Condition Evaluation of Bridges on the Vermont State Highway System

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Reporting on SPR Project # 6606

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AGENCY OF TRANSPORTATION
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16. Abstract

The Vermont Agency of Transportation, Materials and Research Section's R&D Unit is conducting a State Planning and Research (SPR) funded study to determine the correlation between various testing and other procedures currently in use for analyzing the condition of concrete decks on Vermont bridge structures.

A total of thirty-five bridges have been selected for this study, and twelve of these have been tested to date. This investigation commenced in June 1998 and is expected to take two years to complete, with this interim report documenting the findings of this study to date. It is our intent to determine whether or not a correlation or a pattern exists between corrosion potential testing and analytical chloride analysis. This will provide us with a firm understanding of how chloride values in ppm relate to the half cell values of corrosion potential and delamination potential. This study has been conducted over three phases; Phase 1, consisting of selecting thirty-five bridges that are representative of the current bridges on the state highway system, Phase 2, which consisted of actually surveying and testing the selected bridges, and Phase 3, which dealt with the compilation and analyzation of the data acquired during the survey phase.

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WP 1998-R-7
SPR Project # 6606

INTRODUCTION:

The Vermont Agency of Transportation, Materials and Research Section's R&D Unit is conducting a State Planning and Research (SPR) funded study to determine the effects and degree of chloride intrusion in Vermont bridges. A total of thirty-five bridges have been selected for this study, and twelve of these have been tested as of November 1998. This investigation commenced in June 1998 and is expected to be completed by September 2000, with this interim report documenting the findings of this study thus far.

BACKGROUND:

Steel reinforcing bars are embedded into concrete to provide reinforcement of the concrete. This steel can corrode when it is exposed to high concentrations of chlorides. The adjacent concrete will also be damaged and in some cases, will become delaminated around the rebar. In Vermont, as in other northeastern states, bridges are subjected to deicing salts during the winter months. On average, in Vermont, 250 to 500 pounds of salt is used per lane mile, during a single snow event. Over time the chloride from these salts will seep into the concrete bridge structures. Much of the chloride will bind to the cement paste and aggregates (bound chlorides), and the remaining chloride (free chloride) will continue to penetrate down into the bridge surface.

When cement samples are extracted from bridge decks and analytical laboratory chloride tests are performed on these samples, an attempt is made to determine the total chloride (bound and free chloride) content in the cement in parts per million (ppm). However, in actuality, depending on how deep into the bridge deck drilling and sample collection occurs, primarily bound chloride may be the product being analyzed, since the free chlorides have seeped further into the bridge deck. Therefore, several samples are collected and tested over the span(s) of a bridge at 1 and $1^1/_2$ inches deep. Samples are collected from both the wheel paths and the curb locations on the deck, which allows evaluation of the overall chloride intrusion of the structure. It has been established by convention that the chloride corrosion threshold is 250-330 ppm. Chloride results above this range are capable of inducing corrosion of the reinforcing steel.

The corrosion potential (or half-cell) survey is a test method that is designed to assess the condition of the rebar in concrete bridge structures. It can detect both the potential of corrosion (readings$\geq$-0.35V), and potential for delamination (readings $\geq$ -0.40V). This test is less invasive than testing for total chlorides in bridge structures. It requires drilling into a bridge deck to locate a piece of the steel rebar within the structure, to which a probe is attached to act as a ground connection. Then readings are taken using the copper sulfate half-cell electrode, which is placed over the reinforcing steel in a pattern that will provide a representation of the entire bridge condition.

An increasing number of bridges on both state and town highways have been treated with membrane waterproofing systems. Typically these membranes are applied on rehabilitated decks, which may or may not still have a significant amount of chloride present in the deck below the repair area. The membrane is designed to arrest the intrusion of any further chlorides into the concrete deck. The presence of these membrane systems has made corrosion potential testing increasingly difficult. Any holes drilled into these decks will damage the membrane, and may make the deck more susceptible to the ingress of chlorides. Therefore, investigation of the use of an alternative half cell method that is less invasive is being initiated.

OBJECTIVE: .

A majority of bridges on the state highway system are inspected every two years by the Structures Section of the Agency. However, a bridge inspection does not include an analysis of corrosion. It is primarily a visual inspection of the bridge's condition. The analytical chloride determinations and the half-cell surveys furnish data that represents the bridge's internal condition in terms of corrosion. The intent is to determine whether or not a correlation or a pattern exists between these two test methods currently available. This will provide a firm understanding of how chloride values in ppm relate to the half cell values of corrosion potential and delamination potential. Results of these methods on thirty-five randomly selected bridges throughout Vermont will be compared. This study is being conducted over three phases, as described below.

CONDUCT OF THE EVALUATION:

Phase 1 consisted of selecting thirty-five bridges that are representative of the current bridges on the state highway system. The initial bridges selected are listed in Table 1. However, depending on various situations that may arise, these bridges are subject to change. At this time, most of the bridges selected are on state highways with a small number located on interstate and town highways. Once these were selected, copies of the most current bridge inspection evaluations available from the Structures Section, were obtained to provide additional data for the evaluations.

TABLE 1

Addison	VT 17, # 4		Essex	VT 128, #3		Randolph	VT12, #42
Alburg	VT 78, #1		Fairfax	VT 128, #8		Royalton	TH 13, #21
Bradford	VT 25, #9		Fayston	VT 17, #35		Rutland	US 7, #103
Berkshire	VT 105, #27		Londonderry	VT 100, #91		Rupert	VT 30, #66
Brighton	VT 111, #12		Lyndon	I-91, #92S		Ryegate	US 302, #40
Bristol	VT 116, #10		Mendon	US 4, #24		Stowe	VT 108, #3
Bristol	VT 116 #11		Morristown	VT 100, #213		Shaftsbury	VT 67, #4
Calais	VT 14, # 74		Montgomery	VT 118, #21		Townshend	VT 30, #15
Castleton	VT4A, #4		N.Springfield	TH 6, #57		Tunbridge	VT 110, #4
Charleston	VT 105, #80		Pawlet	VT30, #70		Waterford	I-93, #5S
Cornwall	VT 125, #9		Poultney	TH 6, #7		Woodford	VT 9, #12
Elmore	VT 12, #91		Poultney	VT 140, #3			

VT = Vermont
TH = Town Highway

Phase 2 consisted of surveying and testing the selected bridges using the following Materials and Research test procedures:

MRD 41-88	Method of Test for Determining Corrosion Activity in Reinforced Concrete.
MRD 47	Vermont Method for Determination of Total Chloride Ion Content in Cementitious Material.

MRD 41-88 is a test method that evaluates the conductivity over a bridge deck and allows for the determination of the extent of rebar corrosion. MRD 47 consists of testing for chlorides in cement powder, which was sampled at curb and wheel path locations on the bridge.

Phase 3 consists of compiling and analyzing the data acquired.

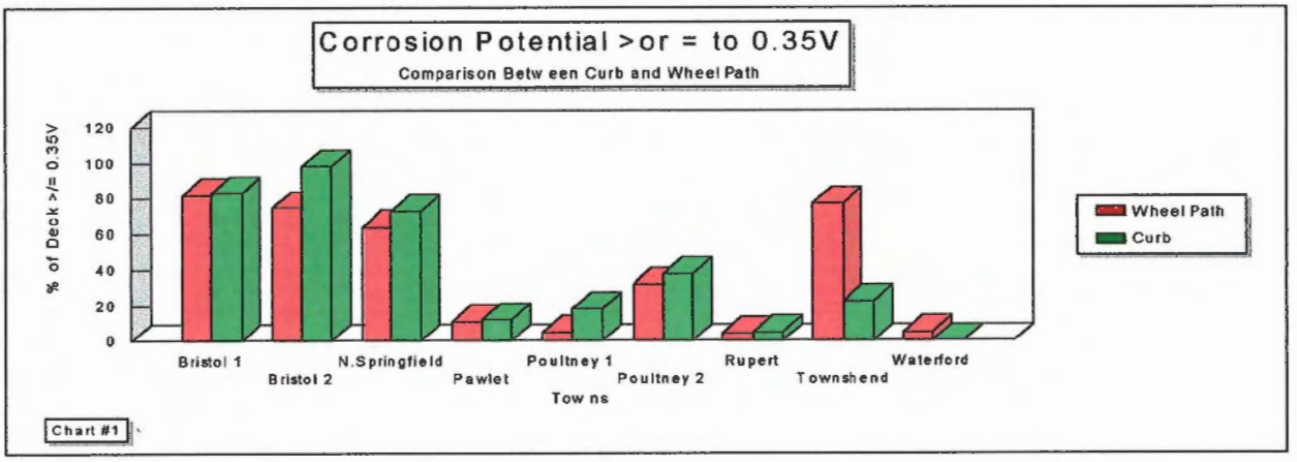
Table 2 shows the results of these tests for the twelve bridges surveyed in 1998. Those bridges on which steel could not be located or cement powder sampled will be retested or resampled in 1999.

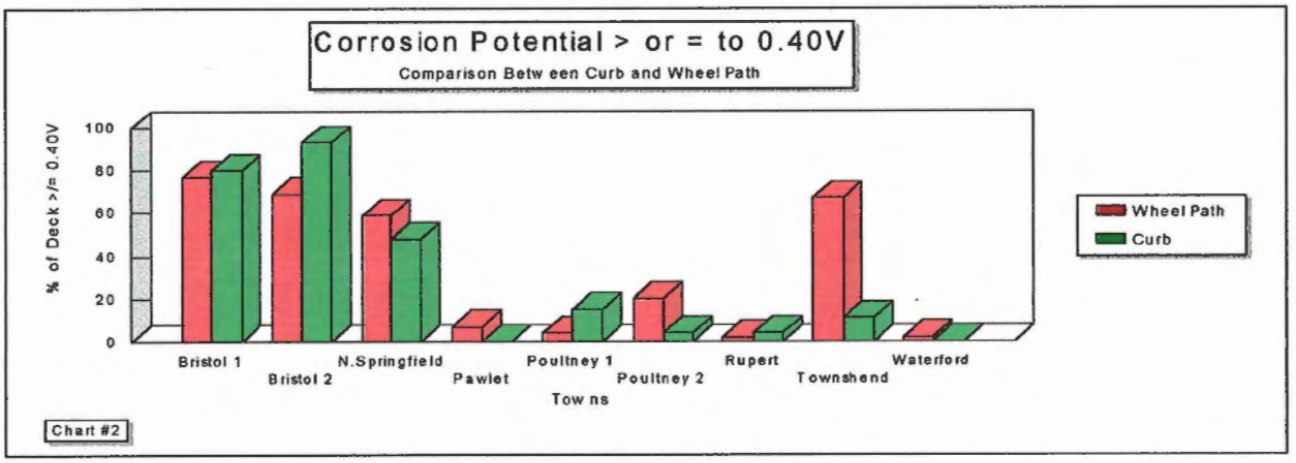
TABLE 2

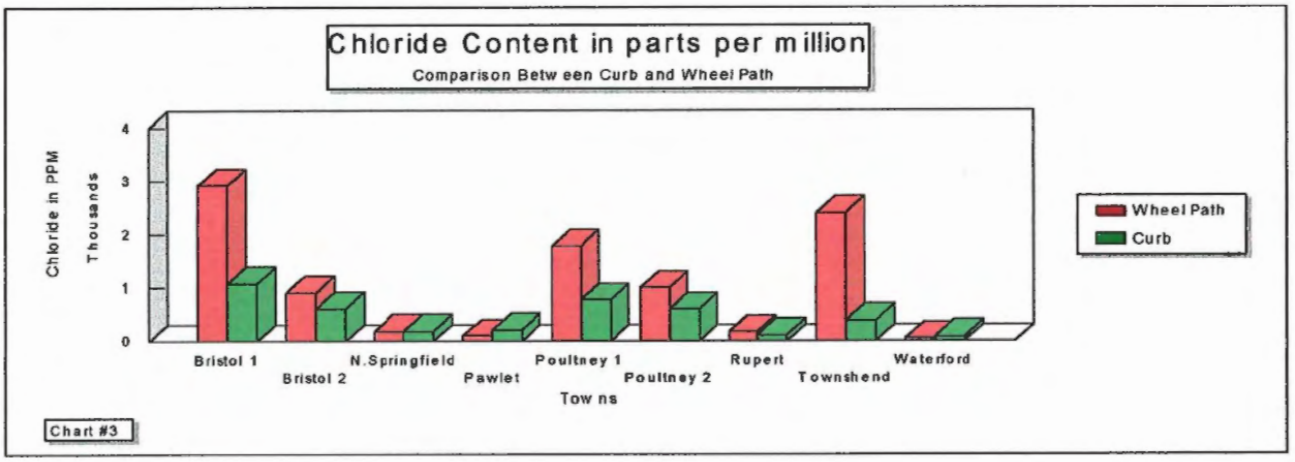
Bridge Identification	Year Constructed	Type of Structure	Average Corrosion Activity %-0.35V	Average Corrosion Activity %-0.40V	Average Curb Corrosion Activity % -0.35V/-0.40V		Average WP Corrosion Activity % -0.35V/-0.40V		Average CT parts per million (ppm) Curb	Average CT parts per million (ppm) Wheel Path
Bristol VT 116, #10	1927	Concrete T-Beam	83%	77%	83%	80%	82%	77%	1075	2909
Bristol VT 116 #11	1926	Concrete T-Beam	72%	66%	98%	93%	75%	69%	606	899
Londonderry VT 100, #91	1934	Concrete T-Beam	Unable to locate steel	Unable to locate steel	N/A	N/A	N/A	N/A	1294	2297
Montgomery VT 118, #21	1953	Steel Beam	74%	65%	68%	44%	94%	83%	No Sample Acquired	3239
N.Springfield TH 6, #57	1927	Steel Beam	66.5%	55.5%	73%	48%	64%	59%	184	185
Pawlet VT30, #70	1934-1949	Steel Beam	10%	3%	12%	0%	11%	7%	203	96
Poultney TH 6, #7	1925-1968	Steel Pony Truss	8%	1%	18%	15%	5%	4%	769	1777
Poultney VT 140, #3	1934	Concrete T-Beam	33%	15.5%	38%	4%	32%	20%	597	994
Rupert VT 30, #66	1939	Concrete T-Beam	5%	4%	5%	4%	4%	2%	106	169
Ryegate US 302, #40	1965	Steel Beam	3%	1%	0%	0%	7%	2%	No Samples Acquired	No Samples Acquired
Townshend VT 30, #15	1952	Concrete Steel Beam	51%	42%	22%	11%	77%	67%	388	2399
Waterford I-93, #5S	1982	Steel Beam or Girder	2%	1%	0%	0%	5%	2%	81	42

Chloride Threshold Value (250-330 ppm) As of January 11, 1999

Three charts have been designed which represent the wheel path and curb comparisons for each bridge. Chart #1 portrays the percentage of each deck that is undergoing active corrosion, represented by values of 0.35V and greater. Chart #2 shows the percentage of each deck that most likely is exhibiting delamination in the top few inches of concrete, which is represented by values greater than 0.40V. Chart #3 portrays total chloride content of the curb and wheel path in ppm.



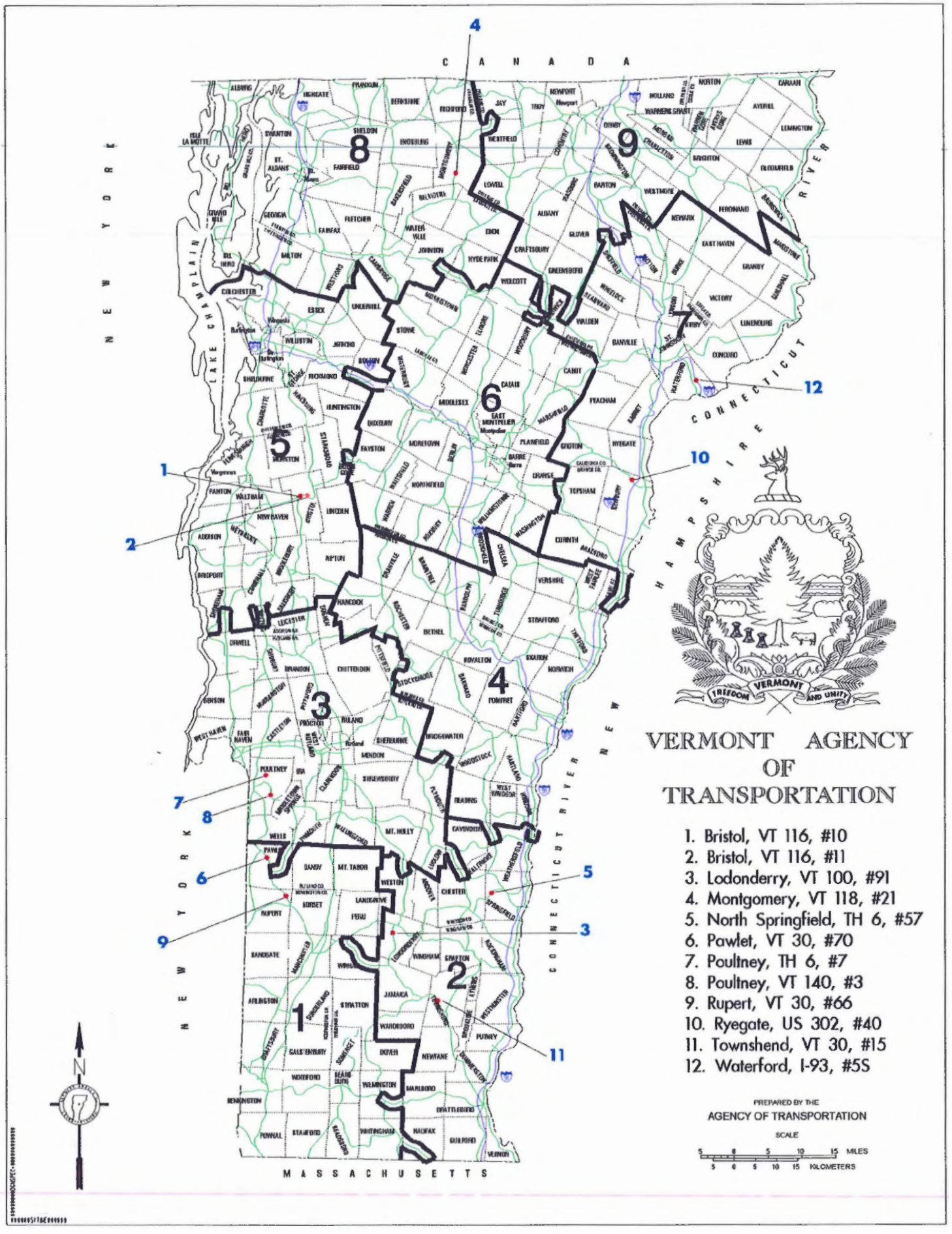




Nine of the twelve bridges surveyed were tested for both chloride content and overall corrosion potential in 1998. Although only a small portion of data has been collected, we have been able to establish that there seems to be some type of correlation between chloride data in ppm and corrosion activity. Bridges with chlorides below the threshold of 330 ppm are exhibiting low corrosion activity percentages of 12% or less. The North Springfield bridge is an outlier to this observation, in that, despite chloride results below the threshold values, high corrosion potential values are present. Additionally, bridges with chloride results between 330 and 1000 ppm generally have a corresponding percentage of corrosion activity of 38% or less. Once again there is an outlier to this observation as well. Bridge #11 in Bristol has chloride results in this range, but is exhibiting high corrosion potentials of 69-98%. In general, results above 1000 ppm have corrosion potentials above 67%, with the exception of Poultney #7, which is exhibiting low corrosion activity values. These observations will need to be re-evaluated as additional bridges are surveyed and results are collected.

FOLLOW UP:

As stated above, the remaining three bridges from 1998 need to have all the tests completed on them prior to September 1999. Approximately twelve more bridges will be selected for testing in 1999. Additional tests, such as ground penetrating radar, may also be incorporated into this project. A final report will be published at the conclusion of this study.



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1. Bristol, VT 116, #10
2. Bristol, VT 116, #11
3. Lodonderry, VT 100, #91
4. Montgomery, VT 118, #21
5. North Springfield, TH 6, #57
6. Pawlet, VT 30, #70
7. Poultney, TH 6, #7
8. Poultney, VT 140, #3
9. Rupert, VT 30, #66
10. Ryegate, US 302, #40
11. Townshend, VT 30, #15
12. Waterford, I-93, #5S

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SCALE

5 0 5 10 15 MILES
5 0 5 10 15 KILOMETERS

Example of a corrosion potential survey in progress

Bristol
VT 116, BR #11

Montgomery
VT 118, BR #21

North Springfield
Main Street, BR #57

North Springfield
Main Street, BR #57
Curb Distress

Poultney
TH 6, BR #7