SD88-04

THE EFFECTS OF INCREASED SALT USAGE ON THE CHLORIDE CONCENTRATION IN SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION BRIDGES AND ROADS

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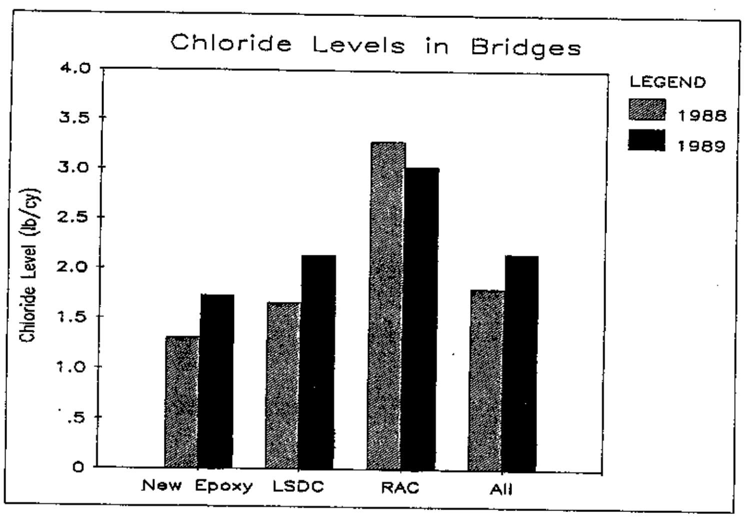
Executive Summary

Due to the concern for public safety during the 1988 Legislative Session, a law (HB 1162) was passed to create a winter safe highway maintenance program which included a special fund to be used for the increased salting of State highways and bridges. Departmental policy and standards were developed to apply more salt for the increased removal of snow and ice. Due to this law and changes in policy, there has been a significant increase in the amount of salt bought by the South Dakota Department Of Transportation (SDDOT). The SDDOT bought 97%, and 144% more salt the first two years after the new policy compared to the year before the new policy. A table showing the amount of salt bought each year since 1972 is shown in Appendix A.

After that legislative action, a project was developed to see what effect the increased use of salt would have on bridges and highways. Fifty-three bridges of three types and 19 sections of highways were sampled. Each of the bridges or highways sections had eight samples removed for analysis. The first samples were taken in the fall of 1988 and the second set of samples ~~were~~ was taken in the summer of 1989. The samples were checked for chloride concentration (pounds per cubic yard) by Atomic Absorption Spectroscopic Analysis. A summary of the results of the project with graphs are shown below.

I. Bridges

A. From 1988 to 1989, the 53 bridges increased in chloride concentration by 19% or 0.35 lbs/cubic yd.



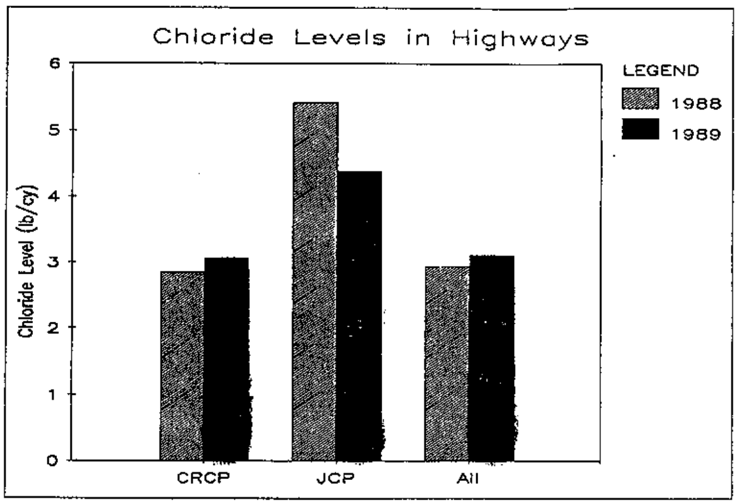
B. Of the 53 bridges, 15 bridges were less than 8 years old and have epoxy coated bars in the top layer of steel. These bridges increased in chloride concentration by 33% or 0.43 lbs/cubic yd.

C. Of the 53 bridges, 28 bridges have Low Slump Dense Concrete Overlays (LSDC). These bridges increased in chloride concentration by 29% or 0.49 lbs/cubic yd.

D. Of the 53 bridges, 8 bridges have a Rubberized Asphalt Chip Seal (RAC) on them. These bridges decreased in concentration by 8% or .25 lbs/cubic yd. However using statistical analysis there is a 1% confidence level that there was a decrease in chloride concentration.

II. Highways

A. From 1988 to 1989, the 19 highway sections increased by 6% or 0.08 lbs/cubic yd. There is only a 65% confidence that there was an increase in chloride concentration.



B. Of the 19 highway sections, 17 were Continuous Reinforced Concrete Pavement (CRCP) sections. These sections increased in chloride concentration by 7% or .21 lbs/cubic yd. There is only a 72% confidence that there was an increase in chloride concentration.

C. Of the 19 highway sections, 2 were Jointed Concrete Pavement (JCP) sections. These sections decreased in chloride concentration by 24% or 1.03 lbs/cubic yd. However by statistical analysis there is a 84% confidence that the means are the same.

Overall three major conclusions can be made from this project.

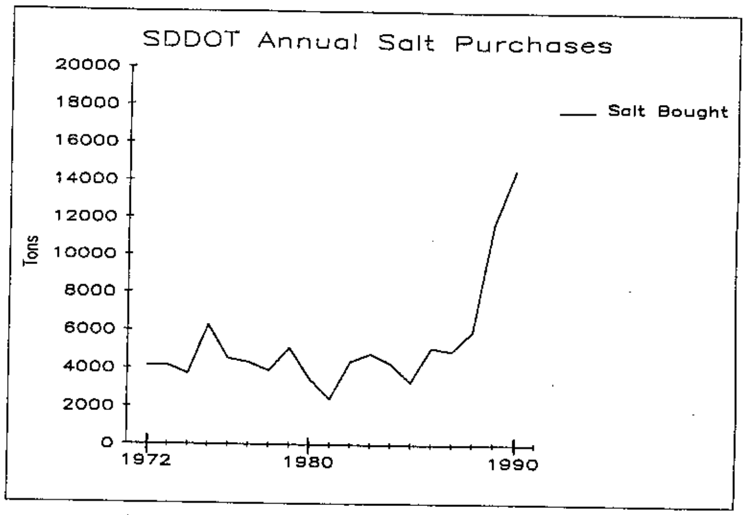
1. The increased use of salt has significantly increased the chloride concentration in the bridges that were tested.

2. The increased use of salt has not led to statistically significant increase in the chloride concentration of the highway sections in the study.

3. The rubberized asphalt chip seals on the bridges which were studied have protected the bridge from new salt penetration. Also the analysis suggests that the chip seal should be applied sooner after the bridge is constructed.

Salt Usage

In fiscal Year 1988, the last year before the new policy, the SDDOT bought 5,974 tons of salt. Fiscal year 1989, the first year after the new program, the SDDOT bought 11,749 tons of salt an increase of 96.67%. Fiscal year 1990, the SDDOT bought 14,606 tons of salt an increase of 144.46% compared to 1988, and an increase of 24.32 % over 1989. A graph showing the amount of salt bought each year since 1972 is shown below. A table showing the amount of salt bought each fiscal year since 1972 is included in Appendix A.



Sampling Program

During the fall of 1988, Mr. Daniel P. Johnston selected 53 bridges and 19 sections of highways to be included in the chloride concentration study. The bridges were of three types, the first being new bridges which have epoxy coated bars used in the top layer of steel. The second type consists of bridges which have been overlayed with Low Slump Dense Concrete. The last type consists of bridges which have a rubberized asphalt chip seal on them. The highway sections consist of two types, the first being Continuous Reinforced Concrete Pavement and the last being Jointed Plain Concrete Pavement.

All the bridges and highways were sampled identically. A hole is drilled with a 3/4 inch drill bit to a depth of approximately 1/4 inch. Then the hole is cleaned with a brush and vacuum cleaner. The hole is then drilled to a depth of approximately 1 inch. The sample is then spooned out into a plastic bag, marked and returned to the laboratory for analysis. The original 1988 samples were collected by Mr. Raymond Rathbun and Mr. Glenn Marrington during the fall of 1988. The 1989 samples were collected by Mr. Raymond Rathbun and interns during the summer of 1989. Samples will be continued to be collected by Mr. Rathbun each summer. There is total of 576 samples collected from all parts of the state.

Samples are stored in the chemical test laboratory until the construction season is completed. The sample is then ground so it passes a #200 screen, then digested in nitric acid, filtered and diluted to 100 milliliters. The sample is added to a bottle with a known amount of silver, and allowed to digest for an hour. The sample is then filtered and tested on the Atomic Absorption (AA) Spectrophotometer for the amount of silver remaining. A calibration chart is then used to determine the chloride concentration. The procedure for the processing of the sample and testing on the AA were developed by Mr. Dale July and myself. All samples were run by Mr. Jerry Schaefer and Mr. Lloyd Simons during the fall months.

A table giving the exact location of all samples with descriptions and results is included in Appendix B. A map showing the location of all samples is also included in Appendix B.

Results

The results are developed from the information collected in 1988 and 1989. Samples will continue to be collect over the next several years. The results will be broken down into three areas consisting of general results, bridge results and highway results.

I. Overall Results

Overall 61.11% of the samples increased, 36.11% decreased, 1.39% of the samples remained the same and 1.39% of the samples were undeterminable. Statistical analysis was applied and this was determined to be a normal distribution of samples. Also statistical theory says around 2/3 of the samples following a direction gives a sound basis for a theory. In this case almost 2/3 of the samples increased in chloride concentration, giving validity to the results of increased chloride concentration. A table giving all the individual results is shown in Appendix B.

II. Bridges

A. Overall from 1988 to 1989, the 53 bridges increased in chloride concentration by 19.45% or 0.3519 lbs/cubic yd. The average chloride concentration in the bridges increased from 1.8099 lbs/cubic yd in 1988 to 2.1618 lbs/cubic yd in 1989. There is a 99.5% confidence that there was an increase in chloride concentration.

B. Of the 53 bridges, 15 bridges were less than 8 years old and the top layer of steel was epoxy coated bars. These bridges increased in chloride concentration by 32.65% or 0.4268 lbs/cubic yd. The average chloride concentration in these bridges increased from 1.3075 lbs/cubic yd in 1988 to 1.7343 lbs/cubic yd in 1989. There is a 96% confidence that there was an increase in chloride concentration.

C. Of the 53 bridges, 28 bridges have Low Slump Dense Concrete Overlays on them. These bridges increased in chloride concentration by 29.29% or 0.4851 lbs/cubic yd. The average chloride concentration increased from 1.656 lbs/cubic yd in 1988 to 2.1411 lbs/cubic yd in 1989. There is a 98% confidence that there was an increase in chloride concentration.

D. Of the 53 bridges, 8 bridges have a Rubberized Asphalt Chip Seal on them. These bridges decreased in chloride concentration by 7.748% or .2546 lbs/cubic yd. However using statistical analysis there is a 1% confidence that there was an decrease in chloride concentration. The average chloride concentration in these bridges decreased from 3.2906 lbs/cubic yd in 1988 to 3.0359 lbs/cubic yd in 1989.

III. Highways

A. Overall from 1988 to 1989, the 19 highway sections increased by 6.16% or 0.0803 lbs/cubic yd. There is only a 65% confidence that there was an increase in chloride concentration. Statistical theory says unless you have a 90% confidence limit then the theory is not very sound. In this case, the increased use of salt has had very little determinable effect on the highway sections. The average chloride concentration in the highway sections increased from 2.9412 lbs/cubic yd in 1988 to 3.1224 lbs/cubic yd in 1989.

B. Of the 19 highway sections, 17 were Continuous Reinforced Concrete Pavement sections. These sections increased in chloride concentration by 7.4% or .211 lbs/cubic yd. There is only a 72% confidence that there was an increase in chloride concentration. The average chloride concentration in these sections increased from 2.8515 lbs/cubic yd in 1988 to 3.0625 lbs/cubic yd in 1989.

C. Of the 19 highway sections, 2 were Jointed Concrete Pavement Sections. These sections decreased in chloride concentration by 23.54% or 1.0313 lbs/cubic yd. However by statistical analysis there is a 84% confidence that the means are the same. The average chloride concentration in these sections decreased from 5.4125 lbs/cubic yd in 1988 to 4.3813 lbs/cubic yd.

Conclusions

From the results and analysis of this study several conclusions can be drawn.

1. There has been a large increase in the amount of salt that is being applied to our highways and bridges.

2. The increased use of salt has significantly increased the chloride concentration of the bridges in this study. This increase is important, because once salt has been introduced into the bridge it is next to impossible to remove it.

3. The rubberized asphalt chip seal on bridges appear to be an effective method of keeping new salt from being introduced into the bridge. But, the bridges which have been chip sealed have a higher level of salt in them then the other bridges, indicating that we could be waiting too long before the bridge is chip sealed. The average age of the bridge before it is chip sealed is 10.5 years, ranging up to 20 years. The number of chip sealed bridges in this study will be expanded next year to get a better correlation.

4. No correlation between age or geographical area could be found using the data. This is probably because of the variability of the weather and the way the maintenance foremen apply the salt.

APPENDIX A - AMOUNT OF SALT BOUGHT BY SDDOT BY FISCAL YEAR SINCE 1972

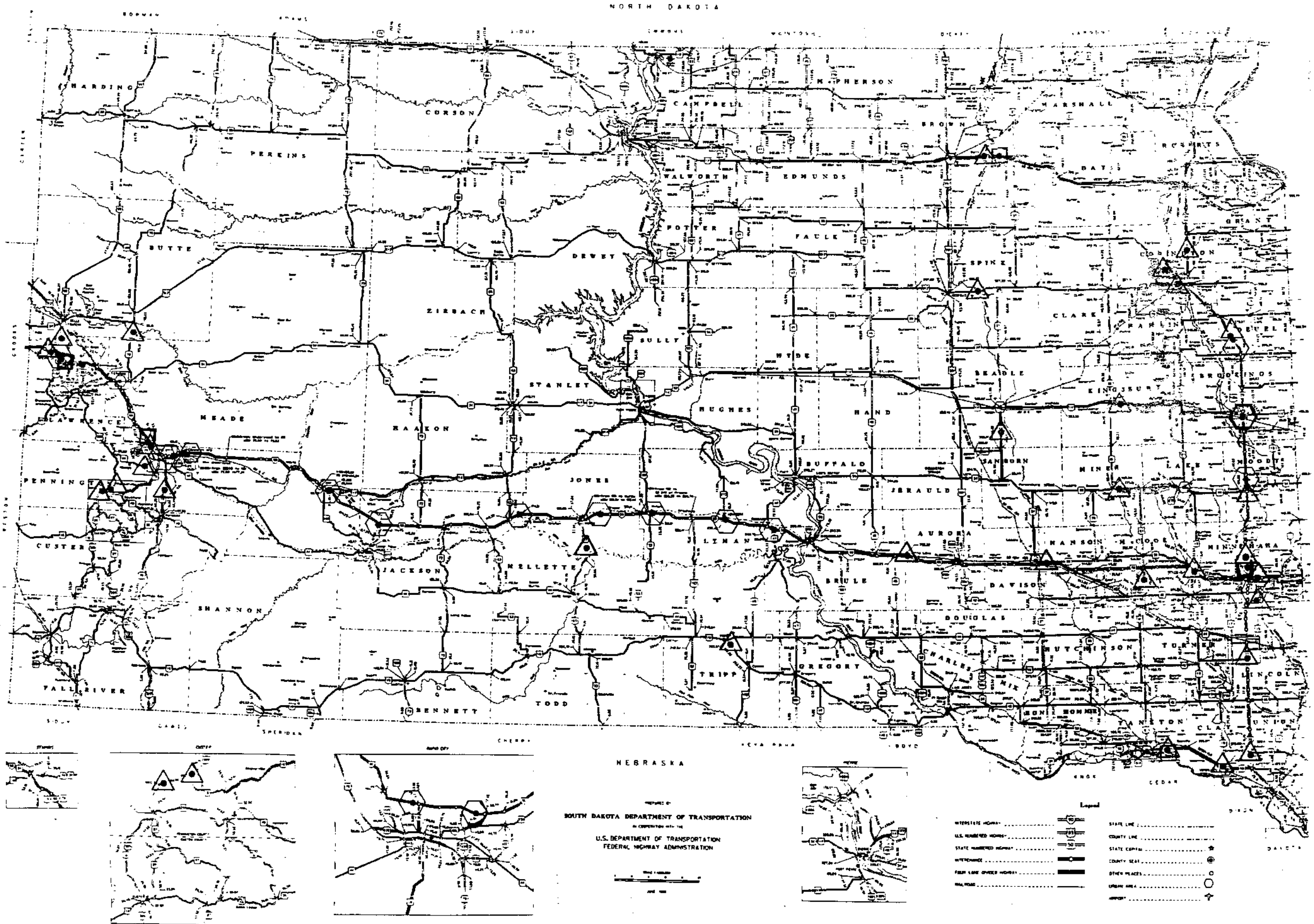
Fiscal Year	Tons of Salt Bought
1972	4,127
1973	4,145
1974	3,705
1975	6,261
1976	4,509
1977	4,320
1978	3,886
1979	5,089
1980	3,471
1981	2,418
1982	4,352
1983	4,777
1984	4,306
1985	3,312
1986	5,121
1987	4,921
1988	5,974
1989	11,749
1990	14,606

APPENDIX B: TABLE OF SAMPLE LOCATION, DESCRIPTION AND RESULTS

Highway	MRM	LANE	Structure No.	YR. Built	Year Improved And Type	1988 Chloride Concentration (lbs/cubic yd)	1989 Chloride Concentration (lbs/cubic yd)
I29	111-132	SB		1968	1968 CRCP	3.8375	4.6750
I29	111-132	NB		1968	1968 CRCP	6.1250	5.7250
I29	133-158	NB		1972	1972 CRCP	1.9750	2.5750
I29	133-158	SB		1972	1972 CRCP	2.9500	3.5000
I29	30.92	SB	64-5-164	1961	1983 LSDC	0.9375	1.2250
I29	30.92	NB	64-6-164	1961	1983 LSDC	1.1750	0.6375
I29	59.74	SB	42-64-166	1960	1983 LSDC	1.1000	1.1750
I29	59.74	NB	42-65-166	1960	1983 LSDC	1.2125	0.8875
I29	90.49	SB	50-175-100	1963	1984 LSDC	0.7875	3.0125
I29	90.49	NB	50-176-100	1963	1984 LSDC	2.1000	1.9750
I29	111.84	SB	51-65-130	1967	1984 LSDC	3.0125	2.1375
I29	111.84	NB	51-66-130	1967	1984 LSDC	0.4413	2.2875
I29	157.63	NB	20-35-220	1973	1986 LSDC	1.3375	1.5875
I29	157.63	SB	20-34-220	1973	1986 LSDC	0.4500	1.6000
I29	188.17	SB	15-215-78	1974	1986 LSDC	0.1500	0.6000
I29	84.92	SB	50-180-155	1962	1982 RACS	6.4125	5.1000
I29	188.17	NB	15-216-78	1974	1986 LSDC	0.2875	0.5750
I29	84.92	NB	50-181-155	1962	1982 RACS	7.3125	6.2125
I90	10.08	WB	41-91-58	1971	1983 RACS	3.1625	3.5750
I90	10.08	EB	41-91-59	1971	1983 RACS	2.2125	3.2625
I90	51.49	WB	47-128-603	1984	1987 RACS	1.5375	1.5000
I90	51.49	EB	47-128-604	1984	1987 RACS	0.8750	0.7375
I90	10-19	WB		1973	1973 CRCP	3.7750	4.6000
I90	10-19	EB		1973	1973 CRCP	2.5875	2.1875
I90	112-131	EB		1974	1974 CRCP	0.3500	0.8500
I90	132-174	EB		1969	1969 CRCP	1.0125	1.2625
I90	132-174	WB		1969	1969 CRCP	1.6125	1.1750
I90	174-198	EB		1970	1970 CRCP	1.3500	3.3250
I90	174-198	WB		1970	1970 CRCP	1.2375	3.1875
I90	57-59	EB		1960	1960 JCP	4.9250	4.3500
I90	57-59	WB		1960	1960 JCP	6.1000	4.6625
I90	61-66	EB		1963	1963 JCP	4.7875	4.1625
I90	61-66	WB		1963	1963 JCP	6.0375	4.6000
I90	213-236	EB		1971	1971 CRCP	2.6875	3.3500
I90	213-236	WB		1971	1971 CRCP	3.2125	3.9000
I90	236-251	WB		1972	1972 CRCP	2.6875	1.4625
I90	236-251	EB		1972	1972 CRCP	2.0500	1.8750
I90	7.02	WB	41-61-56	1974	1985 LSDC	2.9375	1.0750
I90	7.02	EB	41-61-57	1974	1985 LSDC	0.7875	1.9625
I90	53.93	EB	52-383-264	1959	1984 LSDC	4.3375	3.6125
I90	53.93	WB	52-383-263	1973	1984 LSDC	1.1750	2.4125
I90	293.52	EB	2-14-138	1964	1987 LSDC	0.0650	0.9000
I90	293.52	WB	2-14-137	1964	1987 LSDC	2.3250	1.0000
I90	334.54	WB	31-1-106	1967	1987 New Epoxy	0.4500	1.2000
I90	334.54	EB	31-1-107	1967	1988 New Epoxy	0.9125	0.2000
I90	379.66	WB	50-20-141	1964	1987 New Epoxy	0.5250	1.6625
I90	379.66	EB	50-20-142	1964	1987 New Epoxy	0.8625	1.0500

APPENDIX B: TABLE OF SAMPLE LOCATION, DESCRIPTION AND RESULTS

Highway	MRM	LANE	Structure No.	YR. Built	Year Improved And Type	1988 Chloride Concentration (lbs/cubic yd)	1989 Chloride Concentration (lbs/cubic yd)
I90	399.56	EB	50-210-168	1960	1986 LSDC	1.9000	2.3538
I90	399.56	WB	50-210-167	1960	1986 LSDC	1.8750	2.1750
I229	3.12	SB	50-200-233	1985	1985 New Epoxy	1.0875	2.7875
I229	3.12	NB	50-201-233	1985	1985 New Epoxy	1.6000	2.8375
US 12	305.76	WB	7-267-329	1975	1984 RACS	2.4125	2.8750
US 12	301.2	WB	7-222-329	1975	1983 LSDC	0.0000	0.8250
US 14	381.69		39-177-117	1988	1988 New Epoxy	0.4875	0.5750
US 16	42.64		52-256-401	1986	1986 New Epoxy	2.5500	2.5875
US 16	45.16		52-273-394	1985	1985 New Epoxy	2.2750	3.2125
SD 18	254.73		62-215-291	1973	1983 LSDC	1.1000	2.9125
SD 20	395.64		15-156-143	1958	1979 LSDC	0.1625	1.2250
SD 34	366.83		49-168-130	1986	1986 New Epoxy	1.1000	1.8650
SD 37	120.06	NB	3-240-257	1970	1984 LSDC	1.0500	1.4500
SD 37	120.06	SB	3-239-257	1972	1984 LSDC	1.5625	1.5625
SD 40	39.71		52-369-321	1967	1988 LSDC	2.0375	4.1000
SD 50	381.15		68-107-180	1980	1980 New Epoxy	0.3750	1.6875
SD 50	390.05	WB	68-180-199	1976	1981 RACS	2.4000	1.0250
SD 50	390.05	EB	68-180-200	1985	1985 New Epoxy	0.8500	1.6500
SD 79	68.33		52-436-393	1961	1984 LSDC	2.5250	1.7625
SD 79	127.15		10-310-399	1985	1985 New Epoxy	2.7650	1.7250
US 81	54.83		44-110-156	1982	1982 New Epoxy	1.6375	0.5250
US 83	58.86		38-192-284	1956	1986 LSDC		1.2000
US 85	50.15		41-94-100	1986	1986 New Epoxy	2.1250	2.4500
US 212	315.66		58-183-250	1968	1983 LSDC	1.6000	1.2750
US 212	376.59		15-181-180	1960	1974 LSDC	7.9500	12.4750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