WISDOT SALT BRINE PROJECT 2020-2021

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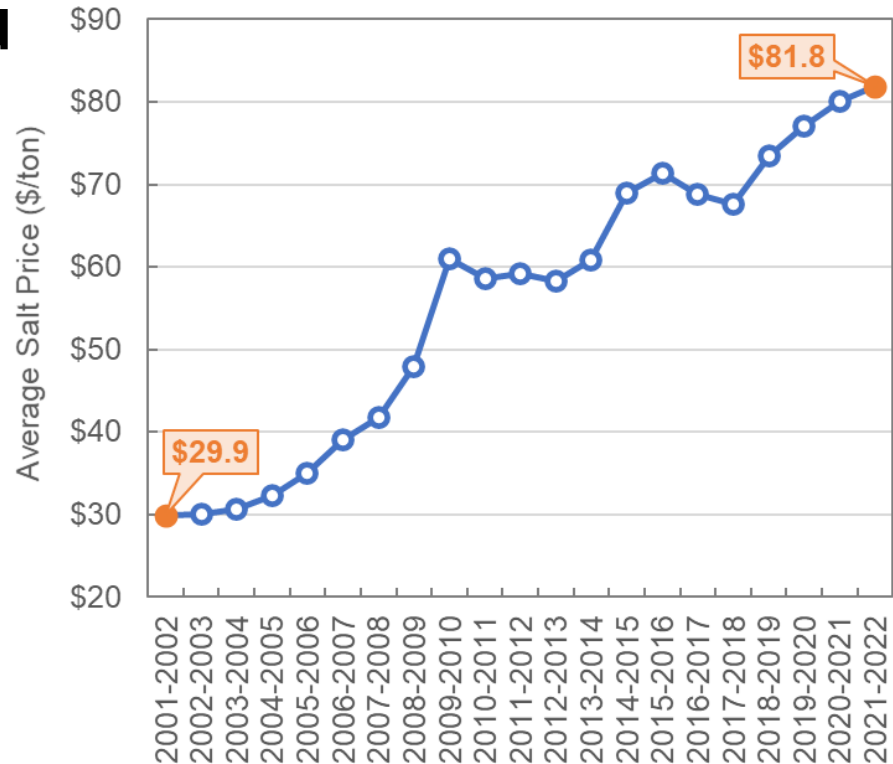**University of Wisconsin – Madison**

Introduction

❖ **Salt has been traditionally used**
- ▪ Public and staff expectation
- ▪ Level of service
- ▪ Experience

❖ **Concerns with salt use**
- ▪ Increasing cost
- ▪ Limited budgets
- ▪ Environmental impacts
  - o Soil, flora, and fauna
  - o Surface and underground water
  - o Human health
  - o Additives

WISCONSIN
T O P S

Introduction

❖ **Wisconsin lakes**
  ▪ 8 lakes illustration
  ▪ Long-term chloride trends
  ▪ Significant urban land cover increase in chloride concentrations
  ▪ Forested landscape stable concentrations

❖ **Conclusive evidence of effect of chlorides**
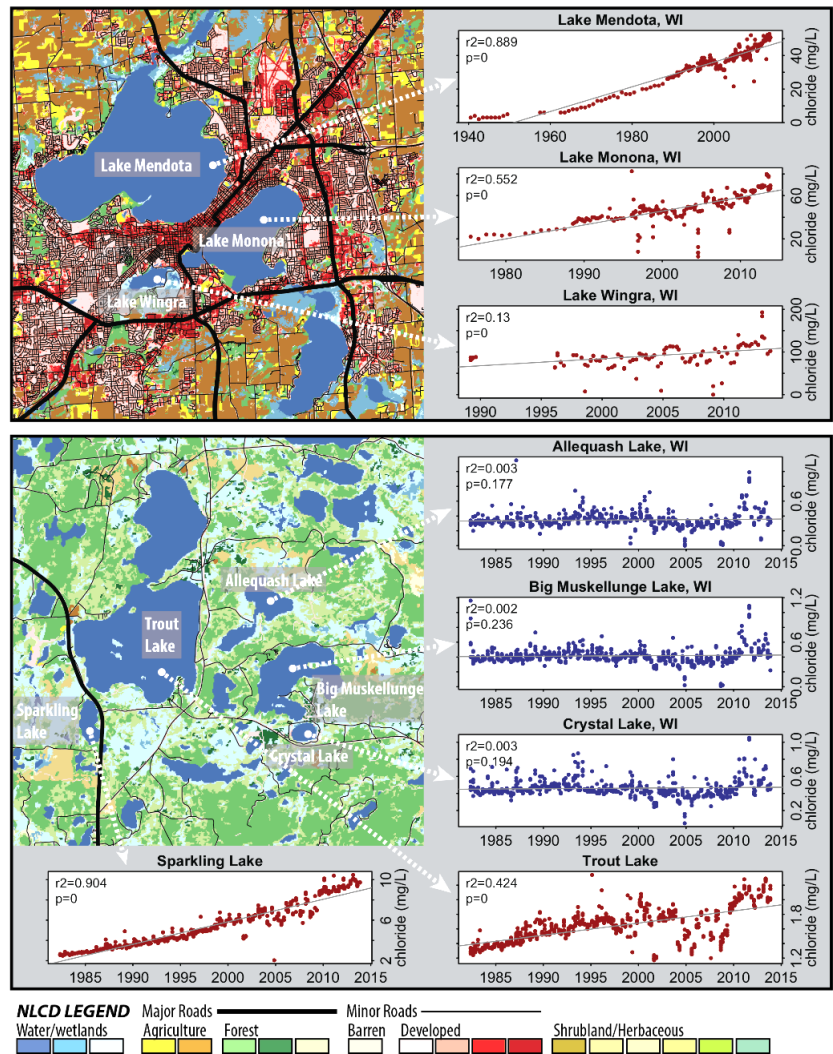 ▪ Water
  ▪ Microorganisms
  ▪ Fish and plants

Image: Dugan 2015

Objectives

- **Expand field data collection from previous research efforts**
- **Evaluate Wisconsin salt brine applications**
  - Salt use
  - Time to bare/wet
  - Pavement friction*
  - Benefit-Cost
- **Comparison of salt brine and solid salt**
  - Winter of 2020-2021
  - Study and control routes
  - Field data collection under same conditions

Methodology

Study Design

❖ **Study in parallel**
- Divided road
- Salt in one direction
- Salt brine opposite direction

❖ **Split study**
- Dividing a route in two sections
- Salt one section
- Salt brine other section

❖ **Independent study**
- Study and control not available in the same area
- Routes with similar conditions may be selected

Methodology

Data Collection

- **Route information**
  - Location, length, number of lanes, start/end
- **Equipment information**
  - Brine makers, storage, trucks, spraying systems, pumps
- **Storm event online report form**
  - Study and control routes
  - Storm information, weather conditions
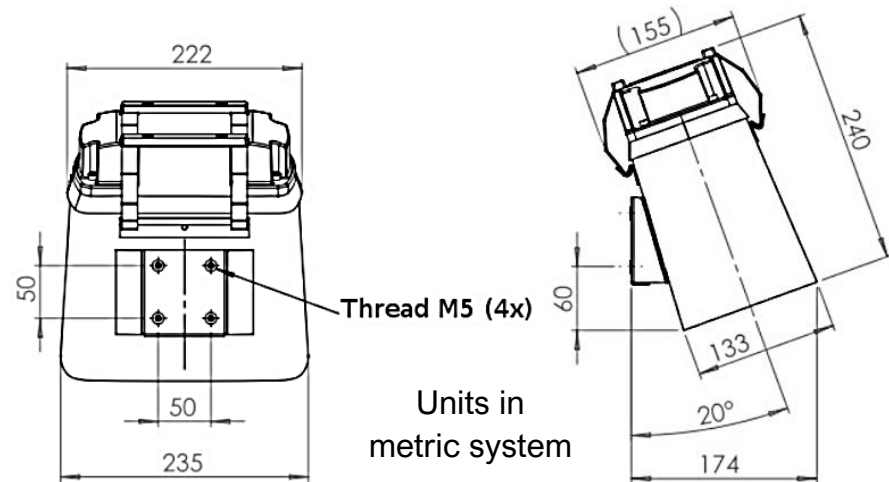 - Materials, quantities, application rates, time to bare/wet
- **Pavement friction***

Methodology

Data Collection

Pavement friction*

Advanced Road Weather Information Sensor (MARWIS)

- Status-LED
- Connection plug
- Temperature-humidity-sensor (exchangeable)
- Pyrometer
- 2 receivers
- 4 transmitters

222

50

50

235

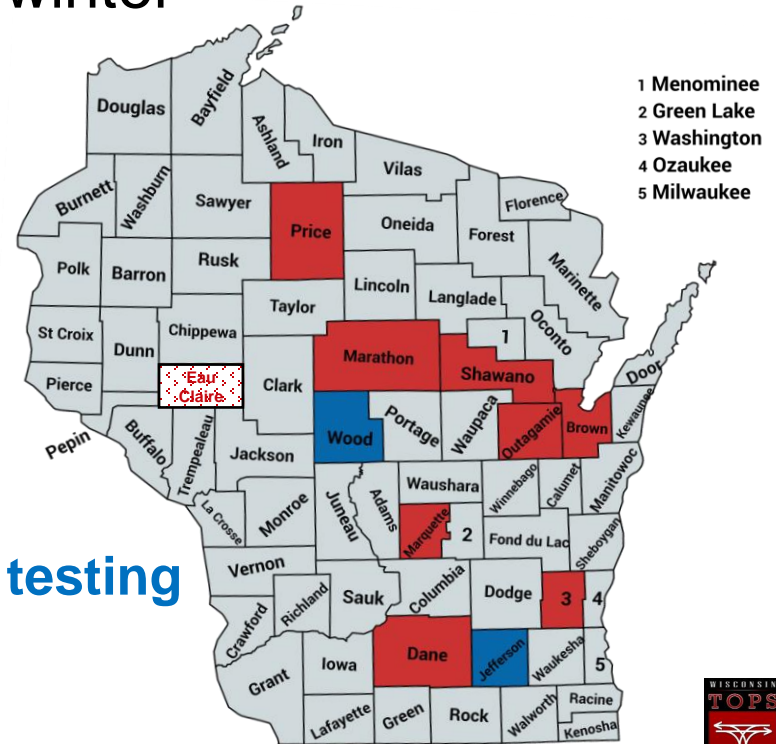Thread M5 (4x)

(155)

240

60

133

20°

174

Units in metric system

Methodology

Data Collection

- Field data collection **2020-2021** winter
- Participation of 11 counties (10 submitted data)

1 Menominee
2 Green Lake
3 Washington
4 Ozaukee
5 Milwaukee

Storm data
Storm data and friction testing
Data not submitted

Methodology

Data Collection

County	Storm Data	Friction Data
	Reports	Runs
Brown	11	
Dane	18	
Jefferson	20	152
Marathon	14	
Marquette	13	
Outagamie	16	
Price	2	
Shawano	18	
Washington	18	
Wood	13	120
Total	**143**	**272**

Methodology

Data Analysis

- **Salt use**
- **Time to bare/wet**
- **Pavement friction* analysis**
- **Benefit-cost analysis**

Methodology

Data Analysis

❖ **Salt use, time to bare/wet, and pavement friction**

▪ Pairwise site and group comparison

▪ T-test to compare site or group observations

❖ **Benefit-Cost**

▪ Cost of salt brine per gallon **was not** estimated

▪ Instead, benefit-cost of introducing salt brine applications into existing solid salt applications

▪ For a horizon of 10 years

Methodology

Data Analysis

Benefit-Cost (B/C)

$$\text{B/C} = \frac{\text{BENEFIT } (\$/\text{ln-mi/storm}) \times \text{SALT BRINE ROUTES } (\text{ln-mi}) \times \text{STORMS } (\text{storms over 10 years})}{\text{COST } (\$ \text{ over 10 years})}$$

Methodology

Data Analysis

Benefit

	Control Route	Study Route	Route
	Solid Salt	**Salt Brine** **Solid Salt**	Material

BENEFIT = ($/ln-mi/storm)

Control Route		Study Route	
Salt		**Salt Water Electricity** / **Salt**	Cost
Trucking		**Trucking**	
Lane-miles Storms	**−**	**Lane-miles Storms**	Coverage
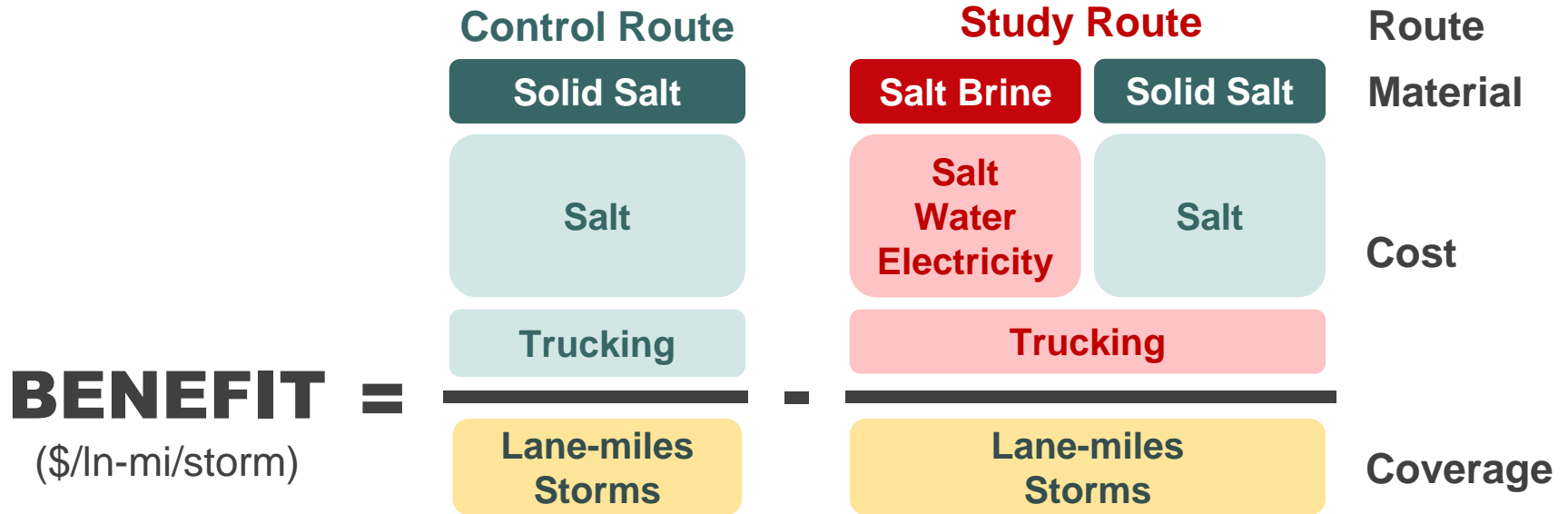
Methodology

Data Analysis

Cost

COST
($ over 10 years)

=

Salt Brine Production
Brine maker **Storage** **Pumps**
Trucks

Salt brine truck ex. $200,000	**-**	**Salt truck** ex. $150,000

Investment per truck ex. $50,000

+

Maintenance over 10 years

Brine maker **Storage** **Pumps**	**Trucks**
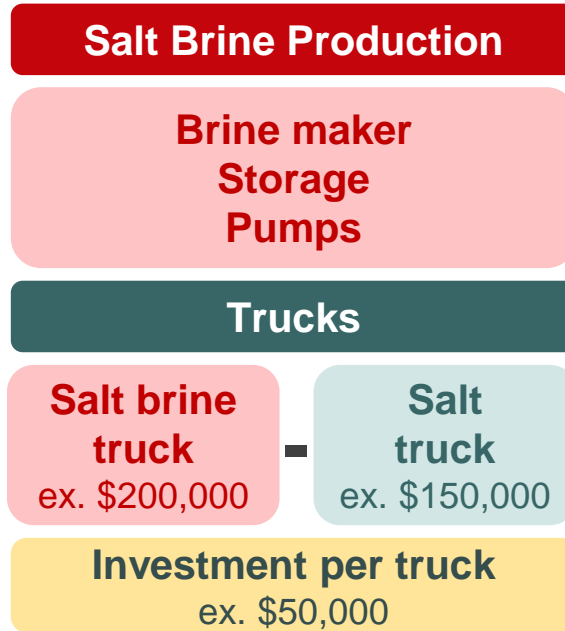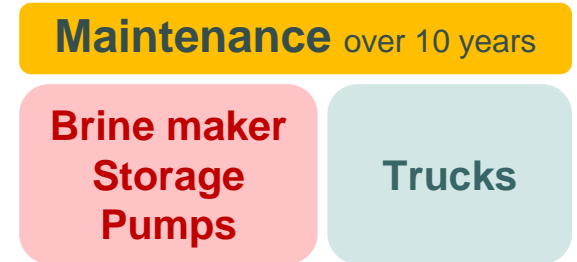
Results

Salt Use

Overall amount of salt used by route

Salt per Lane-Mile (lb)						
County	Storms	Study Routes	Control Routes	Difference		
				Unit	Percentage	p-value
Brown	10	789	1037	249	24.0%	0.085
Jefferson	8	807	1035	229	22.1%	0.265
Marquette	13	356	426	70	16.4%	0.276
Shawano	8	330	463	133	28.8%	0.058
Washington	14	744	944	200	21.2%	0.072
Wood	21	307	420	113	26.8%	0.007
All	**74**	**520**	**675**	**155**	**23.0%**	**< 0.001**

23% reduction of salt

Results

Time to Bare/Wet

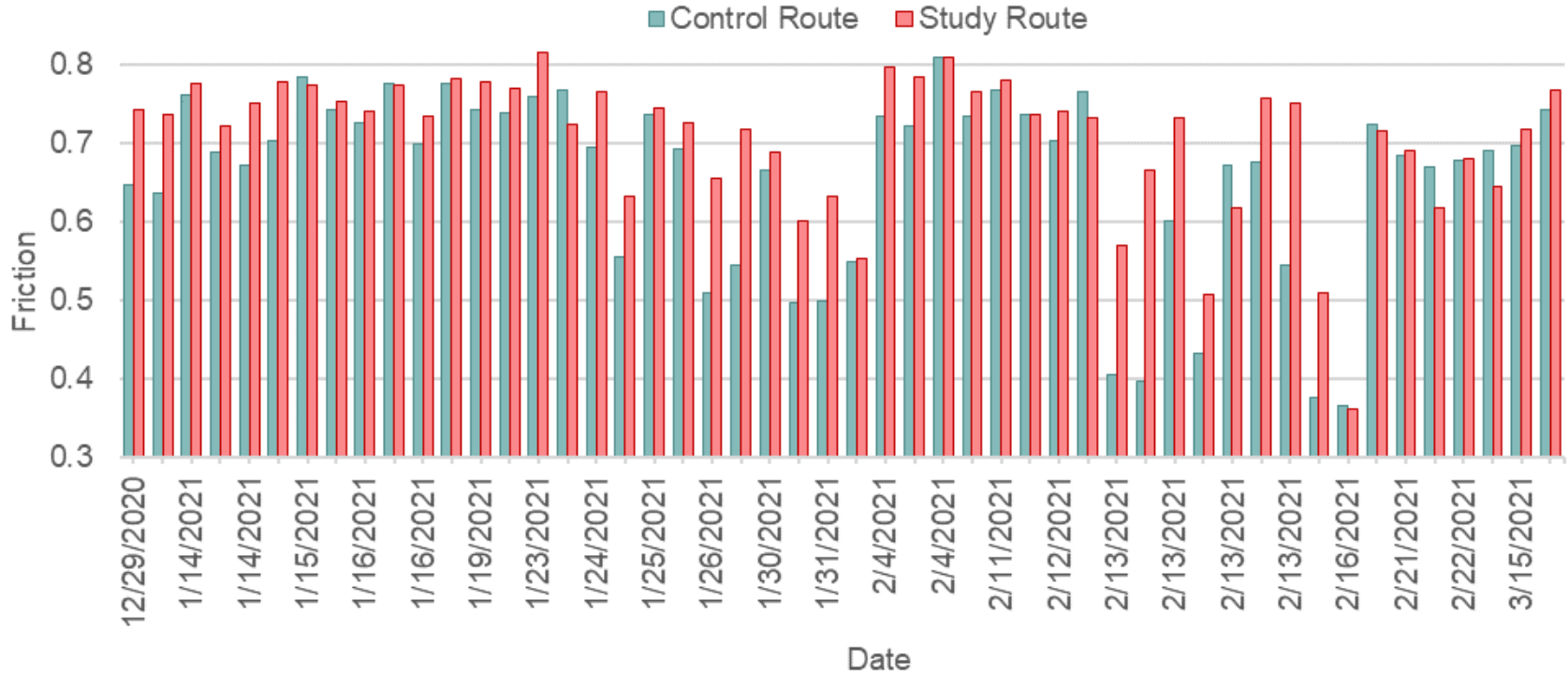| County	Storms	Mean Time to Bare/Wet (hr)		Comparison		
		Study	Control	Difference	%	p-value
Brown	10	24.4	26.3	1.9	7.2	0.078
Jefferson	4	28.0	32.2	4.3	13.2	0.077
Outagamie	12	19.0	22.1	3.1	14.0	0.453
Shawano	8	12.6	13.4	0.8	6.0	0.042
Wood	21	14.0	16.5	2.5	15.2	0.039
All	**55**	**17.8**	**20.2**	**2.4**	**11.9**	**< 0.001**

12% reduction in time to bare/wet

Results
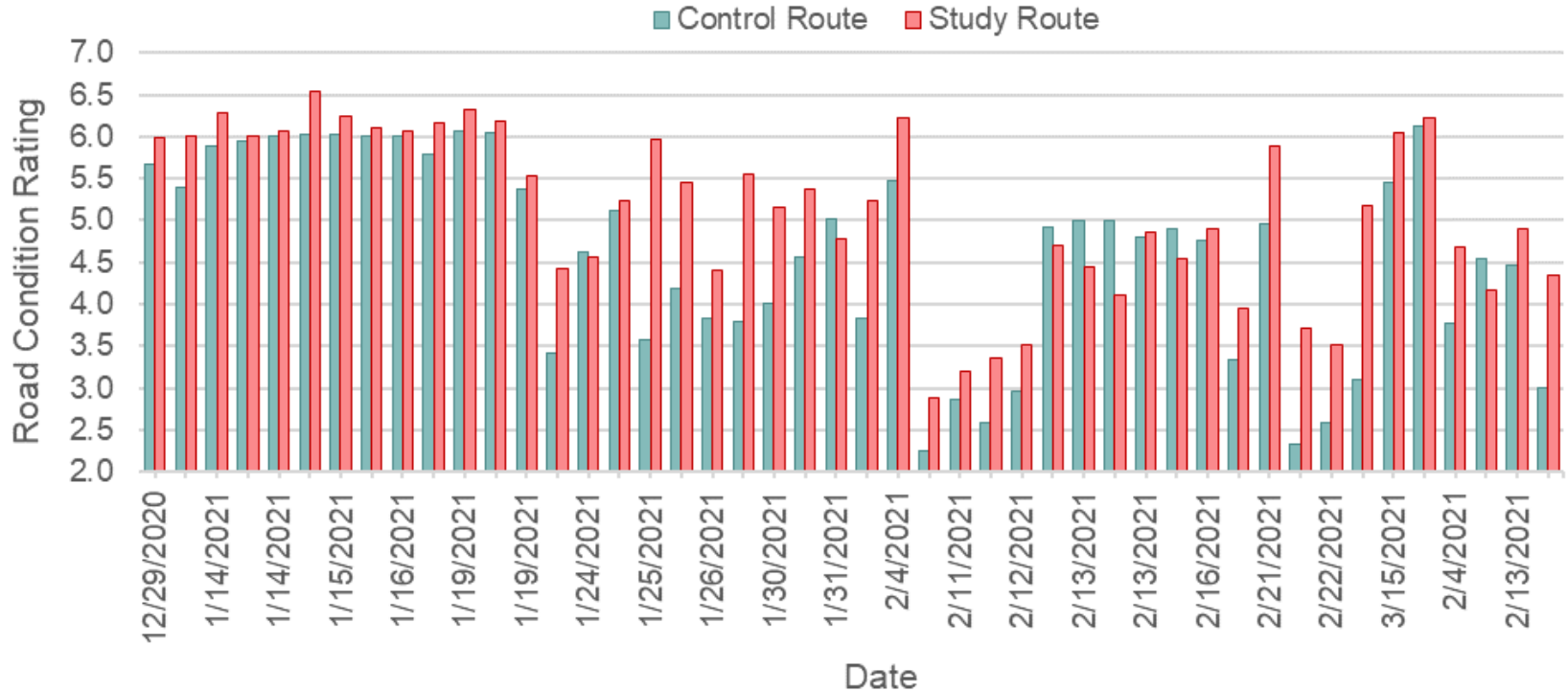## Pavement Friction*

41 out of 50 observations had higher pavement friction

Results

Road Condition Rating

39 out of 46 observations had higher road condition rating

Results

Pavement Friction* and Road Condition Rating

| Description	Mean Pavement Friction	Mean Road Condition Rating
Study Route	0.703	5.339
Control Route	0.651	4.633
Difference	0.052	0.707
% (p-value)	8.1 (0.017)	15.3 (0.002)

❖ **Pavement friction* was 8.1% higher**

❖ **Road condition rating was 15.3% higher**

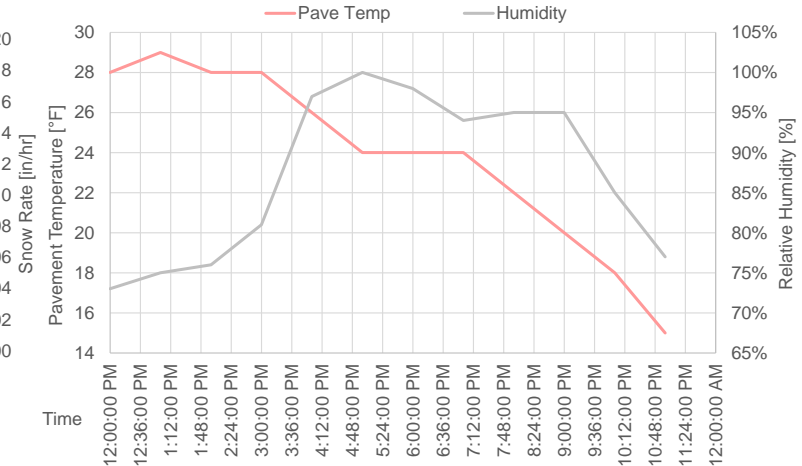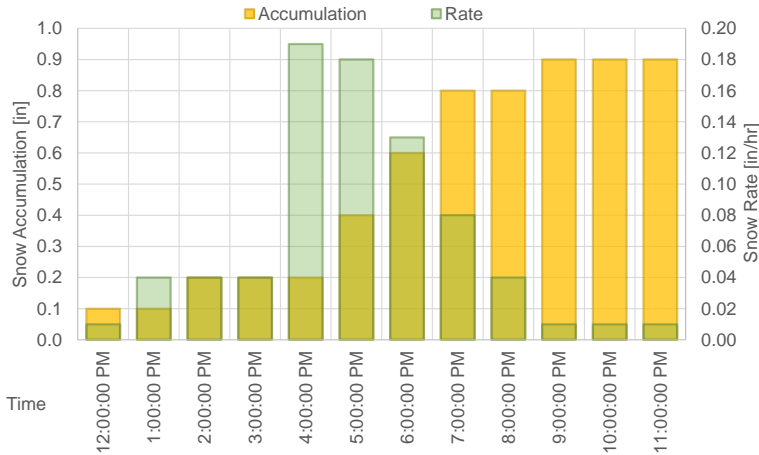# Results Pavement Friction* Time Series

Storow on 01/15/2021

- Relatively warm and steady temperature between 30°F-34°F

- Pavement friction seemed to improve after truck applied material
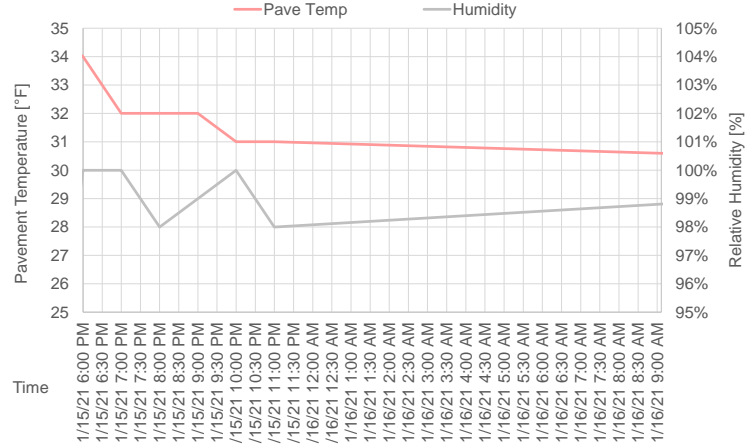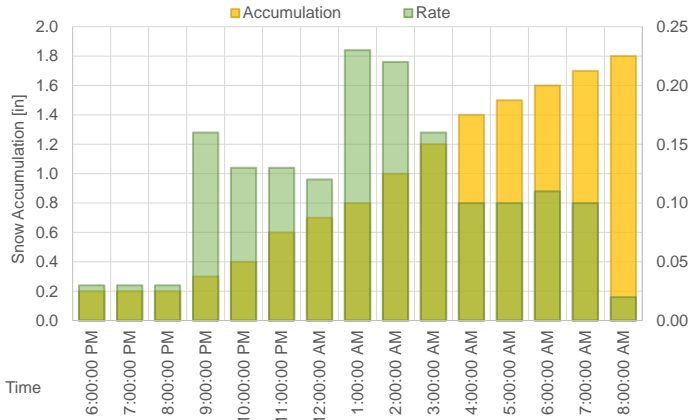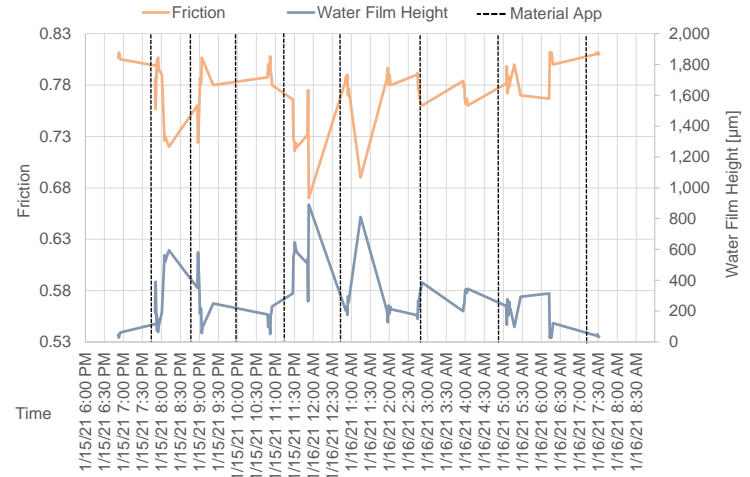
Results Pavement Friction* Time Series

Storm on 01/19/2021

- Variable humidity and dropping temperature from 29°F to 15°F

- Friction is highly correlated to water film height
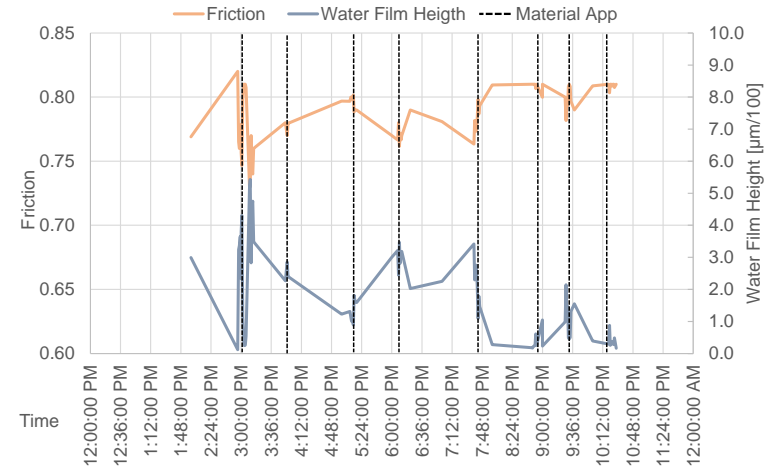
Results **Pavement Friction* Time Series**

Storm on 02/13/2021

- Very low temperature (<3°F)

- Formation of ice (between 1-3 PM)

- Calcium Chloride and solid salt

- Frequent application improved friction and reduced ice %
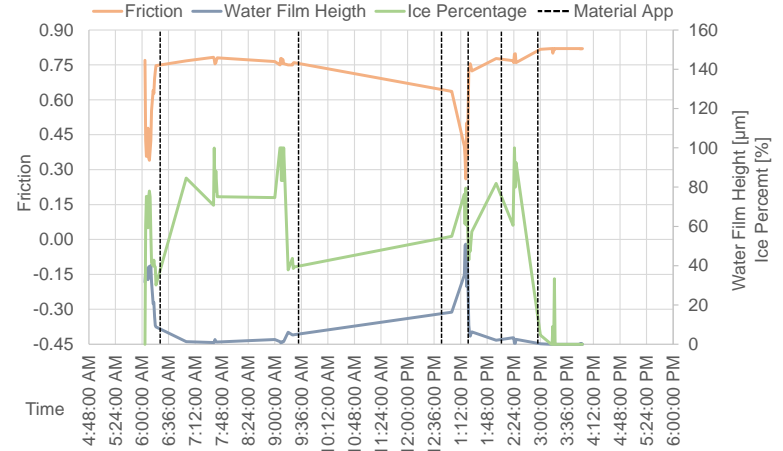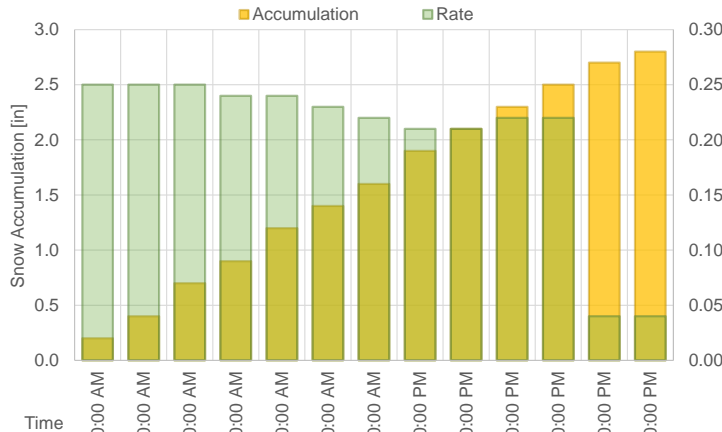
Results

Benefit-Cost (B/C)

Benefit by storm
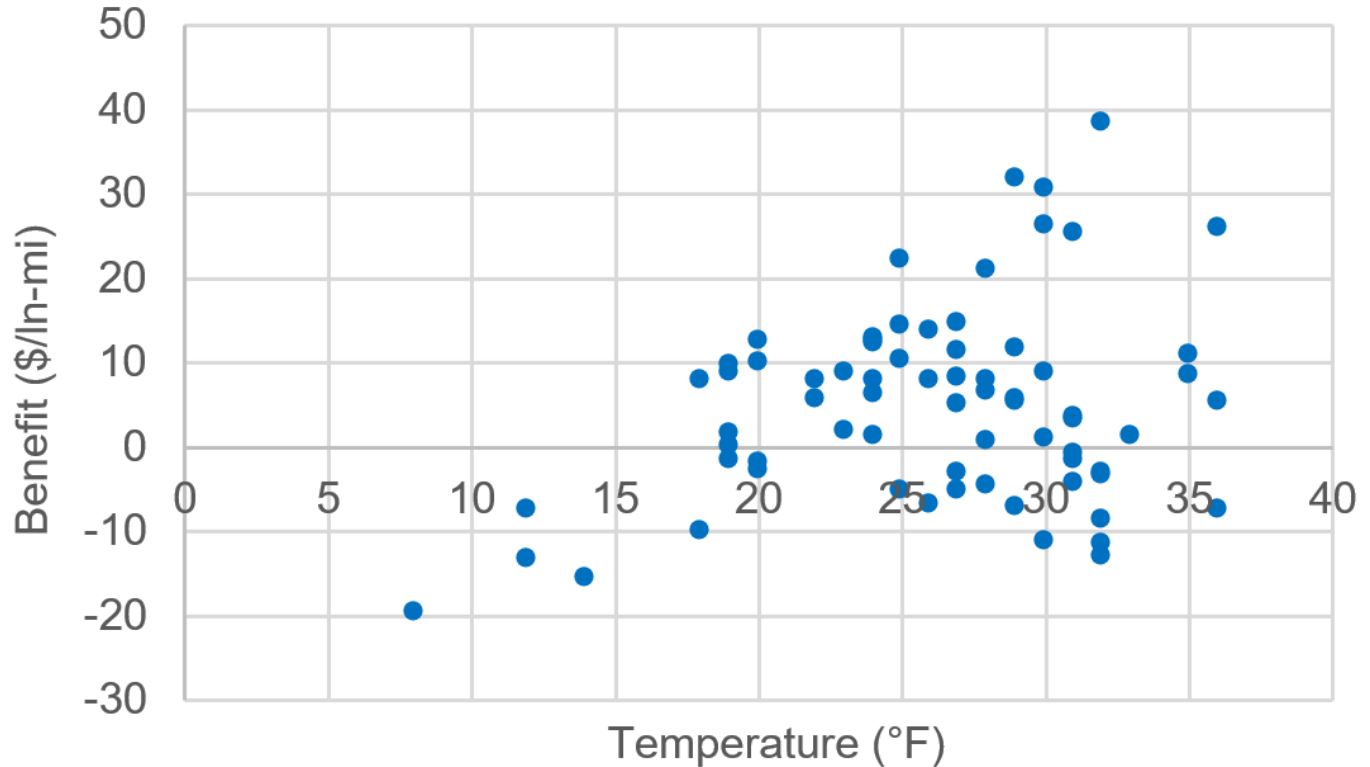
Results

Benefit-Cost (B/C)

Number of storms by temperature and snow intensity

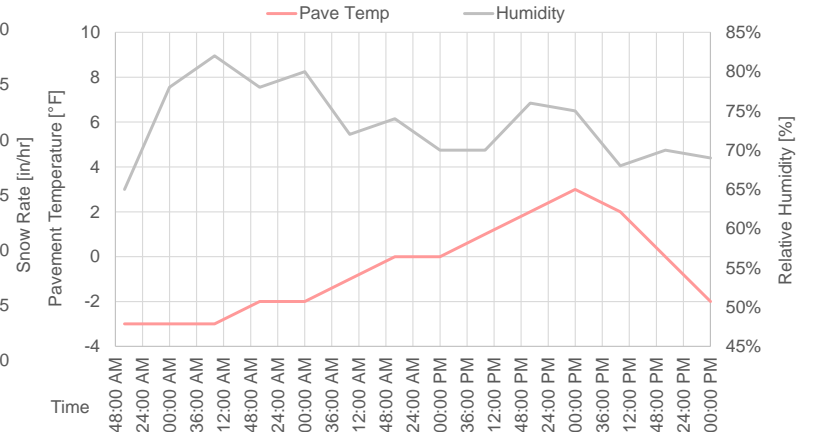| Temperature	Bins	Snow Intensity	
		Light	**Moderate/Heavy**
	Bins	**1**	**2**
<15°F	**O**	4	0
15°F-19°F	**A**	3	4
20°F-24°F	**B**	8	6
>24°	**C**	31	15
All		**46**	**25**

Snow intensity: Light   ≤ 5 inches in 24 hours

Moderate/heavy > 5 inches in 24 hours

Results

Benefit-Cost (B/C)

Benefit by bin

Temperature, snow intensity

Temperature		Snow Intensity	
		Light	**Moderate/Heavy**
	Bins	**1**	**2**
<15°F	**O**	O1	O2
15°F-19°F	**A**	A1	A2
20°F-24°F	**B**	B1	B2
>24°	**C**	C1	C2

Bin	Storms	Study ($/ln-mi/storm)			Control ($/ln-mi/storm)			Benefit ($/ln-mi/storm)		
		Min	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
A1	3	7.62	**16.54**	25.43	9.08	**19.92**	25.34	-0.08	**3.38**	8.77
A2	4	11.10	**22.44**	30.37	18.91	**23.94**	28.96	-10.02	**1.49**	9.60
B1	8	0.91	**15.82**	30.76	13.46	**24.12**	38.59	1.97	**8.30**	12.55
B2	6	11.38	**28.17**	38.27	18.85	**32.85**	48.37	-2.83	**4.68**	12.84
C1	31	5.10	**22.09**	62.04	7.38	**28.80**	87.58	-11.34	**6.72**	38.26
C2	15	2.93	**36.72**	79.33	8.01	**42.03**	79.25	-13.08	**5.31**	31.83
All	67	0.91	**24.93**	79.33	7.38	**30.88**	87.58	-13.08	**5.95**	38.26

Results

Benefit-Cost (B/C)

Storms per season

Historical data

Temperature		Snow Intensity	
		Light	Moderate/Heavy
	Bins	1	2
<15°F	O	O1	O2
15°F-19°F	A	A1	A2
20°F-24°F	B	B1	B2
>24°	C	C1	C2

County	Winter Storms per Season by Bin								
	O1	O2	A1	A2	B1	B2	C1	C2	All
Brown	2	1	2	1	3	3	17	6	**34**
Jefferson	2	3	2	1	2	2	11	7	**29**
Marquette	2	2	1	1	2	2	9	6	**26**
Shawano	3	3	3	2	4	3	8	10	**35**
Washington	4	1	2	1	4	2	16	4	**34**
Wood	4	3	3	1	3	2	13	7	**36**
All	**17**	**12**	**12**	**7**	**18**	**13**	**74**	**40**	**193**

Results

Benefit-Cost (B/C)

Cost of investment and lane-miles treated by county

County	Brine Maker ($)	Storage/ Loading ($)	Add-ons/ Trucks ($)	Maintenance ($/year)	Investment and Maintenance ($/10 years)	Salt Brine Treated Lane-Miles (ln-mi)	
						IH/STH	IH/STH/CTH
Brown	$175,000	$45,000	$195,480	$15,000	$565,480	400	800
Jefferson	$150,000	$45,000	$418,563	$31,484	$928,403	550	1,080
Marquette	$191,100	$49,000	$195,480	$15,000	$585,580	246	674
Shawano	$175,000	$45,000	$195,480	$15,000	$565,480	524	524
Washington	$175,000	$45,000	$195,480	$15,000	$565,480	613	613
Wood	$163,650	$45,000	$418,563	$15,000	$777,213	429	1,079
All	**$1,029,750**	**$274,000**	**$1,619,046**	**$106,484**	**$3,987,636**	**2,762**	**4,770**

Results

Benefit-Cost (B/C)

IH and STH highways

Temperature		Snow Intensity	
		Light	**Moderate/Heavy**
	Bins	**1**	**2**
<15°F	**O**	O1	O2
15°F-19°F	**A**	A1	A2
20°F-24°F	**B**	B1	B2
>24°	**C**	C1	C2

County	Lane-Miles (ln-mi) IH/STH	Benefit by Bin ($ over 10-years)[1]						Benefit ($/10-year)	Cost ($/10-year)	Benefit-Cost Ratio (B/C)
		A1	**A2**	**B1**	**B2**	**C1**	**C2**			
Brown	400	$25,371	$3,733	$99,597	$49,092	$443,433	$116,914	$738,140	$565,480	1.31
Jefferson	550	$34,865	$10,258	$85,540	$41,762	$401,620	$193,523	$767,567	$928,403	0.83
Marquette	246	$9,353	$3,669	$43,343	$24,416	$152,728	$83,256	$316,765	$585,580	0.54
Shawano	524	$44,330	$15,652	$152,267	$70,458	$290,543	$282,040	$855,290	$565,480	1.51
Washington	613	$49,248	$5,720	$216,218	$46,571	$653,789	$142,515	$1,114,061	$565,480	1.97
Wood	429	$36,305	$8,011	$111,341	$47,668	$382,156	$151,137	$736,618	$777,213	0.95
All	**2,762**	**$199,471**	**$47,043**	**$708,305**	**$279,967**	**$2,324,270**	**$969,386**	**$4,528,442**	**$3,987,636**	**1.14**

Notes: [1] A=15°-19°F, B=20°-25°F, C= above 24°F, 1=light snow (≤ 5 inches in 24 hours), 2=moderate/heavy snow (> 5 inches in 24 hours).

Benefit-Cost (B/C) equal to 1.14

Results

Benefit-Cost (B/C)

IH, STH, and CTH highways

Temperature		Snow Intensity	
		Light	Moderate/Heavy
	Bins	1	2
<15°F	O	O1	O2
15°F-19°F	A	A1	A2
20°F-24°F	B	B1	B2
>24°	C	C1	C2

County	Lane-Miles (ln-mi)	Benefit by Bin ($ over 10-years)[1]						Benefit ($/10-year)	Cost ($/10-year)	Benefit-Cost Ratio (B/C)
	IH/STH/CTH	A1	A2	B1	B2	C1	C2			
Brown	800	$50,743	$7,465	$199,194	$98,184	$886,867	$233,828	$1,476,281	$565,480	2.61
Jefferson	1,080	$68,503	$20,156	$168,070	$82,054	$789,110	$380,236	$1,508,128	$928,403	1.62
Marquette	674	$25,651	$10,063	$118,873	$66,964	$418,877	$228,341	$868,768	$585,580	1.48
Shawano	524	$44,315	$15,647	$152,217	$70,435	$290,449	$281,949	$855,013	$565,480	1.51
Washington	613	$49,250	$5,720	$216,229	$46,573	$653,821	$142,522	$1,114,115	$565,480	1.97
Wood	1,079	$91,253	$20,137	$279,857	$119,814	$960,554	$379,884	$1,851,498	$777,213	2.38
All	**4,770**	**$329,715**	**$79,187**	**$1,134,439**	**$484,025**	**$3,999,676**	**$1,646,761**	**$7,673,803**	**$3,987,636**	**1.92**

Notes: [1] A=15°-19°F, B=20°-25°F, C= above 24°F, 1=light snow (≤ 5 inches in 24 hours), 2=moderate/heavy snow (> 5 inches in 24 hours).

Benefit-Cost (B/C) equal to 1.92

Summary of Results

Salt Use

Significant reduction in salt use of 23.0%

Time to Bare/Wet

Significant reduction in time to bare/wet of 11.9%

Friction

8.1% higher on study route than control route

Road Condition Rating

15.3% higher on study route than control route

Benefit-Cost (B/C)

B/C equal to 1.14 for IH/STH highways

B/C equal to 1.92 for IH/STH/CTH highways

Conclusions

Results of this study conclusively indicate that salt brine applications:

- ❖ Reduced the amount of salt used
- ❖ Improved time to bare/wet
- ❖ Presented better pavement friction conditions
- ❖ Benefits outweighed the cost of investment to introduce salt brine to existing solid salt applications

Questions

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