



**SCS, Inc.**

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# Cost-Effectively Extending Service Lives of Severely Deteriorated Concrete

**Substructures**  
NE Bridge Preservation Partnership  
September 29, 2010

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# In This Presentation

We will discuss:

- Quantifying corrosion in RC substructures (answering “how bad is bad?”)
- Recommending and designing corrosion protection to extend service life cost effectively
- Partnering with owners to solve problems



# 11 Bridges in Richmond, VA



# Evaluation

- How much delam/spall at present?
- Chlorides at various depths?
- Future penetration and effects of chlorides?
- Active corrosion occurring? How quickly?
- How much future damage?
- Presence and progression of ASR?

**High risk of prescribing a poor solution  
without proper diagnosis...**



**LEGEND:**

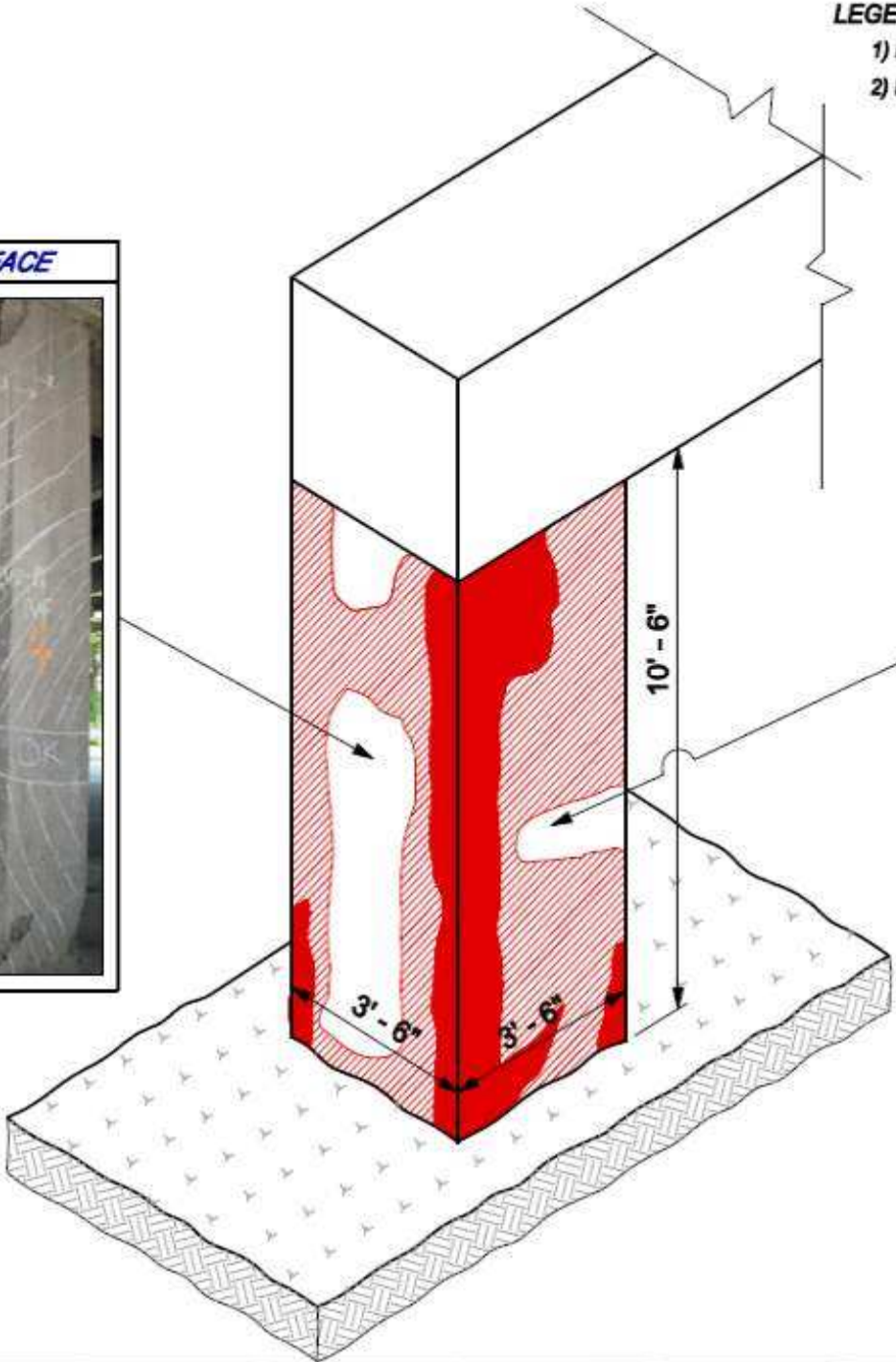
1) RED HATCHED AREA REPRESENTS DELAMINATION - 

2) RED FILLED AREA REPRESENTS SPALLING - 

**PIER 1 COLUMN 4 EAST FACE**



**PIER 1 COLUMN 4 NORTH FACE**



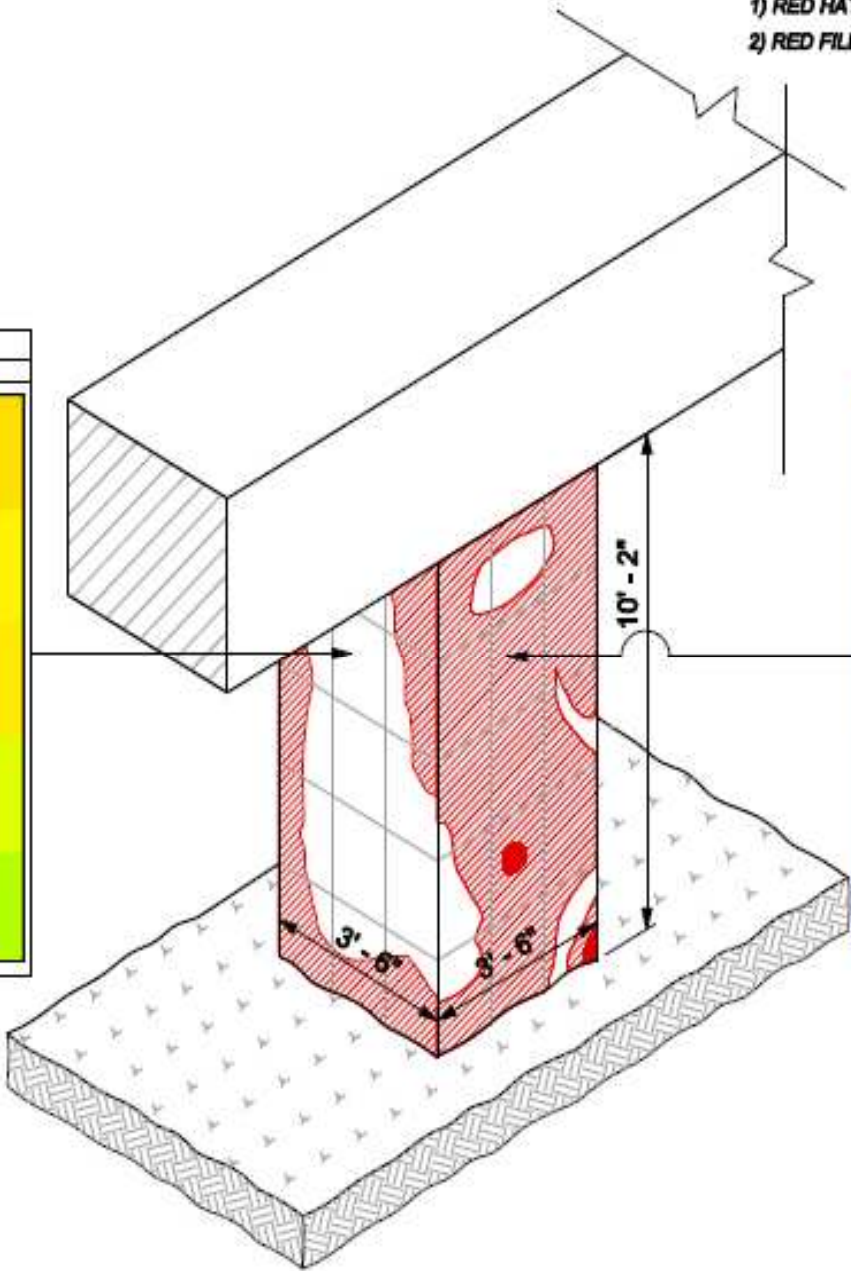
**LEGEND:**

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- 2) RED FILLED AREA REPRESENTS SPALLING



**PIER 1 COLUMN 2 EAST FACE**

COVER			HALF-CELL		
1.30	2.10	2.30	-333	-375	-390
2.30	2.15	1.85	-325	-307	-305
1.30	1.75	1.75	-391	-228	-342
2.60	1.65	2.00	-382	-178	-300
2.10	1.90	2.30	-255	-226	-268

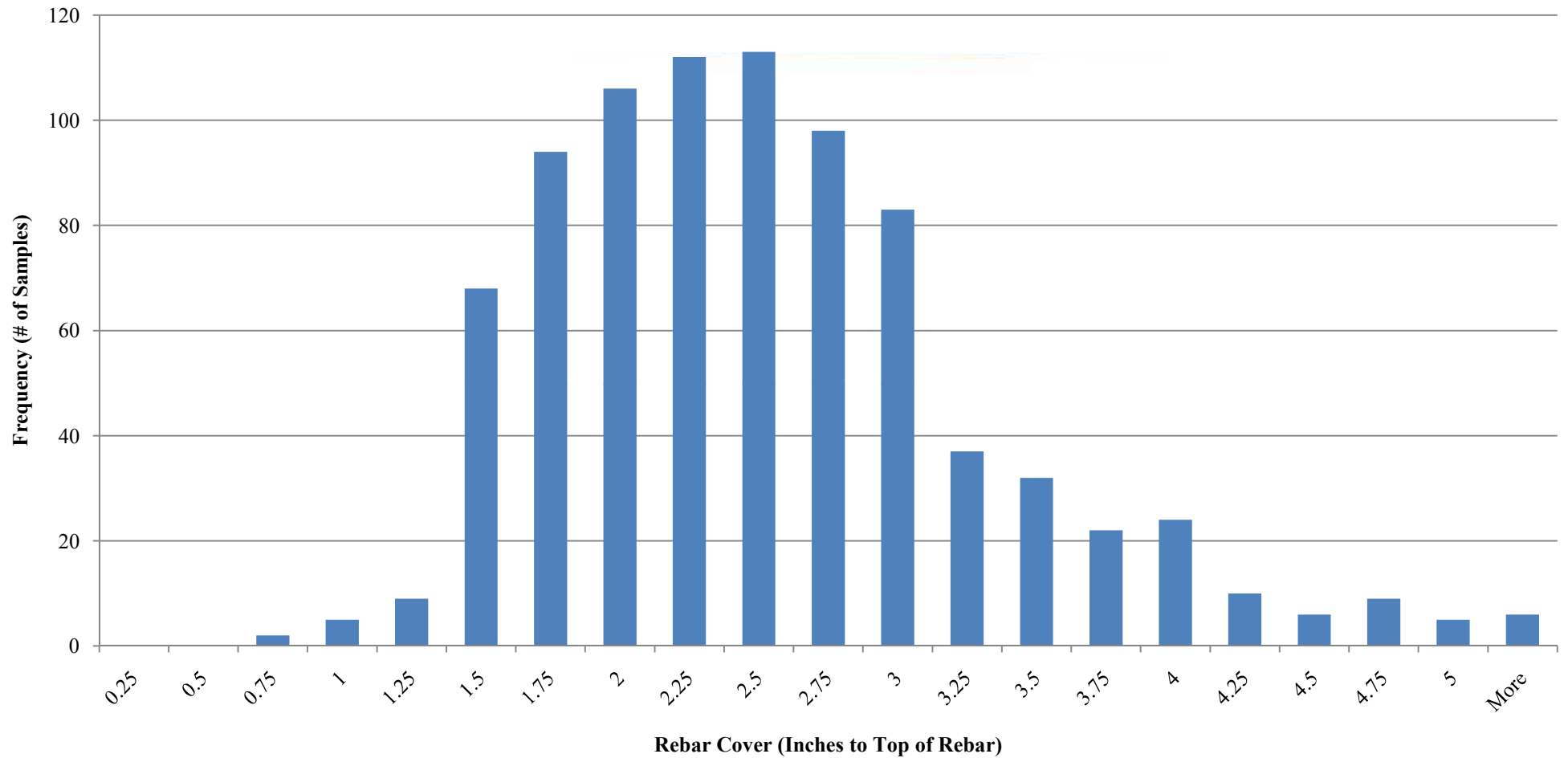


**PIER 1 COLUMN 2 NORTH FACE**

COVER			HALF-CELL		
2.10	1.90	2.20	-370	-375	-347
2.15	1.90	2.35	-344	-258	-264
2.15	1.90	1.85	-328	-222	-240
2.15	1.90	1.90	-288	-233	-288
2.20	1.75	2.15	-300	-301	-248

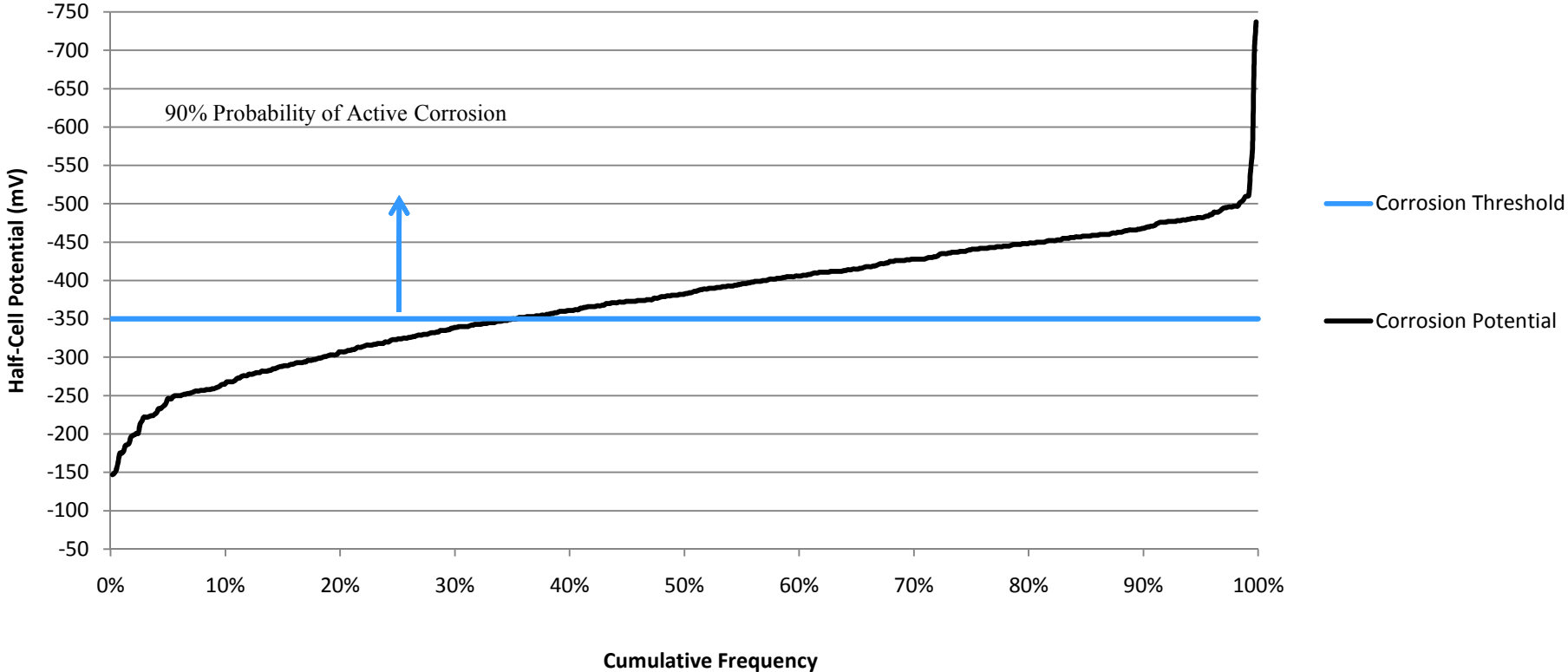
**PIER 1 COLUMN 2  
EAST/NORTH ELEVATION  
N.T.S.**

## Boulevard - Structure Total Rebar Cover Histogram

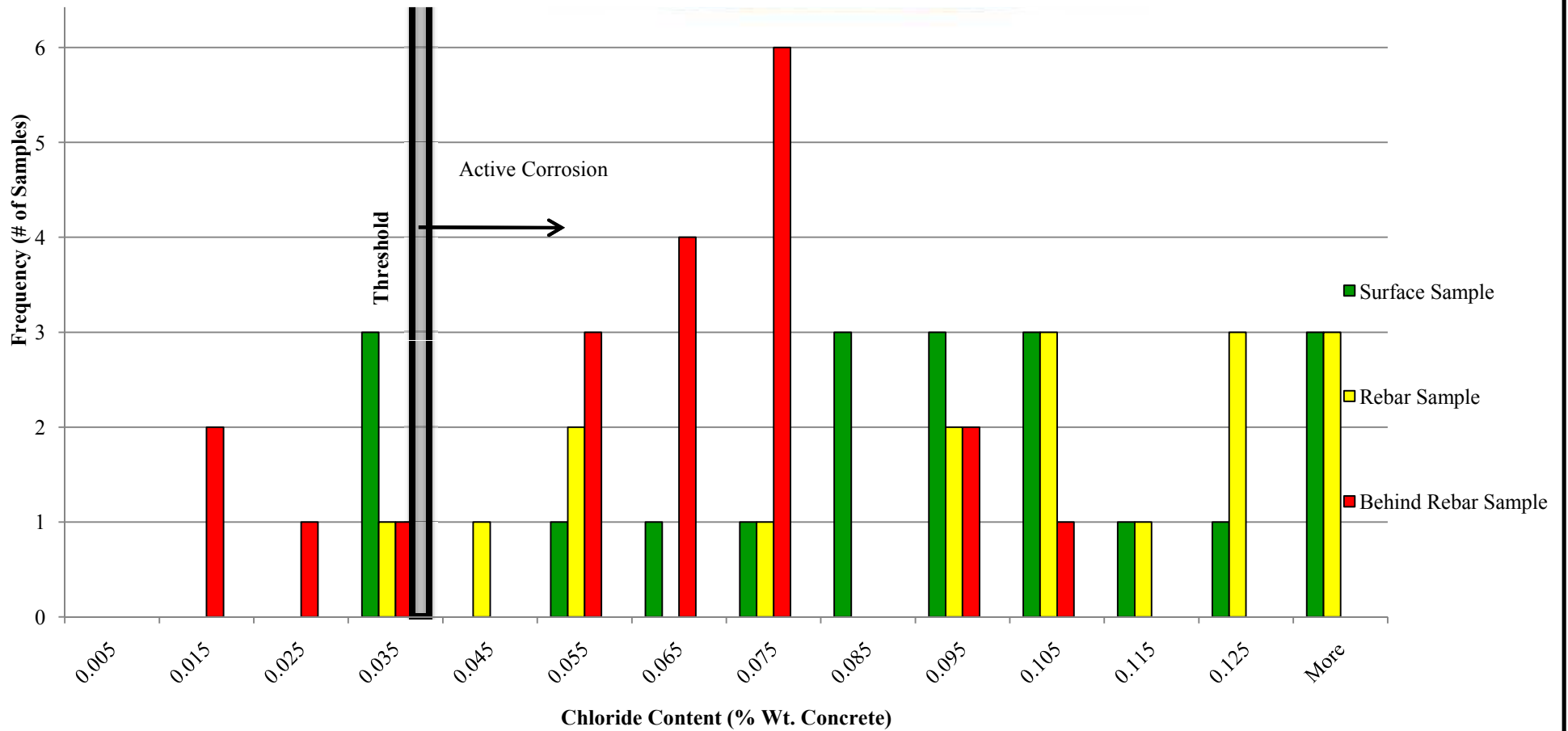




# Boulevard – Structure Total Corrosion Potential



# Boulevard – Structure Total Chloride Concentration Histogram

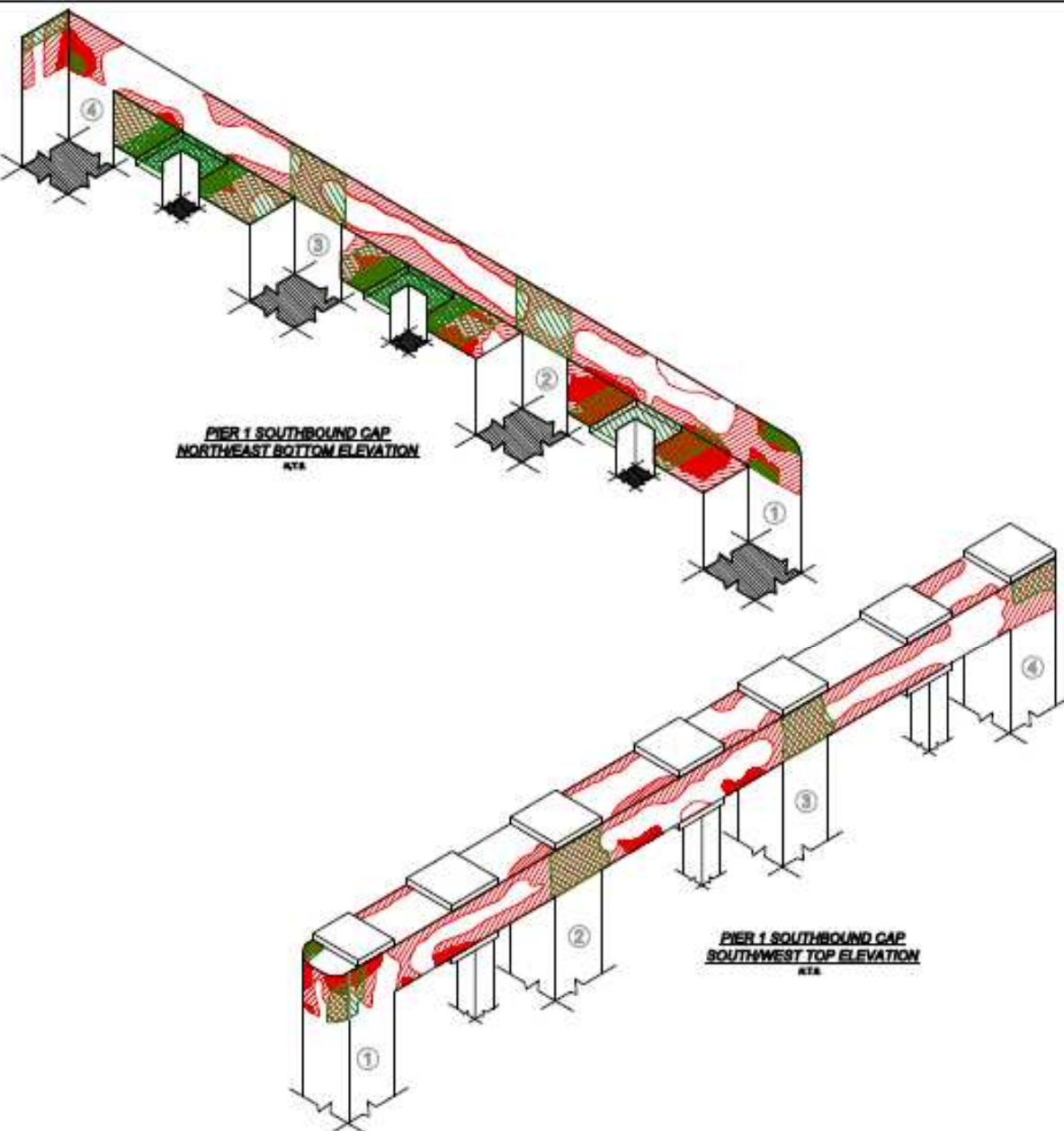


**Table 3. Comparison of Concrete Damage**

No.	Bridge Member	Past Concrete Damage (sq.ft.)	2009 Concrete Damage (sq.ft.)	Damage Increase percentage	Comments
1	Lombardy - Pier 2 - Southbound Cap	61	110	80%	2000 data
2	Lombardy - Pier 2 - Column 1	13	33	154%	2000 data
3	Lombardy - Pier 2 - Column 3	25	47	88%	2000 data
4	Lombardy - Pier 2 - Northbound Cap	152	248	63%	2000 data
5	Overbrook - Abutment B - Northbound	10	22	120%	2000 data
6	Overbrook - Pier 1 - Northbound Cap	69	150	117%	2000 data
7	Overbrook - Pier 2 - Southbound Cap	114	127	11%	2000 data
8	Overbrook - Pier 2 - Column 1	3	13	333%	2000 data
9	Overbrook - Pier 2 - Column 8	16	49	206%	2000 data
10	Robinhood - Pier 1 - Southbound Cap	127	223	76%	2000 data
11	Robinhood - Pier 1 - Column 1	15	45	200%	2000 data
12	Robinhood - Pier 1 - Column 2	3	39	1200%	2000 data
13	Robinhood - Pier 1 - Northbound Cap	19	36	89%	2000 data
14	Sherwood - Pier 1 - Southbound Cap	83	171	106%	2000 data
15	Sherwood - Pier 2 - Column 5	10	22	120%	2000 data
16	Boulevard - Abutment B - Northbound	9	34	278%	1997 data
17	Boulevard - Pier 1 - Southbound Cap	230	379	65%	1997 data
18	Boulevard - Pier 1 - Column 2	50	79	58%	1997 data
19	Hermitage - Abutment B - Southbound	15	37	147%	1997 data
20	Hermitage - Pier 1 - Column 1	2	37	1750%	1997 data
21	Hermitage - Pier 1 - Column 2	1	22	2100%	1997 data
22	Hermitage - Pier 1 - Column 3	3	21	600%	1997 data
23	Hermitage - Pier 2 - Northbound Cap Outside	1	29	2800%	1997 data
24	Hermitage - Pier 2 - Column 10	1	12	1100%	1997 data
25	Hermitage - Pier 3 - Northbound Cap Inside	1	51	5000%	1997 data
26	Laburnum - Abutment B - Southbound	76	119	57%	1997 data

**LEGEND:**

- 1) RED HATCHED AREA REPRESENTS DELAMINATION (SIVA CORROSION SERVICES - 2009)
- 2) RED FILLED AREA REPRESENTS SPALLING (SIVA CORROSION SERVICES - 2009)
- 3) GREEN HATCHED AREA REPRESENTS DELAMINATION (ALPHA CORPORATION - 1997)
- 4) GREEN DOUBLE-HATCHED AREA REPRESENTS SPALL (ALPHA CORPORATION - 1997)

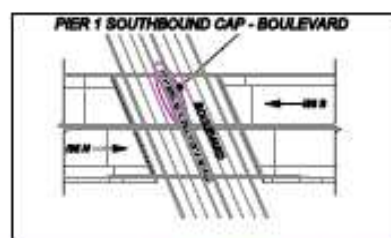


**Spall and Delamination Comparison over Boulevard  
2009 Siva Corrosion Services and 1997 Alpha Corporation**

Bridge Member	1997 Structure Damage (ft <sup>2</sup> )	2009 Structure Damage (ft <sup>2</sup> )	Damage Increase Percentage (1997-2009)
<b>Pier 1</b>			
Pier 1 - Southbound Cap - North Face	52	120	131%
Pier 1 - Southbound Cap - South Face	42	122	190%
Pier 1 - Southbound Cap - West Face	2	11	450%
Pier 1 - Southbound Cap - East Face	5	9	80%
Pier 1 - Southbound Cap - Top Face	3	18	500%
* Pier 1 - Southbound Cap - Bottom Face	127	99	-
<b>Total: Pier 1 - Southbound Cap</b>	<b>231</b>	<b>379</b>	<b>64%</b>
* Patch work for steel columns has caused a decrease in damaged concrete. Patches constitute 25% of bottom surface area. Patches are included in total surface area.			
<b>Total: Pier 1 - Column 1-4</b>	<b>168</b>	<b>302</b>	<b>80%</b>
<b>Total: Pier 1 - SB Cap &amp; Column 1-4</b>	<b>399</b>	<b>681</b>	<b>71%</b>

Notes:

- 1997 structure damage supplied by Alpha Corporation.
- 2009 structure damage supplied by Siva Corrosion Services.
- All calculations & pictorial representations of concrete damage are an estimation of actual concrete damage, based on dimensions & locations taken onsite.
- Siva Corrosion Services conducted spall and delamination survey for approximately 50% of the total structure.




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<b>PIER 1 SOUTHBOUND CAP DELAM &amp; SPALL COMPARISON</b>	
DESIGNED: _____	CHECKED: M.M.
CHECKED: C.C.	CHECKED: M.M.

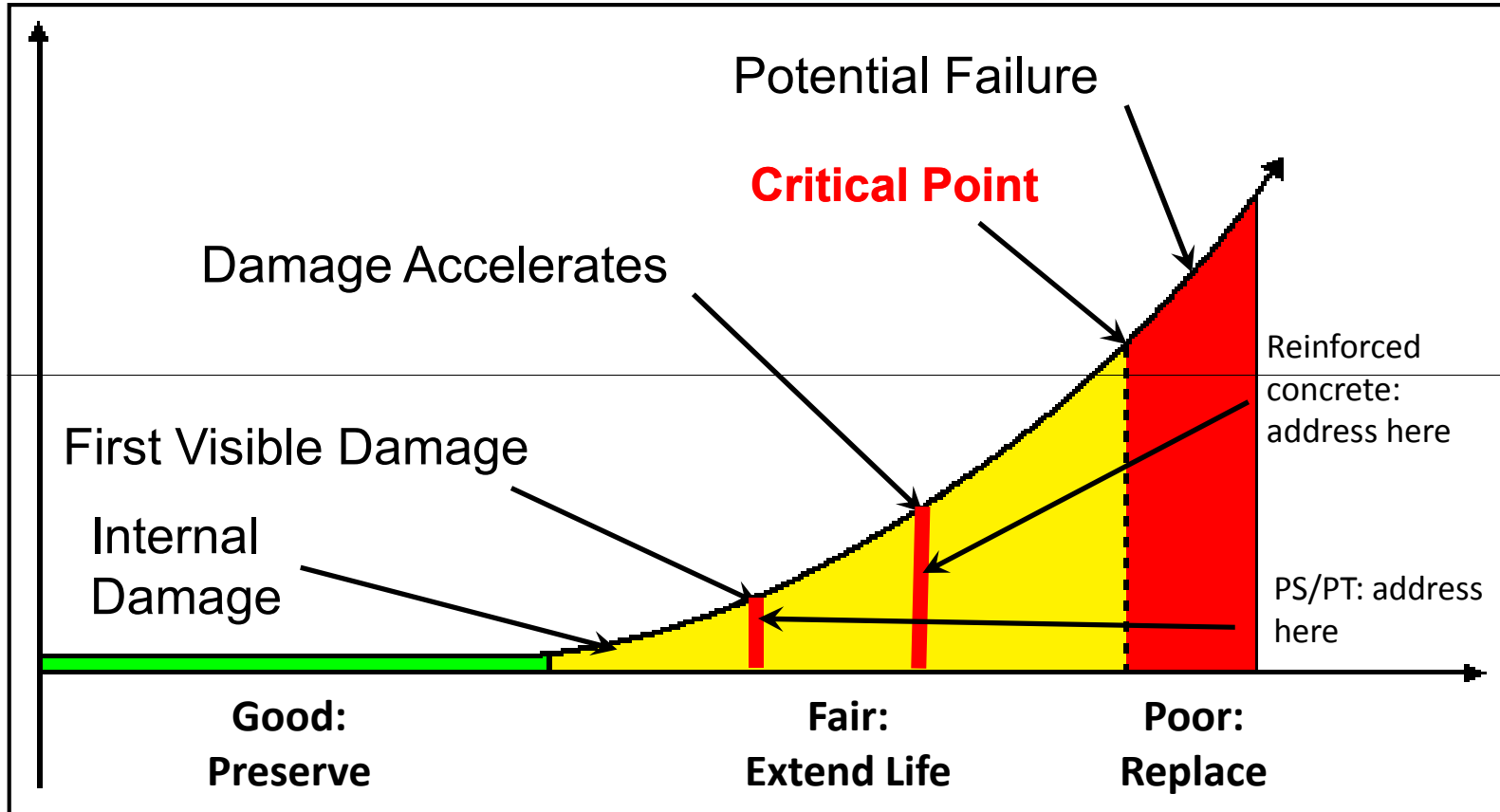
**VIRGINIA DEPARTMENT OF TRANSPORTATION**

**1 95 OVER BOULEVARD**

HORIZONTAL SCALE N.T.S.	DRAWING NUMBER
VERTICAL SCALE N.T.S.	<b>B1</b>
SURVEY BOOK N/A	SHEETS 3 OF 3
DATE OCTOBER 2009	PROJECT 0048-01

# Corrosion Cost Progression

Cost of Maintenance



Condition of Structure



# Conclusions

- Visible concrete damage – significant increase
- Developed a concrete damage % for each element
- Average recorded cover – moderate to high
- Majority of potential tests – active corrosion
- High chloride readings behind rebars
- Near future concrete damage will result
- Significant weakening of the structure within five years



# Recommendations

- Based on a unique methodology, we developed recommendations for repair / replace / life extension
- Concrete repairs on all bridges
- ECE to lower chloride level near rebars and repolarize rebars
- Sacrificial CP to maintain polarization of rebars
- 25-year additional life for structures
- Sprayed Zinc Alloy – widely used, easy to apply



<b>S. No.</b>	<b>Structure</b>	<b>Replacement cost</b>	<b>Repair cost</b>	<b>Cost Savings</b>	<b>Repair cost/ Replacement cost, %</b>
1	Boulevard	\$1,931,202	\$402,300	<b>\$1,528,902</b>	21%
2	Hermitage Road	\$3,240,312	\$619,720	<b>\$2,620,592</b>	19%
3	Laburnum Avenue	\$1,730,258	\$380,480	<b>\$1,349,778</b>	22%
4	Lombardy/CSX	\$5,821,420	\$2,019,420	<b>\$3,802,000</b>	35%
5	Overbrook Road	\$1,147,005	\$312,240	<b>\$834,765</b>	27%
6	Ramp-A	\$926,000	\$146,440	<b>\$779,560</b>	16%
7	Robin Hood Road	\$1,877,817	\$568,560	<b>\$1,309,257</b>	30%
8	Sherwood Avenue	\$1,595,045	\$397,700	<b>\$1,197,345</b>	25%
9	Upham Brook Run	\$2,287,719	\$429,620	<b>\$1,858,099</b>	19%
10	Westwood Avenue	\$3,592,000	\$402,440	<b>\$3,189,560</b>	11%
	<b>Total</b>	<b>\$24,148,778</b>	<b>\$5,678,920</b>	<b><u>\$18,469,858</u></b>	<b>24%</b>

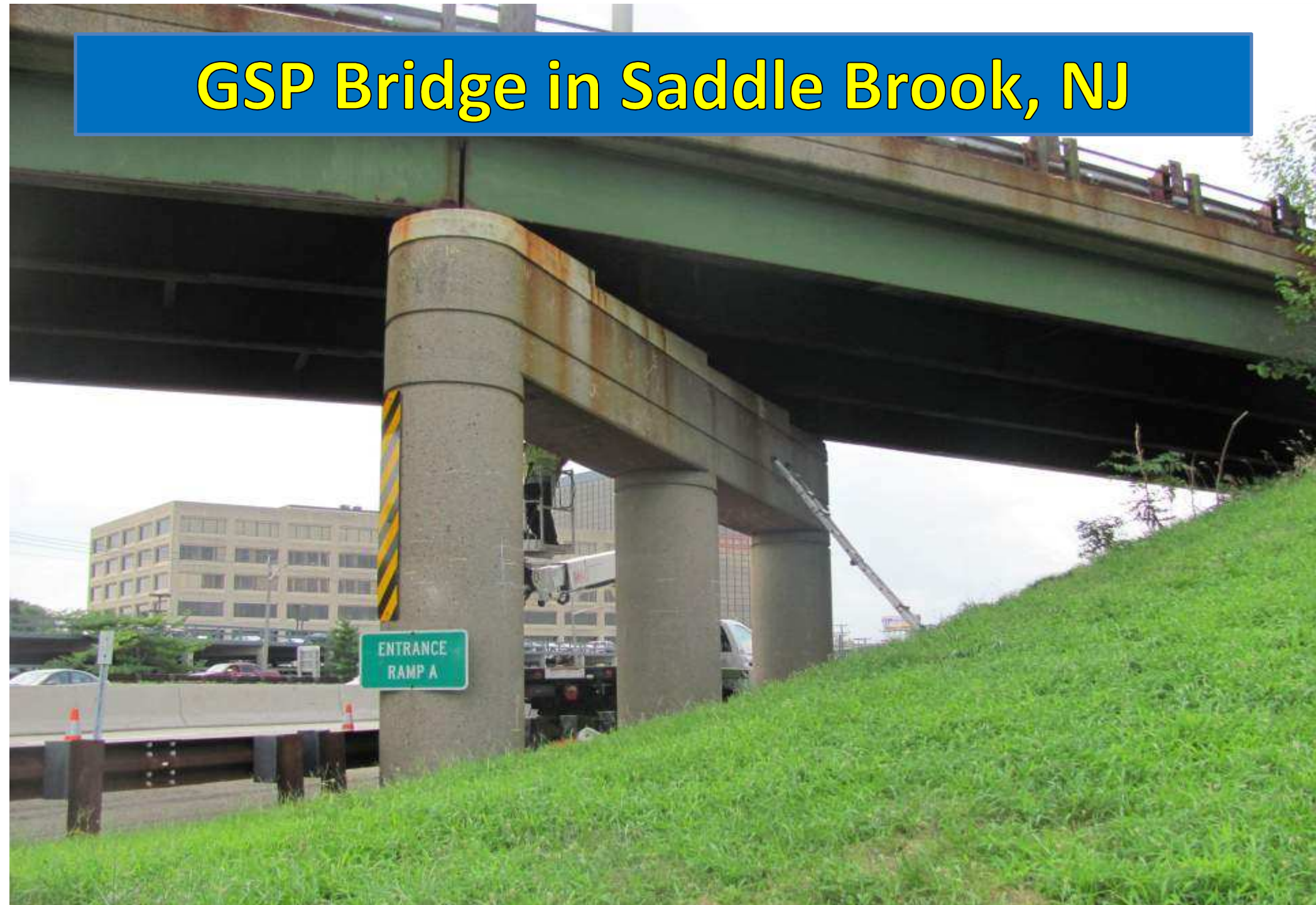


# Benefits

- Why testing?
- To understand where and how big the problems are
- To properly design the solution
- Department will save \$18,400,000
- 25-years additional life
- Peace of mind



# GSP Bridge in Saddle Brook, NJ



# Problems

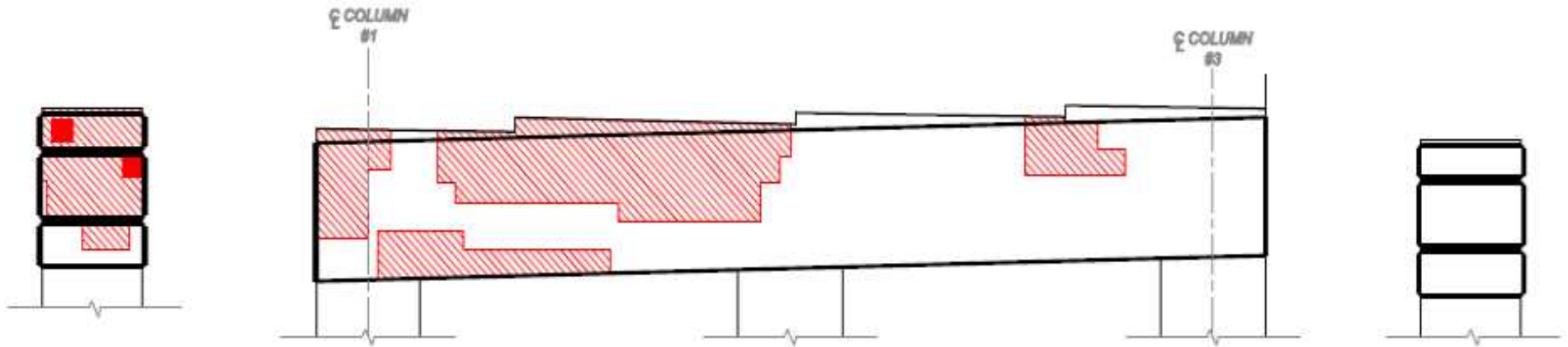
- Concerns existed pertaining to the condition of a reinforced concrete pier in New York City area
- The owner wanted to compare sounding data to NDT data to identify the similarities/differences
- The owner wanted to quantify corrosion
- The owner wanted to understand cost effective service life extension options



**LEGEND:**

1) RED HATCHED AREA REPRESENTS DELAMINATION - 

2) RED FILLED AREA REPRESENTS SPALLING - 



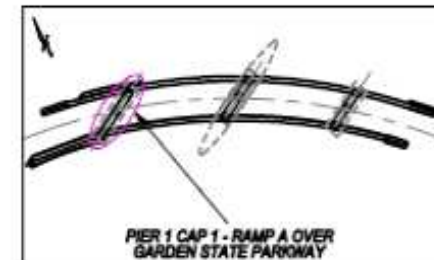
**WEST FACE**

**SOUTH FACE**

**EAST FACE**

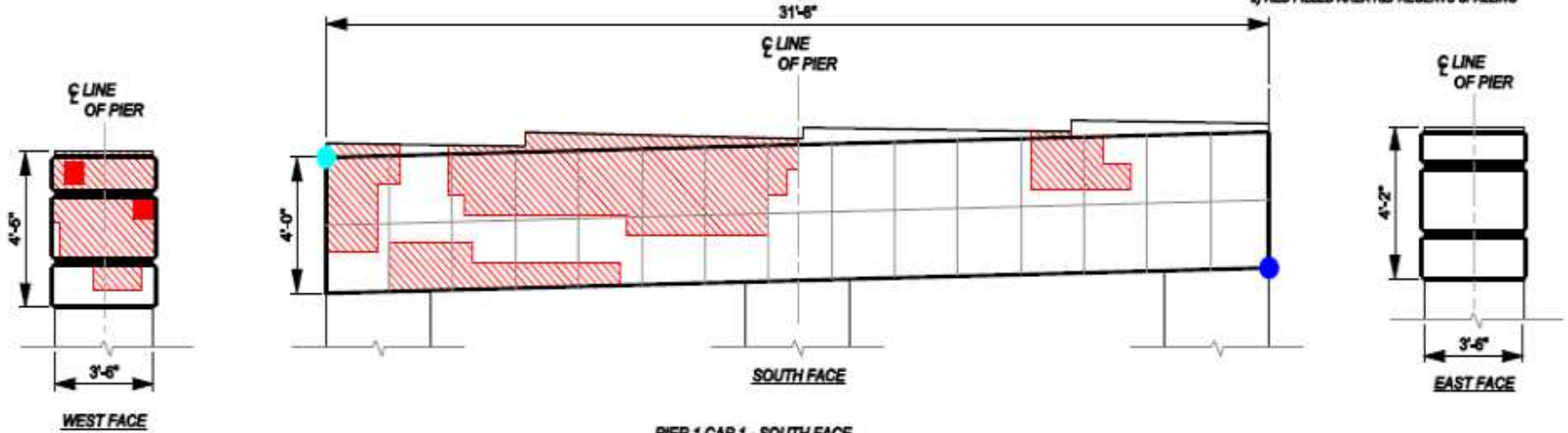


**PIER 1 CAP 1 - SOUTH FACE  
RAMP A OVER GARDEN STATE PARKWAY  
K.T.S.**



**LEGEND:**

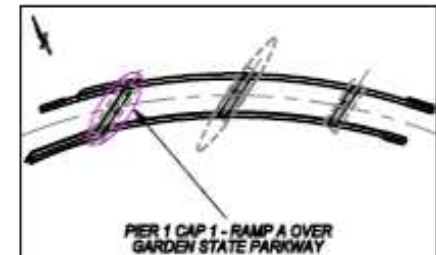
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**PIER 1 CAP 1 - SOUTH FACE  
RAMP A OVER GARDEN STATE PARKWAY  
N.T.S.**

PIER 1 CAP 1 - RAMP A OVER GARDEN STATE PARKWAY														
COVER														
2.70	3.05	3.30	3.15	3.35	3.35	3.95	2.95	2.95	2.75	2.60	2.80	2.55	2.90	2.95
2.76	3.00	3.25	3.25	3.50	3.40	4.45	3.15	3.20	3.10	2.95	3.15	3.15	3.55	3.75
POTENTIAL														
-622	-386	-466	-432	-430	-433	-284	-249	-232	-223	-277	-517	-263	-82	-96
-541	-340	-450	-435	-305	-275	-206	-383	-298	-232	-218	-265	-130	-27	-109

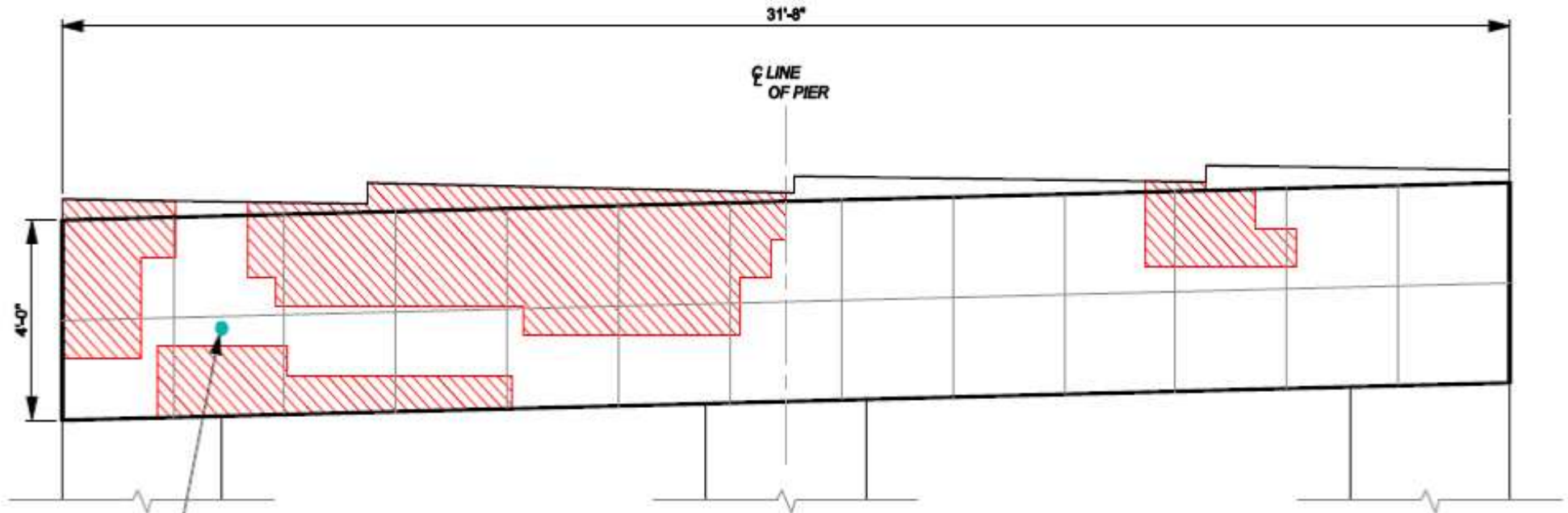
\* NOTE: COVER & POTENTIAL READINGS TAKEN FROM CENTER LINE OF WEST FACE CAP END TO CENTER LINE OF EAST FACE CAP END.



**PIER 1 CAP 1 - RAMP A OVER  
GARDEN STATE PARKWAY**

**LEGEND:**

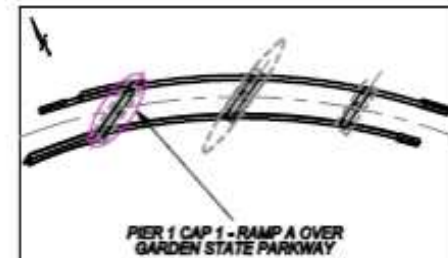
- 1) RED HATCHED AREA REPRESENTS DELAMINATION
- 2) RED FILLED AREA REPRESENTS SPALLING
- 3) CYAN FILLED CIRCLE REPRESENTS CHLORIDE DRILLING LOCATION

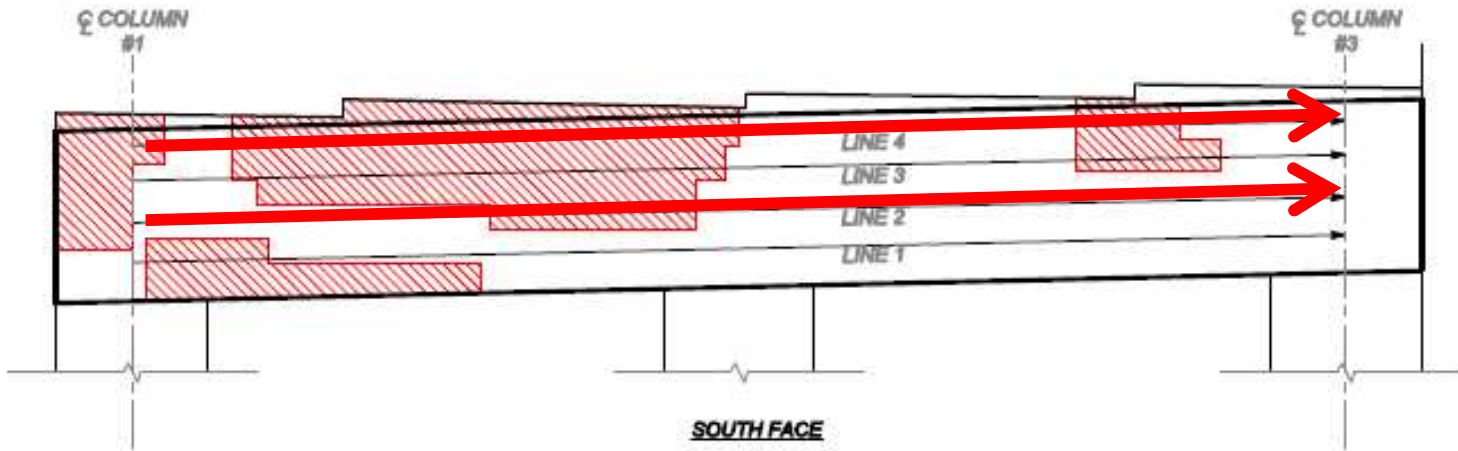


**CHLORIDE TESTING LOCATIONS AND RESULTS**

LOCATION	DEPTH	Cl, WT % POWDER
SOUTH FACE - B2 - 1	0" - 1"	0.103
SOUTH FACE - B2 - 2	1" - 2"	0.038
SOUTH FACE - B2 - 3	2" - 3"	0.028
SOUTH FACE - B2 - 4	3" - 4"	0.011
SOUTH FACE - B2 - 5	4" - 5"	0.008
SOUTH FACE - B2 - 6	5" - 6"	0.007

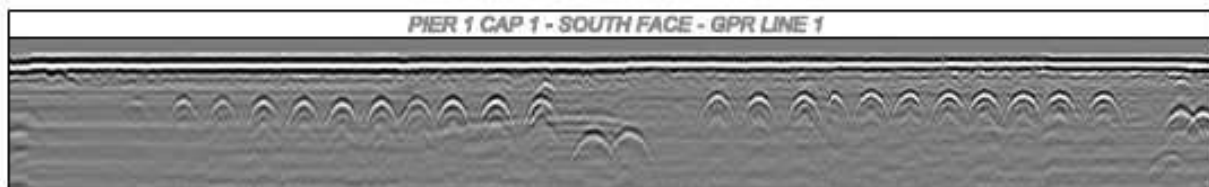
**PIER 1 CAP 1 - SOUTH FACE -  
RAMP A OVER GARDEN STATE PARKWAY**  
N.T.S.





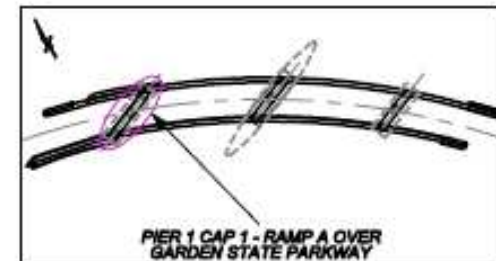
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\* NOTE: GPR READINGS TAKEN FROM CENTER LINE OF COLUMN 1 TO CENTER LINE OF COLUMN 3.

**PIER 1 CAP 1 - SOUTH FACE**  
**RAMP A OVER GARDEN STATE PARKWAY**  
 N.T.S.

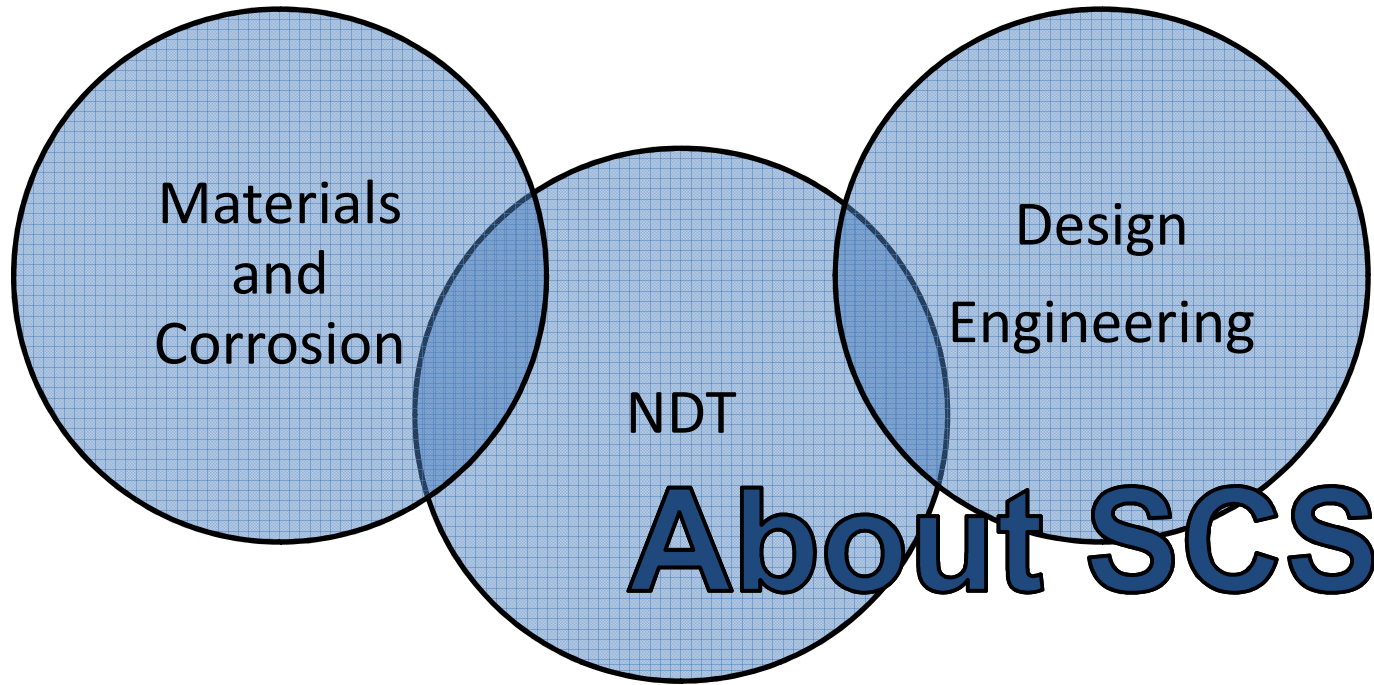


# Solutions by SCS

- Determined the current condition of the pier
- Quantified the extent of corrosion
- Predicted future corrosion activity in the pier
- Recommended possible corrosion protection systems to extend service life
- Identified corrosion using both NDT and sounding







## Structure Types:

- Reinforced Concrete
- Steel
- Pre-Stressed
- Post-Tensioned
- Cable Stayed

In-Depth  
Evaluation

Life  
Extension  
System  
Design

Installation  
Inspection



# Who We Are

- An independent firm with materials, NDT, and corrosion expertise
- Listen to the needs of our clients
- Quantify the magnitude of deterioration problems and identify all possible solutions
- Recommend the most cost-effective solution
- Save time and costs - offer knowledge and experience to solve material degradation problems
- “The owner is our #1 priority”



# Thank You

# Questions?

**Siva Venugopalan**  
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