



Corrosion Assessment of Reinforced Concrete Structures Using NDE Techniques

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Jorge Costa, P.E.

Outline

- Corrosion of Steel in Concrete
- Initiation and Propagation
- Testing and Assessment
- Analysis and Diagnostics
- Conclusions
- Questions

Corrosion of Steel in Concrete



Nature of Corrosion

Man Made Metals and Nature



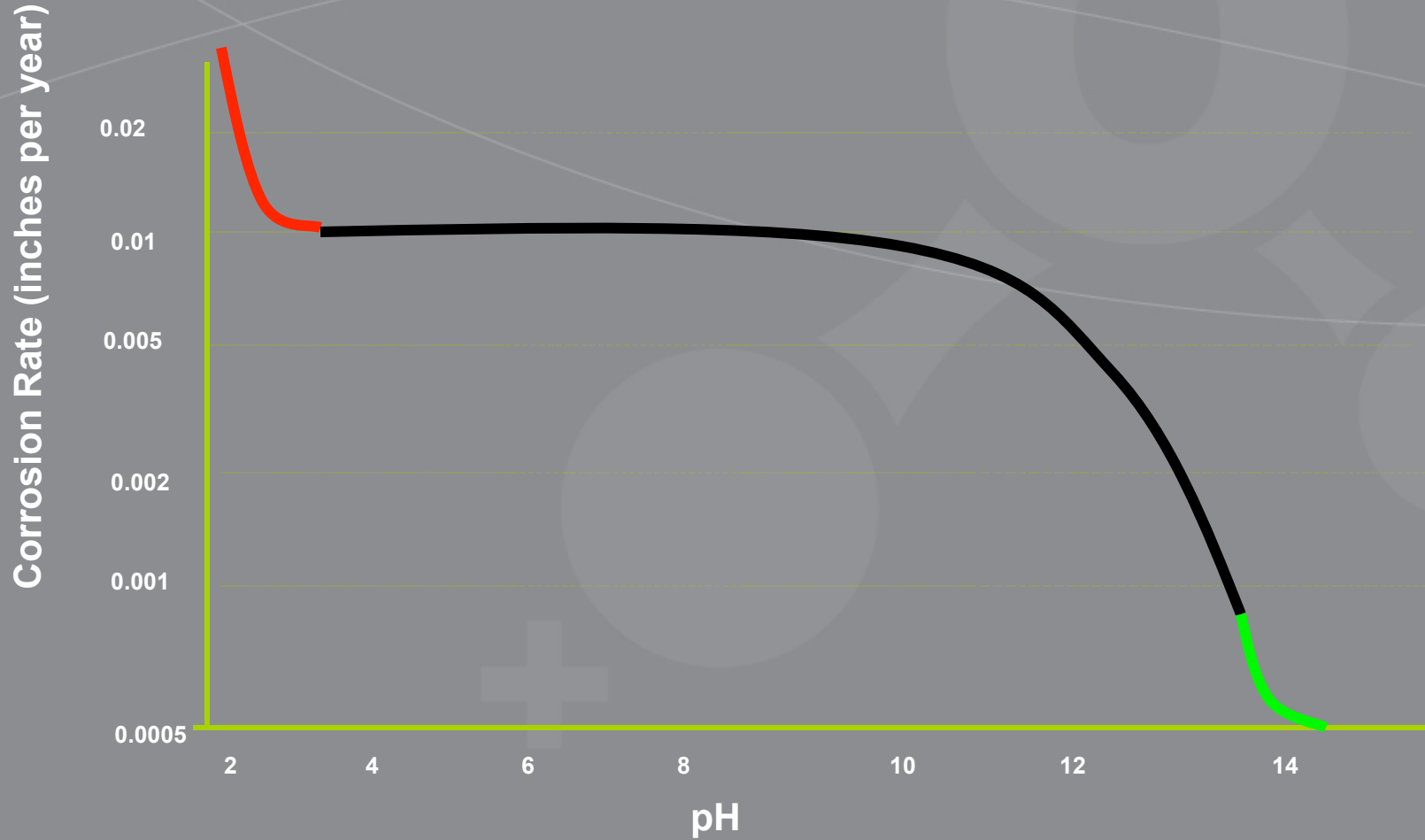
Corrosion Cell

- Anode
- Cathode
- Electrical path between anode and cathode
- Electrolyte (Ionic Path)

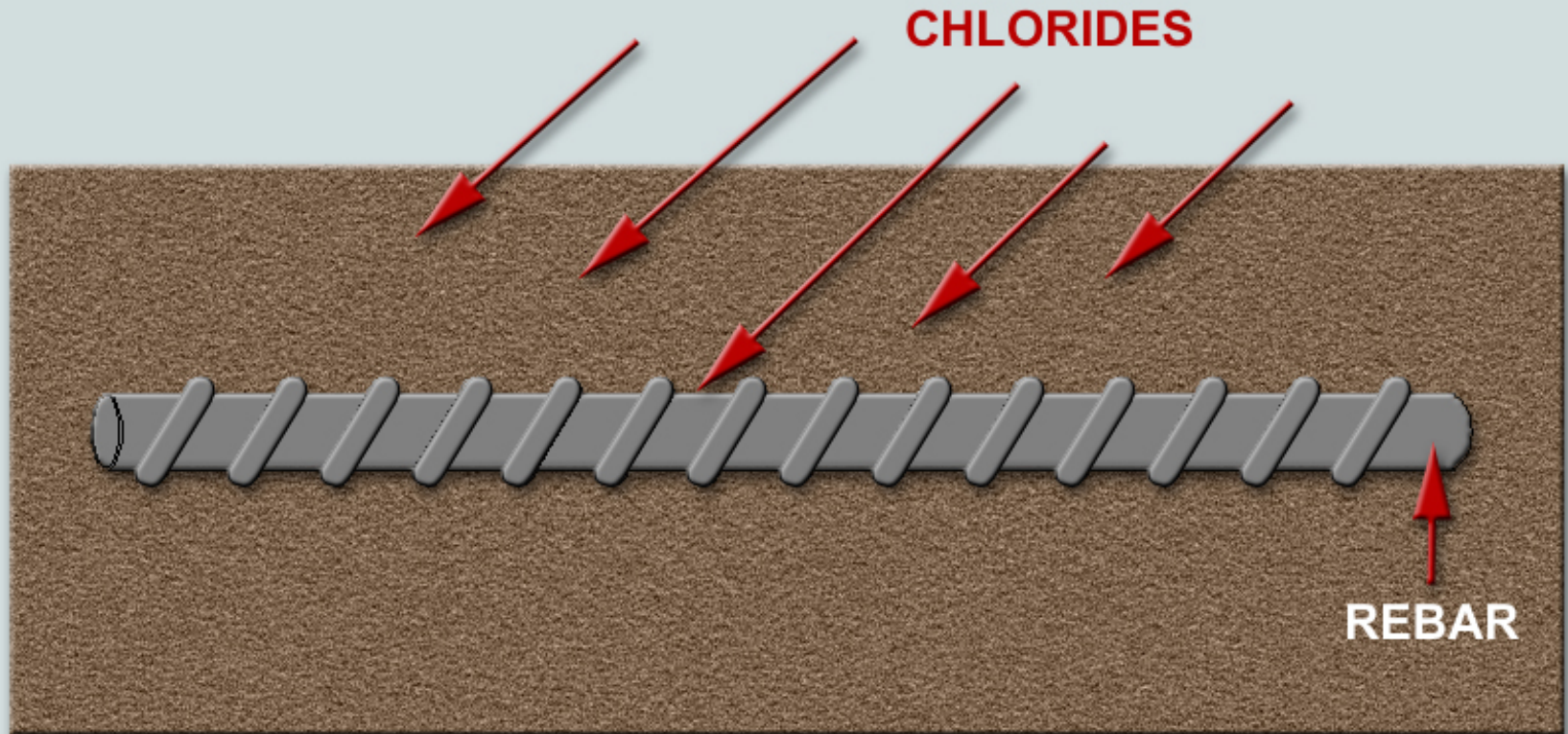
Concrete and Mortar as Corrosion Environments

- High Resistivity
- Low Porosity
- High Alkalinity (high pH)

Corrosion in Concrete

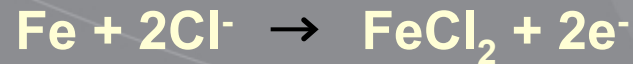


Corrosion of Steel in Concrete

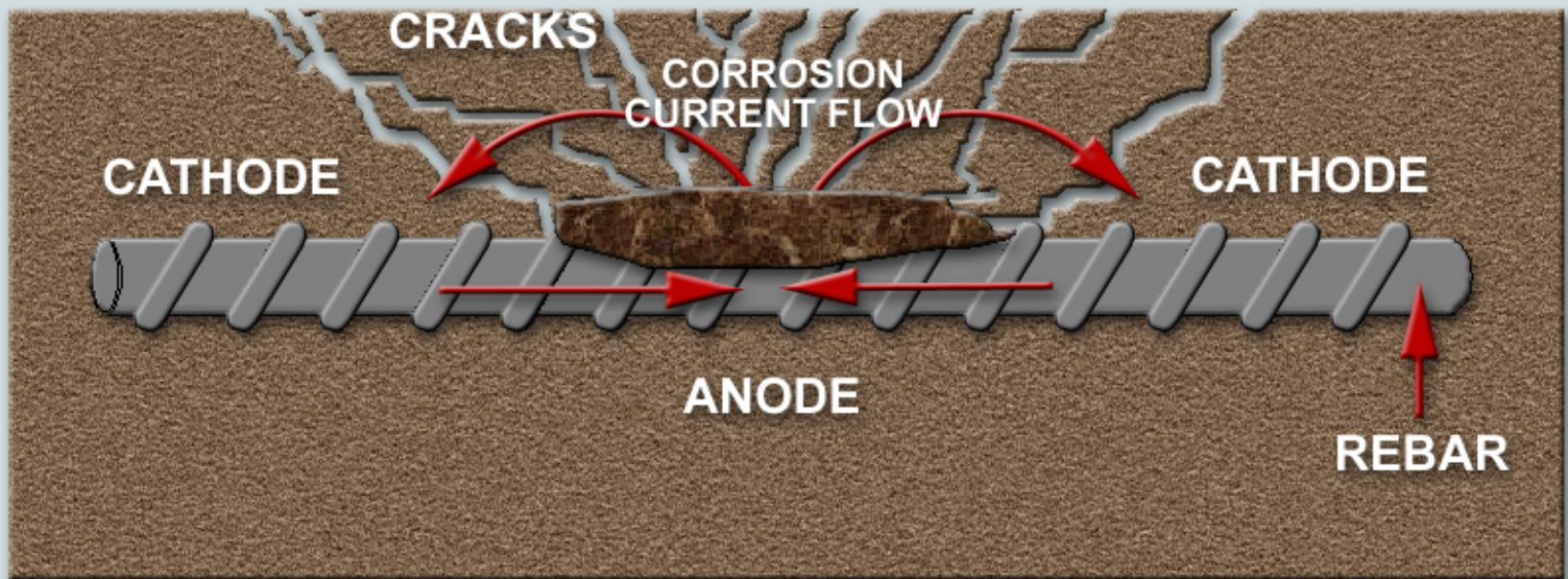


Corrosion of Steel in Concrete

Reactions



Corrosion of Steel in Concrete



REBAR CORROSION



REBAR CORROSION

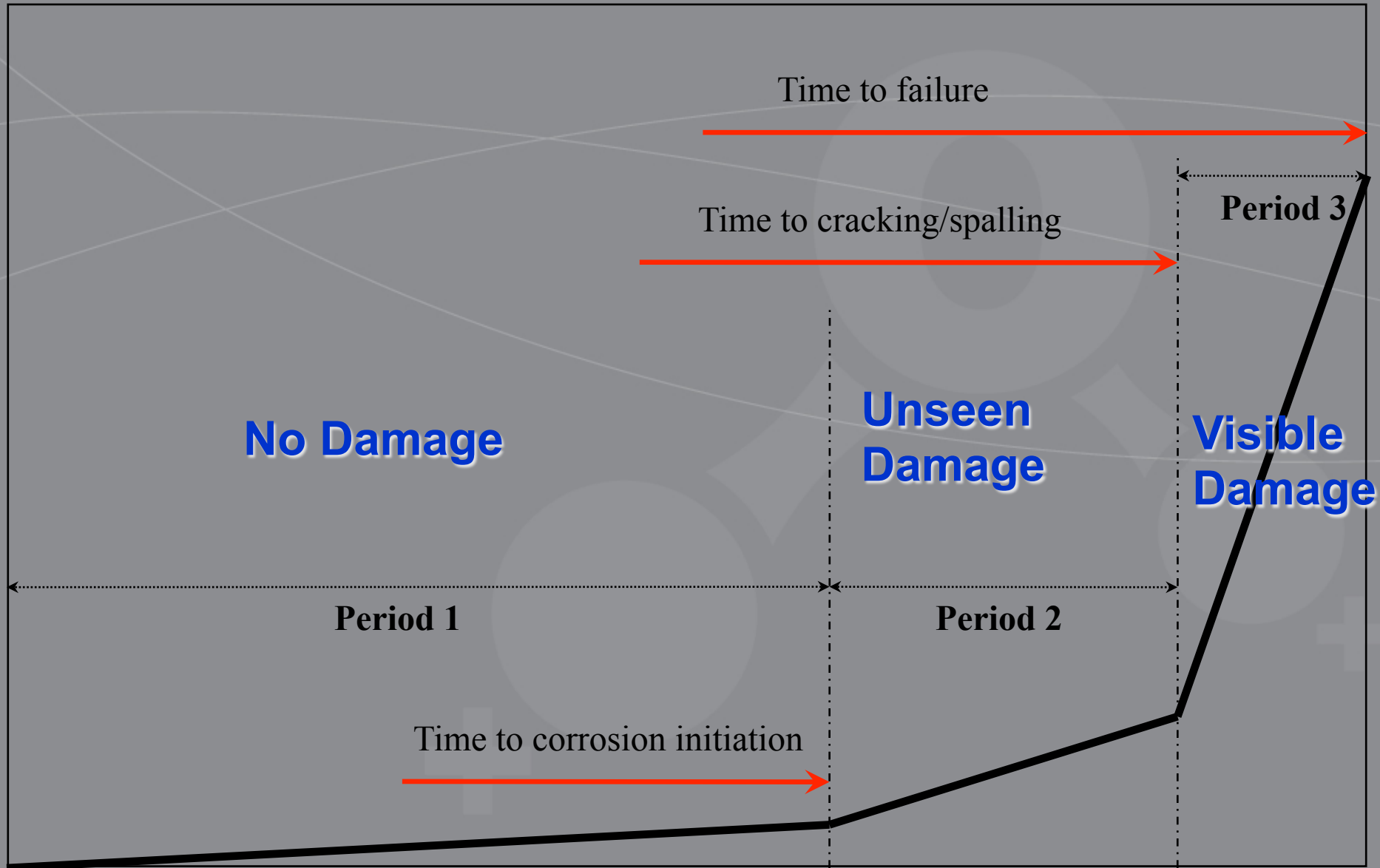


REBAR CORROSION





Corrosion of Steel in Concrete



NDE Techniques

- Testing during period 2
- Pre-requisite: Electrical continuity
 - Necessary to perform potential mapping
 - Measures extent of electrical contact between bars
 - Need to know to understand potential and corrosion data
- Resistivity
- Electrochemical Potential Measurements
- Corrosion Rate Measurements

Verifying Steel Continuity



NDE Techniques

- Resistivity tests
 - Four pin method
 - Resistance of concrete influenced by
 - Moisture
 - Salts
 - Temperature
 - Indirect measurement of corrosion
 - Measurement affected by steel reinforcement

Resistivity Probe

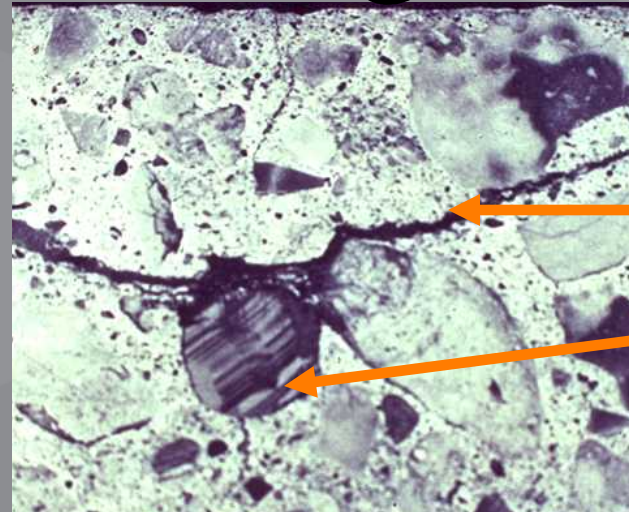
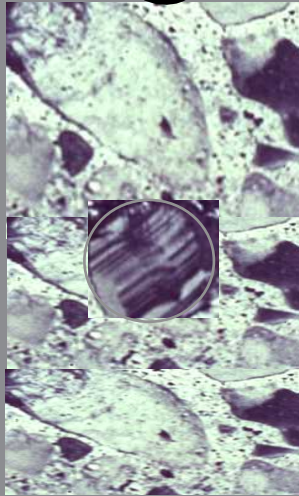
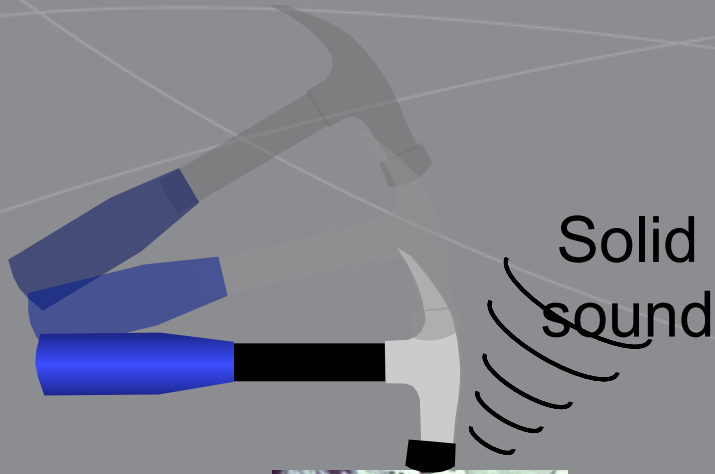


NDE Techniques

- Acoustic response
 - Chain Dragging
 - Hammer Test
 - Solid sound indication of good concrete
 - Hollow sound indication of damaged concrete
 - Not a measure of corrosion



Acoustic Emission



Delam
Corroding
Rebar

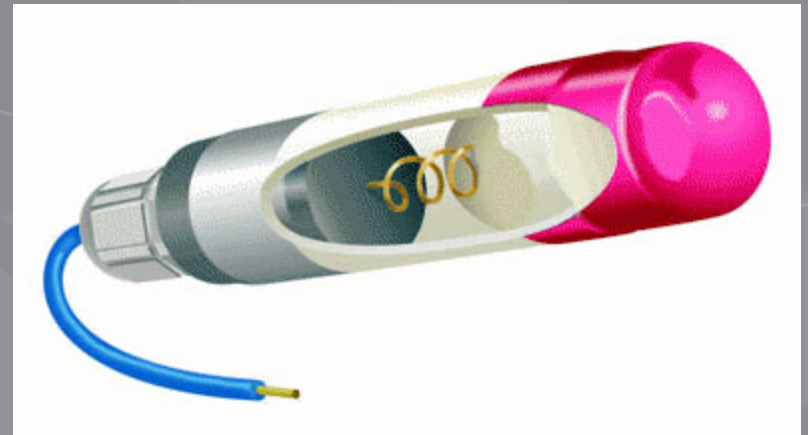
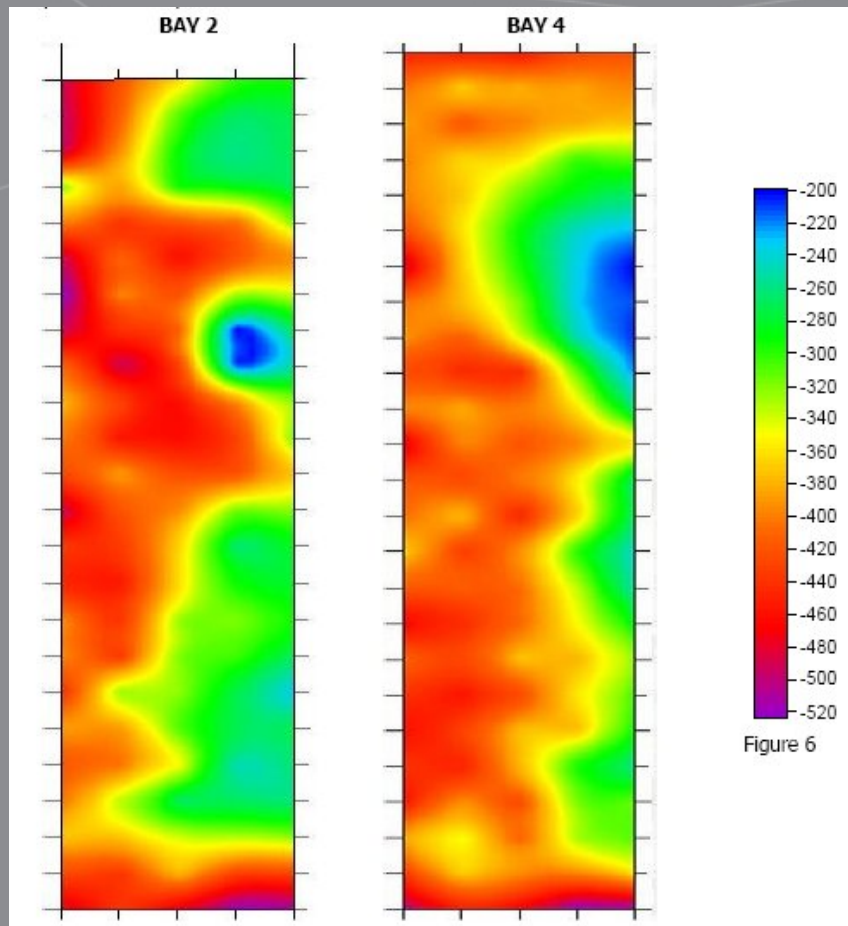
NDE Techniques

- Potential Measurements
 - Portable reference cell
 - High Input Impedance Voltmeter
 - Connection to the steel reinforcing
 - Follow ASTM C-876-09 Standard
 - Potential is > -0.2 V 90% probability there is no corrosion
 - Potential is between -0.2 and -0.35 V uncertain
 - Potential is < -0.35 V 90% probability there is corrosion
 - Potential measurements affected by:
 - Electrical continuity
 - Oxygen availability
 - Temperature

Potential Mapping



Potential Mapping

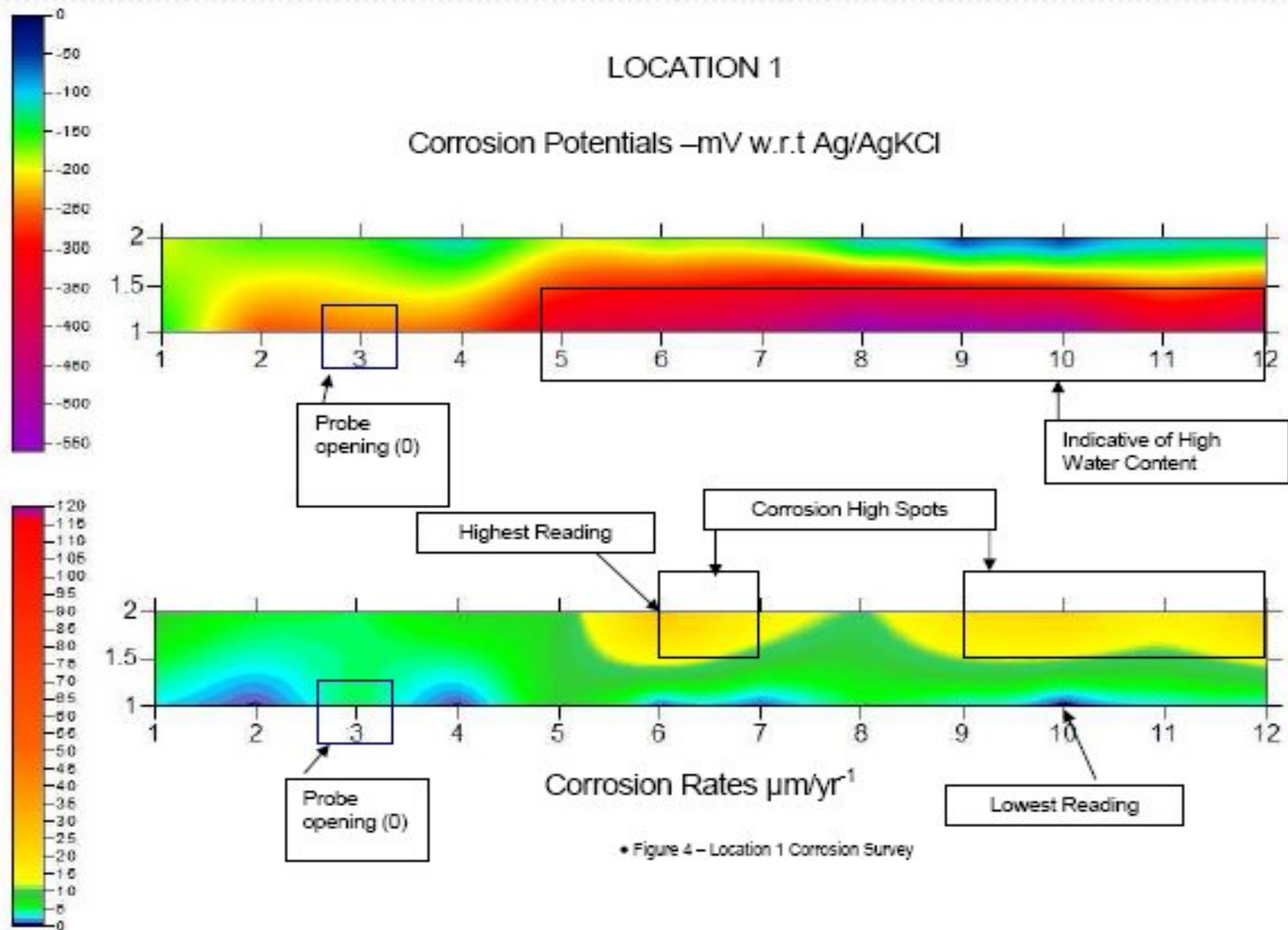


Corrosion Rate Measurements

- Linear Polarization Resistance (LPR)
 - Small voltage applied between probe and steel
 - Current flow is measured, resistance is calculated
 - Corrosion rate is inversely proportional to polarization resistance
 - Instruments present data in terms of corrosion rate
 - Readings can vary with temperature and humidity
 - Look at trends over time

LPR Probes





Analytical Laboratory Testing

Chloride Ion (Cl^-) Content
Carbonation

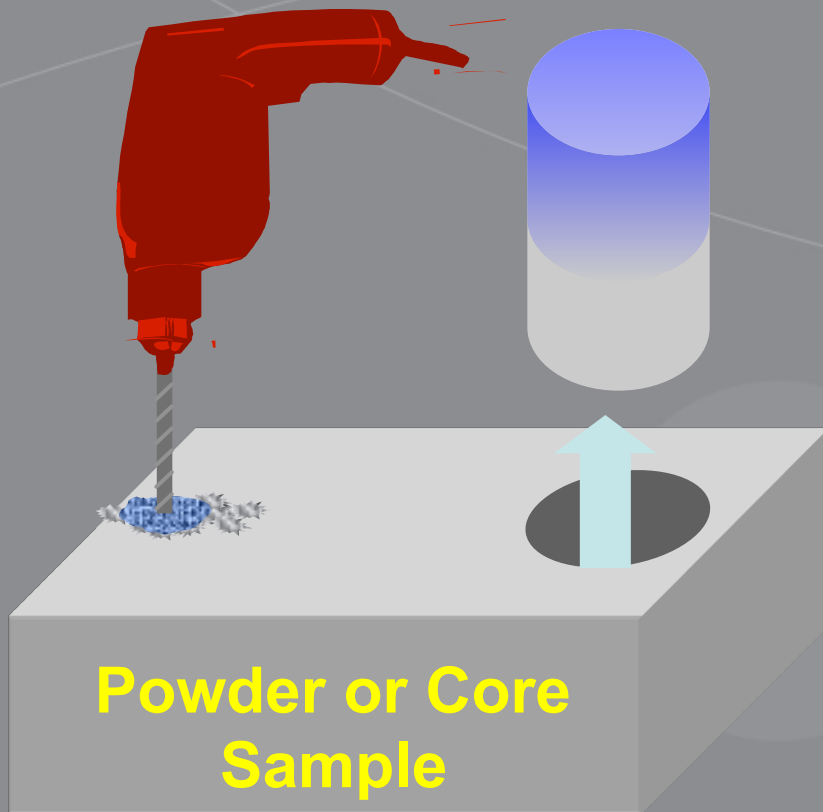
Concrete Core Extraction

Wet Diamond Core Extraction Techniques

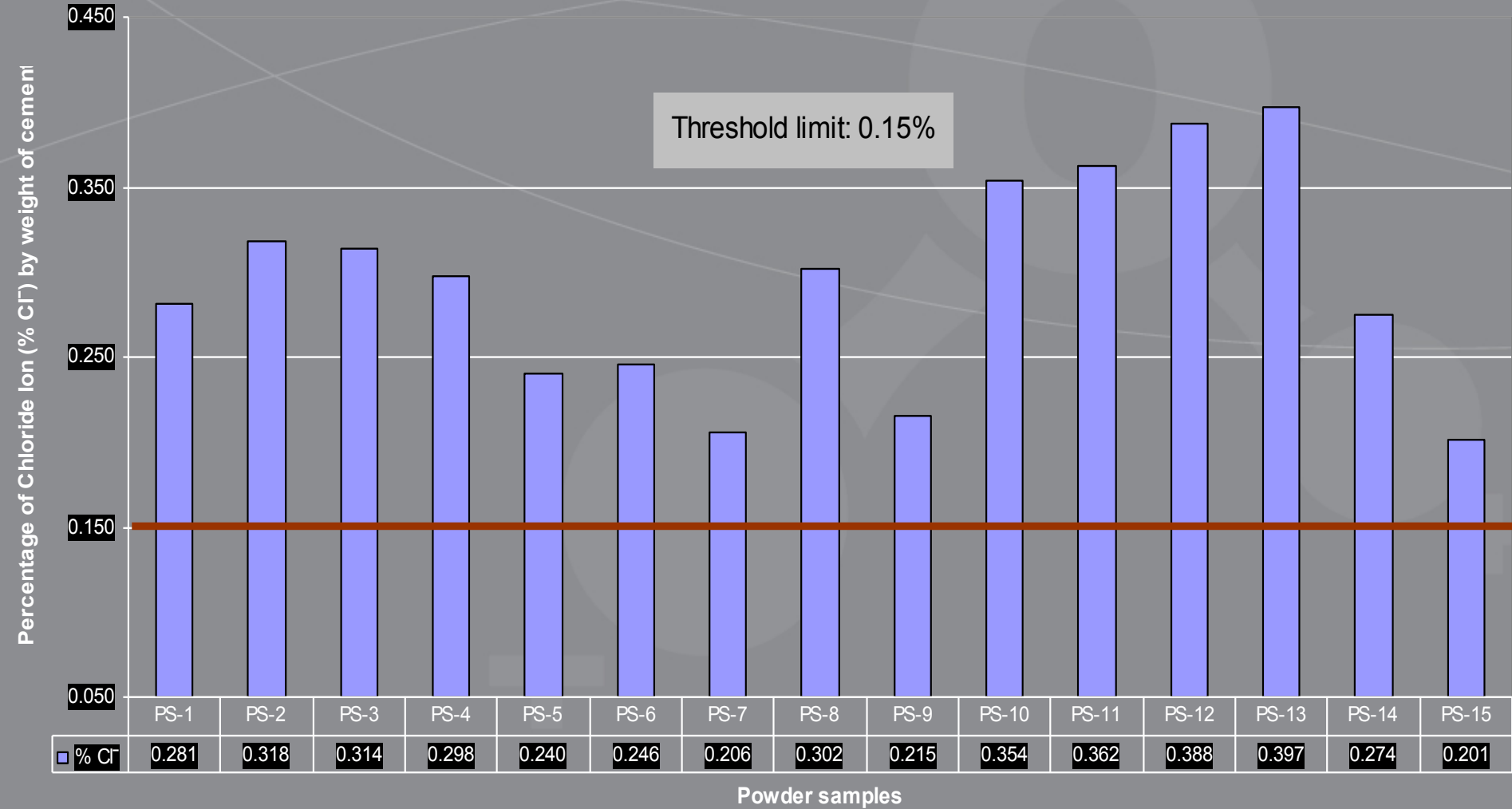
Core Length and Diameter According to ACI Guidelines



Measuring Chlorides – Depth and %



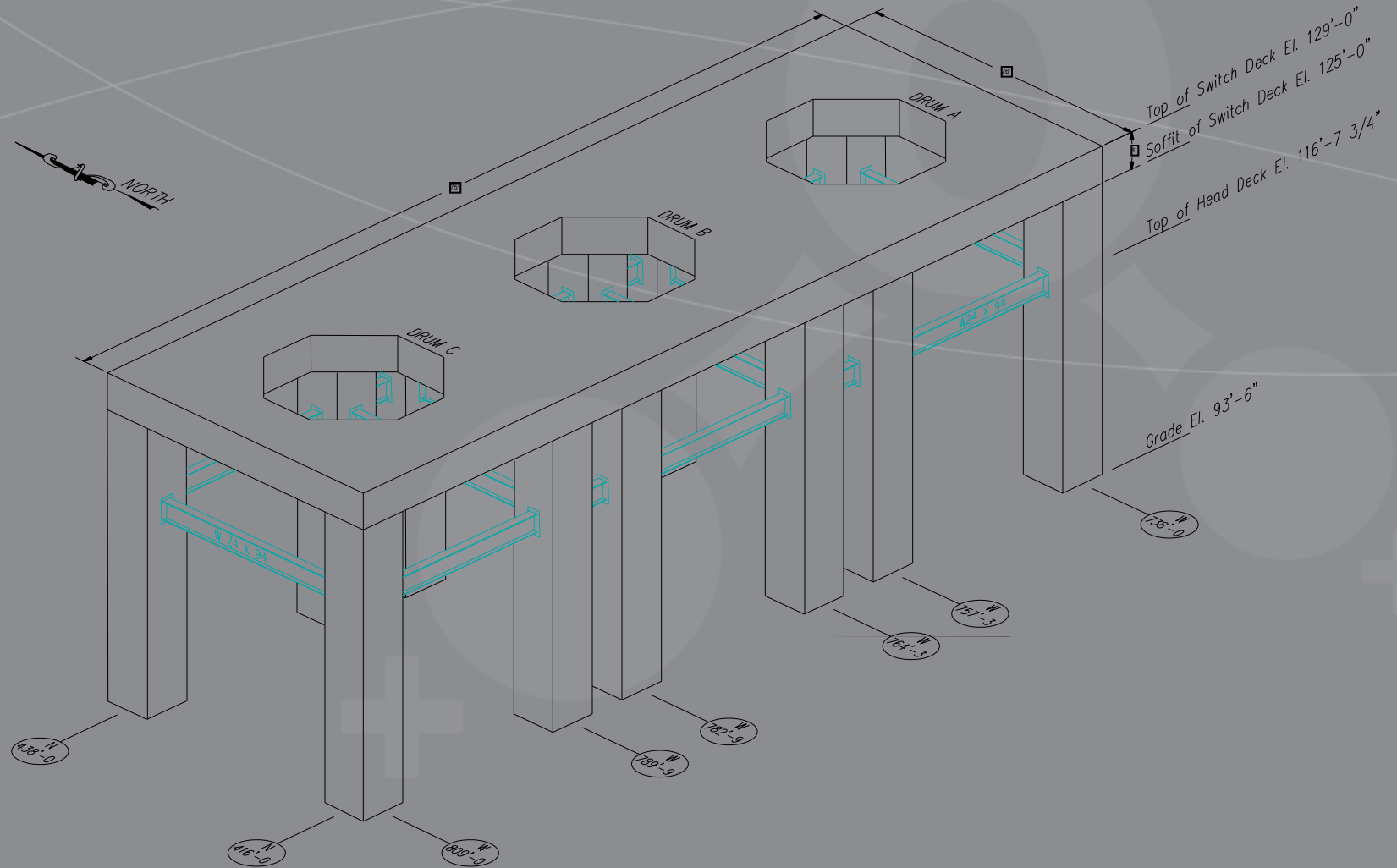
Water Soluble Chloride Content



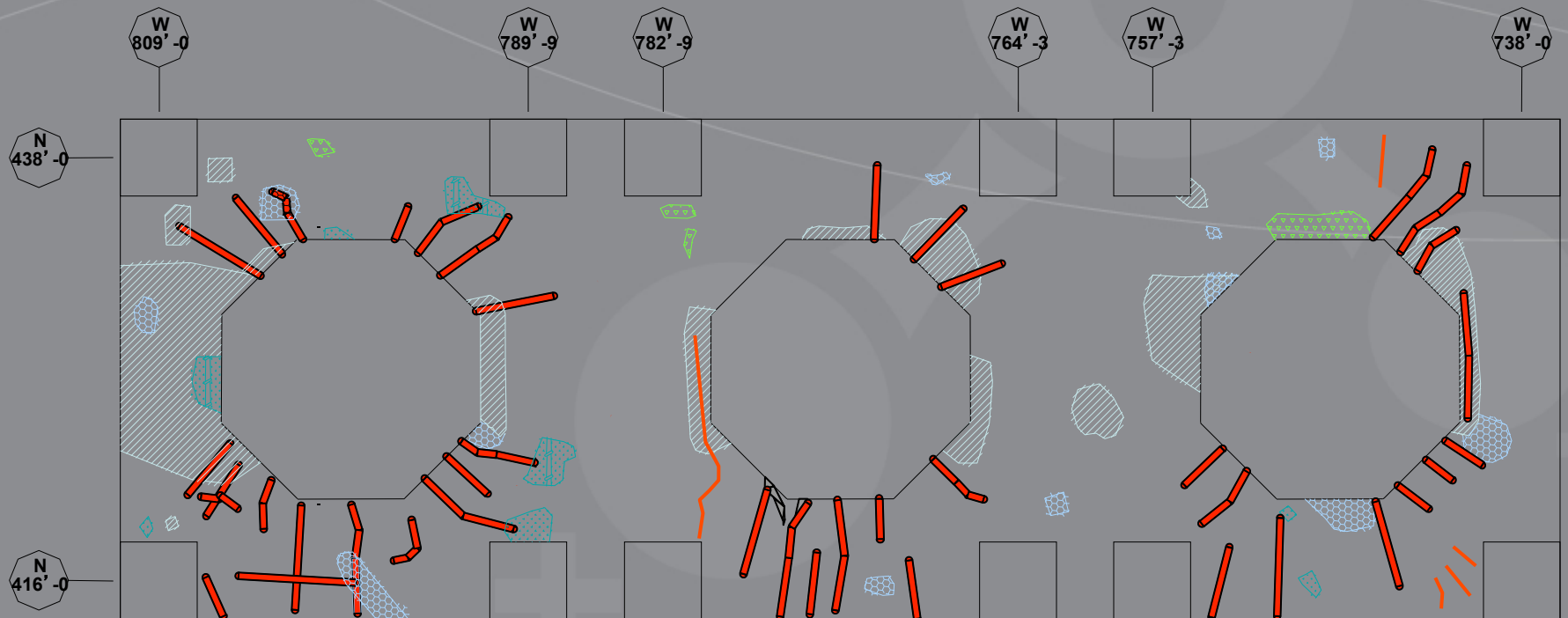
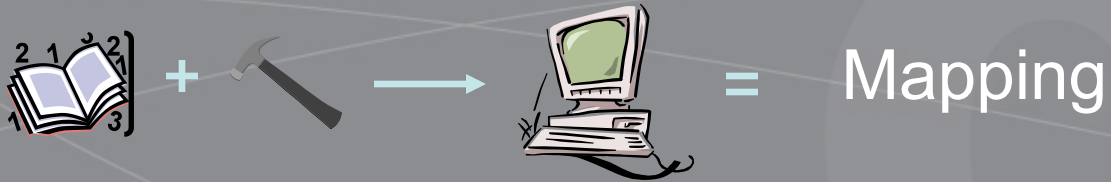
Detecting Carbonation



Condition Survey Mapping

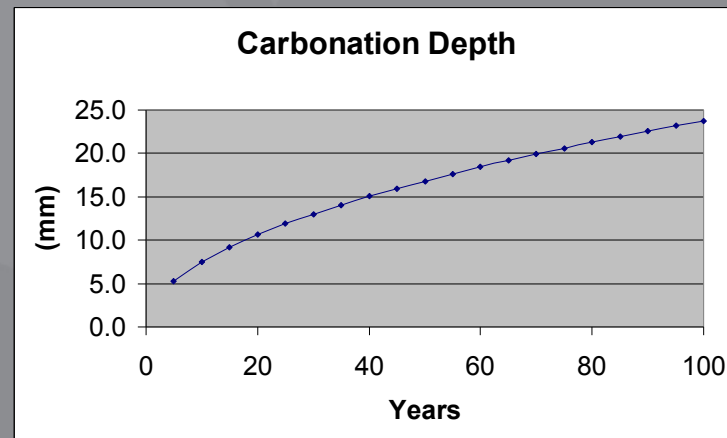
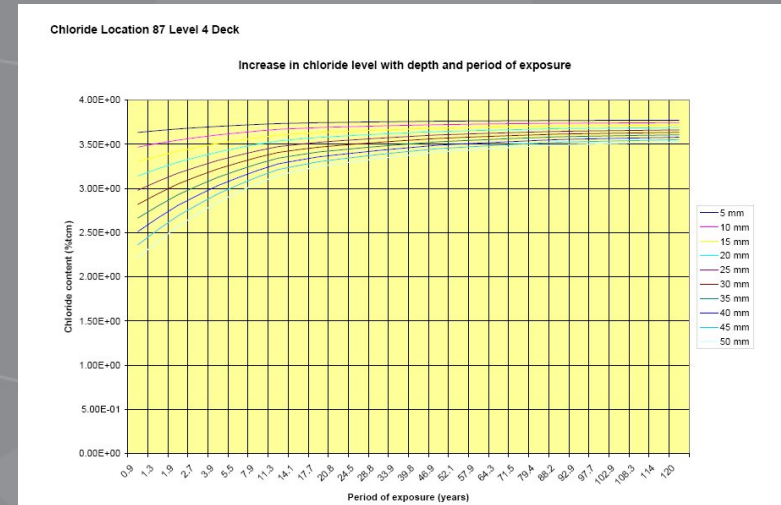
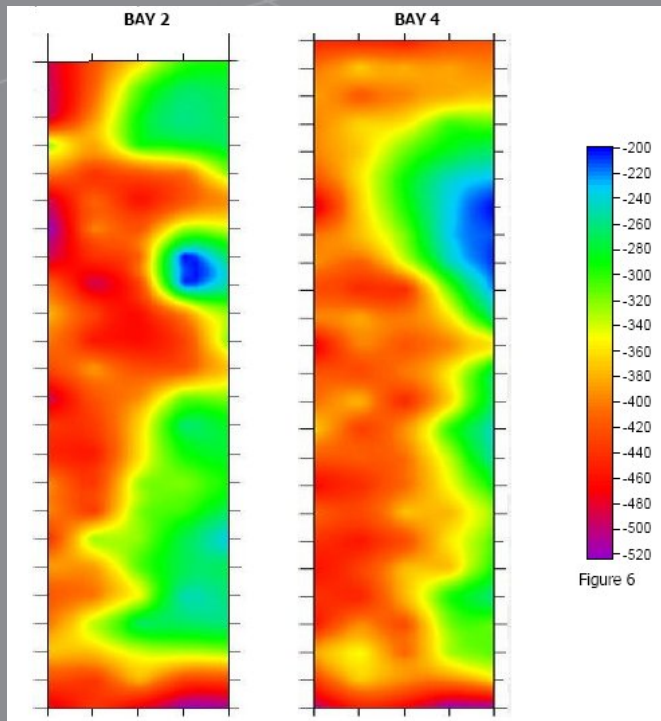


Condition Survey Drawings



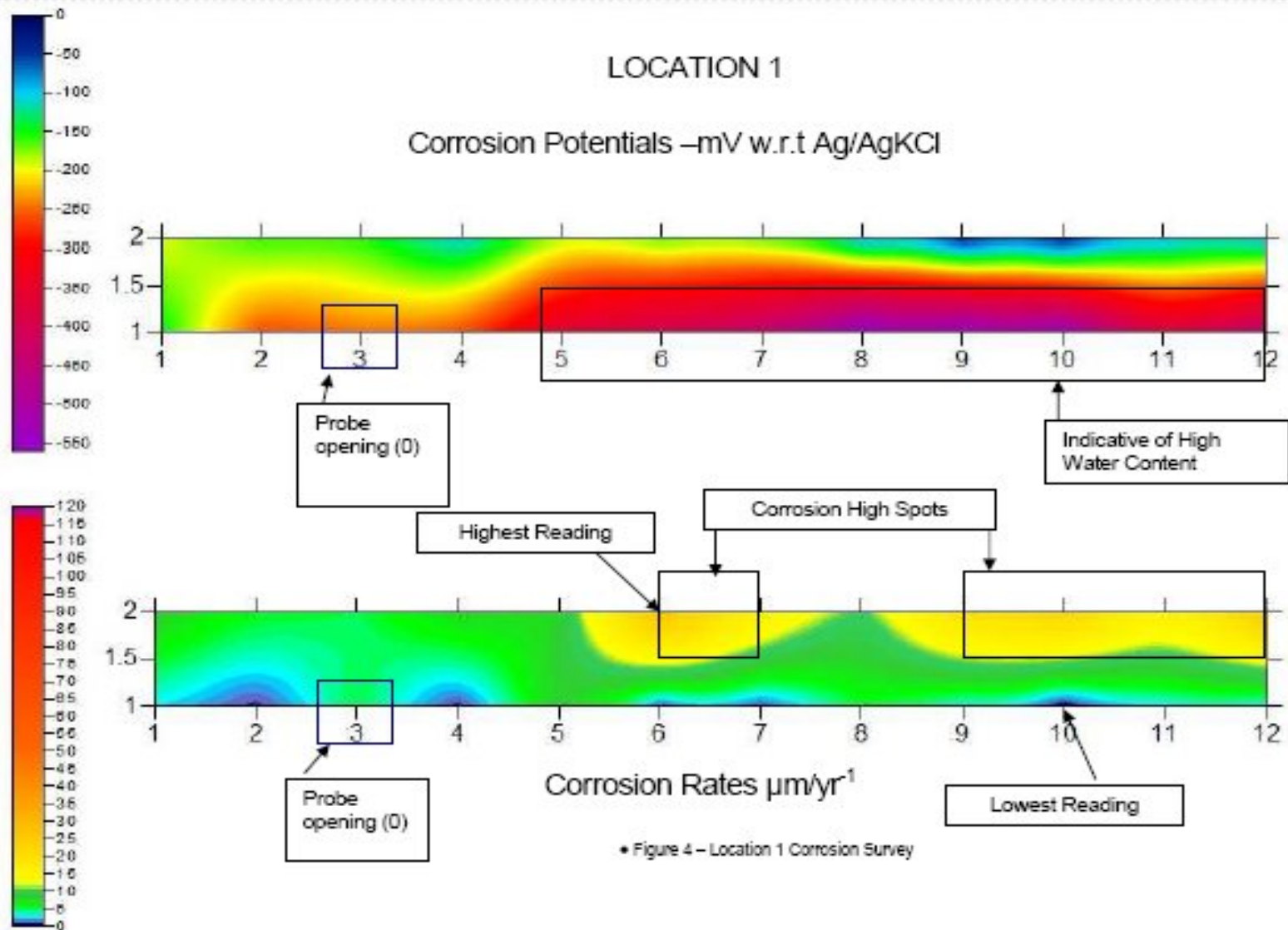
NTS

Corrosion Testing, Diagnostics & Modelling



Condition Assessment





Sample Project

Coal Fired Power Plant Hyperbolic Cooling Towers





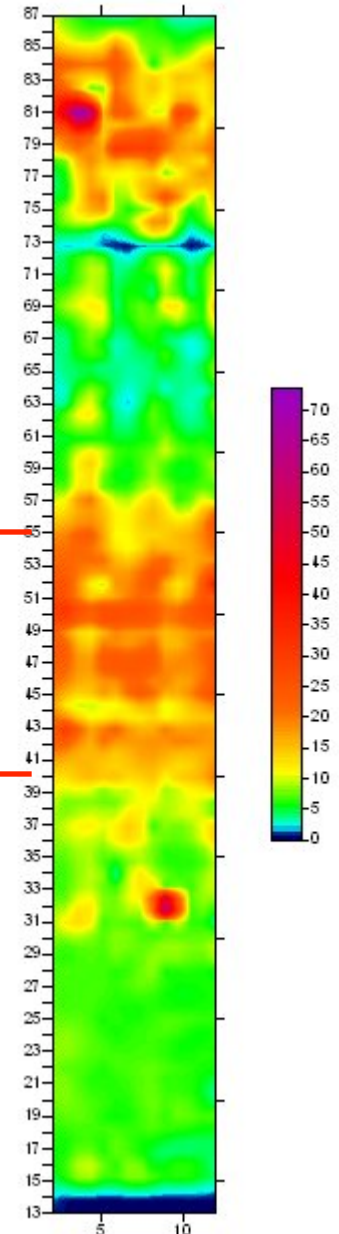
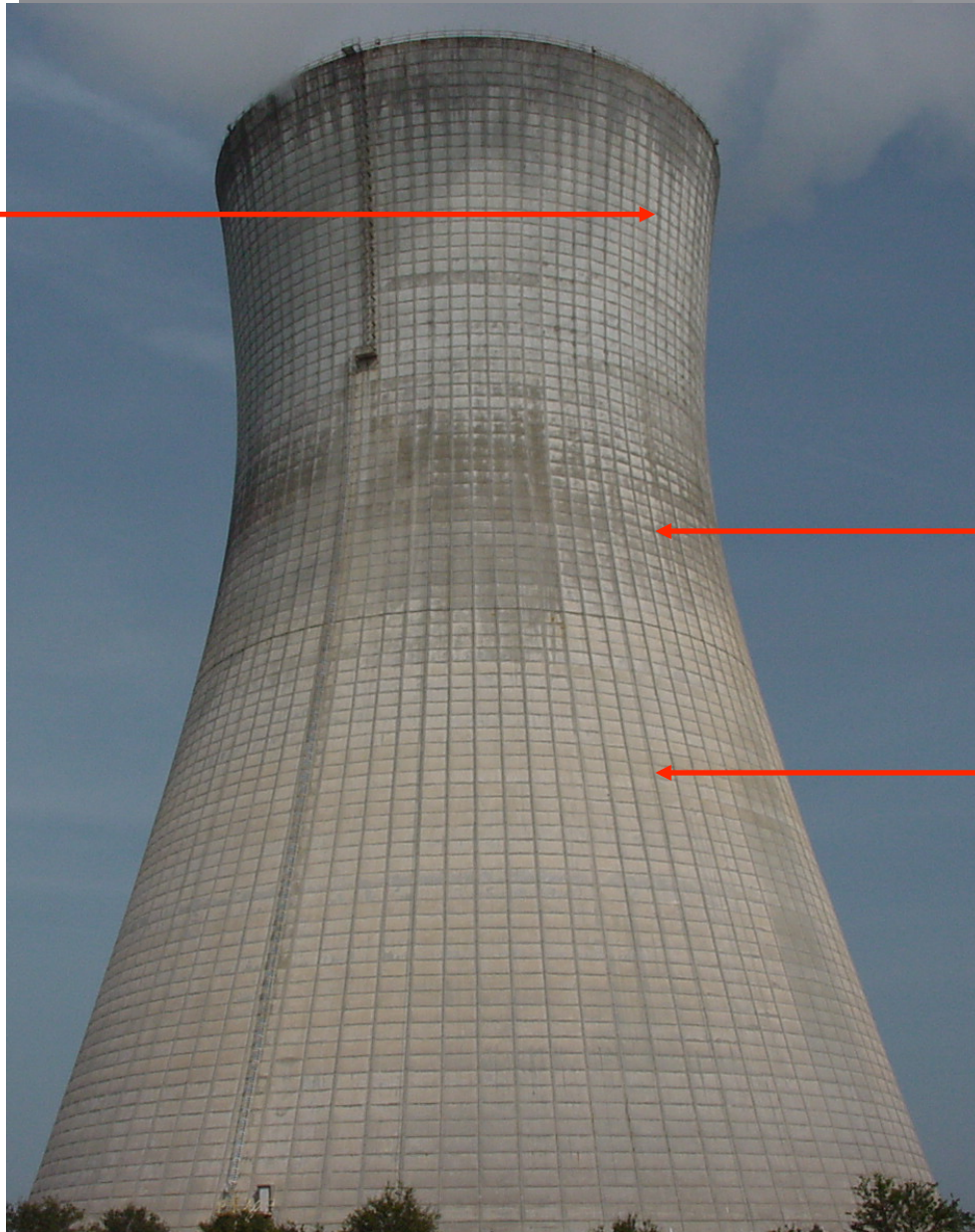
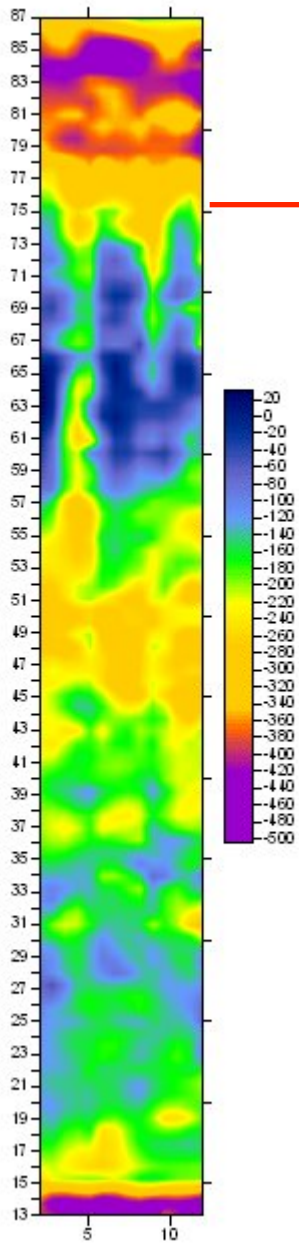




Cooling Towers







General Overview

Corrosion Assessment – Cooling Towers

- Combination of NDE and SDE Techniques
 - Visual Inspections
 - Electrical Continuity Testing
 - Concrete Resistivity
 - Potential Mapping
 - Corrosion Rate – LPR
 - Chloride, Carbonation Testing
- Current Condition
- Predictive Corrosion and Damage Model
- Comprehensive Repair and Protection Strategy















Conclusions

- Corrosion is an electrochemical phenomenon
- Measurement techniques selected so that they are appropriate for period in life cycle model
- No one techniques alone provides a definitive answer.
- Repair and protection strategies are optimized
- Highest ROI

The background is a solid dark gray. It features several faint, light gray geometric elements: a large circle in the upper right, a smaller circle in the lower right, and two plus signs, one in the lower left and one in the lower right. Thin, curved lines sweep across the frame, intersecting the circles and plus signs.

Thank you

Questions?