Predicting Road Weather Emergencies:

Advancements in Storm Forecasting and Risk Communication

Chad Hahn
Warning Coordination Meteorologist
National Weather Service - Des Moines, Iowa

chad.hahn@noaa.gov

Overview

- TECHNOLOGY
  - Investment in supercomputing
  - Weather observing advancements
- RESEARCH
  - Crash analysis findings & application
- COMMUNICATION
  - Messaging amplification through cross-agency coordination
  - Conveying possibilities & uncertainty
  - Snow squall warning (reaching motorists in winter)
  - Winter storm severity index

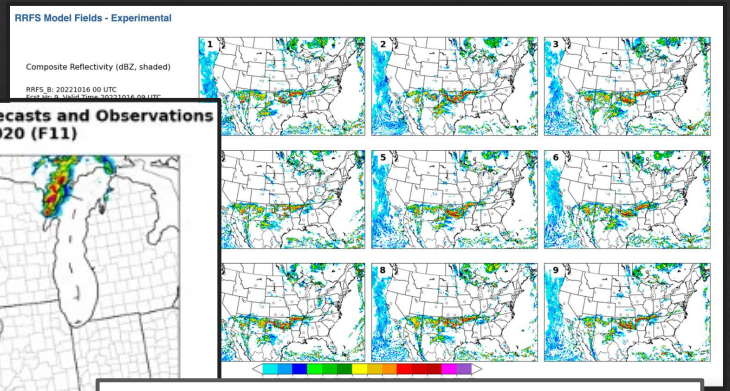
NWS Investment in Supercomputing

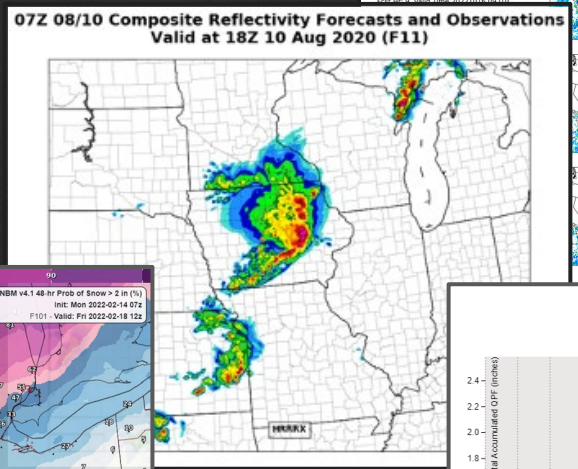
Twin supercomputer named DOGWOOD and CACTUS each operating at a speed of 12.1 petaflops, which is 3 times faster than NOAA's former system.

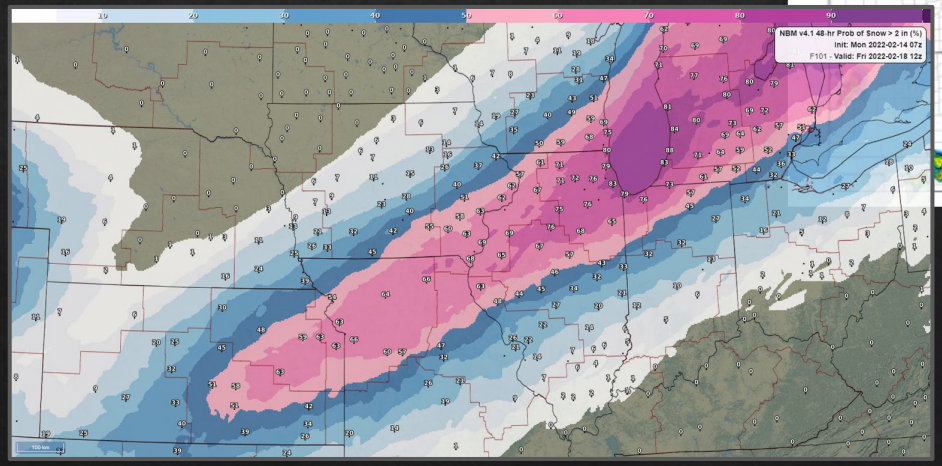
Combined with other NOAA supercomputers, capacity is now 42 petaflops.

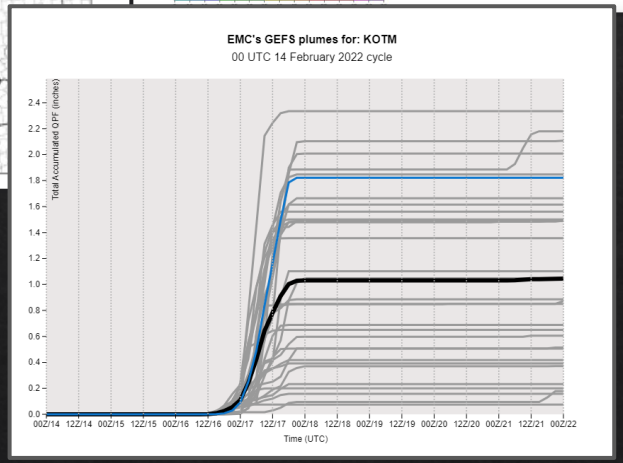
Supercomputing Weather Forecast Advancements

1. Larger Number of Individual Model Simulations
2. Collaborative Development in the Cloud
3. Higher Spatial & Temporal Resolutions
4. More Realistic Model Physics
5. Enhances the National Blended Model

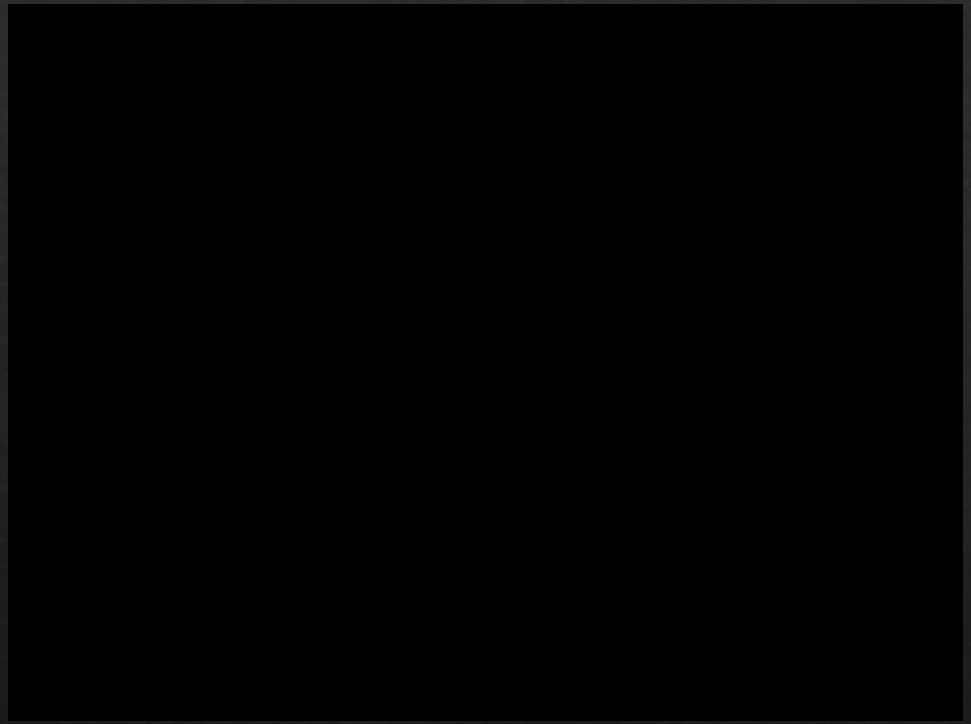




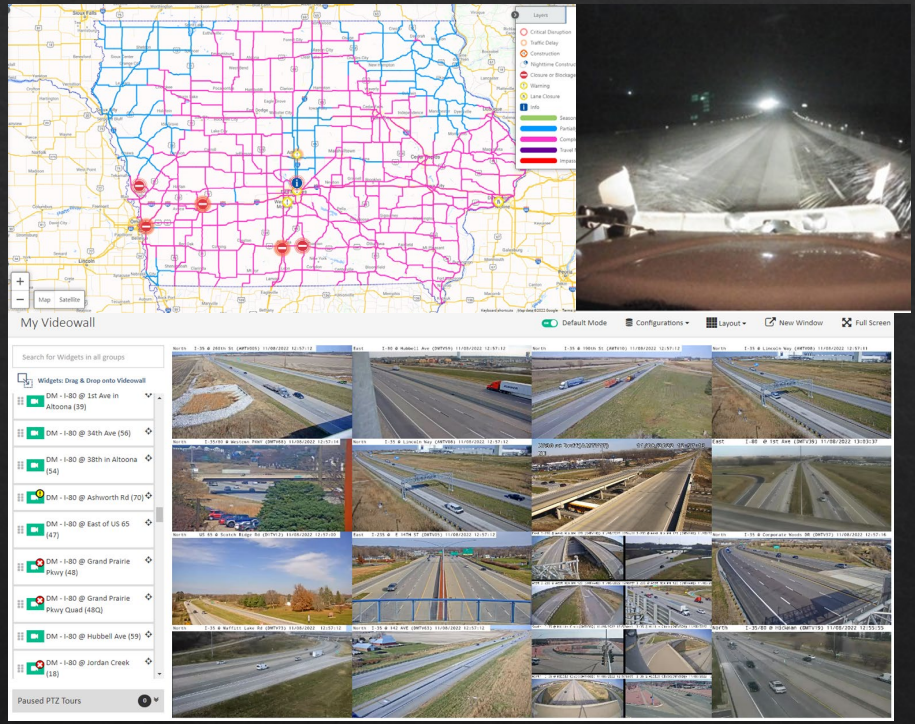




Weather Observing Advancements

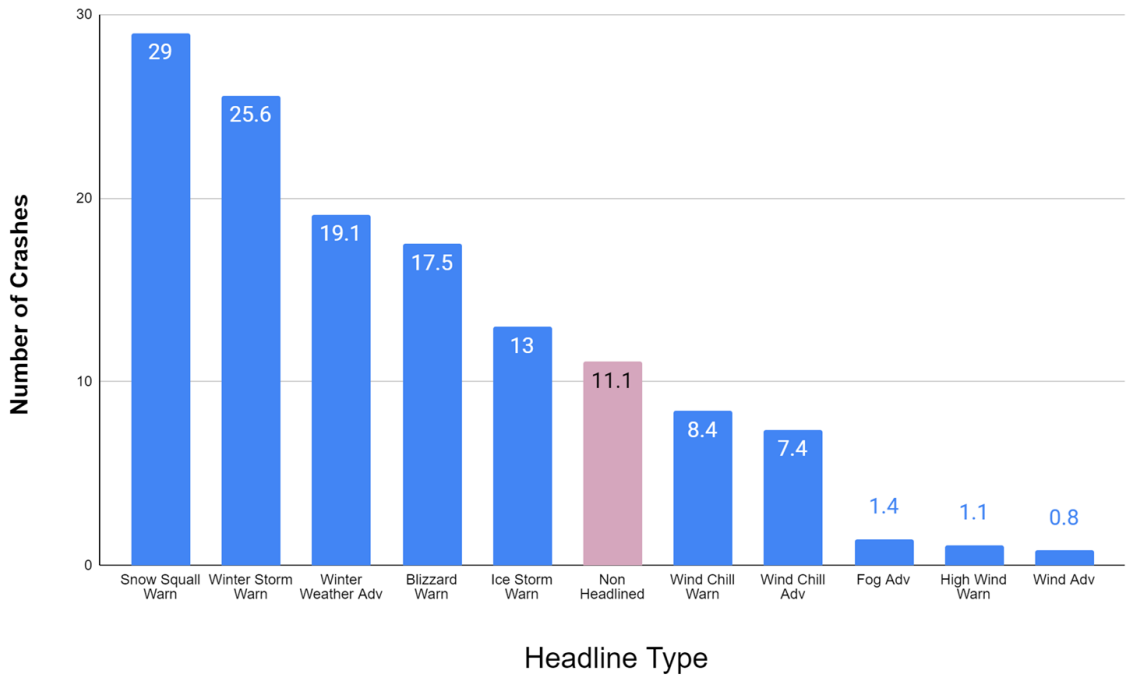


Satellite Showing Blowing Snow



Real-time DOT Information

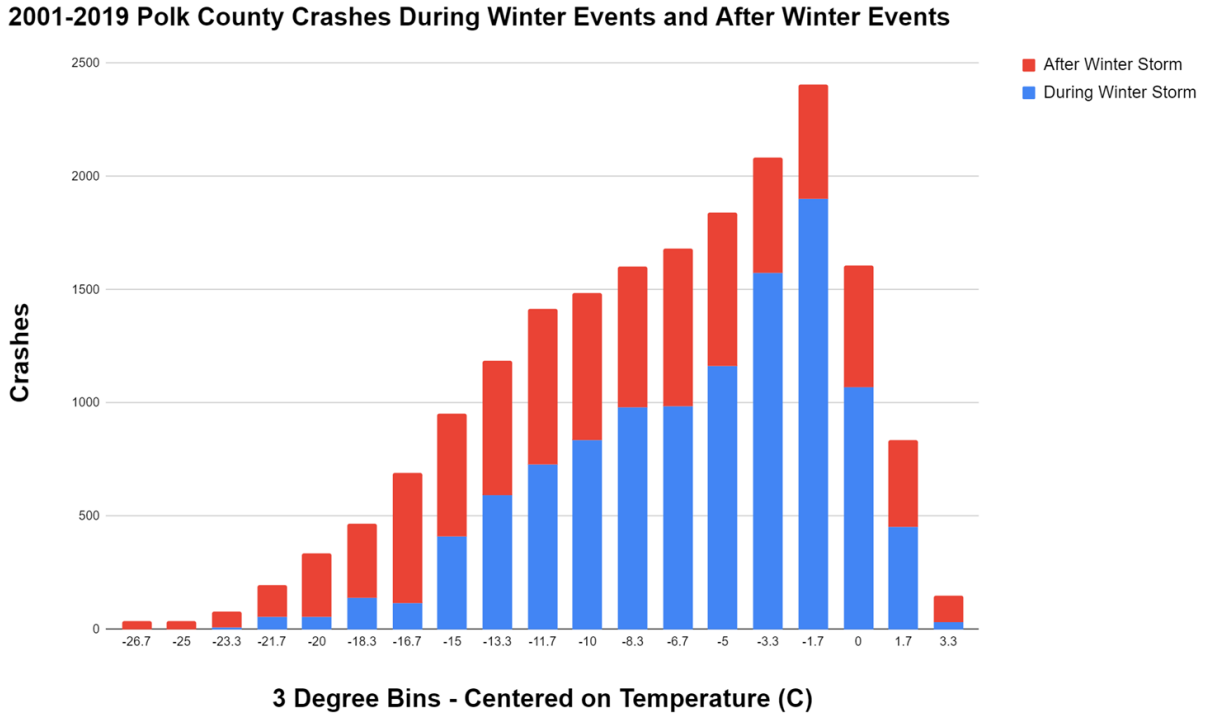
Crash Analysis Findings & Application



Travel Impacts

#1	**Snow Squalls**
#2	**Major Winter Storms**
#3	**Winter Storms**
#4	**Blizzards**
#5	**Ice Storms**
#6	**Sub-Advisory**
or	
	Non Advisory
#7-8	**Wind Chill**
Events	

Crash Analysis Findings & Application



Temperature Impacts

Warmer Conditions:

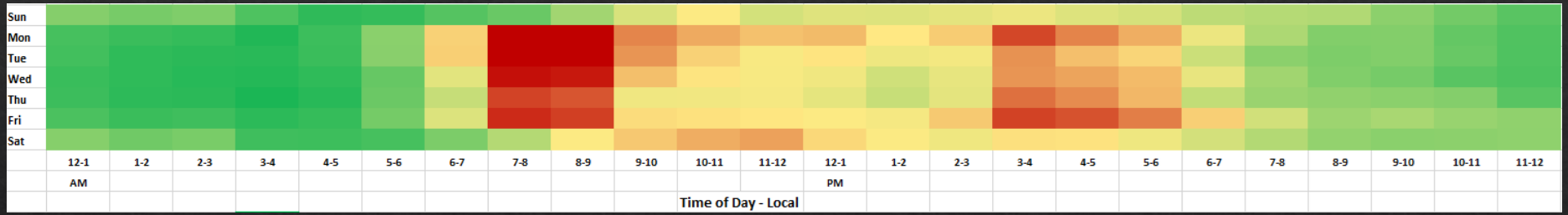
Fewer crashes after events than during events at those temperatures.

Colder Conditions:

More similar numbers of crashes before/after events at those temperatures.

Crash Analysis Findings & Application

Crash Heat Map of Central Iowa Counties 2001 to Spring 2022 - Peak Crash Periods & Travel Impacts



Winter Travel Messaging - Targets of Opportunity:

- Morning and afternoon weekday rush hours
- Saturday & Sunday late morning through afternoon/evening
- Slight increase in late night Friday/Saturday and late Sunday evening

Crash Analysis Findings & Application

Heat Map Analysis of Polk County 2001 to 2019 - After Winter Event and Precipitation Has Ended

- Visibility Equal or Greater than 6 statute miles (9.67 km)
- Temperatures across a spectrum of -16 F to 38 F (-26.7 C to 3.3 C)
- Wind/wind gust across 5 binned categories in mph (kmh = ~ 1.61 x mph)

								Visbility is >= 6.0 miles											
Wind > 45 mph	0	0	0	0	0	0	0	0	0	1	1	10	2	0	2	3	3	7	0
Wind 35 to 45 mph	0	0	0	0	4	10	17	13	17	7	15	14	42	51	10	24	23	7	7
Wind 25 to 35 mph	0	0	2	2	5	41	30	47	49	73	80	92	56	80	40	51	53	52	8
Wind 15 to 25 mph	0	1	2	7	29	26	116	120	109	170	84	105	137	114	89	79	48	44	24
Wind 0 to 15 mph	37	35	65	131	234	241	356	338	372	416	416	328	372	319	251	236	201	121	49
Temperature in F	-16	-13	-10	-7	-4	-1	2	5	8	11	14	17	20	23	26	29	32	35	38
Temperature in C	-26.7	-25	-23.3	-21.7	-20	-18.3	-16.7	-15	-13.3	-11.7	-10	-8.3	-6.7	-5	-3.3	-1.7	0	1.7	3.3

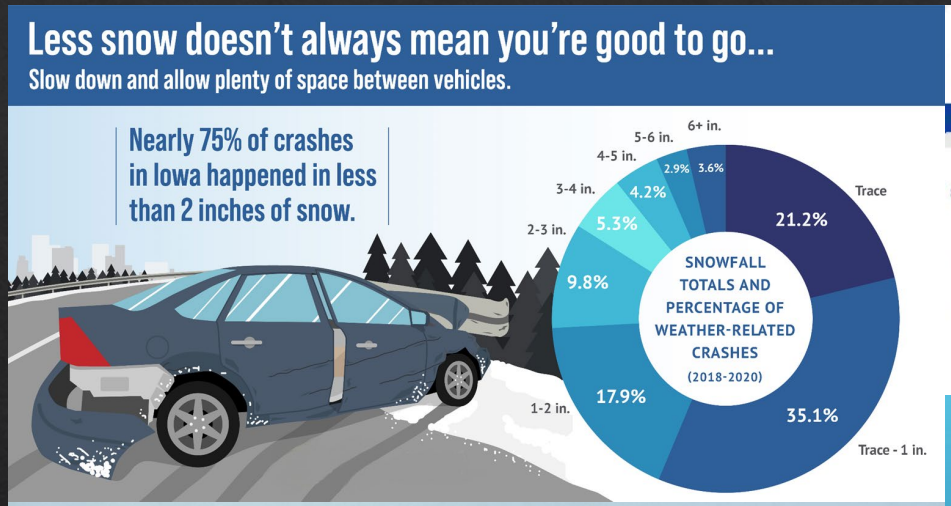
When No Precipitation is Occurring:

Crashes tend to be more frequent in colder temperatures and during periods of light to modest winds.

This May be Due To:

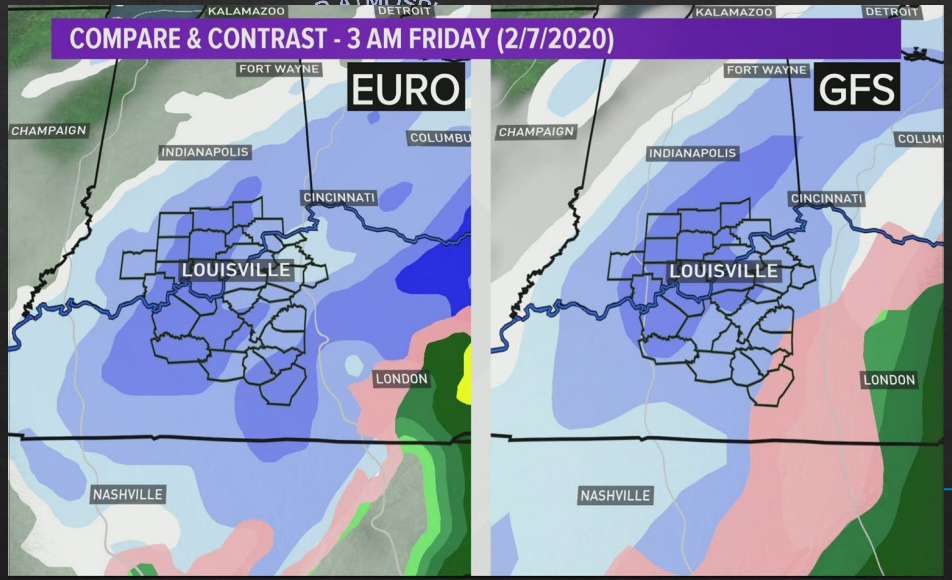
Ground blowing snow - Continued impacts to Road Conditions - Complacency of Motorists

Messaging Amplification through Cross-Agency Coordination

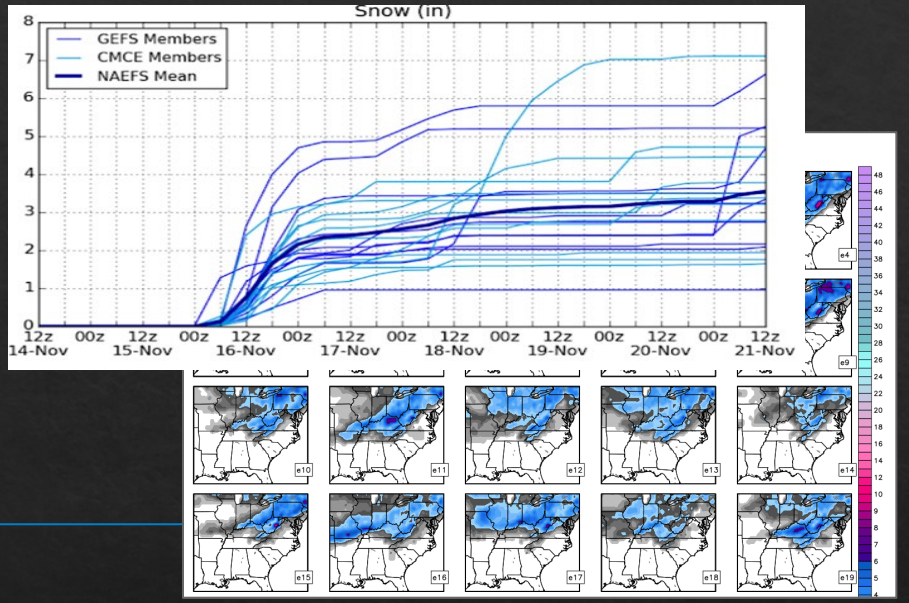


National Weather Service - Des Moines, Iowa

Conveying Possibilities & Uncertainties



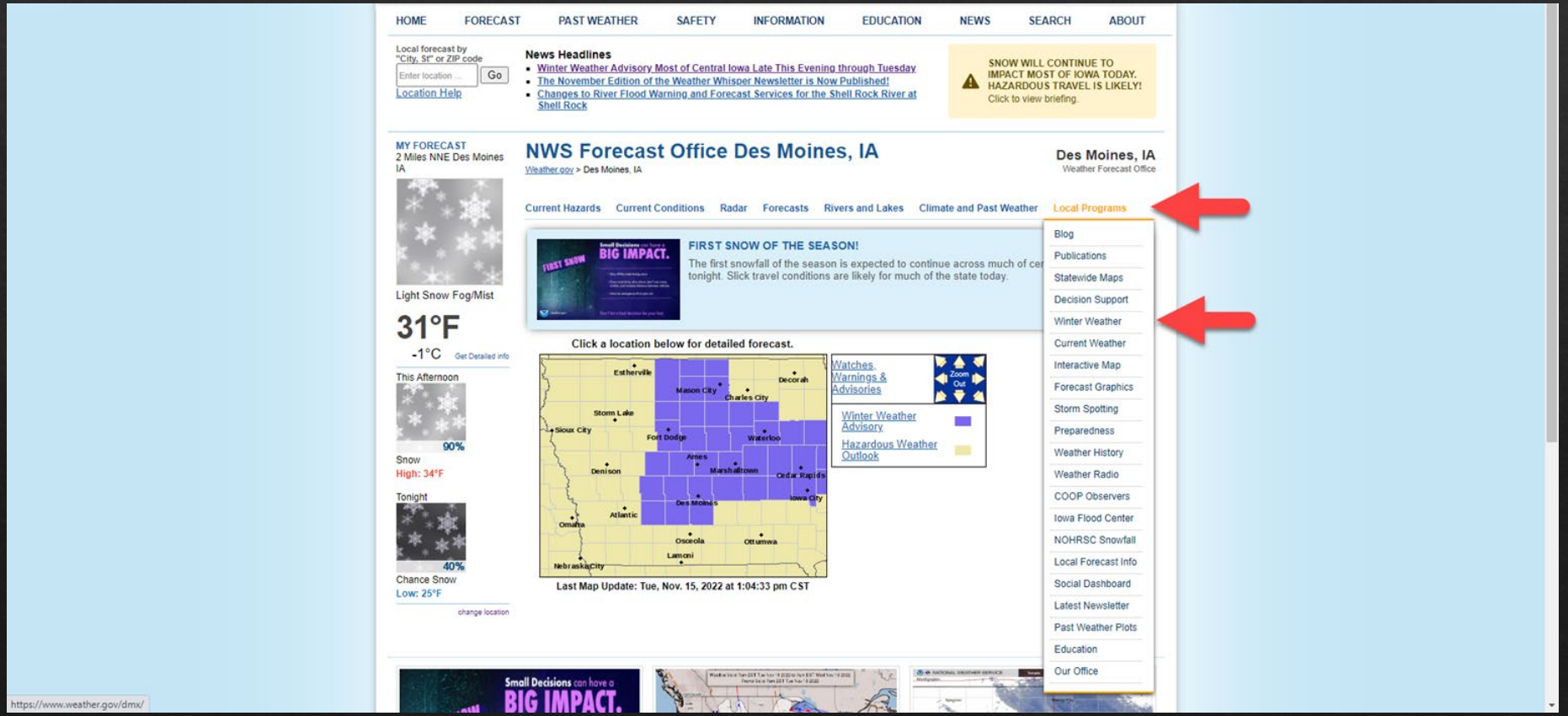
You've probably heard of a couple of our weather models like the American (GFS) or the European (Euro)...



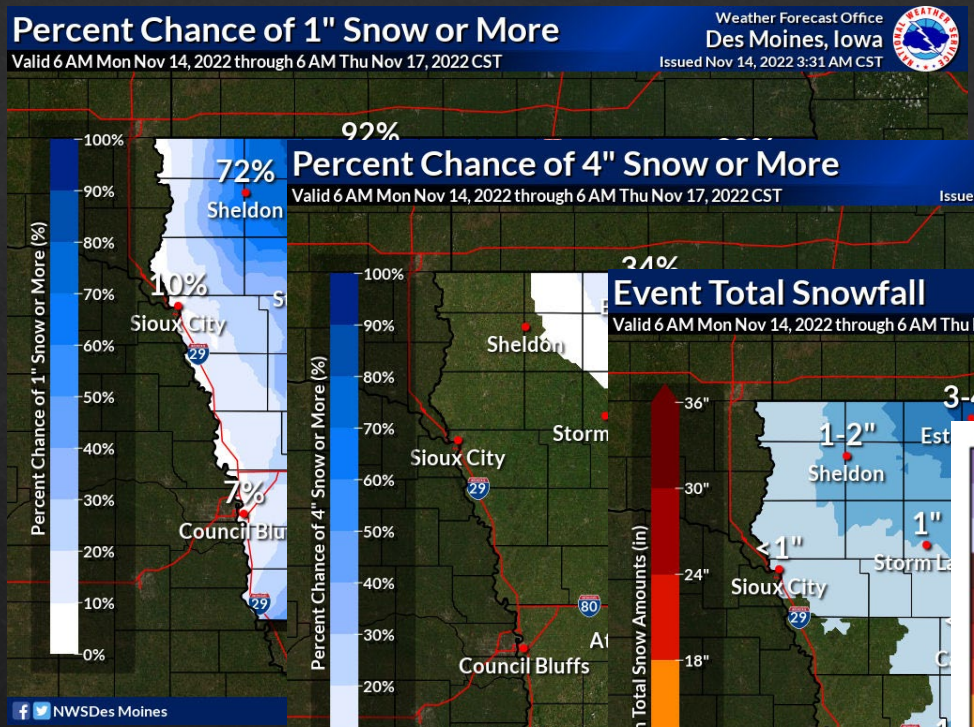
...but now due to increased technology, we actually have access to <u>over a hundred models!</u>

Conveying Possibilities & Uncertainties

https://www.weather.gov/desmoines



Types of Products:



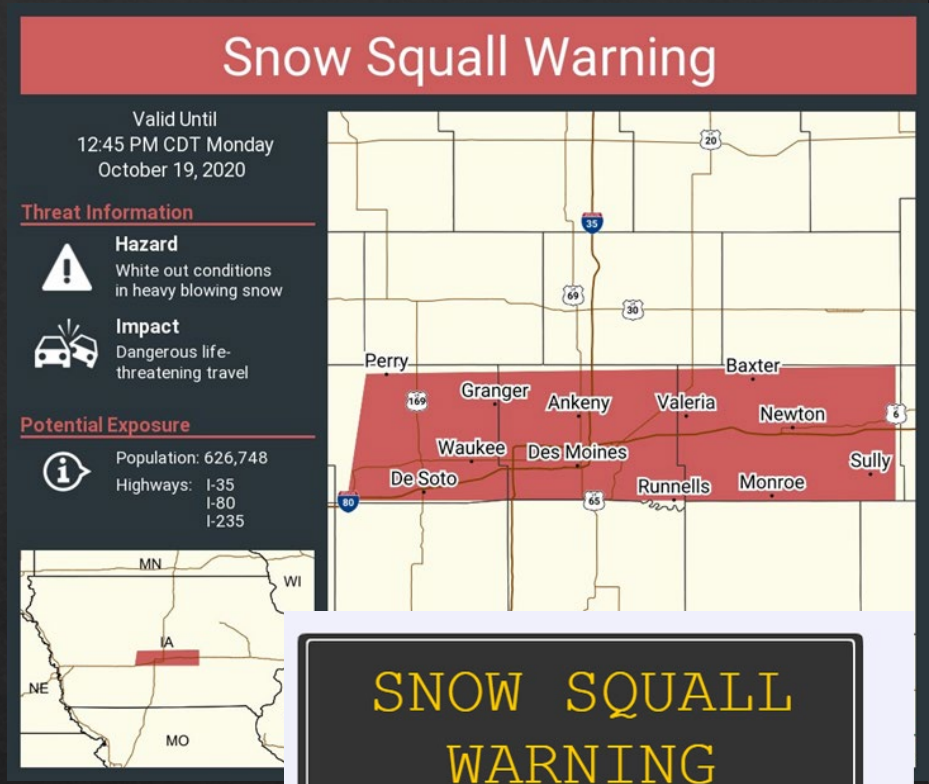
Conveying Possibilities & Uncertainties

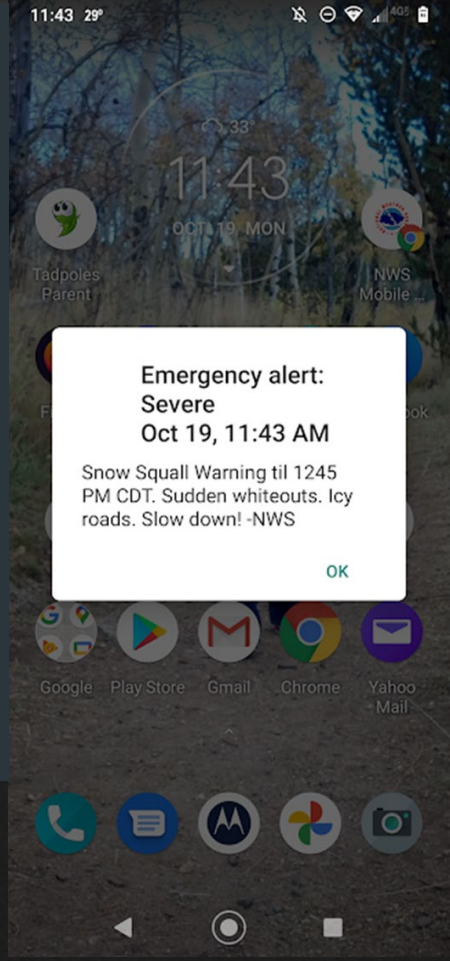
	Snow Amount Potential			Chance of Seeing More Snow Than							
Location	Low End Snowfall	Expected Snowfall	High End Snowfall	>=0.1"	>=1"	>=2"	>=4"	>=6"	>=8"	>=12"	>=18"
Estherville, IA	1	3	5	98%	92%	79%	34%	6%	0%	0%	0%
Mason City, IA	2	3	5	100%	97%	86%	32%	2%	0%	0%	0%
Fort Dodge, IA	1	3	4	97%	88%	65%	12%	0%	0%	0%	0%
Waterloo, IA	2	3	4	100%	97%	79%	7%	0%	0%	0%	0%
Carroll, IA	0	1	2	82%	52%	20%	1%	0%	0%	0%	0%
Ames, IA	1	3	4	99%	93%	72%	10%	0%	0%	0%	0%
Marshalltown, IA	2	3	4	100%	97%	78%	11%	0%	0%	0%	0%
Grinnell, IA	2	3	4	100%	96%	80%	12%	0%	0%	0%	0%
Des Moines, IA	1	2	4	98%	90%	62%	7%	0%	0%	0%	0%
Atlantic, IA	0	1	2	80%	50%	18%	0%	0%	0%	0%	0%
Creston, IA	<1	2	3	97%	79%	43%	4%	0%	0%	0%	0%
Ottumwa, IA	1	2	3	100%	91%	51%	3%	0%	0%	0%	0%
Greenfield, IA	<1	2	3	94%	77%	44%	4%	0%	0%	0%	0%
Corning, IA	<1	1	2	91%	63%	21%	0%	0%	0%	0%	0%
Centerville, IA	1	2	3	99%	91%	56%	2%	0%	0%	0%	0%
Audubon, IA	0	<1	2	79%	48%	18%	1%	0%	0%	0%	0%
Boone, IA	1	3	4	98%	92%	71%	12%	0%	0%	0%	0%
Waverly, IA	2	3	4	100%	96%	76%	13%	0%	0%	0%	0%
Allison, IA	2	3	4	100%	97%	78%	15%	0%	0%	0%	0%
Rockwell City, IA	<1	1	3	93%	73%	40%	4%	0%	0%	0%	0%
Osceola, IA	<1	1	3	98%	81%	44%	4%	0%	0%	0%	0%
Denison, IA	0	<1	1	73%	30%	6%	0%	0%	0%	0%	0%
Adel, IA	<1	2	3	97%	84%	53%	6%	0%	0%	0%	0%
Bloomfield, IA	1	2	3	99%	93%	61%	3%	0%	0%	0%	0%
Lamoni, IA	1	2	3	98%	87%	53%	1%	0%	0%	0%	0%
Hampton, IA	2	3	5	100%	97%	86%	27%	1%	0%	0%	0%
Jefferson, IA	<1	2	3	94%	77%	46%	6%	0%	0%	0%	0%
Grundy Center, IA	2	3	4	100%	98%	81%	13%	0%	0%	0%	0%
Guthrie Center, IA	<1	1	3	93%	71%	41%	6%	0%	0%	0%	0%
Webster City, IA	1	3	4	98%	92%	72%	17%	1%	0%	0%	0%
Garner, IA	2	4	5	99%	97%	88%	42%	7%	0%	0%	0%
Eldora, IA	2	3	4	99%	96%	79%	19%	1%	0%	0%	0%
Humboldt, IA	1	2	4	97%	88%	65%	15%	1%	0%	0%	0%
Newton, IA	2	3	4	99%	96%	78%	10%	0%	0%	0%	0%
Algona, IA	1	3	5	98%	92%	77%	31%	6%	0%	0%	0%
Chariton, IA	1	2	3	99%	91%	63%	4%	0%	0%	0%	0%
Winterset, IA	<1	2	3	97%	81%	45%	4%	0%	0%	0%	0%
Oskaloosa, IA	1	3	4	99%	94%	71%	6%	0%	0%	0%	0%
Knoxville, IA	1	3	4	99%	92%	69%	5%	0%	0%	0%	0%
Albia, IA	1	2	4	99%	94%	68%	6%	0%	0%	0%	0%
Emmetsburg, IA	1	2	5	97%	89%	70%	23%	3%	0%	0%	0%
Pocahontas, IA	<1	1	3	96%	77%	46%	7%	0%	0%	0%	0%
Mount Ayr, IA	<1	2	3	97%	82%	43%	1%	0%	0%	0%	0%
Sac City, IA	0	<1	2	80%	44%	14%	0%	0%	0%	0%	0%
Toledo, IA	2	3	4	100%	96%	76%	5%	0%	0%	0%	0%
Bedford, IA	<1	2	3	93%	71%	28%	0%	0%	0%	0%	0%
Indianola, IA	1	2	3	99%	91%	62%	4%	0%	0%	0%	0%
Corydon, IA	1	2	3	99%	88%	52%	4%	0%	0%	0%	0%
Forest City, IA	3	5	6	99%	97%	92%	59%	16%	1%	0%	0%
Northwood, IA	3	4	6	100%	99%	95%	59%	11%	0%	0%	0%
Clarion, IA	2	3	5	99%	95%	81%	25%	1%	0%	0%	0%

Snowfall ranges and probabilities for all 51 counties in central Iowa

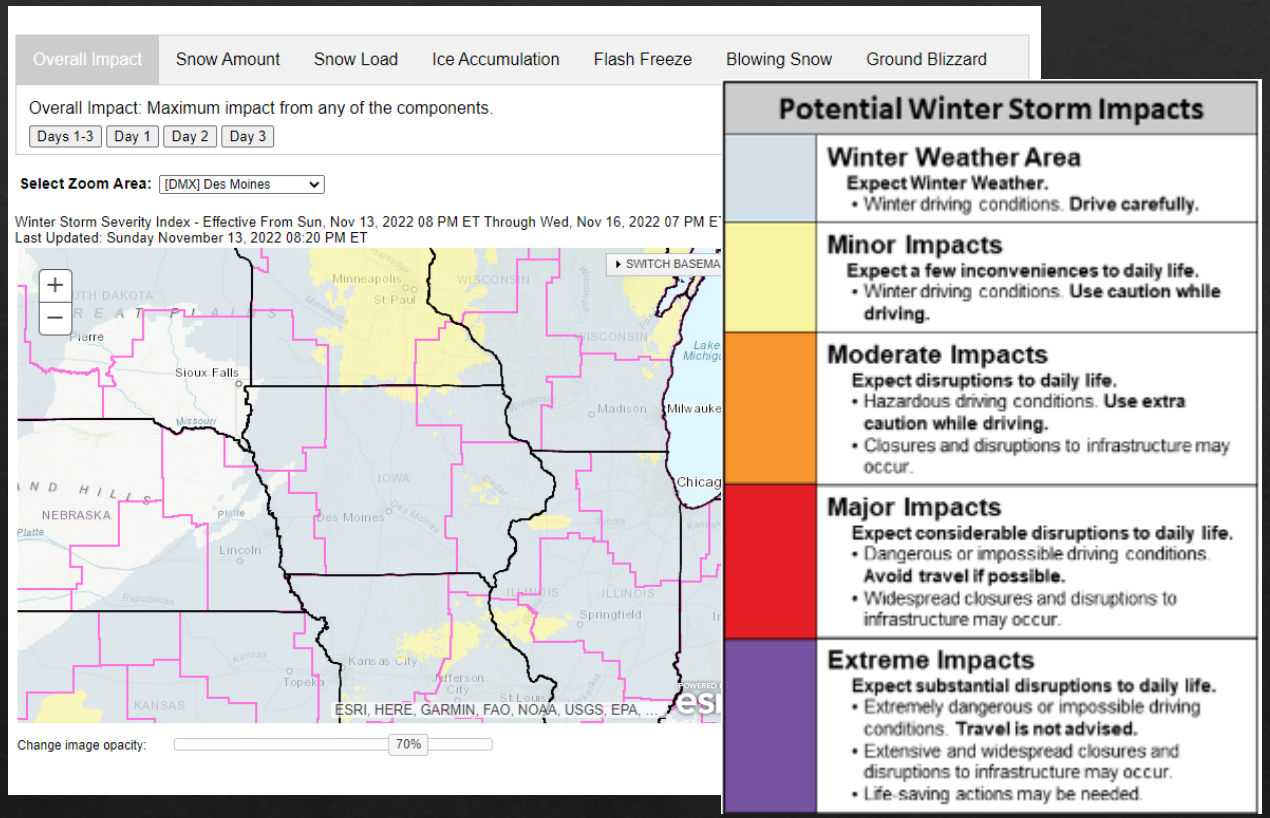
Snow Squall Warnings

Brief (30-60 minutes) warnings issued for short duration intense bursts of snow & wind leading to whiteout visibility & flash freezes on roads





Winter Storm Severity Index- WSSI



Potential Winter Storm Impacts

Winter Weather Area
Expect Winter Weather.
- Winter driving conditions. **Drive carefully.**

Minor Impacts
Expect a few inconveniences to daily life.
- Winter driving conditions. **Use caution while driving.**

Moderate Impacts
Expect disruptions to daily life.
- Hazardous driving conditions. **Use extra caution while driving.**
- Closures and disruptions to infrastructure may occur.

Major Impacts
Expect considerable disruptions to daily life.
- Dangerous or impossible driving conditions. **Avoid travel if possible.**
- Widespread closures and disruptions to infrastructure may occur.

Extreme Impacts
Expect substantial disruptions to daily life.
- Extremely dangerous or impossible driving conditions. **Travel is not advised.**
- Extensive and widespread closures and disruptions to infrastructure may occur.
- Life-saving actions may be needed.

WSSI Specifics

- Defines Greatest Threats for Area
- Easy to understand
- Based on specific winter inputs
- Produced 5x daily
- Complement to official weather forecast

Predicting Road Weather Emergencies:

Advancements in Storm Forecasting and Risk Communication

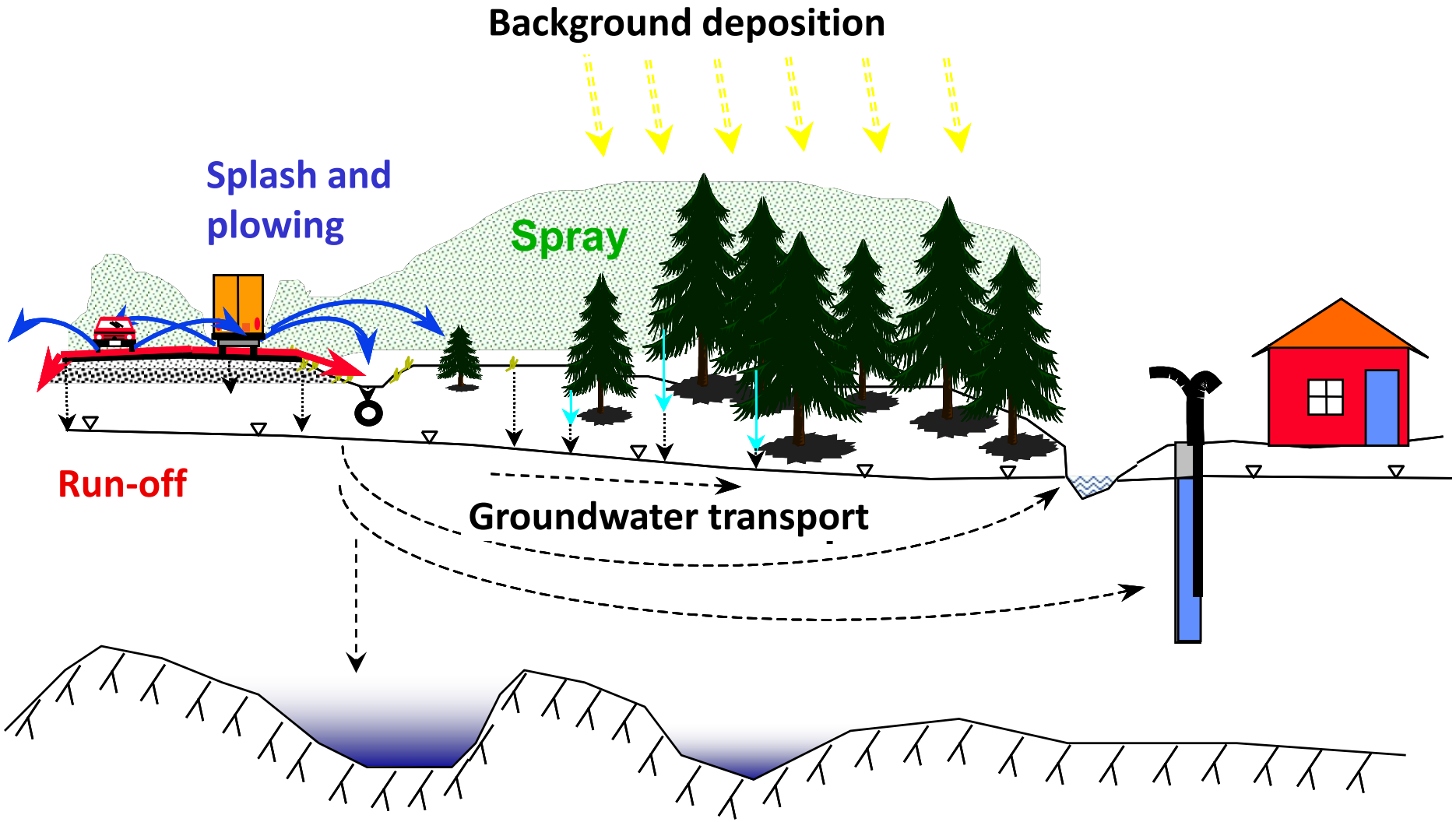
Chad Hahn
Warning Coordination Meteorologist
National Weather Service - Des Moines, Iowa

chad.hahn@noaa.gov

The loss of salt from the road surface – a coin with two sides: environmental implications

- Göran Blomqvist, PhD, senior researcher, VTI, Sweden

Environmental implications…



Impacts:

- Infrastructure
- Groundwater
- Surface waters
- Vegetation
- Soils
- Fauna
- Cultural heritage

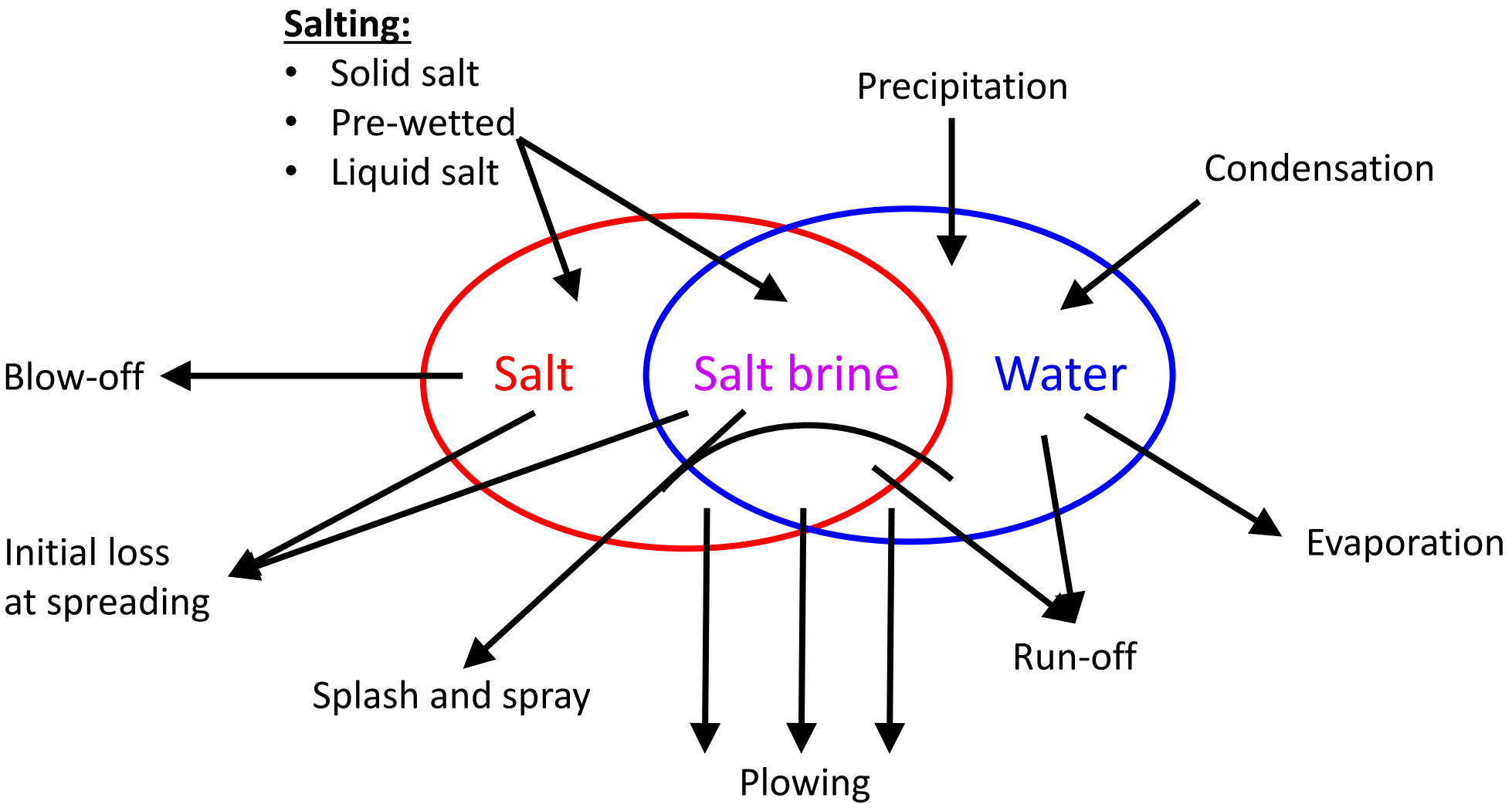
Environmental research:

- Unfortunately, emphasis on environmental research is too often on the effect & impact side of the system, whithout connecting it to the decisions that road keepers and contractors have to do!

Key is understanding the processes

So, let´s discuss the salt- and water balance

Highways:


Salting:
• Solid salt
• Pre-wetted
• Liquid salt
Precipitation
Condensation
Blow-off
Salt
Salt brine
Water
Initial loss
at spreading
Splash and spray
Plowing
Run-off
Evaporation

Cycleways:





Salting:

- Brine,
- 'Spiked' brine,
- Dry salt

Ploughing, Splashing, Dragging

Meltwater-inflow

Precipitation

Condensation (frost, damp)

Salt

Salt solution

Water

Initial loss at spreading

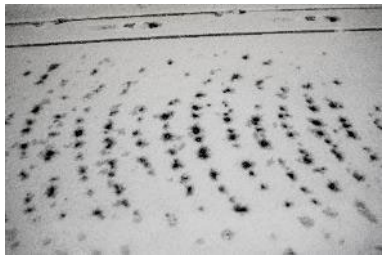
Splash and spray

Evaporation

Run-off

Snow clearance:

- Brooming,
- Ploughing

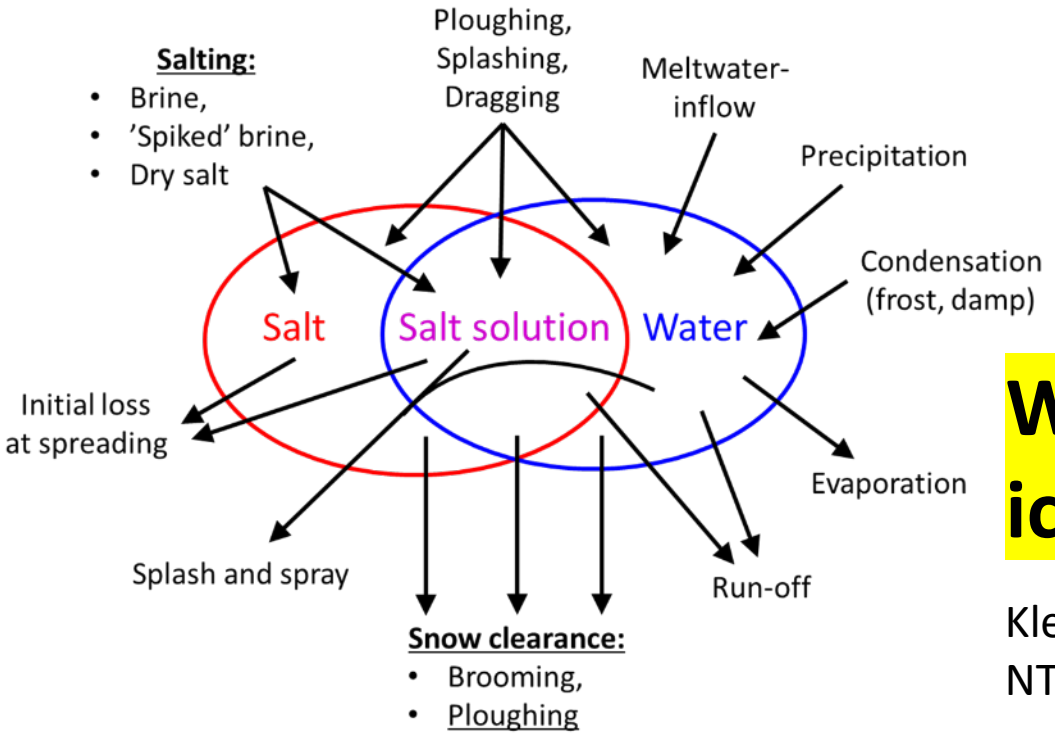




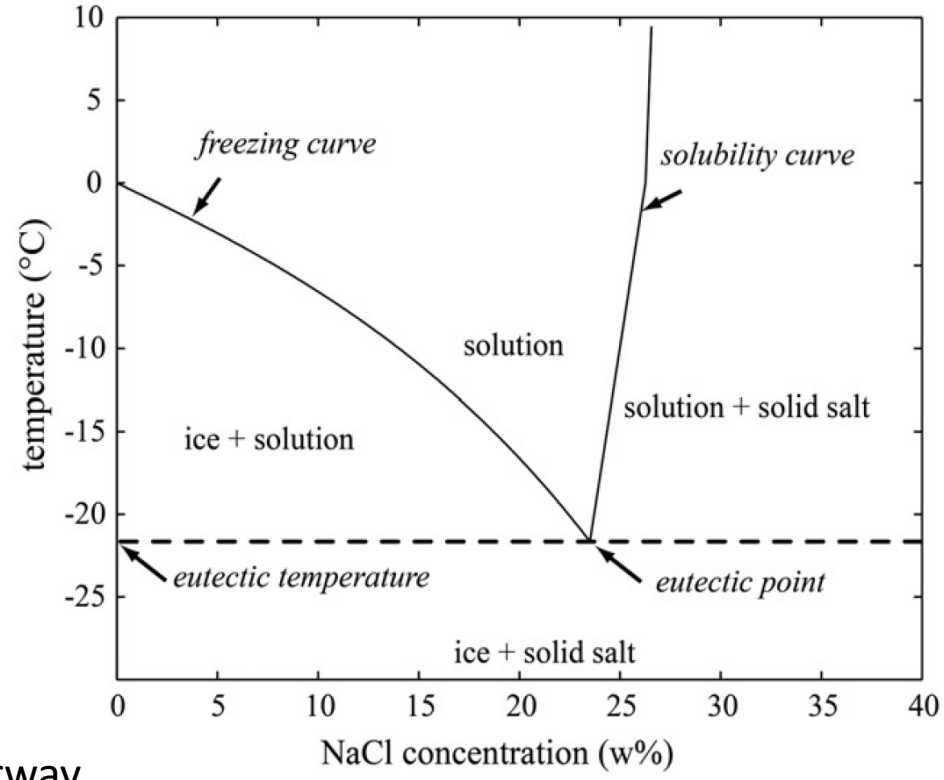

What is the optimal salt dose?

- How much salt is there to start with?
- How much 'water'?
- When can you pass the place next time?
- What will happen in the mean time?

+ Safety margin



Temperature and wetness!



What about ice quality?

Klein-Paste & Wåhlin,
NTNU, Trondheim, Norway

Climate change adaption

Impact on winter maintenance:

- Salt consumption from
  a) snow-related and
  b) temperature related
  Winter maintenance

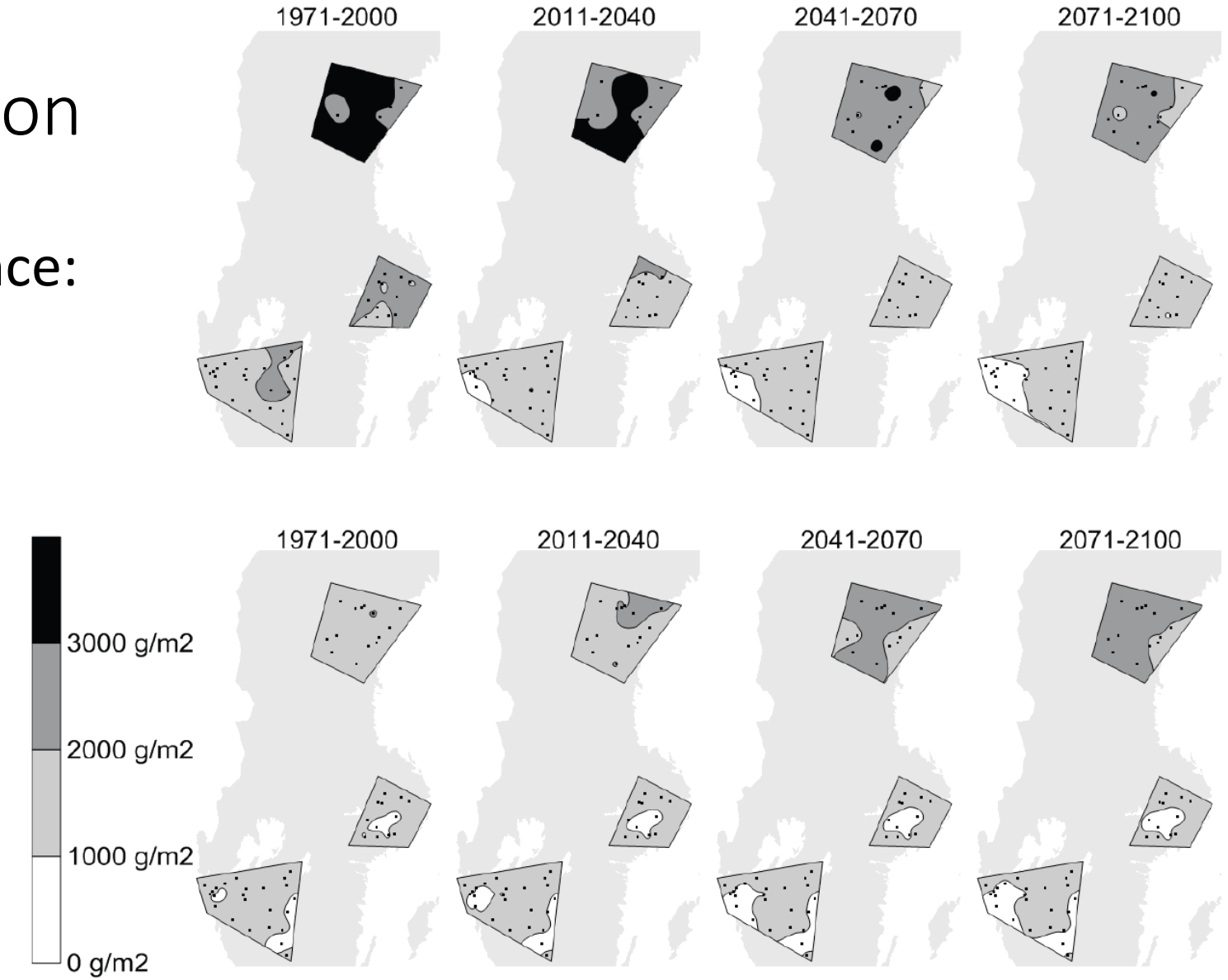


FIGURE 5 Development in yearly salt consumption (g/m^2) (1 g/m^2 = 0.029 oz/yd^2) for snow-related maintenance (top) and temperature-related maintenance (bottom).

(ARVIDSSON, BLOMQVIST & ÖBERG, 2012)

A field case from Highway E18, Sagån

Let us follow a field case from January, 2022:

Two days, three salting occasions and nine detailed cross-sections of the residual salt on the road surface

Sagån, Testsite E18

2010

AADT: 20.000+

Research facilities

International

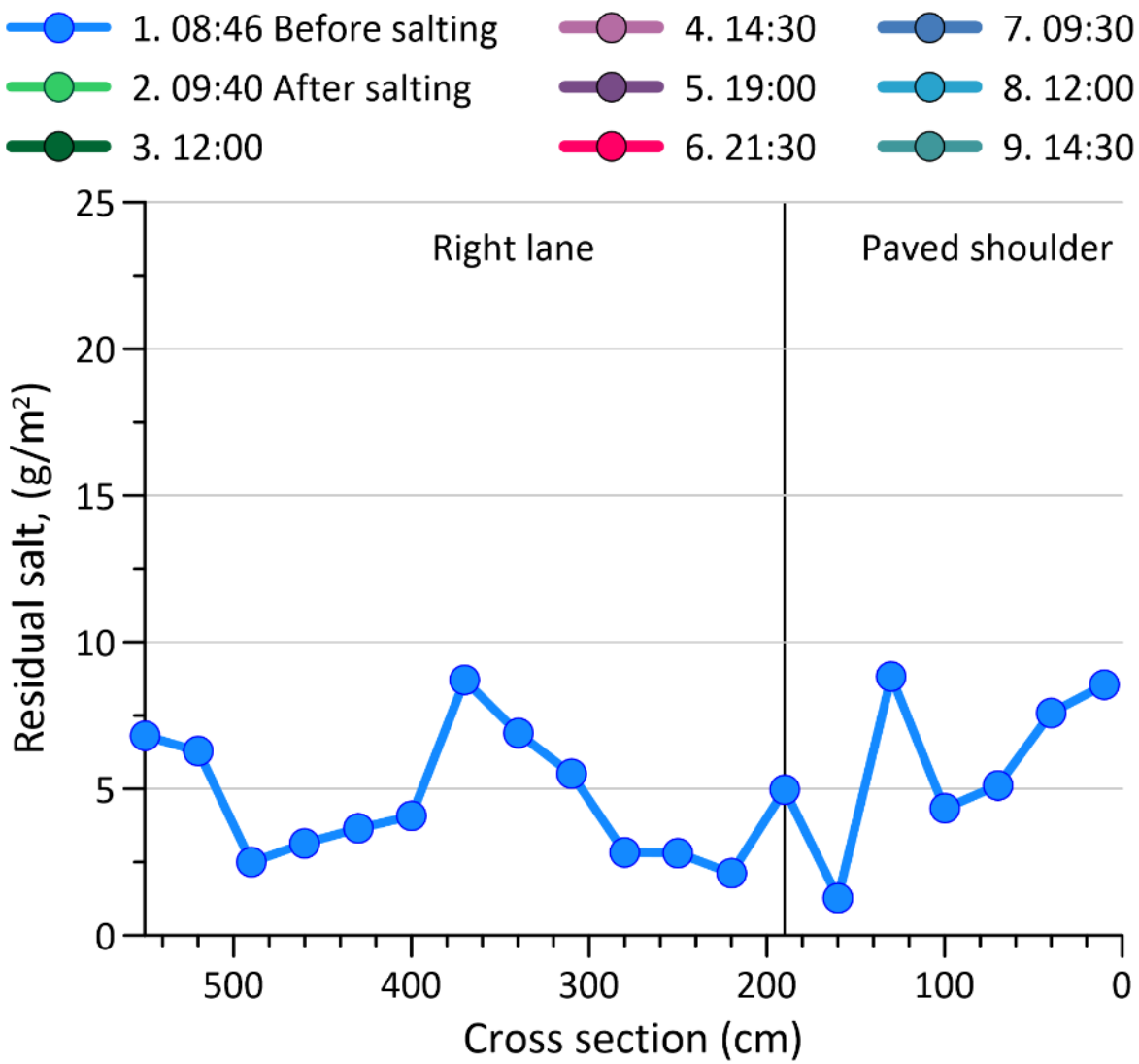
Reference measurements of salt:

Wet Salt Sampler (WSS)

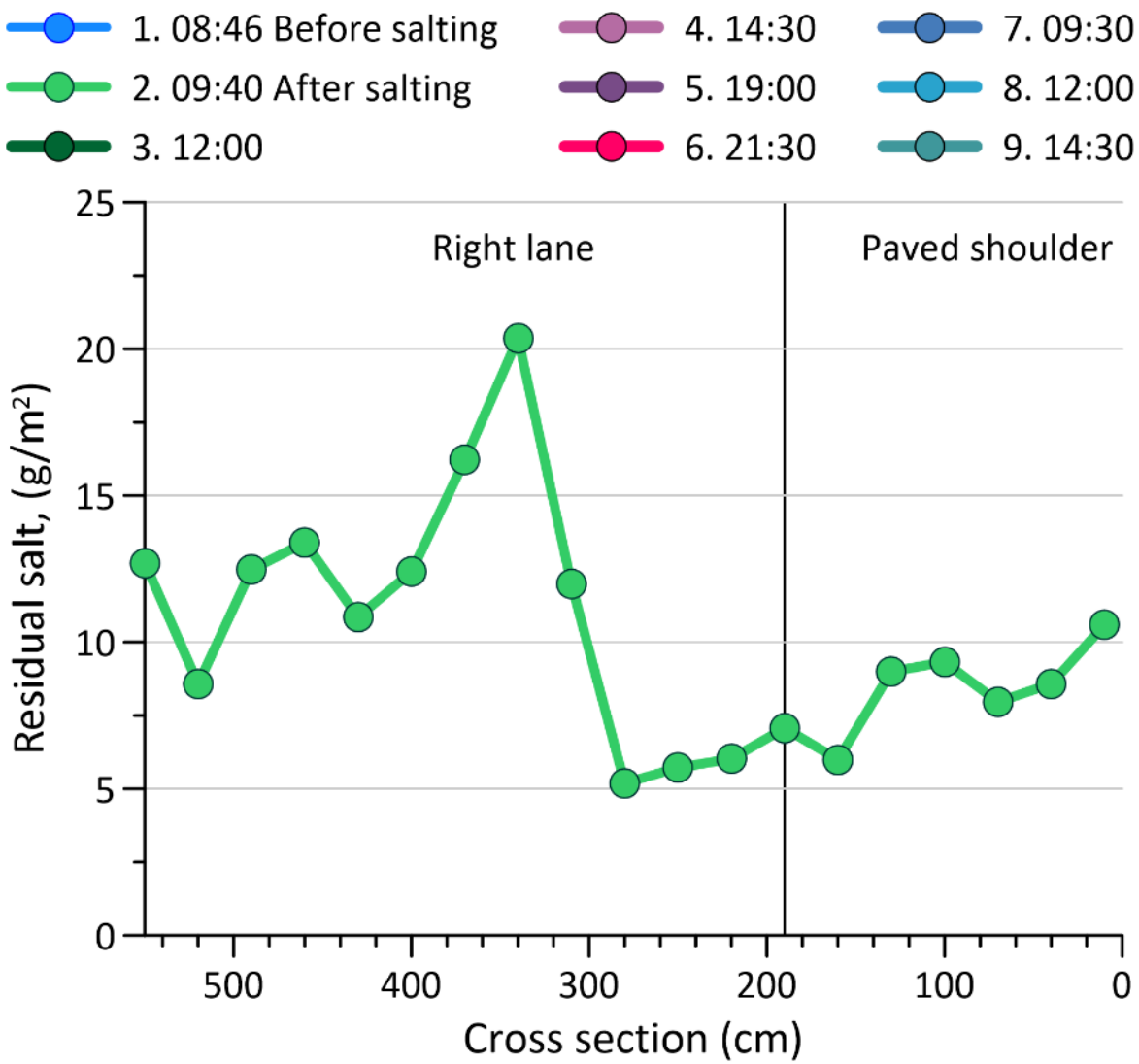
- Electric Conductivity
- Temperature
- Time and GPS-coordinates

- Single board microcontroller
- Open source, public-domain software

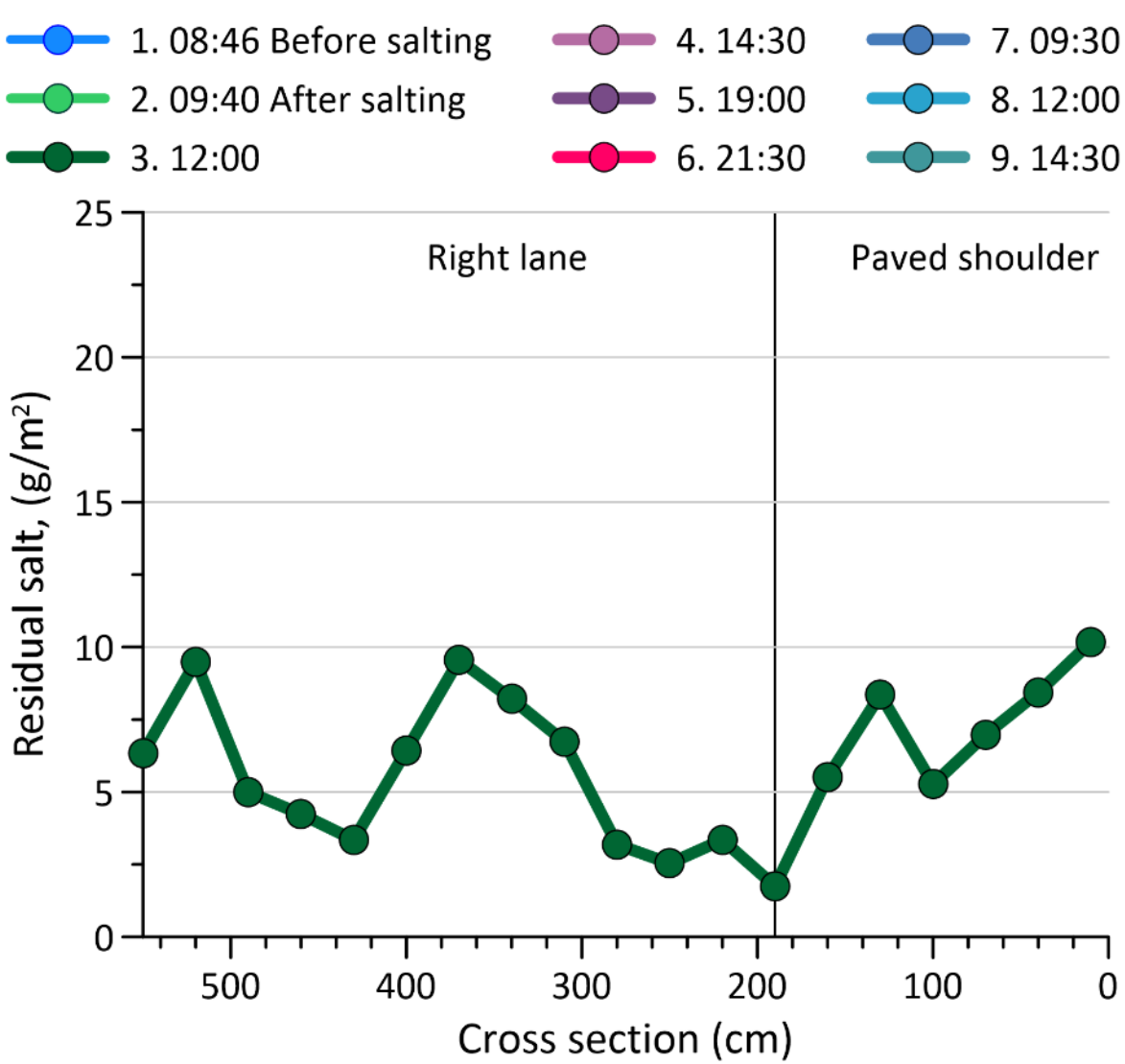
- Allows high salt concentrations
- Dissolves salt crystals
- Allows sampling

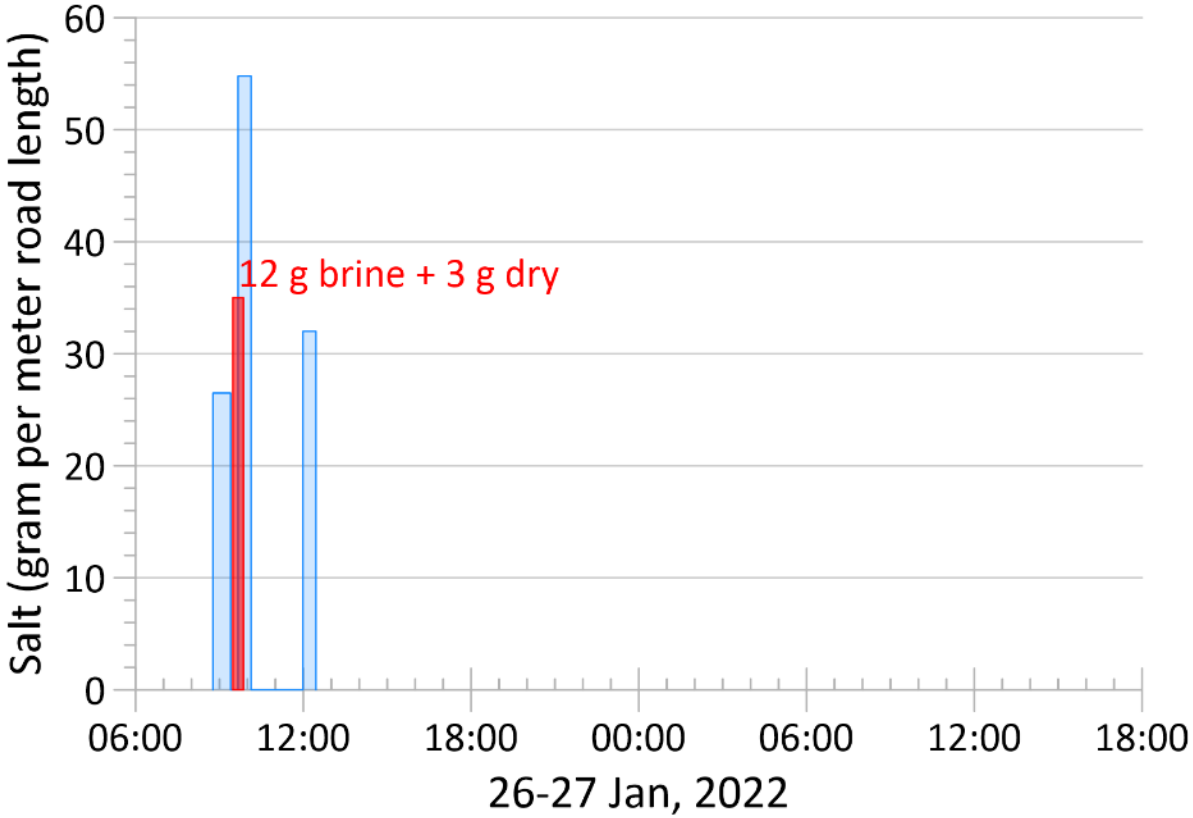

1. 08:46 Before salting
2. 09:40 After salting
3. 12:00
4. 14:30
5. 19:00
6. 21:30
7. 09:30
8. 12:00
9. 14:30
Right lane
Paved shoulder
Residual salt, (g/m²)
25
20
15
10
5
0
500
400
300
200
100
0
Cross section (cm)

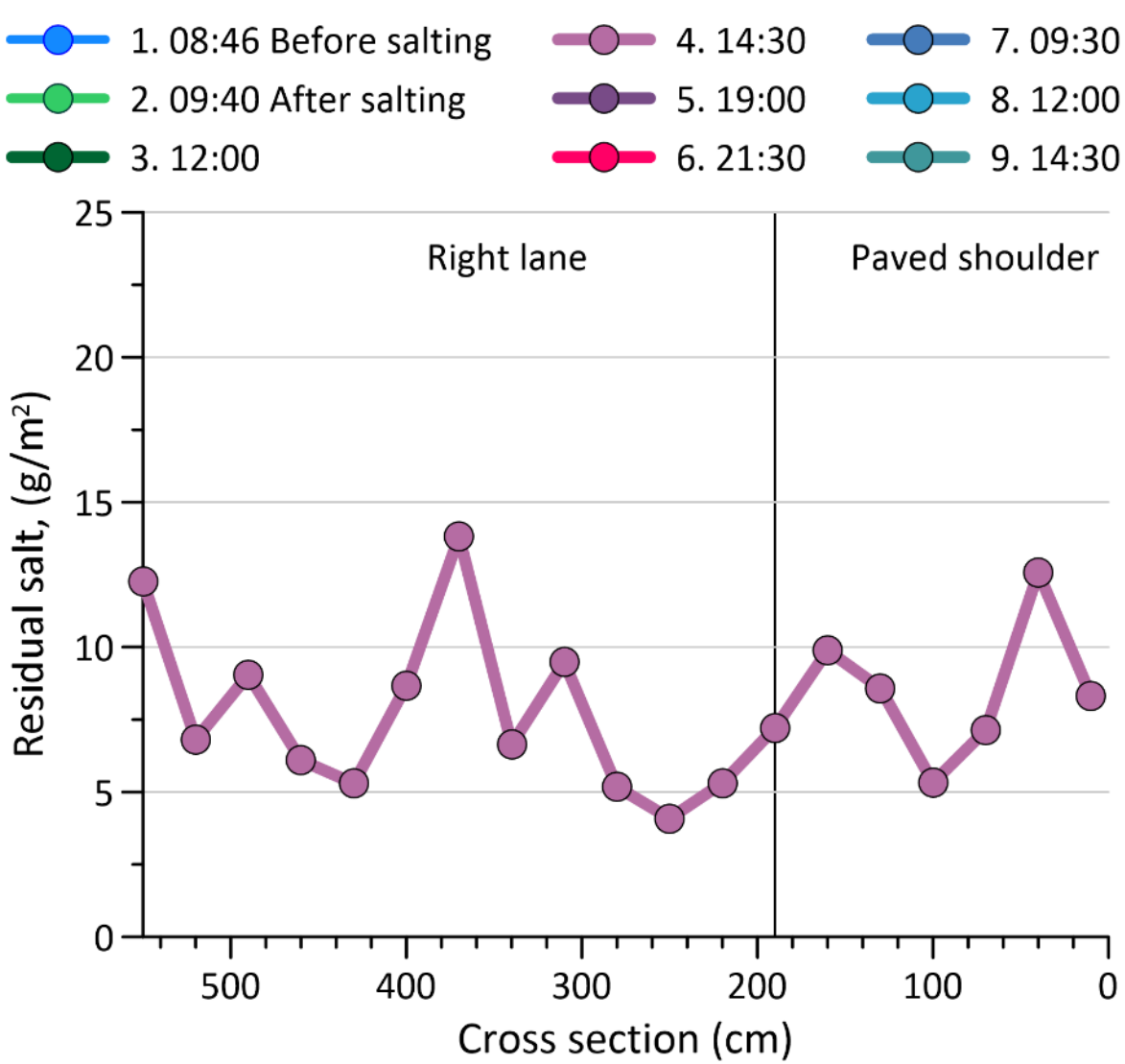

Falkoping
WYN 088
18:00

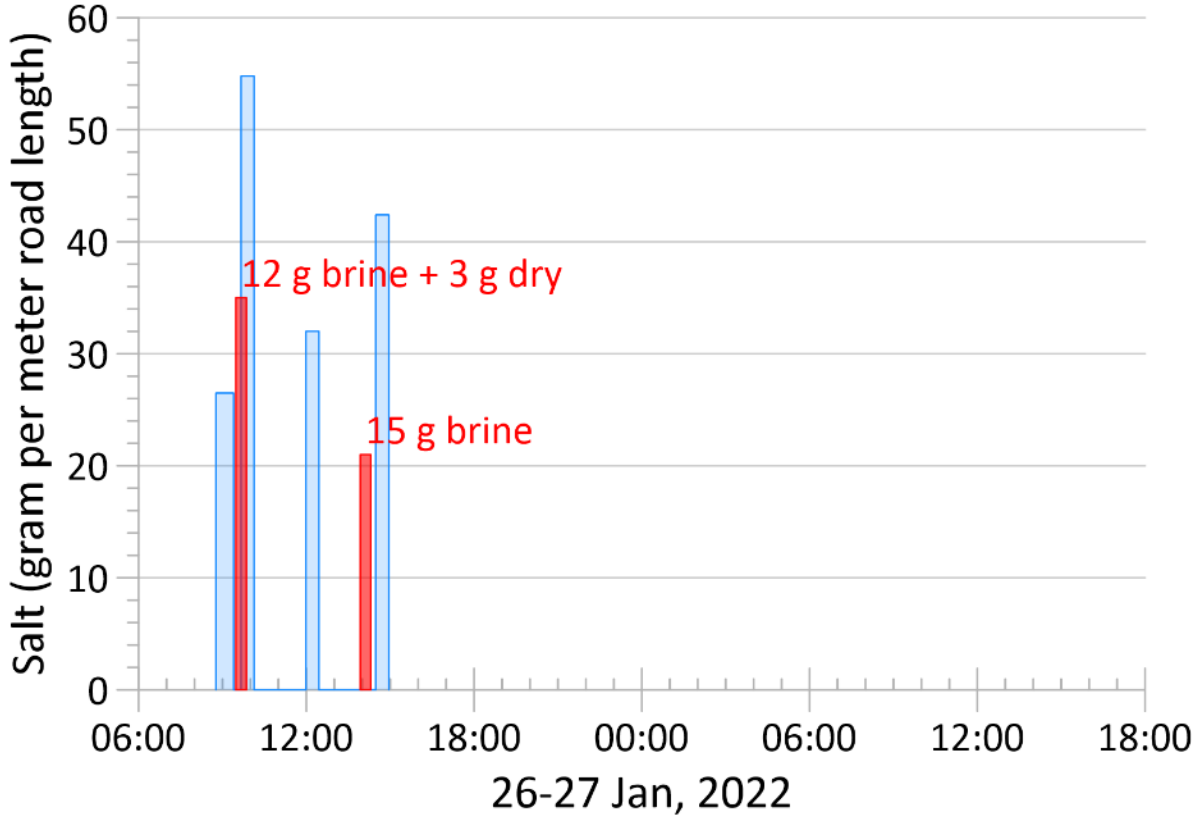

1. 08:46 Before salting
2. 09:40 After salting
3. 12:00
4. 14:30
5. 19:00
6. 21:30
7. 09:30
8. 12:00
9. 14:30
Right lane
Paved shoulder
Residual salt, (g/m²)
25
20
15
10
5
0
500
400
300
200
100
0
Cross section (cm)

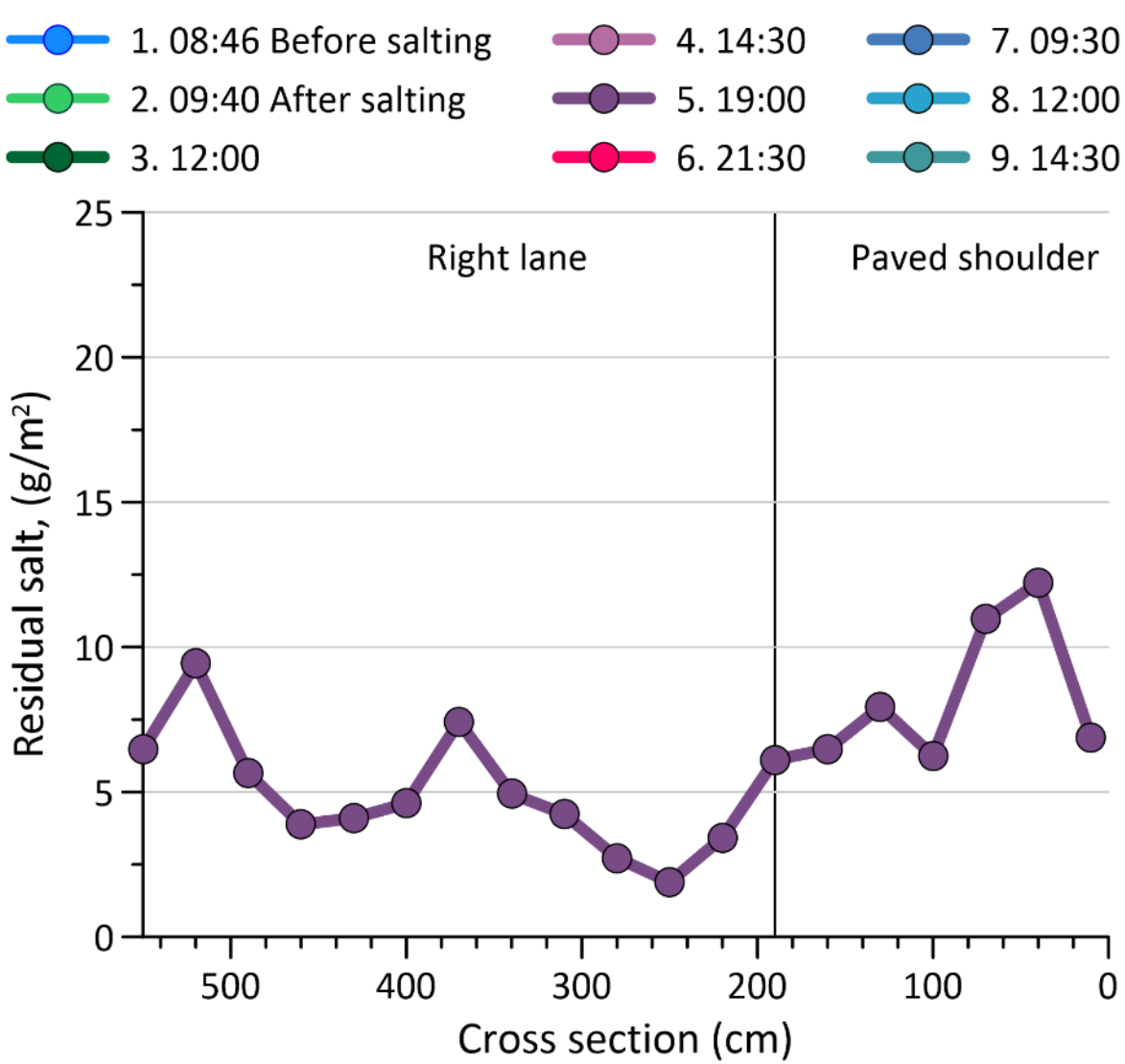

Falkoping
WYN 088
18:00

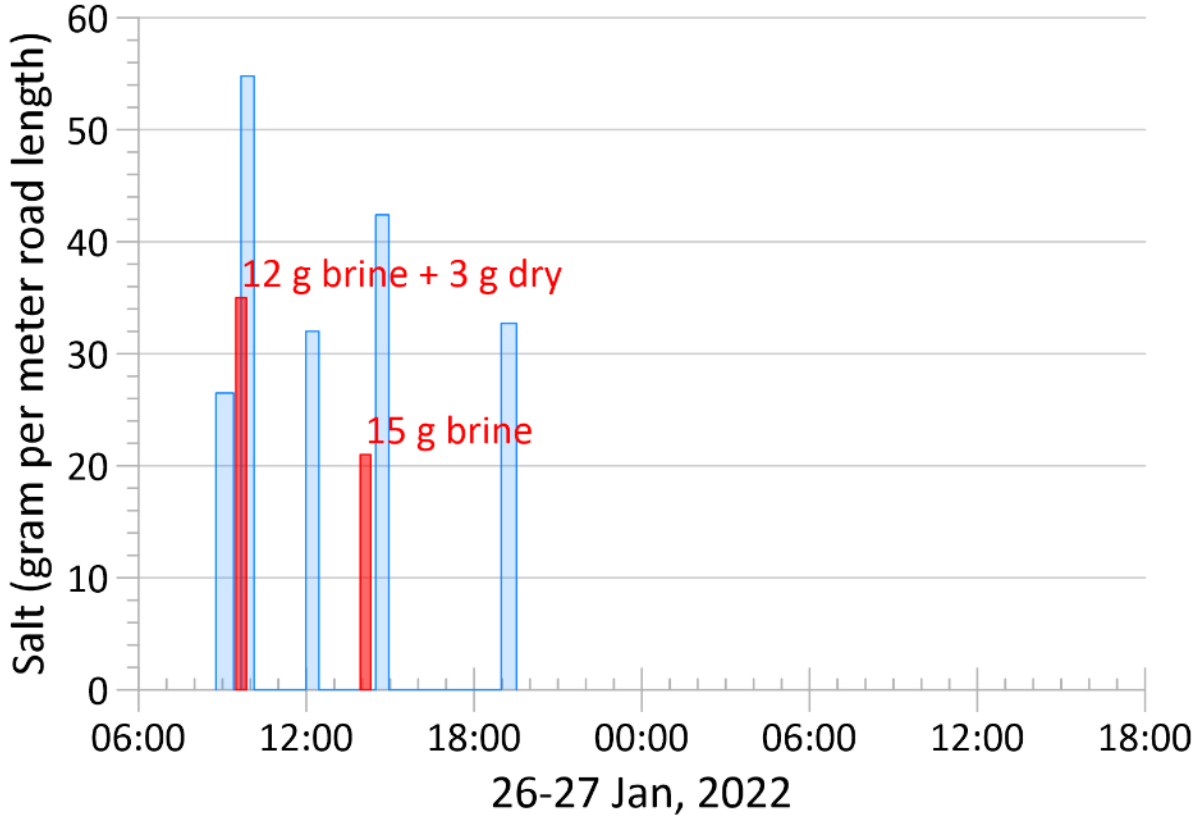

1. 08:46 Before salting
2. 09:40 After salting
3. 12:00
4. 14:30
5. 19:00
6. 21:30
7. 09:30
8. 12:00
9. 14:30
Right lane
Paved shoulder
Residual salt, (g/m²)
0
5
10
15
20
25
500
400
300
200
100
0
Cross section (cm)

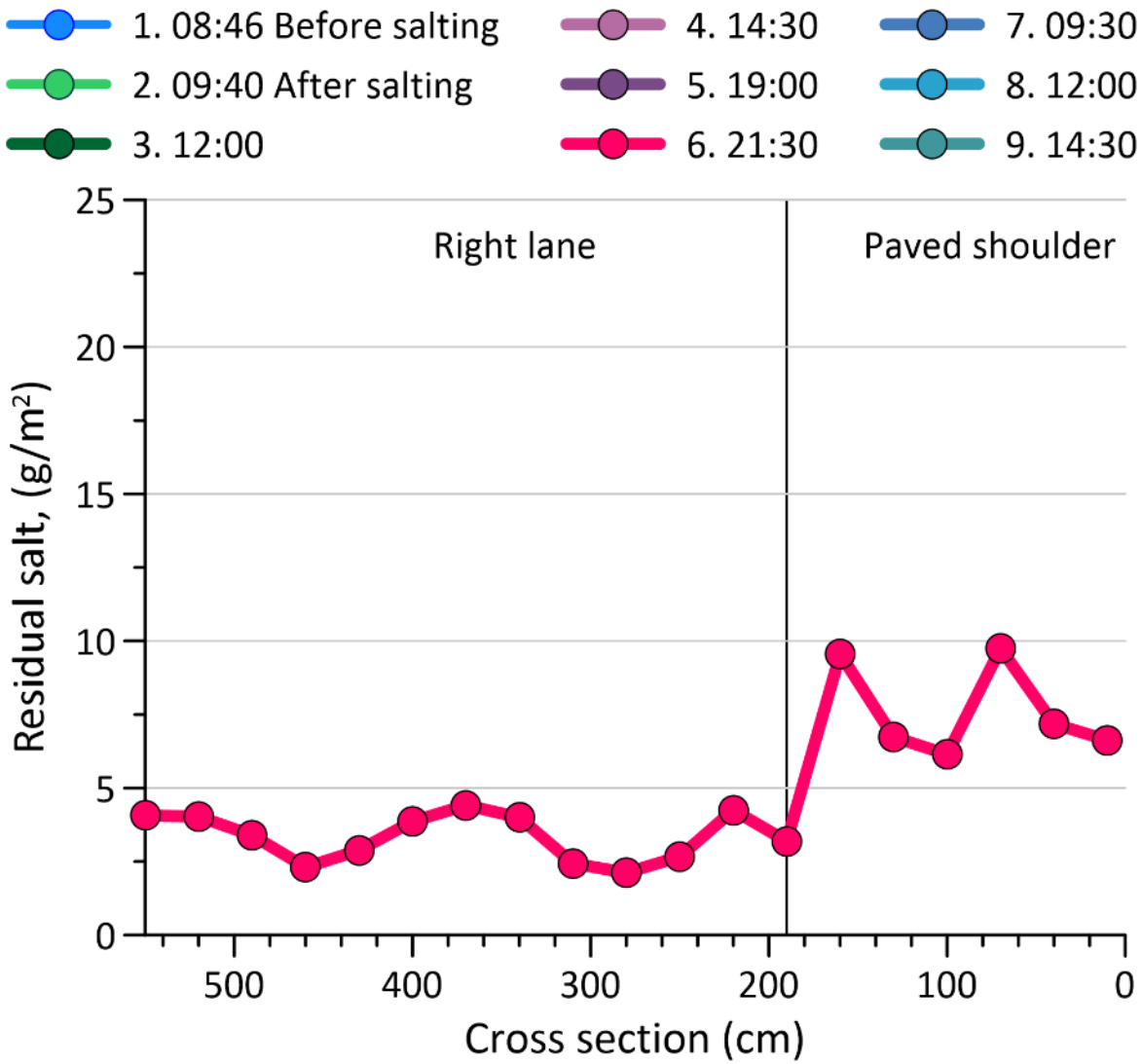

Salt (gram per meter road length)
0
10
20
30
40
50
60
12 g brine + 3 g dry
06:00
12:00
18:00
00:00
06:00
12:00
18:00
26-27 Jan, 2022

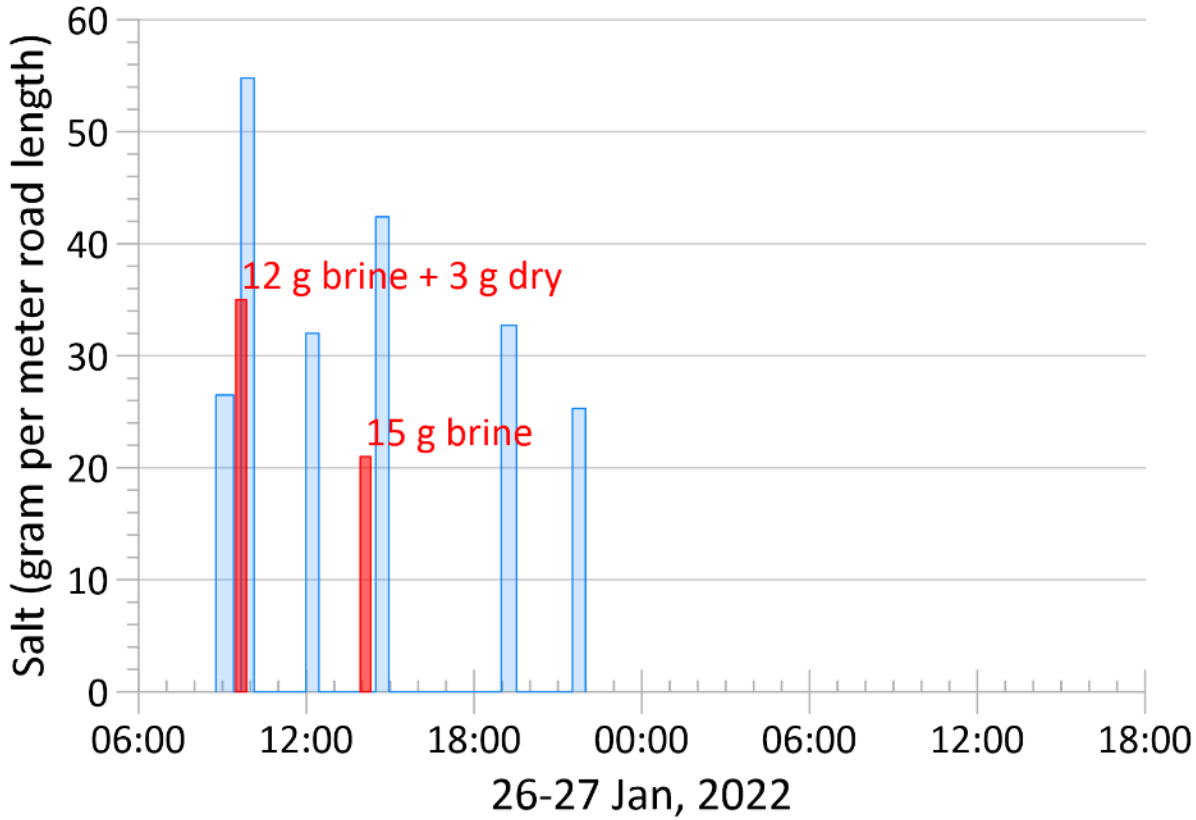

1. 08:46 Before salting
2. 09:40 After salting
3. 12:00
4. 14:30
5. 19:00
6. 21:30
7. 09:30
8. 12:00
9. 14:30
Right lane
Paved shoulder
Residual salt, (g/m²)
Cross section (cm)
25
20
15
10
5
0
500
400
300
200
100
0

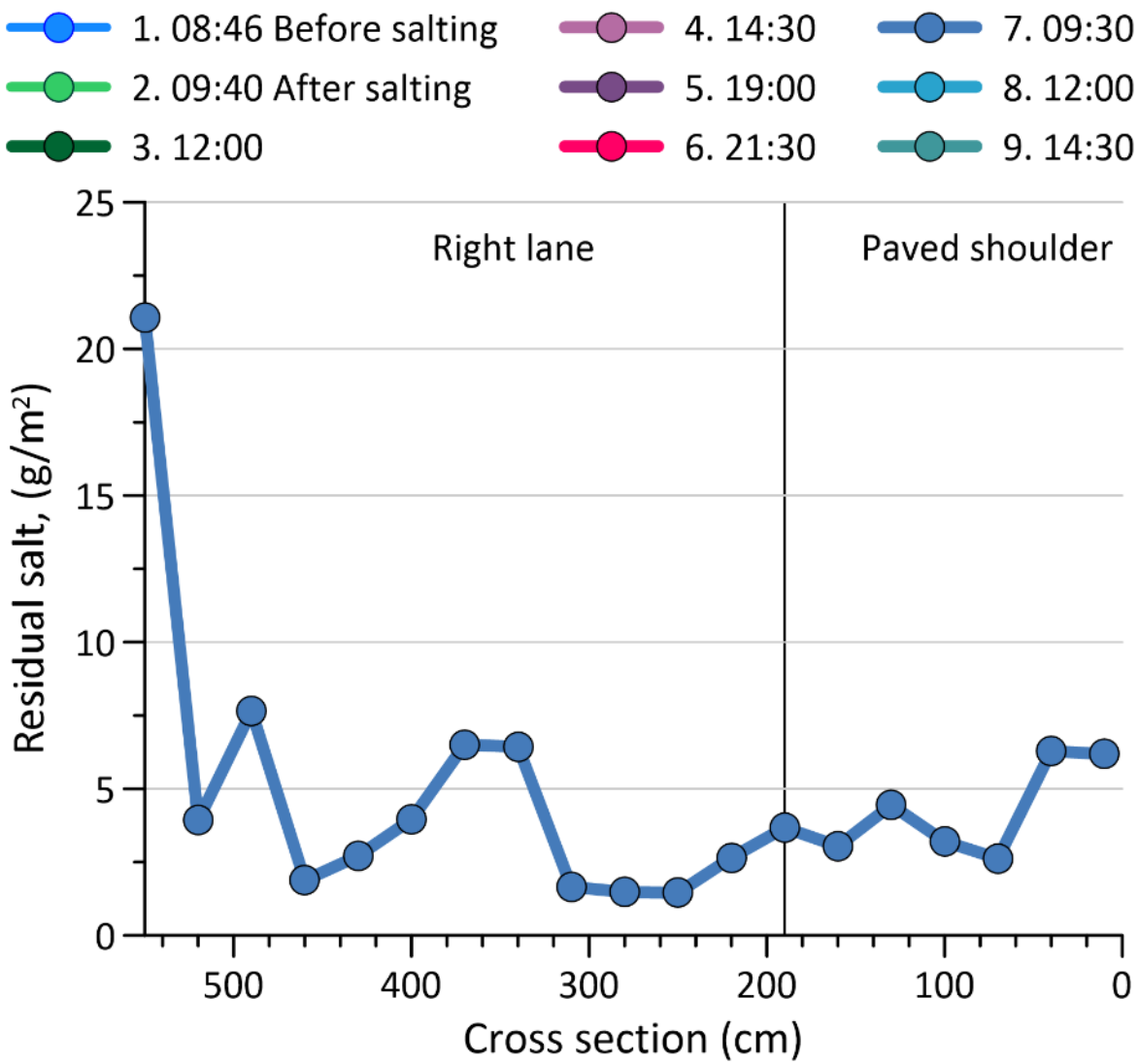

Salt (gram per meter road length)
12 g brine + 3 g dry
15 g brine
60
50
40
30
20
10
0
06:00
12:00
18:00
00:00
06:00
12:00
18:00
26-27 Jan, 2022

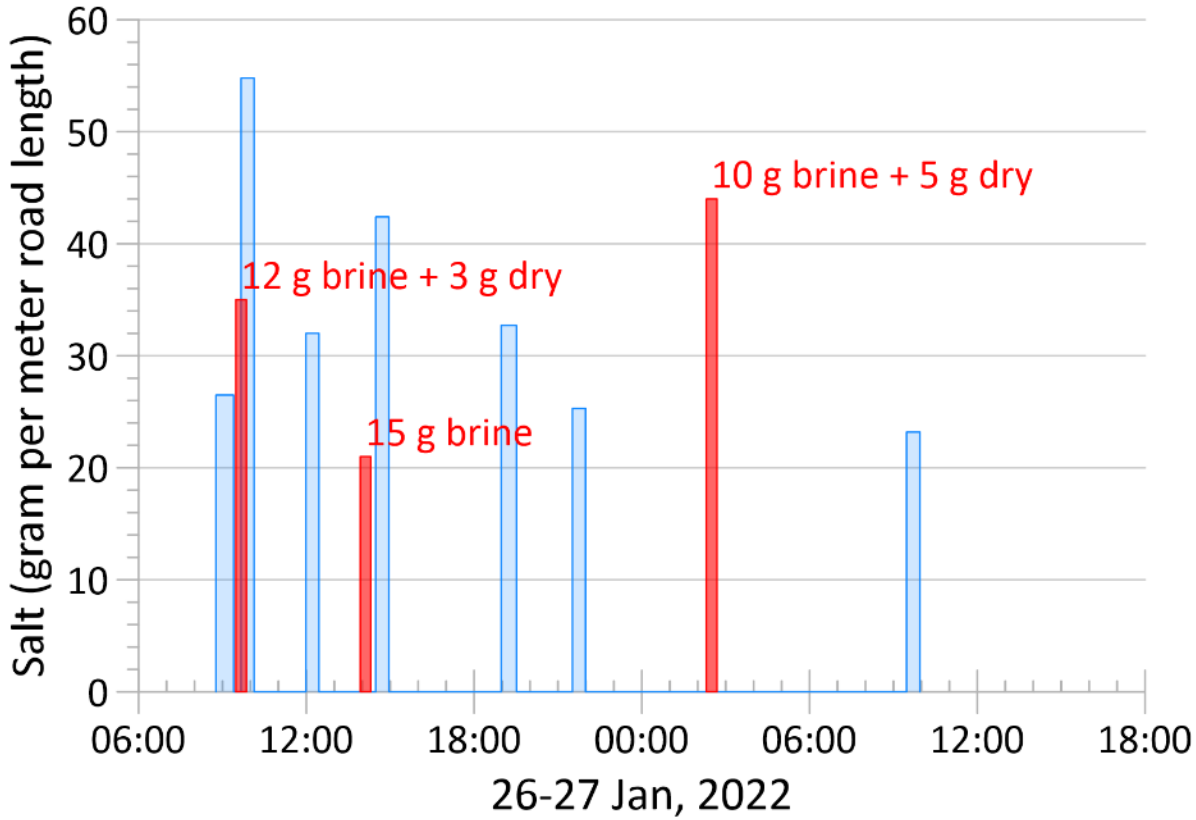

1. 08:46 Before salting
2. 09:40 After salting
3. 12:00
4. 14:30
5. 19:00
6. 21:30
7. 09:30
8. 12:00
9. 14:30
Right lane
Paved shoulder
Residual salt, (g/m²)
Cross section (cm)
25
20
15
10
5
0
500
400
300
200
100
0

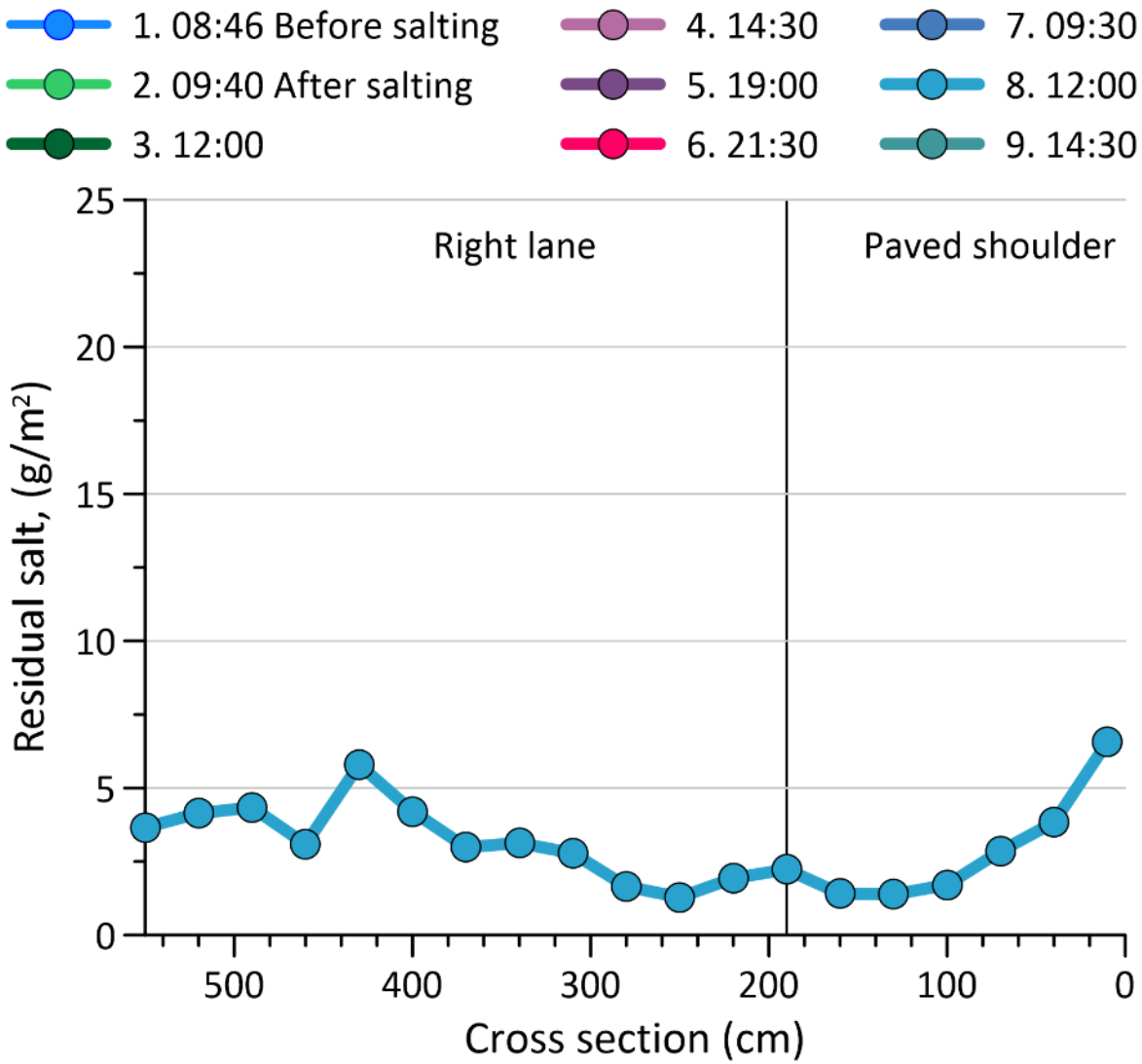

Salt (gram per meter road length)
12 g brine + 3 g dry
15 g brine
60
50
40
30
20
10
0
06:00
12:00
18:00
00:00
06:00
12:00
18:00
26-27 Jan, 2022

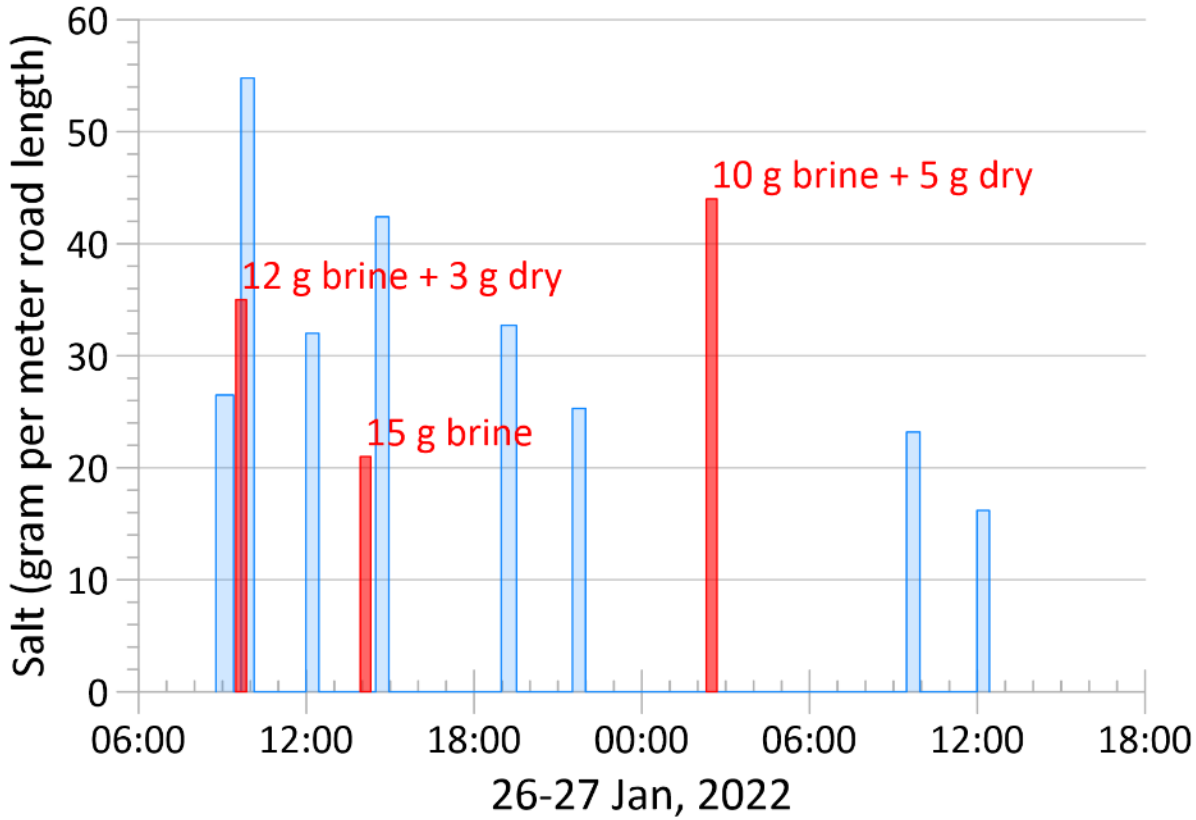

1. 08:46 Before salting
2. 09:40 After salting
3. 12:00
4. 14:30
5. 19:00
6. 21:30
7. 09:30
8. 12:00
9. 14:30
Right lane
Paved shoulder
Residual salt, (g/m²)
Cross section (cm)
25
20
15
10
5
0
500
400
300
200
100
0

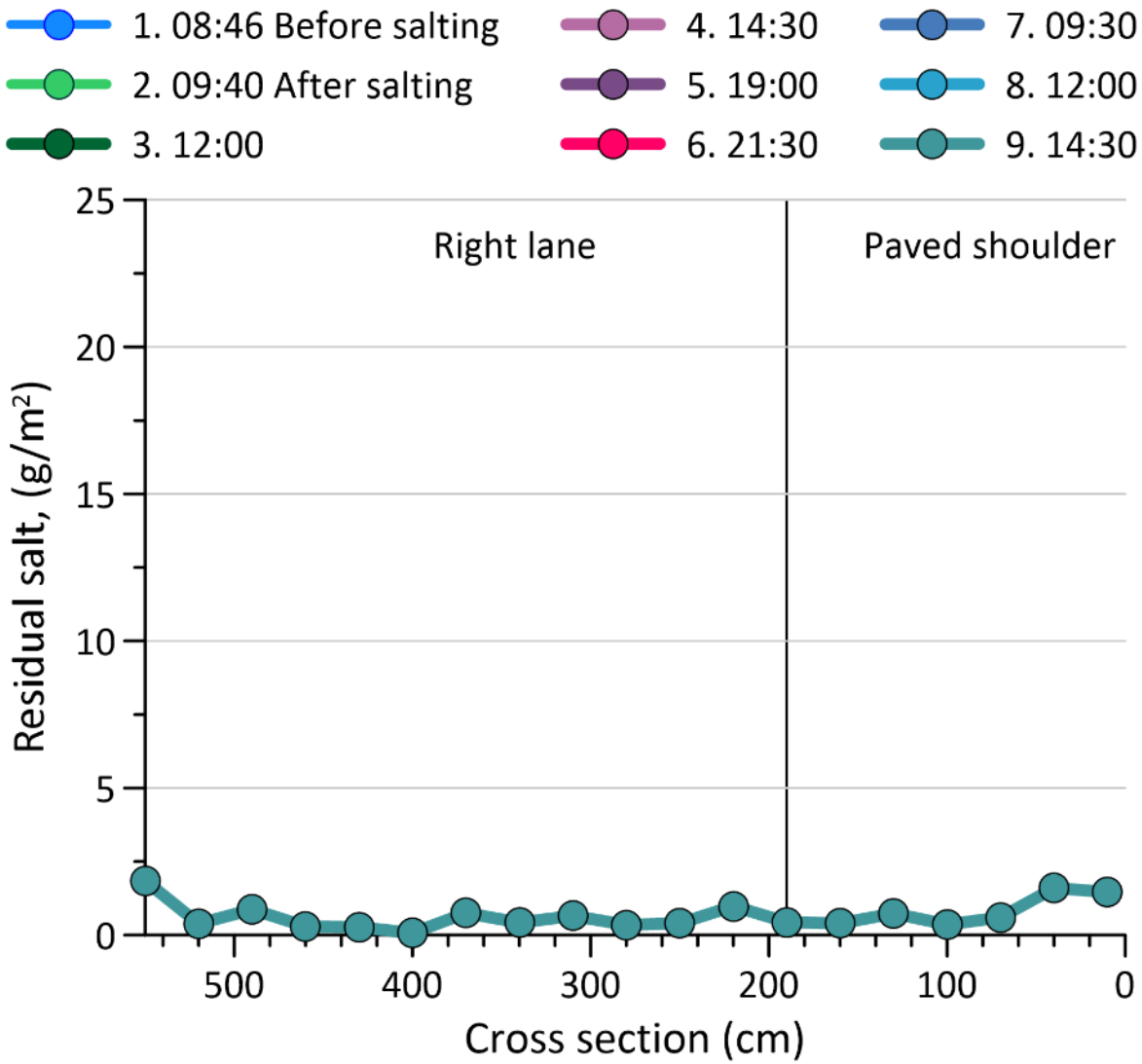

Salt (gram per meter road length)
12 g brine + 3 g dry
15 g brine
60
50
40
30
20
10
0
06:00
12:00
18:00
00:00
06:00
12:00
18:00
26-27 Jan, 2022

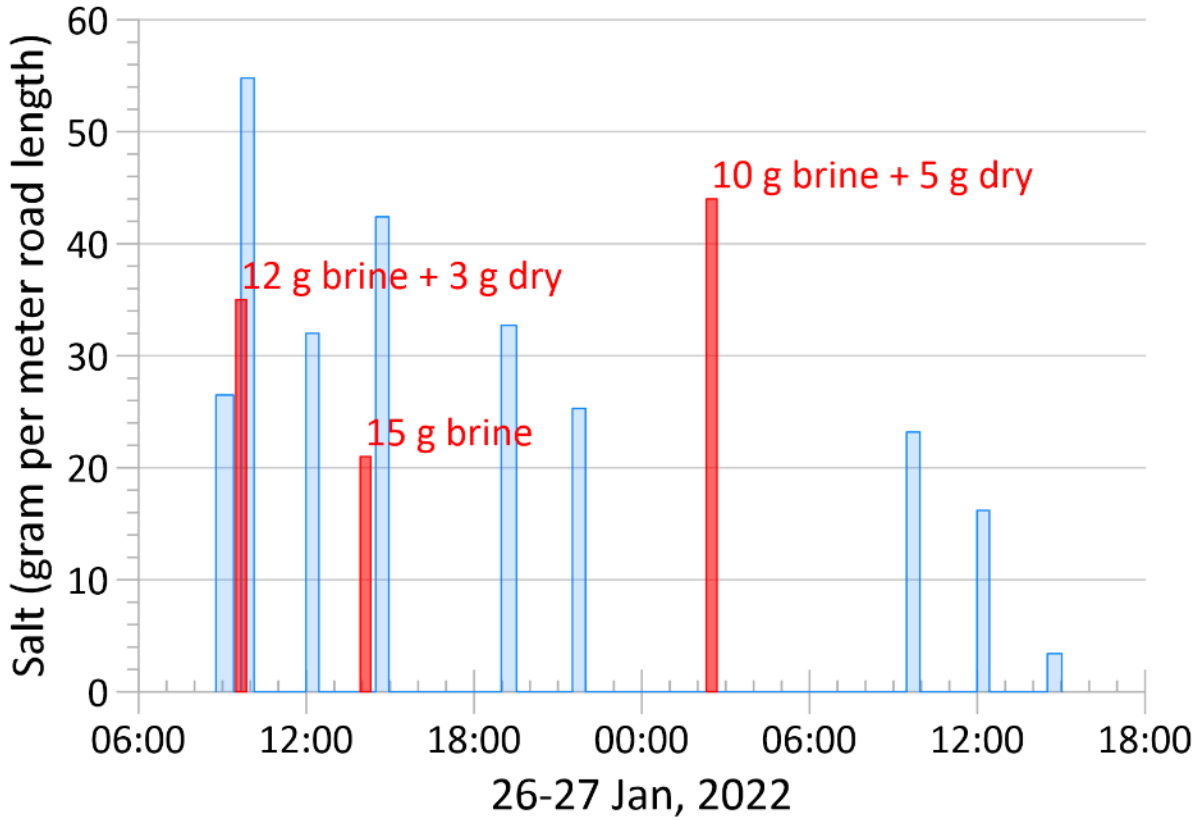

1. 08:46 Before salting
2. 09:40 After salting
3. 12:00
4. 14:30
5. 19:00
6. 21:30
7. 09:30
8. 12:00
9. 14:30
Right lane
Paved shoulder
Residual salt, (g/m²)
Cross section (cm)
25
20
15
10
5
0
500
400
300
200
100
0


Salt (gram per meter road length)
12 g brine + 3 g dry
15 g brine
10 g brine + 5 g dry
60
50
40
30
20
10
0
06:00
12:00
18:00
00:00
06:00
12:00
18:00
26-27 Jan, 2022


1. 08:46 Before salting
2. 09:40 After salting
3. 12:00
4. 14:30
5. 19:00
6. 21:30
7. 09:30
8. 12:00
9. 14:30
Right lane
Paved shoulder
Residual salt, (g/m²)
Cross section (cm)
25
20
15
10
5
0
500
400
300
200
100
0

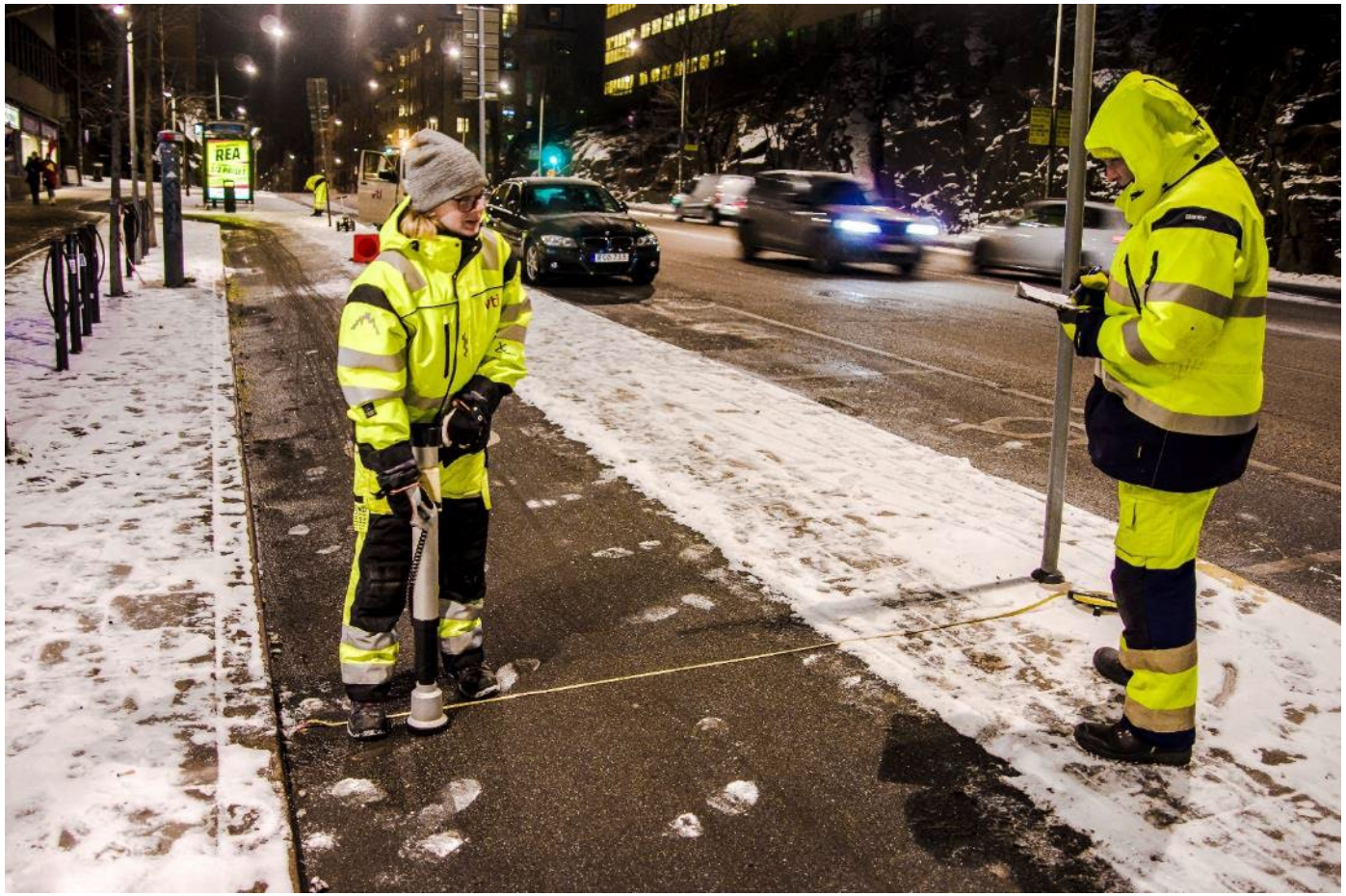

Salt (gram per meter road length)
12 g brine + 3 g dry
15 g brine
10 g brine + 5 g dry
60
50
40
30
20
10
0
06:00
12:00
18:00
00:00
06:00
12:00
18:00
26-27 Jan, 2022


1. 08:46 Before salting
2. 09:40 After salting
3. 12:00
4. 14:30
5. 19:00
6. 21:30
7. 09:30
8. 12:00
9. 14:30
Right lane
Paved shoulder
Residual salt, (g/m²)
25
20
15
10
5
0
500
400
300
200
100
0
Cross section (cm)

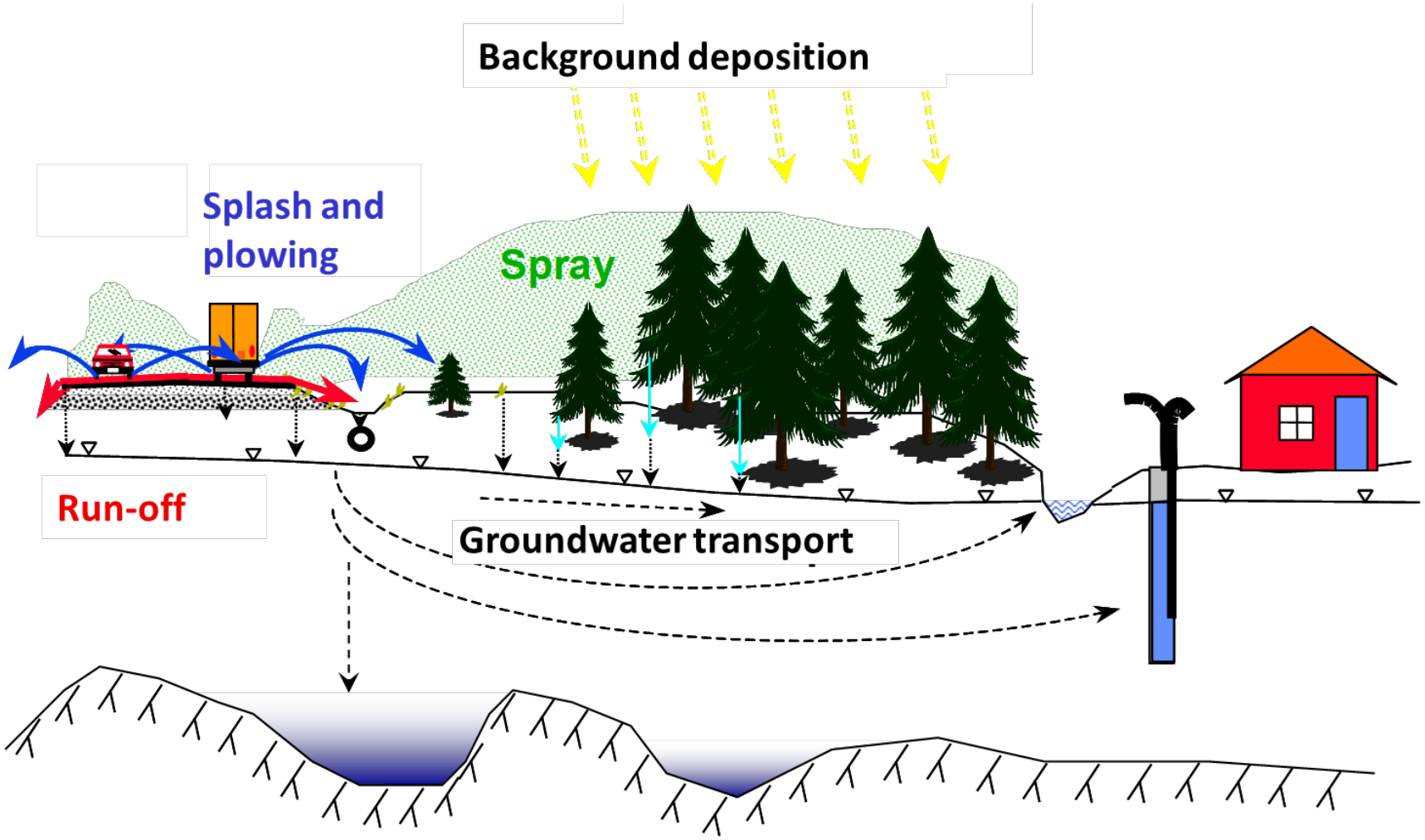

Salt (gram per meter road length)
60
50
40
30
20
10
0
12 g brine + 3 g dry
15 g brine
10 g brine + 5 g dry
06:00
12:00
18:00
00:00
06:00
12:00
18:00
26-27 Jan, 2022

Residual salt monitoring – different methods

- How do they work?
- What does the measured value represent

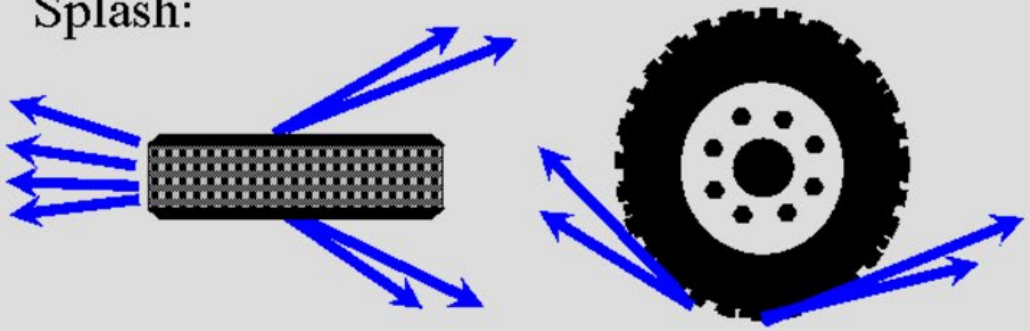


But, where did the salt go?

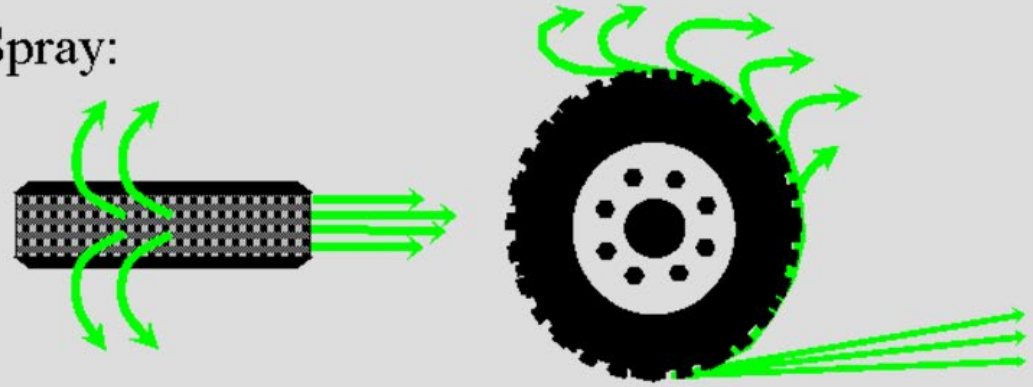


Splash and spray generation mechanisms

Splash:



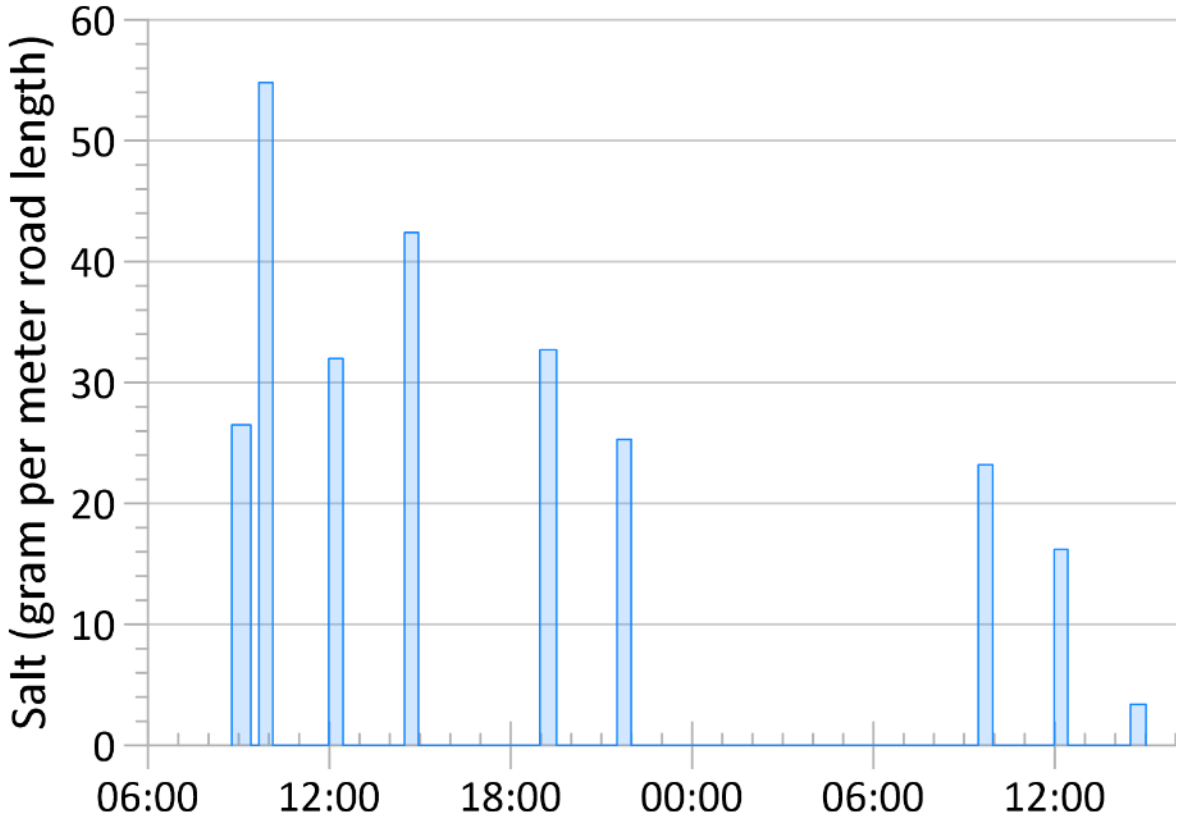
Spray:

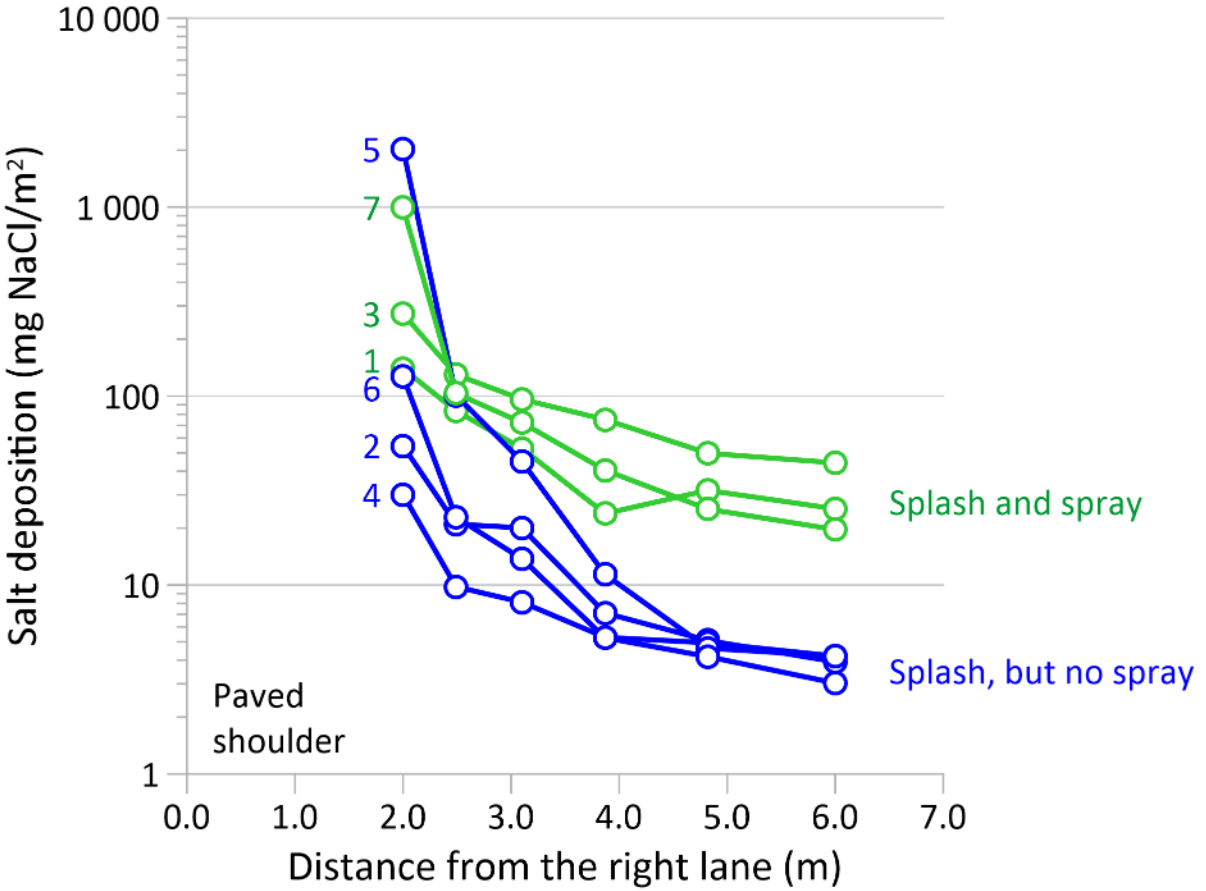


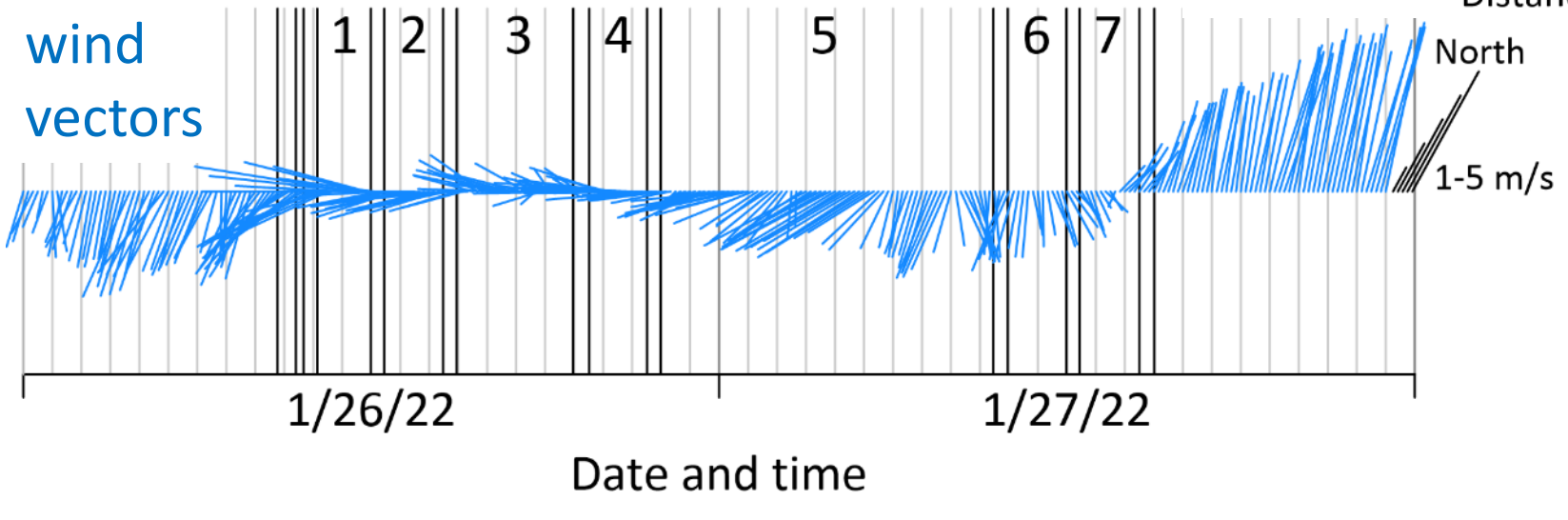
After: Weir and Strange 1978, U.S.D.O.T. Report No FHWA-RD-79-84

How do we measure splash and spray?

- Petri dishes collect the deposition
- The content is analysed at the lab.


Salt (gram per meter road length)
60
50
40
30
20
10
0
06:00
12:00
18:00
00:00
06:00
12:00


Salt deposition (mg NaCl/m²)
10 000
1 000
100
10
1
5
7
3
1
6
2
4
Splash and spray
Splash, but no spray
Paved
shoulder
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Distance from the right lane (m)


wind
vectors
1
2
3
4
5
6
7
North
1-5 m/s
1/26/22
1/27/22
Date and time

- Understand the processes,
- Monitor the status,
- Remember ”ice quality”, not ”melting capacity”,
- Know where your sensitive environments are.

Thank you for listening!

Contact:
goran.blomqvist@vti.se

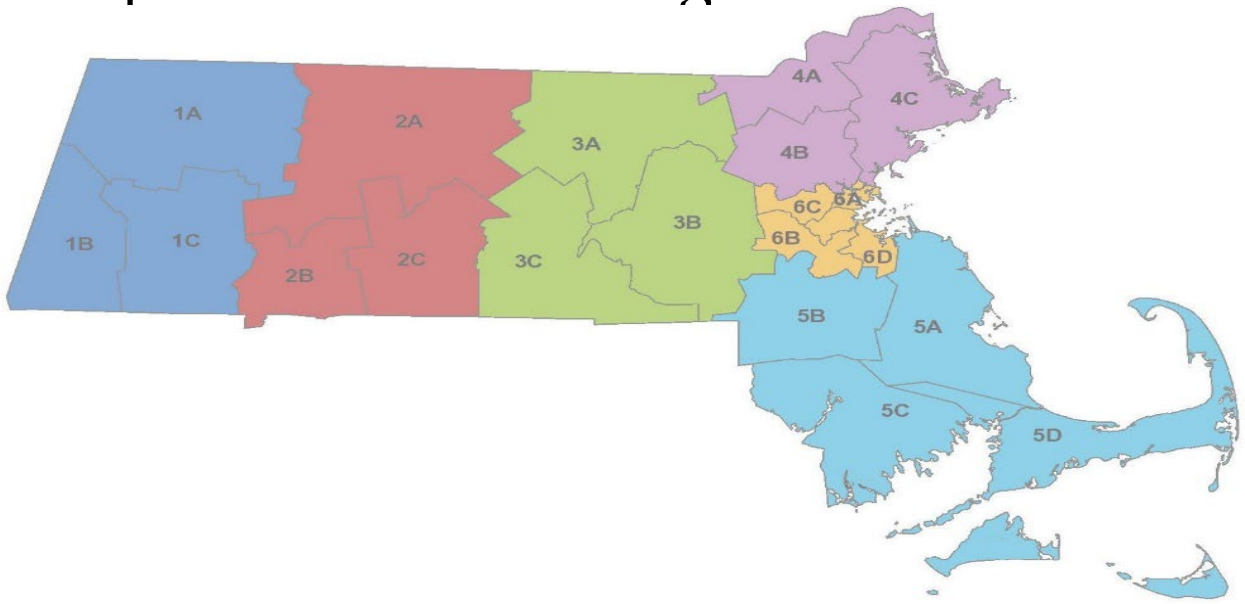
Leveraging Technology for Better Materials Management and Cost Savings at MassDOT

Introductions

- Mark Goldstein, Lead Statewide Snow & Ice Engineer

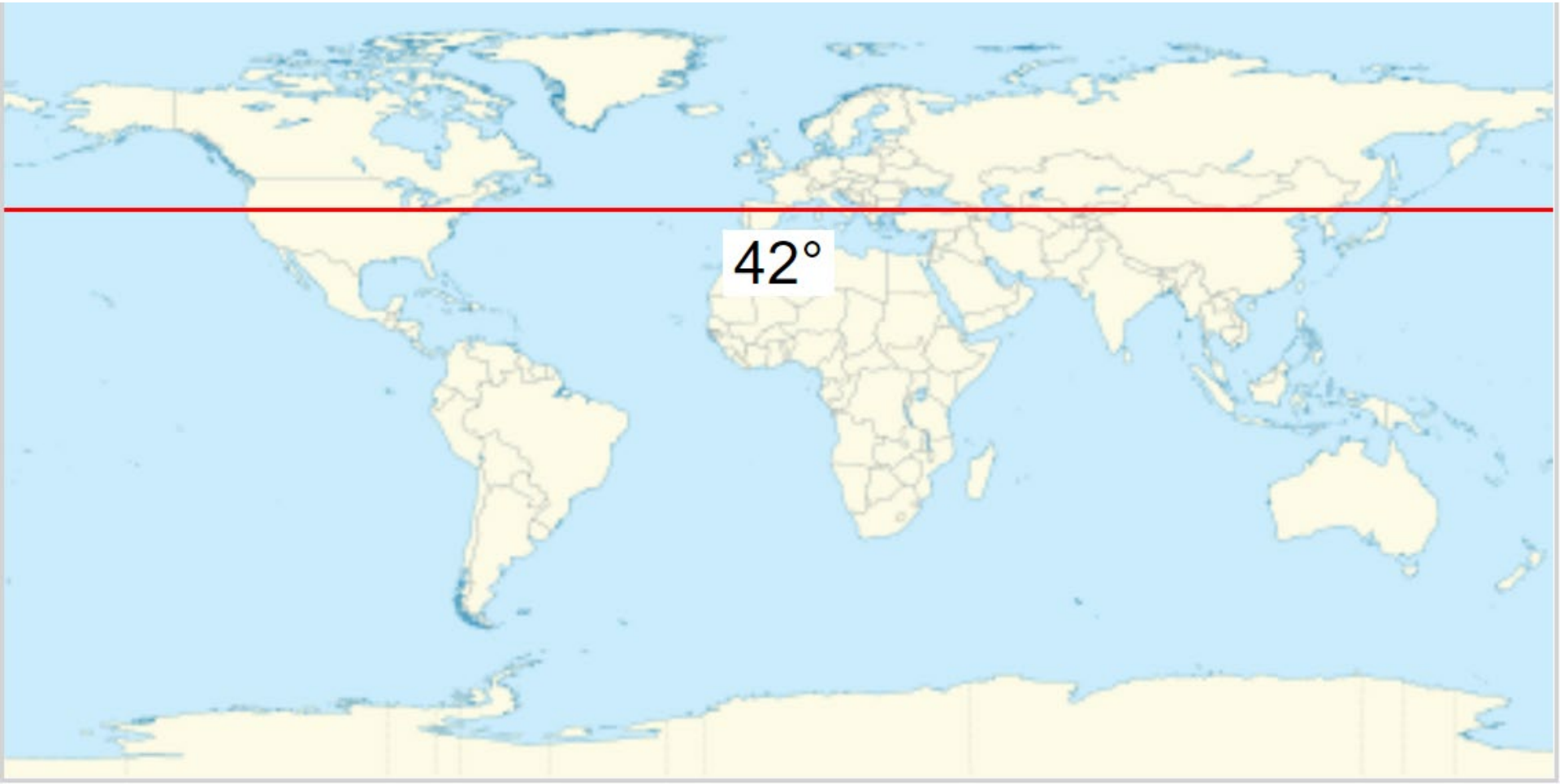
Overview

- Perform snow and ice removal on 15,000+ lane miles.
- 6 Districts and 20 sub-Districts
- 150 Depots/ Salt Storage Locations
- Over 700 personnel at the height of a storm



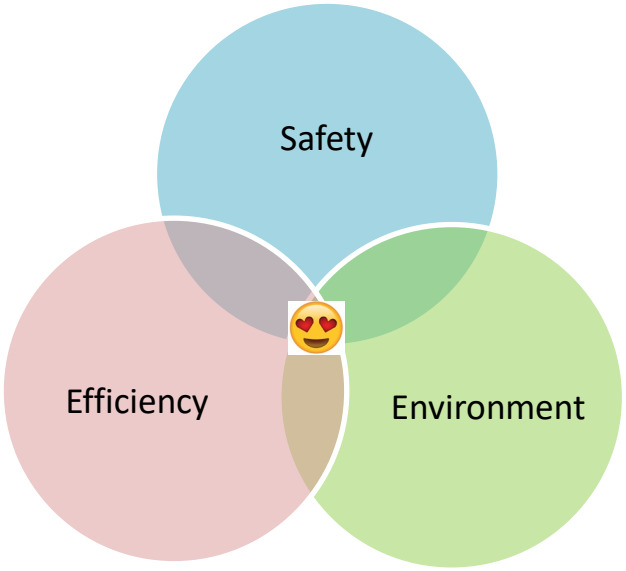

HIGHEST TURNPIKE
ELEVATION 1724 FEET
NEXT HIGHEST ELEVATION
ON I-90
OACOMA, SOUTH DAKOTA
1729 FEET


Edmonton
Calgary
Ottawa
Montreal
Toronto
Chicago
United States
New York
Philadelphia
Indianapolis
Columbus
San Jose
Oklahoma City
Charlotte
Los Angeles
Phoenix
Dallas
Tijuana
Ciudad Juárez
300 km


42°

Snow and Ice Program: Goals

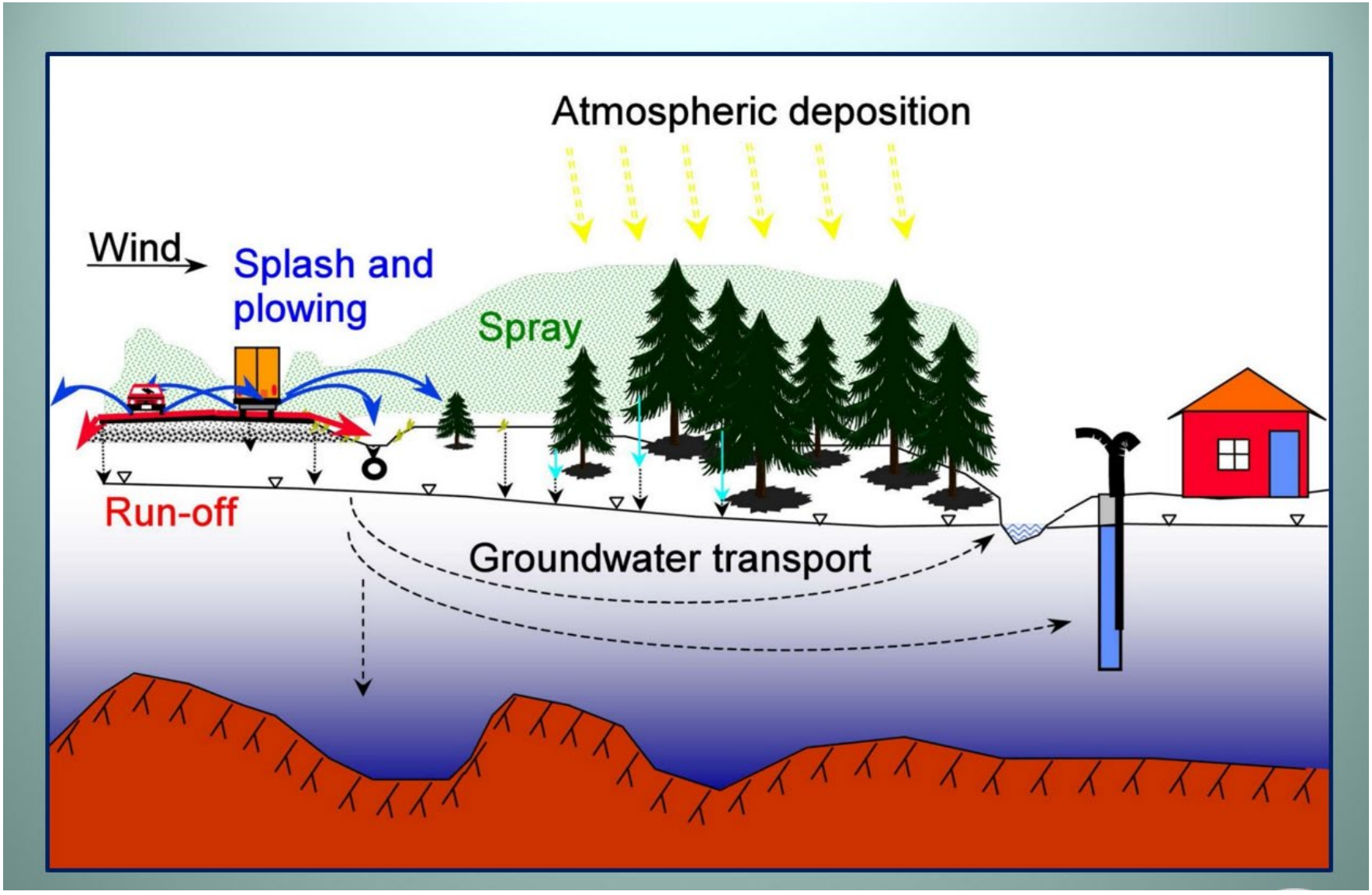
- Public Safety
- Efficiency and Effectiveness
- Environment



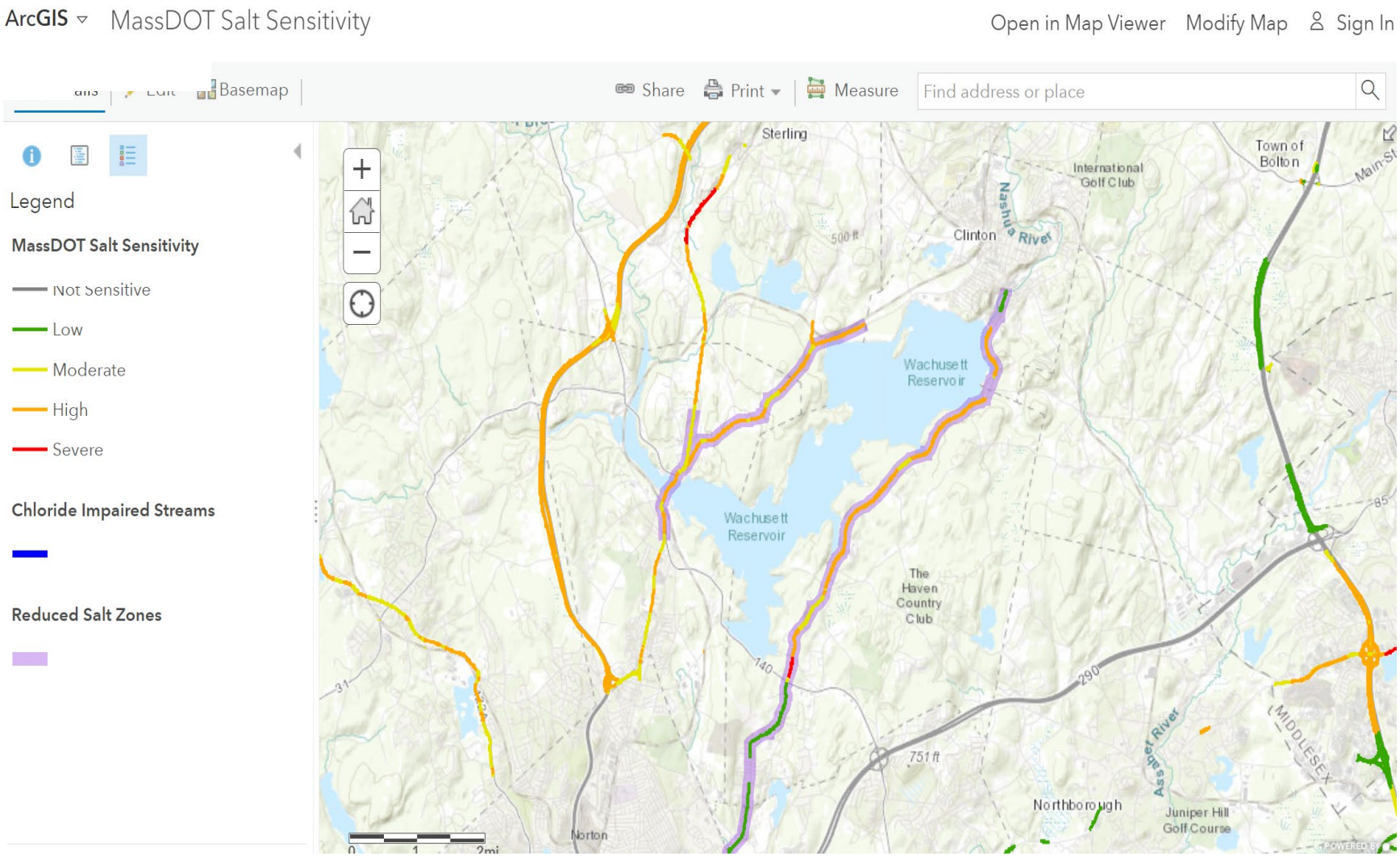
Environmental Issues

- Water Supply
- Chloride Impairments
- Corrosion
- Sand Impacts

Salt Will Find Its Way Into the Environment



GIS Resources as a Training Aid



“Success Through Innovation”

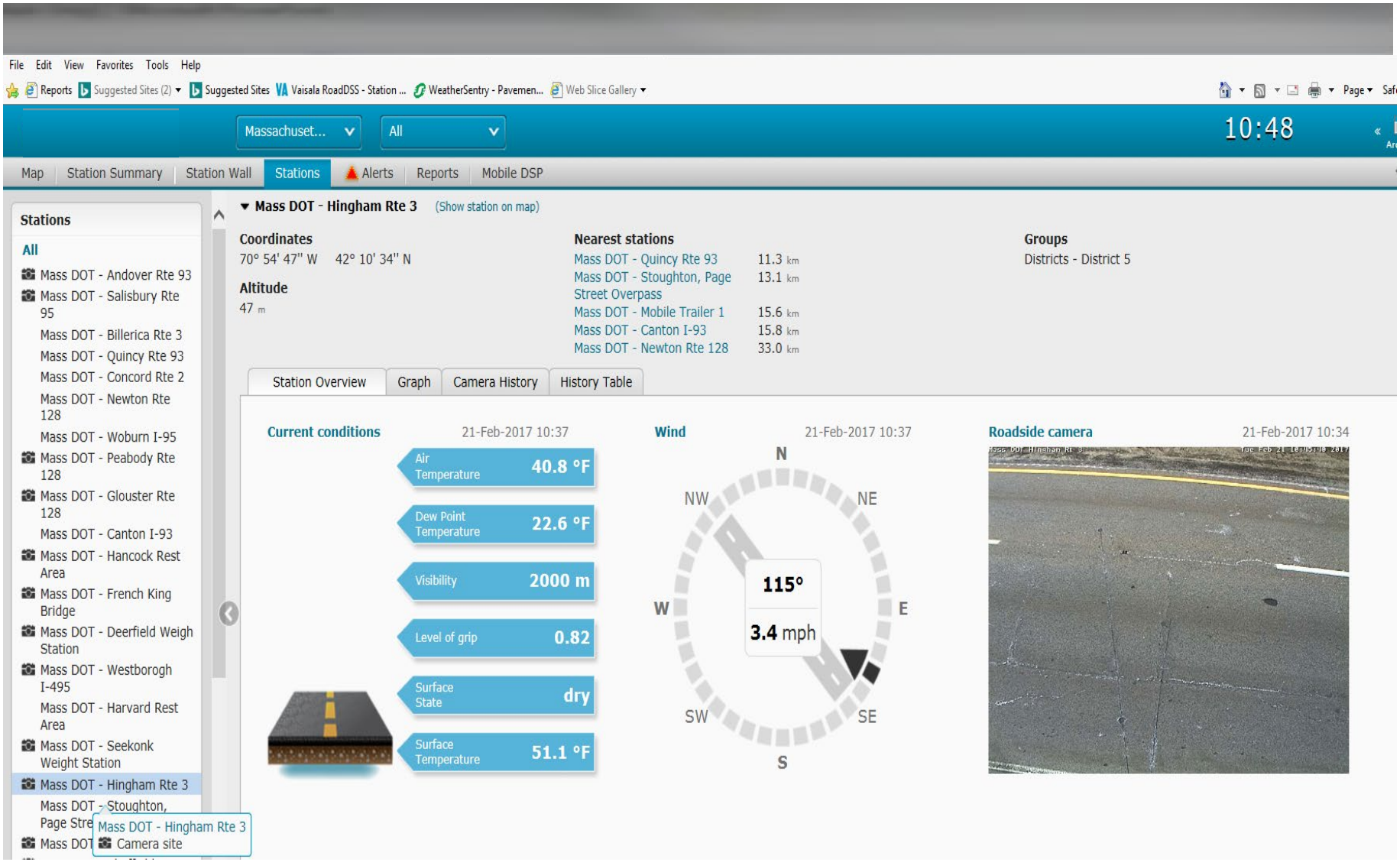
- Pre-treatment
- Pre-wetting
- Closed-loop Controllers
- Pavement Friction Sensors/Meters
- RWIS Stations w/ cameras
- Tow Plows
- Segmented Plow Blades
- GPS/AVL Devices
- Loader Scales
- Reconfiguring Equipment Routes to do More with Less

RWIS / Pavement Friction Meters

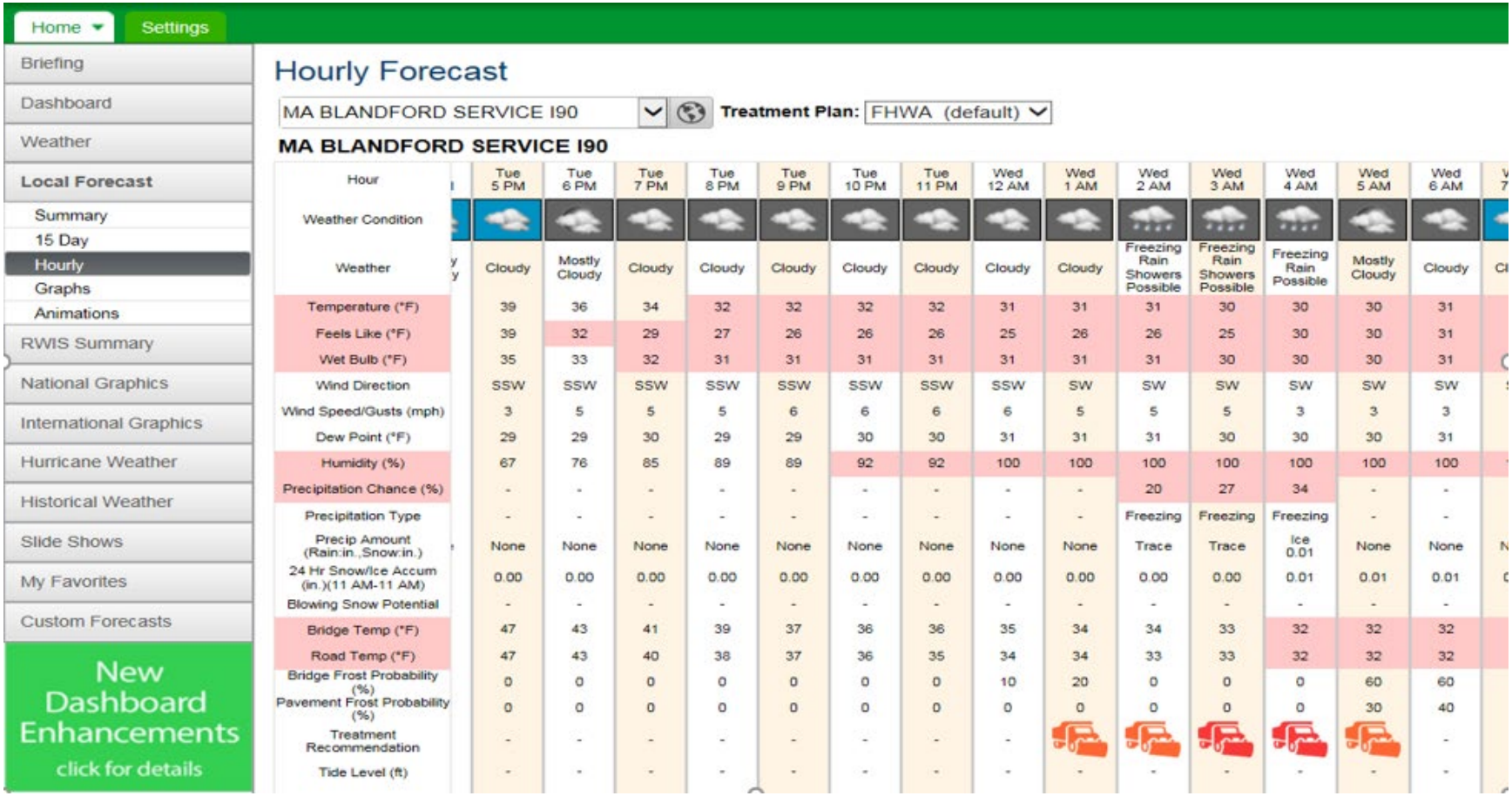
Road Weather Information Systems

Non-Intrusive Friction Meters

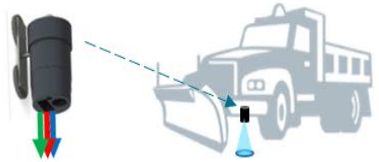
RWIS Site-Specific Information

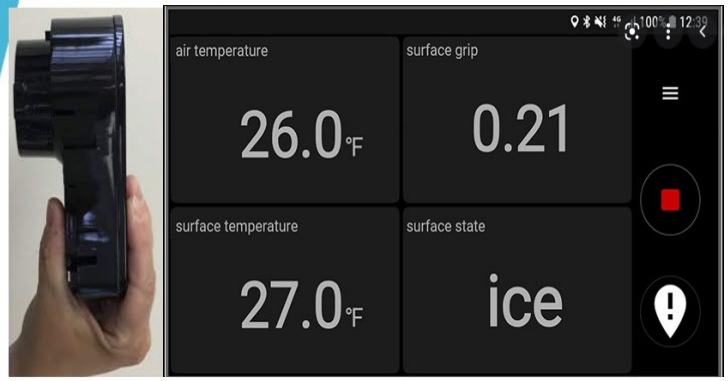


RWIS Treatment Recommendations

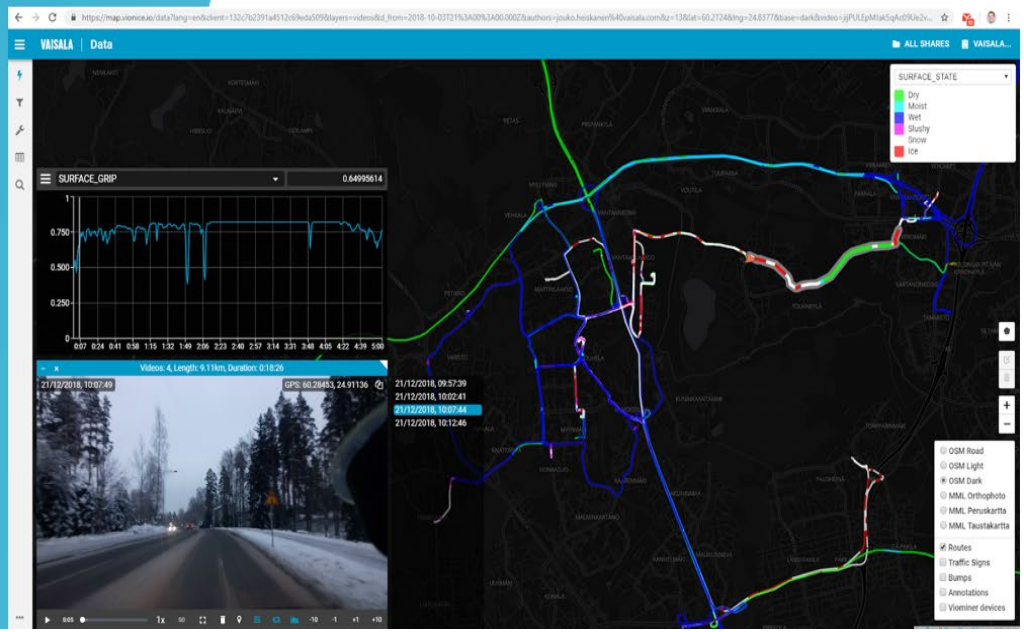


Hour	Tue 5 PM	Tue 6 PM	Tue 7 PM	Tue 8 PM	Tue 9 PM	Tue 10 PM	Tue 11 PM	Wed 12 AM	Wed 1 AM	Wed 2 AM	Wed 3 AM	Wed 4 AM	Wed 5 AM	Wed 6 AM
Weather Condition														
Weather	Cloudy	Mostly Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Freezing Rain Showers Possible	Freezing Rain Showers Possible	Freezing Rain Possible	Mostly Cloudy	Cloudy
Temperature (°F)	39	36	34	32	32	32	32	31	31	31	30	30	30	31
Feels Like (°F)	39	32	29	27	26	26	26	25	26	26	25	30	30	31
Wet Bulb (°F)	35	33	32	31	31	31	31	31	31	31	30	30	30	31
Wind Direction	SSW	SSW	SSW	SSW	SSW	SSW	SSW	SSW	SW	SW	SW	SW	SW	SW
Wind Speed/Gusts (mph)	3	5	5	5	6	6	6	6	5	5	5	3	3	3
Dew Point (°F)	29	29	30	29	29	30	30	31	31	31	30	30	30	31
Humidity (%)	67	76	85	89	89	92	92	100	100	100	100	100	100	100
Precipitation Chance (%)	-	-	-	-	-	-	-	-	-	20	27	34	-	-
Precipitation Type	-	-	-	-	-	-	-	-	-	Freezing	Freezing	Freezing	-	-
Precip Amount (Rain:in.,Snow:in.)	None	None	None	None	None	None	None	None	None	Trace	Trace	Ice 0.01	None	None
24 Hr Snow/Ice Accum (in.)(11 AM-11 AM)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Blowing Snow Potential	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bridge Temp (°F)	47	43	41	39	37	36	36	35	34	34	33	32	32	32
Road Temp (°F)	47	43	40	38	37	36	35	34	34	33	33	32	32	32
Bridge Frost Probability (%)	0	0	0	0	0	0	0	10	20	0	0	0	60	60
Pavement Frost Probability (%)	0	0	0	0	0	0	0	0	0	0	0	0	30	40
Treatment Recommendation	-	-	-	-	-	-	-	-						-
Tide Level (ft)	-	-	-	-	-	-	-	-	-	-	-	-	-	-





Mobile Detector



Pavement Grip Values

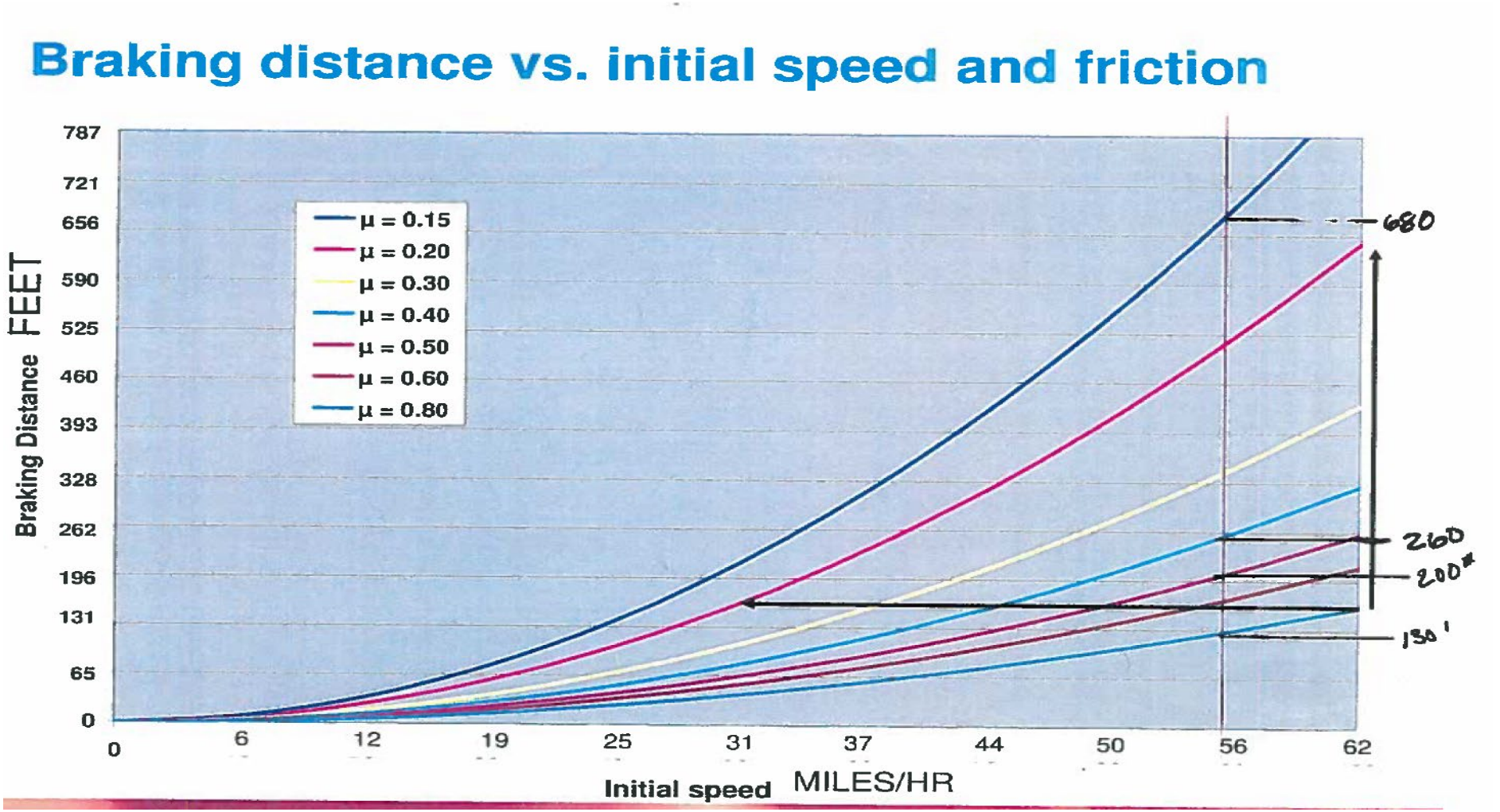


Photo Documenting Roadway Friction

Integration with Spreader Controllers

Use of Winter Severity Index (WSI) to Assess Performance / Salt Efficiency

Winter Severity Index (WSI) used as performance measure to monitor annual road salt usage efficiency

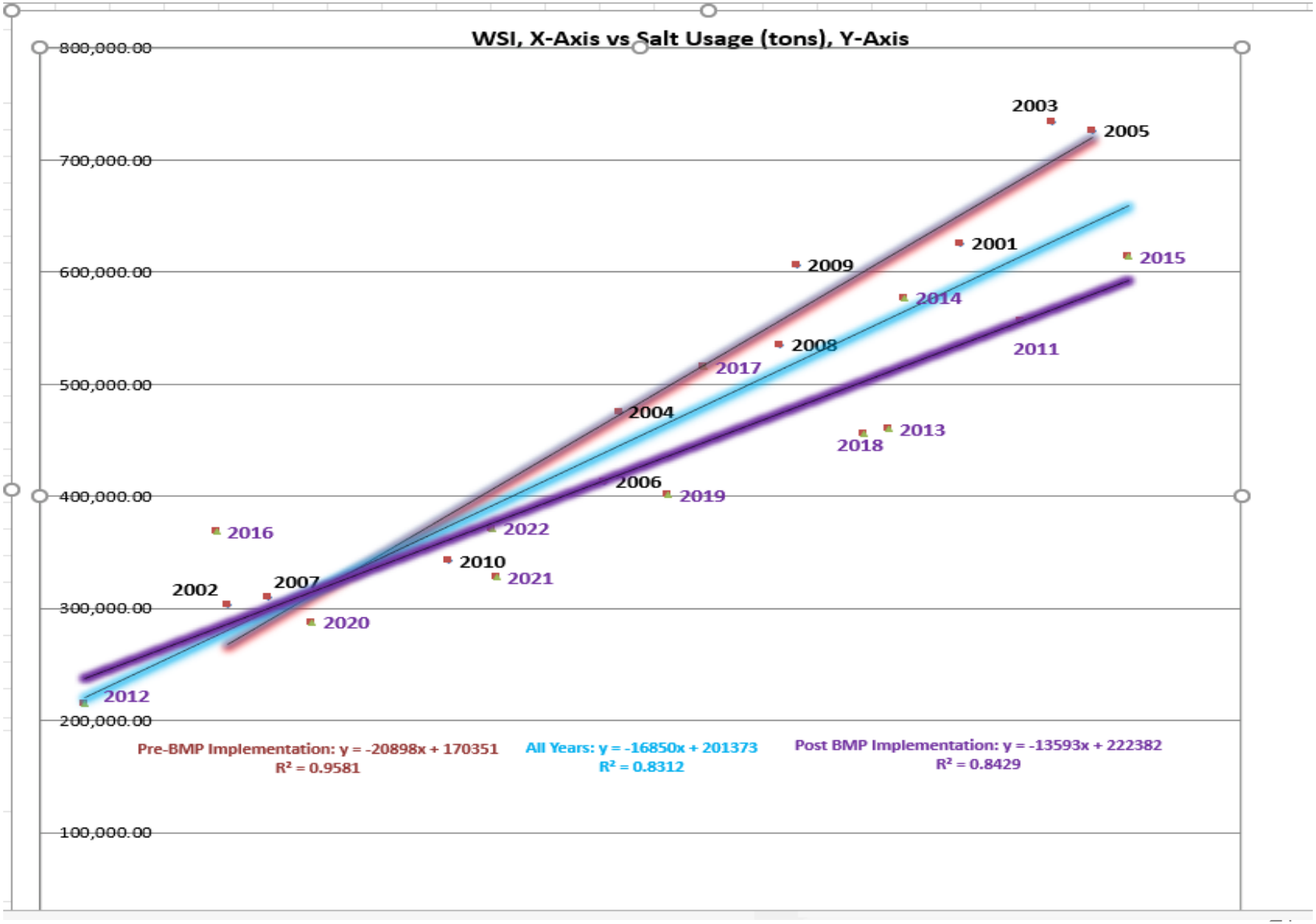
Boselly Index, Based on 3 Weather Parameters

Daily Snowfall

Daily Average and Minimum Temperature

Number of Days with Frost Potential

WSI and Salt Use Data



In Summary…

- We want to thank the TRB for the opportunity to talk with you all today.