CAIT-UTC-059

Nondestructive Evaluation of Four Sister Bridges in Virginia Using Manual NDE Technologies and Robotic Platform RABIT

Final Report
July 2015

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16. Abstract

Understanding the factors that influence the performance of a bridge is a very important topic and due to the complexity of bridges, this is rather a hard task because there are multiple factors, which can influence the performance of a bridge. These factors can include design practices, construction quality, environmental factors, and truckload.

Sister bridges are parallel bridges that generally have identical design and construction quality. The main difference between these structures is often the load factor; therefore, there is a great opportunity for studying these structures. Within this research project, condition assessment of two sets of sister bridges in Virginia will be conducted using manual NDE technologies as well as the robotic platform RABIT^{TM}. The following NDE methods will be used in both the automated and manual testing: Impact Echo, Ultrasonic Surface Waves, Ground Penetrating Radar and Electrical Resistivity method. The data collected from all the technologies will be analyzed and the results presented in terms of condition maps and calculated condition indices.

17. Key Words	18 Distributional Statement
Non Destructive Evaluation, Non Destructive Testing, NDE, NDT, Bridge Performance, Concrete Bridge Deck, Performance of Sister Bridges	

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Table 1. List of the bridges

Structure No.	Surveyed Date	Ratings on a scale 0 (worst) to 100 (best)					Concrete modulus (USW)	
		Combined	Delamination (IE)	Corrosion (ER)	Corrosion (HCP)	Deterioration (GPR)	Mean (ksi)	STDEV (ksi)
000000000014178	May 26-28, 2015		39.9	40.9	23.7	33.4	3,008	988
000000000014180	May 29, Jun 18, 2015		52.1	72.1	-	40.6	3,514	1,582
000000000014216	Jun 15, 2015		47.9	59.0	-	15.8	3,625	764
000000000014218	Jun 16-17, 2015		53.1	82.2	-	40.3	3,638	1,016

2. BRIDGE NO. 000000000014178

2.1. Delamination Condition Surveyed by Impact Echo

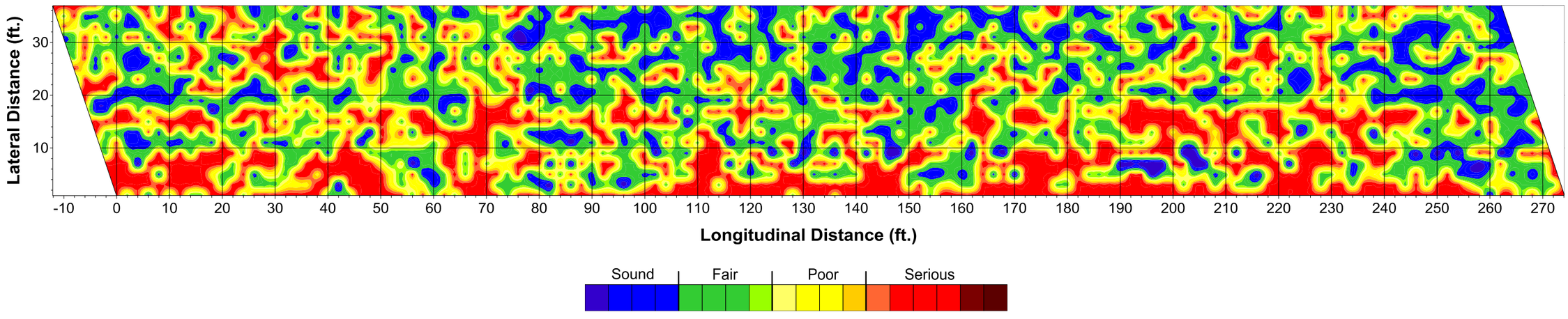

Figure 1. Delamination condition map of bridge no. 000000000014178

Table 2. Delamination assessment of the surveyed sections of bridge no. 000000000014178: percentage of deck area in various states of delamination

Survey Method	Condition Rating	Distribution (%)			
		Good	Fair	Poor	Serious
Manual	39.9	21	31	7	41

2.2. Concrete Modulus Surveyed by Ultrasonic Surface Wave

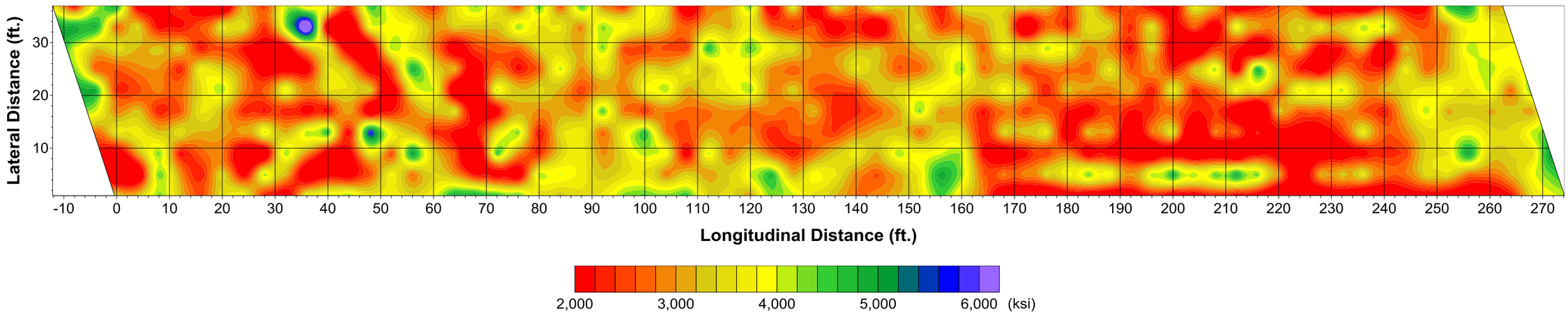

Figure 2. Concrete modulus map of bridge no. 000000000014178

Table 3. Concrete quality assessment of the surveyed sections of bridge no. 000000000014178: average modulus and modulus variability

Survey Method	Distribution (%)			Mean *E* (ksi)	Standard Deviation (ksi)
	< 3,500 ksi	3,500 - 4,500 ksi	> 4,500 ksi		
Manual	68	27	5	3,008	988

2.3. Corrosion Rate Surveyed by Electrical Resistivity

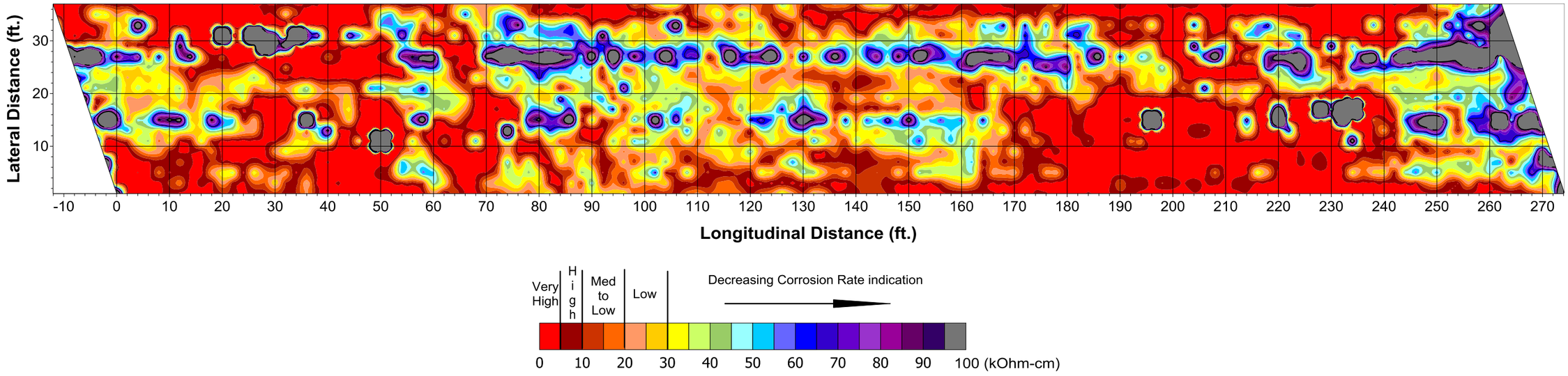

Figure 3. Map of electrical resistivity and expected corrosion rates of bridge no. 000000000014178

Table 4. Corrosion assessment of the surveyed sections of bridge no. 000000000014178: percentage of deck area with various corrosion rates

Survey Method	Condition Rating	Distribution (%)			
		High	Moderate	Low	Very Low
Manual	40.9	44	17	17	22

2.4. Corrosion Rate Surveyed by Half-Cell Potential

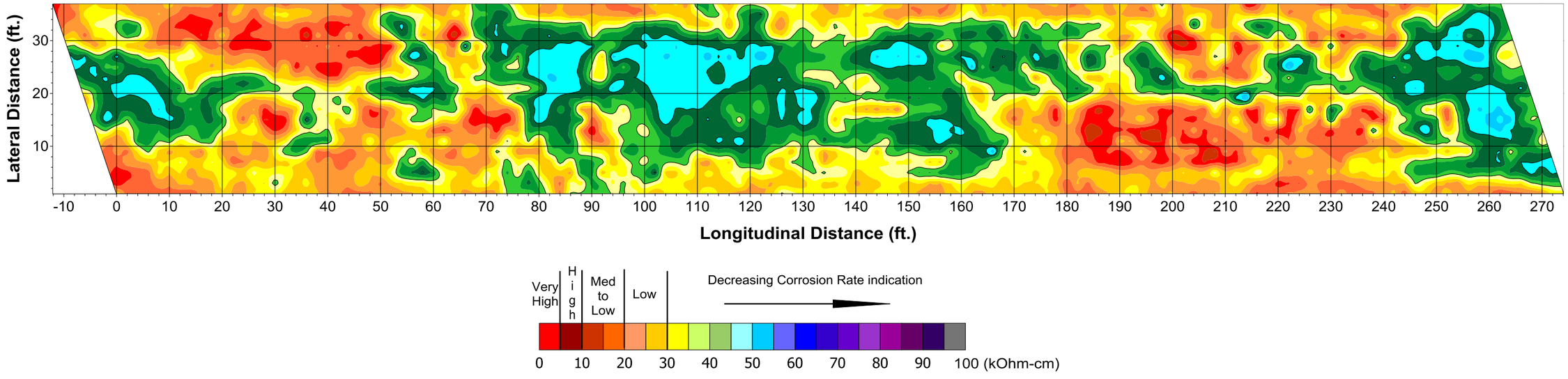

Figure 4. Map of potential and expected corrosion activity of bridge no. 000000000014178

Table 5. Active corrosion assessment of the surveyed sections of bridge no. 000000000014178: percentage of deck area with various corrosion activities

Condition Rating	Distribution (%)		
	90% Probability of Corrosion	Transition	90% Probability of No Corrosion
23.7	60	32	8

2.5. Overall Deck Condition Surveyed by Ground Penetrating Radar

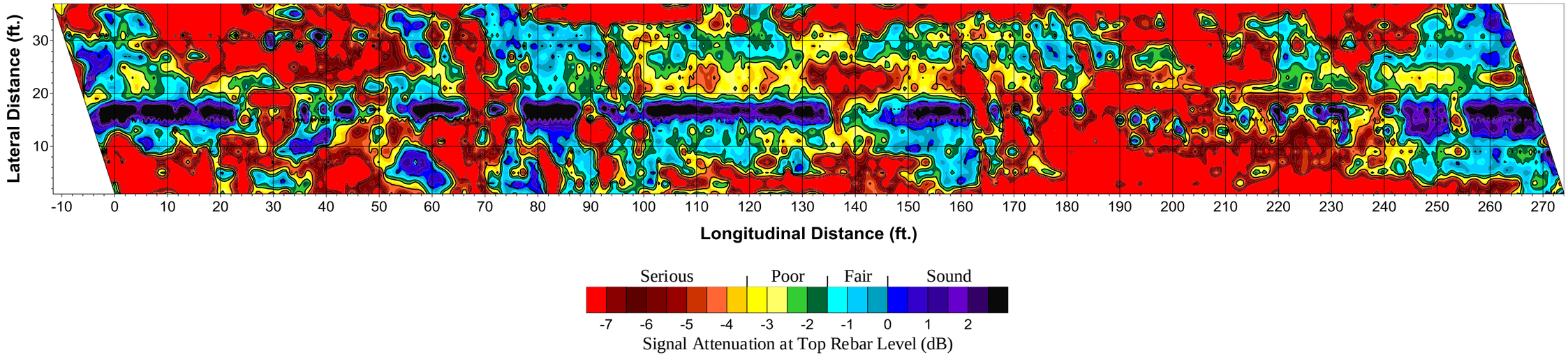

Figure 5. Map of signal attenuation and deck condition of bridge no. 000000000014178

Table 6. Overall deck condition of the surveyed section of bridge no. 000000000014178: percentage of deck area in various states of condition

Survey Method	Condition Rating	Distribution (%)			
		Good	Fair	Poor	Serious
Manual	33.4	11	19	22	48

3. BRIDGE NO. 000000000014180

3.1. Delamination Condition Surveyed by Impact Echo

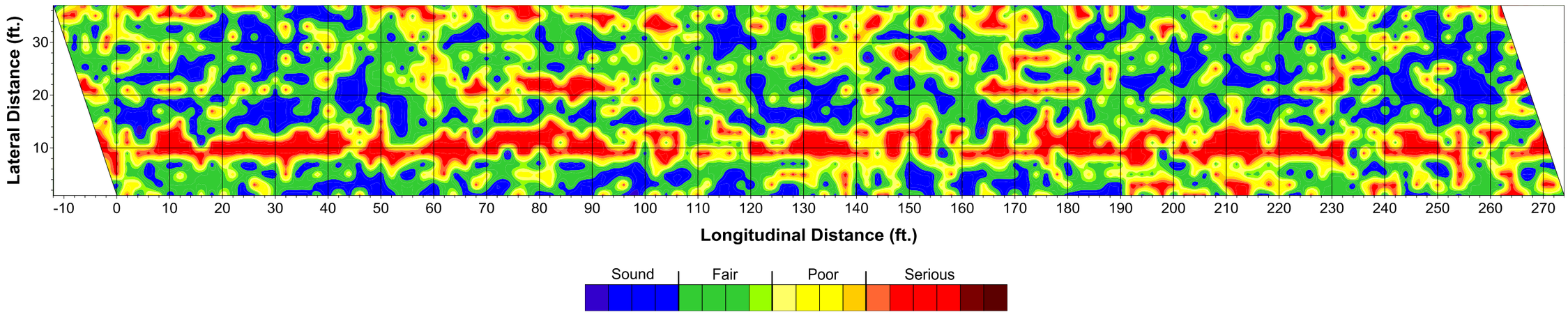

Figure 6. Delamination condition map of bridge no. 000000000014180

Table 7. Delamination assessment of the surveyed sections of bridge no. 000000000014180: percentage of deck area in various states of delamination

Survey Method	Condition Rating	Distribution (%)			
		Good	Fair	Poor	Serious
Manual	52.1	28	34	14	24

3.2. Concrete Modulus Surveyed by Ultrasonic Surface Wave

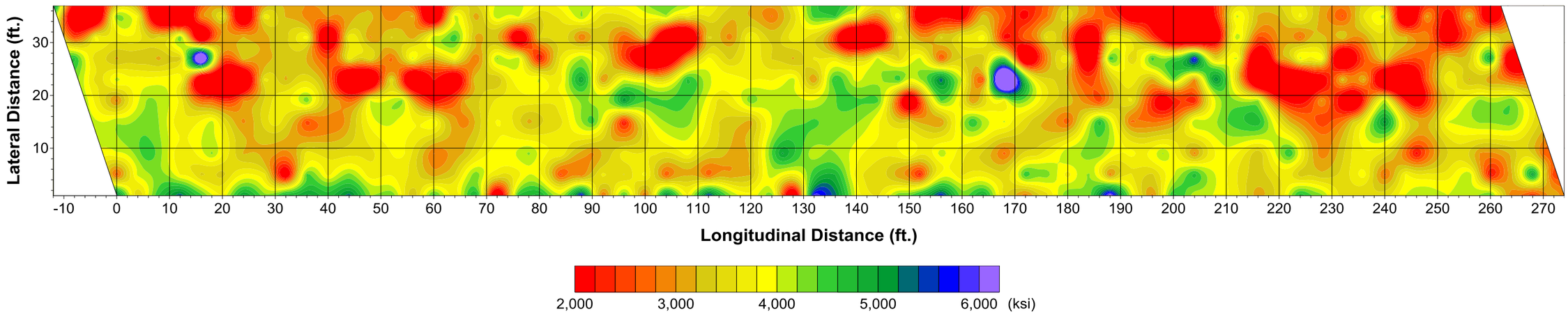

Figure 7. Concrete modulus map of bridge no. 000000000014180

Table 8. Concrete quality assessment of the surveyed sections of bridge no. 000000000014180: average modulus and modulus variability

Survey Method	Distribution (%)			Mean *E* (ksi)	Standard Deviation (ksi)
	< 3,500 ksi	3,500 - 4,500 ksi	> 4,500 ksi		
Manual	48	41	11	3,514	1,582

3.3. Corrosion Rate Surveyed by Electrical Resistivity

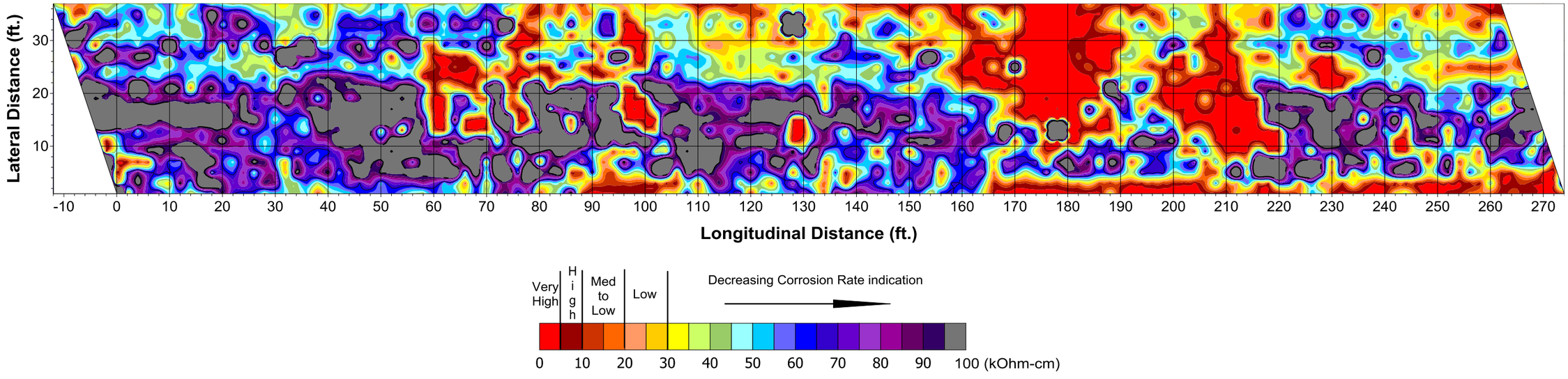

Figure 8. Map of electrical resistivity and expected corrosion rates of bridge no. 000000000014180

Table 9. Corrosion assessment of the surveyed sections of bridge no. 000000000014180: percentage of deck area with various corrosion rates

Survey Method	Condition Rating	Distribution (%)			
		High	Moderate	Low	Very Low
Manual	72.1	20	8	12	61

3.4. Overall Deck Condition Surveyed by Ground Penetrating Radar

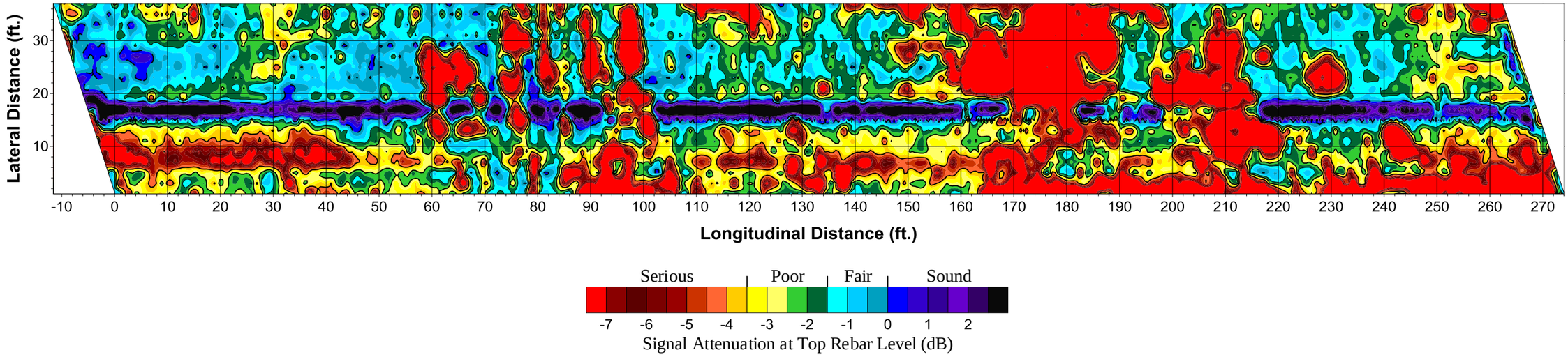

Figure 9. Map of signal attenuation and deck condition of bridge no. 000000000014180

Table 10. Overall deck condition of the surveyed section of bridge no. 000000000014180: percentage of deck area in various states of condition

Survey Method	Condition Rating	Distribution (%)			
		Good	Fair	Poor	Serious
Manual	40.6	12	22	33	33

4. BRIDGE NO. 000000000014216

4.1. Delamination Condition Surveyed by Impact Echo

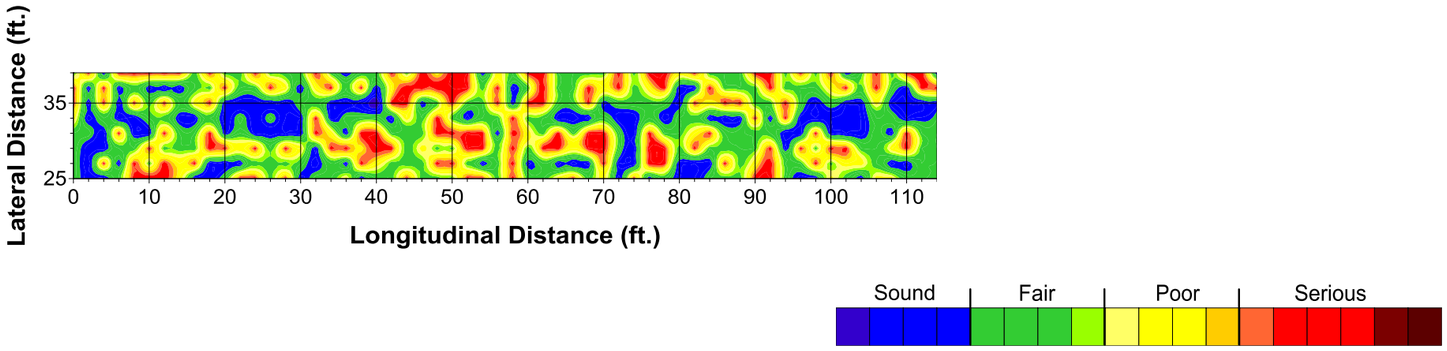

Figure 10. Delamination condition map of bridge no. 000000000014216

Table 11. Delamination assessment of the surveyed sections of bridge no. 000000000014216: percentage of deck area in various states of delamination

Survey Method	Condition Rating	Distribution (%)			
		Good	Fair	Poor	Serious
Manual	47.9	26	36	8	30

4.2. Concrete Modulus Surveyed by Ultrasonic Surface Wave

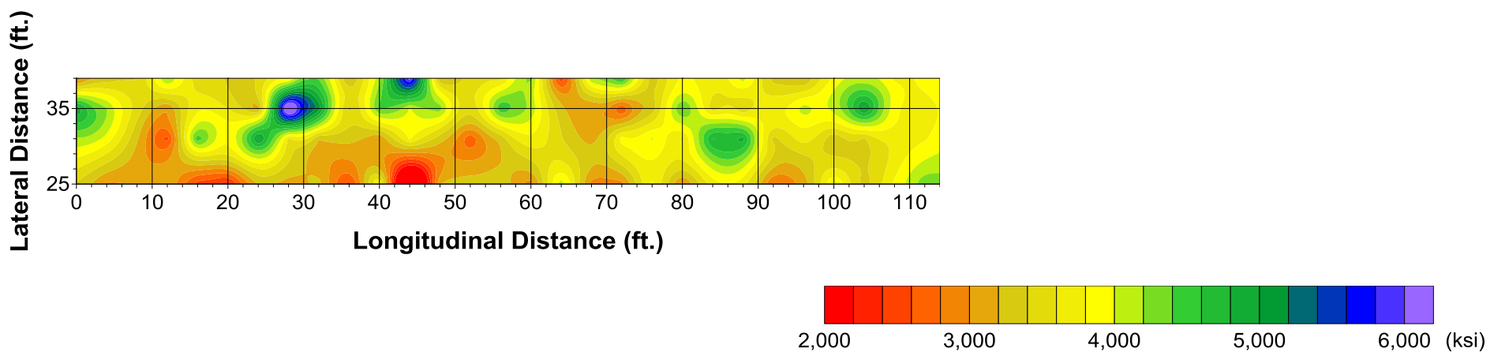

Figure 11. Concrete modulus map of bridge no. 000000000014216

Table 12. Concrete quality assessment of the surveyed sections of bridge no. 000000000014216: average modulus and modulus variability

Survey Method	Distribution (%)			Mean *E* (ksi)	Standard Deviation (ksi)
	< 3,500 ksi	3,500 - 4,500 ksi	> 4,500 ksi		
Manual	50	41	10	3,625	764

4.3. Corrosion Rate Surveyed by Electrical Resistivity

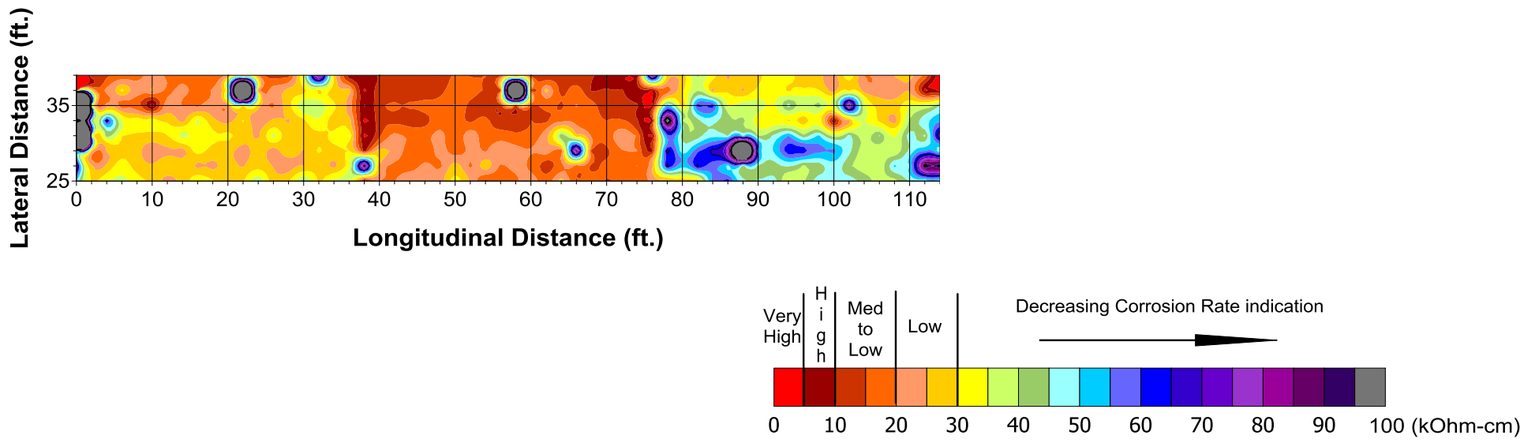

Figure 12. Map of electrical resistivity and expected corrosion rates of bridge no. 000000000014216

Table 13. Corrosion assessment of the surveyed sections of bridge no. 000000000014216: percentage of deck area with various corrosion rates

Survey Method	Condition Rating	Distribution (%)			
		High	Moderate	Low	Very Low
Manual	59.0	6	43	31	20

4.4. Overall Deck Condition Surveyed by Ground Penetrating Radar

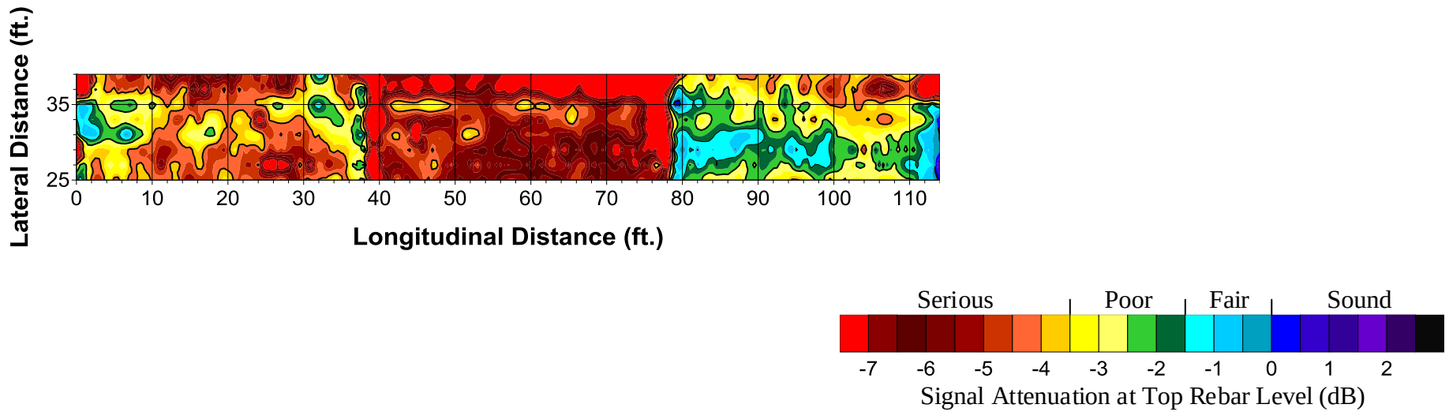

Figure 13. Map of signal attenuation and deck condition of bridge no. 000000000014216

Table 14. Overall deck condition of the surveyed section of bridge no. 000000000014216: percentage of deck area in various states of condition

Survey Method	Condition Rating	Distribution (%)			
		Good	Fair	Poor	Serious
Manual	15.8	1	7	26	67

5. BRIDGE NO. 000000000014218

5.1. Delamination Condition Surveyed by Impact Echo

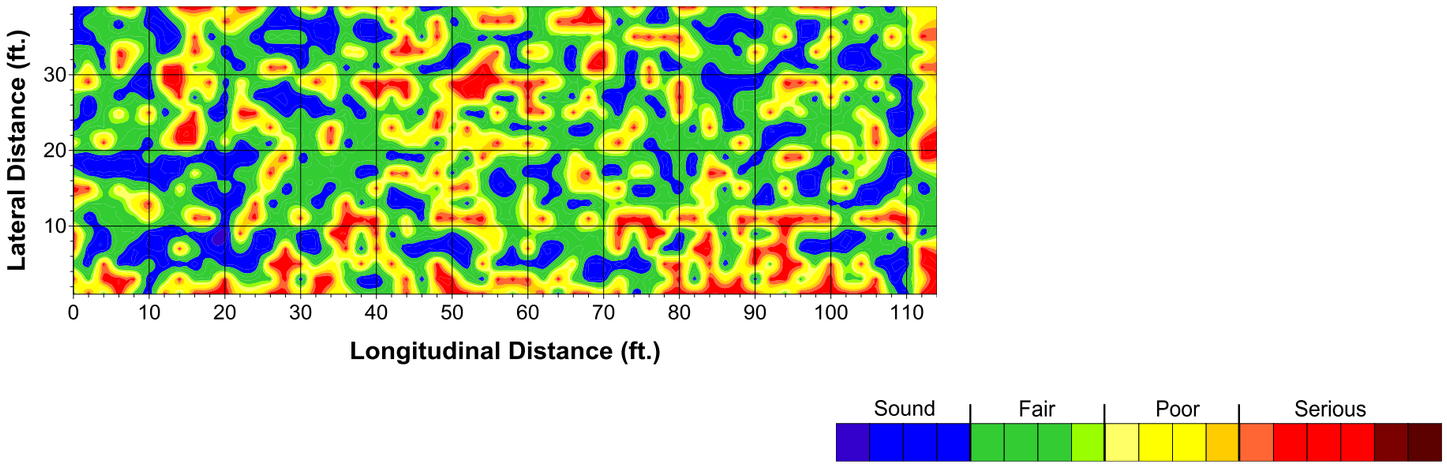

Figure 14. Delamination condition map of bridge no. 000000000014218

Table 15. Delamination assessment of the surveyed sections of bridge no. 000000000014218: percentage of deck area in various states of delamination

Survey Method	Condition Rating	Distribution (%)			
		Good	Fair	Poor	Serious
Manual	53.1	30	35	11	24

5.2. Concrete Modulus Surveyed by Ultrasonic Surface Wave

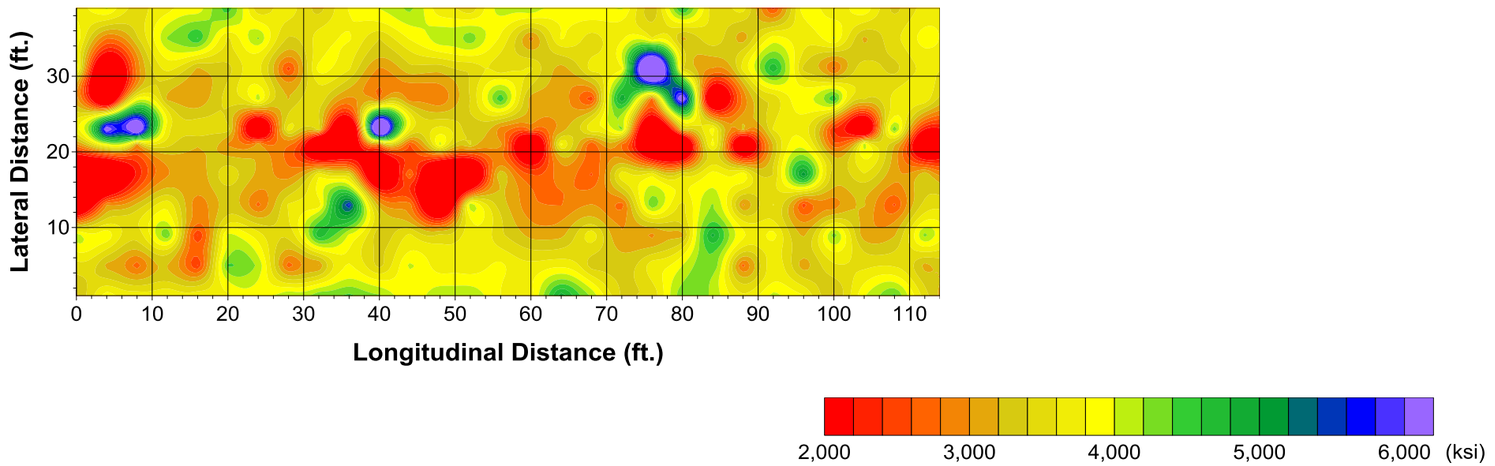

Figure 15. Concrete modulus map of bridge no. 000000000014218

Table 16. Concrete quality assessment of the surveyed sections of bridge no. 000000000014218: average modulus and modulus variability

Survey Method	Distribution (%)			Mean *E* (ksi)	Standard Deviation (ksi)
	< 3,500 ksi	3,500 - 4,500 ksi	> 4,500 ksi		
Manual	48	45	6	3,638	1,016

5.3. Corrosion Rate Surveyed by Electrical Resistivity

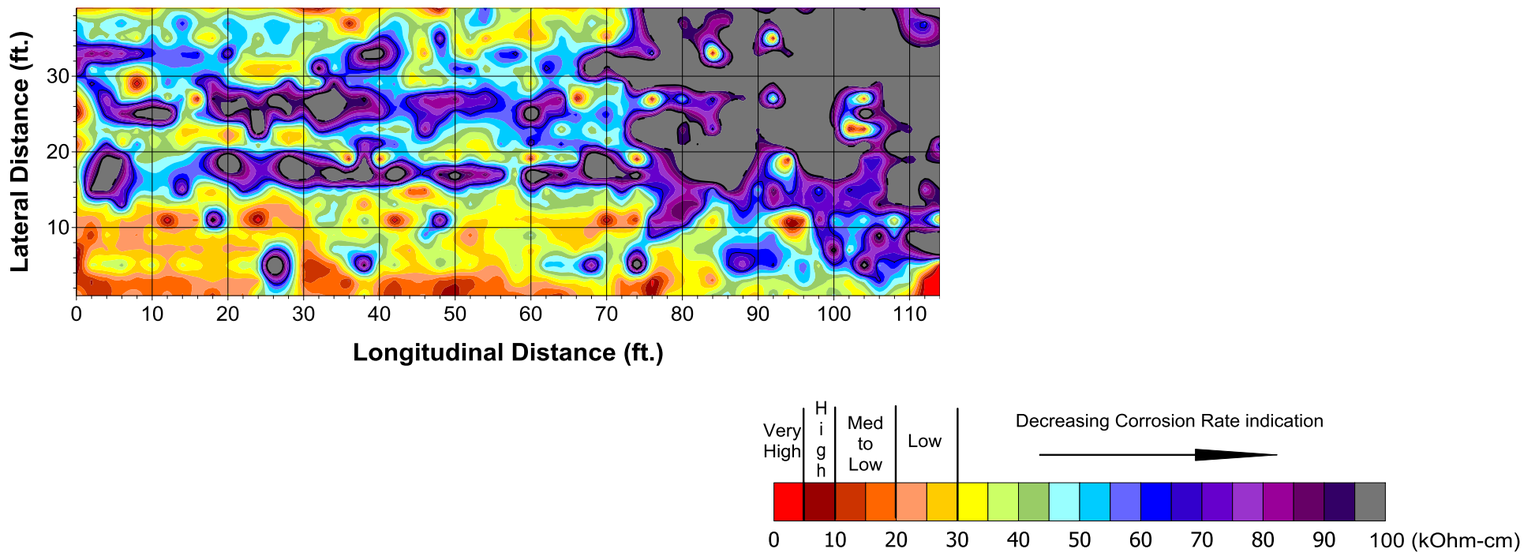

Figure 16. Map of electrical resistivity and expected corrosion rates of bridge no. 000000000014218

Table 17. Corrosion assessment of the surveyed sections of bridge no. 000000000014218: percentage of deck area with various corrosion rates

Survey Method	Condition Rating	Distribution (%)			
		High	Moderate	Low	Very Low
Manual	82.2	4	12	24	61

5.4. Overall Deck Condition Surveyed by Ground Penetrating Radar

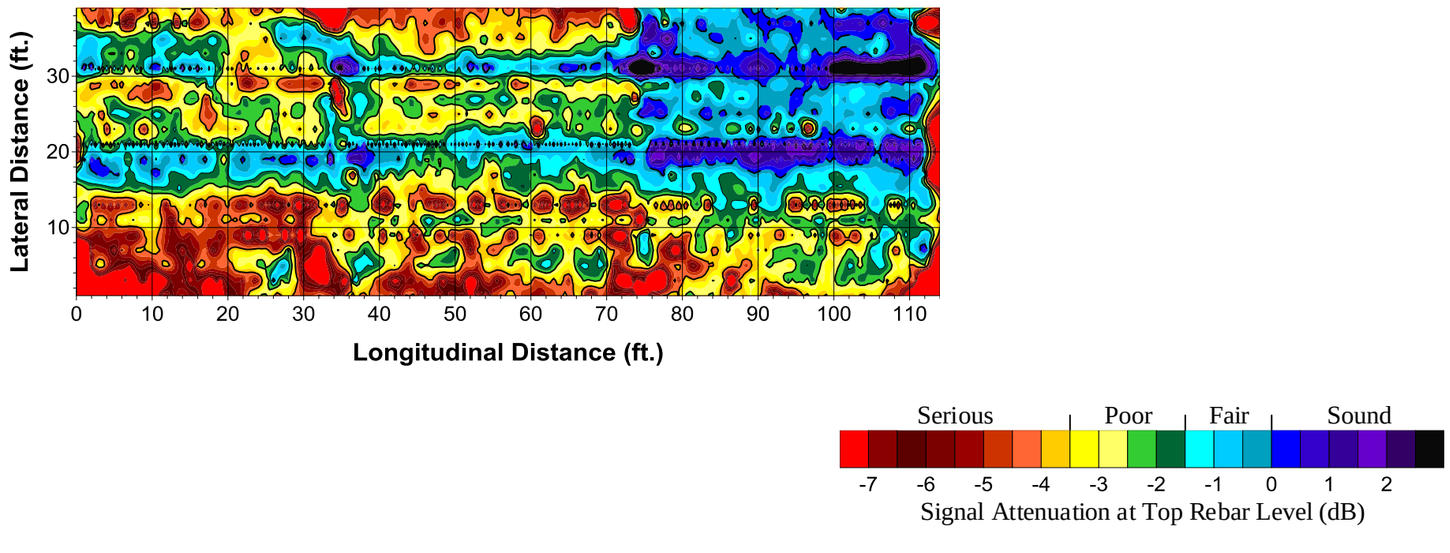

Figure 17. Map of signal attenuation and deck condition of bridge no. 000000000014218

Table 18. Overall deck condition of the surveyed section of bridge no. 000000000014218: percentage of deck area in various states of condition

Survey Method	Condition Rating	Distribution (%)			
		Good	Fair	Poor	Serious
Manual	40.3	14	18	36	33