad eq.18$$

The type of failure expected with this condition of cracking is delamination cracking.

If the cover depth and bar spacing are between the two criteria, then the type of failure is uncertain(4).

### **3.0 Experimental Design**

#### **3.1 Background**

In order to better establish the time period of the corrosion phase of the Cady-Weyes deterioration model, a large scale experiment was undertaken at Virginia Tech. The experiment included studying the theoretically significant variables in order to establish the relationship between the significant variables and first cracking of the concrete due to the corrosion of the reinforcing steel.

Since the project was designed to study the corrosion phase only, the diffusion phase was eliminated. This was done by introducing salt to the mix water instead of allowing the salt to enter the concrete by diffusing through the surface. Different amounts of salts were added in order to determine how the chloride ion content influences the initiation of corrosion and the corrosion rate.

The corrosion current densities of the embedded steel were monitored with two corrosion meters, the K.C. Clear 3-LP device (32) and the Gecor device manufactured by Geocisa Inc.(33).

The large scale specimens were designed to simulate a bridge deck commonly used in overpass bridges. The only exception was the replacement of the bottom layer of steel reinforcement with fiberglass-epoxy bars. This was done so that only the top layer of steel would be subject to corrosion.

Different exposure conditions were also studied. Forty of the large scale

specimens were placed outdoors in an environment similar to bridge deck exposure conditions. The remaining sixteen large scale specimens were kept indoors so that the temperature would remain fairly constant. Also, the indoor specimens were kept at a near constant moisture content by wetting the specimens once a week and covering them with four mil plastic sheets.

The time to cracking criteria in the Deterioration model is based on work published by Bazant(4). In his work, Bazant proposes how several different states of corrosion create sufficient amounts of corrosion products to cause damage in the concrete. The steady-state corrosion phase is one of these states in which Bazant has developed equations to predict both the time to cracking and the mode of cracking of the concrete(4).

## 3.2 Specimen Matrix

### **3.2.1 Outdoor Slab Series**

The slab series were designed to simulate a range of typical bridge deck design conditions. The following variables were used in the matrix design: chloride content, cover depth, bar size, bar spacing, and exposure condition. In order to distinguish between the slabs, the following labeling scheme was created with each slab receiving a designation such as OA2850.6-1 where:

O = exposure condition, O = Outdoor, I = Indoor

A = Series, A, B, C, D

2 = Cover depth, in

8 = Bar spacing, in

5 = Bar diameter, # of 1/8 in units

0.6 = Chloride ion content, lbs/yd<sup>3</sup> of concrete

1 = Slab # 1

In the series designation, "A" indicates a 2 in (5.08 cm) cover depth with #5 bars at an 8 in (20.32 cm) spacing while "B" indicates a 3 in (7.62 cm) cover depth with #5 bars at an 8 in (20.32 cm) spacing. A designation of "C" indicates a 2 in (5.08 cm) cover depth with #5 bars at a 6 in (15.24 cm) spacing while "D" indicates a 2 in (5.08 cm) cover depth with #6 bars at an 8 in (20.32 cm) spacing.

A total of 56 slabs were constructed. Forty of these slabs were stored outdoors while the remaining sixteen were stored indoors. The matrix for the outdoor slabs is presented in Table 4.

Table 4 - Outdoor Slab Matrix

| Chloride Content, lbs/yd <sup>3</sup> | Bar Size, 1/8 " | Bar Spacing, in | # Slabs with 2" Cover | # Slabs with 3" cover |
|---------------------------------------|-----------------|-----------------|-----------------------|-----------------------|
| 0.0                                   | 5               | 8               | 2                     | 2                     |

|     |   |   |   |      |
|-----|---|---|---|------|
| 0.6 | 5 | 8 | 3 | 3    |
| 1.2 | 5 | 8 | 3 | 3    |
|     | 5 | 6 | 3 | None |
|     | 6 | 8 | 3 | None |
| 2.4 | 5 | 8 | 3 | 3    |
| 4.8 | 5 | 8 | 3 | 3    |
| 9.6 | 5 | 8 | 3 | 3    |

Note: 1 in = 2.54 cm

### 3.2.2 Indoor Slab Series

Sixteen slabs were stored indoors in order to maintain a constant exposure temperature. All of the indoor slabs were constructed with a two inch (5.08 cm) cover depth and # 5 bars at an 8 in (20.32 cm) spacing. The matrix for the indoor specimens is in Table 5.

Table 5 - Indoor Slab Matrix

| Chloride Content, lbs/yd <sup>3</sup> | # of Slabs |
|---------------------------------------|------------|
| 0.0                                   | 2          |
| 0.6                                   | 3          |
| 1.2                                   | 3          |

|     |   |
|-----|---|
| 2.4 | 3 |
| 4.8 | 3 |
| 9.6 | 2 |

### 3.2.3 Block Series

In addition to the large scale slab specimens, smaller test blocks were cast along with the slabs. The blocks contain only one #4 bar with a two inch cover depth. Two test blocks were cast at each of the 6 different chloride contents, making a total of 12 blocks. However, reinforcing bars in some of the blocks were removed in order to assess the corrosion condition of the steel. The matrix of the blocks follows in Table 6.

Table 6 - Block Matrix

| Series | # Indoor Blocks | # Original Outdoor Blocks | # Remaining Outdoor Blocks |
|--------|-----------------|---------------------------|----------------------------|
| 0.0    | 1               | 2                         | 2                          |
| 0.6    | 1               | 2                         | 2                          |
| 1.2    | 1               | 2                         | 2                          |
| 2.4    | 1               | 2                         | 1                          |
| 4.8    | 1               | 2                         | 1                          |
| 9.6    | 1               | 2                         | 1                          |

### 3.3 Specimen Materials

#### **3.3.1 Slab Series Materials**

A #57 crushed limestone from the Blacksburg, Virginia area and a siliceous natural sand from Wythville, Virginia were used for the coarse and fine aggregates. The properties of these aggregates are presented in Table 7.

Table 7 - Aggregate Properties

| Aggregate Properties                    |  |
|---|--|
| Course Aggregate: #57 Crushed Limestone |  |
| Dry Rodded Unit Weight                  | 96.4 lbs/ft <sup>3</sup> (1544 kg/m <sup>3</sup> ) |
| Voids in Dry Rodded Agg.                | 44.2%  |
| Bulk Specific Gravity (Dry)             | 2.77   |
| Bulk Specific Gravity (SSD)             | 2.78   |
| Apparent Specific Gravity               | 2.81   |
| Absorption                              | 0.62%  |
| Fine Aggregate: Siliceous Natural Sand  |  |
| Bulk Specific Gravity (Dry)             | 2.60   |
| Bulk Specific Gravity (SSD)             | 2.66   |
| Apparent Specific Gravity               | 2.66   |
| Absorption                              | 0.35%  |
| Fineness Modulus                        | 2.8  |

The cement used in the mixture was a Type I portland cement obtained from Tarmac Cement Co. in Roanoke, Virginia. Daravair, an air entrainment agent produced by W.R. Grace & Co., was used in the mixture to provide the necessary entrained air for freezing and thawing durability required for bridge decks. Also, granular sodium chloride from Fisher Scientific Co. was introduced into the mixture water to simulate salts introduced into the concrete by winter maintenance activities.

The steel reinforcement was manufactured by Roanoke Electric Steel Co. in Roanoke, Virginia. The fiberglass-epoxy bars were manufactured by International Grating, located in Houston, Texas.

The batches were designed to meet specifications for a typical bridge deck concrete. Table 8 presents the six mixture batch weights.

Table 8 - Mixture Batch Weights

| Series | 0.0<br>lb/yd <sup>3</sup> | 0.6<br>lb/yd <sup>3</sup> | 1.2<br>lb/yd <sup>3</sup> |
|--------|---------------------------|---------------------------|---------------------------|
|--------|---------------------------|---------------------------|---------------------------|



|             |                     |                           |                           |                           |
|-------------|---------------------|---------------------------|---------------------------|---------------------------|
| Cement      | lb/yd <sup>3</sup>  | 635                       | 635                       | 632                       |
| Water       | gal/yd <sup>3</sup> | 34.3                      | 32.3                      | 32.2                      |
| W/C Ratio   |                     | 0.45                      | 0.42                      | 0.42                      |
| Coarse Agg. | lb/yd <sup>3</sup>  | 1780                      | 1780                      | 1728                      |
| Fine Agg.   | lb/yd <sup>3</sup>  | 1197                      | 1197                      | 1191                      |
| Daravair    | oz/yd <sup>3</sup>  | 9.8                       | 8.5                       | 8.5                       |
| Salt        | lb/yd <sup>3</sup>  | 0                         | 1                         | 2                         |
| Chloride    | lb/yd <sup>3</sup>  | 0                         | 0.6                       | 1.2                       |
| Slump       | inches              | 6                         | 4                         | 6.75                      |
| Unit Wt.    | lb/ft <sup>3</sup>  | 148.8                     | 146.4                     | 143.2                     |
| Air Content | %                   | 3.2                       | 5                         | 5.4                       |
| Series      |                     | 2.4<br>lb/yd <sup>3</sup> | 4.8<br>lb/yd <sup>3</sup> | 9.6<br>lb/yd <sup>3</sup> |
| Cement      | lb/yd <sup>3</sup>  | 632                       | 632                       | 628                       |
| Water       | gal/yd <sup>3</sup> | 31.2                      | 33.2                      | 32.7                      |
| W/C Ratio   |                     | 0.41                      | 0.44                      | 0.43                      |
| Coarse Agg. | lb/yd <sup>3</sup>  | 1798                      | 1779                      | 1797                      |
| Fine Agg.   | lb/yd <sup>3</sup>  | 1177                      | 1187                      | 1189                      |
| Daravair    | oz/yd <sup>3</sup>  | 9.8                       | 9.7                       | 11.1                      |
| Salt        | lb/yd <sup>3</sup>  | 4                         | 8                         | 16                        |
| Chloride    | lb/yd <sup>3</sup>  | 2.4                       | 4.9                       | 9.7                       |
| Slump       | inches              | 3.25                      | 4                         | 4                         |
| Unit Wt.    | lb/ft <sup>3</sup>  | 149.1                     | 149.1                     | 142.6                     |
| Air Content | %                   | 4.2                       | 4.7                       | 6.7                       |

Compressive strength tests were conducted on each batch at 3, 7, and 28 days.

The results are presented in Table 9.

Table 9 - Compressive Strength Results

| Series                  | 0<br>lb/yd <sup>3</sup> | 0.6<br>lb/yd <sup>3</sup> | 1.2<br>lb/yd <sup>3</sup> | 2.4<br>lb/yd <sup>3</sup> | 4.8<br>lb/yd <sup>3</sup> | 9.6<br>lb/yd <sup>3</sup> |
|-------------------------|-------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| 3 Day<br>Test<br>(Psi)  | 3020                    | 3820                      | 3380                      | 3780                      | 3860                      | 3580                      |
|                         | 3060                    | 3660                      | 3380                      | 3860                      | 3780                      | 3740                      |
| 7 Day<br>Test<br>(Psi)  | 3780                    | 4380                      | 4140                      | 4580                      | 4540                      | 4100                      |
|                         | 3580                    | 4420                      | 4100                      | 4580                      | 4260                      | 4100                      |
| 28 Day<br>Test<br>(Psi) | 4460                    | 5370                      | 5050                      | 5490                      | 5130                      | 4500                      |
|                         | 4380                    | 5810                      | 4930                      | 5770                      | 5130                      | 4620                      |

Note: 1 psi = 6.894 kPa

### 3.3.2 Block Series Materials

The concrete blocks were cast from the same batch of concrete which was used for the large slab specimens; therefore, their properties may be found in Table 8. The steel reinforcement was also provided by Roanoke Electric Steel, located in Roanoke, Virginia.

## 3.4 Specimen Design

### 3.4.1 Slab Series Design

All fifty six of the slabs are constructed in the same manner. The total dimensions are 46.5 in (118.1 cm) by 46.5 in (118.1 cm) by 8.5 in (21.6 cm). Five steel reinforcing bars are located in the top mat. The steel bars have 42 in (106.7 cm)

of clear bar with the remaining 2.25 in (5.7 cm) at both ends taped with electroplating tape. Three #4 fiberglass-epoxy bars were placed in the top mat in order to act as temperature reinforcement. These bars were connected with plastic ties to ensure that the steel bars were isolated from each other. The bottom mat of reinforcement consists of a mat of 6 fiberglass-epoxy bars, also connected with plastic ties. Also, two type T thermocouples were attached to the second and fourth bar so that the temperature at the bar level could be determined. A low modulus epoxy, Epon 828 produced by Shell, was used to coat the sides of the slabs in order to simulate a continuous structure. The design is shown in Figure 8.

Corrosion rate measurements were taken on a monthly basis. In order to reduce the number of measurements to a manageable number, the measurements were taken on the even number bars one month and then the odd number bars the next month. The following month, the process would return to the even number bars. Therefore, an average of 2.5 corrosion rate measurements were taken on each slab monthly.

### **3.4.2 Block Series Design**

All of the blocks were cast with a single #4 bar with a 2 in cover depth. The blocks were 11.5 in wide by 13 in deep by 7 in thick. The specimens also contain a type T thermocouple located at the bar level. The sides of the blocks were coated with the same low modulus epoxy used in the large slab specimens in order to

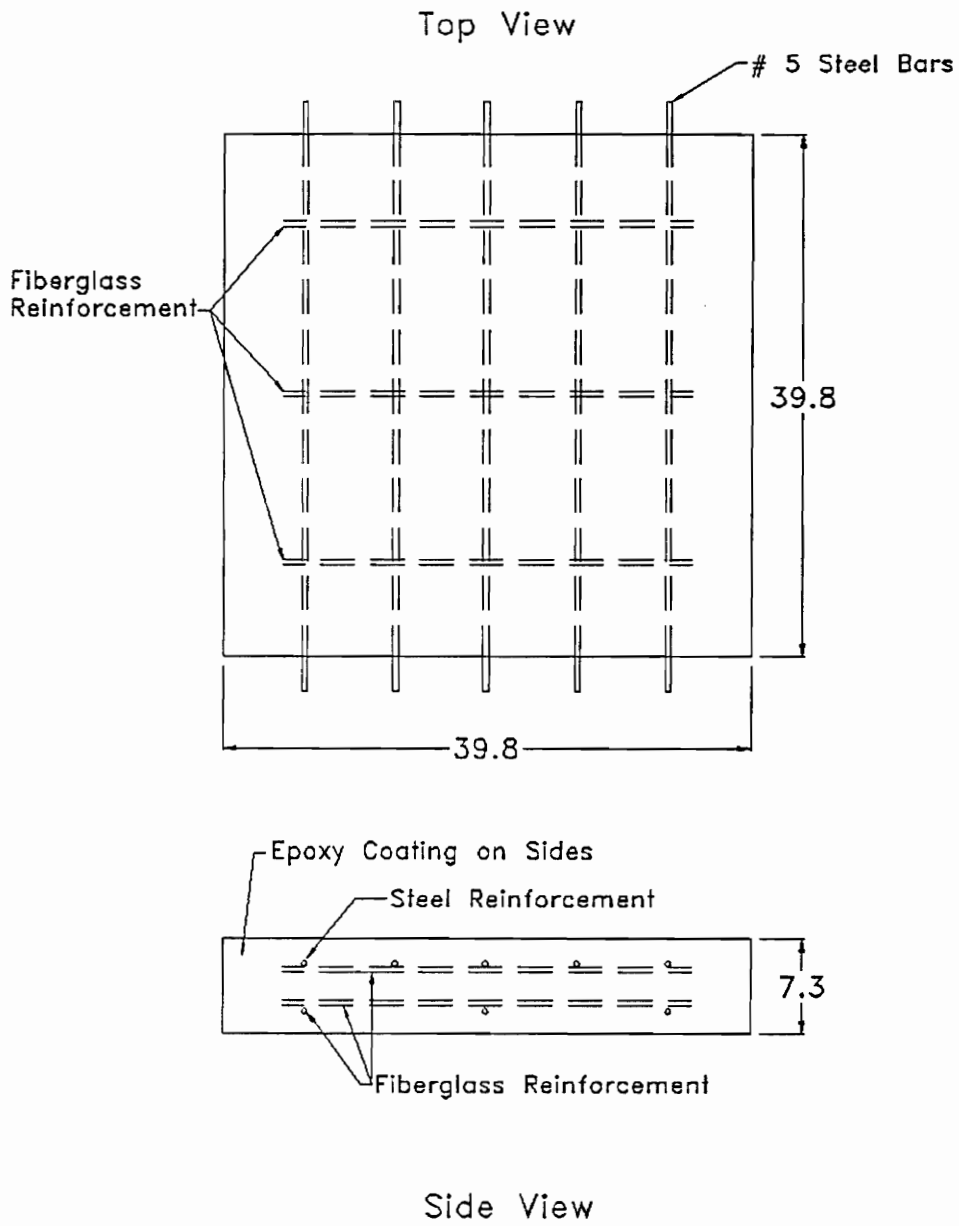


Figure 8 - Slab Series Design

simulate a continuous structure. A diagram of the blocks is presented in Figure 9.

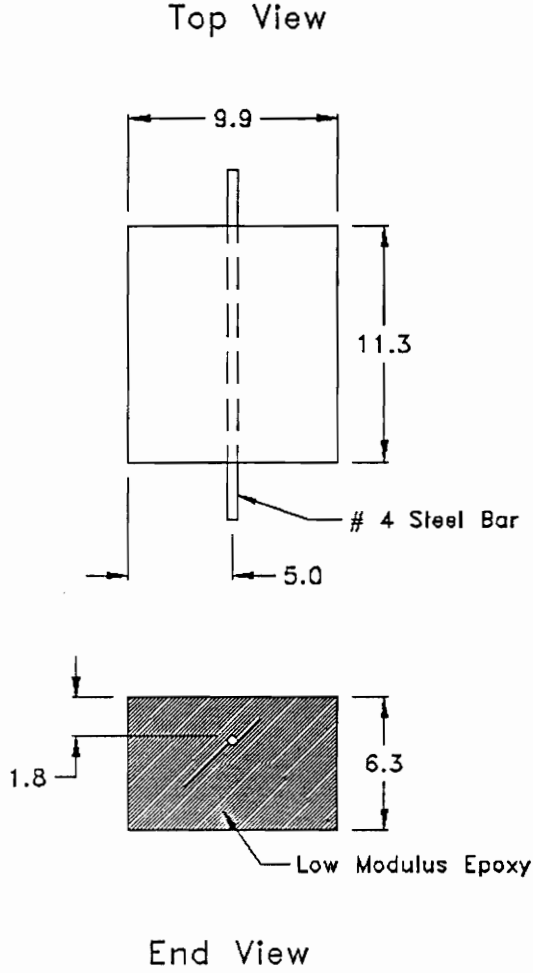


Figure 9 – Block Series Design

## 4.0 Results and Discussion

### 4.1 Measured Corrosion Rates

#### 4.1.1 Measured Corrosion Rates

Individual corrosion rate measurements are presented in the Appendices A and B. Appendix A contains the measurements taken during Peterson's study(5) while Appendix B contains the measurements taken during this study. Identical corrosion rate measurement techniques were used in order to minimize the variability in the two studies.

The monthly measurements for all specimens having a two inch cover depth were averaged and are shown as a function of time in months after the specimens were cast, see Figures 10-33. Two significant observations may be drawn from these graphs. First, since a mA/ft<sup>2</sup> is approximately equal to a uA/cm<sup>2</sup>, it is evident that the 3-LP device measures a corrosion rate much higher than the Gecor device. Second, the measurements on most of the outdoor specimens show an increase during the two springs over which the measurements were taken. This indicates that the spring season is likely to have the highest measured corrosion rate. This is in good agreement with the present understanding of the influence of temperature and concrete moisture content on corrosion rates, as temperature and moisture content increase the corrosion rate increases. During summer the concrete will tend to have a higher

temperature and lower moisture content than the spring and the corrosion rate may decrease. Winter will tend to have lower temperatures and possibly lower moisture contents than the spring and thus the corrosion rate may be somewhat depressed. Fall will tend to have only moderate temperatures and moisture. Therefore, spring, with its increasing temperatures and moisture, will likely have the highest measured corrosion rates, as indicated in Figures 10-33.

The interaction of temperature and moisture content on the corrosion process is not fully addressed in this study, except as implied by the measured temperatures for the outdoor 9.6 series.

The measured 3-LP corrosion rates as a function of temperature for the first nine months after construction is shown in Figure 34 and Figure 35 and presents the remaining months. Also, the same relationships for the same time periods for the Gecor device are presented in Figures 36 and 37. Although the corrosion rate measurements failed to reach a steady state condition during the study, it was determined that after the first nine months, the measurements appeared to indicate a somewhat steady state.

A simple linear regression of the data over the first nine months and the remaining months was performed in order to determine the influence of temperature on the measured corrosion rates, as illustrated in Table 10. It is expected that the moisture content of the concrete and the temperature will interact as they influence the measured corrosion rates. However, moisture content of the concrete was not taken at

the time that the corrosion rates were taken.

Table 10 - Measured Corrosion Rates as a Function of Temperature for the OA2859.6 Slab Series

| Device | Time (months) | Slope ( $i_{\text{corr}}/\text{temp}$ ) | R <sup>2</sup> |
|--------|---------------|---|----------------|
| 3-LP   | 1-9           | -0.14                                   | 0.29           |
|        | 10-23         | 0.13                                    | 0.68           |
| Gecor  | 1-9           | 0.0068                                  | 0.14           |
|        | 10-23         | 0.0065                                  | 0.34           |

Over the initial period of corrosion, the slope of the corrosion rate as a function of the temperature for the 3-LP device is -0.14 while the slope over the remaining 13 months it is 0.13. This indicates that during the early stage of corrosion following placing, an increase in temperature has a negative influence on corrosion rate. But, after the early stage of corrosion, temperature does have the expected positive influence on corrosion rate. The negative influence of temperature on the measured corrosion rate may be related to the fact that the 3-LP device does not have a guard ring electrode and therefore was polarizing larger areas which have large cathode/anode ratios. As the time progresses, the cathode/anode ratios decrease, and the 3-LP polarizes a smaller area, which allows for the temperature to have a positive effect on the measured corrosion rates.

For the Gecor device, the influence of temperature on corrosion rate does not appear as evident, as indicated by a slope of 0.0068 over the early stage of corrosion



and a similar slope of 0.0065 over the later stage of corrosion. Since the Gecor device uses a guard ring electrode, it is less likely to allow the cathode/anode ratio to influence the area which is being polarized.

#### **4.1.2 Monthly Distribution of Corrosion Rates**

Weather conditions and changes in testing schedules have resulted in different numbers of corrosion rate readings over the 24 month time period. The sample sizes range from zero, when weather did not permit measurements to be taken, to 46, for preliminary data in Peterson's study(5). Most of the months average 7.5 readings per slab series. For such a small sample size, statistical analysis is difficult for monthly readings for a series. However, an attempt was made to address this topic.

One way to illustrate the variability of a set of monthly readings for a given series is a corrosion rate frequency diagram, see Figures 38-40, for the OA2859.6 series. For both the Gecor and the 3-LP devices, Figures 38-40 show the distribution for 1, 2, and 8 months after casting. A dominating characteristic such as lower tail or upper tail skewness does not occur in the frequency distributions. Therefore, the assumption of a normal distribution for the monthly data seems appropriate.

#### **4.1.3 Variability of Corrosion Rates**

Accuracy is desired in corrosion rate measurements; however, precision is required. Measurements lacking precision would be of little use in predicting the time

to cracking from the measured rates. To investigate the precision of the measured corrosion rates, the variability, measured as the sample standard deviation, was computed for each month in all of the series. Since the 3-LP measurements are higher than the Gecor measurements, the standard deviation was normalized by dividing by the mean which is the coefficient of variation. The average coefficient of variation for all of the months in a given series and the sample standard deviation of the coefficient of variations is presented in Table 11.

Table 11 - Variability of Corrosion Rate Measurements

|        |        | Outdoor 285 Series |      | Indoor 285 Series |      |
|--------|--------|--------------------|------|-------------------|------|
| Series |        | Gecor              | 3-LP | Gecor             | 3-LP |
| 9.6    | COV, % | 38                 | 15   | 30                | 20   |
|        | s, %   | 12                 | 8    | 30                | 13   |
| 4.8    | COV, % | 28                 | 14   | 40                | 18   |
|        | s, %   | 10                 | 10   | 20                | 10   |
| 2.4    | COV, % | 38                 | 12   | 30                | 13   |
|        | s, %   | 61                 | 5    | 10                | 5    |
| 1.2    | COV, % | 23                 | 26   | 39                | 20   |
|        | s, %   | 8                  | 17   | 16                | 3    |
| 0.6    | COV, % | 28                 | 21   | 30                | 17   |
|        | s, %   | 11                 | 10   | 10                | 6    |
| 0.0    | COV, % | 25                 | 21   | 37                | 20   |

|  |      |    |    |    |   |
|--|------|----|----|----|---|
|  | s, % | 10 | 10 | 24 | 7 |
|--|------|----|----|----|---|

In all cases except for one, the coefficient of variation for the Gecor device is as high or higher than the coefficient of variation for the 3-LP device. Also, in all cases except for one, the sample standard deviation of the coefficient of variation is as high or higher for the Gecor device than it is for the 3-LP device. These two facts indicate that the measured corrosion rates from the Gecor device are more variable, or less precise, than the measured corrosion rates from the 3-LP device.

#### 4.1.4 Equivalent Average Corrosion Rate

The corrosion rates as a function of time presented in Figures 10-33 illustrate the variability encountered in measuring corrosion rates over time. This is true for both the indoor and outdoor specimens. In order to compare the total amount of metal loss between the different series, the accumulated metal loss must be determined. This may be done by integrating the area under the corrosion rate curves. The integrated area will be in the units of corrosion rate density times time, (amperes / area) x (time), or mA(days) / ft<sup>2</sup> or uA(days) / cm<sup>2</sup>. Then, the average corrosion rate may be determined by dividing the area under the corrosion rate profile by the time over which the measurements have been taken.

Corrosion rate density measurements are presented for 24 months for all series

except for the 9.6 series which has measurements for 22 months because the specimens were cast two months later. In order to compare the two different corrosion rate density devices, units of mA/ft<sup>2</sup> are used for both. (The relationship of 1 mA/ft<sup>2</sup> = 1.076 uA/cm<sup>2</sup> is used to convert the Gecor data to mA/ft<sup>2</sup>). Table 12 presents the corrosion rate density times and Table 13 presents the equivalent corrosion rate densities for the measured time periods.

Table 12 - Corrosion Rate Density Times

| Series | Outdoor 285 Series                |                                    | Indoor 285 Series                 |                                    |
|--------|-----------------------------------|------------------------------------|-----------------------------------|------------------------------------|
|        | 3-LP<br>(mA/ft <sup>2</sup> )days | GECOR<br>(mA/ft <sup>2</sup> )days | 3-LP<br>(mA/ft <sup>2</sup> )days | GECOR<br>(mA/ft <sup>2</sup> )days |
| 0.0    | 520.6                             | 33.6                               | 707.4                             | 33.0                               |
| 0.6    | 641.7                             | 35.6                               | 788.6                             | 39.1                               |
| 1.2    | 800.8                             | 50.9                               | 1070.8                            | 52.6                               |
| 2.4    | 973.5                             | 70.6                               | 1088.4                            | 55.9                               |
| 4.8    | 2758.9                            | 195.2                              | 2203.2                            | 143.7                              |
| 9.6    | 5216.7                            | 295.2                              | 5564.0                            | 362.3                              |

Table 13 - Equivalent Corrosion Rate Densities

| Series | Outdoor 285 Series |                  | Indoor 285 Series |                  |
|--------|--------------------|------------------|-------------------|------------------|
|        | 3-LP<br>mA/sqft    | GECOR<br>mA/sqft | 3-LP<br>mA/sqft   | GECOR<br>mA/sqft |

|     |      |       |      |       |
|-----|------|-------|------|-------|
| 0.0 | 0.71 | 0.046 | 0.97 | 0.045 |
| 0.6 | 0.88 | 0.049 | 1.08 | 0.053 |
| 1.2 | 1.09 | 0.070 | 1.46 | 0.072 |
| 2.4 | 1.33 | 0.096 | 1.49 | 0.076 |
| 4.8 | 3.77 | 0.267 | 3.01 | 0.196 |
| 9.6 | 7.77 | 0.403 | 8.29 | 0.540 |

As shown in Table 13, the equivalent corrosion rate densities for the 3-LP device is higher for all indoor and outdoor series than is the average measured corrosion rate for the Gecor device. Also, the equivalent corrosion rate densities, which are a measure of the expected metal loss, are greater for the indoor series than for the outdoor series, except for the 4.8 series. This may result from the near constant temperature and moisture contents of the concrete at the time the measurements were taken as compared to the outdoor series. Table 13 also demonstrates that a large increase in the equivalent corrosion rate densities occurs between the 2.4 and the 4.8 series.

Guidelines proposed by K.C. Clear for the 3-LP device indicate that no damage will occur with corrosion rates less than  $0.2 \text{ mA/ft}^2$ , damage may be expected within 2-10 years for measured corrosion rates between 1 and  $10 \text{ mA/ft}^2$ , and damage may be expected in 10-15 years for measured corrosion rates between  $0.2$  and  $1 \text{ mA/ft}^2$ . The equivalent average corrosion rates indicate that damage should occur within 10-15

years for the 0.0 and the 0.6 series and that damage should occur within 2-10 years for the 1.2, 2.4, 4.8, and the 9.6 series. From the weight loss tests, active corrosion has only occurred in the 9.6 series, which showed damage after nearly two years, a shorter time period than predicted. Unless corrosion initiates in the other series, damage will not occur in the predicted time periods(32).

Guidelines proposed by Geocisa Inc. indicate that negligible corrosion will occur when the measured corrosion rate is less than  $0.1 \text{ uA/cm}^2$  and that active corrosion will occur when the measured corrosion rate is greater than  $0.2 \text{ uA/cm}^2$ . The equivalent average measured corrosion rates from the outdoor specimens indicate that negligible corrosion will occur in the 0.0, 0.6, 1.2, and the 2.4 series and active corrosion will occur in the 4.8 and the 9.6 series. The weight loss tests indicate that only the 9.6 series had active corrosion; therefore, all measured corrosion rates predict as the guidelines suggest except for the 4.8 series, which predicts active corrosion but shows negligible corrosion(33).

## 4.2 Weight Loss Measurements

### **4.2.1 Weight Loss of Outdoor Specimens**

At the age of 22 months, the OA2859.6 series were visibly cracked to the unaided human eye. Cores were taken from this series in order to determine the amount of metal loss required to cause cracking. Even though cracking did not occur

in any of the other series, cores were also taken from the OA2854.8, OA2852.4, and OA2851.2 series.

A control section of bar having undergone no corrosion was not available in the slabs. As a result, it was necessary to use a remaining bar which had not been cast in the slabs. The bars were removed from the cores and cleaned in accordance with ASTM G 1-90, Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens(34). Specifically, method C.3.5 was used in the cleaning process. Three bars approximately 2 inches in length were removed, one from each of the slabs in the series, for a total of three bars per series. After being photographed and cleaned, the bars were weighed to the nearest 0.0001 g and measured to the nearest 0.001 inch. The weight per length of the bars was then computed and subtracted from the weight per length of the control bar. The average results and the standard deviations of the results are presented in Table 14.

Table 14- Average Weight Loss of Outdoor Specimens

| Outdoor Series | Weight Loss, g/cm | $s_{n-1}$ , g/cm |
|----------------|-------------------|------------------|
| 1.2            | -0.0102           | 0.0483           |
| 2.4            | -0.0034           | 0.0517           |
| 4.8            | -0.0140           | 0.0149           |
| 9.6            | 0.1969            | 0.1733           |

As shown in Table 14, only the OA2859.6 series had a measurable metal loss when compared to the control bars. The small negative weight gains of the other three series result partially from the fact that the actual cored bar sections were not measured prior to being cast into the slabs. The visual observations of the bars support the results of the weight loss tests which indicate that only the 9.6 series had undergone noticeable corrosion. Figure 41 presents all nine of the bars removed from the 1.2, 2.4, and 4.8 series as well as one of the bars removed from the 9.6 series. In the photograph, no appreciable signs of corrosion are noticed on any of the bars except for the 9.6 series which the weight loss tests indicate the presence of corrosion. Figure 42 presents a microscope photograph of the surface of the steel for one of the bars in the 4.8 series. It can be seen that the surface is free of any corrosion products.

#### **4.2.2 Equivalent Corrosion Rate from Weight Loss**

Faraday's First Law, which states that the metal loss per unit of time is proportional to the corrosion current. The weight loss may be converted to a corrosion rate having units of mass loss per area times time. This corrosion rate may be converted to a corrosion rate density having units of current per unit area ( $\text{mA}/\text{ft}^2$  or  $\mu\text{A}/\text{cm}^2$ ).

ASTM G 1-90, Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens(34), presents the conversion from weight loss to a corrosion rate having units of mass per area times time. The corrosion rate is determined as in



equation 19:

$$\text{Corrosion Rate} = \frac{(K \times W)}{(A \times T \times D)} \quad \text{eq.19}$$

where K = a constant ( $3.45(10^6)$ ) for the corrosion rate in mills per year, W = mass loss in grams, A = area in  $\text{cm}^2$ , T = time of exposure in hours, D = density of steel =  $7.855 \text{ g/cm}^3$ , and corrosion rate is mills per year. For the weight loss of the OA2859.6 series, for a unit bar length of 1cm, the following factors are used: W = 0.1969 g (measured weight loss),  $A = 2\pi r L = 2 \times 3.14 \times (5/8) (0.5) (2.54) (1) = 4.99 \text{ cm}^2$ , T = 22 months ( $30.5 (24) = 16,104$  hours). Therefore the equivalent corrosion rate is 1.076 mills per year. Then, from Faraday's First Law, the actual average corrosion rate density based on the weight loss is  $2.185 \text{ mA/ft}^2$  for the OA2859.6 series. Since there was neither corrosion observed nor weight loss measured for the other series, the actual average corrosion rate density from all other series may be assumed to be  $0 \text{ mA/ft}^2$ .

#### 4.3 Measured Versus Actual Corrosion Rates

The average measured corrosion rates densities in Table 12 can now be compared to the actual average corrosion rate densities from the weight loss tests. It will be assumed that the OA2850.0 and the OA2850.6 series have no visible signs of

corrosion, since the OA2851.2 series and the OA2854.8 series showed extremely small evidence of corrosion. For the outdoor two inch cover depth series, the 3-LP and the Gecor average measured corrosion rate densities and the actual corrosion rate densities from the metal loss tests are presented in Table 15.

Table 15 - Measured and Actual Corrosion Rates

| Series | 3-LP Device                  |                            | Gecor Device                 |                            |
|--------|------------------------------|----------------------------|------------------------------|----------------------------|
|        | Measured, mA/ft <sup>2</sup> | Actual, mA/ft <sup>2</sup> | Measured, mA/ft <sup>2</sup> | Actual, mA/ft <sup>2</sup> |
| 0.0    | 0.71                         | 0                          | 0.046                        | 0                          |
| 0.6    | 0.88                         | 0                          | 0.049                        | 0                          |
| 1.2    | 1.09                         | 0                          | 0.070                        | 0                          |
| 2.4    | 1.33                         | 0                          | 0.096                        | 0                          |
| 4.8    | 3.77                         | 0                          | 0.267                        | 0                          |
| 9.6    | 7.77                         | 2.185                      | 0.403                        | 2.185                      |

As illustrated in Table 15 the 3-LP device measures a much higher corrosion rate density than what is actually observed from the weight loss tests in all series. Also, the Gecor device measures a corrosion rate density higher than what is observed up to the series in which corrosion had initiated, the OA2859.6 series, where it measures a much lower corrosion rate density. The only difference between the series is the amount of chloride ions added to the concrete. Since the average corrosion rate

increases as the amount of chloride ions increase, the relationship between the two needs to be investigated.

In most instances, the amount of chloride ions added to the concrete will not be known. Thus, the actual amount of chlorides must be measured using a standard laboratory test method. Table 16 presents the amount of chloride ions added to the concrete and measured in the concrete in Peterson's study(5) The laboratory test methods used were the Rapid Method(35), the Acid Soluble Method (ASTM C 114-88, Standard Test Method for Chemical Analysis of Hydraulic Cement)(36), and the Water Soluble Method (AASHTO T 260-84, Standard Method of Sampling and Testing for Total Chloride Ion in Concrete and Concrete Raw Materials)(37).

Table 16 - Chloride Ion Contents of Outdoor Specimens

| Series | Added Cl <sup>-</sup> , lbs/yd <sup>3</sup> | Measured Cl <sup>-</sup> , Rapid Soluble | Measured Cl <sup>-</sup> , Acid Soluble | Measured, Cl <sup>-</sup> , Water Soluble |
|--------|---|--|---|---|
| 0.0    | 0.0   | 0.00                                     | 0.00                                    | 0.00                                      |
| 0.6    | 0.6   | 0.64                                     | 0.62                                    | 0.07                                      |
| 1.2    | 1.2   | 1.34                                     | 1.69                                    | 0.49                                      |
| 2.4    | 2.4   | 2.52                                     | 2.40                                    | 1.32                                      |
| 4.8    | 4.8   | 5.66                                     | 5.48                                    | 3.47                                      |
| 9.6    | 9.6   | 11.47                                    | 8.29                                    | 7.94                                      |

In an attempt to explain why the measured corrosion rates and the observed

corrosion rates from the weight loss tests differ, the two were plotted against the chloride ion contents. The corrosion rate densities as a function of the added chloride ions and the three different measured chloride ions are presented in Figures 43-46. As shown, the relationships appear to be somewhat exponential in nature. Therefore, an attempt to describe the curves using exponential functions was made. But, this proved impossible because of the large number of observed corrosion rate densities from the weight loss tests that were zero in value. Other types of regression techniques were employed and a second order polynomial best described the relationship between the corrosion rate densities and the chloride contents.

As observed in Figures 43-46, it is clear that both the measured and the observed corrosion current densities increase with increasing chloride ion content, irregardless of the manner in which the amount of chloride was determined. It follows that the precision of the corrosion rate devices may be increased by accounting for the chloride ion content of the concrete. In this study, the chloride ions were added at the time of mixing. Also, there is no way of knowing the chloride ion content at the actual surface of the steel which is undergoing corrosion. Nonetheless, the measured chloride ion contents at the bar level, which are often used to determine the likelihood of the initiation of corrosion, may also be used in an attempt to determine whether the measured corrosion rate is a function of the chloride ion content.

The following formulas in Table 17 provide a way in which the actual corrosion rate may be determined by knowing the measured corrosion rate and the

chloride ion concentration in the concrete. The equations should be used with caution, since only six different chloride contents provide information on the corrosion rates in this study. For the equations, the adjusted R-squared values of the regression are provided. These values, which are high, indicate that the models describe most of the variability in the data. Again, they must be considered with caution, since this is a limited study.

Table 17 - Actual Corrosion Rates as a Function of the Measured Corrosion Rates and the Chloride Ion Content

| Chloride Type, C (lbs/yd <sup>3</sup> ) | 3-LP Actual Corrosion Rate, mA/sqft          | R <sup>2</sup> -Adj | GECOR Actual Corrosion Rate, mA/sqft        | R <sup>2</sup> -Adj |
|---|--|---------------------|---|---------------------|
| Added                                   | $0.29 - 0.051C + 0.055C^2 - 0.35(I_{corr})$  | 99.5                | $0.20 - 0.010C + 0.040C^2 - 4.01(I_{corr})$ | 99.                 |
| Rapid                                   | $0.33 - 0.0011C + 0.038C^2 - 0.41(I_{corr})$ | 99.7                | $0.21 + 0.025C + 0.026C^2 - 4.49(I_{corr})$ | 99.                 |
| Acid                                    | $-1.78 - 0.32C - 0.19C^2 + 2.54(I_{corr})$   | 87.3                | $0.75 + 0.078C + 0.11C^2 - 16.6(I_{corr})$  | 99.                 |
| Water                                   | $0.24 + 0.022C + 0.063C^2 - 0.28(I_{corr})$  | 99.8                | $0.19 + 0.080C + 0.046C^2 - 3.81(I_{corr})$ | 99.                 |

The term  $i_{corr}$  in the above formulas is the measured corrosion rate in mA/ft<sup>2</sup>. Since the above formulas are second order polynomials, it is possible to predict negative actual corrosion rates when the measured corrosion rates are low. A small negative actual corrosion rate should be considered as a condition when corrosion is not occurring. For the first equation which predicts for the 3-LP device as a function

of the added chloride content and the measured corrosion rate, Table 18 shows the following predictions of the actual corrosion rate. Also, the 95% prediction intervals are given, which indicates that one can be 95% confident that the value of any future actual corrosion rate at that given chloride content will be contained within that interval.

Table 18 - Predicted Corrosion Rates and 95% Prediction Intervals

| Added Cl <sup>-</sup> Content lbs/yc <sup>3</sup> | Predicted <i>i</i> <sub>corr</sub> , mA/sqft | 95% P.I.     |
|---|--|--------------|
| 0.0   | 0.049  | (-0.29,0.39) |
| 0.6   | -0.021                                       | (-0.33,0.29) |
| 1.2   | -0.065                                       | (-0.37,0.24) |
| 2.4   | 0.028  | (-0.35,0.40) |
| 4.8   | 0.012  | (-0.37,0.39) |
| 9.6   | 2.18   | (1.80,2.57)  |

For the first five series, the predicted value is close to the actual value of zero, even though some of the predictions are negative. For the last series, the predicted value of 2.18 mA/ft<sup>2</sup> closely predicts the observed value of 2.185 mA/ft<sup>2</sup>.

#### 4.4 Observed Versus Predicted Time to Cracking

##### **4.4.1 Observed Cracking**

The OA2859.6 series were visibly cracked 22 months after being cast. The

cracking appeared as a fine crack directly above and parallel with the bars, see Figure 47. The surface had been wetted with water in order to contrast the crack. Within two weeks, cracks were noticed above 13 of the 15 total bars which comprise the series. The cracks grew rapidly until they spanned the entire length of the bars. However, the cracks did not widen. Instead, cracks which at one point appeared open on the surface would, within approximately 3 weeks, appear closed with a white solid filling the crack, possibly hydration of unused cement grains or carbonation products. The solid which filled the cracks is shown in Figure 48.

It is believed that the lack of live loading on the specimens allows for the cracks to, in effect, heal themselves. This phenomenon is known to exist, especially in massive structures, where microfractures may be healed due to the autogenous hydration of unhydrated cement grains in the presence of excess water(14).

Three cores were taken from the series. A close visual inspection showed that the mode of cracking included cracks directly above the bar and the beginning of delamination cracking extending horizontally from the middle of each side of the bar. The delamination cracking did not extend to the adjacent bars. Also, none of the cracks clearly created a plane which completely separated the adjacent surfaces of concrete. The cracking plane appeared interrupted by areas of solid concrete; nonetheless, the cracking was sufficient to create a continuous crack on the surface of the concrete. Again, the lack of live loading may help to explain why the plane did not appear visually continuous to the unaided human eye.

The reinforcing steel bars were then removed and photographed under a microscope. The seldom encountered characteristic of the corrosion products on the reinforcing steel was the presence of green rust, as shown in Figure 49. This gel type substance would rapidly react with the oxygen in the air to create a solid substance, possibly akagenite, while giving off an orange colored watery substance which was tested and found to have a pH of approximately 5. The low pH supports the presence of green rust. Green rust, which is known to be soluble in water, has the capacity to move away from the surface of the steel and chemically change to an expansive product elsewhere in the concrete. This appears to be the case because the presence of corrosion products were observed with the unaided eye and the microscope in cracks and voids as far as 2.5 in. away from the surface of the steel.

Most of the corrosion products appeared on the top half of the bars. However, some corrosion products did appear near voids on the underside of the reinforcing steel, as shown in Figure 50. Most of these products were soft and did not completely fill the voids. Since they did not completely fill the voids, they did not contribute any pressure which lead to the cracking. But, they will still contribute to the weight loss of the steel reinforcing bars.

Corrosion products ranging from orange to red to black appeared on the surface of the reinforcing steel, in cracks, and in voids. The presence of such different types of corrosion products found in so many different locations, as shown in Figure 51, indicates that not all metal loss will create products which will cause expansive forces



at the surface of the reinforcing steel. And, the different types of corrosion products will cause different magnitudes of expansive forces.

At the time of first cracking, the concrete ohmic resistance was lower than the preceding months. Measurements taken during the month in which first cracking occurred indicate an average concrete ohmic resistance of 0.5 kilo-ohms while the average concrete ohmic resistance for the three preceding months was 1.0 kilo-ohms. However, the temperature of the concrete during the month which first cracking occurred was 93.0 degrees fahrenheit, which is much higher than the concrete temperature during any of the three preceding months. Since concrete ohmic resistance is a function of the temperature of the concrete and the moisture content of the concrete, and moisture content of the concrete is not known, it is difficult to conclude that the change in concrete ohmic resistance is due to the first cracking.

#### **4.4.2 Predicted Cracking**

The average measured corrosion rates for the two corrosion rate devices was used in order to predict when cracking should occur according to Bazant's equations(4 ). The average measured corrosion rates of 7.77 mA/sqft and 0.403 mA/sqft for the 3-LP and the Gecor devices respectively are first converted to the units g/(cm<sup>2</sup>days). The conversion, from ASTM G 1-90, Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens(3), follows in equation 20:

Therefore,  $1 \text{ mA/ft}^2 = 2.6923(10^{-5})\text{g}/(\text{cm}^2\text{days})$ , and the average corrosion rate

$$1 \text{ mA/ft}^2 \frac{0.4297 \text{ mpy}}{1 \text{ mA/ft}^2} \frac{1(10)^4(7.855) \text{ g/m}^2 \text{ h}}{3.45(10^6) \text{ mpy}} \frac{1 \text{ m}^2}{100^2 \text{ cm}^2} \frac{24 \text{ hour}}{1 \text{ day}} \text{ eq.20}$$

densities of  $7.77 \text{ mA/ft}^2$  and  $0.403 \text{ mA/ft}^2$  are equivalent to  $2.09(10^{-4}) \text{ g/(cm}^2 \text{ Days)}$  and  $1.09(10^{-5}) \text{ g/(cm}^2 \text{ Days)}$ .

The following parameters are used for the OA2859.6 series:  $D = 1.59 \text{ cm}$ ,  $L = 5.08 \text{ cm}$ ,  $s = 20.32 \text{ cm}$ ,  $f' t = 3.45 \text{ MPa}$ ,  $E = 2.07(10^4) \text{ MPa}$ ,  $\nu = 0.18$ ,  $E_{ef} = E/(1 + \phi_{cr})$ , and  $\phi_{cr} = 2$ . Therefore, the bar hole flexibility,  $\delta_{pp}$ , is equal to  $2.79(10^{-4}) \text{ cm/MPa}$ . Since the spacing  $s = 20.32 \text{ cm} > 6D = 6(1.59) = 9.54$ , Bazant predicts inclined cracking, and the limiting value of  $\Delta D$  is equal to  $6.15(10^{-3}) \text{ cm}$ . The predicted time to cracking,  $t_{cor} = \rho_{cor}(D)(\Delta D)/[s(jr)]$ , is then equal to 8 days for the 3-LP device and 161 days for the Gecor device. A much longer time to cracking equal to approximately 671 days was observed.

The actual corrosion rate obtained from the weight loss test may also be used to predict cracking using Bazant's formulas. The average corrosion rate density from the metal loss test for the OA2859.6 series of  $2.185 \text{ mA/ft}^2$  is equal to  $5.88(10^{-5}) \text{ g/(cm}^2 \text{ Days)}$ . The geometry dictates that the bar hole flexibility and the limiting value for the change in diameter will be the same. Therefore, the predicted time to cracking will be 30 days. This value, too, is much lower than the observed 671 days.

#### 4.5 Modifications to the Time to Cracking Equations

As presented in the previous section, Bazant's equations for the prediction of the time to cracking due to the expansive corrosion products underestimates the observed time to cracking. When using the corrosion rate obtained from the weight loss data, the equations predict cracking to occur 22 times earlier than observed. In order to explain such a large discrepancy, the equations were closely investigated. This investigation revealed that the equations were being used incorrectly in two different ways.

First, the term Bazant uses for the rate of corrosion,  $j_r$ , has been found to be comprised of different units than the  $i_{\text{corr}}$  term obtained from today's corrosion rate devices. According to Bazant,  $j_r$  is the rate of rust production over an area equal to a unit length of the bar times the spacing of the bars. But,  $i_{\text{corr}}$ , the corrosion current density, which in the past has been used for  $j_r$ , is the corrosion current density for the surface area of one bar. Therefore, the area in an  $i_{\text{corr}}$  term must be converted to the equivalent area in the  $j_r$  term to use Bazant's equations as he presents them.

Second, a corrosion current density obtained from today's devices is converted to the rate of metal loss using Faraday's First Law. But, as noted above, the  $j_r$  term in Bazant's equations is the rate of rust production instead of the rate of metal loss. Thus, a second conversion is necessary in order to use an  $i_{\text{corr}}$  term in place of the  $j_r$  term.

To avoid having to perform two conversions for the  $i_{\text{corr}}$  term prior its use in Bazant's equations, the equations may be rewritten as a function of the metal loss

instead of as a function of the rust production. Bazant defines the mass of the steel consumed,  $M_{st}$ , to be equal to 0.523 times the mass of the rust which is produced,  $M_r$ , where 0.523 is equal to the molecular weight of the steel divided by the molecular weight of the rust assumed to be in the form  $Fe(OH)_3$ . Therefore, the increase in volume for a unit length of a bar in terms of  $M_{st}$  and the increase in the diameter  $D$  which is  $\Delta D$ , as presented by Bazant, follows in equation 21(4):

$$\frac{M_{st}}{(0.523) \rho_r} - \frac{M_{st}}{\rho_{st}} = [(D + \Delta D)^2 - D^2] \frac{\pi}{4} \quad eq.21$$

Assuming the density of the rust,  $\rho_r$ , to equal the density of the steel,  $\rho_{st}$ , divided by four, the equation becomes equation 22:

$$M_{st} \frac{4}{\pi \rho_{st}} \left[ \frac{1}{0.523 / 4} - 1 \right] + D^2 = D^2 + 2 D \Delta D + (\Delta D)^2 \quad eq.22$$

With  $\Delta D$  being small compared to  $D$  and the density of the steel,  $\rho_{st}$ , being  $7.85 \text{ g/cm}^3$ , the equation becomes equation 23:

$$M_{st} (0.539) = D (\Delta D) \quad eq.23$$

The mass of the steel consumed per a unit length of a bar,  $M_{st}$ , can now be easily determined as a function of the  $i_{corr}$  term and the time over which corrosion has occurred,  $t_{cor}$ . In order to make  $i_{corr}$  the rate of metal loss per a unit length of a bar, it is multiplied by the circumference of the bar,  $\pi D$ . With  $i_{corr}$  in the units  $\text{g}/(\text{cm}^2\text{-days})$ , the equation becomes  $M_{st} = i_{corr} \times \pi D \times t_{cor}$ . Placing this relationship in the equation 23 (derived from Bazant's equations), Bazant's equation becomes

equation 24:

$$i_{cor} \pi D t_{cor} 0.539 = D (\Delta D) \quad eq.24$$

Solving for the time to cracking,  $t_{cor}$ , and with the constant  $1 / (0.539 \times \pi) = 0.590 \text{ g/cm}^2 = \rho_{cor}$ , the revised Bazant equation is equation 25:

$$t_{cor} = \rho_{cor} \frac{\Delta D}{i_{cor}} \quad eq.25$$

The revised Bazant equation can now be used to check the predicted time to cracking from the observed time to cracking of the OA2859.6 series by using its equivalent corrosion rate from the metal loss test. However, since the observed mode of cracking was different than the predicted mode of cracking, the critical value of  $\Delta D$  will be different. The two modes, shown in Figure 45, are presented with the corresponding equilibrium of forces. The critical value of  $\Delta D$  for the observed case is equal to  $9.23(10^{-3}) \text{ cm}$ . This value and the corrosion rate of  $2.185 \text{ mA/ft}^2$  which equals  $5.88(10^{-5}) \text{ g/(cm}^2 \text{ - days)}$  provides a predicted time to cracking equal to 93 days, which is 7 times shorter than the observed 671 days. Before the modifications were made to Bazant's equations, they predicted a time to cracking which was 22 times shorter than the observed time to cracking.

Even after modifying Bazant's equations for today's corrosion rate devices, the predicted time to cracking underestimates the observed time to cracking. Nonetheless, inspection of the corroded bars and the surrounding concrete indicates that this should be the case. In the equations, Bazant assumes that the corrosion products will occupy

a volume approximately 7.6 times the volume of the steel which was consumed to produce the corrosion products. This value is obtained from the fact that a unit mass (1 g) of steel will be converted to  $1/0.523 = 1.9$  g of corrosion products. Since the corrosion products have a density equal to  $1/4$  the density of the steel, the volume of corrosion products will be  $(1.9 \text{ g}) / (1/4 \text{ g/cm}^3) = 7.6 \text{ cm}^3$ . Also, all of the corrosion products will produce expansion on the surrounding concrete. Clearly, from inspection of the bars, not all of these requirements will be met.

As evident from the corrosion products found as far as 2.5 inches away from the surface of the reinforcing steel, many corrosion products are likely to migrate away from the surface of the reinforcing steel. The presence of the green rust supports this reasoning. Also, many corrosion products, especially those on the bottom of the steel reinforcing bars, formed in voids where they could cause no pressure to the concrete.

A further modification of Bazant's equations is necessary to account for the fact that not all of the corrosion products will produce expansive forces to the surrounding concrete. Since only one series of specimens has cracked, determining the term in the equations which must be modified will be difficult. If there were more than one series of specimens which had cracked, then the term needing modification may become more apparent. A logical way to modify the equations is to back calculate with the observed time to cracking and the equivalent corrosion rate from the weight loss tests to determine the actual density of the corrosion products which satisfy the solution. It was found that if the density of the corrosion products,  $\rho_r$ , is taken to equal the

density of steel,  $\rho_{st}$ , then the equations provide the observed time to cracking. The equation would then appear as follows in equation 26:

$$t_{cor} = \rho_{cor} \frac{\Delta D}{i_{cor}} \quad eq.26$$

Where  $\rho_{cor} = 4.28 \text{ g/cm}^2$ .

# IA2850.0 Corrosion Rate Profile

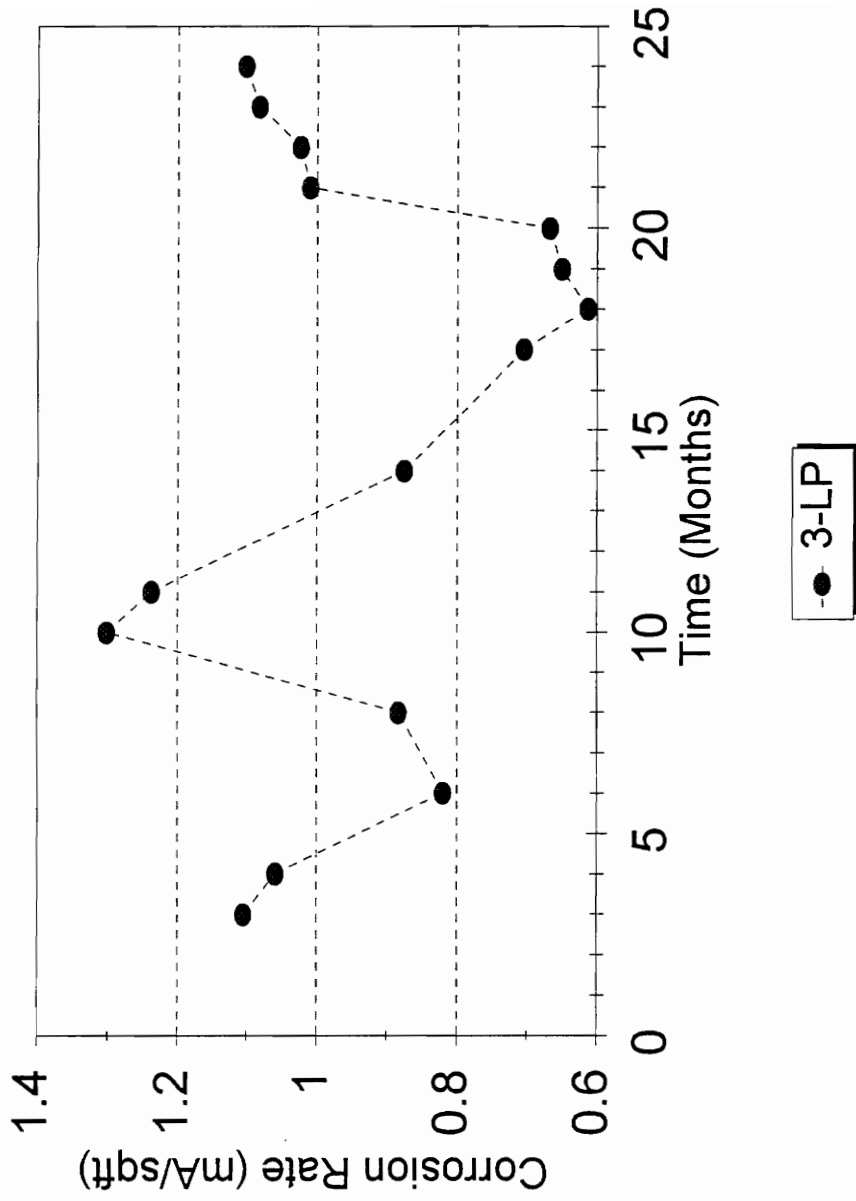


Figure 10 - IA2850.0 Corrosion Rate Profile



# IA2850.0 Corrosion Rate Profile

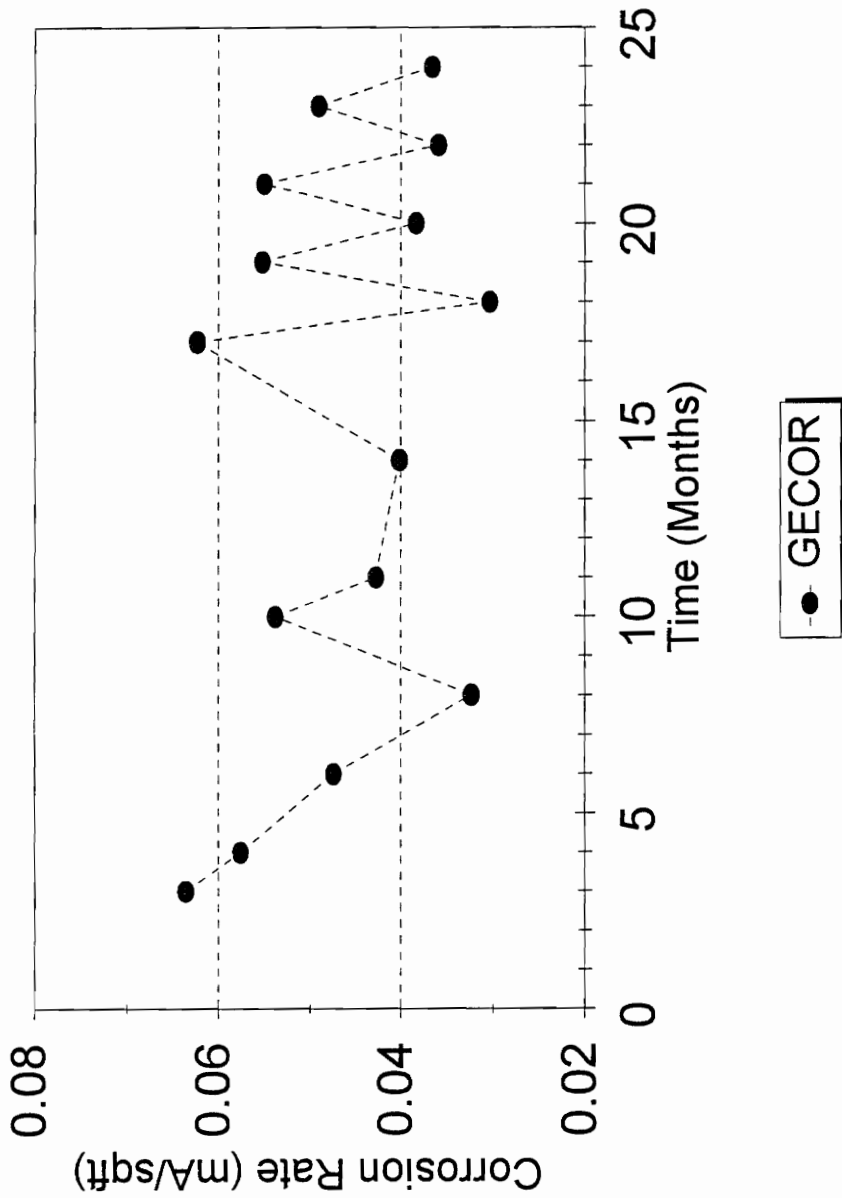


Figure 11 - IA2850.0 Corrosion Rate Profile

# IA2850.6 Corrosion Rate Profile

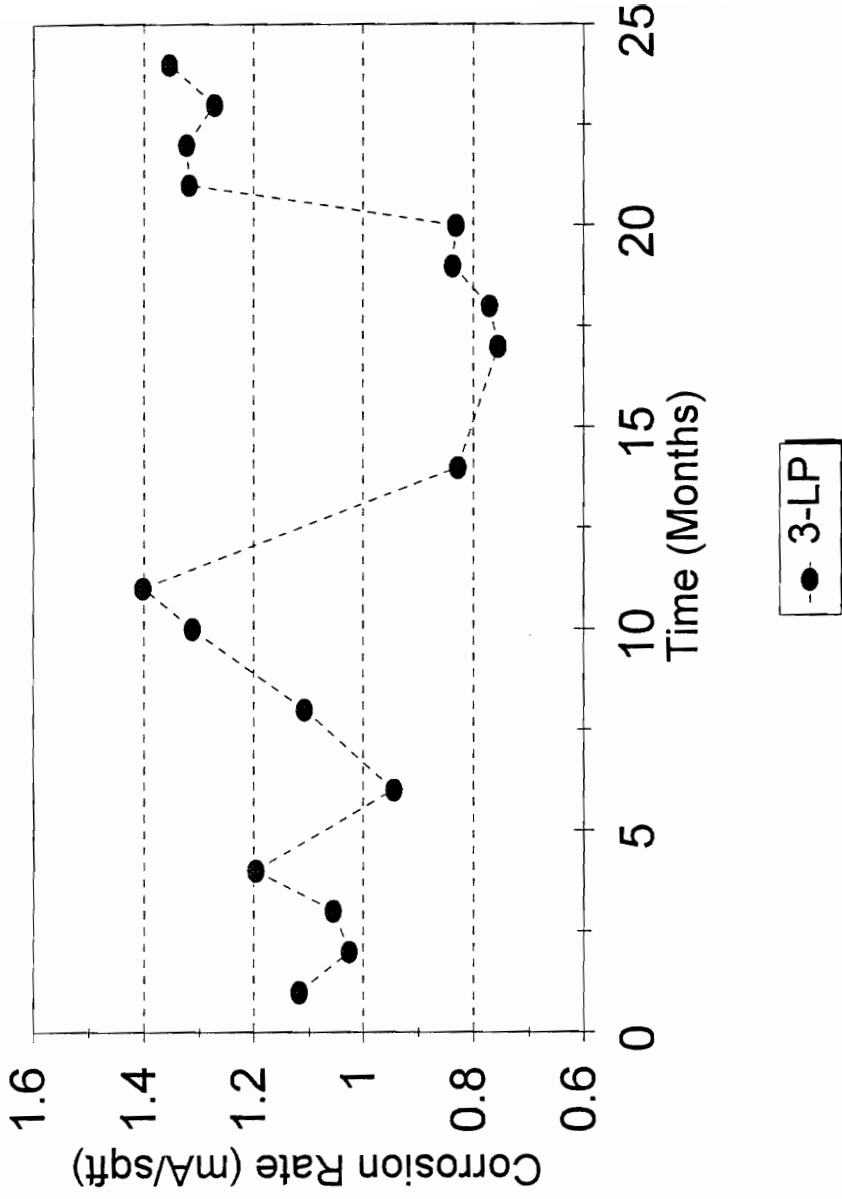


Figure 12 - IA2850.6 Corrosion Rate Profile

# IA2850.6 Corrosion Rate Profile

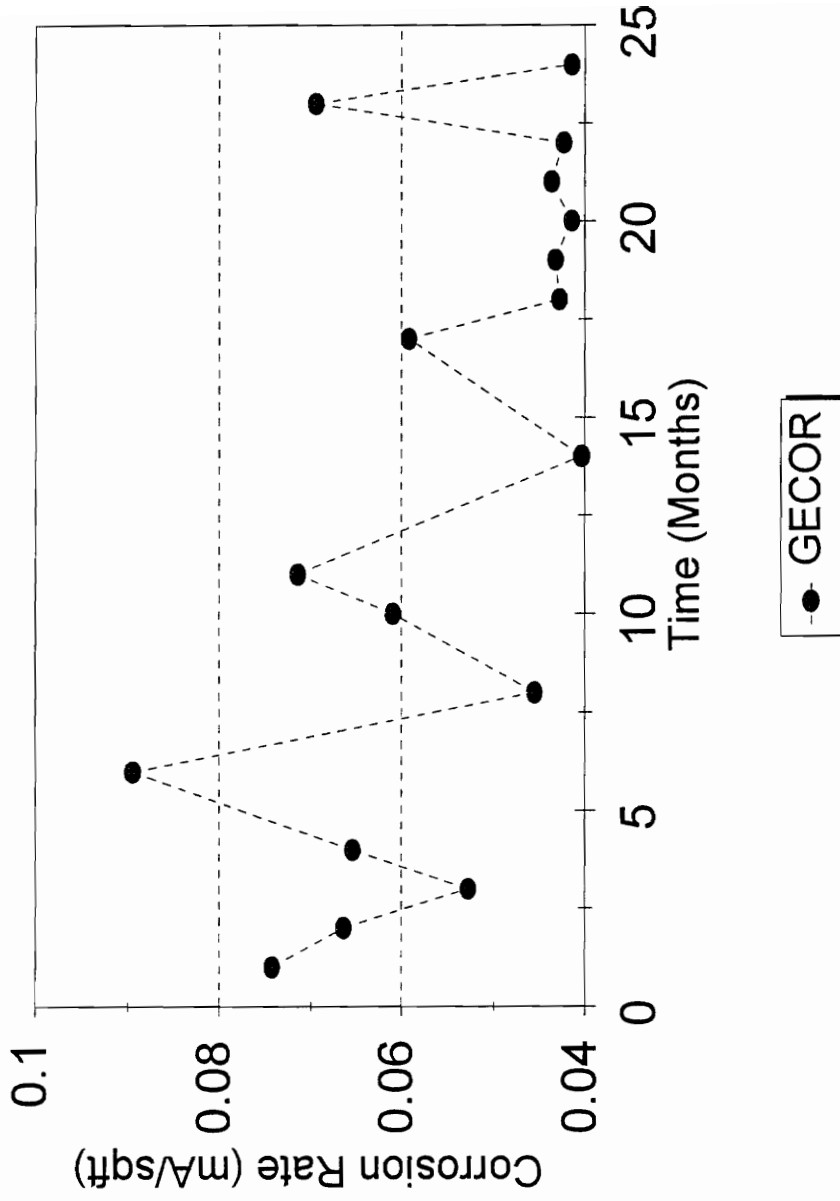


Figure 13 - IA2850.6 Corrosion Rate Profile

# IA2851.2 Corrosion Rate Profile

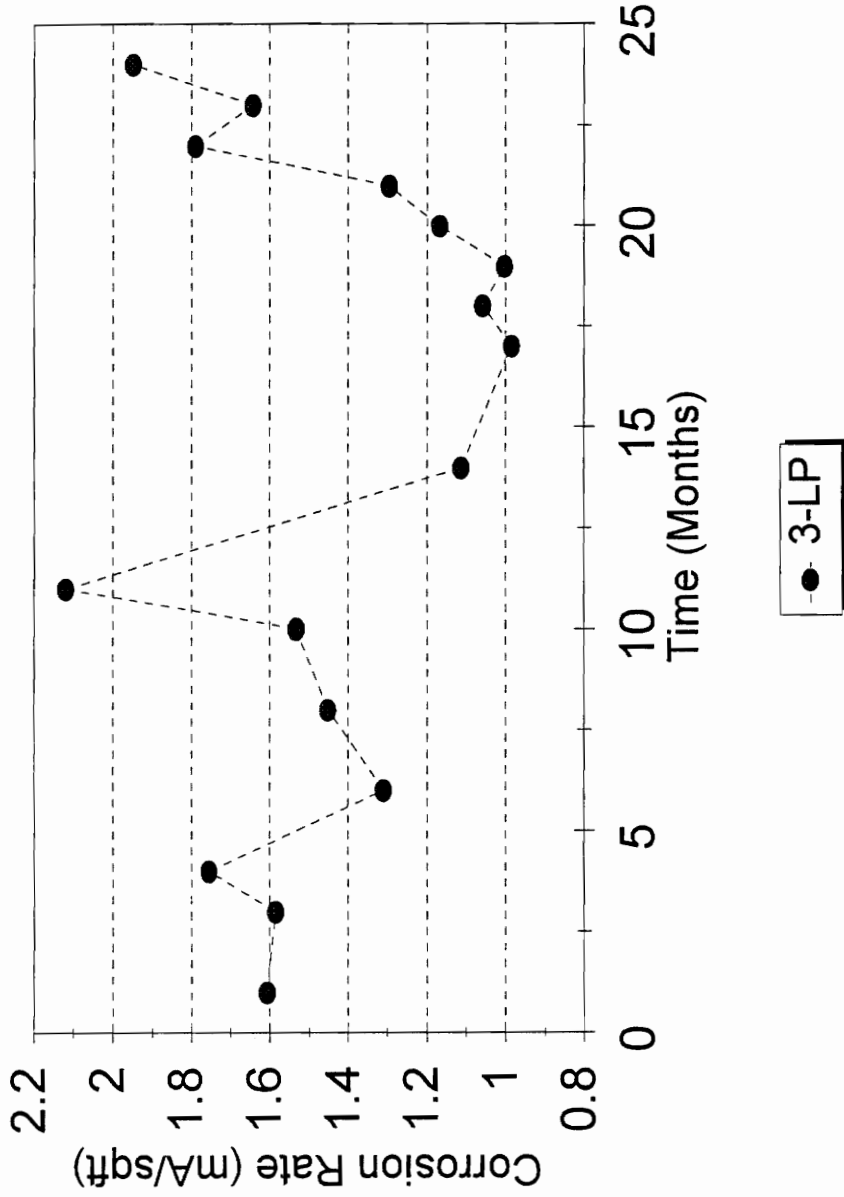


Figure 14 - IA2851.2 Corrosion Rate Profile

# IA2851.2 Corrosion Rate Profile

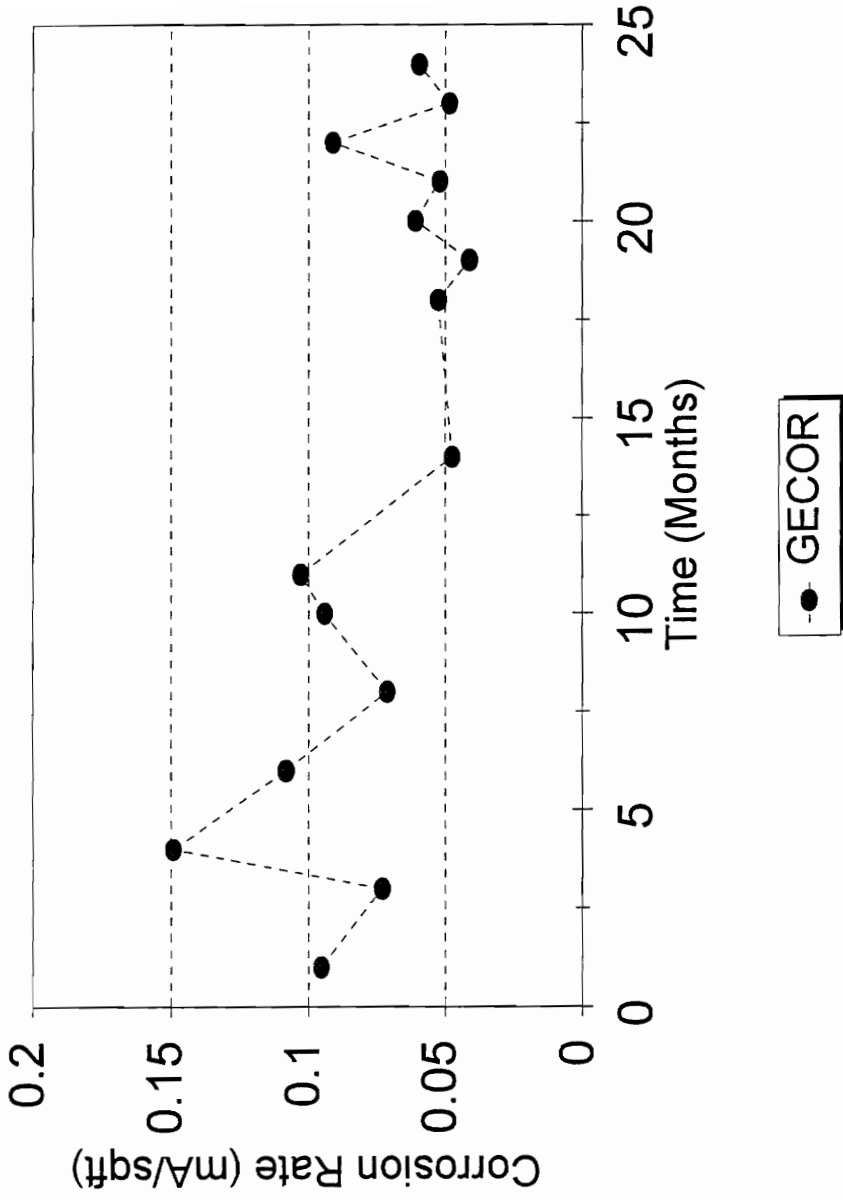


Figure 15 - IA2851.2 Corrosion Rate Profile

# IA2852.4 Corrosion Rate Profile

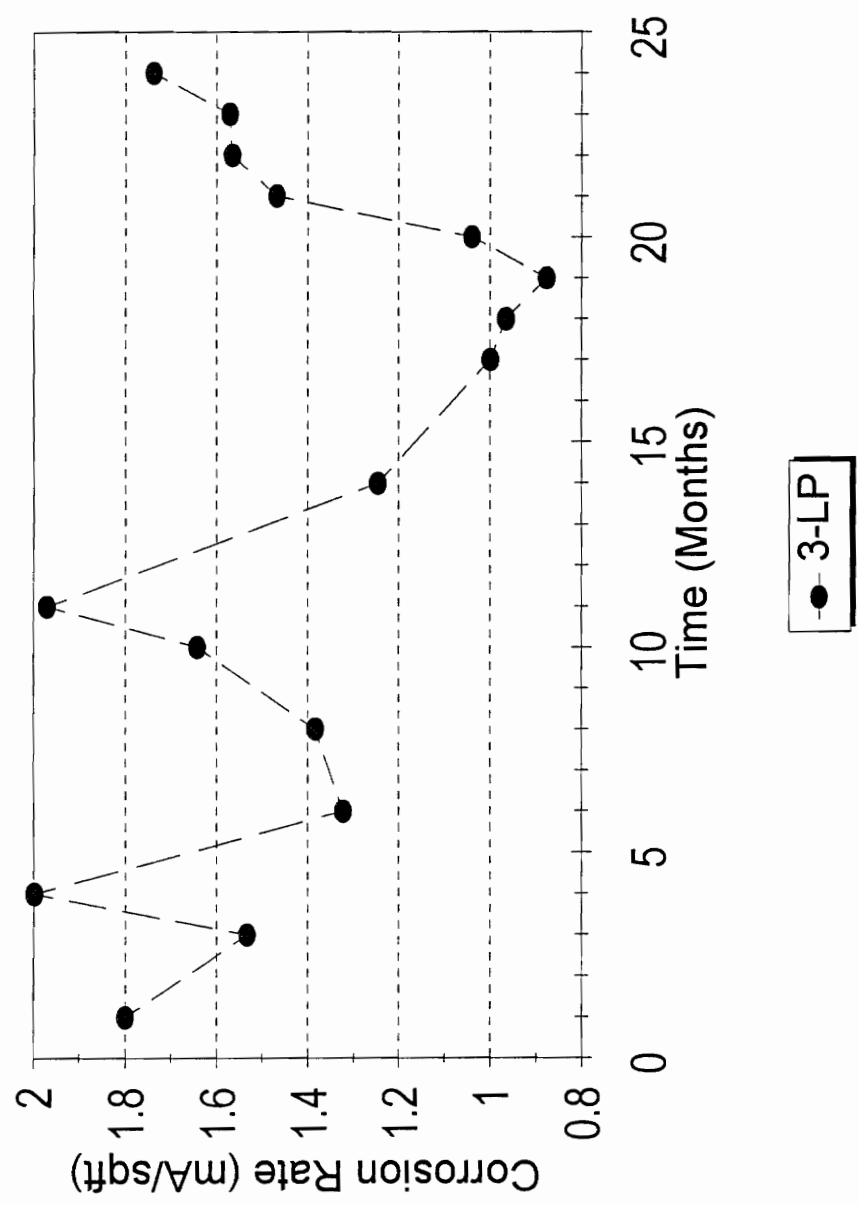


Figure 16 - IA2852.4 Corrosion Rate Profile

# IA2852.4 Corrosion Rate Profile

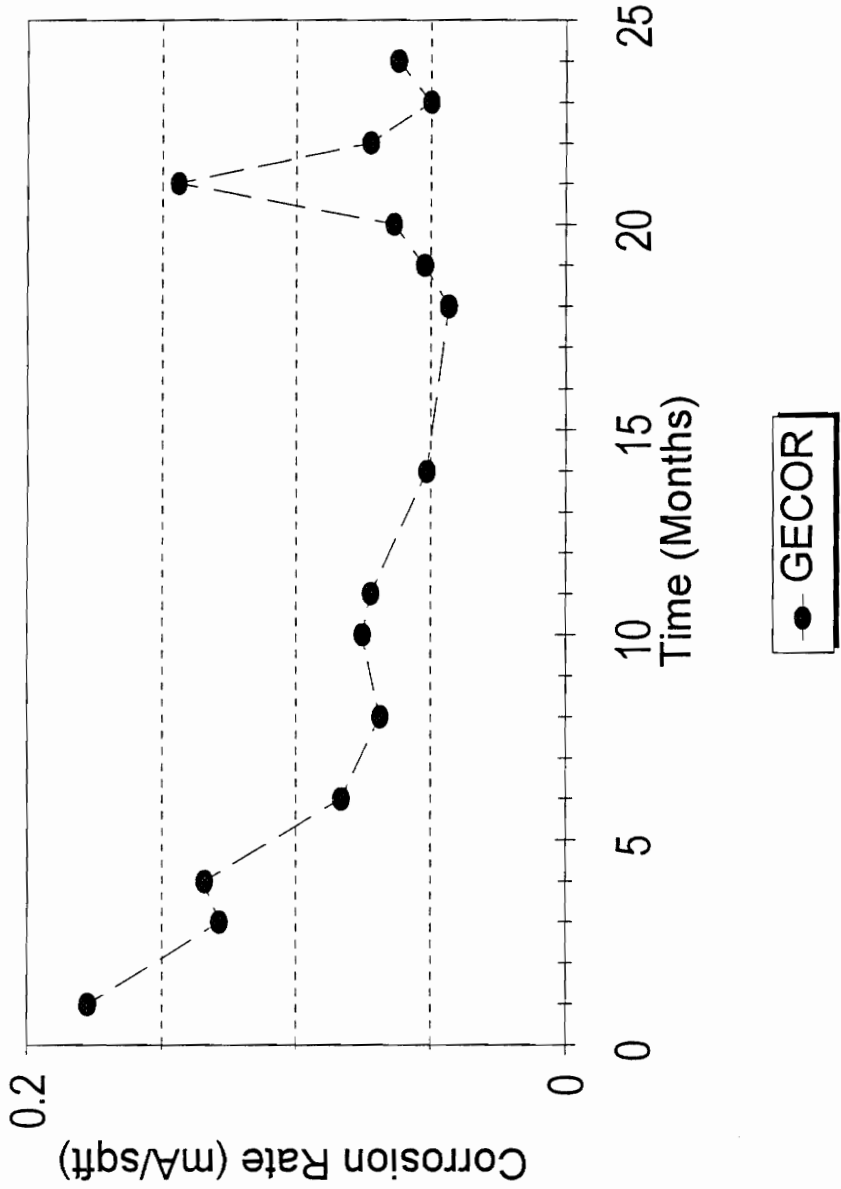


Figure 17 - IA2852.4 Corrosion Rate Profile

# IA2854.8 Corrosion Rate Profile

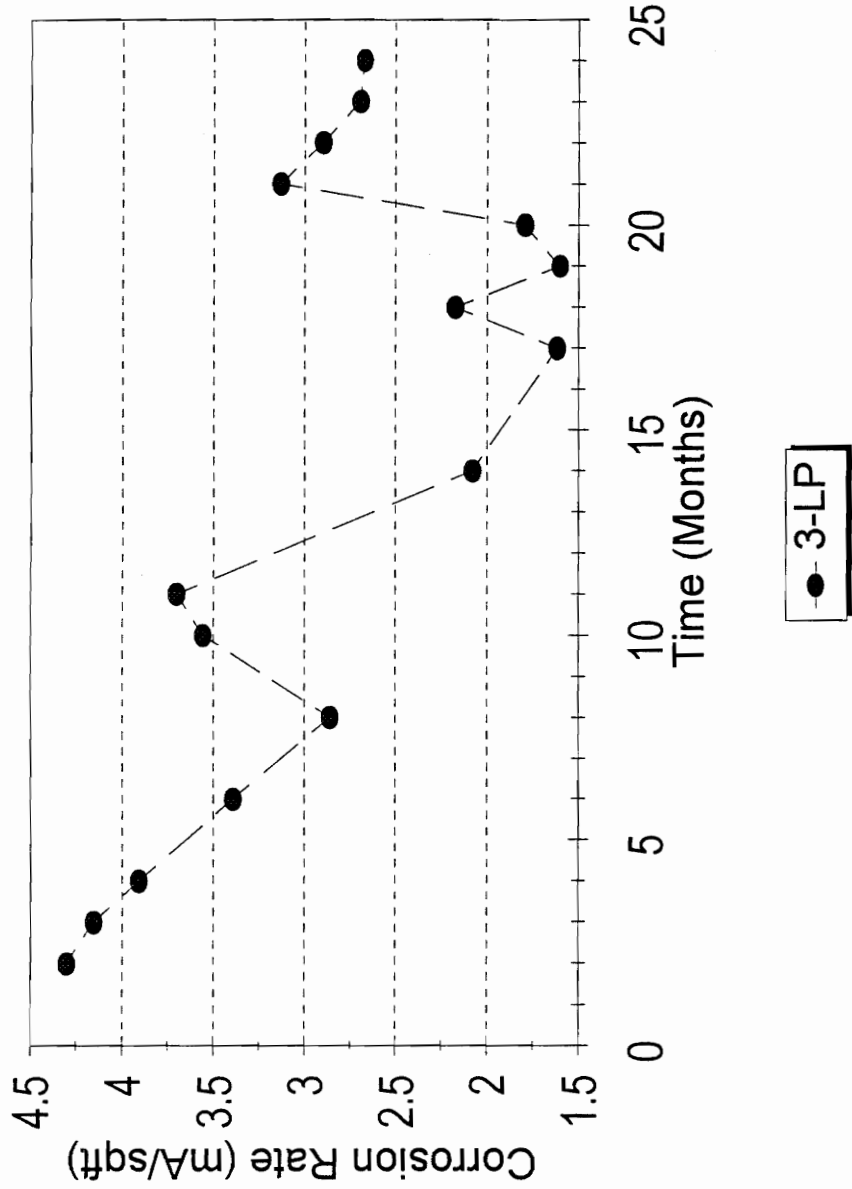


Figure 18 - IA2854.8 Corrosion Rate Profile



# IA2854.8 Corrosion Rate Profile

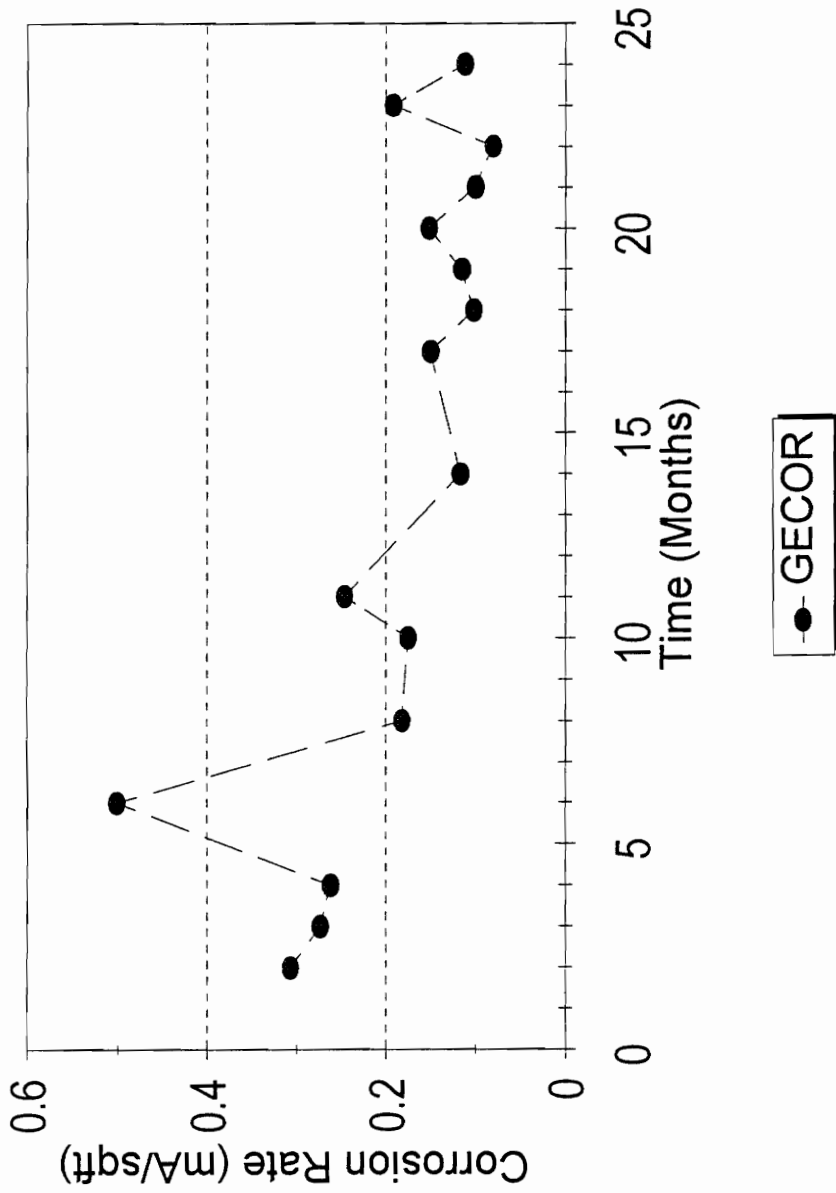


Figure 19 - IA2854.8 Corrosion Rate Profile

# IA2859.6 Corrosion Rate Profile

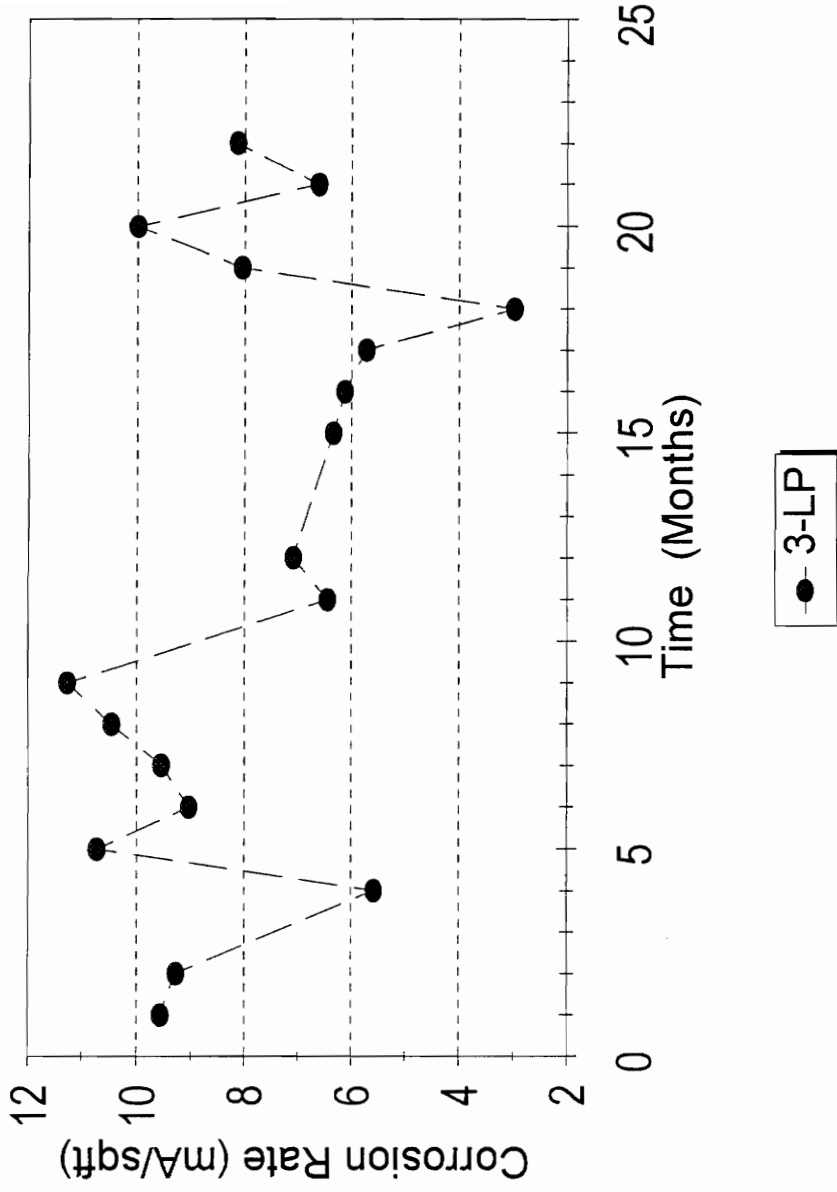


Figure 20 - IA2859.6 Corrosion Rate Profile

# IA2859.6 Corrosion Rate Profile

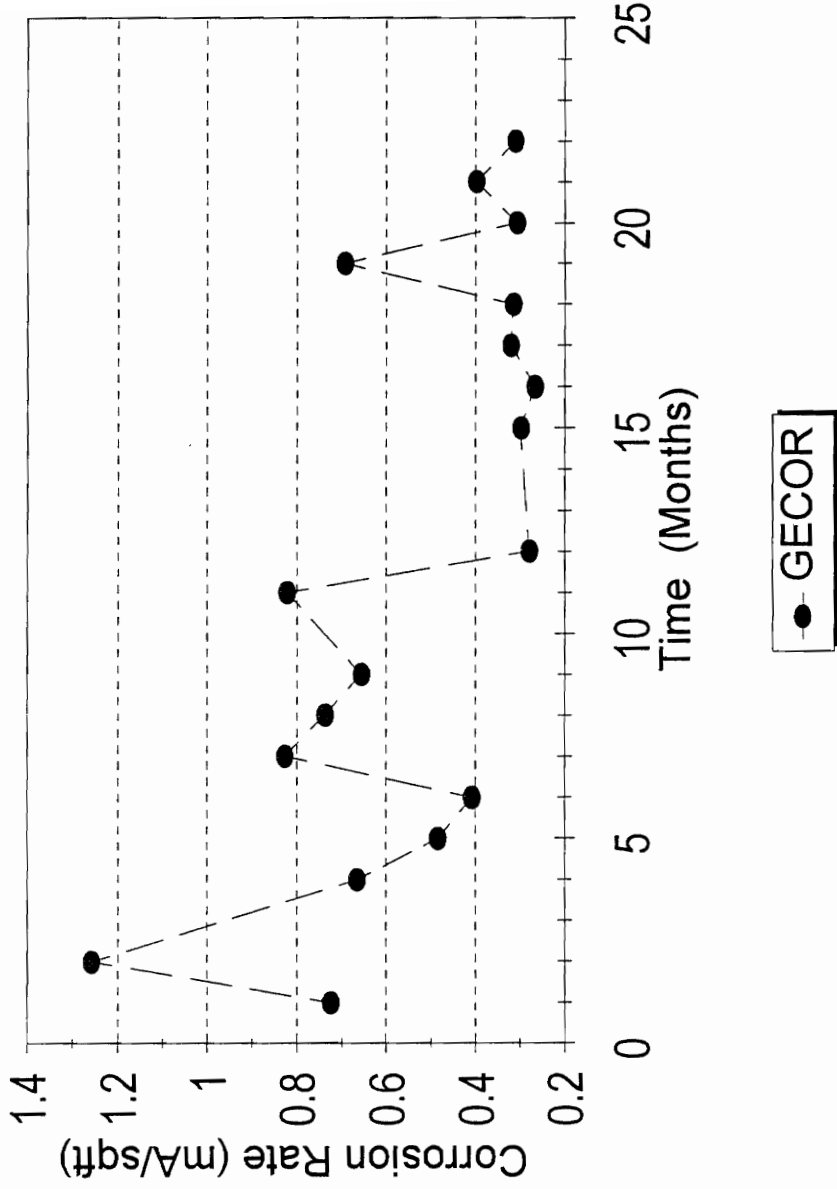


Figure 21 - IA2859.6 Corrosion Rate Profile

# OA2850.0 Corrosion Rate Profile

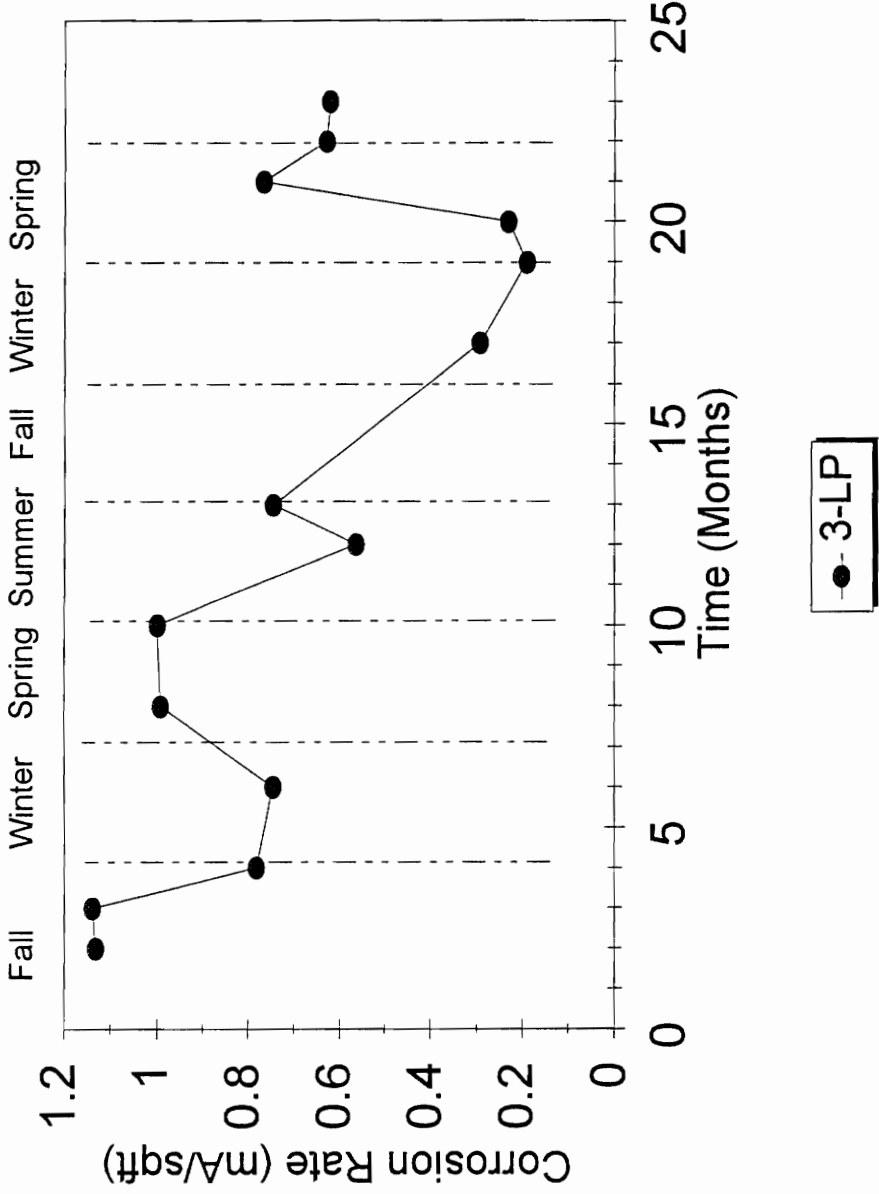


Figure 22 - OA2850.0 Corrosion Rate Profile

# OA2850.0 Corrosion Rate Profile

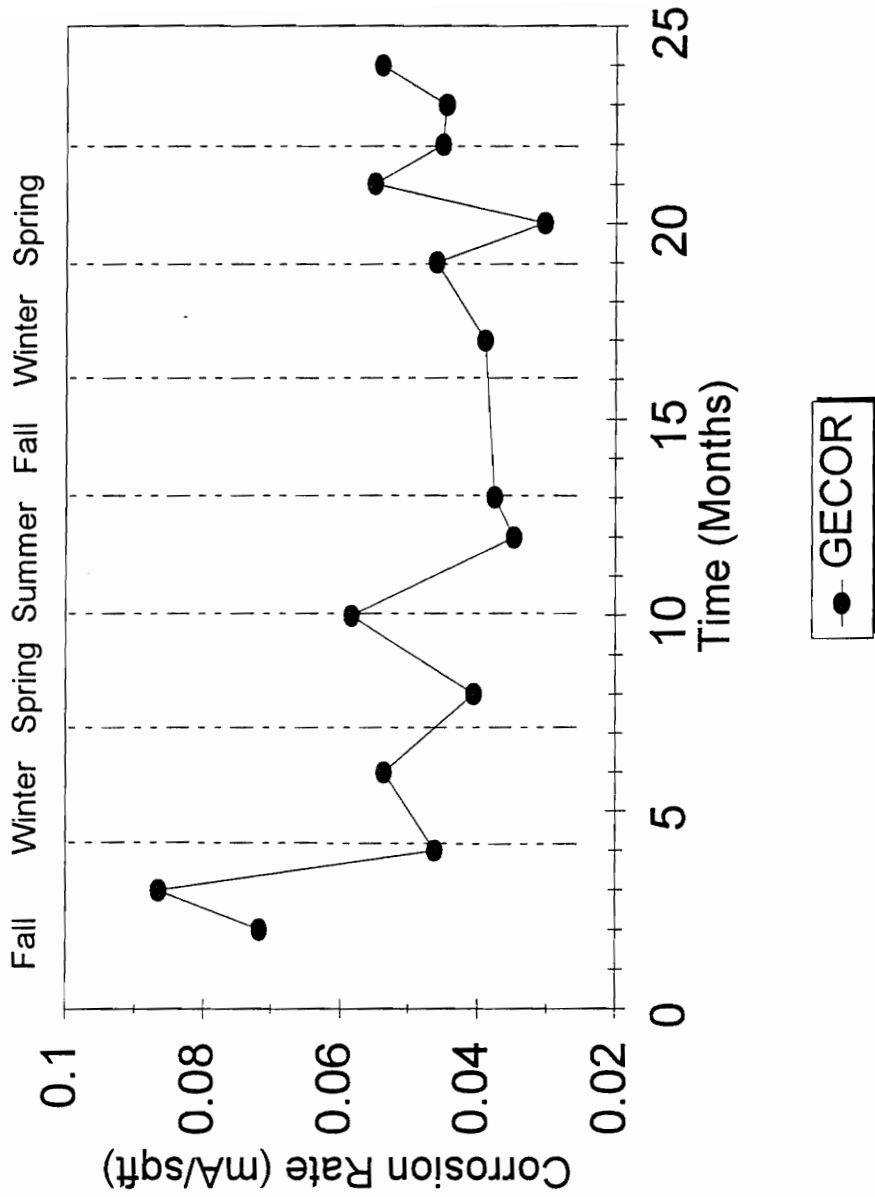


Figure 23 - OA2850.0 Corrosion Rate Profile

# OA2850.6 Corrosion Rate Profile

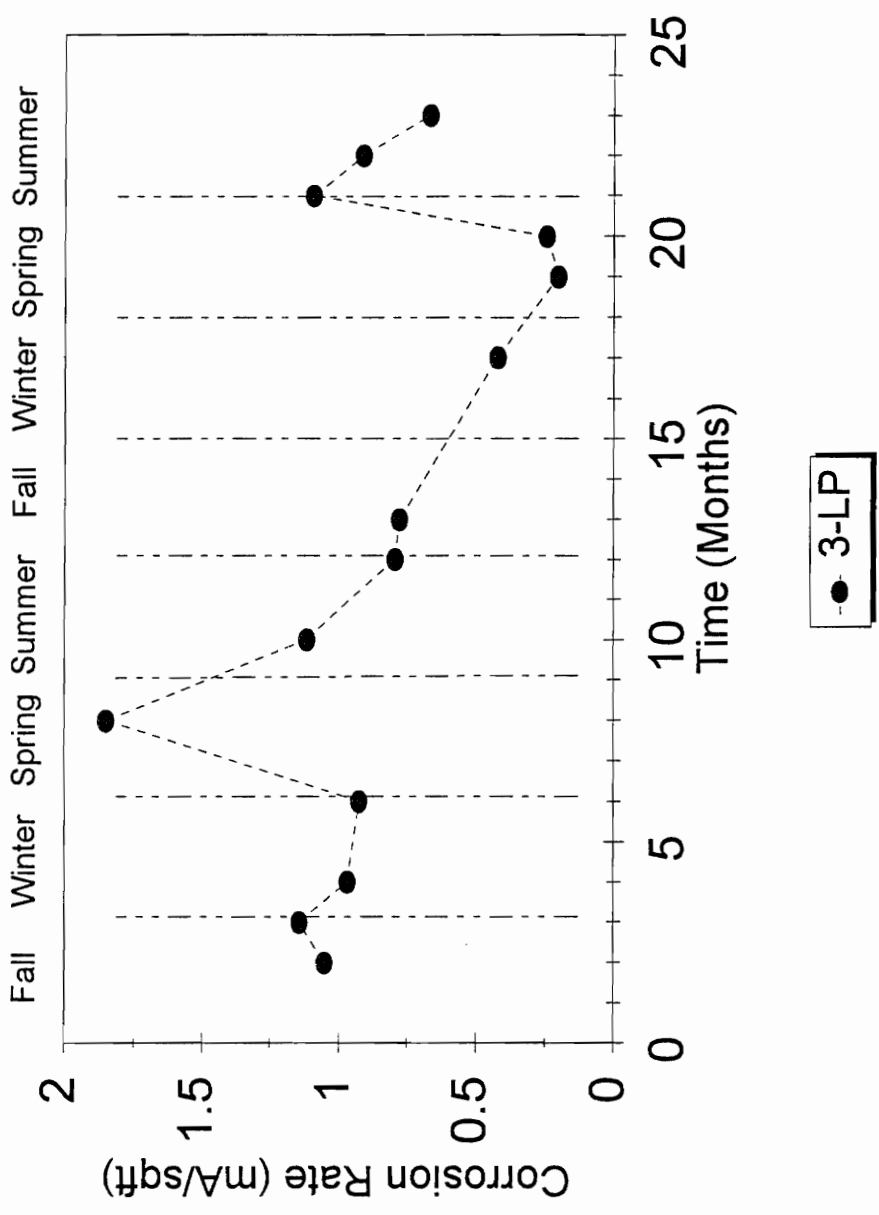


Figure 24 - OA2850.6 Corrosion Rate Profile

# OA2850.6 Corrosion Rate Profile

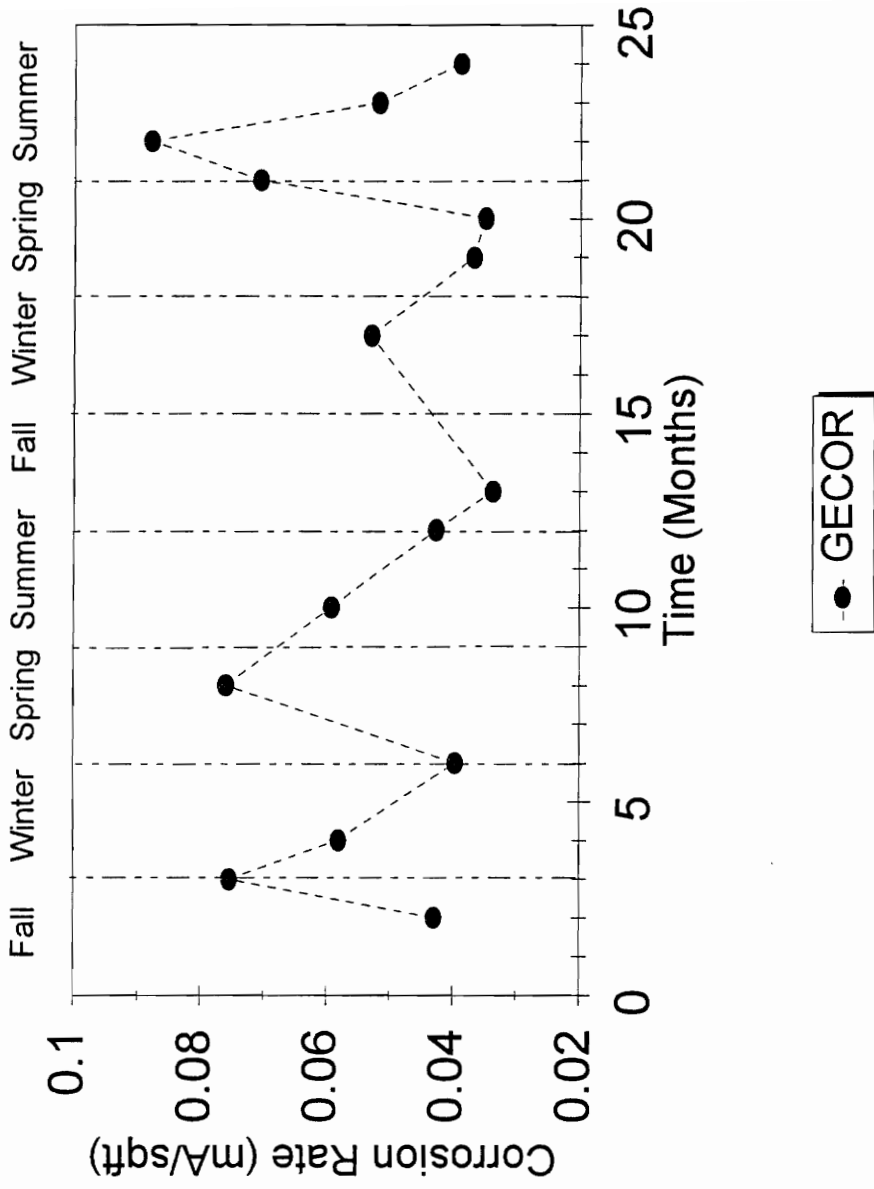


Figure 25 - OA2850.6 Corrosion Rate Profile

# OA2851.2 Corrosion Rate Profile

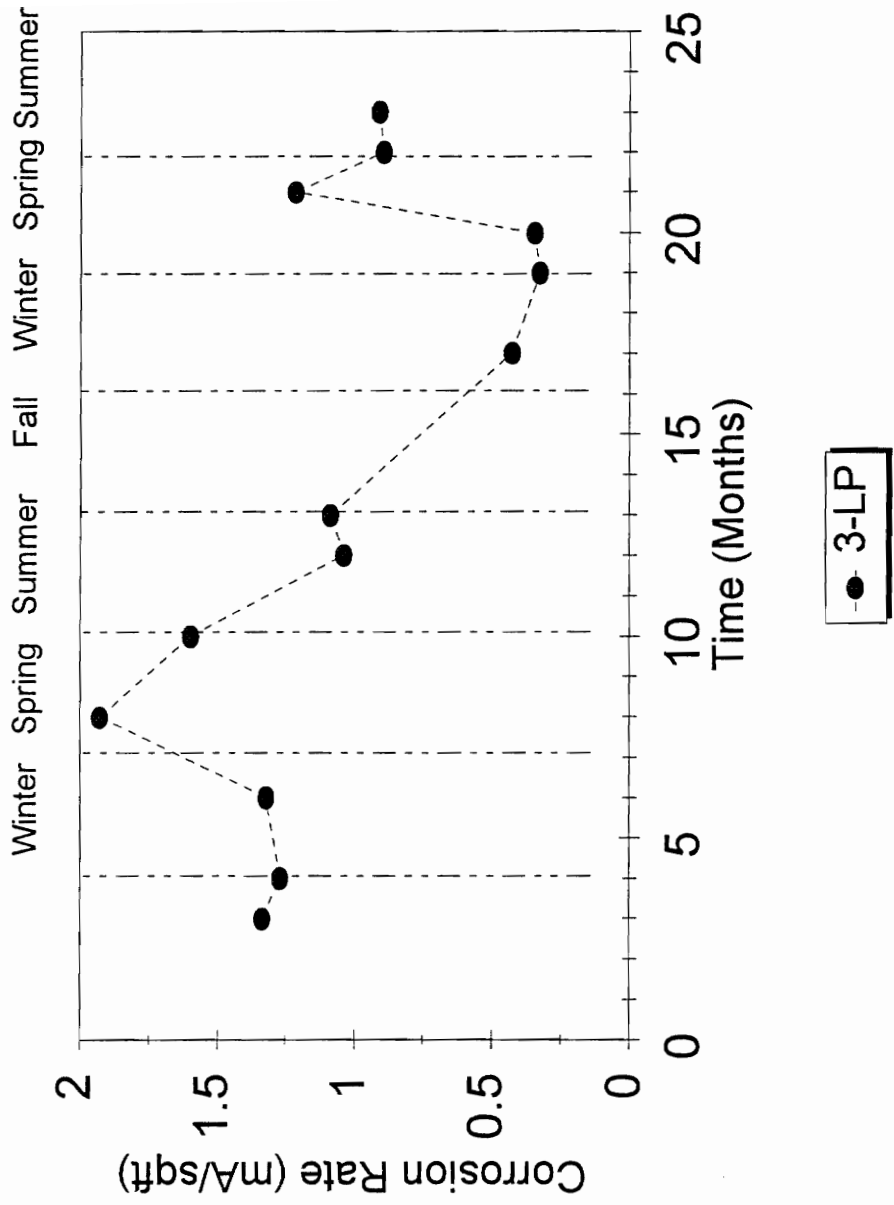


Figure 26 - OA2851.2 Corrosion Rate Profile



# OA2851.2 Corrosion Rate Profile

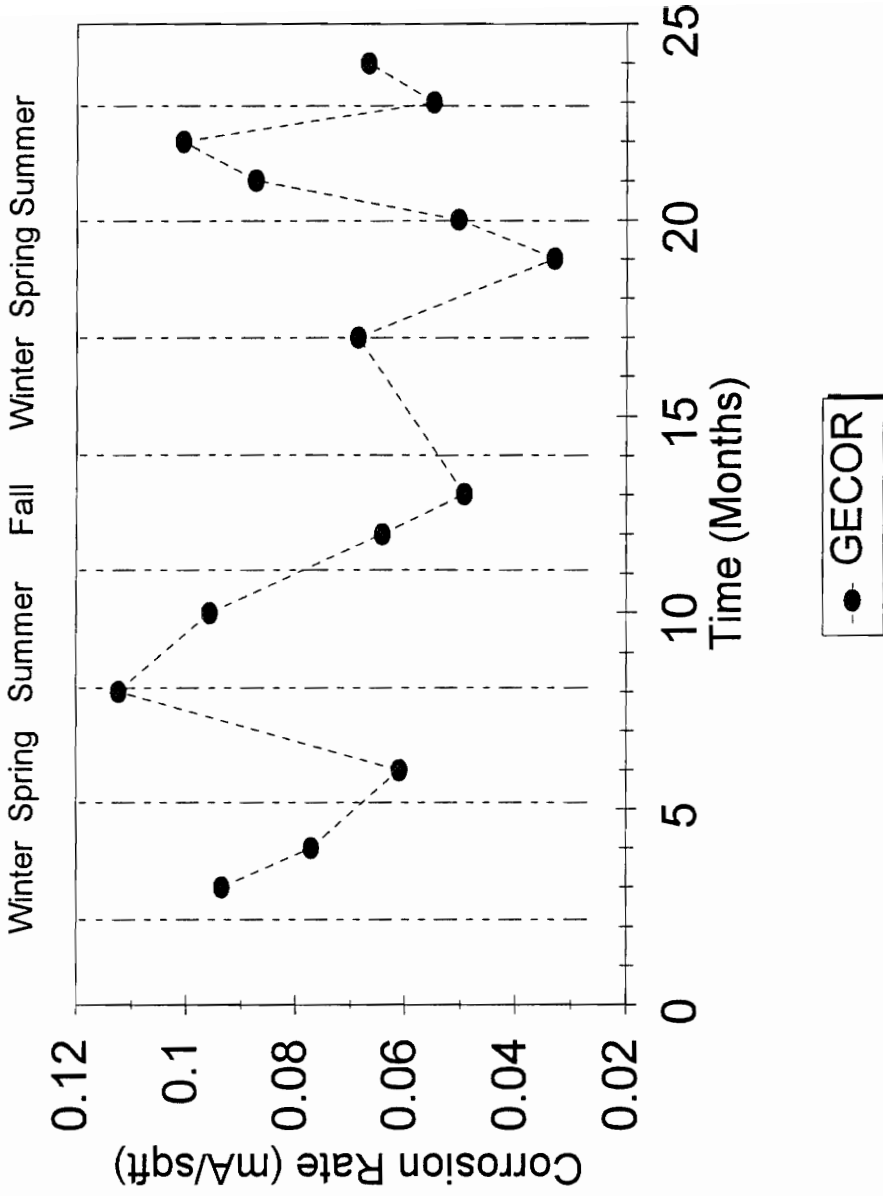


Figure 27 - OA2851.2 Corrosion Rate Profile

# OA2852.4 Corrosion Rate Profile

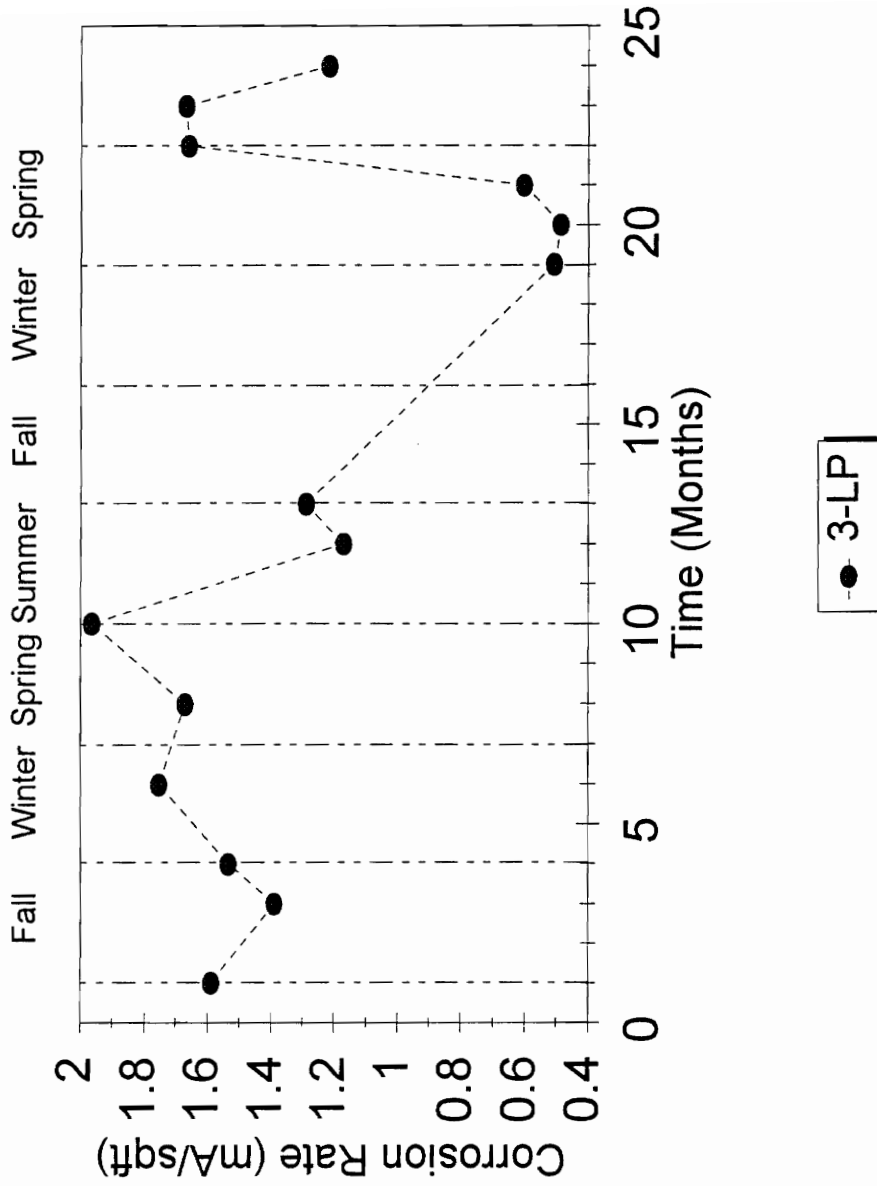


Figure 28 - OA2852.4 Corrosion Rate Profile

# OA2852.4 Corrosion Rate Profile

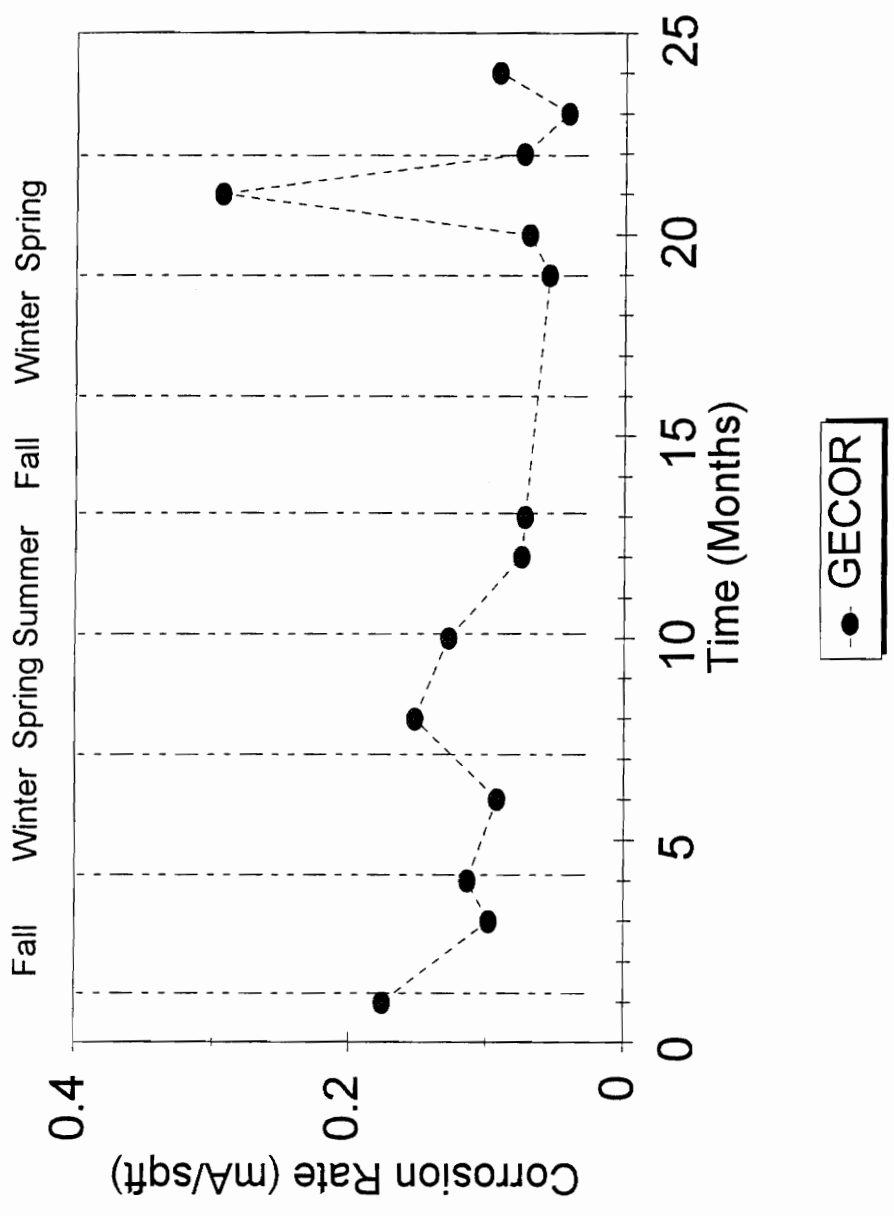
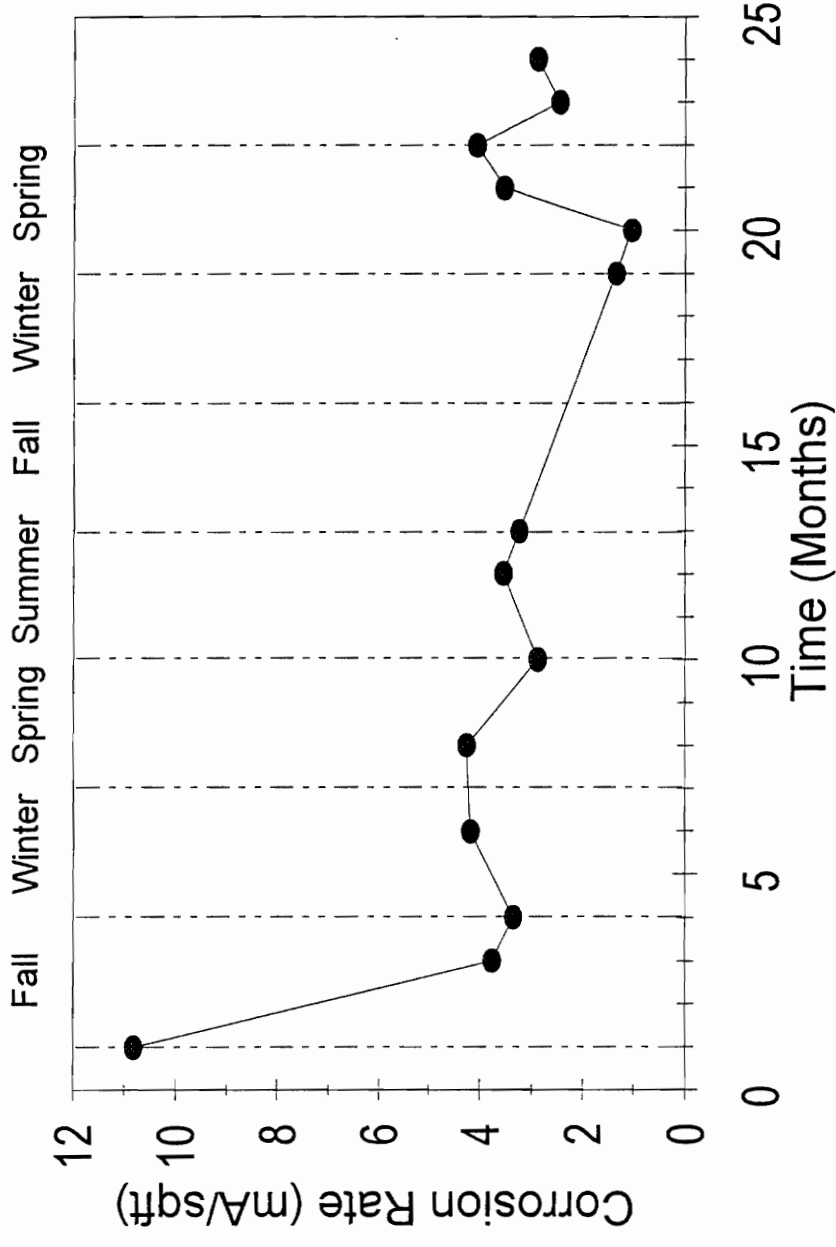


Figure 29 - OA2852.4 Corrosion Rate Profile

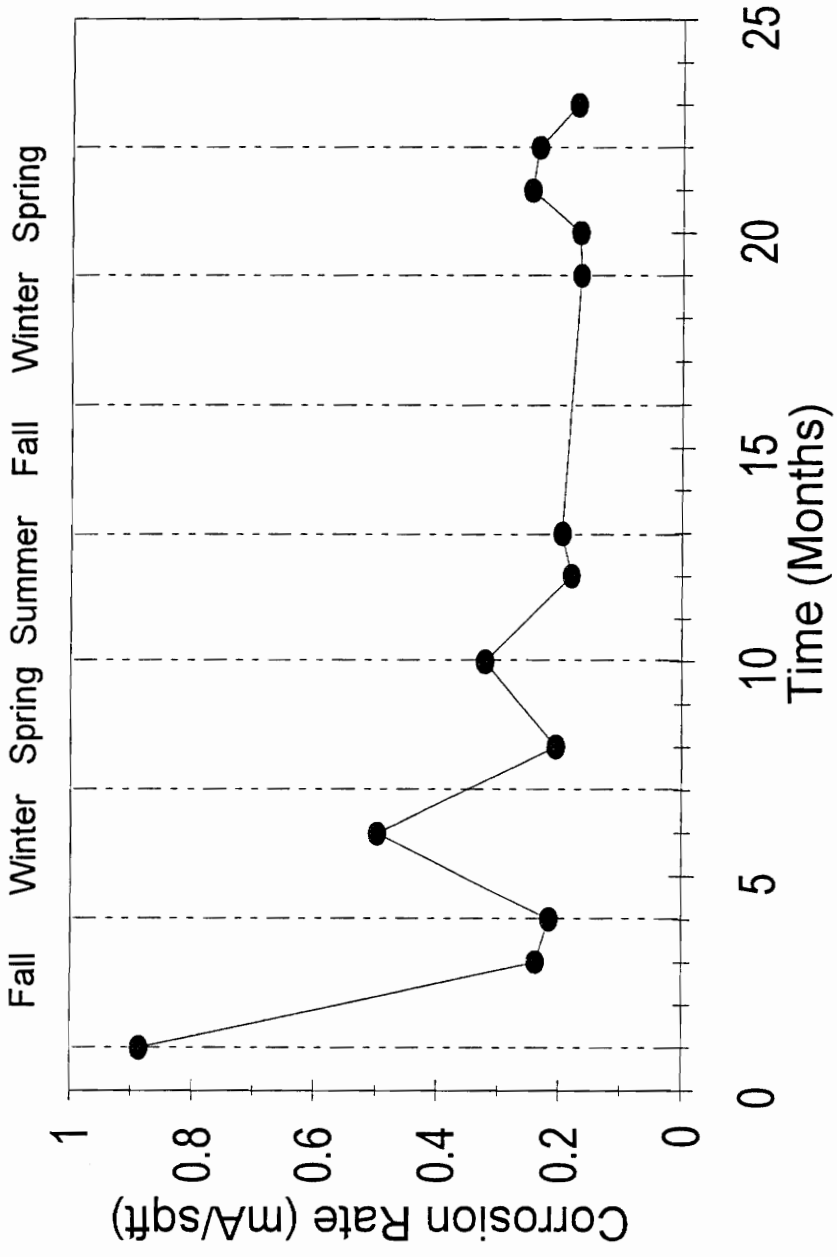
# OA2854.8 Corrosion Rate Profile



● 3-LP

Figure 30 - OA2854.8 Corrosion Rate Profile

# OA2854.8 Corrosion Rate Profile



● GECOR

Figure 31 - OA2854.8 Corrosion Rate Profile

# OA2859.6 Corrosion Rate Profile

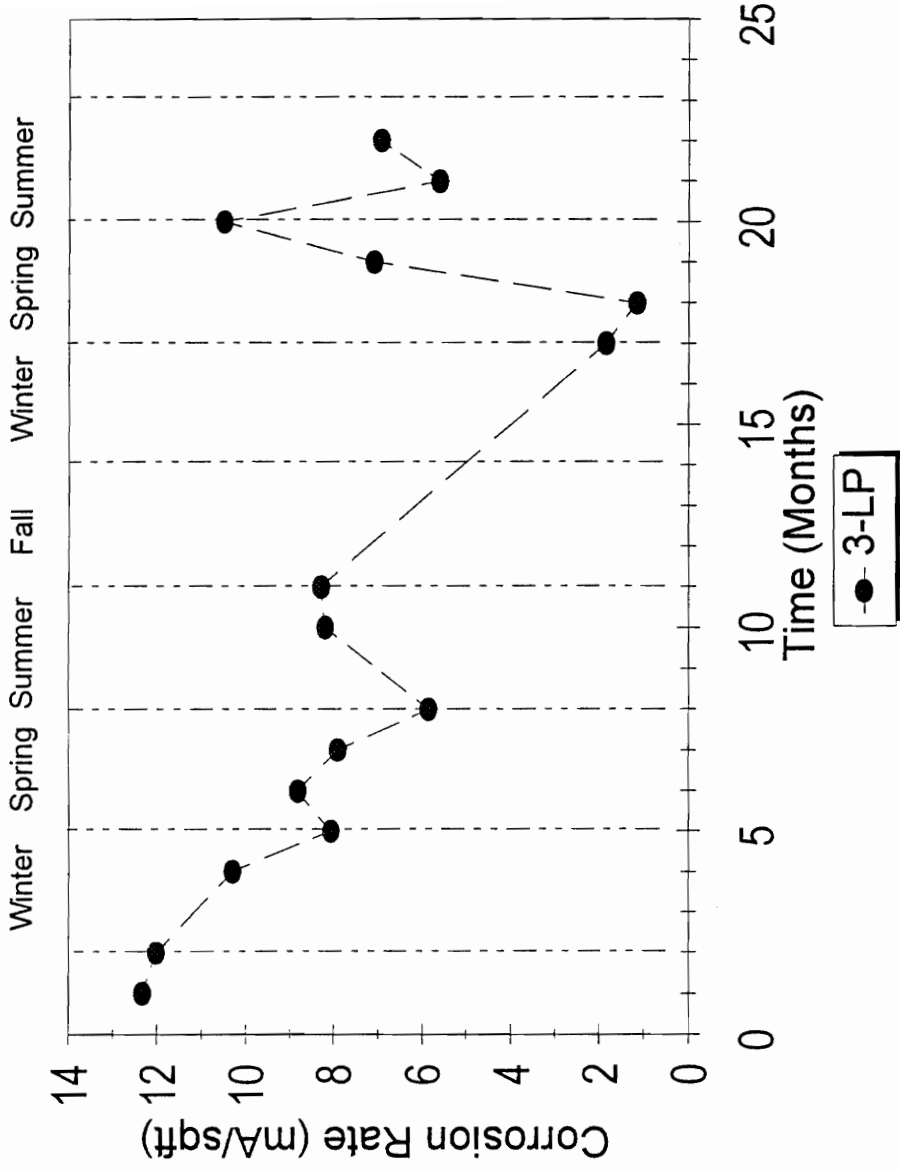


Figure 32 - OA2859.6 Corrosion Rate Profile

# OA2859.6 Corrosion Rate Profile

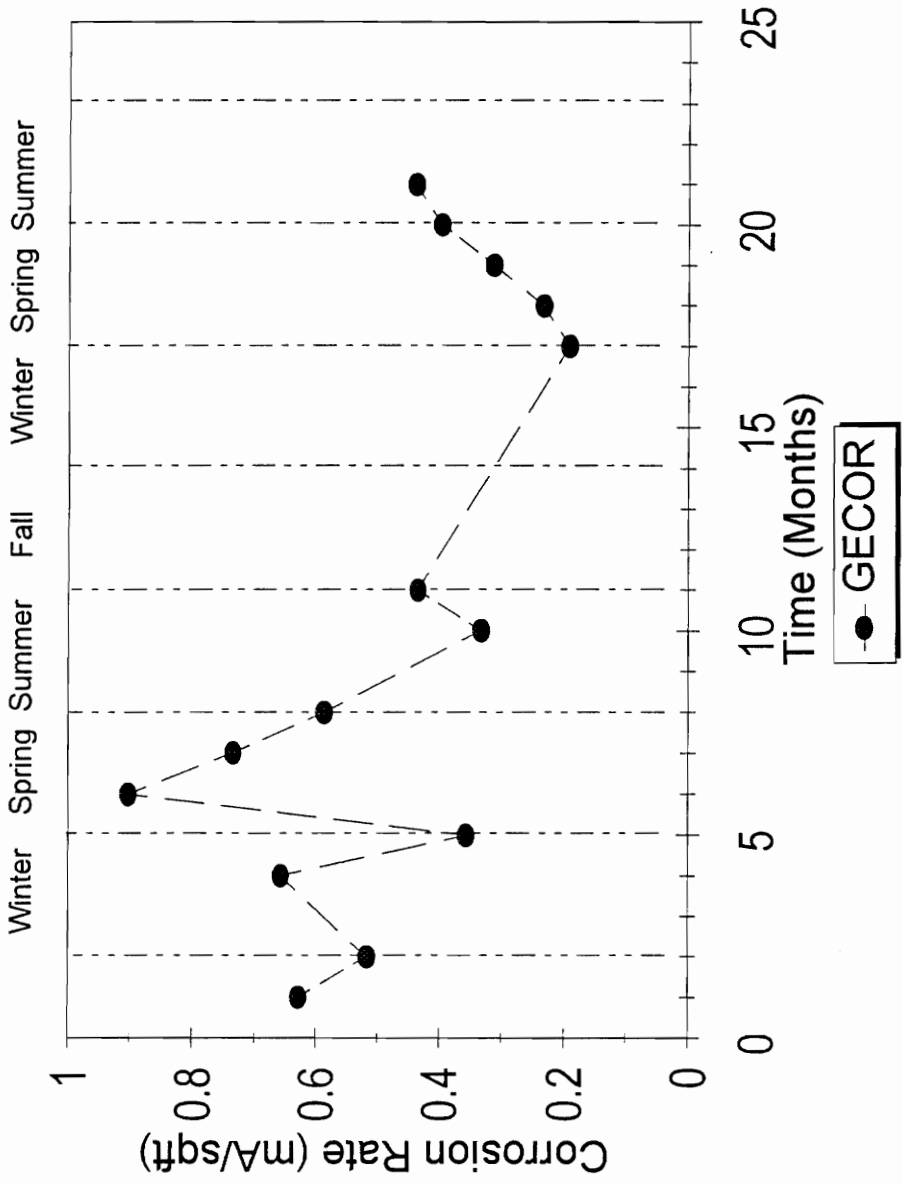


Figure 33 - OA2859.6 Corrosion Rate Profile

icorr vs Temperature  
OA2859.6 Series Months 1-9

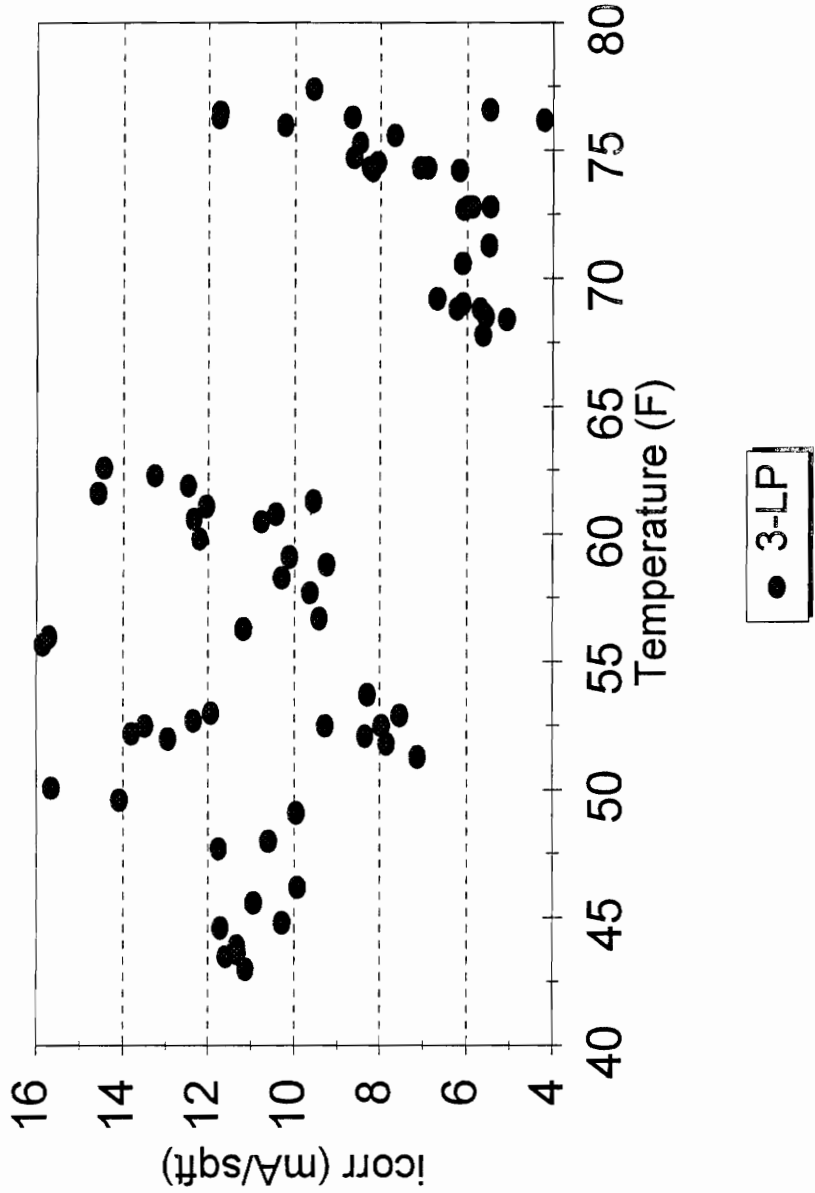


Figure 34 - icorr vs Temperature, 3-LP, Months 1-9



icorr vs Temperature  
OA2859.6 Series Months 11-23

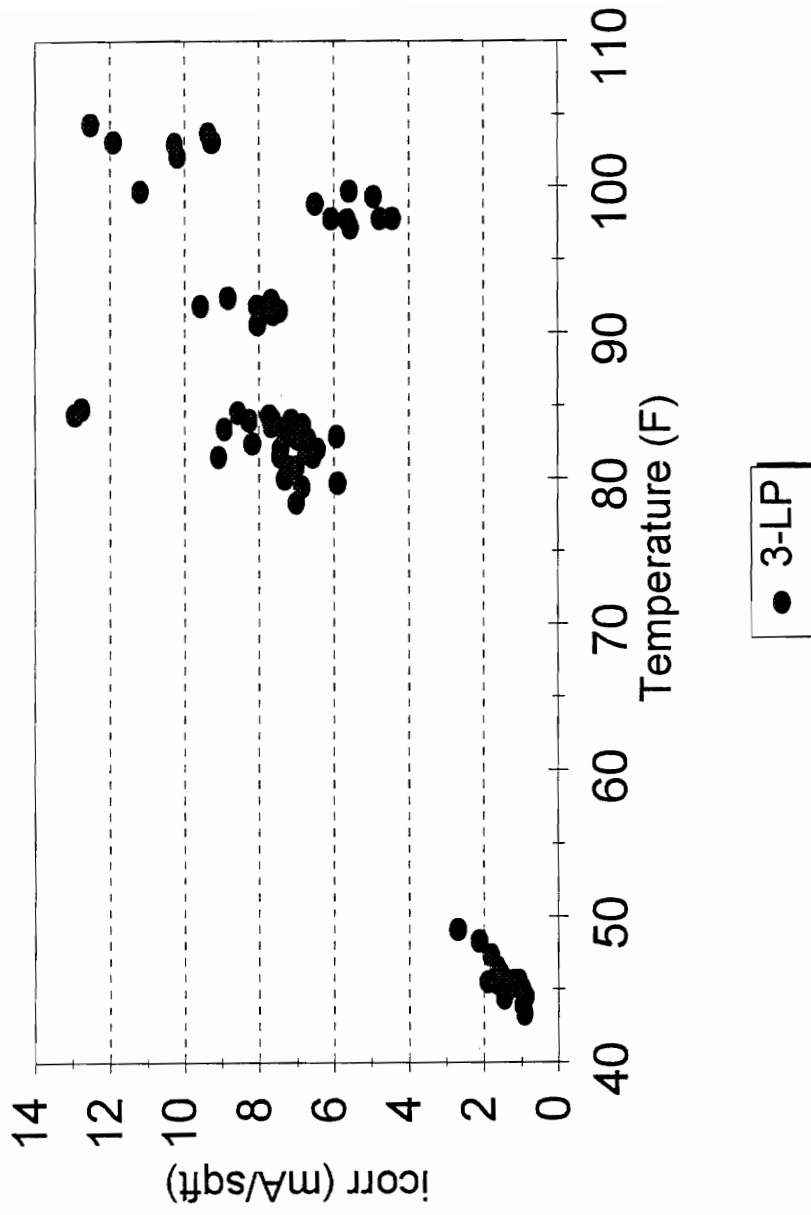


Figure 35 - icorr vs Temperature, 3-LP, Months 11-23

icorr vs Temperature  
OA2859.6 Series Months 1-9

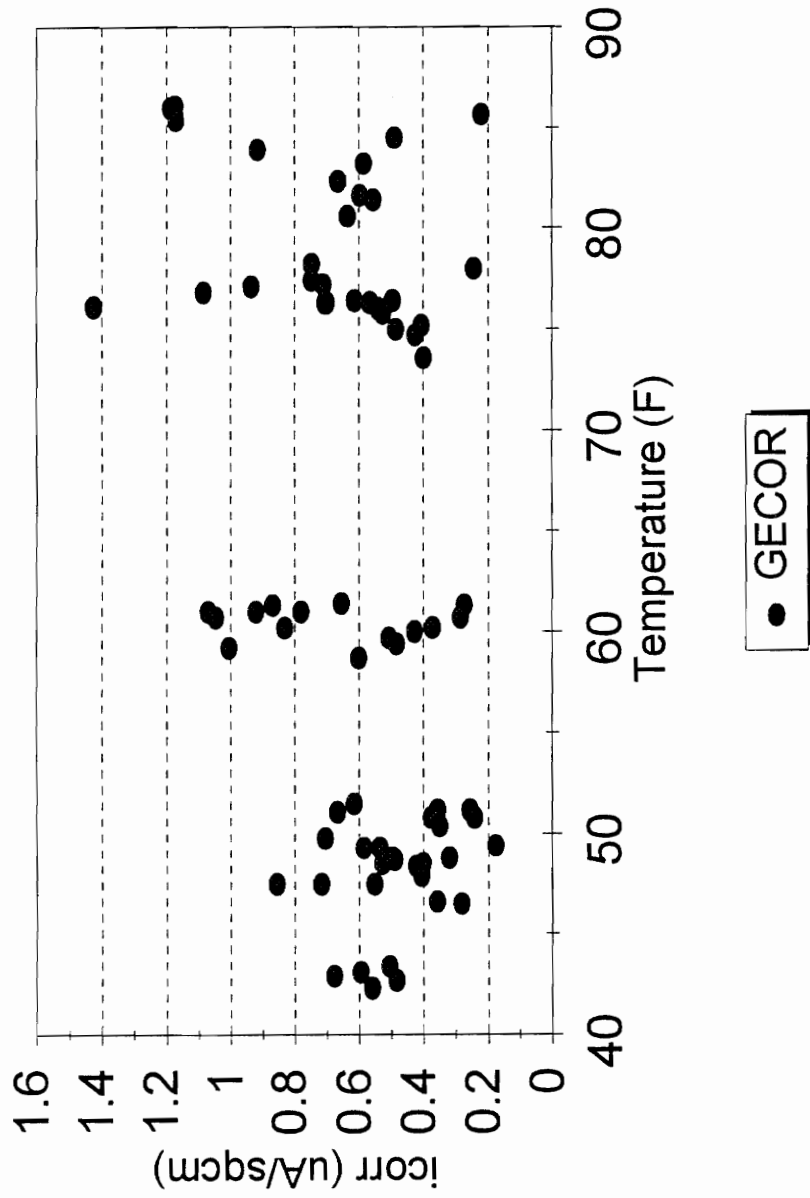


Figure 36 - icorr vs Temperature, Gecor Months 1-9

icorr vs Temperature  
OA2859.6 Series Months 11-23

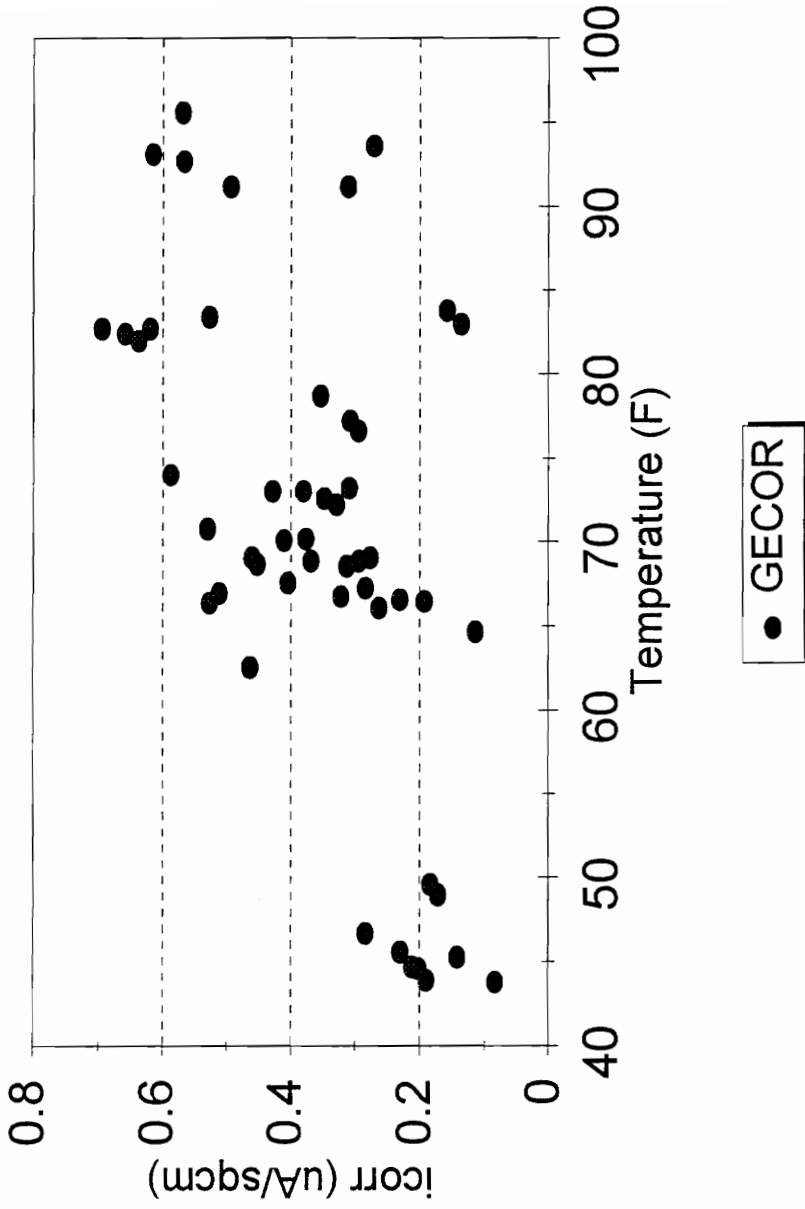
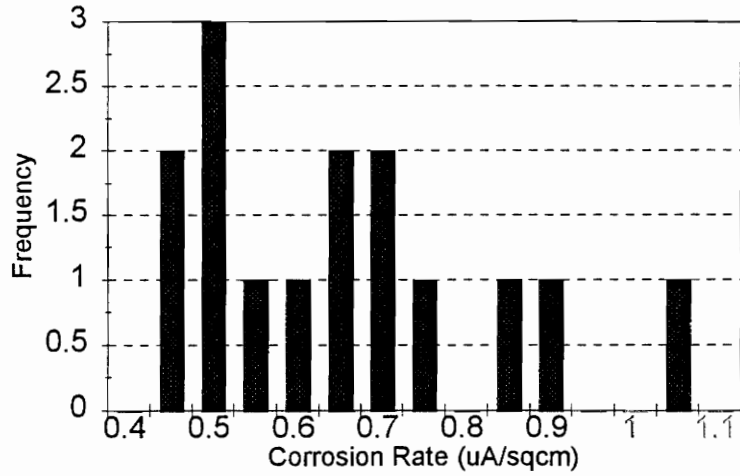


Figure 37 - icorr vs Temperature, Gecor, Months 11-23

Distribution of Corrosion Rates  
 Month 1 - OA2859.6 GECOR



Distribution of Corrosion Rates  
 Month 1 - OA2859.6 3-LP

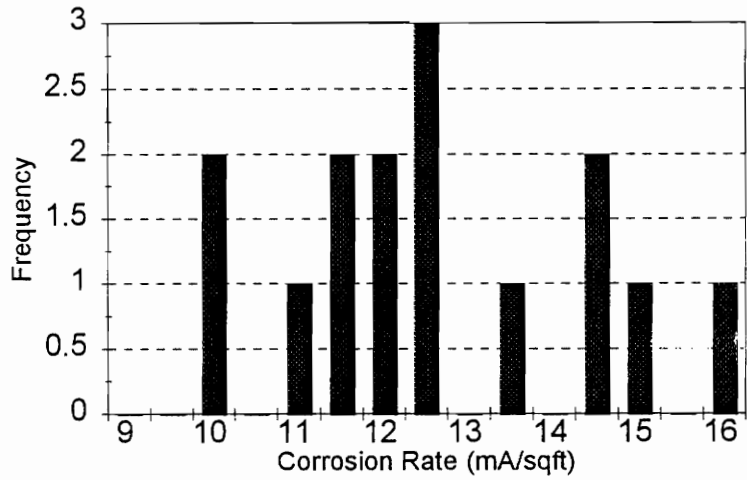
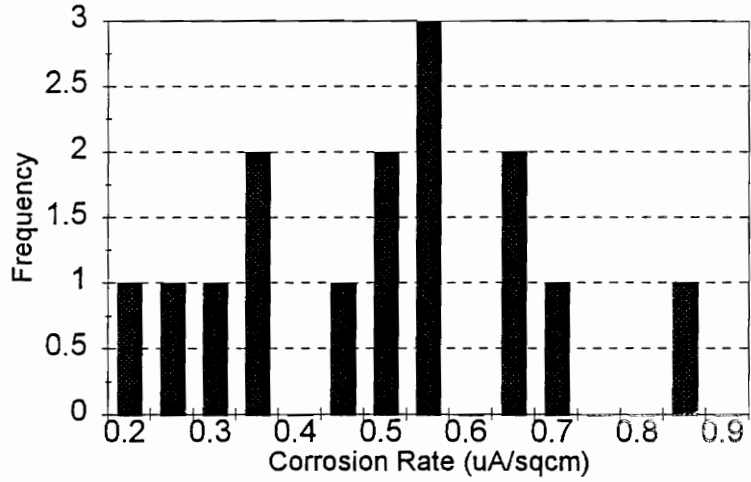


Figure 38 - Month 1, OA2859.6 Distribution

Distribution of Corrosion Rates  
Month 2 - OA2859.6 GECOR



Distribution of Corrosion Rates  
Month 2 - OA2859.6 3-LP

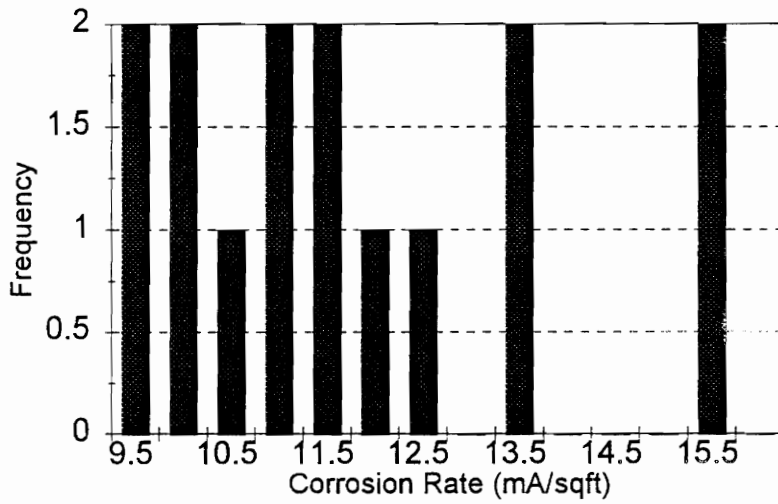
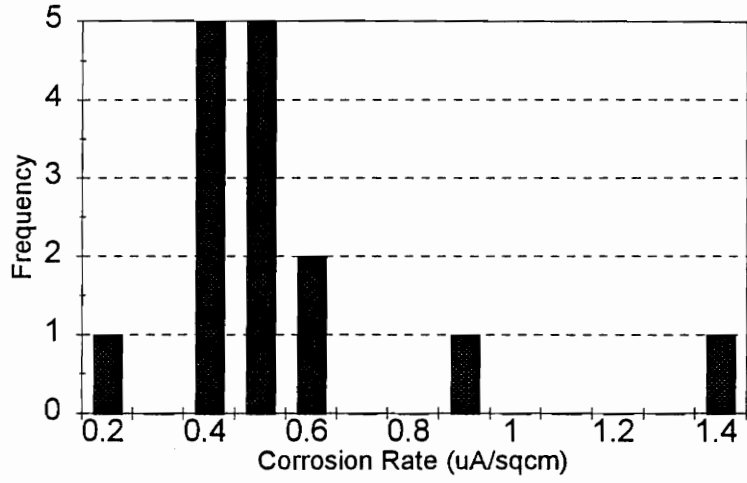


Figure 39 - Month 2, OA2859.6 Distribution

Distribution of Corrosion Rates  
 Month 8 - OA2859.6 GECOR



Distribution of Corrosion Rates  
 Month 8 - OA2859.6 3-LP

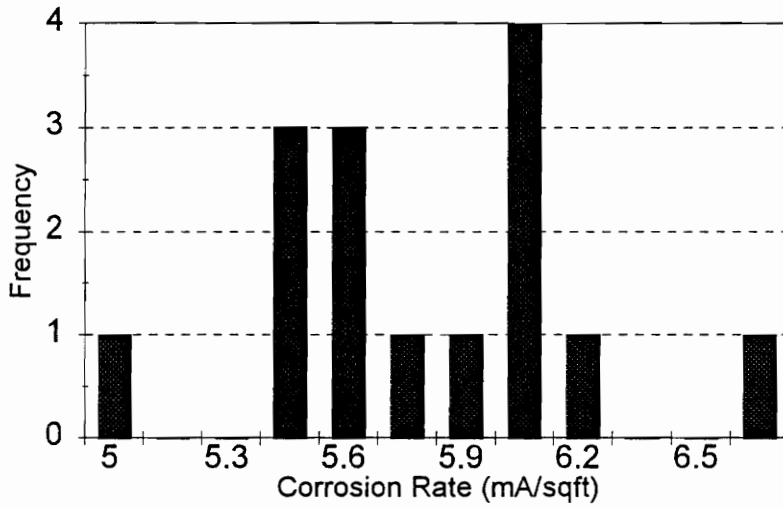


Figure 40 - Month 8, OA2859.6 Distribution

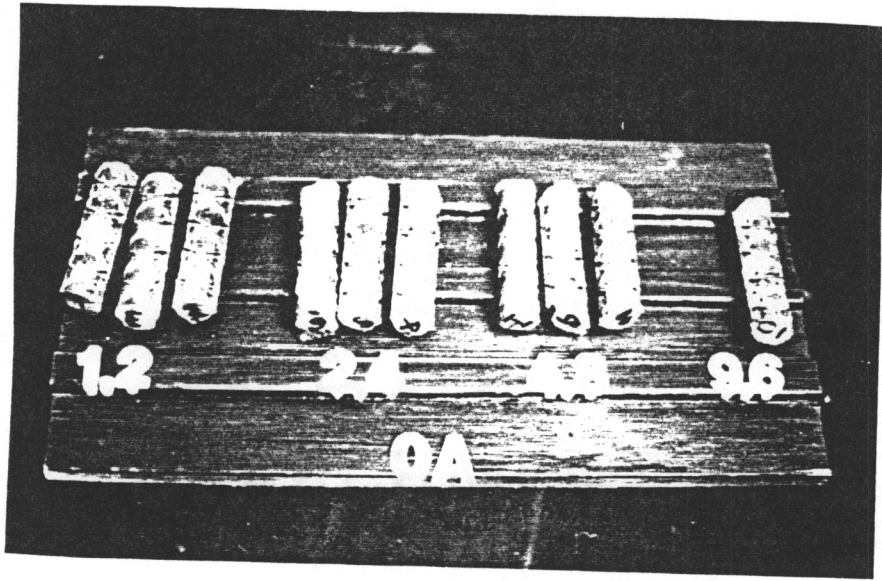


Figure 41 - Bars Prior to Cleaning

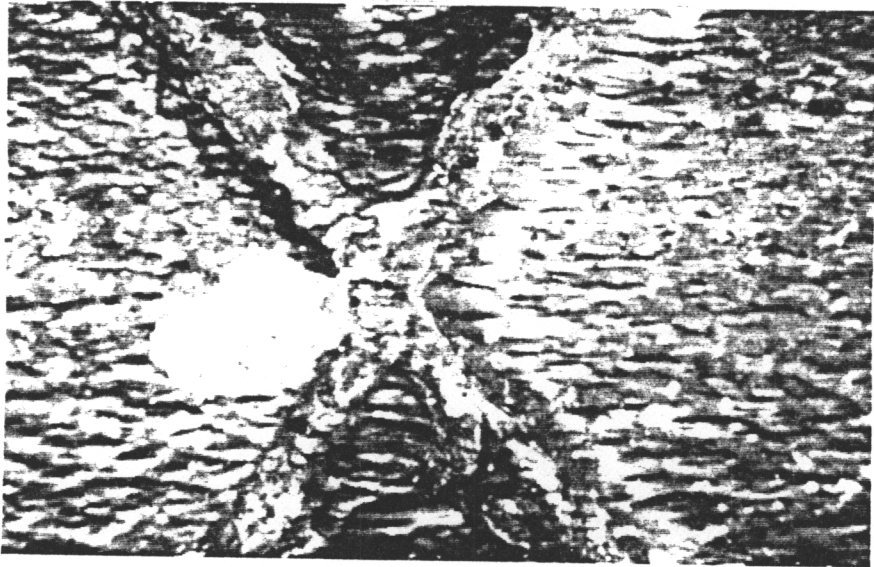


Figure 42 - Surface of Bar in OA2854.8 Series

# Corrosion Rates vs Chloride Contents

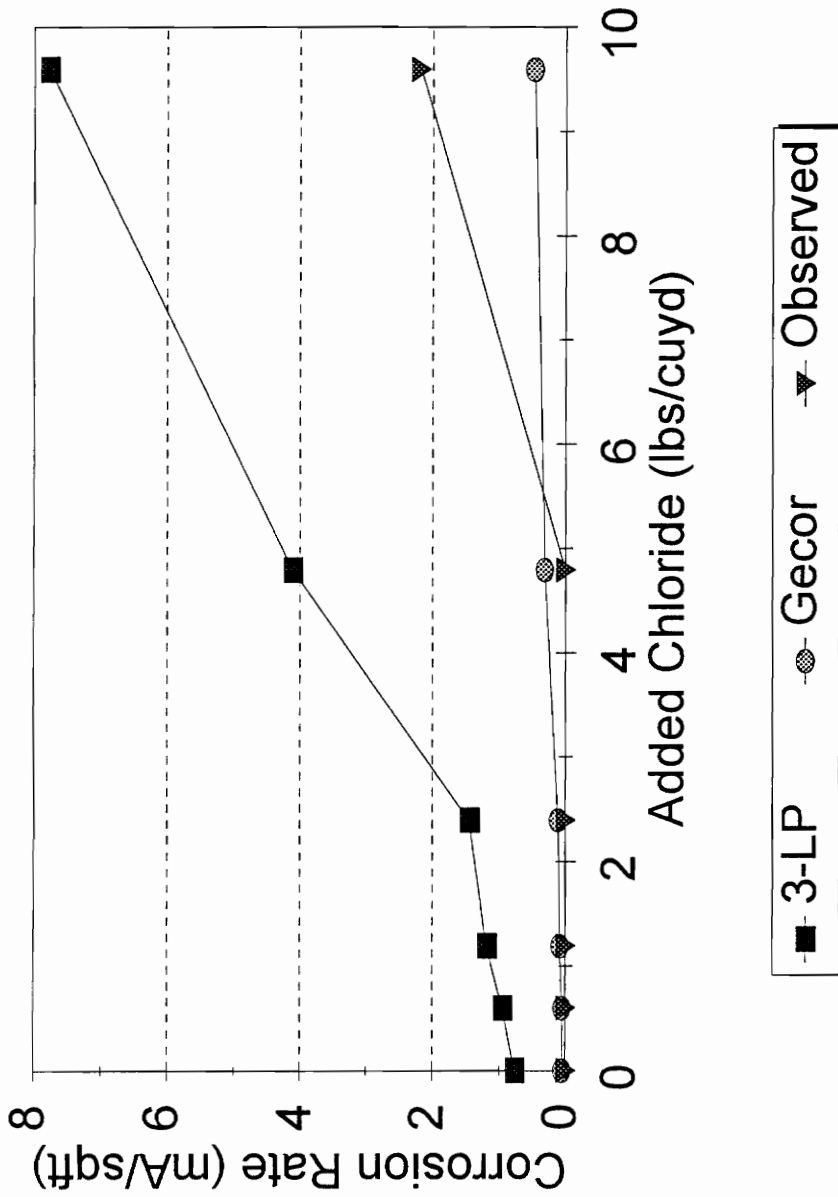


Figure 43 - Corrosion Rates as a Function of the Added Chloride Ions



# Corrosion Rates vs Chloride Contents

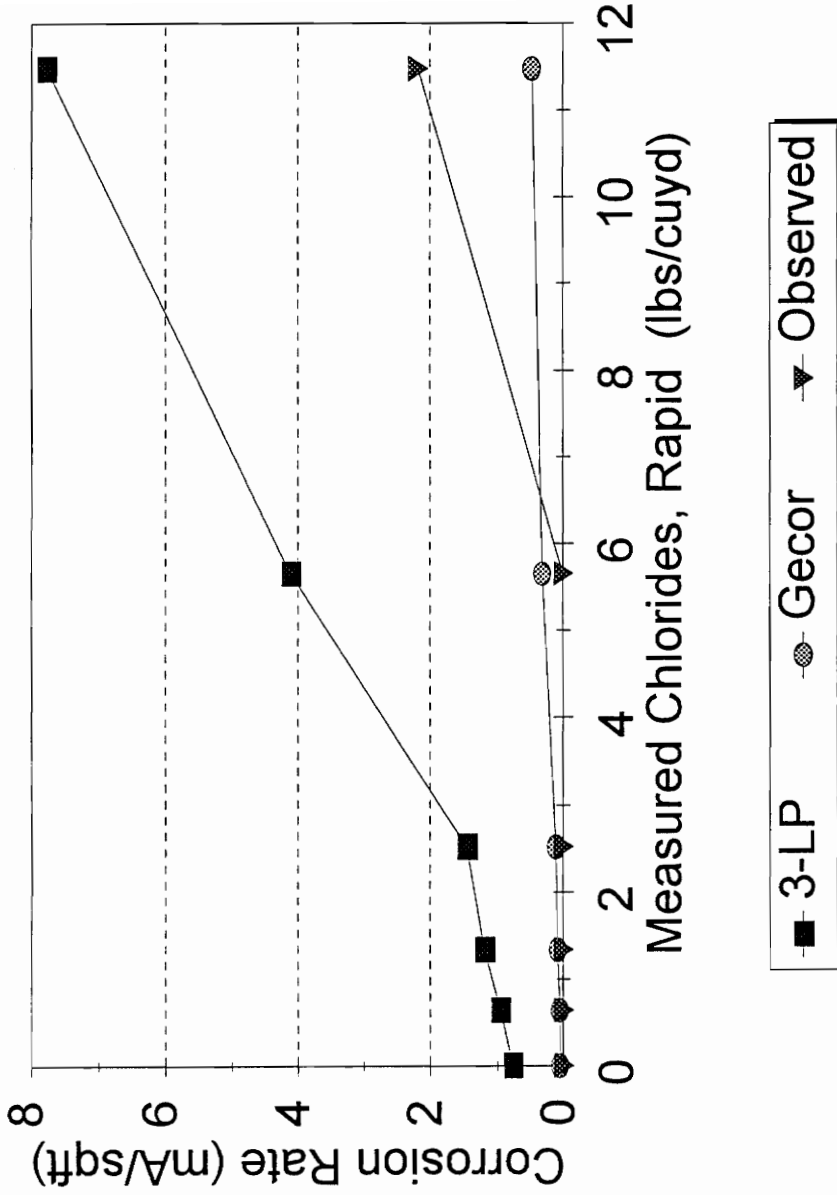


Figure 44 - Corrosion Rates as a Function of the Rapid Analysis Chloride Ions

# Corrosion Rates vs Chloride Contents

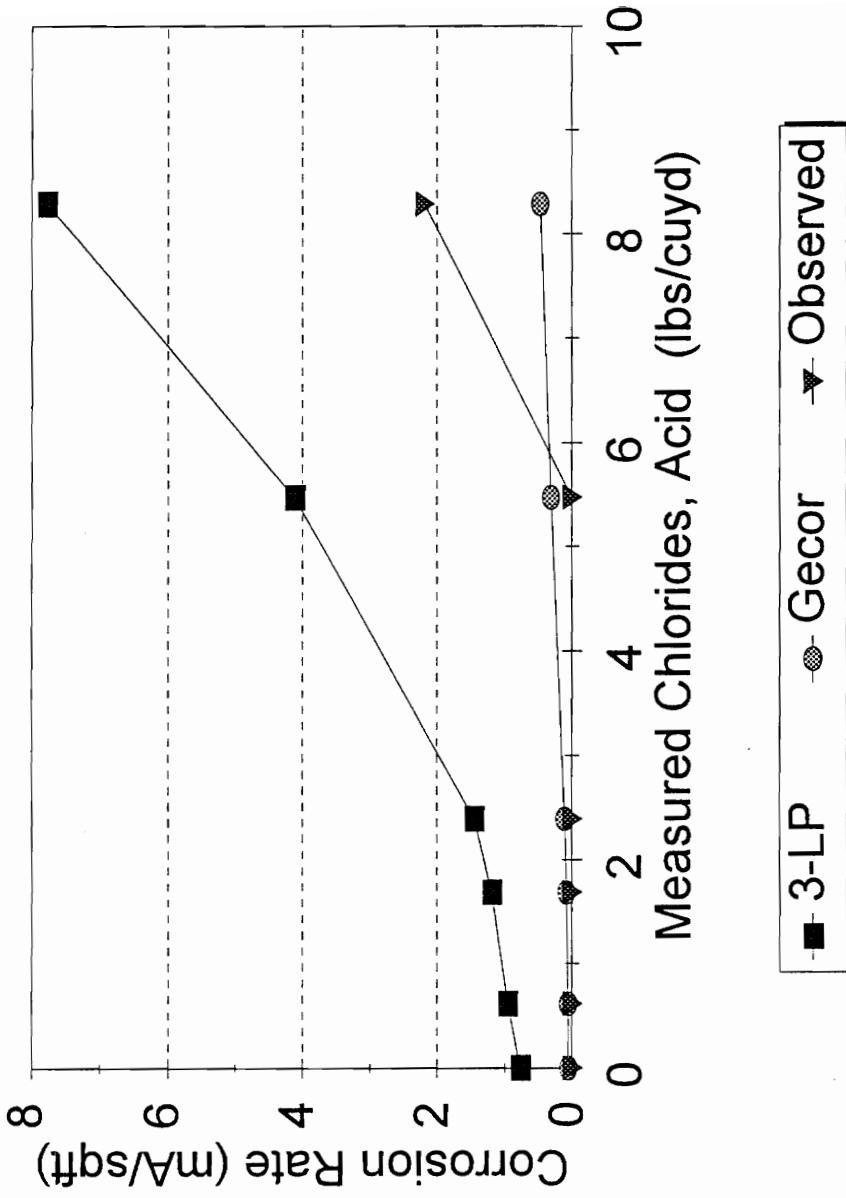


Figure 45 - Corrosion Rates as a Function of the Acid Soluble Analysis of Chloride Ions

# Corrosion Rates vs Chloride Contents

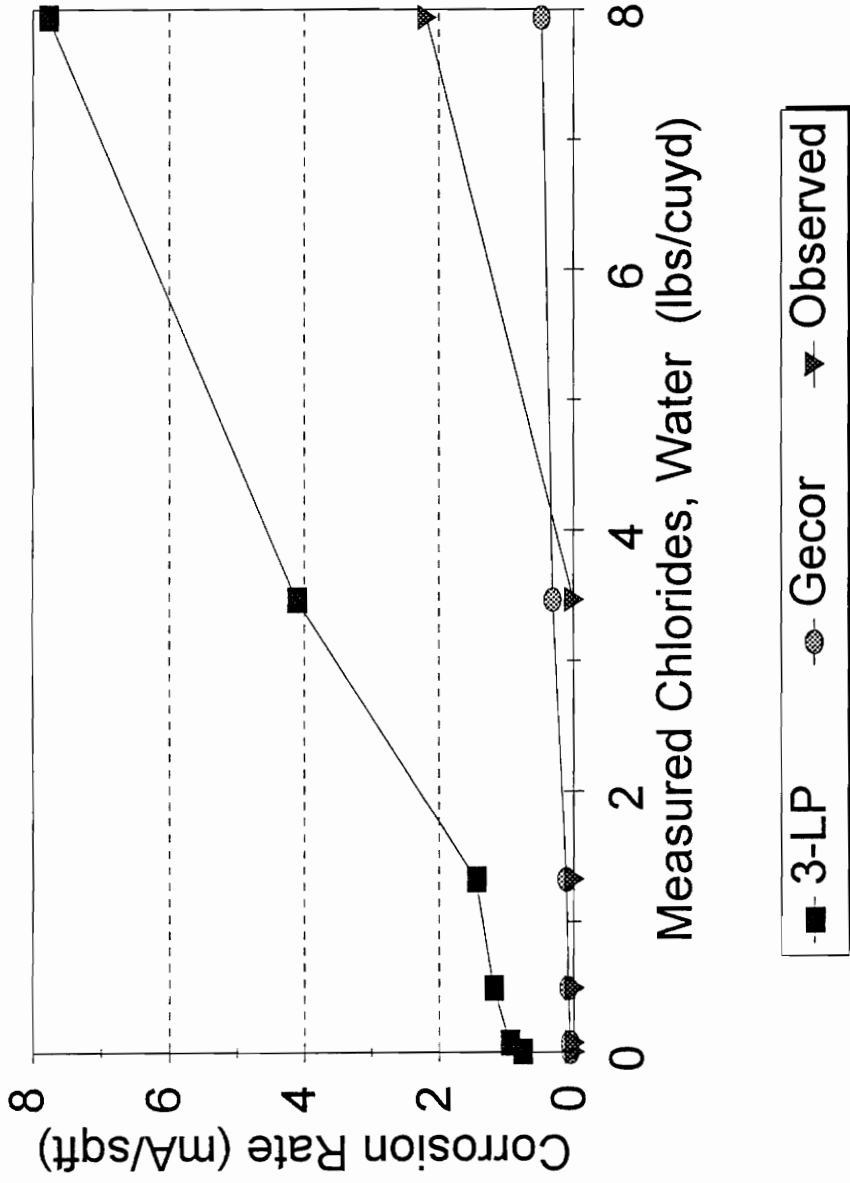


Figure 46 - Corrosion Rates as a Function of the Water Soluble Analysis of Chloride Ions

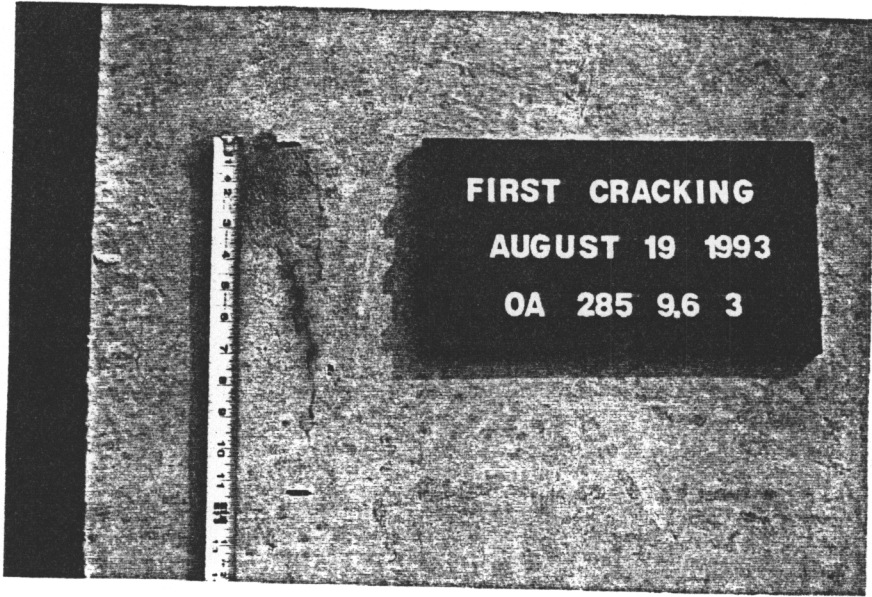


Figure 47 - First Cracking of OA2859.6 Series



Figure 48 - Solid Products Filling Cracks

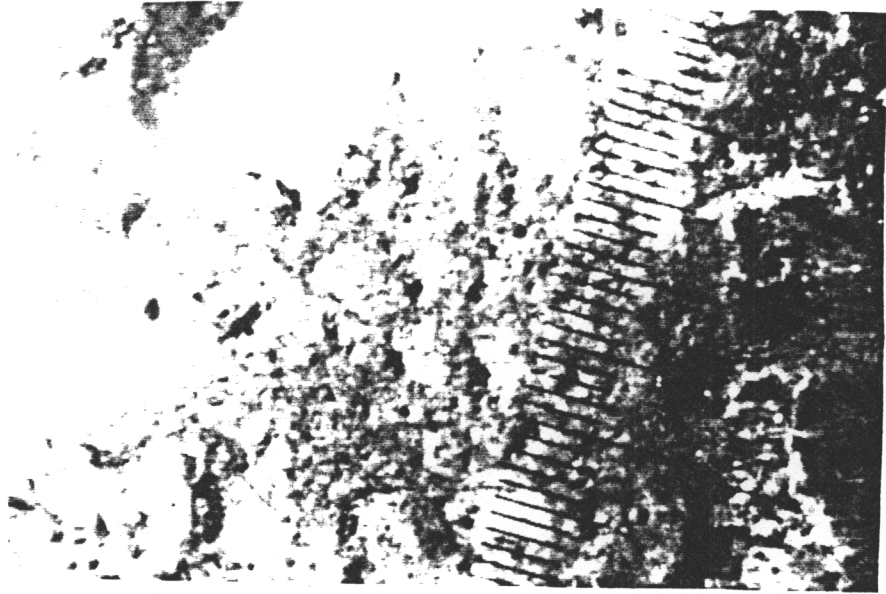


Figure 49 - Green Rust

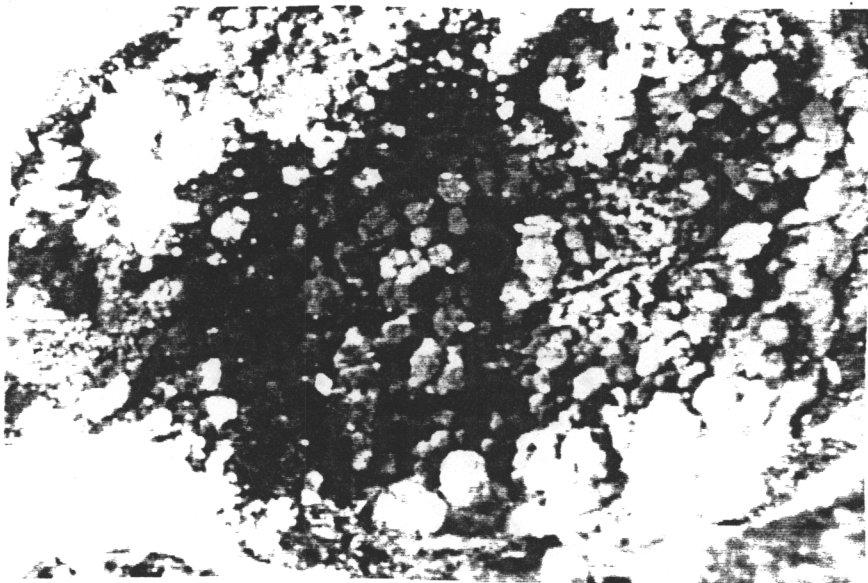


Figure 50 - Corrosion Products Formed in Voids on Underside of Bar

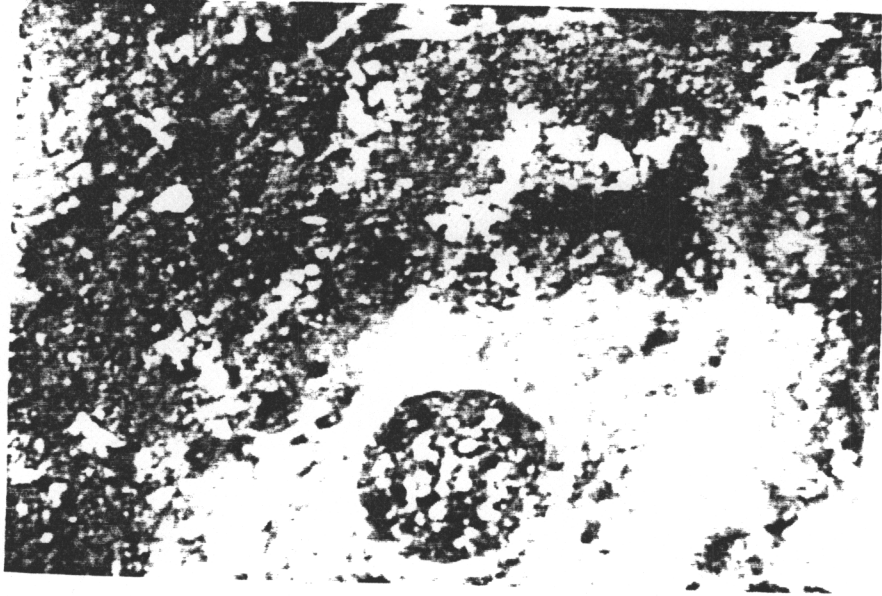
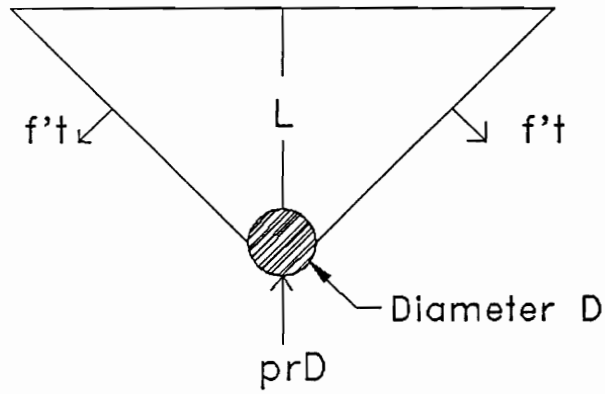


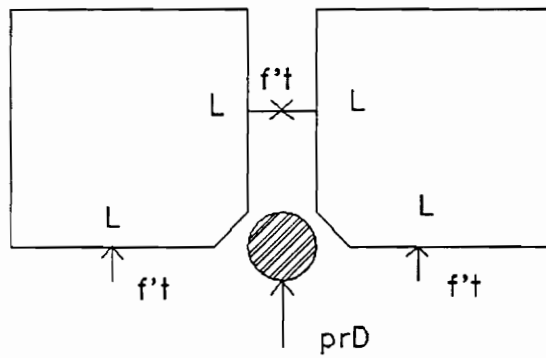
Figure 51 - Various Types of Corrosion Products

Predicted Mode of Failure ( $s > 6D$ )



Equilibrium:  $2(L)f't = prD = D(\Delta D)/(\text{bar hole flexibility})$

Observed Mode of Failure ( $s = 12.8D$ )



Equilibrium:  $3(L)f't = prD = D(\Delta D)/(\text{bar hole flexibility})$

Figure 52 – Modes of Failure

## 5.0 Conclusions

1. Measured corrosion rates for steel reinforcement in chloride contaminated concrete with 0 to 9.6 lbs/yd<sup>3</sup> of chloride ions appeared highest during the spring months over the two year study.
2. Measured corrosion rates for the 3-LP device are not directly influenced by the temperature of the concrete immediately after placing of the concrete; however, once a steady state of corrosion is reached, the measured corrosion rates become directly influenced by the temperature of the concrete.
3. The measured corrosion rates taken over similar specimens may be assumed to follow a normal distribution when taken at approximately the same time.
4. Measured corrosion rates from the 3-LP device appear more precise than measured corrosion rates from the Gecor device based on coefficient of variation.
5. During the two year study, corrosion initiated and continued at an added chloride ion content somewhere between 4.8 and 9.6 lbs/yd<sup>3</sup> .



6. Corrosion products resulting from a weight loss of 0.1969 g/cm of bar length caused cracking in the two inch cover depth outdoor specimens containing 9.6 lb/yd<sup>3</sup> of chloride ions. This metal loss is equivalent to a corrosion current density of 2.185 mA/ft<sup>2</sup> over the 22 months of readings.
7. The measured corrosion rates increased as the chloride ion contents in the concrete increased.
8. At the time of first cracking, green rust accounted for a considerable amount of the corrosion products. Also, for the two inch cover depth specimens, the cracking occurred directly above and parallel with the bars, as well as horizontal cracking at the bar level.
9. A modification to Bazant's cracking criteria is proposed in an attempt to better predict the time to cracking of chloride contaminated concrete due to the corrosion of the reinforcing steel.

## 6.0 Recommendations for Further Study

1. A study should be performed in order to better understand how the moisture content and the temperature of the concrete interact and influence the corrosion rates of steel in concrete. This study should focus on improving the precision of the corrosion rate measurement devices.
2. The three inch cover depth outdoor specimens containing 9.6 lb/yd<sup>3</sup> chloride ions should be monitored until a time in which cracking occurs. At that time, a large sample of bars should be removed and the weight loss determined in an attempt to better define the amount of metal loss required to cause cracking.
3. The mode of cracking should be investigated in a system containing loading of the specimens. Including repetitive live loads such as those imposed by the vehicles on a bridge deck system may indicate a different time to and mode of cracking than observed in the static conditions in this study.

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## **Appendix A**

### **Existing Data**

Table A-1 Specimen IA2850.0-1

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/17/91 | 1        | 4.7                        | 0.045              | 1.8             | 0.51                   | 64.4                 | 2                      | 0.9452             | 63.7                 |
| 11/17/91 | 3        | 8.2                        | 0.072              | 0.1             | 0.43                   | 64.4                 | 11                     | 1.1412             | 63.7                 |
| 11/17/91 | 5        | 23.5                       | 0.060              | 0.4             | 0.48                   | 64.4                 | 28                     | 1.2805             | 63.7                 |
| 12/21/91 | 2        | 40.7                       | 0.085              | 0.1             | 0.85                   | 67.0                 | -45                    | 1.4250             | 66.0                 |
| 12/21/91 | 4        | 36.2                       | 0.034              | 1.0             | 0.44                   | 66.0                 | -23                    | 0.9080             | 66.0                 |
| 2/23/92  | 1        | 11.5                       | 0.044              | 0.0             | 1.17                   | 64.3                 | -48                    | 0.6366             | 64.1                 |
| 2/23/92  | 3        | 16.0                       | 0.045              | 0.0             | 0.97                   | 64.4                 | -40                    | 0.9348             | 64.1                 |
| 2/23/92  | 5        | 27.0                       | 0.053              | 0.0             | 0.93                   | 64.4                 | -22                    | 0.9503             | 64.1                 |
| 4/24/92  | 2        | 36.2                       | 0.034              | 0.0             | 1.31                   | 65.5                 | -72                    | 0.8756             | 62.3                 |
| 4/24/92  | 4        | 38.5                       | 0.045              | 0.0             | 1.11                   | 65.3                 | -80                    | 0.9274             | 62.4                 |
| 6/9/92   | 1        | 39.7                       | 0.067              | 0.0             | 0.42                   | 72.2                 | 36                     | 1.5251             | 72.8                 |
| 6/9/92   | 3        | 35.2                       | 0.053              | 0.1             | 0.47                   | 72.2                 | 28                     | 1.6582             | 72.8                 |
| 6/9/92   | 5        | 24.2                       | 0.052              | 0.1             | 0.61                   | 72.3                 | 25                     | 1.1361             | 72.9                 |
| 7/13/92  | 2        | 76.5                       | 0.061              | 0.0             | 0.57                   | 78.9                 | 24                     | 1.2124             | 79.0                 |
| 7/13/92  | 4        | 59.5                       | 0.034              | 0.0             | 0.81                   | 78.6                 | 8                      | 1.5509             | 79.1                 |
| 10/7/92  | 1        | 18.5                       | 0.05               | 0               | 0.77                   | 60.7                 | -11                    | 1.0143             | 60.6                 |
| 10/7/92  | 3        | 31.0                       | 0.048              | 0.0             | 0.81                   | 60.8                 | -3                     | 0.8905             | 60.8                 |
| 10/7/92  | 5        | 24.0                       | 0.036              | 0.0             | 0.99                   | 60.9                 | 2                      | 0.8337             | 61.0                 |

\* MEASUREMENT OMITTED

Table A-2 Specimen 1A2850.0-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                      |                      | 3LP                    |                    |                      |  |
|----------|----------|----------------------------|--------------------|-----------------|----------------------|----------------------|------------------------|--------------------|----------------------|--|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RE<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | Icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |  |
| 11/19/91 | 2        | 77.2                       | 0.077              | 0.0             | 1.29                 | 62.9                 | 7                      | 1.0735             | 62.3                 |  |
| 11/19/91 | 4        | 86.0                       | 0.131 *            | -0.5            | 1.22                 | 62.9                 | 15                     | 1.0834             | 62.3                 |  |
| 12/21/91 | 1        | 23.0                       | 0.052              | 0.0             | 0.76                 | 64.0                 | -45                    | 1.0133             | 64.0                 |  |
| 12/21/91 | 3        | 14.5                       | 0.089              | -0.1            | 0.54                 | 64.0                 | -46                    | 1.1526             | 64.0                 |  |
| 12/21/91 | 5        | 0.7                        | 0.028              | 0.1             | 0.71                 | 64.0                 | -74                    | 0.7976             | 64.0                 |  |
| 2/24/92  | 2        | 30.5                       | 0.047              | 0.1             | 0.52                 | 62.2                 | -36                    | 1.0174             | 62.4                 |  |
| 2/24/92  | 4        | 30.7                       | 0.048              | 0.0             | 0.53                 | 62.5                 | -53                    | 0.5572             | 62.1                 |  |
| 4/24/92  | 1        | 72.5                       | 0.033              | 0.0             | 1.28                 | 58.6                 | -83                    | 0.7264             | 58.8                 |  |
| 4/24/92  | 3        | 77.5                       | 0.018              | 0.0             | 0.64                 | 58.6                 | -55                    | 1.0752             | 58.8                 |  |
| 4/24/92  | 5        | 57.5                       | 0.032              | 0.0             | 1.15                 | 58.6                 | -87                    | 0.8110             | 58.9                 |  |
| 6/10/92  | 2        | 53.5                       | 0.039              | -0.1            | 0.71                 | 67.1                 | 32                     | 1.0453             | 67.3                 |  |
| 6/10/92  | 4        | 52.5                       | 0.058              | 0.0             | 0.61                 | 67.2                 | 19                     | 1.1392             | 67.2                 |  |
| 7/13/92  | 1        | 64.3                       | 0.037              | 0.0             | 0.79                 | 79.2                 | 6                      | 0.8502             | 79.2                 |  |
| 7/13/92  | 3        | 85.7                       | 0.041              | 0.0             | 0.74                 | 79.2                 | 40                     | 1.3496             | 79.2                 |  |
| 7/13/92  | 5        | 74.3                       | 0.041              | 0.0             | 0.76                 | 79.2                 | 20                     | 1.2269             | 79.3                 |  |
| 10/7/92  | 2        | 13.7                       | 0.033              | 0.0             | 0.67                 | 61.2                 | 10                     | 0.7522             | 60.4                 |  |
| 10/7/92  | 4        | 24.5                       | 0.034              | 0.0             | 0.67                 | 61.2                 | 16                     | 0.8833             | 60.5                 |  |

\* MEASUREMENT OMITTED

Table A-3 Specimen OA2850.0-1

| DATE     | POSITION | GEOCISA                    |                     |                 |                        |                      | 3LP                    |                     |                      |
|----------|----------|----------------------------|---------------------|-----------------|------------------------|----------------------|------------------------|---------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA./sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA./sqft) | TEMP.<br>(degrees F) |
| 11/15/91 | 1        | 31.2                       | 0.058               | 0.0             | 0.50                   | 59.2                 | 33                     | 0.9318              | 51.6                 |
| 11/15/91 | 3        | 22.0                       | 0.144               | -0.2            | 0.78                   | 58.4                 | 35                     | 1.0432              | 52.4                 |
| 11/15/91 | 5        | 28.7                       | 0.080               | 0.0             | 0.59                   | 57.7                 | 42                     | 1.2877              | 53.1                 |
| 12/24/91 | 2        | 47.7                       | 0.063               | 0.0             | 0.98                   | 43.5                 | -9                     | 0.8729              | 33.3                 |
| 12/24/91 | 4        | 53.0                       | 0.057               | 0.0             | 1.08                   | 42.6                 | 2                      | 1.0473              | 32.7                 |
| 2/4/92   | 1        | -33.5                      | 0.030               | 0.0             | 1.02                   | 38.7                 | -27                    | 0.5902              | 32.8                 |
| 2/4/92   | 3        | -27.2                      | 0.073               | 0.0             | 1.39                   | 39.1                 | -28                    | 0.8554              | 32.7                 |
| 2/4/92   | 5        | -13.5                      | 0.069               | 0.0             | 1.63                   | 39.5                 | -14                    | 0.7543              | 32.7                 |
| 4/24/92  | 2        | 72.1                       | 0.038               | 0.0             | 1.38                   | 71.0                 | 6                      | 1.3414              | 65.7                 |
| 4/24/92  | 4        | 68.1                       | 0.056               | 0.2             | 1.19                   | 71.6                 | -32                    | 1.4002              | 68.1                 |
| 6/13/92  | 1        | 51.2                       | 0.060               | 0.0             | 1.71                   | 69.6                 | 16                     | 1.0907              | 71.9                 |
| 6/13/92  | 3        | 34.0                       | 0.057               | 0.0             | 1.61                   | 69.7                 | 5                      | 1.1165              | 71.9                 |
| 6/13/92  | 5        | 33.5                       | 0.043               | 0.0             | 1.81                   | 69.8                 | 2                      | 0.8791              | 71.9                 |
| 8/4/92   | 2        | 7.5                        | 0.042               | 0.0             | 3.12                   | 62.0                 | -17                    | 0.7274              | 63.4                 |
| 8/4/92   | 4        | 12.7                       | 0.039               | 0.0             | 2.57                   | 62.2                 | -37                    | 0.5716              | 63.2                 |
| 9/24/92  | 1        | -57.5                      | 0.036               | 0.0             | 2.95                   | 53.1                 | -186                   | 0.7347              | 78.8                 |
| 9/24/92  | 3        | -69.2                      | 0.041               | 0.0             | 2.41                   | 53.6                 | -186                   | 0.6862              | 80.1                 |
| 9/24/92  | 5        | -62.0                      | 0.036               | -0.3            | 3.33                   | 54.1                 | -184                   | 0.7140              | 80.4                 |

\* MEASUREMENT OMITTED

Table A-4 Specimen OA2850.0-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/15/91 | 2        | 31.0                       | 0.103              | 0.0             | 0.64                   | 60.8                 | 27                     | 1.3496             | 51.6                 |
| 11/15/91 | 4        | 13.2                       | 0.048              | 0.1             | 0.62                   | 59.7                 | 14                     | 1.0855             | 53.1                 |
| 12/24/91 | 1        | 5.5                        | 0.037              | 0.0             | 1.39                   | 41.7                 | -43                    | 0.9564             | 33.7                 |
| 12/24/91 | 3        | 8.0                        | 0.043              | 0.0             | 1.28                   | 41.7                 | -33                    | 0.5355             | 34.1                 |
| 12/24/91 | 5        | 13.7                       | 0.031              | 0.0             | 1.44                   | 41.8                 | -36                    | 0.4942             | 34.4                 |
| 2/4/92   | 2        | -21.2                      | 0.063              | 0.0             | 1.21                   | 42.5                 | -28                    | 0.7491             | 32.9                 |
| 2/4/92   | 4        | -35.5                      | 0.033              | 0.0             | 1.34                   | 43.1                 | -46                    | 0.7801             | 34.5                 |
| 4/24/92  | 1        | 61.6                       | 0.023              | 0.0             | 1.20                   | 77.8                 | -53                    | 0.7636             | 68.9                 |
| 4/24/92  | 3        | 63.7                       | 0.054              | 0.0             | 1.11                   | 77.3                 | -40                    | 1.0256             | 68.4                 |
| 4/24/92  | 5        | 61.2                       | 0.032              | -0.4            | 1.32                   | 76.8                 | -96                    | 0.4262             | 68.0                 |
| 6/13/92  | 2        | 18.0                       | 0.052              | 0.0             | 1.66                   | 69.6                 | -33                    | 0.8647             | 74.5                 |
| 6/13/92  | 4        | 36.2                       | 0.080              | 0.0             | 1.67                   | 70.1                 | -18                    | 1.0473             | 74.6                 |
| 8/4/92   | 1        | -14.0                      | 0.023              | 0.0             | 3.01                   | 61.8                 | -40                    | 0.4819             | 62.6                 |
| 8/4/92   | 3        | -8.0                       | 0.036              | 0.0             | 2.78                   | 61.6                 | -42                    | 0.5180             | 62.9                 |
| 8/4/92   | 5        | -0.5                       | 0.034              | 0.0             | 2.44                   | 61.4                 | -39                    | 0.5221             | 63.1                 |
| 9/24/92  | 2        | -66.2                      | 0.030              | 0.0             | 2.23                   | 54.7                 | -201                   | 0.7192             | 79.8                 |
| 9/24/92  | 4        | -33.5                      | 0.045              | -0.1            | 2.81                   | 55.5                 | -182                   | 0.8688             | 80.3                 |

\* MEASUREMENT OMITTED

Table A-5 Specimen IA2850.6-1

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/19/91 | 2        | 107.5                      | 0.060              | -0.1            | 1.40                   | 63.3                 | 36                     | 1.1484             | 63.2                 |
| 11/19/91 | 4        | 96.7                       | 0.042              | 0.1             | 1.40                   | 63.3                 | 12                     | 1.0772             | 63.3                 |
| 12/21/91 | 1        | 27.2                       | 0.035              | 0.0             | 0.50                   | 68.0                 | -26                    | 1.1402             | 67.0                 |
| 12/21/91 | 3        | 42.5                       | 0.035              | 1.4             | 0.73                   | 68.0                 | -31                    | 1.3156             | 67.0                 |
| 12/21/91 | 5        | 22.7                       | 0.038              | 1.9             | 0.77                   | 68.0                 | -50                    | 0.8286             | 67.0                 |
| 2/24/92  | 2        | 58.7                       | 0.056              | 0.0             | 0.65                   | 64.9                 | -5                     | 0.7130             | 64.8                 |
| 2/24/92  | 4        | 31.7                       | 0.036              | 0.0             | 0.96                   | 65.0                 | -11                    | 0.9132             | 64.3                 |
| 4/22/92  | 1        | 85.2                       | 0.020              | 0.0             | 0.99                   | 60.7                 | -40                    | 0.8688             | 60.8                 |
| 4/22/92  | 3        | 99.7                       | 0.054              | 0.0             | 0.83                   | 60.7                 | -23                    | 1.1701             | 60.8                 |
| 4/22/92  | 5        | 83.5                       | 0.028              | -0.1            | 0.90                   | 60.7                 | -36                    | 1.1402             | 60.7                 |
| 6/10/92  | 2        | 68.2                       | 0.048              | 0.0             | 0.81                   | 70.8                 | 39                     | 1.2021             | 68.9                 |
| 6/10/92  | 4        | 91.0                       | 0.065              | 0.0             | 0.64                   | 70.9                 | 53                     | 1.2692             | 68.7                 |
| 7/13/92  | 1        | 74.0                       | 0.051              | 0.0             | 0.62                   | 82.6                 | 32                     | 1.2382             | 81.4                 |
| 7/13/92  | 3        | 98.5                       | 0.081              | 0.0             | 0.55                   | 82.6                 | 54                     | 1.6221             | 81.4                 |
| 7/13/92  | 5        | 82.2                       | 0.046              | -0.6            | 0.65                   | 82.7                 | 35                     | 1.2681             | 81.5                 |
| 10/7/92  | 2        | 24                         | 0.034              | -0.1            | 0.72                   | 63.3                 | 5                      | 0.8337             | 63.5                 |
| 10/7/92  | 4        | 67.7                       | 0.057              | 0.0             | 0.70                   | 63.5                 | 38                     | 1.0081             | 63.6                 |

\* MEASUREMENT OMITTED



Table A-6 Specimen IA2850.6-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      |                        | 3LP                |                      |  |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|--|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |  |
| 11/17/91 | 1        | -8.2                       | 0.066              | 0.0             | 0.65                   | 63.7                 | 10                     | 1.0607             | 64.2                 |  |
| 11/17/91 | 3        | -8.0                       | 0.046              | 0.0             | 0.56                   | 63.7                 | 22                     | 1.0680             | 64.2                 |  |
| 11/17/91 | 5        | -16.5                      | 0.042              | 0.0             | 0.79                   | 63.7                 | 4                      | 0.9204             | 64.2                 |  |
| 12/21/91 | 2        | 56.2                       | 0.086              | 0.0             | 0.75                   | 68.0                 | 3                      | 1.3693             | 68.0                 |  |
| 12/21/91 | 4        | 41.2                       | 0.082              | 0.0             | 0.88                   | 68.0                 | 0                      | 1.0783             | 68.0                 |  |
| 2/24/92  | 1        | -37.0                      | 0.112              | 0.0             | 0.49                   | 65.4                 | -23                    | 0.8791             | 65.8                 |  |
| 2/24/92  | 3        | -53.0                      | 0.125              | 0.0             | 0.53                   | 65.5                 | -28                    | 1.1061             | 65.8                 |  |
| 2/24/92  | 5        | -53.7                      | 0.105              | 0.0             | 0.52                   | 65.6                 | -34                    | 1.0607             | 65.8                 |  |
| 4/22/92  | 2        | 81.3                       | 0.065              | 0.0             | 0.98                   | 67.2                 | 11                     | 1.0195             | 67.3                 |  |
| 4/22/92  | 4        | 83.3                       | 0.052              | 0.0             | 1.11                   | 67.4                 | -1                     | 1.1773             | 67.5                 |  |
| 6/9/92   | 1        | 56.7                       | 0.059              | 0.0             | 0.79                   | 74.2                 | 20                     | 1.1257             | 73.3                 |  |
| 6/9/92   | 3        | 68.2                       | 0.054              | 0.0             | 0.75                   | 74.2                 | 33                     | 1.2558             | 73.3                 |  |
| 6/9/92   | 5        | 56.5                       | 0.109              | -0.2            | 0.81                   | 74.2                 | 29                     | 1.3321             | 73.3                 |  |
| 7/13/92  | 2        | 90.7                       | 0.068              | 0.0             | 0.64                   | 79.1                 | 30                     | 1.3239             | 80.2                 |  |
| 7/13/92  | 4        | 90.7                       | 0.090              | -0.1            | 0.82                   | 78.8                 | 32                     | 1.3909             | 80.1                 |  |
| 10/7/92  | 1        | 14.0                       | 0.037              | 0.0             | 1.00                   | 62.0                 | -21                    | 0.7223             | 62.1                 |  |
| 10/7/92  | 3        | 37.7                       | 0.041              | 0.0             | 0.79                   | 62.0                 | -10                    | 0.9070             | 62.2                 |  |
| 10/7/92  | 5        | 16.7                       | 0.032              | -0.1            | 0.92                   | 62.0                 | -34                    | 0.6511             | 62.3                 |  |

\* MEASUREMENT OMITTED

Table A-7 Specimen IA2850.6-3

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/17/91 | 1        | 45.7                       | 0.043              | -0.3            | 0.51                   | 63.7                 | 54                     | 1.0102             | 64.2                 |
| 11/17/91 | 3        | 7.2                        | 0.059              | 0.4             | 0.44                   | 63.7                 | 26                     | 0.9483             | 64.2                 |
| 11/17/91 | 5        | 37.5                       | 0.064              | 0.0             | 0.66                   | 63.7                 | 47                     | 1.2093             | 64.2                 |
| 12/21/91 | 2        | 72.0                       | 0.084              | 0.0             | 0.59                   | 66.0                 | 13                     | 1.3507             | 66.0                 |
| 12/21/91 | 4        | 54.2                       | 0.098              | 0.0             | 0.55                   | 66.0                 | 0                      | 1.2950             | 66.0                 |
| 2/24/92  | 1        | -36.5                      | 0.072              | 0.0             | 0.47                   | 63.8                 | -1                     | 0.9410             | 64.2                 |
| 2/24/92  | 3        | -54.2                      | 0.105              | 0.0             | 0.39                   | 63.8                 | -34                    | 0.9916             | 64.2                 |
| 2/24/92  | 5        | -38.0                      | 0.105              | 0.0             | 0.50                   | 63.8                 | -11                    | 0.9514             | 64.2                 |
| 4/22/92  | 2        | 122.1                      | 0.062              | 0.0             | 0.82                   | 66.4                 | 94                     | 1.2485             | 66.8                 |
| 4/22/92  | 4        | 127.3                      | 0.038              | 0.0             | 1.02                   | 66.3                 | 17                     | 1.1309             | 66.9                 |
| 6/9/92   | 1        | 39.2                       | 0.047              | 0.0             | 0.44                   | 73.5                 | 48                     | 1.4270             | 73.2                 |
| 6/9/92   | 3        | 57.7                       | 0.067              | 0.0             | 0.39                   | 73.4                 | 72                     | 1.7263             | 73.2                 |
| 6/9/92   | 5        | 36.0                       | 0.039              | 0.0             | 0.46                   | 73.2                 | 60                     | 1.1608             | 73.1                 |
| 7/13/92  | 2        | 81.7                       | 0.089              | -0.6            | 0.60                   | 78.9                 | 38                     | 1.4394             | 78.0                 |
| 7/13/92  | 4        | 83.7                       | 0.075              | 0.0             | 0.66                   | 78.8                 | 29                     | 1.5323             | 78.3                 |
| 10/7/92  | 1        | 2.2                        | 0.041              | 0.1             | 1.54                   | 60.9                 | -37                    | 0.7285             | 60.5                 |
| 10/7/92  | 3        | 55.0                       | 0.036              | 0.0             | 0.91                   | 61.0                 | 17                     | 0.9720             | 60.3                 |
| 10/7/92  | 5        | 34.7                       | 0.045              | 0.0             | 1.21                   | 61.1                 | -4                     | 0.8069             | 60.2                 |

\* MEASUREMENT OMITTED

Table A-8 Specimen OA2850.6-1

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      |                        | 3LP                |                      |  |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|--|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |  |
| 11/15/91 | 1        | 66.7                       | 0.112              | 0.0             | 0.52                   | 58.4                 | 43                     | 1.1216             | 49.7                 |  |
| 11/15/91 | 3        | 62.0                       | 0.067              | -0.1            | 0.58                   | 58.2                 | 54                     | 1.3228             | 50.5                 |  |
| 11/15/91 | 5        | 75.5                       | 0.065              | 0.0             | 0.67                   | 58.0                 | 33                     | 1.3104             | 51.3                 |  |
| 12/24/91 | 2        | 68.5                       | 0.068              | 0.0             | 1.07                   | 41.3                 | -19                    | 0.6149             | 35.5                 |  |
| 12/24/91 | 4        | 89.7                       | 0.053              | 0.1             | 1.29                   | 41.3                 | -17                    | 1.0658             | 36.6                 |  |
| 2/4/92   | 1        | -19.0                      | 0.058              | -0.1            | 1.60                   | 41.9                 | -24                    | 0.8523             | 35.0                 |  |
| 2/4/92   | 3        | -9.2                       | 0.036              | -1.0            | 0.87                   | 42.6                 | -43                    | 0.8410             | 35.3                 |  |
| 2/4/92   | 5        | -9.2                       | 0.045              | 0.0             | 0.82                   | 43.3                 | -23                    | 0.8657             | 35.6                 |  |
| 4/24/92  | 2        | 112.4                      | 0.032              | 0.0             | 1.97                   | 74.8                 | -26                    | 3.0264             | 69.6                 |  |
| 4/24/92  | 4        | 121.1                      | 0.066              | 0.0             | 1.02                   | 74.8                 | -20                    | 1.7799             | 69.2                 |  |
| 6/13/92  | 1        | 38.0                       | 0.062              | 0.0             | 1.77                   | 66.3                 | 16                     | 1.2970             | 74.8                 |  |
| 6/13/92  | 3        | 52.2                       | 0.073              | 0.0             | 1.58                   | 66.4                 | 8                      | 1.3569             | 74.4                 |  |
| 6/13/92  | 5        | 52.7                       | 0.070              | 0.0             | 1.49                   | 66.4                 | 30                     | 1.3558             | 73.9                 |  |
| 8/4/92   | 2        | 35.2                       | 0.054              | -0.1            | 2.96                   | 61.8                 | -5                     | 0.7605             | 64.2                 |  |
| 8/4/92   | 4        | 41.0                       | 0.045              | 0.0             | 2.24                   | 62.2                 | -4                     | 0.7120             | 64.2                 |  |
| 9/24/92  | 1        | -35.0                      | 0.029              | 0.1             | 2.48                   | 54.2                 | -179                   | 0.6232             | 81.9                 |  |
| 9/24/92  | 3        | -5.2                       | 0.043              | 0.0             | 2.59                   | 54.2                 | -175                   | 0.9080             | 91.4                 |  |
| 9/24/92  | 5        | -5.0                       | 0.042              | 0.0             | 2.23                   | 54.2                 | -161                   | 0.9410             | 80.9                 |  |

\* MEASUREMENT OMITTED

Table A-9 Specimen OA2850.6-2

| DATE     | POSITION | GEOCISA                    |                          |                 |                        | 3LP                  |                        |                    |                      |
|----------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/15/91 | 2        | 77.0                       | 0.059                    | 0.0             | 0.51                   | 58.6                 | 64                     | 1.1443             | 49.7                 |
| 11/15/91 | 4        | 81.5                       | 0.068                    | 0.0             | 0.66                   | 57.9                 | 63                     | 1.1206             | 50.9                 |
| 12/24/91 | 1        | 76.7                       | 0.053                    | 0.0             | 1.09                   | 41.0                 | 63                     | 0.9688             | 36.7                 |
| 12/24/91 | 3        | 72.0                       | 0.073                    | -0.1            | 1.05                   | 41.6                 | 8                      | 1.4217             | 36.9                 |
| 12/24/91 | 5        | 82.0                       | 0.067                    | 0.0             | 1.17                   | 42.2                 | 19                     | 0.9368             | 37.2                 |
| 2/5/92   | 2        | 72.7                       | 0.031                    | 0.1             | 0.74                   | 43.2                 | 14                     | 0.9565             | 38.0                 |
| 2/5/92   | 4        | 16.0                       | 0.026                    | 0.0             | 0.47                   | 42.8                 | 9                      | 0.9730             | 38.6                 |
| 4/24/92  | 1        | 132.4                      | 0.090                    | 0.0             | 0.81                   | 80.5                 | -9                     | 1.0834             | 70.8                 |
| 4/24/92  | 3        | 151.6                      | 0.123                    | 0.0             | 0.52                   | 79.9                 | -8                     | 2.0038             | 70.9                 |
| 4/24/92  | 5        | 110.1                      | 0.069                    | -0.2            | 1.11                   | 79.3                 | 3                      | 2.1091             | 71.0                 |
| 6/13/92  | 2        | 70.7                       | 0.003                    | 0.0             | 17.75                  | 68.3                 | 16                     | 0.9555             | 76.6                 |
| 6/13/92  | 4        | 57.0                       | 0.059                    | 0.0             | 1.23                   | 68.4                 | 24                     | 1.1350             | 76.1                 |
| 8/4/92   | 1        | 58.2                       | 0.037                    | 0.2             | 2.15                   | 61.9                 | 15                     | 0.8203             | 64.5                 |
| 8/4/92   | 3        | 42.5                       | 0.046                    | 0.3             | 2.11                   | 61.9                 | -1                     | 0.9782             | 64.5                 |
| 8/4/92   | 5        | 68.0                       | 0.042                    | -0.1            | 1.99                   | 62.0                 | 11                     | 0.7316             | 64.5                 |
| 9/24/92  | 2        | 15.0                       | 0.030                    | 0.1             | 2.44                   | 56.3                 | -185                   | 0.6160             | 87.2                 |
| 9/24/92  | 4        | -4.0                       | 0.034                    | 0.0             | 2.59                   | 56.5                 | -183                   | 0.7419             | 87.0                 |

\* MEASUREMENT OMITTED

Table A-10 Specimen OA2850.6-3

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/15/91 | 1        | 75.5                       | 0.094              | -0.2            | 0.59                   | 57.8                 | 52                     | 1.1773             | 49.6                 |
| 11/15/91 | 3        | 46.2                       | 0.077              | 0.0             | 0.66                   | 57.7                 | 36                     | 1.1020             | 50.1                 |
| 11/15/91 | 5        | 42.0                       | 0.062              | 0.0             | 0.78                   | 57.5                 | 28                     | 0.8595             | 50.5                 |
| 12/24/91 | 2        | 61.5                       | 0.045              | 0.0             | 1.33                   | 41.2                 | 14                     | 0.7831             | 39.2                 |
| 12/24/91 | 4        | 54.7                       | 0.048              | 0.0             | 1.30                   | 42.2                 | 8                      | 0.9925             | 39.2                 |
| 2/5/92   | 1        | 13.5                       | 0.047              | 0.1             | 1.29                   | 43.5                 | 21                     | 1.0514             | 39.2                 |
| 2/5/92   | 3        | -7.7                       | 0.042              | 0.0             | 0.66                   | 44.6                 | -10                    | 1.0081             | 39.1                 |
| 2/5/92   | 5        | 2.5                        | 0.032              | 0.1             | 0.64                   | 45.7                 | -8                     | 0.8482             | 39.0                 |
| 4/24/92  | 2        | 105.4                      | 0.061              | 0.0             | 1.20                   | 80.1                 | -36                    | 1.0556             | 71.1                 |
| 4/24/92  | 4        | 127.1                      | 0.091              | 0.0             | 0.74                   | 79.1                 | -13                    | 1.8883             | 72.4                 |
| 6/13/92  | 1        | 54.2                       | 0.050              | 0.0             | 1.33                   | 69.2                 | -9                     | 0.8575             | 78.1                 |
| 6/13/92  | 3        | 52.5                       | 0.068              | 0.0             | 1.22                   | 69.3                 | -3                     | 1.0411             | 78.0                 |
| 6/13/92  | 5        | 73.5                       | 0.089              | -0.1            | 1.24                   | 69.3                 | -2                     | 0.9472             | 77.9                 |
| 8/4/92   | 2        | 42.2                       | 0.036              | 0.0             | 2.79                   | 62.0                 | -2                     | 0.6501             | 65.0                 |
| 8/4/92   | 4        | 34.2                       | 0.039              | 0.0             | 2.33                   | 62.3                 | -4                     | 0.9101             | 65.2                 |
| 9/24/92  | 1        | -21.2                      | 0.023              | -0.3            | 3.03                   | 56.5                 | -139                   | 0.6769             | 87.2                 |
| 9/24/92  | 3        | -18.0                      | 0.029              | 0.0             | 2.69                   | 56.8                 | -79                    | 0.8554             | 87.2                 |
| 9/24/92  | 5        | 1.2                        | 0.040              | -0.3            | 2.98                   | 57.1                 | -69                    | 0.8554             | 87.2                 |

\* MEASUREMENT OMITTED

Table A-11 Specimen IA2851.2-1

| DATE     | POSITION | GEOCISA                    |                    |                 |                        | 3LP                  |                        |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/17/91 | 2        | 53.5                       | 0.075              | 1.2             | 0.38                   | 63.3                 | 53                     | 1.7283             | 63.3                 |
| 11/17/91 | 4        | 63.5                       | 0.059              | 0.7             | 0.40                   | 63.2                 | 63                     | 1.7046             | 63.3                 |
| 12/21/91 | 1        | 80.5                       | 0.058              | 1.0             | 0.50                   | 67.0                 | 8                      | 2.4950             | 67.0                 |
| 12/21/91 | 3        | 62.2                       | 0.234              | 0.0             | 0.41                   | 66.5                 | 14                     | 2.0895             | 67.0                 |
| 12/21/91 | 5        | 67.5                       | 0.113              | 0.0             | 0.67                   | 66.0                 | 22                     | 1.6086             | 67.0                 |
| 2/24/92  | 2        | 51.7                       | 0.130              | 0.0             | 0.34                   | 64.3                 | 1                      | 1.6002             | 64.8                 |
| 2/24/92  | 4        | 64.2                       | 0.091              | 0.0             | 0.47                   | 64.5                 | 19                     | 1.2504             | 64.7                 |
| 4/24/92  | 1        | 59.7                       | 0.063              | 0.0             | 0.80                   | 60.4                 | -33                    | 1.4642             | 61.5                 |
| 4/24/92  | 3        | 103.2                      | 0.067              | 0.0             | 0.48                   | 60.4                 | -14                    | 1.8532             | 61.8                 |
| 4/24/92  | 5        | 87.7                       | 0.104              | -0.1            | 0.70                   | 60.4                 | -31                    | 2.0028             | 62.1                 |
| 6/10/92  | 2        | 58.2                       | 0.108              | 0.0             | 0.57                   | 70.2                 | 59                     | 1.4064             | 68.7                 |
| 6/10/92  | 4        | 95.2                       | 0.071              | 0.0             | 0.42                   | 70.2                 | 61                     | 1.9130             | 68.7                 |
| 7/13/92  | 1        | 71.7                       | 0.108              | 0.0             | 0.45                   | 81.7                 | 50                     | 2.2370             | 81.4                 |
| 7/13/92  | 3        | 105.5                      | 0.124              | 0.0             | 0.33                   | 81.9                 | 69                     | 2.5425             | 81.4                 |
| 7/13/92  | 5        | 72.7                       | 0.213              | -0.1            | 0.50                   | 82.0                 | 39                     | 2.3309             | 81.4                 |
| 10/7/92  | 2        | 77.2                       | 0.051              | 0.0             | 0.54                   | 62.9                 | 43                     | 1.1134             | 62.6                 |
| 10/7/92  | 4        | 56.2                       | 0.032              | 0.0             | 0.46                   | 63.3                 | 26                     | 1.0339             | 62.9                 |

\* MEASUREMENT OMITTED

Table A-12 Specimen IA2851.2-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/19/91 | 1        | 122.7                      | 0.101              | 0.0             | 0.78                   | 62.2                 | 22                     | 2.2154             | 62.2                 |
| 11/19/91 | 3        | 99.5                       | 0.064              | 0.0             | 0.80                   | 62.1                 | 28                     | 1.3631             | 62.0                 |
| 11/19/91 | 5        | 99.5                       | 0.193              | -0.2            | 0.89                   | 62.0                 | 13                     | 1.2083             | 61.9                 |
| 12/21/91 | 2        | 26.0                       | 0.041              | 1.1             | 0.25                   | 66.0                 | 17                     | 1.4425             | 65.0                 |
| 12/21/91 | 4        | 84.7                       | 0.267              | 1.9             | 0.40                   | 65.0                 | 12                     | 1.5529             | 65.0                 |
| 2/24/92  | 1        | 54.0                       | 0.200              | 0.0             | 0.58                   | 62.7                 | -15                    | 1.6982             | 62.4                 |
| 2/24/92  | 3        | 40.2                       | 0.070              | 0.1             | 0.55                   | 62.7                 | -11                    | 1.4227             | 62.4                 |
| 2/24/92  | 5        | 38.5                       | 0.059              | 0.0             | 0.54                   | 62.7                 | -10                    | 1.0946             | 62.4                 |
| 4/24/92  | 2        | 114.0                      | 0.055              | 0.0             | 0.72                   | 59.1                 | -47                    | 1.2289             | 59.4                 |
| 4/24/92  | 4        | 125.5                      | 0.062              | 0.0             | 0.57                   | 59.1                 | -45                    | 1.3527             | 59.4                 |
| 6/10/92  | 1        | 20.7                       | 0.063              | 0.0             | 0.52                   | 67.3                 | 9                      | 1.1051             | 68.0                 |
| 6/10/92  | 3        | 71.5                       | 0.171              | 0.0             | 0.49                   | 67.3                 | 46                     | 1.3496             | 68.0                 |
| 6/10/92  | 5        | 52.2                       | 0.111              | 0.0             | 0.45                   | 67.3                 | 32                     | 1.6798             | 68.0                 |
| 7/13/92  | 2        | 112.5                      | 0.076              | -0.4            | 0.40                   | 79.2                 | 60                     | 1.4807             | 78.9                 |
| 7/13/92  | 4        | 114.2                      | 0.059              | 0.1             | 0.38                   | 79.3                 | 60                     | 1.7325             | 79.0                 |
| 10/7/92  | 1        | 24.5                       | 0.028              | 0.0             | 0.21                   | 61.3                 | 2                      | 0.8059             | 61.3                 |
| 10/7/92  | 3        | 48.2                       | 0.047              | -0.1            | 0.51                   | 61.2                 | 9                      | 1.5189             | 61.3                 |
| 10/7/92  | 5        | 9.2                        | 0.067              | 0.0             | 0.54                   | 61.1                 | 5                      | 0.9947             | 61.4                 |

\* MEASUREMENT OMITTED

Table A-13 Specimen IA2851.2-3

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/19/91 | 1        | 104.5                      | 0.323 *            | -0.9            | 1.18                   | 62.2                 | 61                     | 2.0472             | 62.0                 |
| 11/19/91 | 3        | 104.5                      | 0.055              | 0.0             | 0.96                   | 62.0                 | 56                     | 1.3569             | 62.1                 |
| 11/19/91 | 5        | 105.0                      | 0.036              | -0.1            | 0.98                   | 61.9                 | 48                     | 1.0587             | 62.2                 |
| 12/21/91 | 2        | 59.7                       | 0.119              | -0.1            | 0.44                   | 65.0                 | 8                      | 1.6107             | 65.0                 |
| 12/21/91 | 4        | 61.2                       | 0.212              | -0.7            | 0.40                   | 64.0                 | 14                     | 1.4910             | 65.0                 |
| 2/24/92  | 1        | 63.2                       | 0.160              | 0.0             | 0.58                   | 62.3                 | 4                      | 1.3113             | 62.8                 |
| 2/24/92  | 3        | 57.3                       | 0.084              | 0.0             | 0.53                   | 62.3                 | -13                    | 1.1576             | 62.8                 |
| 2/24/92  | 5        | 48.2                       | 0.071              | 0.0             | 0.43                   | 62.3                 | -1                     | 0.9399             | 62.8                 |
| 4/24/92  | 2        | 128.5                      | 0.095              | -0.1            | 0.57                   | 59.9                 | -75                    | 1.1061             | 59.1                 |
| 4/24/92  | 4        | 26.5                       | 0.053              | 0.0             | 0.55                   | 60.0                 | -42                    | 1.1526             | 59.3                 |
| 6/10/92  | 1        | 57.2                       | 0.079              | 0.0             | 0.50                   | 67.8                 | 30                     | 1.4642             | 68.0                 |
| 6/10/92  | 3        | 70.7                       | 0.075              | 0.0             | 0.45                   | 67.8                 | 52                     | 1.6644             | 67.9                 |
| 6/10/92  | 5        | 59.5                       | 0.076              | -0.1            | 0.53                   | 67.8                 | 38                     | 1.6840             | 67.9                 |
| 7/13/92  | 2        | 110.5                      | 0.076              | 0.1             | 0.37                   | 79.4                 | 55                     | 2.3031             | 79.2                 |
| 7/13/92  | 4        | 119.7                      | 0.064              | 0.0             | 0.38                   | 79.2                 | 75                     | 2.2133             | 78.2                 |
| 10/7/92  | 1        | -15.7                      | 0.046              | 0.0             | 0.67                   | 60.8                 | -23                    | 1.2805             | 61.0                 |
| 10/7/92  | 3        | 32.5                       | 0.062              | -0.1            | 0.63                   | 60.8                 | 5                      | 1.1092             | 61.0                 |
| 10/7/92  | 5        | 14.7                       | 0.047              | 0.0             | 0.53                   | 60.9                 | 0                      | 1.0473             | 61.0                 |

\* MEASUREMENT OMITTED



Table A-14 Specimen OA2851.2-1

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/15/91 | 1        | 111.7                      | 0.081              | 0.0             | 0.42                   | 56.7                 | 97                     | 1.2279             | 47.5                 |
| 11/15/91 | 3        | 96.2                       | 0.085              | 0.0             | 0.53                   | 56.8                 | 83                     | 1.4136             | 48.8                 |
| 11/15/91 | 5        | 108.2                      | 0.087              | 0.1             | 0.53                   | 56.9                 | 85                     | 1.5116             | 49.1                 |
| 12/24/91 | 2        | 115.5                      | 0.069              | 0.0             | 0.91                   | 41.8                 | 67                     | 1.1772             | 41.7                 |
| 12/24/91 | 4        | 106.7                      | 0.096              | 0.0             | 0.90                   | 41.8                 | 48                     | 1.3577             | 41.6                 |
| 2/5/92   | 1        | 51.2                       | 0.053              | 0.0             | 1.17                   | 47.4                 | 28                     | 1.2391             | 40.7                 |
| 2/5/92   | 3        | 50.5                       | 0.083              | 0.0             | 0.64                   | 47.5                 | 22                     | 1.1896             | 40.4                 |
| 2/5/92   | 5        | 56.5                       | 0.049              | 0.0             | 0.87                   | 47.6                 | 34                     | 1.3980             | 40.1                 |
| 4/24/92  | 2        | 138.2                      | 0.127              | 0.0             | 0.51                   | 84.6                 | 3                      | 1.7717             | 78.2                 |
| 4/24/92  | 4        | 132.7                      | 0.074              | 0.0             | 0.67                   | 82.0                 | 26                     | 2.0018             | 77.8                 |
| 6/13/92  | 1        | 82.7                       | 0.101              | 0.0             | 0.97                   | 70.8                 | 34                     | 1.4869             | 72.2                 |
| 6/13/92  | 3        | 61.7                       | 0.091              | 0.0             | 0.93                   | 70.5                 | 25                     | 1.0050             | 72.3                 |
| 6/13/92  | 5        | 77.0                       | 0.086              | 0.0             | 0.97                   | 70.2                 | 15                     | 1.2506             | 72.4                 |
| 8/4/92   | 2        | 60.0                       | 0.059              | 0.0             | 2.18                   | 62.4                 | 13                     | 1.0164             | 65.8                 |
| 8/4/92   | 4        | 60.0                       | 0.055              | -0.2            | 2.62                   | 62.4                 | 16                     | 0.9637             | 65.9                 |
| 9/24/92  | 1        | 34.7                       | 0.071              | 0.0             | 2.37                   | 61.4                 | -59                    | 0.9163             | 88.3                 |
| 9/24/92  | 3        | -19.5                      | 0.038              | 0.0             | 2.24                   | 61.3                 | -69                    | 1.0680             | 87.8                 |
| 9/24/92  | 5        | -7.2                       | 0.040              | -0.1            | 2.76                   | 61.2                 | 57                     | 1.2176             | 87.3                 |

\* MEASUREMENT OMITTED

Table A-15 Specimen OA2851.2-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/15/91 | 2        | 98.5                       | 0.079              | -0.4            | 0.45                   | 58.4                 | 84                     | 1.1856             | 48.2                 |
| 11/15/91 | 4        | 109.2                      | 0.089              | 0.1             | 0.40                   | 57.6                 | 85                     | 1.2516             | 48.4                 |
| 12/24/91 | 1        | 100.2                      | 0.039              | 0.6             | 0.90                   | 41.9                 | 37                     | 1.1132             | 42.9                 |
| 12/24/91 | 3        | 104.7                      | 0.073              | 0.1             | 0.90                   | 41.9                 | 42                     | 1.3495             | 42.9                 |
| 12/24/91 | 5        | 102.7                      | 0.081              | 0.0             | 0.91                   | 42.0                 | 35                     | 1.2092             | 43.0                 |
| 2/5/92   | 2        | 28.2                       | 0.063              | 0.3             | 1.05                   | 48.0                 | 21                     | 1.1988             | 40.6                 |
| 2/5/92   | 4        | 51.0                       | 0.096              | 0.0             | 1.19                   | 47.4                 | 29                     | 1.4630             | 40.5                 |
| 4/24/92  | 1        | 136.5                      | 0.166              | 0.0             | 0.42                   | 70.2                 | -8                     | 1.4147             | 76.9                 |
| 4/24/92  | 3        | 141.2                      | 0.110              | 0.0             | 0.51                   | 70.6                 | 16                     | 2.5920             | 76.9                 |
| 4/24/92  | 5        | 138.9                      | 0.095              | 0.0             | 0.82                   | 71.0                 | 15                     | 1.3785             | 76.9                 |
| 6/13/92  | 2        | 70.0                       | 0.080              | 0.0             | 0.91                   | 70.7                 | 32                     | 1.6004             | 73.2                 |
| 6/13/92  | 4        | 70.0                       | 0.097              | 0.0             | 0.80                   | 70.9                 | 26                     | 1.6675             | 73.2                 |
| 8/4/92   | 1        | 80.0                       | 0.068              | 0.0             | 2.07                   | 62.4                 | 15                     | 1.0917             | 66.8                 |
| 8/4/92   | 3        | 63.7                       | 0.071              | 0.0             | 1.79                   | 62.4                 | 2                      | 1.0700             | 66.7                 |
| 8/4/92   | 5        | 71.2                       | 0.061              | 0.2             | 2.02                   | 62.4                 | 12                     | 0.9348             | 66.6                 |
| 9/24/92  | 2        | -9.0                       | 0.044              | 0.3             | 2.19                   | 61.9                 | 196                    | 0.8771             | 87.6                 |
| 9/24/92  | 4        | 13.2                       | 0.050              | 0.2             | 2.00                   | 62.7                 | 164                    | 1.2155             | 87.8                 |

\* MEASUREMENT OMITTED

Table A-16 Specimen OA2851.2-3

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/15/91 | 1        | 90.2                       | 0.092              | 0.0             | 0.69                   | 56.3                 | 76                     | 1.3321             | 45.7                 |
| 11/15/91 | 3        | 92.5                       | 0.141              | -0.1            | 0.76                   | 56.4                 | 72                     | 1.2413             | 44.2                 |
| 11/15/91 | 5        | 95.7                       | 0.094              | -0.1            | 0.53                   | 56.5                 | 65                     | 1.5261             | 42.6                 |
| 12/24/91 | 2        | 129.5                      | 0.095              | 0.0             | 0.99                   | 41.4                 | 66                     | 1.3175             | 43.5                 |
| 12/24/91 | 4        | 108.2                      | 0.087              | 0.0             | 0.97                   | 41.4                 | 42                     | 1.3577             | 43.5                 |
| 2/5/92   | 1        | 37.7                       | 0.045              | 0.1             | 0.74                   | 46.8                 | 38                     | 1.6301             | 47.9                 |
| 2/5/92   | 3        | 44.2                       | 0.047              | 0.0             | 0.92                   | 46.7                 | 22                     | 1.1669             | 49.0                 |
| 2/5/92   | 5        | 31.2                       | 0.053              | 0.1             | 0.43                   | 46.6                 | 5                      | 1.2824             | 50.2                 |
| 4/24/92  | 2        | 131.1                      | 0.079              | -0.7            | 1.19                   | 78.6                 | 6                      | 2.5115             | 77.9                 |
| 4/24/92  | 4        | 132.1                      | 0.136              | 0.1             | 0.42                   | 79.6                 | 6                      | 1.8325             | 78.9                 |
| 6/13/92  | 1        | 70.5                       | 0.100              | 0.1             | 0.86                   | 70.9                 | 31                     | 1.9626             | 74.6                 |
| 6/13/92  | 3        | 74.0                       | 0.124              | 0.0             | 0.93                   | 71.1                 | 31                     | 2.0781             | 74.5                 |
| 6/13/92  | 5        | 81.2                       | 0.087              | 0.0             | 1.02                   | 71.4                 | 40                     | 1.7479             | 74.4                 |
| 8/4/92   | 2        | 69.2                       | 0.056              | 0.0             | 1.76                   | 63.4                 | 16                     | 1.1123             | 66.8                 |
| 8/4/92   | 4        | 77.7                       | 0.080              | 0.0             | 1.55                   | 63.5                 | 15                     | 1.0731             | 67.0                 |
| 9/24/92  | 1        | 39.0                       | 0.051              | 0.0             | 2.33                   | 62.2                 | 148                    | 1.2444             | 87.0                 |
| 9/24/92  | 3        | 38.7                       | 0.065              | 0.1             | 2.13                   | 62.2                 | 152                    | 1.3527             | 87.4                 |
| 9/24/92  | 5        | 49.7                       | 0.036              | -0.2            | 2.25                   | 62.1                 | 61                     | 0.7955             | 87.8                 |

\* MEASUREMENT OMITTED

Table A-17 Specimen JA2852.4-1

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/19/91 | 2        | 137.0                      | 0.111              | 0.0             | 1.07                   | 62.3                 | 39                     | 1.7067             | 62.9                 |
| 11/19/91 | 4        | 123.7                      | 0.155              | -0.1            | 0.94                   | 62.3                 | 45                     | 1.6644             | 62.9                 |
| 12/21/91 | 1        | 122.7                      | 0.134              | -0.1            | 0.51                   | 64.0                 | 40                     | 2.0338             | 64.0                 |
| 12/21/91 | 3        | 69.7                       | 0.102              | 0.0             | 0.66                   | 64.0                 | 6                      | 1.5921             | 63.5                 |
| 12/21/91 | 5        | 67.7                       | 0.196              | -0.1            | 0.73                   | 64.0                 | 5                      | 2.1627             | 63.0                 |
| 2/24/92  | 2        | 62.2                       | 0.087              | 0.0             | 0.68                   | 62.5                 | -10                    | 1.1999             | 62.5                 |
| 2/24/92  | 4        | 64.2                       | 0.078              | 0.0             | 0.67                   | 62.4                 | 0                      | 1.4258             | 62.5                 |
| 4/24/92  | 1        | 105.7                      | 0.110              | 0.0             | 0.87                   | 58.5                 | -61                    | 1.2981             | 58.4                 |
| 4/24/92  | 3        | 122.0                      | 0.068              | 0.0             | 0.95                   | 58.2                 | -56                    | 0.9091             | 58.7                 |
| 4/24/92  | 5        | 110.0                      | 0.065              | 0.0             | 1.02                   | 57.8                 | -59                    | 1.1804             | 59.0                 |
| 6/10/92  | 2        | 63.5                       | 0.080              | 0.5             | 0.54                   | 67.2                 | 41                     | 1.5395             | 67.8                 |
| 6/10/92  | 4        | 76.0                       | 0.056              | -0.1            | 0.57                   | 67.2                 | 31                     | 1.2687             | 67.8                 |
| 7/13/92  | 1        | 73.2                       | 0.039              | 0.0             | 0.77                   | 78.3                 | 52                     | 2.3691             | 80.1                 |
| 7/13/92  | 3        | 90.7                       | 0.050              | 0.2             | 0.62                   | 78.3                 | 86                     | 2.0317             | 80.4                 |
| 7/13/92  | 5        | 74.7                       | 0.054              | -0.1            | 0.60                   | 78.2                 | 30                     | 1.5488             | 80.7                 |
| 10/7/92  | 2        | 81.5                       | 0.049              | 0.0             | 0.55                   | 60.2                 | 69                     | 1.2723             | 59.9                 |
| 10/7/92  | 4        | 86.0                       | 0.032              | 0.0             | 0.54                   | 60.2                 | 70                     | 1.2475             | 60.1                 |

\* MEASUREMENT OMITTED

Table A-18 Specimen IA2852.4-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/19/91 | 1        | 152.5                      | 0.142              | -0.1            | 1.32                   | 62.9                 | 90                     | 1.3517             | 62.8                 |
| 11/19/91 | 3        | 136.7                      | 0.176              | 0.0             | 1.21                   | 62.9                 | 68                     | 1.4332             | 62.6                 |
| 11/19/91 | 5        | 99.2                       | 0.132              | -0.1            | 0.92                   | 62.9                 | 35                     | 1.2733             | 62.4                 |
| 12/21/91 | 2        | 104.7                      | 0.137              | -0.1            | 0.72                   | 66.0                 | 30                     | 2.1184             | 65.0                 |
| 12/21/91 | 4        | 46.5                       | 0.055              | -0.4            | 0.68                   | 66.0                 | -8                     | 2.0915             | 66.0                 |
| 2/24/92  | 1        | 93.7                       | 0.990 *            | 0.0             | 0.50                   | 64.5                 | 30                     | 1.2721             | 64.9                 |
| 2/24/92  | 3        | 46.5                       | 0.119              | 0.1             | 0.53                   | 64.5                 | -24                    | 1.3608             | 64.9                 |
| 2/24/92  | 5        | 53.2                       | 0.101              | 0.6             | 0.53                   | 64.6                 | -11                    | 1.3361             | 64.9                 |
| 4/24/92  | 2        | 123.7                      | 0.073              | 0.0             | 0.64                   | 60.5                 | -1                     | 1.3600             | 60.7                 |
| 4/24/92  | 4        | 115.7                      | 0.043              | 0.3             | 0.62                   | 60.4                 | -7                     | 1.4642             | 60.4                 |
| 6/10/92  | 1        | 73.0                       | 0.093              | 0.0             | 0.69                   | 70.1                 | 39                     | 1.7521             | 68.4                 |
| 6/10/92  | 3        | 103.2                      | 0.080              | 0.1             | 0.56                   | 70.2                 | 51                     | 1.9945             | 68.4                 |
| 6/10/92  | 5        | 105.7                      | 0.069              | 0.1             | 0.62                   | 70.3                 | 51                     | 1.3063             | 68.5                 |
| 7/13/92  | 2        | 131.7                      | 0.082              | 0.0             | 0.51                   | 82.1                 | 81                     | 1.8697             | 81.2                 |
| 7/13/92  | 4        | 128.2                      | 0.064              | 0.0             | 0.50                   | 82.0                 | 86                     | 1.9481             | 81.2                 |
| 10/7/92  | 1        | 53.7                       | 0.061              | 0.0             | 0.79                   | 63.3                 | 20                     | 1.1515             | 63.0                 |
| 10/7/92  | 3        | 88.5                       | 0.044              | 0.0             | 0.65                   | 63.3                 | 48                     | 1.3775             | 63.1                 |
| 10/7/92  | 5        | 72.2                       | 0.061              | 0.0             | 0.69                   | 63.3                 | 25                     | 0.9400             | 63.3                 |

\* MEASUREMENT OMITTED

Table A-19 Specimen IA2852.4-3

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/19/91 | 1        | 108.2                      | 0.072              | 0.0             | 1.02                   | 63.1                 | 31                     | 1.5426             | 63.0                 |
| 11/19/91 | 3        | 130.7                      | 0.064              | 0.1             | 1.00                   | 63.0                 | 46                     | 1.7098             | 62.9                 |
| 11/19/91 | 5        | 157.5                      | 0.177              | -0.1            | 1.23                   | 62.8                 | 66                     | 1.5890             | 62.8                 |
| 12/21/91 | 2        | 116.7                      | 0.185              | 0.0             | 0.61                   | 67.0                 | 12                     | 1.8883             | 66.0                 |
| 12/21/91 | 4        | 89.2                       | 0.131              | 0.0             | 0.55                   | 67.0                 | -1                     | 2.1072             | 66.0                 |
| 2/24/92  | 1        | 78.7                       | 0.059              | 0.0             | 0.72                   | 64.8                 | 7                      | 1.2989             | 64.6                 |
| 2/24/92  | 3        | 73.7                       | 0.064              | 0.0             | 0.65                   | 64.8                 | 7                      | 1.3536             | 64.6                 |
| 2/24/92  | 5        | 104.2                      | 0.074              | 0.6             | 0.67                   | 64.9                 | 26                     | 1.3371             | 64.6                 |
| 4/24/92  | 2        | 101.0                      | 0.055              | 0.1             | 0.70                   | 60.4                 | -19                    | 1.6355             | 59.9                 |
| 4/24/92  | 4        | 107.2                      | 0.067              | 0.0             | 0.65                   | 60.0                 | -17                    | 1.8408             | 59.6                 |
| 6/10/92  | 1        | 104.0                      | 0.069              | 0.0             | 0.66                   | 70.4                 | 54                     | 1.7469             | 68.6                 |
| 6/10/92  | 3        | 84.5                       | 0.079              | 0.0             | 0.66                   | 70.3                 | 40                     | 1.8047             | 68.6                 |
| 6/10/92  | 5        | 80.7                       | 0.076              | 0.0             | 0.62                   | 70.3                 | 29                     | 1.7387             | 68.6                 |
| 7/13/92  | 2        | 117.5                      | 0.106              | 0.0             | 0.49                   | 81.8                 | 77                     | 1.8325             | 81.0                 |
| 7/13/92  | 4        | 126.2                      | 0.110              | 0.0             | 0.53                   | 82.1                 | 81                     | 2.1937             | 81.4                 |
| 10/7/92  | 1        | 54.7                       | 0.061              | 0.0             | 0.74                   | 62.8                 | 15                     | 1.6386             | 62.6                 |
| 10/7/92  | 3        | 67.2                       | 0.057              | 0.0             | 0.67                   | 62.7                 | 15                     | 1.2506             | 62.6                 |
| 10/7/92  | 5        | 75.7                       | 0.047              | 0.0             | 0.76                   | 62.6                 | 28                     | 1.0907             | 62.6                 |

\* MEASUREMENT OMITTED

Table A-20 Specimen OA2852.4-1

| DATE     | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/14/91 | 1        | 127.7                      | 0.077                    | 0.0             | 0.12                   | 53.7                 | 104                    | 1.2558             | 43.4                 |
| 11/14/91 | 3        | 155.0                      | 0.077                    | 0.3             | 0.38                   | 53.5                 | 131                    | 1.1680             | 43.7                 |
| 11/14/91 | 5        | 125.0                      | 0.141                    | 0.0             | 1.06                   | 53.3                 | 106                    | 1.8243             | 44.0                 |
| 12/24/91 | 2        | 127.0                      | 0.127                    | 0.0             | 0.90                   | 46.0                 | 34                     | 1.5290             | 48.3                 |
| 12/24/91 | 4        | 71.7                       | 0.071                    | 0.0             | 1.02                   | 46.2                 | 7                      | 1.4072             | 47.2                 |
| 2/22/92  | 1        | 25.2                       | 0.123                    | -3.2            | 0.52                   | 50.8                 | 12                     | 1.4671             | 56.2                 |
| 2/22/92  | 3        | 67.0                       | 0.069                    | 0.0             | 0.92                   | 51.0                 | 56                     | 1.6817             | 56.5                 |
| 2/22/92  | 5        | 42.7                       | 0.073                    | 0.0             | 0.83                   | 51.2                 | 24                     | 1.7477             | 56.7                 |
| 4/24/92  | 2        | 147.0                      | 0.182                    | 0.0             | 0.67                   | 88.0                 | -30                    | 1.4126             | 61.4                 |
| 4/24/92  | 4        | 138.2                      | 0.127                    | 0.0             | 0.71                   | 87.2                 | -11                    | 1.5859             | 63.9                 |
| 6/13/92  | 1        | 71.0                       | 0.138                    | 0.0             | 1.13                   | 75.5                 | 42                     | 1.6571             | 80.6                 |
| 6/13/92  | 3        | 85.5                       | 0.119                    | 0.0             | 0.92                   | 75.5                 | 50                     | 1.7882             | 80.5                 |
| 6/13/92  | 5        | 72.5                       | 0.122                    | 0.0             | 1.08                   | 75.5                 | 30                     | 1.6922             | 80.4                 |
| 8/4/92   | 2        | 89.7                       | 0.056                    | 0.0             | 2.16                   | 65.0                 | 21                     | 1.0556             | 71.6                 |
| 8/4/92   | 4        | 108.2                      | 0.069                    | 0.0             | 1.86                   | 65.0                 | 43                     | 1.4807             | 71.4                 |
| 9/24/92  | 1        | 83.0                       | 0.066                    | -0.1            | 2.47                   | 64.3                 | -35                    | 1.3424             | 73.7                 |
| 9/24/92  | 3        | 91.2                       | 0.042                    | 0.1             | 2.35                   | 64.4                 | -33                    | 1.2764             | 74.1                 |
| 9/24/92  | 5        | 84.5                       | 0.060                    | 0.0             | 1.98                   | 64.6                 | -42                    | 1.1453             | 74.4                 |

\* MEASUREMENT OMITTED

Table A-21 Specimen OA2852.4-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/14/91 | 2        | 112.0                      | 0.074              | 0.0             | 0.21                   | 53.8                 | 95                     | 1.2898             | 44.4                 |
| 11/14/91 | 4        | 123.2                      | 0.087              | 0.0             | 0.87                   | 53.9                 | 100                    | 1.6664             | 44.4                 |
| 12/24/91 | 1        | 157.7                      | 0.104              | 0.0             | 1.15                   | 47.1                 | 76                     | 1.4640             | 49.1                 |
| 12/24/91 | 3        | 113.0                      | 0.088              | 0.0             | 1.01                   | 46.9                 | 33                     | 1.4991             | 48.6                 |
| 12/24/91 | 5        | 114.5                      | 0.126              | 0.0             | 1.04                   | 46.7                 | 34                     | 1.5930             | 48.0                 |
| 2/22/92  | 2        | 26.0                       | 0.084              | 0.1             | 0.57                   | 56.5                 | 21                     | 1.7002             | 58.4                 |
| 2/22/92  | 4        | 32.0                       | 0.083              | -0.3            | 0.58                   | 56.7                 | 34                     | 1.8416             | 58.2                 |
| 4/24/92  | 1        | 166.7                      | 0.253              | 0.0             | 0.66                   | 90.1                 | -32                    | 1.8862             | 64.6                 |
| 4/24/92  | 3        | 140.7                      | 0.153              | 0.1             | 0.72                   | 90.2                 | -70                    | 1.6313             | 64.8                 |
| 4/24/92  | 5        | 160.7                      | 0.189              | 0.0             | 1.08                   | 90.4                 | -13                    | 1.3404             | 65.0                 |
| 6/13/92  | 2        | 96.7                       | 0.124              | 0.0             | 1.47                   | 75.9                 | 48                     | 2.0224             | 84.1                 |
| 6/13/92  | 4        | 84.2                       | 0.139              | 0.0             | 1.03                   | 75.2                 | 54                     | 2.0761             | 83.6                 |
| 8/4/92   | 1        | 110.7                      | 0.070              | 0.0             | 3.04                   | 65.2                 | 44                     | 1.3063             | 73.8                 |
| 8/4/92   | 3        | 101.0                      | 0.069              | 0.0             | 2.43                   | 65.0                 | 18                     | 1.0876             | 73.7                 |
| 8/4/92   | 5        | 134.0                      | 0.065              | 0.3             | 1.70                   | 64.8                 | 40                     | 0.8162             | 73.7                 |
| 9/24/92  | 2        | 59.2                       | 0.104              | 0.0             | 1.83                   | 66.1                 | -1                     | 1.4105             | 78.0                 |
| 9/24/92  | 4        | 39.5                       | 0.082              | 0.0             | 2.13                   | 65.6                 | -25                    | 1.2444             | 78.0                 |

\* MEASUREMENT OMITTED



Table A-22 Specimen OA2852.4-3

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/14/91 | 1        | 147.0                      | 0.117              | 0.0             | 0.44                   | 53.5                 | 111                    | 1.1340             | 43.9                 |
| 11/14/91 | 3        | 124.0                      | 0.105              | 0.0             | 0.32                   | 53.2                 | 110                    | 1.4869             | 43.9                 |
| 11/14/91 | 5        | 131.0                      | 0.106              | 0.0             | 0.72                   | 52.9                 | 109                    | 1.2785             | 43.9                 |
| 12/24/91 | 2        | 115.5                      | 0.123              | 0.0             | 0.96                   | 45.6                 | 29                     | 1.7673             | 47.6                 |
| 12/24/91 | 4        | 118.5                      | 0.157              | 0.0             | 1.00                   | 46.3                 | 32                     | 1.4784             | 48.5                 |
| 2/22/92  | 1        | 55.7                       | 0.099              | -0.6            | 0.60                   | 56.9                 | 57                     | 1.7302             | 58.4                 |
| 2/22/92  | 3        | 48.7                       | 0.167              | 1.0             | 0.83                   | 56.6                 | 52                     | 1.9974             | 58.7                 |
| 2/22/92  | 5        | 29.0                       | 0.039              | 0.0             | 1.36                   | 56.3                 | 33                     | 1.8581             | 59.0                 |
| 4/24/92  | 2        | 153.5                      | 0.048              | 0.6             | 0.75                   | 89.2                 | -28                    | 1.7025             | 65.8                 |
| 4/24/92  | 4        | 124.2                      | 0.111              | 0.0             | 1.06                   | 89.0                 | -25                    | 2.1411             | 65.9                 |
| 6/13/92  | 1        | 96.5                       | 0.126              | 0.1             | 1.22                   | 75.7                 | 44                     | 2.1565             | 84.6                 |
| 6/13/92  | 3        | 127.7                      | 0.146              | 0.1             | 0.80                   | 75.8                 | 66                     | 2.1958             | 84.7                 |
| 6/13/92  | 5        | 129.5                      | 0.107              | 0.0             | 0.97                   | 75.9                 | 80                     | 2.1246             | 84.9                 |
| 8/4/92   | 2        | 103.5                      | 0.095              | 0.0             | 2.81                   | 65.3                 | 19                     | 1.2269             | 74.3                 |
| 8/4/92   | 4        | 107.7                      | 0.102              | 0.0             | 2.70                   | 65.5                 | 33                     | 1.2145             | 74.6                 |
| 9/24/92  | 1        | 90.2                       | 0.075              | -0.1            | 1.68                   | 67.8                 | -11                    | 1.1268             | 79.2                 |
| 9/24/92  | 3        | 58.2                       | 0.087              | 0.0             | 1.68                   | 67.5                 | -83                    | 1.5395             | 79.1                 |
| 9/24/92  | 5        | 85.5                       | 0.065              | -0.1            | 1.78                   | 67.2                 | -92                    | 1.2176             | 79.0                 |

\* MEASUREMENT OMITTED

Table A-23 Specimen IA2854.8-1

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/17/91 | 1        | 142.7                      | 0.252              | 0.0             | 0.30                   | 64.4                 | 144                    | 3.4814             | 63.7                 |
| 11/17/91 | 3        | 115.0                      | 0.302              | -0.2            | 0.36                   | 64.4                 | 123                    | 3.9179             | 63.7                 |
| 11/17/91 | 5        | 174.2                      | 0.339              | 0.0             | 0.32                   | 64.4                 | 170                    | 4.5628             | 63.7                 |
| 12/21/91 | 2        | 163.0                      | 0.182              | -0.2            | 0.36                   | 68.0                 | 104                    | 4.1759             | 68.0                 |
| 12/21/91 | 4        | 96.7                       | 0.223              | -2.1            | 0.32                   | 68.0                 | 72                     | 4.3038             | 68.0                 |
| 2/24/92  | 1        | 214.0                      | 0.223              | 0.2             | 0.52                   | 65.8                 | 105                    | 3.0487             | 65.3                 |
| 2/24/92  | 3        | 148.5                      | 0.247              | 0.4             | 0.50                   | 65.8                 | 90                     | 3.3252             | 65.3                 |
| 2/24/92  | 5        | 150.0                      | 0.207              | 0.0             | 0.52                   | 65.8                 | 80                     | 2.7815             | 65.3                 |
| 4/22/92  | 2        | 271.8                      | 0.136              | 0.0             | 0.47                   | 67.8                 | 27                     | 1.0267             | 67.1                 |
| 4/22/92  | 4        | 263.9                      | 0.135              | 0.0             | 0.48                   | 67.8                 | -3                     | 1.0968             | 67.0                 |
| 6/9/92   | 1        | 154.2                      | 0.136              | -0.1            | 0.34                   | 72.4                 | 142                    | 4.0912             | 73.4                 |
| 6/9/92   | 3        | 183.5                      | 0.249              | 0.2             | 0.31                   | 72.4                 | 169                    | 4.3090             | 73.4                 |
| 6/9/92   | 5        | 155.2                      | 0.288              | 0.0             | 0.34                   | 72.4                 | 146                    | 3.2833             | 73.4                 |
| 7/13/92  | 2        | 141.7                      | 0.282              | 0.0             | 0.41                   | 79.4                 | 91                     | 4.1903             | 79.3                 |
| 7/13/92  | 4        | 181.2                      | 0.287              | -0.2            | 0.46                   | 79.4                 | 124                    | 3.5557             | 79.3                 |
| 10/7/92  | 1        | 77.2                       | 0.094              | 0.0             | 0.57                   | 62.4                 | 31                     | 1.9337             | 61.9                 |
| 10/7/92  | 3        | 104.5                      | 0.139              | 0.0             | 0.53                   | 62.4                 | 57                     | 2.2649             | 61.9                 |
| 10/7/92  | 5        | 122.7                      | 0.092              | 0.0             | 0.58                   | 62.4                 | 76                     | 1.8408             | 61.9                 |

\* MEASUREMENT OMITTED

Table A-24 Specimen IA2854.8-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/17/91 | 1        | 142.0                      | 0.173              | 0.0             | 0.42                   | 63.6                 | 137                    | 3.7353             | 63.8                 |
| 11/17/91 | 3        | 105.5                      | 0.299              | 0.1             | 0.32                   | 63.6                 | 112                    | 4.7021             | 63.8                 |
| 11/17/91 | 5        | 156.0                      | 0.295              | -0.3            | 0.35                   | 63.6                 | 164                    | 3.4082             | 63.8                 |
| 12/21/91 | 2        | 139.7                      | 0.276              | 0.4             | 0.49                   | 68.0                 | 90                     | 4.1965             | 68.0                 |
| 12/21/91 | 4        | 168.0                      | 0.442              | 0.0             | 0.42                   | 68.0                 | 109                    | 3.5650             | 68.0                 |
| 2/24/92  | 1        | 144.0                      | 0.760              | -2.5            | 2.24                   | 65.1                 | 96                     | 2.8723             | 65.8                 |
| 2/24/92  | 3        | 110.2                      | 0.289              | -0.4            | 0.36                   | 65.2                 | 89                     | 3.8544             | 65.8                 |
| 2/24/92  | 5        | 108.0                      | 0.629              | -1.2            | 0.35                   | 65.3                 | 98                     | 3.4438             | 65.7                 |
| 4/22/92  | 1        | 252.5                      | 0.296              | 0.0             | 0.48                   | 67.5                 | 122                    | 3.4412             | 67.2                 |
| 4/22/92  | 3        | 261.3                      | 0.219              | 0.0             | 0.48                   | 67.5                 | 109                    | 3.4814             | 67.2                 |
| 4/22/92  | 5        | 253.7                      | 0.147              | 0.3             | 0.61                   | 67.5                 | 55                     | 2.5249             | 67.2                 |
| 6/9/92   | 2        | 195.0                      | 0.222              | 0.2             | 0.45                   | 74.4                 | 156                    | 3.9592             | 73.5                 |
| 6/9/92   | 4        | 137.0                      | 0.126              | -0.3            | 0.50                   | 74.3                 | 109                    | 3.0058             | 73.3                 |
| 7/13/92  | 1        | 199.5                      | 0.240              | 0.0             | 0.58                   | 79.3                 | 125                    | 3.6919             | 80.4                 |
| 7/13/92  | 3        | 191.5                      | 0.263              | -0.2            | 0.52                   | 79.3                 | 116                    | 3.5495             | 80.3                 |
| 7/13/92  | 5        | 153.5                      | 0.156              | -0.5            | 0.60                   | 79.3                 | 85                     | 2.6952             | 80.2                 |
| 10/7/92  | 2        | 184.5                      | 0.090              | 0.4             | 0.43                   | 61.9                 | 140                    | 2.3351             | 62.4                 |
| 10/7/92  | 4        | 138.2                      | 0.247              | -0.2            | 0.58                   | 63.3                 | 78                     | 2.5569             | 62.2                 |

\* MEASUREMENT OMITTED

Table A-25 Specimen IA2854.8-3

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/17/91 | 2        | 126.0                      | 0.273              | 0.0             | 0.30                   | 63.5                 | 132                    | 4.2532             | 63.8                 |
| 11/17/91 | 4        | 160.5                      | 0.260              | 0.3             | 0.33                   | 63.6                 | 172                    | 5.1902             | 63.8                 |
| 12/21/91 | 1        | 138.2                      | 0.223              | -0.1            | 0.46                   | 66.0                 | 69                     | 3.9076             | 66.0                 |
| 12/21/91 | 3        | 133.5                      | 0.236              | 0.2             | 0.42                   | 66.0                 | 90                     | 3.9045             | 66.0                 |
| 12/21/91 | 5        | 105.5                      | 0.256              | -0.1            | 0.44                   | 66.0                 | 59                     | 3.3081             | 66.0                 |
| 2/24/91  | 2        | 25.7                       | 0.563              | -0.9            | 0.35                   | 63.8                 | 134                    | 3.2767             | 64.0                 |
| 2/24/91  | 4        | 96.2                       | 1.092              | -0.5            | 0.33                   | 63.6                 | 104                    | 4.5519             | 63.9                 |
| 4/22/92  | 2        | 283.7                      | 0.184              | 0.0             | 0.43                   | 66.3                 | 154                    | 4.3317             | 67.0                 |
| 4/22/92  | 4        | 287.8                      | 0.158              | 0.0             | 0.47                   | 66.3                 | 140                    | 4.1232             | 66.8                 |
| 6/9/92   | 1        | 118.5                      | 0.144              | 0.0             | 0.33                   | 72.8                 | 118                    | 3.2472             | 73.0                 |
| 6/9/92   | 3        | 175.0                      | 0.144              | -0.1            | 0.31                   | 72.7                 | 206                    | 3.5444             | 73.0                 |
| 6/9/92   | 5        | 92.2                       | 0.095              | 0.0             | 0.34                   | 72.7                 | 102                    | 3.0315             | 73.0                 |
| 7/13/92  | 2        | 173.2                      | 0.278              | -0.2            | 0.42                   | 78.7                 | 128                    | 4.4576             | 78.3                 |
| 7/13/92  | 4        | 176.5                      | 0.222              | -0.3            | 0.38                   | 78.9                 | 114                    | 3.7869             | 78.4                 |
| 10/7/92  | 1        | 84.0                       | 0.128              | 0.0             | 0.90                   | 61.1                 | 30                     | 1.8553             | 60.3                 |
| 10/7/92  | 3        | 120.0                      | 0.064              | 0.0             | 1.29                   | 61.1                 | 74                     | 2.0565             | 60.4                 |
| 10/7/92  | 5        | 60.7                       | 0.085              | -0.6            | 0.74                   | 61.1                 | 30                     | 1.8150             | 60.5                 |

\* MEASUREMENT OMITTED

Table A-26 Specimen OA2854.8-1

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/14/91 | 1        | 165.7                      | 0.268              | 0.0             | 0.47                   | 47.2                 | 180                    | 4.1934             | 46.8                 |
| 11/14/91 | 3        | 190.2                      | 0.195              | 0.0             | 0.49                   | 47.0                 | 207                    | 3.8147             | 46.3                 |
| 11/14/91 | 5        | 160.7                      | 0.188              | 0.0             | 0.39                   | 46.7                 | 170                    | 3.5743             | 47.7                 |
| 12/24/91 | 2        | 217.0                      | 0.255              | 0.1             | 0.71                   | 44.8                 | 124                    | 3.5150             | 46.6                 |
| 12/24/91 | 4        | 234.5                      | 0.181              | 0.1             | 0.71                   | 45.6                 | 138                    | 3.3334             | 46.5                 |
| 2/22/92  | 1        | 138.5                      | 0.478              | -0.2            | 0.38                   | 57.3                 | 125                    | 4.2341             | 58.2                 |
| 2/22/92  | 3        | 145.7                      | 0.613              | -0.4            | 0.50                   | 58.2                 | 143                    | 4.1629             | 59.0                 |
| 2/22/92  | 5        | 130.5                      | 0.444              | -1.2            | 0.62                   | 59.2                 | 133                    | 4.4374             | 59.8                 |
| 4/24/92  | 2        | 223.7                      | 0.235              | 0.0             | 0.91                   | 65.5                 | 69                     | 4.0108             | 67.2                 |
| 4/24/92  | 4        | 237.2                      | 0.270              | -0.1            | 0.73                   | 64.0                 | 46                     | 1.3981             | 65.2                 |
| 6/15/92  | 1        | 311.7                      | 0.584              | 0.0             | 0.81                   | 73.1                 | 229                    | 2.8025             | 67.0                 |
| 6/15/92  | 3        | 204.5                      | 0.363              | -0.1            | 0.77                   | 72.7                 | 140                    | 2.5456             | 67.3                 |
| 6/15/92  | 5        | 223.0                      | 0.294              | 0.0             | 0.82                   | 72.3                 | 158                    | 2.9934             | 67.5                 |
| 8/4/92   | 2        | 253.5                      | 0.124              | 0.0             | 0.97                   | 65.9                 | 168                    | 3.0223             | 90.2                 |
| 8/4/92   | 4        | 244.0                      | 0.187              | 0.0             | 1.21                   | 65.9                 | 153                    | 3.1708             | 90.7                 |
| 9/24/92  | 1        | 245.2                      | 0.169              | -0.1            | 0.90                   | 70.2                 | 52                     | 3.1389             | 81.3                 |
| 9/24/92  | 3        | 202.7                      | 0.284              | 0.1             | 1.98                   | 69.7                 | 17                     | 2.8025             | 81.3                 |
| 9/24/92  | 5        | 198.5                      | 0.213              | 0.1             | 1.49                   | 69.2                 | 11                     | 3.5537             | 81.3                 |

\* MEASUREMENT OMITTED

Table A-27 Specimen OA2854.8-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/14/91 | 2        | 153.2                      | 0.199              | -0.2            | 0.36                   | 49.3                 | 182                    | 3.7218             | 49.1                 |
| 11/14/91 | 4        | 157.5                      | 0.241              | 0.0             | 0.39                   | 48.3                 | 168                    | 3.8797             | 49.1                 |
| 12/24/91 | 1        | 198.2                      | 0.180              | 0.2             | 0.71                   | 46.0                 | 111                    | 3.1302             | 47.2                 |
| 12/24/91 | 3        | 245.5                      | 0.206              | 0.0             | 0.66                   | 46.1                 | 141                    | 3.3551             | 46.9                 |
| 12/24/91 | 5        | 177.5                      | 0.161              | -0.5            | 0.79                   | 46.3                 | 95                     | 2.7381             | 46.7                 |
| 2/22/92  | 2        | 170.0                      | 1.281 *            | -0.9            | 0.58                   | 57.9                 | 115                    | 4.8077             | 60.8                 |
| 2/22/92  | 4        | 189.5                      | 0.623 *            | -6.7            | 0.61                   | 58.3                 | 137                    | 5.0667             | 60.9                 |
| 4/24/92  | 1        | 262.5                      | 0.237              | -0.1            | 0.72                   | 67.4                 | 95                     | 4.5257             | 76.6                 |
| 4/24/92  | 3        | 262.0                      | 0.264              | 0.1             | 0.62                   | 67.4                 | 111                    | 4.4545             | 77.0                 |
| 4/24/92  | 5        | 215.5                      | 0.189              | 0.0             | 0.78                   | 67.4                 | 100                    | 5.0209             | 77.3                 |
| 6/15/92  | 2        | 236.0                      | 0.351              | 0.0             | 0.75                   | 74.5                 | 184                    | 3.2627             | 67.8                 |
| 6/15/92  | 4        | 203.7                      | 0.260              | 0.0             | 0.76                   | 74.7                 | 153                    | 3.1770             | 67.4                 |
| 8/4/92   | 1        | 251.5                      | 0.137              | 0.0             | 1.66                   | 66.0                 | 198                    | 3.2720             | 91.3                 |
| 8/4/92   | 3        | 293.0                      | 0.216              | 0.0             | 1.41                   | 66.2                 | 231                    | 3.8023             | 90.8                 |
| 8/4/92   | 5        | 256.5                      | 0.161              | 0.0             | 1.45                   | 66.4                 | 185                    | 3.7961             | 90.3                 |
| 9/24/92  | 2        | 225.7                      | 0.183              | 0.0             | 0.96                   | 70.5                 | 35                     | 3.6105             | 81.8                 |
| 9/24/92  | 4        | 160.2                      | 0.184              | 0.0             | 1.21                   | 70.6                 | 64                     | 3.0140             | 80.9                 |

\* MEASUREMENT OMITTED

Table A-28 Specimen OA2854.8-3

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/14/91 | 1        | 147.7                      | 0.157              | 0.0             | 0.35                   | 49.4                 | 165                    | 3.5155             | 48.6                 |
| 11/14/91 | 3        | 122.0                      | 0.484              | -0.3            | 0.53                   | 48.8                 | 161                    | 3.6269             | 48.8                 |
| 11/14/91 | 5        | 163.2                      | 0.176              | 0.0             | 0.40                   | 48.3                 | 178                    | 3.8665             | 48.9                 |
| 12/24/91 | 2        | 215.7                      | 0.297              | 0.1             | 0.69                   | 44.6                 | 112                    | 3.7193             | 46.2                 |
| 12/24/91 | 4        | 208.0                      | 0.239              | 0.7             | 0.72                   | 44.4                 | 106                    | 3.7172             | 45.2                 |
| 2/22/92  | 1        | 183.2                      | 0.049              | -0.2            | 8.94                   | 61.4                 | 118                    | 4.0402             | 59.6                 |
| 2/22/92  | 3        | 176.7                      | 0.358              | -0.2            | 0.16                   | 61.5                 | 119                    | 3.2829             | 59.4                 |
| 2/22/92  | 5        | 191.7                      | 0.478              | 0.0             | 0.94                   | 61.6                 | 141                    | 3.4882             | 59.2                 |
| 4/24/92  | 2        | 191.0                      | 0.106              | 0.0             | 0.92                   | 71.0                 | 74                     | 5.2067             | 77.5                 |
| 4/24/92  | 4        | 215.5                      | 0.143              | 0.0             | 0.67                   | 70.7                 | 81                     | 5.2500             | 76.8                 |
| 6/15/92  | 1        | 258.0                      | 0.323              | 0.0             | 0.78                   | 75.6                 | 186                    | 2.6116             | 68.1                 |
| 6/15/92  | 3        | 170.2                      | 0.163              | 0.2             | 0.75                   | 75.0                 | 149                    | 2.9351             | 68.1                 |
| 6/15/92  | 5        | 212.5                      | 0.239              | 0.1             | 0.74                   | 74.4                 | 152                    | 2.7230             | 68.1                 |
| 8/4/92   | 2        | 267.7                      | 0.193              | 0.0             | 1.35                   | 66.6                 | 184                    | 3.7611             | 89.7                 |
| 8/4/92   | 4        | 235.0                      | 0.251              | 0.0             | 1.11                   | 66.6                 | 172                    | 4.1263             | 89.7                 |
| 9/24/92  | 1        | 248.7                      | 0.275              | 0.0             | 1.63                   | 69.4                 | 112                    | 3.0759             | 83.1                 |
| 9/24/92  | 3        | 181.5                      | 0.101              | 0.0             | 1.59                   | 69.7                 | 106                    | 3.9819             | 83.1                 |
| 9/24/92  | 5        | 222.7                      | 0.167              | 0.0             | 1.00                   | 70.0                 | 84                     | 2.7942             | 83.1                 |

\* MEASUREMENT OMITTED

Table A-29 Specimen IA2859 6-1

| DATE     | POSITION | GEOCISA                    |                    |                 |                        | 3LP                  |                        |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/17/91 | 1        | 331.2                      | 0.759              | 0.0             | 0.30                   | 63.8                 | 326                    | 9.9686             | 63.6                 |
| 11/17/91 | 3        | 308.2                      | 0.812              | 0.0             | 0.29                   | 63.8                 | 314                    | 9.2597             | 63.6                 |
| 11/17/91 | 5        | 308.7                      | 0.600              | 0.0             | 0.30                   | 63.8                 | 308                    | 8.0370             | 63.6                 |
| 11/20/91 | 2        | 367.0                      | 0.650              | 0.5             | 0.33                   | 63.9                 | 353                    | 9.5321             | 63.9                 |
| 11/20/91 | 4        | 346.7                      | 0.763              | 0.1             | 0.36                   | 63.9                 | 335                    | 8.4291             | 63.9                 |
| 12/10/91 | 1        | 312.0                      | 0.671              | 0.0             | 0.44                   | 66.6                 | 288                    | 8.8006             | 66.4                 |
| 12/10/91 | 3        | 318.7                      | 0.392              | 0.0             | 0.40                   | 66.4                 | 286                    | 9.3547             | 66.4                 |
| 12/10/91 | 5        | 324.2                      | 0.343              | 0.1             | 0.43                   | 66.3                 | 284                    | 9.8180             | 66.4                 |
| 12/21/91 | 2        | 314.2                      | 0.819              | 0.0             | 0.29                   | 69.0                 | 248                    | 12.8144            | 69.0                 |
| 12/21/91 | 4        | 332.7                      | 1.263              | -0.3            | 0.31                   | 69.0                 | 284                    | 6.8277             | 69.0                 |
| 2/24/92  | 1        | 356.7                      | 0.861              | 0.0             | 0.67                   | 65.8                 | 291                    | 6.3336             | 64.6                 |
| 2/24/92  | 3        | 306.5                      | 0.629              | 0.4             | 0.55                   | 65.1                 | 232                    | 5.5454             | 64.4                 |
| 2/24/92  | 5        | 263.2                      | 0.582              | 0.0             | 0.55                   | 64.4                 | 191                    | 4.9305             | 64.3                 |
| 3/24/92  | 2        | 352.5                      | 0.540              | 0.0             | 0.40                   | 64.9                 | 303                    | 10.5915            | 64.6                 |
| 3/24/92  | 4        | 411.0                      | 0.472              | -0.6            | 0.36                   | 64.7                 | 334                    | 11.4860            | 64.4                 |
| 4/22/92  | 1        | 381.4                      | 0.416              | 0.0             | 0.45                   | 67.8                 | 293                    | 7.0423             | 67.5                 |
| 4/22/92  | 3        | 387.3                      | 0.451              | 0.0             | 0.61                   | 67.8                 | 295                    | 8.5849             | 67.5                 |
| 4/22/92  | 5        | 387.7                      | 0.385              | 0.0             | 0.67                   | 67.9                 | 317                    | 8.9688             | 67.5                 |
| 5/17/92  | 2        | 357.0                      | 0.890              | 0.0             | 0.49                   | 66.2                 | 326                    | 9.3928             | 66.3                 |
| 5/17/92  | 4        | 445.5                      | 1.006              | -0.2            | 0.46                   | 66.4                 | 388                    | 10.2823            | 66.2                 |
| 6/9/92   | 2        | 347.5                      | 0.656              | 0.0             | 0.30                   | 73.8                 | 330                    | 11.2440            | 73.1                 |
| 6/9/92   | 4        | 383.7                      | 0.462              | 0.1             | 0.28                   | 74.3                 | 365                    | 10.4608            | 73.8                 |
| 6/30/92  | 1        | 382.2                      | 0.893              | 0.0             | 0.40                   | 76.5                 | 357                    | 8.6829             | 76.9                 |
| 6/30/92  | 3        | 439.5                      | 0.628              | 0.1             | 0.36                   | 76.7                 | 377                    | 9.2639             | 76.7                 |
| 6/30/92  | 5        | 411.7                      | 0.539              | 0.0             | 0.35                   | 77.0                 | 355                    | 9.6054             | 76.6                 |
| 7/13/92  | 1        | 399.7                      | 0.570              | 0.2             | 0.46                   | 80.3                 | 347                    | 8.2413             | 80.9                 |
| 7/13/92  | 3        | 402.2                      | 0.729              | 0.0             | 0.41                   | 79.9                 | 334                    | 9.9335             | 80.3                 |
| 7/13/92  | 5        | 387.5                      | 0.656              | 0.0             | 0.42                   | 79.4                 | 317                    | 8.8326             | 79.6                 |
| 9/1/92   | 2        | 320.0                      | 1.379              | 0.0             | 0.49                   | 75.0                 | 242                    | 8.8315             | 75.0                 |
| 9/1/92   | 4        | 422.2                      | 0.922              | 0.0             | 0.44                   | 75.2                 | 303                    | 4.7196             | 75.2                 |
| 10/7/92  | 2        | 319.2                      | 0.247              | 0.1             | 0.48                   | 63.3                 | 254                    | 7.3931             | 63.0                 |
| 10/7/92  | 4        | 385.2                      | 0.347              | 0.2             | 0.42                   | 62.3                 | 333                    | 7.8915             | 62.4                 |

\* MEASUREMENT OMITTED



Table A-30 Specimen IA2859.6-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                        | 3LP                  |                        |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/17/91 | 2        | 307.2                      | 0.709              | -0.1            | 0.30                   | 63.8                 | 298                    | 8.9265             | 63.5                 |
| 11/17/91 | 4        | 326.7                      | 0.532              | 0.1             | 0.33                   | 63.8                 | 311                    | 8.4012             | 63.6                 |
| 11/19/91 | 1        | 326.2                      | 0.869              | 0.5             | 0.33                   | 63.9                 | 320                    | 10.6042            | 63.9                 |
| 11/19/91 | 3        | 342.5                      | 0.795              | 2.7             | 0.34                   | 63.9                 | 332                    | 12.0189            | 63.9                 |
| 11/19/91 | 5        | 349.2                      | 0.761              | 0.1             | 0.34                   | 63.9                 | 343                    | 10.5578            | 63.9                 |
| 12/10/91 | 2        | 334.0                      | 1.124              | -0.2            | 0.44                   | 66.4                 | 260                    | 6.8783             | 66.6                 |
| 12/10/91 | 4        | 348.2                      | 1.986              | 0.1             | 0.44                   | 66.4                 | 280                    | 7.4901             | 66.6                 |
| 12/21/91 | 1        | 322.1                      | 1.824              | -1.3            | 0.29                   | 66.0                 | 304                    | 11.6660            | 66.0                 |
| 12/21/91 | 3        | 331.5                      | 2.396              | 0.7             | 0.28                   | 66.5                 | 245                    | 10.2410            | 66.5                 |
| 12/21/91 | 5        | 318.7                      | 1.762              | 0.5             | 0.31                   | 67.0                 | 244                    | 8.9987             | 67.0                 |
| 2/24/92  | 2        | 326.7                      | 0.579              | -0.1            | 0.51                   | 65.7                 | 250                    | 5.6063             | 65.6                 |
| 2/24/92  | 4        | 329.5                      | 0.677              | 0.4             | 0.61                   | 65.7                 | 260                    | 5.5289             | 66.0                 |
| 3/24/92  | 1        | 382.5                      | 0.366              | -0.2            | 0.36                   | 63.3                 | 300                    | 10.5925            | 63.2                 |
| 3/24/92  | 3        | 396.2                      | 0.687              | 0.0             | 0.37                   | 63.3                 | 327                    | 11.3023            | 63.4                 |
| 3/24/92  | 5        | 379.5                      | 0.361              | -0.1            | 0.36                   | 63.4                 | 312                    | 9.7403             | 63.5                 |
| 4/22/92  | 2        | 392.1                      | 0.316              | 0.2             | 0.47                   | 66.0                 | 336                    | 9.6972             | 67.4                 |
| 4/22/92  | 4        | 401.0                      | 0.474              | 0.0             | 0.53                   | 66.6                 | 338                    | 10.9055            | 67.2                 |
| 5/17/92  | 1        | 407.0                      | 0.627              | 0.0             | 0.48                   | 65.2                 | 368                    | 8.6076             | 66.2                 |
| 5/17/92  | 3        | 455.5                      | 1.115              | -0.3            | 0.46                   | 65.7                 | 407                    | 10.6455            | 66.2                 |
| 5/17/92  | 5        | 413.5                      | 0.501              | 0.1             | 0.48                   | 66.2                 | 382                    | 8.8563             | 66.2                 |
| 6/9/92   | 1        | 366.5                      | 0.476              | 0.2             | 0.31                   | 72.6                 | 355                    | 10.6496            | 73.0                 |
| 6/9/92   | 3        | 394.7                      | 1.601              | 0.1             | 0.33                   | 72.7                 | 343                    | 12.7453            | 72.9                 |
| 6/9/92   | 5        | 357.0                      | 0.368              | 0.1             | 0.33                   | 72.8                 | 357                    | 10.4309            | 72.8                 |
| 6/30/92  | 2        | 431.7                      | 0.962              | 0.0             | 0.35                   | 74.9                 | 377                    | 10.1523            | 75.1                 |
| 6/30/92  | 4        | 454.0                      | 0.796              | 0.0             | 0.35                   | 75.1                 | 387                    | 11.4772            | 75.1                 |
| 7/13/92  | 2        | 437.0                      | 0.444              | 0.1             | 0.40                   | 79.2                 | 392                    | 15.4260            | 79.1                 |
| 7/13/92  | 4        | 455.0                      | 0.883              | -0.1            | 0.36                   | 79.0                 | 401                    | 13.9329            | 79.4                 |
| 9/1/92   | 1        | 427.5                      | 0.973              | 0.0             | 0.44                   | 76.4                 | 289                    | 6.0321             | 76.4                 |
| 9/1/92   | 3        | 442.0                      | 0.445              | -0.1            | 0.43                   | 76.5                 | 338                    | 7.6841             | 76.5                 |
| 9/1/92   | 5        | 346.7                      | 0.391              | 0.0             | 0.43                   | 76.6                 | 216                    | 5.0199             | 76.6                 |
| 10/7/92  | 1        | 319.0                      | 0.239              | 0.0             | 0.58                   | 61.3                 | 276                    | 6.1250             | 61.8                 |
| 10/7/92  | 3        | 383.7                      | 0.288              | 0.0             | 0.52                   | 61.3                 | 327                    | 7.6016             | 61.5                 |
| 10/7/92  | 5        | 291.0                      | 0.275              | 0.3             | 0.50                   | 61.4                 | 237                    | 6.4779             | 61.1                 |

\* MEASUREMENT OMITTED

Table A-31 Specimen OA2859 6-1

| DATE     | POSITION | GEOCISA                 |                 |              |                    | 3LP               |                     |                 |                   |
|----------|----------|-------------------------|-----------------|--------------|--------------------|-------------------|---------------------|-----------------|-------------------|
|          |          | POTENTIAL Ag/AgCl (-mV) | icorr (uA/sqcm) | BALANCE (mV) | OHMIC RES (K-Ohms) | TEMP. (degrees F) | POTENTIAL CSE (-mV) | icorr (mA/sqft) | TEMP. (degrees F) |
| 11/13/91 | 1        | 385.7                   | 0.667           | 0.2          | 0.22               | 51.1              | 383                 | 15.6695         | 50.1              |
| 11/13/91 | 3        | 366.2                   | 0.706           | 0.0          | 0.24               | 49.8              | 372                 | 14.0939         | 49.6              |
| 11/13/91 | 5        | 358.7                   | 0.585           | 0.0          | 0.24               | 49.3              | 351                 | 9.9655          | 49.1              |
| 11/19/91 | 2        | 423.2                   | 0.656           | 0.0          | 0.24               | 61.4              | 415                 | 13.2705         | 62.3              |
| 11/19/91 | 4        | 401.7                   | 0.601           | 0.2          | 0.24               | 58.7              | 398                 | 12.2222         | 59.8              |
| 12/10/91 | 1        | 416.0                   | 0.356           | 0.0          | 0.50               | 51.2              | 350                 | 15.8749         | 55.7              |
| 12/10/91 | 3        | 410.2                   | 0.376           | 0.0          | 0.53               | 50.8              | 338                 | 15.7201         | 56.0              |
| 12/10/91 | 5        | 399.0                   | 0.350           | 0.0          | 0.47               | 50.4              | 328                 | 11.1955         | 56.3              |
| 12/24/91 | 2        | 412.7                   | 0.678           | -0.4         | 0.59               | 42.9              | 339                 | 9.9343          | 46.2              |
| 12/24/91 | 4        | 395.7                   | 0.505           | 0.0          | 0.65               | 43.4              | 305                 | 10.2995         | 44.8              |
| 2/22/92  | 1        | 381.5                   | 1.072           | -3.6         | 1.31               | 61.0              | 328                 | 12.4857         | 61.9              |
| 2/22/92  | 3        | 342.0                   | 0.782           | 0.0          | 0.68               | 61.0              | 290                 | 10.7834         | 60.5              |
| 2/22/92  | 5        | 335.5                   | 0.922           | 0.9          | 0.44               | 61.0              | 306                 | 10.1334         | 59.1              |
| 3/24/92  | 2        | 318.2                   | 0.282           | -0.6         | 0.77               | 46.5              | 257                 | 7.1404          | 51.3              |
| 3/24/92  | 4        | 321.7                   | 0.421           | 0.1          | 0.66               | 48.4              | 274                 | 9.2895          | 52.5              |
| 4/24/92  | 2        | 456.5                   | 0.489           | -0.3         | 0.59               | 84.5              | 265                 | 5.4884          | 76.6              |
| 4/24/92  | 4        | 460.7                   | 1.188           | -0.4         | 0.44               | 86.0              | 290                 | 9.5806          | 77.4              |
| 5/17/92  | 1        | 442.0                   | 0.566           | 0.0          | 0.57               | 76.3              | 368                 | 8.2000          | 74.2              |
| 5/17/92  | 3        | 441.2                   | 0.706           | 0.6          | 0.50               | 76.3              | 375                 | 8.6386          | 74.7              |
| 5/17/92  | 5        | 422.7                   | 0.702           | 0.0          | 0.55               | 76.3              | 372                 | 8.4890          | 75.3              |
| 6/15/92  | 1        | 460.0                   | 1.425           | -1.9         | 0.61               | 76.1              | 368                 | 5.0880          | 68.4              |
| 6/15/92  | 3        | 438.0                   | 0.935           | -1.2         | 0.80               | 77.1              | 359                 | 5.5730          | 68.5              |
| 6/15/92  | 5        | 442.2                   | 0.244           | -2.3         | 0.21               | 78.0              | 347                 | 5.6112          | 68.6              |
| 6/30/92  | 2        | 442.0                   | 0.406           | 0.0          | 0.78               | 75.2              | 386                 | 6.1157          | 70.6              |
| 6/30/92  | 4        | 437.5                   | 0.401           | 0.0          | 0.65               | 73.6              | 373                 | 5.5038          | 71.3              |
| 8/4/92   | 2        | 454.0                   | 0.527           | 0.1          | 1.61               | 66.4              | 421                 | 8.8511          | 92.4              |
| 8/4/92   | 4        | 429.0                   | 0.284           | 0.0          | 1.20               | 67.3              | 384                 | 7.6821          | 92.2              |
| 9/1/92   | 2        | 468.5                   | 0.658           | 0.0          | 0.69               | 82.4              | 348                 | 8.1856          | 82.4              |
| 9/1/92   | 4        | 437.0                   | 0.694           | 0.0          | 0.69               | 82.7              | 322                 | 6.9856          | 82.7              |
| 9/24/92  | 1        | 459.5                   | 0.277           | 0.0          | 1.07               | 69.1              | 355                 | 7.6738          | 83.6              |
| 9/24/92  | 3        | 423.0                   | 0.411           | 0.0          | 1.00               | 70.1              | 325                 | 8.2743          | 84.0              |
| 9/24/92  | 5        | 437.5                   | 0.377           | 0.0          | 0.83               | 70.2              | 323                 | 8.5808          | 84.5              |

\* MEASUREMENT OMITTED

Table A-32 Specimen OA2859 6-2

| DATE     | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |  |  |
|----------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|--|--|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |  |  |
| 11/13/91 | 2        | 357.0                      | 0.616              | 0.1             | 0.22                   | 51.5                 | 373                    | 11.7702            | 47.7                 |  |  |
| 11/13/91 | 4        | 342.0                      | 0.528              | -0.1            | 0.24                   | 48.5                 | 337                    | 10.6145            | 48.0                 |  |  |
| 11/19/91 | 1        | 470.0                      | 0.870              | 0.3             | 0.25                   | 61.3                 | 425                    | 14.4561            | 62.6                 |  |  |
| 11/19/91 | 3        | 429.0                      | 0.830              | 0.1             | 0.24                   | 60.2                 | 405                    | 14.5913            | 61.6                 |  |  |
| 11/19/91 | 5        | 414.2                      | 1.004              | 0.0             | 0.22                   | 59.2                 | 416                    | 12.3491            | 60.6                 |  |  |
| 12/10/91 | 2        | 416.5                      | 0.255              | 0.0             | 0.59                   | 51.2                 | 344                    | 11.9456            | 53.0                 |  |  |
| 12/10/91 | 4        | 401.7                      | 0.242              | -0.2            | 0.55                   | 50.8                 | 319                    | 12.3656            | 52.7                 |  |  |
| 12/24/91 | 1        | 421.7                      | 0.560              | -0.5            | 0.53                   | 42.3                 | 337                    | 10.9536            | 45.6                 |  |  |
| 12/24/91 | 3        | 399.5                      | 0.485              | -0.2            | 0.62                   | 42.7                 | 323                    | 11.7264            | 44.6                 |  |  |
| 12/24/91 | 5        | 365.5                      | 0.595              | -0.1            | 0.53                   | 43.1                 | 293                    | 11.3188            | 43.6                 |  |  |
| 2/22/92  | 2        | 353.2                      | 0.273              | 0.0             | 0.10                   | 61.3                 | 312                    | 10.4419            | 60.8                 |  |  |
| 2/22/92  | 4        | 328.7                      | 0.285              | 0.0             | 2.40                   | 60.7                 | 296                    | 9.4339             | 56.7                 |  |  |
| 3/24/92  | 1        | 329.0                      | 0.405              | 0.0             | 0.87                   | 47.9                 | 269                    | 7.9771             | 52.5                 |  |  |
| 3/24/92  | 3        | 329.5                      | 0.358              | -0.4            | 0.68                   | 46.6                 | 274                    | 8.3578             | 52.1                 |  |  |
| 3/24/92  | 5        | 352.0                      | 0.536              | 0.0             | 0.53                   | 49.3                 | 287                    | 7.8564             | 51.8                 |  |  |
| 4/24/92  | 1        | 446.5                      | 1.173              | 0.0             | 0.40                   | 86.1                 | 270                    | 10.2451            | 76.0                 |  |  |
| 4/24/92  | 3        | 428.0                      | 5.058 *            | -0.4            | 0.46                   | 85.7                 | 274                    | 4.2244             | 76.2                 |  |  |
| 4/24/92  | 5        | 451.3                      | 1.171              | -0.1            | 0.42                   | 85.4                 | 288                    | 11.7423            | 76.5                 |  |  |
| 5/17/92  | 2        | 431.5                      | 0.749              | 0.0             | 0.51                   | 77.4                 | 374                    | 8.0752             | 74.5                 |  |  |
| 5/17/92  | 4        | 422.7                      | 3.925 *            | -2.1            | 0.49                   | 78.2                 | 364                    | 7.6759             | 75.6                 |  |  |
| 6/15/92  | 2        | 451.5                      | 0.636              | -0.1            | 0.61                   | 80.6                 | 356                    | 5.6380             | 67.8                 |  |  |
| 6/15/92  | 4        | 465.0                      | 0.597              | 0.0             | 0.59                   | 81.6                 | 354                    | 6.2385             | 68.8                 |  |  |
| 6/30/92  | 1        | 412.5                      | 0.497              | 0.0             | 0.77                   | 76.4                 | 362                    | 5.9960             | 72.8                 |  |  |
| 6/30/92  | 3        | 410.2                      | 0.540              | -0.3            | 0.77                   | 76.0                 | 340                    | 5.4657             | 72.8                 |  |  |
| 6/30/92  | 5        | 439.0                      | 0.527              | 0.0             | 0.68                   | 75.8                 | 368                    | 6.0858             | 72.7                 |  |  |
| 8/4/92   | 1        | 411.5                      | 0.231              | 0.0             | 0.72                   | 66.6                 | 398                    | 9.5806             | 91.8                 |  |  |
| 8/4/92   | 3        | 408.7                      | 0.322              | 1.4             | 1.09                   | 66.8                 | 367                    | 7.4839             | 91.5                 |  |  |
| 8/4/92   | 5        | 446.2                      | 0.512              | -0.1            | 1.05                   | 67.0                 | 392                    | 7.6470             | 91.3                 |  |  |
| 9/1/92   | 1        | 406.0                      | 0.527              | 0.1             | 0.61                   | 83.4                 | 308                    | 8.9378             | 83.4                 |  |  |
| 9/1/92   | 3        | 410.5                      | 0.136              | 0.0             | 1.18                   | 83.0                 | 317                    | 7.2838             | 83.0                 |  |  |
| 9/1/92   | 5        | 459.7                      | 0.619              | -0.6            | 0.57                   | 82.7                 | 341                    | 6.9794             | 82.7                 |  |  |
| 9/24/92  | 2        | 429.7                      | 0.405              | 0.0             | 0.84                   | 67.6                 | 324                    | 7.1600             | 84.0                 |  |  |
| 9/24/92  | 4        | 431.7                      | 0.369              | 0.0             | 0.83                   | 68.9                 | 333                    | 7.7398             | 84.3                 |  |  |

\* MEASUREMENT OMITTED

Table A-33 Specimen OA2859 6-3

| DATE     | POSITION | GEOCISA                    |                    |                 |                       |                      | 3LP                    |                    |                      |
|----------|----------|----------------------------|--------------------|-----------------|-----------------------|----------------------|------------------------|--------------------|----------------------|
|          |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 11/13/91 | 1        | 345.7                      | 0.496              | 0.0             | 0.23                  | 48.8                 | 350                    | 11.3379            | 43.9                 |
| 11/13/91 | 3        | 352.7                      | 0.489              | -0.3            | 0.25                  | 48.7                 | 367                    | 11.6020            | 43.5                 |
| 11/13/91 | 5        | 332.0                      | 0.402              | 0.0             | 0.25                  | 48.5                 | 347                    | 11.1428            | 43.0                 |
| 11/19/91 | 2        | 400.2                      | 0.484              | -1.3            | 0.24                  | 59.4                 | 406                    | 12.0581            | 61.1                 |
| 11/19/91 | 4        | 411.2                      | 0.428              | -1.6            | 0.37                  | 60.0                 | 406                    | 9.5621             | 61.3                 |
| 12/10/91 | 1        | 450.0                      | 0.552              | 0.4             | 0.66                  | 47.5                 | 358                    | 13.5006            | 52.5                 |
| 12/10/91 | 3        | 431.2                      | 0.854              | 0.0             | 0.56                  | 47.5                 | 356                    | 13.8132            | 52.2                 |
| 12/10/91 | 5        | 427.4                      | 0.717              | -0.1            | 0.58                  | 47.5                 | 343                    | 12.9599            | 52.0                 |
| 12/24/91 | 2        | 412.7                      | 0.678              | -0.4            | 0.59                  | 42.9                 | 339                    | 9.9343             | 46.2                 |
| 12/24/91 | 4        | 395.7                      | 0.505              | 0.0             | 0.65                  | 43.4                 | 305                    | 10.2995            | 44.8                 |
| 2/22/92  | 1        | 363.0                      | 1.046              | -0.1            | 0.38                  | 60.7                 | 320                    | 10.3057            | 58.3                 |
| 2/22/92  | 3        | 353.7                      | 0.372              | -0.7            | 0.11                  | 60.2                 | 325                    | 9.2678             | 58.8                 |
| 2/22/92  | 5        | 316.7                      | 0.508              | 0.0             | 0.81                  | 59.7                 | 293                    | 9.6454             | 57.7                 |
| 3/24/92  | 2        | 339.7                      | 0.320              | 0.0             | 0.59                  | 48.8                 | 280                    | 7.5593             | 52.9                 |
| 3/24/92  | 4        | 336.0                      | 0.176              | 0.7             | 0.77                  | 49.4                 | 279                    | 8.2970             | 53.7                 |
| 4/24/92  | 2        | 478.5                      | 0.915              | 0.4             | 0.43                  | 83.9                 | 289                    | 8.6850             | 76.3                 |
| 4/24/92  | 4        | 424.2                      | 0.219              | 0.0             | 0.67                  | 85.7                 | 287                    | 11.7671            | 76.3                 |
| 5/17/92  | 1        | 421.0                      | 0.613              | 0.0             | 0.54                  | 76.4                 | 359                    | 6.9113             | 74.3                 |
| 5/17/92  | 3        | 425.0                      | 1.086              | 0.6             | 0.53                  | 76.8                 | 377                    | 8.2475             | 74.3                 |
| 5/17/92  | 5        | 432.7                      | 0.711              | 0.0             | 0.56                  | 77.2                 | 372                    | 7.0980             | 74.3                 |
| 6/15/92  | 1        | 431.0                      | 0.557              | 0.3             | 0.63                  | 81.4                 | 356                    | 5.6989             | 68.8                 |
| 6/15/92  | 3        | 447.2                      | 0.666              | -0.1            | 0.60                  | 82.3                 | 371                    | 6.1054             | 69.0                 |
| 6/15/92  | 5        | 464.7                      | 0.585              | 0.0             | 0.62                  | 83.2                 | 382                    | 6.7008             | 69.2                 |
| 6/30/92  | 2        | 460.0                      | 0.426              | 0.0             | 0.72                  | 74.7                 | 391                    | 5.8970             | 72.8                 |
| 6/30/92  | 4        | 457.5                      | 0.486              | 0.0             | 0.69                  | 75.0                 | 398                    | 6.1879             | 74.2                 |
| 8/4/92   | 2        | 448.2                      | 0.263              | 0.0             | 0.88                  | 66.1                 | 413                    | 8.0463             | 90.6                 |
| 8/4/92   | 4        | 445.2                      | 0.193              | 0.0             | 1.80                  | 66.5                 | 399                    | 8.0711             | 91.8                 |
| 9/1/92   | 2        | 453.5                      | 0.637              | 0.0             | 0.65                  | 82.0                 | 335                    | 6.4542             | 82.0                 |
| 9/1/92   | 4        | 423.2                      | 0.158              | 0.0             | 1.56                  | 83.8                 | 329                    | 7.6253             | 83.8                 |
| 9/24/92  | 1        | 435.7                      | 0.453              | 0.1             | 0.94                  | 68.7                 | 327                    | 7.6418             | 84.0                 |
| 9/24/92  | 3        | 427.2                      | 0.294              | 0.0             | 1.00                  | 68.9                 | 329                    | 12.9403            | 84.4                 |
| 9/24/92  | 5        | 461.7                      | 0.460              | 0.0             | 0.98                  | 69.1                 | 358                    | 12.7783            | 84.8                 |

\* MEASUREMENT OMITTED

## **Appendix B**

### **Data Taken During this Study**

Table B-1 IA2850.0-1

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/13/93 | 2        | 0.5                        | 0.035                    | 0.00            | 0.78                   | 60.0                 | -60                    | 0.5912             | 59.9                 |
| 1/13/93 | 4        | 18.0                       | 0.044                    | 0.00            | 0.59                   | 60.0                 | -39                    | 0.8874             | 60.0                 |
| 2/12/93 | 2        | -11.0                      | 0.025                    | -0.40           | 0.66                   | 59.3                 | 0                      | 0.9091             | 59.3                 |
| 2/12/93 | 4        | -28.0                      | 0.064                    | 0.00            | 0.67                   | 59.5                 | -162                   | 0.7790             | 59.5                 |
| 3/8/93  | 1        | -44.5                      | 0.050                    | -0.10           | 0.73                   | 61.0                 | -84                    | 0.6088             | 61.2                 |
| 3/8/93  | 3        | -33.5                      | 0.059                    | 0.00            | 0.73                   | 61.2                 | -66                    | 0.7037             | 61.4                 |
| 3/8/93  | 5        | -33.2                      | 0.117                    | 0.00            | 0.85                   | 61.4                 | -76                    | 0.4334             | 61.6                 |
| 4/22/93 | 2        | 7.2                        | 0.038                    | 0.00            | 0.76                   | 62.3                 | -57                    | 0.8213             | 62.3                 |
| 4/22/93 | 4        | 6.2                        | 0.057                    | 0.00            | 0.81                   | 62.0                 | -34                    | 0.6831             | 62.1                 |
| 5/19/93 | 1        | -57.2                      | *.076                    | -2.30           | 0.83                   | 70.4                 | -81                    | 1.3445             | 70.4                 |
| 5/19/93 | 3        | -50.0                      | *.115                    | 3.80            | 0.71                   | 70.8                 | -95                    | 1.2516             | 70.4                 |
| 5/19/93 | 5        | -47.5                      | *.067                    | -5.60           | 0.78                   | 71.2                 | -70                    | 1.0618             | 70.4                 |
| 6/21/93 | 2        | 10.2                       | *.029                    | 1.00            | 0.63                   | 76.2                 | -16                    | 1.4570             | 75.6                 |
| 6/21/93 | 4        | -22.0                      | 0.035                    | 0.00            | 0.81                   | 76.3                 | -60                    | 0.8905             | 76.2                 |
| 7/19/93 | 1        | 0.5                        | 0.060                    | 0.00            | 0.76                   | 77.0                 | -8                     | 1.1278             | 77.1                 |
| 7/19/93 | 3        | 12.7                       | *.042                    | 0.50            | 0.77                   | 77.2                 | -6                     | 1.0659             | 77.1                 |
| 7/19/93 | 5        | 1.7                        | 0.030                    | 0.10            | 0.86                   | 77.4                 | 2                      | 0.8915             | 77.1                 |
| 8/11/93 | 2        | -11.0                      | 0.059                    | -0.10           | 0.63                   | 73.5                 | -83                    | 1.0772             | 73.3                 |
| 8/11/93 | 4        | -38.5                      | *.036                    | 2.10            | 0.60                   | 73.8                 | -95                    | 1.3981             | 73.8                 |

\* MEASUREMENT OMITTED

Table B-2 IA2850.0-2

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/27/93 | 2        | -51.2                      | 0.108                    | -0.3            | 0.83                   | 56.6                 | -82                    | 0.7223             | 56.6                 |
| 1/27/93 | 4        | -66.0                      | *.128                    | -1.2            | 1.06                   | 56.6                 | -71                    | 0.6150             | 56.6                 |
| 2/13/93 | 1        | -42.0                      | 0.027                    | 0.0             | 0.87                   | 56.8                 | -87                    | 0.3250             | 56.8                 |
| 2/13/93 | 3        | -44.7                      | 0.008                    | 0.0             | 1.02                   | 56.8                 | -66                    | 0.5510             | 57.0                 |
| 2/13/93 | 5        | -52.0                      | 0.028                    | 0.0             | 1.02                   | 56.8                 | -98                    | 0.5025             | 57.2                 |
| 3/9/93  | 2        | -46.0                      | 0.029                    | 0.1             | 0.82                   | 57.9                 | -56                    | 0.7656             | 58.1                 |
| 3/9/93  | 4        | -41.5                      | 0.021                    | 0.0             | 0.90                   | 57.7                 | -47                    | 0.7378             | 58.1                 |
| 4/23/93 | 1        | 8.7                        | 0.024                    | 0.0             | 1.29                   | 60.4                 | -49                    | 0.5211             | 60.9                 |
| 4/23/93 | 3        | 19.5                       | 0.037                    | 0.0             | 1.09                   | 60.4                 | -34                    | 0.6955             | 60.5                 |
| 4/23/93 | 5        | 3.5                        | 0.036                    | -0.1            | 1.23                   | 60.4                 | -63                    | 0.6150             | 60.1                 |
| 5/18/93 | 2        | -30.5                      | 0.085                    | -0.1            | 0.80                   | 69.4                 | -55                    | 0.7945             | 69.5                 |
| 5/18/93 | 4        | -36.7                      | *.032                    | 1.4             | 0.71                   | 69.6                 | -49                    | 0.9710             | 69.3                 |
| 6/21/93 | 1        | -24.0                      | 0.025                    | 0.1             | 0.88                   | 74.5                 | -58                    | 0.6377             | 75.0                 |
| 6/21/93 | 3        | -16.0                      | 0.037                    | -0.1            | 0.76                   | 74.6                 | -48                    | 0.9617             | 75.1                 |
| 6/21/93 | 5        | -40.7                      | 0.036                    | 0.1             | 0.86                   | 74.7                 | -77                    | 0.7863             | 75.2                 |
| 7/19/93 | 2        | 17.7                       | 0.051                    | 0.0             | 0.60                   | 78.1                 | -18                    | 1.0122             | 78.2                 |
| 7/19/93 | 4        | 23.5                       | 0.055                    | 0.0             | 0.58                   | 78.3                 | -13                    | 1.3156             | 77.9                 |
| 8/11/93 | 1        | -51.5                      | 0.028                    | 0.1             | 0.74                   | 72.5                 | -86                    | 0.8812             | 72.6                 |
| 8/11/93 | 3        | -41.5                      | 0.023                    | 0.0             | 0.62                   | 72.5                 | -84                    | 1.1350             | 72.6                 |
| 8/11/93 | 5        | -50.7                      | *.019                    | 2.4             | 0.67                   | 72.5                 | -95                    | 1.0226             | 72.6                 |

\* MEASUREMENT OMITTED

Table B-3 OA2850.0-1

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/7/93  | 2        | -36.5                      | 0.044                    | 0.2             | 2.73                   | 45.1                 | -101                   | 0.4014             | 40.6                 |
| 1/7/93  | 4        | -59.5                      | 0.032                    | 0.0             | 3.18                   | 45.1                 | -121                   | 0.1323             | 40.6                 |
| 3/8/93  | 1        | -23.0                      | 0.054                    | 0.1             | 2.91                   | 46.4                 | -205                   | 0.2167             | 32.1                 |
| 3/8/93  | 3        | -37.0                      | 0.062                    | 0.0             | 2.77                   | 46.4                 | -208                   | 0.2074             | 32.1                 |
| 3/8/93  | 5        | -49.0                      | 0.042                    | 0.0             | 3.07                   | 46.4                 | -214                   | 0.1527             | 32.1                 |
| 4/2/93  | 2        | -29.5                      | *.024                    | 0.5             | 4.26                   | 46.2                 | -110                   | 0.3116             | 48.7                 |
| 4/2/93  | 4        | -1.5                       | 0.030                    | 0.0             | 4.71                   | 46.2                 | -157                   | 0.2167             | 48.5                 |
| 5/12/93 | 1        | 8.0                        | 0.055                    | 0.0             | 0.77                   | 79.5                 | -20                    | 1.0360             | 66.8                 |
| 5/12/93 | 3        | -26.0                      | *.021                    | 3.4             | 0.69                   | 78.9                 | -56                    | 0.8894             | 66.4                 |
| 5/12/93 | 5        | -33.5                      | *.017                    | 9.6             | 0.77                   | 78.5                 | -58                    | 0.5706             | 66.0                 |
| 6/8/93  | 2        | -33.5                      | 0.044                    | 0.0             | 2.15                   | 85.2                 | -91                    | 0.6624             | 69.8                 |
| 6/8/93  | 4        | -58.5                      | 0.037                    | 0.1             | 1.79                   | 85.2                 | -98                    | 0.7584             | 69.5                 |
| 7/20/93 | 1        | -1.5                       | 0.043                    | 0.1             | 1.81                   | 101.8                | -50                    | 0.6831             | 96.5                 |
| 7/20/93 | 3        | -15.7                      | 0.046                    | 0.0             | 1.71                   | 103.0                | -80                    | 0.6655             | 96.1                 |
| 7/20/93 | 5        | -11.7                      | 0.045                    | 0.0             | 1.97                   | 104.2                | -79                    | 0.5139             | 95.7                 |

\* MEASUREMENT OMITTED



Table B-4 OA2850.0-2

| DATE    | POSITION | GEOCISA                    |                          |                 |                       |                      | 3LP                  |                    |                    |
|---------|----------|----------------------------|--------------------------|-----------------|-----------------------|----------------------|----------------------|--------------------|--------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTI<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees) |
| 1/7/93  | 1        | -66.2                      | 0.032                    | 0.0             | 3.19                  | 46.3                 | -151                 | 0.2930             | 41.6               |
| 1/7/93  | 3        | -60.7                      | 0.049                    | 0.0             | 2.64                  | 46.6                 | -136                 | 0.3931             | 41.8               |
| 1/7/93  | 5        | -68.0                      | 0.038                    | 0.4             | 3.41                  | 46.9                 | -128                 | 0.2394             | 42.0               |
| 3/8/93  | 2        | -51.2                      | 0.039                    | 0.0             | 3.18                  | 46.5                 | -222                 | 0.1754             | 32.5               |
| 3/8/93  | 4        | -68.0                      | 0.033                    | -0.1            | 3.59                  | 46.9                 | -214                 | 0.1971             | 32.0               |
| 4/2/93  | 1        | -45.7                      | 0.025                    | 0.0             | 4.07                  | 46.2                 | -216                 | 0.1713             | 48.6               |
| 4/2/93  | 3        | -34.0                      | 0.036                    | 0.0             | 3.80                  | 46.2                 | -166                 | 0.2332             | 48.6               |
| 4/2/93  | 5        | -26.0                      | *.033                    | 0.1             | 4.13                  | 46.2                 | -143                 | 0.2208             | 48.6               |
| 5/12/93 | 2        | -71.0                      | *.021                    | 0.7             | 0.59                  | 77.9                 | -75                  | 0.6769             | 66.1               |
| 5/12/93 | 4        | -55.0                      | *.064                    | -4.4            | 0.58                  | 77.9                 | -46                  | 0.6593             | 66.1               |
| 6/8/93  | 1        | -79.7                      | 0.051                    | 0.0             | 1.91                  | 86.9                 | -106                 | 0.4581             | 69.7               |
| 6/8/93  | 3        | -64.2                      | 0.057                    | 0.0             | 1.54                  | 86.9                 | -120                 | 0.6346             | 69.7               |
| 6/8/93  | 5        | -74.5                      | 0.037                    | 0.1             | 1.62                  | 86.9                 | -112                 | 0.6284             | 69.7               |
| 8/15/93 | 1        | -103.5                     | 0.042                    | 0.2             | 0.97                  | 89.5                 | -77                  | *0.0991            | 67.9               |
| 8/15/93 | 3        | -63.7                      | 0.071                    | -0.1            | 1.22                  | 89.5                 | -88                  | *0.1166            | 67.9               |
| 8/15/93 | 5        | -97.7                      | 0.049                    | 0.0             | 1.10                  | 89.5                 | -80                  | *0.0887            | 67.9               |

\* MEASUREMENT OMITTED

Table B-5 IA2850.6-1

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/27/93 | 1        | -7.2                       | *.169              | -4.3            | 0.42                   | 61.1                 | -67                    | 0.6955             | 60.5                 |
| 1/27/93 | 3        | 26.2                       | *.113              | -4.5            | 0.46                   | 61.1                 | -59                    | 0.9968             | 60.7                 |
| 1/27/93 | 5        | -36.5                      | *.153              | 4.5             | 0.68                   | 61.1                 | -73                    | 0.6645             | 60.9                 |
| 2/13/93 | 2        | -38.2                      | *.026              | -0.8            | 0.64                   | 59.9                 | -17                    | 0.6851             | 59.5                 |
| 2/13/93 | 4        | -42.2                      | 0.034              | 0.0             | 0.72                   | 59.7                 | -27                    | 0.9410             | 59.5                 |
| 3/9/93  | 1        | -83.0                      | *.019              | 3.6             | 0.68                   | 62.6                 | -60                    | 0.6790             | 62.5                 |
| 3/9/93  | 3        | -68.2                      | *.024              | 5.1             | 0.63                   | 62.2                 | -35                    | 1.1804             | 62.0                 |
| 3/9/93  | 5        | -62.2                      | 0.058              | 0.0             | 0.84                   | 61.8                 | -53                    | 0.7708             | 61.4                 |
| 4/23/93 | 2        | 63.5                       | 0.043              | 0.0             | 1.09                   | 64.0                 | -3                     | 0.8915             | 63.4                 |
| 4/23/93 | 4        | 62.2                       | 0.060              | 0.0             | 1.03                   | 63.7                 | 8                      | 1.1051             | 63.1                 |
| 5/18/93 | 1        | -10.5                      | 0.031              | 0.1             | 0.96                   | 70.8                 | -32                    | 0.9524             | 72.0                 |
| 5/18/93 | 3        | 2.0                        | 0.061              | 0.0             | 0.85                   | 71.0                 | -26                    | 1.6644             | 71.3                 |
| 5/18/93 | 5        | -14.7                      | 0.039              | 0.0             | 0.98                   | 71.2                 | -33                    | 1.1835             | 70.6                 |
| 6/21/93 | 2        | 17.5                       | *.027              | 1.6             | 0.66                   | 75.9                 | 11                     | 1.3414             | 74.8                 |
| 6/21/93 | 4        | 19.5                       | 0.044              | 0.0             | 0.64                   | 75.3                 | 17                     | 1.4291             | 74.2                 |
| 7/19/93 | 1        | 1.2                        | 0.037              | 0.0             | 0.58                   | 79.8                 | 5                      | 1.0329             | 79.6                 |
| 7/19/93 | 3        | 18.7                       | 0.040              | 0.4             | 0.47                   | 79.8                 | 13                     | 1.6571             | 79.7                 |
| 7/19/93 | 5        | 8.0                        | 0.042              | 0.1             | 0.58                   | 79.8                 | 10                     | 1.3569             | 79.8                 |
| 8/11/93 | 2        | 1.5                        | 0.021              | 0.3             | 0.51                   | 74.3                 | -27                    | 1.3342             | 73.6                 |
| 8/11/93 | 4        | 6.2                        | 0.034              | -0.1            | 0.55                   | 74.1                 | -19                    | 1.7624             | 73.7                 |

\* MEASUREMENT OMITTED

Table B-6 IA2850.6-2

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/13/93 | 2        | -12.7                      | 0.034                    | 0.0             | 0.59                   | 62.0                 | -218                   | 0.7285             | 61.7                 |
| 1/13/93 | 4        | -35.7                      | 0.067                    | 0.0             | 0.78                   | 61.7                 | -44                    | 0.6790             | 61.7                 |
| 2/12/93 | 1        | -24.0                      | 0.075                    | -0.1            | 0.93                   | 60.4                 | -156                   | 0.7047             | 60.6                 |
| 2/12/93 | 3        | -15.7                      | 0.046                    | 0.0             | 1.00                   | 60.6                 | -140                   | 0.8523             | 60.6                 |
| 2/12/93 | 5        | -34.7                      | 0.045                    | -0.1            | 1.14                   | 60.8                 | -66                    | 0.8430             | 60.6                 |
| 3/8/93  | 2        | -28.2                      | 0.040                    | 0.0             | 0.75                   | 62.7                 | -57                    | 0.5933             | 62.6                 |
| 3/8/93  | 4        | -30.5                      | 0.038                    | 0.3             | 0.73                   | 62.4                 | -45                    | 0.5902             | 62.2                 |
| 4/22/93 | 1        | -1.5                       | 0.039                    | -0.1            | 1.26                   | 63.4                 | -68                    | 0.8616             | 63.0                 |
| 4/22/93 | 3        | 7.7                        | 0.046                    | 0.0             | 1.11                   | 63.6                 | -9                     | 1.0422             | 63.0                 |
| 4/22/93 | 5        | 41.7                       | 0.030                    | 0.1             | 1.70                   | 63.8                 | -52                    | 0.7656             | 63.0                 |
| 5/19/93 | 2        | -69.0                      | *.164                    | -0.9            | 0.84                   | 72.9                 | -72                    | 1.2114             | 72.1                 |
| 5/19/93 | 4        | -76.0                      | *.025                    | 1.5             | 0.97                   | 75.4                 | -66                    | 1.2558             | 72.4                 |
| 6/21/93 | 1        | -10.5                      | 0.049                    | 0.0             | 0.83                   | 77.3                 | -16                    | 1.2238             | 77.4                 |
| 6/21/93 | 3        | 1.7                        | *.133                    | 0.8             | 0.74                   | 77.5                 | -22                    | 1.6117             | 77.8                 |
| 6/21/93 | 5        | -18.2                      | *.024                    | 1.8             | 0.80                   | 77.7                 | -23                    | 1.1577             | 78.2                 |
| 7/19/93 | 2        | -13.7                      | 0.123                    | 0.0             | 0.87                   | 77.3                 | 6                      | 1.0721             | 77.4                 |
| 7/19/93 | 4        | -4.5                       | 0.069                    | 0.0             | 0.90                   | 77.8                 | 3                      | 1.0349             | 77.9                 |
| 8/11/93 | 1        | -44.0                      | 0.070                    | 0.0             | 1.02                   | 75.5                 | -82                    | 1.7624             | 73.6                 |
| 8/11/93 | 3        | -27.0                      | 0.044                    | 0.1             | 0.82                   | 76.5                 | -73                    | 1.1144             | 74.2                 |
| 8/11/93 | 5        | -43.7                      | 0.027                    | 0.1             | 1.01                   | 77.5                 | -86                    | 1.2764             | 74.8                 |

\* MEASUREMENT OMITTED

Table B-7 IA2850.6-3

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      |                        | 3LP                |                      |  |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|--|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |  |
| 1/13/93 | 2        | -5.5                       | 0.072              | 0.0             | 0.58                   | 59.9                 | -57                    | 0.8079             | 59.7                 |  |
| 1/13/93 | 4        | -2.0                       | 0.064              | -0.1            | 0.61                   | 59.5                 | -63                    | 0.7161             | 59.5                 |  |
| 2/12/93 | 1        | -13.5                      | 0.032              | 0.0             | 0.97                   | 58.8                 | -197                   | 0.7274             | 59.0                 |  |
| 2/12/93 | 3        | 15.2                       | *.026              | -0.5            | 0.72                   | 58.8                 | -140                   | 0.8894             | 59.0                 |  |
| 2/12/93 | 5        | -11.0                      | 0.025              | 0.0             | 0.83                   | 58.8                 | -87                    | 0.5324             | 59.0                 |  |
| 3/8/93  | 2        | -18.7                      | 0.037              | 0.4             | 0.78                   | 60.6                 | -16                    | 1.0308             | 60.6                 |  |
| 3/8/93  | 4        | -20.2                      | *.031              | 5.6             | 0.77                   | 60.6                 | -25                    | 1.0153             | 60.6                 |  |
| 4/22/93 | 1        | 0.0                        | 0.048              | -0.1            | 1.10                   | 61.9                 | -39                    | 0.7522             | 62.2                 |  |
| 4/22/93 | 3        | 17.7                       | 0.035              | 0.0             | 0.82                   | 62.1                 | -84                    | 0.9287             | 62.2                 |  |
| 4/22/93 | 5        | 1.5                        | 0.031              | 0.0             | 1.08                   | 62.3                 | -255                   | 0.3106             | 62.2                 |  |
| 5/19/94 | 2        | -47.0                      | *.095              | -0.7            | 0.68                   | 70.5                 | -70                    | 1.2361             | 70.9                 |  |
| 5/19/94 | 4        | -52.5                      | *.06               | 1.7             | 0.74                   | 70.4                 | -80                    | 1.7190             | 70.5                 |  |
| 6/21/93 | 1        | -22.0                      | *.031              | 1.2             | 0.71                   | 76.0                 | -43                    | 1.4470             | 75.9                 |  |
| 6/21/93 | 3        | 2.7                        | *.035              | 0.8             | 0.60                   | 76.2                 | -16                    | 1.4745             | 75.7                 |  |
| 6/21/93 | 5        | -3.2                       | 0.034              | -0.3            | 0.67                   | 76.4                 | -26                    | 0.8915             | 75.5                 |  |
| 7/19/93 | 2        | 20.5                       | 0.097              | 0.0             | 0.57                   | 76.8                 | 10                     | 1.3569             | 76.9                 |  |
| 7/19/93 | 4        | 16.5                       | 0.078              | 0.0             | 0.60                   | 77.1                 | 7                      | 1.3847             | 76.7                 |  |
| 8/11/93 | 1        | -23.5                      | 0.036              | 0.0             | 0.83                   | 72.8                 | -104                   | 1.1392             | 73.5                 |  |
| 8/11/93 | 3        | -4.0                       | 0.036              | 0.1             | 0.64                   | 73.2                 | -63                    | 1.3981             | 73.5                 |  |
| 8/11/93 | 5        | -34.0                      | 0.064              | -0.2            | 0.75                   | 73.6                 | -103                   | 1.0411             | 73.5                 |  |

\* MEASUREMENT OMITTED

Table B-8 OA2850.6-1

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/7/93  | 2        | -12.5                      | *.043                    | 0.6             | 3.33                   | 46.2                 | -97                    | 0.4437             | 43.8                 |
| 1/7/93  | 4        | -12.5                      | 0.045                    | 0.0             | 3.29                   | 46.0                 | -96                    | 0.3942             | 43.5                 |
| 3/8/93  | 1        | -5.2                       | 0.040                    | 0.0             | 4.01                   | 46.5                 | -163                   | 0.2064             | 33.3                 |
| 3/8/93  | 3        | 13.5                       | 0.050                    | 0.0             | 3.46                   | 46.5                 | -167                   | 0.2342             | 32.8                 |
| 3/8/93  | 5        | 8.2                        | 0.047                    | 0.0             | 4.08                   | 46.5                 | -175                   | 0.2167             | 32.3                 |
| 4/2/93  | 2        | 17.7                       | 0.040                    | 0.0             | 4.31                   | 45.1                 | -67                    | 0.0753             | 46.9                 |
| 4/2/93  | 4        | -8.0                       | 0.032                    | 0.0             | 4.74                   | 45.1                 | -87                    | 0.3054             | 46.9                 |
| 5/12/93 | 1        | -52.0                      | *.028                    | -9.7            | 0.58                   | 80.7                 | -52                    | 0.9751             | 65.5                 |
| 5/12/93 | 3        | -41.0                      | *.19                     | -6.2            | 0.48                   | 79.3                 | -47                    | 1.1340             | 65.7                 |
| 5/12/93 | 5        | -54.2                      | *.132                    | -2.9            | 0.56                   | 78.1                 | -55                    | 1.0411             | 65.9                 |
| 6/8/93  | 2        | -39.2                      | 0.084                    | 0.0             | 1.10                   | 87.7                 | -76                    | 1.2485             | 71.2                 |
| 6/8/93  | 4        | -33.0                      | *.213                    | -0.8            | 1.18                   | 87.5                 | -78                    | 0.9452             | 71.4                 |
| 7/20/93 | 2        | 8.0                        | 0.061                    | 0.0             | 1.84                   | 101.1                | -49                    | 0.7264             | 97.8                 |
| 7/20/93 | 4        | 16.7                       | 0.069                    | 0.2             | 1.78                   | 101.6                | -52                    | 0.8141             | 97.0                 |

\* MEASUREMENT OMITTED

Table B-9 OA2850.6-2

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/7/93  | 1        | -10.2                      | 0.045                    | 0.1             | 3.08                   | 46.4                 | -80                    | 0.4354             | 43.8                 |
| 1/7/93  | 3        | -9.5                       | 0.063                    | 0.0             | 3.00                   | 46.5                 | -74                    | 0.5252             | 43.8                 |
| 1/7/93  | 5        | -9.0                       | 0.055                    | -0.1            | 2.93                   | 46.6                 | -120                   | 0.5685             | 43.8                 |
| 3/8/93  | 2        | -13.2                      | *.018                    | 0.6             | 4.27                   | 46.4                 | -176                   | 0.1568             | 33.6                 |
| 3/8/93  | 4        | -14.7                      | 0.028                    | -0.1            | 4.21                   | 46.7                 | -270                   | 0.0939             | 33.4                 |
| 4/2/93  | 1        | 5.0                        | 0.024                    | -0.5            | 4.69                   | 45.1                 | -99                    | 0.3137             | 46.9                 |
| 4/2/93  | 3        | 4.2                        | *.044                    | -0.6            | 4.09                   | 45.1                 | -120                   | 0.2724             | 46.9                 |
| 4/2/93  | 5        | 16.0                       | 0.033                    | 0.2             | 3.75                   | 45.1                 | -168                   | 0.2249             | 46.9                 |
| 5/13/93 | 2        | -17.0                      | 0.073                    | 0.0             | 1.16                   | 65.4                 | -31                    | 1.1299             | 65.5                 |
| 5/13/93 | 4        | -21.2                      | 0.042                    | 0.4             | 0.96                   | 65.4                 | -44                    | 0.9431             | 65.5                 |
| 6/8/93  | 1        | -66.7                      | 0.047                    | 0.0             | 1.28                   | 91.2                 | -78                    | 0.6820             | 71.7                 |
| 6/8/93  | 3        | -45.5                      | 0.100                    | -0.1            | 1.22                   | 91.2                 | -85                    | 0.9741             | 71.7                 |
| 6/8/93  | 5        | -22.5                      | 0.175                    | 0.0             | 1.02                   | 91.2                 | -84                    | 0.8956             | 71.7                 |
| 8/15/93 | 2        | -57.2                      | 0.031                    | 0.1             | 1.01                   | 87.1                 | -43                    | *.1651             | 71.4                 |
| 8/15/93 | 4        | -56.2                      | 0.047                    | 0.0             | 1.23                   | 87.1                 | -63                    | *.1187             | 71.4                 |

\* MEASUREMENT OMITTED

Table B-10 OA2850.6-3

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/7/93  | 2        | -12.2                      | 0.046              | -0.4            | 3.34                   | 46.4                 | -125                   | 0.3065             | 44.2                 |
| 1/7/93  | 4        | -19.5                      | 0.064              | -0.1            | 3.09                   | 46.5                 | -131                   | 0.2807             | 44.4                 |
| 3/9/93  | 1        | -87.0                      | 0.026              | 0.0             | 1.60                   | 36.8                 | -147                   | 0.3436             | 42.8                 |
| 3/9/93  | 3        | -91.7                      | 0.029              | 0.0             | 1.77                   | 35.9                 | -182                   | 0.1032             | 42.8                 |
| 3/9/93  | 5        | -61.5                      | 0.038              | 0.0             | 1.77                   | 35.4                 | -154                   | 0.2590             | 42.8                 |
| 4/2/93  | 2        | -4.2                       | 0.040              | 0.0             | 4.66                   | 44.6                 | -92                    | 0.3065             | 46.4                 |
| 4/2/93  | 4        | -14.2                      | 0.041              | 0.0             | 4.04                   | 44.6                 | -180                   | 0.2033             | 46.4                 |
| 5/13/93 | 1        | -33.0                      | *.029              | 2.2             | 1.10                   | 65.6                 | -48                    | 0.9276             | 64.2                 |
| 5/13/93 | 3        | -33.2                      | *.044              | 1.3             | 1.13                   | 65.4                 | -40                    | 1.2516             | 64.2                 |
| 5/13/93 | 5        | -17.7                      | 0.097              | 0.1             | 1.16                   | 65.2                 | -40                    | 1.3486             | 64.2                 |
| 6/8/93  | 2        | -37.2                      | 0.058              | 0.0             | 1.25                   | 92.7                 | -87                    | 0.7646             | 71.2                 |
| 6/8/93  | 4        | -52.2                      | 0.064              | 0.0             | 1.26                   | 92.7                 | -100                   | 0.8575             | 71.2                 |
| 7/20/93 | 1        | 10.0                       | 0.037              | 0.1             | 1.86                   | 104.7                | -78                    | 0.5386             | 101.1                |
| 7/20/93 | 3        | -11.2                      | 0.036              | 0.0             | 1.94                   | 104.7                | -73                    | 0.6377             | 101.1                |
| 7/20/93 | 5        | -5.2                       | 0.056              | -0.1            | 2.08                   | 104.7                | -75                    | 0.6253             | 101.1                |

\* MEASUREMENT OMITTED

Table B-11 IA2851.2-1

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/27/93 | 2        | 16.0                       | *1.708                   | -9.4            | 0.46                   | 61.1                 | -66                    | 1.3651             | 60.4                 |
| 1/27/93 | 4        | -7.2                       | *.169                    | 0.1             | 0.42                   | 60.9                 | -30                    | 1.0979             | 60.4                 |
| 2/13/93 | 1        | -49.0                      | 0.107                    | 0.0             | 0.53                   | 60.0                 | -18                    | 1.1020             | 59.5                 |
| 2/13/93 | 3        | -41.7                      | 0.047                    | 0.0             | 0.44                   | 60.0                 | -6                     | 1.2950             | 59.5                 |
| 2/13/93 | 5        | -62.2                      | 0.087                    | 0.0             | 0.62                   | 60.0                 | -40                    | 1.4177             | 59.5                 |
| 3/9/93  | 2        | -43.5                      | 0.034                    | 0.1             | 0.48                   | 61.7                 | 16                     | 0.9049             | 61.7                 |
| 3/9/93  | 4        | -70.7                      | *.032                    | 1.8             | 0.46                   | 62.0                 | -5                     | 1.2372             | 61.8                 |
| 4/23/93 | 1        | 90.5                       | 0.059                    | -0.1            | 0.85                   | 63.5                 | -28                    | 1.1175             | 63.2                 |
| 4/23/93 | 3        | 65.2                       | 0.063                    | 0.0             | 0.68                   | 63.9                 | 3                      | 1.4807             | 63.6                 |
| 4/23/93 | 5        | 58.7                       | 0.082                    | 0.0             | 0.92                   | 64.3                 | -11                    | 1.4993             | 64.0                 |
| 5/18/93 | 2        | 33.0                       | 0.057                    | 0.0             | 0.65                   | 74.0                 | 2                      | 1.2712             | 71.0                 |
| 5/18/93 | 4        | 24.7                       | 0.047                    | 0.0             | 0.54                   | 71.3                 | 3                      | 1.6644             | 71.3                 |
| 6/21/93 | 1        | 31.2                       | 0.103                    | -0.1            | 0.52                   | 75.5                 | 15                     | 1.9987             | 74.8                 |
| 6/21/93 | 3        | 25.0                       | *.118                    | 1.0             | 0.39                   | 75.9                 | 6                      | 2.0926             | 74.8                 |
| 6/21/93 | 5        | 3.7                        | 0.117                    | 0.1             | 0.50                   | 76.3                 | -9                     | 1.9626             | 74.8                 |
| 7/19/93 | 2        | 72.5                       | 0.063                    | 0.0             | 0.35                   | 80.2                 | 72                     | 2.2253             | 79.6                 |
| 7/19/93 | 4        | 41.5                       | 0.045                    | 0.4             | 0.34                   | 80.2                 | 47                     | 1.6499             | 79.6                 |
| 8/11/93 | 1        | 16.0                       | 0.073                    | 0.1             | 0.39                   | 74.8                 | -9                     | 2.0059             | 73.8                 |
| 8/11/93 | 3        | 15.7                       | 0.057                    | 0.0             | 0.33                   | 74.8                 | -3                     | 1.8914             | 73.8                 |
| 8/11/93 | 5        | -10.7                      | 0.046                    | 0.0             | 0.45                   | 74.8                 | -39                    | 2.0647             | 73.8                 |

\* MEASUREMENT OMITTED



Table B-12 IA2851.2-2

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/27/93 | 1        | -22.5                      | *.230              | -6.50           | 0.57                   | 57.5                 | -62                    | 0.6325             | 58.2                 |
| 1/27/93 | 3        | -4.5                       | *.134              | -1.00           | 0.55                   | 57.9                 | -53                    | 1.0845             | 58.3                 |
| 1/27/93 | 5        | -21.2                      | *.227              | -0.80           | 0.60                   | 58.3                 | -74                    | 1.0029             | 58.4                 |
| 2/13/93 | 2        | -52.5                      | 0.030              | -0.40           | 0.54                   | 57.9                 | -72                    | 1.1268             | 58.2                 |
| 2/13/93 | 4        | -49.5                      | 0.031              | 0.40            | 0.50                   | 57.9                 | -109                   | 0.9988             | 58.2                 |
| 3/9/93  | 1        | -82.0                      | 0.060              | 0.00            | 0.67                   | 59.4                 | -73                    | 0.7780             | 59.5                 |
| 3/9/93  | 3        | -74.0                      | 0.053              | 0.00            | 0.58                   | 59.2                 | -59                    | 0.9483             | 59.5                 |
| 3/9/93  | 5        | -73.2                      | 0.027              | 0.10            | 0.61                   | 59.0                 | -68                    | 1.1763             | 59.5                 |
| 4/23/93 | 2        | 41.5                       | 0.059              | 0.00            | 0.70                   | 61.1                 | -24                    | 1.1030             | 61.7                 |
| 4/23/93 | 4        | 39.7                       | 0.041              | 0.00            | 0.68                   | 61.1                 | -70                    | 1.1619             | 61.5                 |
| 5/18/93 | 1        | -17.5                      | *.032              | 0.80            | 0.62                   | 68.6                 | -51                    | 0.8193             | 68.8                 |
| 5/18/93 | 3        | -3.7                       | *.062              | -3.70           | 0.54                   | 69.0                 | -42                    | 1.3517             | 69.0                 |
| 5/18/93 | 5        | -32.2                      | *.067              | -2.70           | 0.64                   | 69.4                 | -66                    | 1.2021             | 69.2                 |
| 6/21/93 | 2        | -18.0                      | 0.047              | 0.00            | 0.50                   | 73.6                 | -60                    | 1.5220             | 74.3                 |
| 6/21/93 | 4        | -21.5                      | 0.032              | 0.30            | 0.47                   | 73.9                 | -51                    | 2.0647             | 73.9                 |
| 7/19/93 | 1        | 5.2                        | 0.031              | 0.00            | 0.46                   | 78.5                 | -22                    | 1.2702             | 78.3                 |
| 7/19/93 | 3        | 4.7                        | 0.043              | 0.10            | 0.31                   | 78.3                 | -21                    | 1.6871             | 78.1                 |
| 7/19/93 | 5        | -17.0                      | 0.043              | 0.00            | 0.42                   | 78.1                 | -22                    | 1.2764             | 77.9                 |
| 8/11/93 | 2        | -40.5                      | *.029              | 1.60            | 0.35                   | 72.8                 | -75                    | 2.3247             | 73.1                 |
| 8/11/93 | 4        | -57.2                      | 0.087              | 0.00            | 0.38                   | 72.6                 | -78                    | 1.5003             | 73.0                 |

\* MEASUREMENT OMITTED

Table B-13 IA2851.2-3

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/27/93 | 2        | -16.0                      | *.256              | -6.50           | 0.51                   | 57.7                 | -60                    | 0.7574             | 57.9                 |
| 1/27/93 | 4        | -28.5                      | *.256              | -1.00           | 0.55                   | 57.7                 | -70                    | 0.9668             | 58.1                 |
| 2/13/93 | 1        | -64.0                      | *.026              | -0.50           | 0.66                   | 57.9                 | -89                    | 1.0514             | 58.2                 |
| 2/13/93 | 3        | -29.7                      | 0.035              | 0.00            | 0.49                   | 57.9                 | -56                    | 0.8182             | 58.2                 |
| 2/13/93 | 5        | -55.0                      | 0.031              | 0.10            | 0.74                   | 57.9                 | -115                   | 0.6604             | 58.2                 |
| 3/9/93  | 2        | -75.7                      | 0.033              | 0.10            | 0.47                   | 59.0                 | -46                    | 1.1268             | 59.0                 |
| 3/9/93  | 4        | -86.5                      | *.025              | 1.10            | 0.52                   | 59.0                 | -60                    | 0.8523             | 59.1                 |
| 4/23/93 | 1        | 44.0                       | 0.047              | 0.00            | 0.87                   | 61.4                 | -29                    | 0.9937             | 61.4                 |
| 4/23/93 | 3        | 53.7                       | 0.053              | 0.00            | 0.65                   | 61.3                 | -20                    | 1.0669             | 61.3                 |
| 4/23/93 | 5        | 28.0                       | 0.083              | 0.00            | 0.95                   | 61.2                 | -75                    | 0.9245             | 61.2                 |
| 5/18/93 | 2        | 7.2                        | *.053              | 0.70            | 0.53                   | 69.3                 | -26                    | 1.3104             | 69.0                 |
| 5/18/93 | 4        | -3.5                       | *.059              | -4.60           | 0.61                   | 69.1                 | -42                    | 1.4559             | 68.9                 |
| 6/21/93 | 1        | 31.2                       | 0.103              | 0.10            | 0.52                   | 74.4                 | -60                    | 1.2258             | 75.2                 |
| 6/21/93 | 3        | 25.0                       | 0.118              | -0.20           | 0.39                   | 74.6                 | -43                    | 1.5818             | 75.2                 |
| 6/21/93 | 5        | 3.7                        | 0.117              | 0.00            | 0.50                   | 74.8                 | -53                    | 1.8718             | 75.2                 |
| 7/19/93 | 2        | 12.7                       | 0.076              | 0.00            | 0.37                   | 78.3                 | -12                    | 1.8109             | 78.9                 |
| 7/19/93 | 4        | 19.5                       | 0.039              | -0.10           | 0.39                   | 77.7                 | -3                     | 1.5808             | 78.5                 |
| 8/11/93 | 1        | -37.2                      | *.04               | 0.50            | 0.43                   | 73.0                 | -75                    | 1.6623             | 73.3                 |
| 8/11/93 | 3        | -14.5                      | 0.034              | -0.30           | 0.39                   | 73.0                 | -54                    | 2.0461             | 73.3                 |
| 8/11/93 | 5        | -19.0                      | *.035              | 2.00            | 0.39                   | 73.0                 | -67                    | 2.1050             | 73.3                 |

\* MEASUREMENT OMITTED

Table B-14 OA2851.2-1

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/7/93  | 1        | 3.7                        | *.111                    | -0.6            | 2.63                   | 46.9                 | -160                   | 0.0856             | 46.4                 |
| 1/7/93  | 3        | 4.7                        | 0.075                    | -0.1            | 2.43                   | 46.9                 | -146                   | 0.2672             | 46.4                 |
| 1/7/93  | 5        | 0.7                        | 0.071                    | 0.0             | 2.65                   | 46.9                 | -202                   | 0.4262             | 46.4                 |
| 3/9/93  | 2        | -86.2                      | 0.018                    | 0.0             | 1.86                   | 35.6                 | -168                   | 0.2260             | 44.9                 |
| 3/9/93  | 4        | -30.7                      | 0.038                    | -0.1            | 1.79                   | 35.6                 | -214                   | 0.0960             | 44.9                 |
| 4/2/93  | 1        | 14.2                       | 0.037                    | -0.4            | 3.82                   | 44.6                 | -156                   | 0.2930             | 46.4                 |
| 4/2/93  | 3        | 16.0                       | 0.039                    | -0.1            | 3.46                   | 44.6                 | -163                   | 0.4447             | 46.4                 |
| 4/2/93  | 5        | 29.0                       | *.042                    | 0.5             | 3.60                   | 44.6                 | -175                   | 0.1950             | 46.4                 |
| 5/13/93 | 2        | -11.5                      | *.11                     | -1.2            | 0.96                   | 65.5                 | -46                    | 0.9276             | 68.3                 |
| 5/13/93 | 4        | 7.7                        | 0.128                    | -0.1            | 1.02                   | 65.3                 | -32                    | 1.1340             | 68.3                 |
| 6/8/93  | 1        | -24.5                      | 0.102                    | 0.0             | 1.14                   | 96.3                 | -100                   | 0.7161             | 73.1                 |
| 6/8/93  | 3        | -37.2                      | 0.095                    | 0.0             | 1.15                   | 95.8                 | -99                    | 0.7471             | 73.1                 |
| 6/8/93  | 5        | -37.7                      | 0.114                    | 0.0             | 1.23                   | 95.4                 | -109                   | 0.5417             | 73.1                 |
| 8/15/93 | 1        | -49.7                      | 0.052                    | 0.3             | 1.15                   | 92.8                 | -37                    | *.1682             | 72.2                 |
| 8/15/93 | 3        | -32.7                      | 0.075                    | 0.3             | 1.08                   | 92.0                 | -33                    | *.1414             | 73.4                 |
| 8/15/93 | 5        | -48.7                      | 0.083                    | -0.2            | 1.35                   | 91.2                 | -28                    | *.1527             | 74.6                 |

\* MEASUREMENT OMITTED

Table B-15 OA2851.2-2

| DATE    | POSITION | GEOCISA                    |  |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu\text{A}/\text{sqcm}$ ) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/7/93  | 2        | -28.2                      | 0.043                                  | -0.4            | 3.39                   | 46.9                 | -46                    | 0.8399             | 46.9                 |
| 1/7/93  | 4        | 1.0                        | 0.059                                  | -0.1            | 2.68                   | 47.1                 | -50                    | 0.7140             | 46.9                 |
| 3/9/93  | 1        | -80.5                      | 0.032                                  | -0.2            | 1.89                   | 37.3                 | -40                    | 0.4509             | 45.1                 |
| 3/9/93  | 3        | -139.5                     | 0.018                                  | 0.0             | 2.12                   | 37.7                 | -75                    | 0.3488             | 45.7                 |
| 3/9/93  | 5        | -55.0                      | 0.046                                  | 0.0             | 1.86                   | 38.1                 | -66                    | 0.4024             | 46.3                 |
| 4/3/93  | 2        | 33.2                       | 0.065                                  | 0.0             | 2.85                   | 41.0                 | -84                    | 0.3900             | 36.8                 |
| 4/3/93  | 4        | 43.7                       | 0.066                                  | -0.3            | 2.60                   | 41.5                 | -166                   | 0.1878             | 37.2                 |
| 5/13/93 | 1        | -3.2                       | 0.068                                  | 0.1             | 1.02                   | 65.8                 | -37                    | 1.5942             | 69.9                 |
| 5/13/93 | 3        | -13.0                      | 0.082                                  | -0.1            | 0.94                   | 65.7                 | -37                    | 1.1763             | 70.3                 |
| 5/13/93 | 5        | -11.2                      | 0.081                                  | 0.0             | 1.02                   | 65.6                 | -56                    | 1.1247             | 70.7                 |
| 6/8/93  | 2        | N/A                        | N/A                                    | N/A             | N/A                    | 95.0                 | -79                    | 1.0494             | 73.8                 |
| 6/8/92  | 4        | -30.0                      | 0.099                                  | 0.0             | 1.09                   | 95.9                 | -90                    | 0.8853             | 75.1                 |
| 7/20/93 | 2        | 15.0                       | 0.059                                  | -0.1            | 1.59                   | 103.2                | -82                    | 0.5510             | 100.4                |
| 7/20/93 | 4        | 0.0                        | 0.051                                  | 0.0             | 1.61                   | 103.8                | -16                    | 1.2650             | 101.8                |

\* MEASUREMENT OMITTED

Table B-16 OA2851.2-3

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/7/93  | 1        | 25.0                       | 0.097                    | -0.1            | 3.14                   | 46.3                 | -94                    | 0.4096             | 46.4                 |
| 1/7/93  | 3        | 29.5                       | 0.065                    | 0.2             | 2.76                   | 46.7                 | -76                    | 0.4396             | 46.6                 |
| 1/7/93  | 5        | 42.7                       | 0.071                    | 0.0             | 2.85                   | 47.1                 | -116                   | 0.2353             | 46.8                 |
| 3/9/93  | 2        | -15.2                      | 0.041                    | 0.0             | 1.94                   | 38.8                 | -86                    | 0.2611             | 47.4                 |
| 3/9/93  | 4        | -19.2                      | 0.039                    | 0.0             | 1.98                   | 38.8                 | -37                    | 0.4912             | 47.6                 |
| 4/3/93  | 1        | -15.0                      | 0.034                    | 0.0             | 3.51                   | 41.4                 | -93                    | 0.3188             | 36.8                 |
| 4/3/93  | 3        | 70.2                       | 0.062                    | 0.3             | 2.63                   | 41.6                 | -37                    | 0.5572             | 36.8                 |
| 4/3/93  | 5        | 50.0                       | *.037                    | 0.5             | 2.83                   | 41.8                 | -82                    | 0.3766             | 36.8                 |
| 5/13/93 | 2        | -4.2                       | 0.078                    | 0.0             | 1.15                   | 66.8                 | -39                    | 1.2733             | 67.9                 |
| 5/13/93 | 4        | -12.7                      | *.042                    | 1.5             | 1.14                   | 67.3                 | -31                    | 1.2733             | 69.6                 |
| 6/8/93  | 1        | -0.2                       | 0.093                    | 0.2             | 1.32                   | 96.0                 | -63                    | 1.1887             | 73.5                 |
| 6/8/93  | 3        | -1.0                       | *.09                     | -2.7            | 1.25                   | 96.4                 | -56                    | 1.2640             | 74.7                 |
| 6/8/93  | 5        | N/A                        | N/A                      | N/A             | N/A                    | 96.9                 | -80                    | 0.7574             | 76.0                 |
| 8/15/93 | 2        | -35.2                      | 0.078                    | 0.1             | 1.25                   | 88.8                 | -14                    | *.196              | 73.9                 |
| 8/15/93 | 4        | -22.7                      | 0.046                    | 0.0             | 1.09                   | 89.6                 | -21                    | *.2012             | 74.8                 |

\* MEASUREMENT OMITTED

Table B-17 IA2852.4-1

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      |                        | 3LP                |                      |  |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|--|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |  |
| 1/27/93 | 1        | -50.2                      | *.236                    | -3.20           | 0.99                   | 56.6                 | -54                    | 1.0029             | 56.6                 |  |
| 1/27/93 | 3        | -27.2                      | *.185                    | -1.60           | 0.77                   | 56.6                 | -55                    | 0.9235             | 57.0                 |  |
| 1/27/93 | 5        | -79.2                      | *.162                    | -0.90           | 0.85                   | 56.6                 | -94                    | 0.7625             | 57.4                 |  |
| 2/13/93 | 2        | 0.0                        | 0.046                    | 0.10            | 0.67                   | 56.6                 | -79                    | 1.0525             | 56.6                 |  |
| 2/13/93 | 4        | 1.2                        | 0.049                    | 0.00            | 0.64                   | 56.6                 | -31                    | 0.9926             | 56.6                 |  |
| 3/9/93  | 1        | -30.7                      | 0.046                    | 0.00            | 0.79                   | 57.8                 | -45                    | 0.9142             | 58.1                 |  |
| 3/9/93  | 3        | -21.2                      | 0.042                    | 0.00            | 0.69                   | 58.0                 | -34                    | 1.0318             | 58.1                 |  |
| 3/9/93  | 5        | -38.0                      | 0.043                    | 0.00            | 0.83                   | 58.2                 | -60                    | 0.8936             | 58.1                 |  |
| 4/23/93 | 2        | 53.0                       | 0.052                    | 0.00            | 0.85                   | 60.2                 | -5                     | 1.0174             | 60.3                 |  |
| 4/23/93 | 4        | 52.2                       | 0.054                    | 0.00            | 0.86                   | 60.4                 | -7                     | 1.0133             | 60.3                 |  |
| 5/18/93 | 1        | -23.0                      | *.05                     | 1.10            | 0.60                   | 69.3                 | -47                    | 1.7799             | 69.3                 |  |
| 5/18/93 | 3        | -8.2                       | 0.186                    | 0.00            | 0.61                   | 69.7                 | -32                    | 1.3765             | 69.7                 |  |
| 5/18/93 | 5        | -22.0                      | *.088                    | -1.80           | 0.59                   | 70.1                 | -44                    | 1.2908             | 70.1                 |  |
| 6/21/93 | 2        | 34.7                       | *.046                    | 4.50            | 0.53                   | 73.6                 | 19                     | 1.8810             | 74.4                 |  |
| 6/21/93 | 4        | 13.5                       | 0.052                    | 0.40            | 0.54                   | 73.1                 | -11                    | 1.6664             | 73.7                 |  |
| 7/19/93 | 1        | 41.0                       | 0.019                    | 0.00            | 0.75                   | 78.0                 | 16                     | 1.7345             | 77.7                 |  |
| 7/19/93 | 3        | 64.5                       | 0.062                    | 0.00            | 0.50                   | 78.4                 | 28                     | 1.5385             | 78.3                 |  |
| 7/19/93 | 5        | 35.2                       | 0.078                    | 0.00            | 0.52                   | 78.8                 | -4                     | 1.5168             | 78.9                 |  |
| 8/11/93 | 2        | 7.2                        | *.038                    | 1.70            | 0.37                   | 71.8                 | -28                    | 1.6272             | 71.7                 |  |
| 8/11/93 | 4        | -27.0                      | *.32                     | -0.90           | 0.42                   | 71.5                 | -54                    | 1.6809             | 71.3                 |  |

\* MEASUREMENT OMITTED

Table B-18 IA2852.4-2

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/27/93 | 2        | 42.2                       | *.148              | -8.6            | 0.58                   | 60.2                 | -18                    | 1.0164             | 60.0                 |
| 1/27/93 | 4        | 51.0                       | *.139              | -11.1           | 0.60                   | 60.0                 | -13                    | 1.0370             | 60.0                 |
| 2/13/93 | 1        | -9.7                       | 0.033              | -0.1            | 0.78                   | 60.1                 | -25                    | 0.6717             | 59.7                 |
| 2/13/93 | 3        | 19.7                       | 0.054              | 0.0             | 0.64                   | 59.7                 | 10                     | 1.0968             | 59.3                 |
| 2/13/93 | 5        | 1.0                        | 0.034              | -0.4            | 0.59                   | 59.3                 | 4                      | 0.7274             | 58.9                 |
| 3/9/93  | 2        | -9.7                       | 0.100              | 0.0             | 0.70                   | 61.5                 | 13                     | 0.9390             | 60.8                 |
| 3/9/93  | 4        | -16.0                      | 0.054              | -0.1            | 0.69                   | 61.5                 | 2                      | 0.7336             | 60.9                 |
| 4/23/93 | 1        | 71.0                       | 0.067              | 0.0             | 0.86                   | 63.3                 | 25                     | 1.0143             | 63.2                 |
| 4/23/93 | 3        | 69.5                       | 0.076              | 0.0             | 0.79                   | 63.2                 | 25                     | 1.2279             | 63.3                 |
| 4/23/93 | 5        | 67.5                       | 0.050              | 0.0             | 0.90                   | 63.1                 | 25                     | 0.9049             | 63.4                 |
| 5/18/93 | 2        | 42.0                       | 0.102              | 0.0             | 0.60                   | 71.8                 | 9                      | 1.4450             | 72.1                 |
| 5/18/93 | 4        | 40.7                       | *.033              | 1.8             | 0.57                   | 71.8                 | 29                     | 1.4301             | 72.0                 |
| 6/21/93 | 1        | 19.0                       | *.176              | -1.9            | 0.63                   | 75.6                 | 17                     | 1.3837             | 75.2                 |
| 6/21/93 | 3        | 41.7                       | 0.093              | 0.0             | 0.53                   | 75.8                 | 43                     | 1.6592             | 75.3                 |
| 6/21/93 | 5        | 18.5                       | 0.053              | 0.0             | 0.56                   | 76.0                 | 30                     | 1.3455             | 75.4                 |
| 7/19/93 | 2        | 71.5                       | 0.070              | 0.1             | 0.45                   | 79.6                 | 67                     | 1.4188             | 79.3                 |
| 7/19/93 | 4        | 69.0                       | 0.043              | -0.2            | 0.47                   | 79.6                 | 74                     | 1.7345             | 79.7                 |
| 8/11/93 | 1        | 21.2                       | *.048              | 1.8             | 0.47                   | 73.0                 | -10                    | 1.8914             | 72.7                 |
| 8/11/93 | 3        | 41.5                       | *.048              | 1.2             | 0.43                   | 73.0                 | 10                     | 1.9440             | 72.9                 |
| 8/11/93 | 5        | 14.5                       | 0.048              | 0.2             | 0.52                   | 73.0                 | -20                    | 1.4291             | 73.1                 |

\* MEASUREMENT OMITTED

Table B-19 IA2852.4-3

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/27/93 | 1        | 26.2                       | *.112                    | -12.2           | 0.71                   | 59.6                 | -54                    | 1.0339             | 59.8                 |
| 1/27/93 | 3        | 12.2                       | *.089                    | -13.4           | 0.78                   | 59.8                 | -59                    | 1.1185             | 59.6                 |
| 1/27/93 | 5        | 20.2                       | *.057                    | -17.9           | 0.72                   | 60.0                 | -58                    | 1.1061             | 59.4                 |
| 2/13/93 | 2        | -3.7                       | 0.025                    | 0.0             | 0.62                   | 58.2                 | 5                      | 0.8802             | 58.2                 |
| 2/13/93 | 4        | 0.2                        | 0.062                    | 0.0             | 0.61                   | 58.2                 | -13                    | 1.3362             | 58.1                 |
| 3/9/93  | 1        | -33.2                      | *.04                     | -0.6            | 0.82                   | 61.1                 | 8                      | 0.7078             | 60.8                 |
| 3/9/93  | 3        | -34.7                      | 0.045                    | 0.1             | 0.76                   | 61.1                 | -17                    | 0.9792             | 60.8                 |
| 3/9/93  | 5        | -25.5                      | 0.036                    | 0.1             | 0.80                   | 61.1                 | -10                    | 0.8182             | 60.8                 |
| 4/23/93 | 2        | 51.2                       | 0.068                    | 0.1             | 0.84                   | 62.9                 | 8                      | 0.8564             | 62.6                 |
| 4/23/93 | 4        | 60.0                       | 0.078                    | 0.0             | 0.90                   | 63.1                 | 15                     | 1.2423             | 62.6                 |
| 5/18/93 | 1        | -6.2                       | *.043                    | 3.3             | 0.63                   | 71.8                 | -20                    | 1.3166             | 71.8                 |
| 5/18/93 | 3        | 0.0                        | *.036                    | 2.5             | 0.66                   | 72.0                 | -7                     | 1.5282             | 72.2                 |
| 5/18/93 | 5        | 0.2                        | *.036                    | 4.9             | 0.66                   | 72.2                 | -10                    | 1.5746             | 72.6                 |
| 6/21/93 | 2        | 19.5                       | 0.050                    | 0.1             | 0.58                   | 74.5                 | 33                     | 1.4797             | 73.9                 |
| 6/21/93 | 4        | 22.2                       | 0.114                    | 0.0             | 0.56                   | 74.5                 | 26                     | 1.5488             | 73.8                 |
| 7/19/93 | 1        | 24.2                       | 0.045                    | 0.0             | 0.56                   | 80.0                 | 25                     | 1.4704             | 80.1                 |
| 7/19/93 | 3        | 13.7                       | 0.041                    | 0.0             | 0.60                   | 80.0                 | 16                     | 1.6571             | 80.1                 |
| 7/19/93 | 5        | 37.5                       | 0.042                    | 0.0             | 0.57                   | 80.0                 | 26                     | 1.5034             | 80.0                 |
| 8/11/93 | 2        | 5.0                        | 0.068                    | 0.0             | 0.51                   | 72.7                 | -25                    | 1.6767             | 72.1                 |
| 8/11/93 | 4        | 3.7                        | 0.070                    | 0.0             | 0.49                   | 72.8                 | -24                    | 1.9203             | 72.4                 |

\* MEASUREMENT OMITTED



Table B-20 OA2852.4-1

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/22/93 | 1        | N/A                        | N/A                      | N/A             | N/A                    | N/A                  | -15                    | 0.5125             | 45.6                 |
| 1/22/93 | 3        | N/A                        | N/A                      | N/A             | N/A                    | N/A                  | -20                    | 0.4574             | 45.4                 |
| 1/22/93 | 5        | N/A                        | N/A                      | N/A             | N/A                    | N/A                  | -33                    | 0.4600             | 45.2                 |
| 3/9/93  | 2        | 66.7                       | 0.042                    | 0.00            | 3.08                   | 50.9                 | -109                   | 0.4963             | 51.0                 |
| 3/9/92  | 4        | 77.2                       | 0.052                    | 0.00            | 2.79                   | 50.5                 | -90                    | 0.4726             | 51.6                 |
| 4/3/93  | 1        | 79.7                       | 0.061                    | 0.40            | 2.69                   | 58.5                 | -39                    | 0.5562             | 46.4                 |
| 4/3/93  | 3        | 112.2                      | 0.063                    | 0.00            | 2.66                   | 57.7                 | -14                    | 0.5799             | 46.5                 |
| 4/3/93  | 5        | 76.2                       | 0.058                    | 0.00            | 2.36                   | 56.9                 | -39                    | 0.6511             | 46.6                 |
| 5/13/93 | 2        | 27.2                       | 0.078                    | 0.10            | 1.29                   | 76.5                 | -23                    | 1.4116             | 75.0                 |
| 5/13/93 | 4        | 22.7                       | 0.068                    | 0.10            | 1.07                   | 76.8                 | -16                    | 1.2960             | 75.6                 |
| 6/9/93  | 1        | 50.5                       | 0.073                    | 0.00            | 2.67                   | 68.0                 | -9                     | 1.6355             | 91.2                 |
| 6/9/93  | 3        | 59.5                       | 0.070                    | 0.00            | 2.24                   | 68.6                 | -12                    | 1.4466             | 92.2                 |
| 6/9/93  | 5        | 56.0                       | 0.066                    | 0.00            | 2.40                   | 69.2                 | -19                    | 1.7531             | 93.2                 |
| 8/15/93 | 2        | 31.0                       | 0.081                    | 0.00            | 1.36                   | 95.2                 | -15                    | *0.2239            | 75.3                 |
| 8/15/93 | 4        | 13.7                       | 0.106                    | 0.10            | 1.02                   | 95.4                 | -16                    | *0.259             | 77.1                 |

\* MEASUREMENT OMITTED

Table B-21 OA2852.4-2

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/22/93 | 2        | N/A                        | N/A                      | N/A             | N/A                    | N/A                  | -21                    | 0.5770             | 45.5                 |
| 1/22/93 | 4        | N/A                        | N/A                      | N/A             | N/A                    | N/A                  | -62                    | 0.5194             | 45.1                 |
| 3/9/93  | 1        | 66.7                       | 0.064                    | 0.0             | 2.68                   | 50.8                 | -99                    | 0.5985             | 50.1                 |
| 3/9/93  | 3        | 37.5                       | 0.054                    | 0.0             | 3.05                   | 51.6                 | -116                   | 0.5108             | 50.9                 |
| 3/9/93  | 5        | 66.5                       | 0.056                    | 0.0             | 3.19                   | 52.5                 | -94                    | 0.4406             | 51.8                 |
| 4/3/93  | 2        | 78.0                       | 0.071                    | 0.0             | 2.69                   | 55.5                 | -20                    | 0.5902             | 46.5                 |
| 4/3/93  | 4        | 64.5                       | 0.081                    | 0.0             | 2.77                   | 57.0                 | -39                    | 0.5820             | 46.9                 |
| 5/14/93 | 1        | 25.0                       | 0.142                    | 0.0             | 0.93                   | 79.3                 | -16                    | 1.6221             | 76.5                 |
| 5/14/93 | 3        | -5.0                       | 0.077                    | 0.0             | 0.85                   | 78.8                 | -19                    | 1.5457             | 76.6                 |
| 5/14/93 | 5        | 1.2                        | 0.048                    | 0.5             | 0.94                   | 18.2                 | -8                     | 1.5859             | 76.7                 |
| 6/9/93  | 2        | 56.0                       | 0.080                    | 0.0             | 2.62                   | 70.3                 | -23                    | 1.6148             | 93.9                 |
| 6/9/93  | 4        | 45.0                       | 0.069                    | -0.3            | 2.90                   | 70.3                 | -16                    | 1.8927             | 95.2                 |
| 7/21/93 | 2        | 69.5                       | 0.040                    | 0.0             | 3.57                   | 67.5                 | 21                     | 1.2227             | 87.4                 |
| 7/21/93 | 4        | 72.5                       | 0.043                    | -0.1            | 3.62                   | 68.8                 | 22                     | 1.2073             | 89.7                 |

\* MEASUREMENT OMITTED

Table B-22 OA2852.4-3

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 3/9/93  | 2        | 34.5                       | 0.059                    | 0.0             | 2.87                   | 49.2                 | -120                   | 0.4757             | 51.0                 |
| 3/9/93  | 4        | 72.7                       | 0.060                    | 0.0             | 2.93                   | 49.8                 | -94                    | 0.4065             | 51.6                 |
| 4/3/93  | 1        | 87.7                       | 0.073                    | 0.0             | 2.41                   | 56.9                 | -36                    | 0.7512             | 49.1                 |
| 4/3/93  | 3        | 76.0                       | 0.072                    | 0.0             | 2.65                   | 57.9                 | -32                    | 0.4984             | 49.3                 |
| 4/3/93  | 5        | 115.0                      | 0.078                    | -0.1            | 2.61                   | 58.9                 | -8                     | 0.6005             | 49.5                 |
| 5/14/93 | 2        | -22.2                      | 1.569                    | 0.4             | 0.89                   | 57.6                 | -28                    | 1.9461             | 77.4                 |
| 5/14/93 | 4        | -6.2                       | 0.078                    | 0.0             | 0.88                   | 57.8                 | -13                    | 2.2081             | 77.5                 |
| 6/9/93  | 1        | 60.7                       | 0.066                    | 0.0             | 2.52                   | 70.2                 | -21                    | 1.5220             | 93.5                 |
| 6/9/93  | 3        | 54.7                       | 0.085                    | 0.0             | 2.48                   | 71.0                 | -17                    | 1.6024             | 93.5                 |
| 6/9/93  | 5        | 62.2                       | 0.081                    | -0.1            | 2.74                   | 71.9                 | -8                     | 1.8831             | 93.5                 |
| 8/15/93 | 1        | 24.0                       | 0.105                    | 0.1             | 1.04                   | 94.7                 | -8                     | *.2394             | 78.9                 |
| 8/15/93 | 3        | 12.0                       | 0.073                    | 0.0             | 1.06                   | 94.9                 | -8                     | *.2415             | 79.5                 |
| 8/15/93 | 5        | 33.2                       | 0.095                    | 0.0             | 1.17                   | 95.1                 | 12                     | *.2198             | 80.1                 |

\* MEASUREMENT OMITTED

Table B-23 IA2854.8-1

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/13/93 | 2        | 78.5                       | 0.085              | -0.1            | 0.51                   | 61.1                 | 27                     | 1.4755             | 61.1                 |
| 1/13/93 | 4        | 54.7                       | 0.161              | -0.2            | 0.48                   | 61.1                 | 5                      | 2.1111             | 61.1                 |
| 2/12/93 | 2        | 47.0                       | 0.089              | 0.0             | 0.47                   | 60.8                 | -101                   | 2.3908             | 60.6                 |
| 2/12/93 | 4        | 64.7                       | 0.114              | 0.1             | 0.48                   | 60.8                 | -97                    | 1.7665             | 60.6                 |
| 3/8/93  | 1        | 4.7                        | 0.128              | -0.4            | 0.53                   | 63.1                 | -1                     | 1.7356             | 62.7                 |
| 3/8/93  | 3        | 40.0                       | 0.080              | 0.2             | 0.47                   | 63.1                 | 31                     | 1.8150             | 62.7                 |
| 3/8/93  | 5        | 47.5                       | *.073              | 0.7             | 0.53                   | 63.1                 | 47                     | 1.5065             | 62.7                 |
| 4/22/93 | 2        | 40.5                       | 0.236              | -0.1            | 0.57                   | 62.8                 | 17                     | 1.9440             | 62.5                 |
| 4/22/93 | 4        | 73.5                       | 0.125              | 0.2             | 0.54                   | 62.8                 | 25                     | 1.8934             | 62.5                 |
| 5/19/93 | 1        | -14.0                      | 0.222              | -0.1            | 0.59                   | 72.2                 | 26                     | 2.8510             | 72.4                 |
| 5/19/93 | 3        | 36.2                       | *.167              | -9.5            | 0.53                   | 72.2                 | 21                     | 3.0223             | 72.4                 |
| 5/19/93 | 5        | 46.0                       | *.295              | 3.6             | 0.57                   | 72.2                 | 25                     | 2.8458             | 72.4                 |
| 6/21/93 | 2        | 46.0                       | *.198              | 11.4            | 0.51                   | 77.4                 | 24                     | 2.5136             | 77.5                 |
| 6/21/93 | 4        | 45.0                       | *.108              | 7.0             | 0.55                   | 77.4                 | 29                     | 2.8211             | 77.5                 |
| 7/19/93 | 1        | 62.5                       | 0.223              | 0.0             | 0.61                   | 77.9                 | 56                     | 2.5775             | 78.2                 |
| 7/19/93 | 3        | 109.5                      | 0.228              | 0.2             | 0.46                   | 77.9                 | 98                     | 2.5817             | 78.2                 |
| 7/19/93 | 5        | 95.0                       | 0.310              | 0.0             | 0.61                   | 77.9                 | 87                     | 2.1514             | 78.2                 |
| 8/11/93 | 2        | 47.0                       | 0.168              | 0.0             | 0.56                   | 74.5                 | -17                    | 2.3753             | 74.3                 |
| 8/11/93 | 4        | 35.5                       | 0.149              | 0.3             | 0.57                   | 74.5                 | -33                    | 2.4145             | 74.3                 |

\* MEASUREMENT OMITTED

Table B-24 IA2854.8-2

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/13/93 | 1        | 66.2                       | 0.222              | 0.0             | 0.45                   | 61.7                 | 27                     | 1.4116             | 61.3                 |
| 1/13/93 | 3        | 78.5                       | 0.220              | 0.0             | 0.40                   | 61.7                 | 39                     | 1.9357             | 61.3                 |
| 1/13/93 | 5        | 40.0                       | 0.139              | 0.0             | 0.50                   | 61.7                 | 0                      | 1.4539             | 61.3                 |
| 2/12/93 | 2        | 102.2                      | 0.088              | 0.1             | 0.54                   | 60.4                 | 65                     | 2.2948             | 60.4                 |
| 2/12/93 | 4        | 29.2                       | 0.079              | 0.4             | 0.57                   | 60.4                 | -98                    | 1.8759             | 60.4                 |
| 3/8/93  | 1        | 42.7                       | 0.125              | 0.0             | 0.54                   | 62.8                 | 22                     | 1.4879             | 63.1                 |
| 3/8/93  | 3        | 55.0                       | *.255              | 1.5             | 0.46                   | 63.0                 | 34                     | 1.9884             | 63.1                 |
| 3/8/93  | 5        | 5.0                        | 0.188              | -0.1            | 0.60                   | 63.2                 | -11                    | 1.4054             | 63.1                 |
| 4/22/93 | 2        | 111.2                      | 0.103              | 0.1             | 0.71                   | 63.6                 | -128                   | 0.5004             | 63.2                 |
| 4/22/93 | 4        | 48.5                       | 0.132              | 0.0             | 0.64                   | 63.6                 | -12                    | 1.8377             | 63.0                 |
| 5/19/93 | 2        | 98.7                       | 0.112              | 0.1             | 0.51                   | 72.8                 | 53                     | 3.7446             | 72.8                 |
| 5/19/93 | 4        | 12.2                       | 0.088              | 0.2             | 0.55                   | 73.1                 | -22                    | 3.1007             | 72.8                 |
| 6/21/93 | 1        | 82.0                       | *.091              | 0.6             | 0.50                   | 77.8                 | 46                     | 2.8169             | 77.7                 |
| 6/21/93 | 3        | 83.2                       | *.104              | 1.5             | 0.42                   | 78.2                 | 58                     | 4.1026             | 78.1                 |
| 6/21/93 | 5        | 44.5                       | *.072              | 1.7             | 0.50                   | 78.6                 | 28                     | 2.6095             | 78.5                 |
| 7/19/93 | 2        | 121.2                      | 0.189              | 0.1             | 0.43                   | 78.3                 | 49                     | 3.0254             | 78.3                 |
| 7/19/93 | 4        | 44.5                       | 0.098              | 0.0             | 0.44                   | 78.6                 | 51                     | 2.7540             | 78.3                 |
| 8/11/93 | 1        | 76.2                       | 0.173              | 0.1             | 0.57                   | 74.8                 | 15                     | 2.1947             | 75.0                 |
| 8/11/93 | 3        | 70.0                       | 0.095              | 0.0             | 0.41                   | 74.8                 | 14                     | 3.2121             | 74.6                 |
| 8/11/93 | 5        | 26.0                       | 0.074              | 0.2             | 0.50                   | 74.8                 | -20                    | 2.5848             | 74.2                 |

\* MEASUREMENT OMITTED

Table B-25 IA2854.8-3

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/13/93 | 1        | 454.7                      | 0.121              | 0.0             | 0.51                   | 59.8                 | 14                     | 1.3610             | 60.0                 |
| 1/13/93 | 3        | 62.0                       | 0.138              | 0.0             | 0.45                   | 59.6                 | 15                     | 1.6644             | 59.8                 |
| 1/13/93 | 5        | 23.2                       | 0.118              | 0.0             | 0.52                   | 59.4                 | -22                    | 1.5333             | 59.6                 |
| 2/12/93 | 2        | 100.2                      | 0.144              | -0.1            | 0.53                   | 58.4                 | -39                    | 2.5744             | 58.2                 |
| 2/12/93 | 4        | 81.5                       | *.102              | 0.7             | 0.47                   | 58.4                 | -57                    | 2.1504             | 58.4                 |
| 3/8/93  | 1        | 18.2                       | *.629              | -3.3            | 0.59                   | 60.8                 | 3                      | 1.5137             | 60.5                 |
| 3/8/93  | 3        | 52.2                       | *.755              | -1.0            | 0.52                   | 60.9                 | 33                     | 1.7366             | 60.7                 |
| 3/8/93  | 5        | -5.5                       | 0.059              | 0.0             | 0.63                   | 61.0                 | -3                     | 1.2227             | 60.9                 |
| 4/22/93 | 2        | 79.7                       | 0.141              | 0.3             | 0.65                   | 62.0                 | 27                     | 2.1854             | 62.4                 |
| 4/22/93 | 4        | 77.0                       | 0.176              | 0.1             | 0.52                   | 62.1                 | 34                     | 2.4176             | 62.2                 |
| 5/19/93 | 2        | 47.0                       | 0.130              | 0.1             | 0.45                   | 71.3                 | -16                    | 3.2503             | 71.4                 |
| 5/19/93 | 4        | 53.5                       | 0.153              | -0.2            | 0.39                   | 71.4                 | 9                      | 3.1182             | 71.5                 |
| 6/21/93 | 1        | 33.2                       | 0.081              | 0.2             | 0.50                   | 76.4                 | 6                      | 2.4929             | 76.4                 |
| 6/21/93 | 3        | 77.5                       | *.093              | 0.8             | 0.39                   | 76.4                 | 19                     | 2.8840             | 76.4                 |
| 6/21/93 | 5        | 24.5                       | *.062              | 2.1             | 0.43                   | 76.4                 | -3                     | 2.9449             | 76.4                 |
| 7/19/93 | 2        | 67.5                       | 0.178              | 0.1             | 0.37                   | 77.7                 | 49                     | 3.0254             | 77.6                 |
| 7/19/93 | 4        | 68.5                       | 0.117              | -0.1            | 0.32                   | 77.8                 | 51                     | 2.7540             | 77.7                 |
| 8/11/93 | 1        | 18.5                       | 0.076              | -0.1            | 0.41                   | 73.9                 | -40                    | 2.6828             | 73.5                 |
| 8/11/93 | 3        | 50.2                       | 0.095              | 0.0             | 0.35                   | 73.7                 | 0                      | 3.5478             | 73.5                 |
| 8/11/93 | 5        | -6.7                       | 0.067              | -0.1            | 0.45                   | 73.5                 | -59                    | 2.3598             | 73.5                 |

\*MEASUREMENT OMITTED

Table B-26 OA2854.8-1

| DATE    | POSITION | GEOCISA                    |  |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu\text{A}/\text{sqcm}$ ) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 3/10/93 | 1        | 169.2                      | 0.260                                  | -0.1            | 1.28                   | 44.8                 | 131                    | 1.5364             | 46.5                 |
| 3/10/93 | 3        | 140.2                      | 0.215                                  | -0.1            | 1.22                   | 44.4                 | 85                     | 1.3012             | 46.4                 |
| 3/10/93 | 5        | 99.7                       | 0.239                                  | 0.0             | 1.19                   | 44.0                 | 59                     | 1.5529             | 46.3                 |
| 4/3/93  | 2        | 224.5                      | 0.161                                  | 0.0             | 1.63                   | 57.0                 | 119                    | 1.2785             | 49.8                 |
| 4/3/93  | 4        | 201.2                      | 0.180                                  | 0.0             | 1.51                   | 57.0                 | 90                     | 1.4384             | 49.4                 |
| 5/14/93 | 1        | 174.5                      | *.077                                  | 1.4             | 0.69                   | 56.2                 | 153                    | 3.2235             | 77.1                 |
| 5/14/93 | 3        | 130.0                      | *.082                                  | 3.8             | 0.70                   | 58.8                 | 91                     | 3.8261             | 75.9                 |
| 5/14/93 | 5        | 103.7                      | *.112                                  | 2.6             | 0.69                   | 61.3                 | 70                     | 4.2037             | 74.7                 |
| 6/9/93  | 2        | 228.5                      | 0.184                                  | -0.1            | 1.60                   | 70.7                 | 131                    | 4.1490             | 97.7                 |
| 6/9/93  | 4        | 242.7                      | 0.291                                  | 0.0             | 1.49                   | 71.0                 | 135                    | 4.3657             | 98.7                 |
| 7/21/93 | 1        | 260.0                      | 0.179                                  | 0.0             | 1.82                   | 68.1                 | 187                    | 2.6002             | 91.0                 |
| 7/21/93 | 3        | 237.2                      | 0.169                                  | 0.0             | 2.08                   | 68.7                 | 190                    | 2.5579             | 92.0                 |
| 7/21/93 | 5        | 170.7                      | 0.169                                  | 0.0             | 1.89                   | 69.3                 | 115                    | 2.6137             | 93.0                 |

\* MEASUREMENT OMITTED

Table B-27 OA2854.8-2

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      |                        | 3LP                |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 3/10/93 | 2        | 147.5                      | 0.142                    | 0.0             | 1.49                   | 44.0                 | 99                     | 1.3445             | 46.2                 |
| 3/10/93 | 4        | 128.7                      | 0.156                    | 0.0             | 1.52                   | 43.8                 | 67                     | 1.3259             | 46.0                 |
| 4/3/93  | 1        | 260.2                      | 0.192                    | 0.0             | 1.63                   | 57.9                 | 24                     | 0.2951             | 50.0                 |
| 4/3/93  | 3        | 265.7                      | 0.229                    | -0.1            | 1.44                   | 57.7                 | 150                    | 1.3662             | 50.2                 |
| 4/3/93  | 5        | 239.2                      | 0.149                    | 0.0             | 1.56                   | 58.5                 | 113                    | 1.2062             | 50.4                 |
| 5/14/93 | 2        | 149.7                      | 0.247                    | 0.0             | 0.70                   | 58.7                 | 109                    | 3.6620             | 75.4                 |
| 5/14/93 | 4        | 182.0                      | *.073                    | 4.3             | 0.71                   | 59.3                 | 135                    | 3.4835             | 75.2                 |
| 6/9/93  | 1        | 243.2                      | 0.149                    | 0.2             | 1.38                   | 71.6                 | 150                    | 3.7425             | 97.5                 |
| 6/9/93  | 3        | 260.7                      | 0.300                    | 0.0             | 1.22                   | 72.0                 | 136                    | 3.9076             | 98.5                 |
| 6/9/93  | 5        | 233.0                      | 0.212                    | -0.1            | 1.34                   | 72.4                 | 126                    | 3.7466             | 99.5                 |
| 8/19/93 | 2        | 142.5                      | *.162                    | 7.3             | N/A                    | 93.0                 | 59                     | 2.8551             | 80.1                 |
| 8/19/93 | 4        | 149.0                      | *.22                     | 11.0            | 0.59                   | 92.1                 | 85                     | 2.9098             | 80.1                 |

\* MEASUREMENT OMITTED



Table B-28 OA2854.8-3

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 3/10/93 | 1        | 133.7                      | 0.084              | -0.1            | 1.66                   | 43.8                 | 77                     | 1.1918             | 45.6                 |
| 3/10/93 | 3        | 141.5                      | 0.088              | 0.2             | 1.60                   | 43.8                 | 80                     | 1.1577             | 45.6                 |
| 3/10/93 | 5        | 127.7                      | 0.112              | 0.0             | 1.69                   | 43.8                 | 64                     | 1.3930             | 45.6                 |
| 4/4/93  | 2        | 127.7                      | 0.098              | -0.1            | 0.83                   | 45.5                 | 90                     | 0.8389             | 43.3                 |
| 4/4/93  | 4        | 143.5                      | *.0142             | -0.7            | 0.84                   | 46.2                 | 82                     | 0.9091             | 42.5                 |
| 5/14/93 | 1        | 182.5                      | *.112              | 6.5             | 0.75                   | 58.2                 | 137                    | 3.3504             | 76.2                 |
| 5/14/93 | 3        | 164.7                      | *.08               | 3.5             | 0.71                   | 59.0                 | 119                    | 3.3205             | 76.0                 |
| 5/14/93 | 5        | 188.7                      | *.062              | 4.6             | 0.88                   | 59.8                 | 77                     | 3.2245             | 75.8                 |
| 6/9/93  | 2        | 168.0                      | 0.240              | -0.1            | 1.35                   | 74.0                 | 83                     | 3.9922             | 100.8                |
| 6/9/93  | 4        | 257.7                      | 0.272              | 0.1             | 1.26                   | 73.7                 | 161                    | 4.5989             | 100.7                |
| 7/21/93 | 2        | 214.5                      | 0.152              | 0.0             | 1.92                   | 71.4                 | 148                    | 2.0080             | 92.9                 |
| 7/21/93 | 4        | 223.0                      | 0.192              | 0.0             | 1.61                   | 72.4                 | 153                    | 2.5063             | 94.7                 |

\* MEASUREMENT OMITTED

Table B-29 IA2859.6-1

| DATE    | POSITION | GEOCISA                 |                 |              |                     |                   | 3LP                 |                 |                   |
|---------|----------|-------------------------|-----------------|--------------|---------------------|-------------------|---------------------|-----------------|-------------------|
|         |          | POTENTIAL Ag/AgCl (-mV) | icorr (uA/sqcm) | BALANCE (mV) | OHMIC RES. (K-Ohms) | TEMP. (degrees F) | POTENTIAL CSE (-mV) | icorr (mA/sqft) | TEMP. (degrees F) |
| 1/13/93 | 1        | 300.7                   | 0.228           | 0.00         | 0.45                | 62.4              | 243                 | 5.1210          | 62.5              |
| 1/13/93 | 3        | 336.5                   | 0.287           | 0.30         | 0.43                | 62.0              | 269                 | 7.0279          | 62.0              |
| 1/13/93 | 5        | 309.2                   | 0.315           | -0.10        | 0.41                | 61.6              | 240                 | 5.9682          | 61.5              |
| 2/12/93 | 1        | 288.5                   | 0.363           | -0.40        | 0.49                | 61.7              | 111                 | 5.2015          | 60.8              |
| 2/12/93 | 3        | 338.7                   | 0.238           | 0.00         | 0.47                | 61.7              | 154                 | 7.0516          | 60.4              |
| 2/12/93 | 5        | 295.5                   | 0.236           | 0.00         | 0.50                | 61.7              | 121                 | 4.8951          | 60.0              |
| 3/8/93  | 2        | 298.0                   | 0.294           | 0.00         | 0.45                | 63.8              | 278                 | 4.3451          | 63.8              |
| 3/8/93  | 4        | 250.5                   | 0.362           | 0.00         | 0.45                | 63.5              | 230                 | 5.0601          | 63.1              |
| 4/22/93 | 1        | 308.7                   | 0.299           | 0.00         | 0.54                | 63.9              | 232                 | 3.5753          | 64.1              |
| 4/22/93 | 3        | 283.2                   | 0.291           | 0.00         | 0.54                | 63.9              | 235                 | 4.7650          | 63.7              |
| 4/22/93 | 5        | 235.2                   | 0.306           | 0.00         | 0.56                | 63.9              | 195                 | 3.7693          | 63.3              |
| 5/19/93 | 1        | 302.7                   | 0.201           | 0.10         | 0.53                | 72.6              | 235                 | 7.0062          | 72.8              |
| 5/19/93 | 3        | 283.5                   | 0.231           | -0.10        | 0.46                | 73.0              | 219                 | 8.1185          | 72.8              |
| 5/19/93 | 5        | 216.5                   | 0.245           | -0.20        | 0.45                | 73.4              | 155                 | 6.4500          | 72.8              |
| 6/21/93 | 2        | 287.7                   | *.269           | 6.10         | 0.42                | 78.5              | 251                 | 6.9721          | 78.5              |
| 6/21/93 | 4        | 336.2                   | *.353           | 3.60         | 0.37                | 78.2              | 292                 | 10.4453         | 78.4              |
| 7/19/93 | 1        | 329.5                   | 0.597           | -0.30        | 0.68                | 79.3              | 303                 | 6.2695          | 80.4              |
| 7/19/93 | 3        | 325.0                   | 0.342           | 0.00         | 0.69                | 79.3              | 292                 | 7.1548          | 79.8              |
| 7/19/93 | 5        | 324.2                   | 0.436           | 0.00         | 0.39                | 79.3              | 301                 | 5.9578          | 79.2              |
| 8/11/93 | 2        | 314.5                   | *.33            | 0.50         | 0.38                | 75.2              | 224                 | 6.1281          | 76.0              |
| 8/11/93 | 4        | 300.0                   | 0.331           | -0.10        | 0.37                | 74.7              | 210                 | 8.1082          | 74.7              |

\* MEASUREMENT OMITTED

Table B-30 IA2859.6-2

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 1/13/93 | 1        | 313.5                      | 0.314                    | -0.1            | 0.48                   | 59.7                 | 237                    | 6.9123             | 59.9                 |
| 1/13/93 | 3        | 346.0                      | 0.314                    | 0.0             | 0.46                   | 60.3                 | 264                    | 7.3684             | 60.5                 |
| 1/13/93 | 5        | 274.5                      | 0.332                    | 0.0             | 0.49                   | 60.9                 | 203                    | 5.6720             | 61.1                 |
| 2/12/93 | 1        | 252.7                      | 0.298                    | -0.4            | 0.50                   | 59.3                 | 83                     | 6.5594             | 59.3                 |
| 2/12/93 | 3        | 337.2                      | 0.227                    | 0.0             | 0.47                   | 59.7                 | 176                    | 7.1455             | 59.7                 |
| 2/12/93 | 5        | 255.5                      | 0.234                    | 0.0             | 0.49                   | 60.1                 | 89                     | 5.9651             | 60.1                 |
| 3/8/93  | 2        | 295.7                      | 0.306                    | 0.0             | 0.44                   | 61.7                 | 277                    | 6.5460             | 61.7                 |
| 3/8/93  | 4        | 285.7                      | *.156                    | 1.6             | 0.43                   | 62.0                 | 261                    | 6.9649             | 62.0                 |
| 4/22/93 | 1        | 290.0                      | 0.352                    | -0.4            | 0.53                   | 63.9                 | 98                     | 0.4973             | 63.3                 |
| 4/22/93 | 3        | 355.2                      | 0.369                    | 0.0             | 0.51                   | 63.9                 | 118                    | 0.5644             | 63.1                 |
| 4/22/93 | 5        | 261.2                      | 0.281                    | 0.0             | 0.53                   | 63.9                 | 217                    | 4.7083             | 52.9                 |
| 5/19/93 | 1        | 255.2                      | 0.564                    | 0.0             | 0.45                   | 71.2                 | 198                    | 6.6781             | 71.3                 |
| 5/19/93 | 3        | 343.2                      | 2.591                    | 0.1             | 0.41                   | 71.3                 | 293                    | 12.3852            | 71.4                 |
| 5/19/93 | 5        | 240.2                      | 0.325                    | 0.0             | 0.43                   | 71.4                 | 276                    | 7.6408             | 71.5                 |
| 6/21/93 | 2        | 312.2                      | 0.280                    | 0.3             | 0.38                   | 76.2                 | 290                    | 9.6199             | 76.5                 |
| 6/21/93 | 4        | 319.7                      | 0.335                    | 0.2             | 0.39                   | 76.7                 | 299                    | 12.9682            | 76.6                 |
| 7/19/93 | 1        | 315.2                      | 0.334                    | 0.1             | 0.35                   | 77.9                 | 294                    | 6.7276             | 78.2                 |
| 7/19/93 | 3        | 349.2                      | 0.339                    | 0.1             | 0.32                   | 78.3                 | 333                    | 8.6179             | 78.4                 |
| 7/19/93 | 5        | 350.5                      | 0.343                    | 0.4             | 0.31                   | 78.7                 | 333                    | 5.0535             | 78.6                 |
| 8/11/93 | 2        | 324.7                      | 0.290                    | 0.1             | 0.35                   | 73.8                 | 243                    | 8.1082             | 74.0                 |
| 8/11/93 | 4        | 333.5                      | *3.062                   | -0.9            | 0.36                   | 74.8                 | 269                    | 10.2008            | 74.8                 |

\* MEASUREMENT OMITTED

Table B-31 OA2859.6-1

| DATE    | POSITION | GEOCISA                    |                    |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>(uA/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 3/10/93 | 2        | 369.0                      | 0.083              | 0.2             | 2.07                   | 43.8                 | 302                    | 1.0814             | 45.6                 |
| 3/10/93 | 4        | 325.7                      | 0.230              | 0.0             | 1.75                   | 45.6                 | 247                    | 2.1349             | 48.3                 |
| 4/4/93  | 1        | 354.0                      | 0.172              | 0.0             | 1.02                   | 48.0                 | 331                    | 0.9029             | 44.5                 |
| 4/4/93  | 3        | 351.7                      | *.135              | 1.1             | 1.07                   | 49.0                 | 296                    | 0.9668             | 43.9                 |
| 4/4/93  | 5        | 326.7                      | 0.463              | -0.1            | 1.06                   | 50.0                 | 282                    | 0.9256             | 43.3                 |
| 5/14/93 | 2        | 405.2                      | *.276              | 5.5             | 0.72                   | 62.6                 | 355                    | 6.8741             | 79.4                 |
| 5/14/93 | 4        | 354.2                      | *.46               | 3.8             | 0.74                   | 62.8                 | 310                    | 6.7513             | 81.8                 |
| 6/9/93  | 1        | 471.5                      | 0.295              | 0.0             | 1.27                   | 72.1                 | 380                    | 9.2990             | 103.1                |
| 6/9/93  | 3        | 464.7                      | 0.329              | 0.0             | 1.20                   | 74.3                 | 372                    | 11.9219            | 103.1                |
| 6/9/93  | 5        | 442.0                      | 0.348              | 0.1             | 1.21                   | 76.6                 | 354                    | 9.2484             | 103.1                |
| 7/21/93 | 1        | 512.5                      | 0.381              | 0.1             | 1.47                   | 72.2                 | 444                    | 4.4493             | 97.8                 |
| 7/21/93 | 3        | 522.0                      | 0.494              | -0.1            | 1.42                   | 72.6                 | 441                    | 6.0868             | 97.8                 |
| 7/21/93 | 5        | 458.7                      | 0.311              | 0.0             | 1.50                   | 73.0                 | 405                    | 4.7795             | 97.8                 |
| 8/19/93 | 2        | 408.5                      | *.818              | 7.0             | 0.51                   | 91.2                 | 340                    | 7.0423             | 80.8                 |
| 8/19/93 | 4        | 421.0                      | *.875              | 4.2             | 0.50                   | 91.2                 | 324                    | 7.1527             | 80.8                 |

\* MEASUREMENT OMITTED

Table B-32 OA2859.6-2

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      | 3LP                    |                    |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 3/10/93 | 1        | 320.5                      | 0.190                    | -0.1            | 1.80                   | 43.9                 | 246                    | 1.8955             | 45.5                 |
| 3/10/93 | 3        | 333.0                      | 0.142                    | 0.1             | 1.66                   | 45.3                 | 256                    | 1.8233             | 47.3                 |
| 3/10/93 | 5        | 336.0                      | 0.284                    | 0.0             | 1.33                   | 46.7                 | 270                    | 2.7127             | 49.1                 |
| 4/4/93  | 2        | 354.5                      | 0.184                    | 0.3             | 1.12                   | 49.0                 | 337                    | 1.2103             | 45.6                 |
| 4/4/93  | 4        | 325.2                      | 0.114                    | 0.0             | 1.15                   | 49.6                 | 320                    | 0.9699             | 45.0                 |
| 5/14/93 | 1        | 354.5                      | N/A                      | N/A             | N/A                    | 64.7                 | 298                    | 7.4468             | 81.5                 |
| 5/14/93 | 3        | 368.2                      | *.349                    | 3.6             | 0.78                   | 65.9                 | 296                    | 6.5831             | 81.5                 |
| 5/14/93 | 5        | 387.0                      | *.481                    | 3.2             | 0.59                   | 67.2                 | 332                    | 9.0885             | 81.5                 |
| 6/9/93  | 2        | 447.0                      | 0.309                    | 0.1             | 1.24                   | 75.3                 | 365                    | 10.2782            | 103.0                |
| 6/9/93  | 4        | 470.5                      | 0.429                    | 0.3             | 1.04                   | 74.9                 | 363                    | 9.3722             | 103.7                |
| 7/21/93 | 2        | 500.2                      | 0.567                    | 0.0             | 1.24                   | 73.2                 | 408                    | 5.5628             | 97.2                 |
| 7/21/93 | 4        | 501.2                      | 0.615                    | -0.2            | 1.23                   | 73.0                 | 438                    | 5.6566             | 97.7                 |
| 8/19/93 | 1        | 363.7                      | *.949                    | 7.6             | 0.46                   | 92.7                 | 291                    | 6.8617             | 83.7                 |
| 8/19/93 | 3        | 384.7                      | *.48                     | 12.1            | 0.51                   | 93.1                 | 311                    | 5.9393             | 82.9                 |
| 8/19/93 | 5        | 405.7                      | *.703                    | 11.8            | 0.40                   | 93.5                 | 352                    | 7.4210             | 82.1                 |

\* MEASUREMENT OMITTED

Table B-33 OA2859.6-3

| DATE    | POSITION | GEOCISA                    |                          |                 |                        |                      |                        | 3LP                |                      |
|---------|----------|----------------------------|--------------------------|-----------------|------------------------|----------------------|------------------------|--------------------|----------------------|
|         |          | POTENTIAL<br>Ag/AgCl (-mV) | icorr<br>( $\mu$ A/sqcm) | BALANCE<br>(mV) | OHMIC RES.<br>(K-Ohms) | TEMP.<br>(degrees F) | POTENTIAL<br>CSE (-mV) | icorr<br>(mA/sqft) | TEMP.<br>(degrees F) |
| 3/10/93 | 2        | 378.7                      | 0.202                    | 0.0             | 1.98                   | 44.6                 | 293                    | 1.6520             | 46.5                 |
| 3/10/93 | 4        | 367.0                      | 0.212                    | 0.0             | 1.81                   | 44.7                 | 282                    | 1.6334             | 45.4                 |
| 4/4/93  | 1        | 353.2                      | *.101                    | 1.7             | 1.15                   | 48.7                 | 324                    | 1.4673             | 44.4                 |
| 4/4/93  | 3        | 331.2                      | *.140                    | 2.5             | 1.21                   | 50.3                 | 298                    | 1.2372             | 45.2                 |
| 4/4/93  | 5        | 375.7                      | *.180                    | 5.8             | 1.15                   | 52.0                 | 331                    | 1.5612             | 46.0                 |
| 5/14/93 | 2        | 378.0                      | 0.313                    | -0.3            | 0.84                   | 66.6                 | 313                    | 7.0268             | 78.3                 |
| 5/14/93 | 4        | 402.5                      | *.422                    | 1.5             | 0.79                   | 68.6                 | 322                    | 5.9094             | 79.7                 |
| 6/9/93  | 1        | 467.0                      | 0.354                    | 0.0             | 1.22                   | 73.8                 | 389                    | 11.2140            | 99.7                 |
| 6/9/93  | 3        | 420.7                      | 0.529                    | 0.0             | 1.04                   | 76.2                 | 330                    | 10.2070            | 102.1                |
| 6/9/93  | 5        | 492.2                      | 0.588                    | 0.0             | 0.91                   | 78.7                 | 406                    | 12.5296            | 104.3                |
| 7/21/93 | 1        | 507.5                      | 0.308                    | 0.0             | 1.19                   | 70.8                 | 445                    | 5.6019             | 99.7                 |
| 7/21/93 | 3        | 445.0                      | 0.271                    | 0.1             | 1.35                   | 74.0                 | 381                    | 4.9487             | 99.3                 |
| 7/21/93 | 5        | 555.5                      | 0.568                    | -0.1            | 1.09                   | 77.2                 | 475                    | 6.5274             | 98.8                 |
| 8/19/93 | 2        | 393.2                      | *.645                    | -3.6            | 0.54                   | 93.6                 | 328                    | 7.3271             | 80.0                 |
| 8/19/93 | 4        | 421.7                      | *.312                    | 7.0             | 0.56                   | 95.6                 | 349                    | 6.7255             | 82.7                 |

\* MEASUREMENT OMITTED

## Vita

Charles D. Newhouse was born in Salem, Missouri on December 29, 1969. He grew up in Gloucester, Virginia where he graduated from Gloucester High School in 1988. He then attended Virginia Polytechnic Institute and State University in the fall of 1988 and graduated with a Bachelor of Science in Civil Engineering in May, 1992.

Mr. Newhouse worked as a research assistant in the Transportation/ Materials Division during the final summer of his undergraduate studies at Virginia Tech. He then entered the Materials Division at Virginia Tech, pursuing a Masters of Science in Civil Engineering. This degree is expected in December, 1993.

A handwritten signature in cursive script, reading "Charles D. Newhouse", is centered on the page. The signature is written in black ink and is underlined.

Charles D. Newhouse