CLEAR ROADS

research for winter highway maintenance

Manual of

Best Management Practices

for Road Salt in Winter Maintenance

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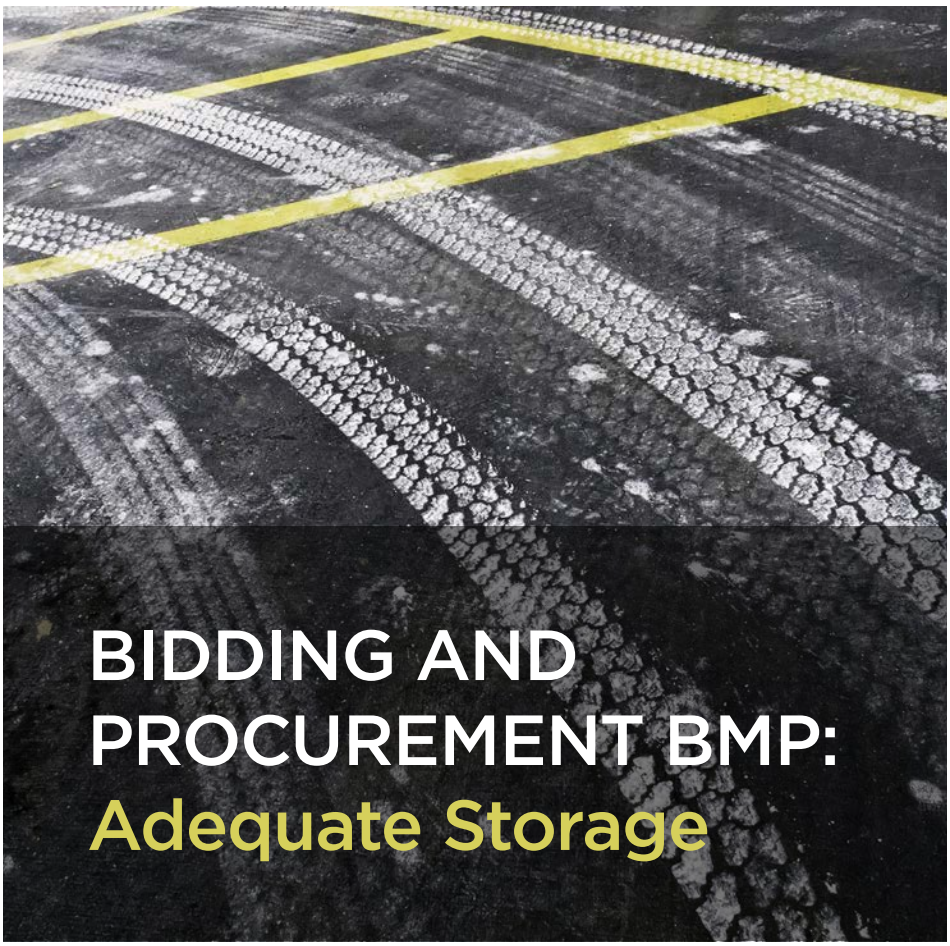
INTRODUCTION

The purpose of this handbook it to present best management practices (BMP) for road salt in winter maintenance in a format that is easy to use and access. While it is understood that individual agency experience may vary, this compilation represents the best practices as determined by a wide group of State and local agencies. The handbook contains two pages for each of the BMPs (with one exception) so that if agencies wish they can print off the two pages for a given BMP and post them or perhaps laminate them to place them in a break room for discussion.

We have done this because the primary challenge with BMPs is implementation. The science behind the BMPs in this document is well known, and the benefits of implementing them have been proven for many years. Yet, they are still not as widely implemented in winter maintenance operations in the US as they should be. Many reports have been written to support the practices described herein but the challenge with such reports is that they often end up on a shelf, unread, unremembered, and most importantly (and disappointingly) unimplemented.

Hence this rather unscientific format for the handbook! All the supporting information for the BMPs in the handbook are given in the project report, which is available from Clear Roads (www.clearroads.org). The goal of this handbook is to avoid the “shelf fate” of a report, and to survive in the environment where it can perhaps do the most good (which would include the break room).

Each agency has its own way of making change. The handbook does not necessarily address implementation (although each BMP includes a few words on the needs associated with implementing that BMP) but does provide a starting point for the implementation. We hope that you find it useful.



BIDDING AND PROCUREMENT BMP: Adequate Storage

According to the Salt Institute's Salt Storage Handbook, an agency should have at least 100% of a normal year's supply stored for its winter operations. As this relates to the bidding process, adequate storage is vital for any agency to ensure it will have enough material for a normal winter season. Agencies that have less than 100% of their yearly supply stored onsite will depend on the vendor to store their needed material and be able to deliver that material throughout the winter season. This is critical because many factors can hamper the delivery of the material and the agency assumes a great deal of risk. Demand for delivery is greatest during the winter season and this is normally when delivery conditions are at their worst. Contracts require that salt be delivered in a timely manner to all agencies so vendors must meet these demands. This means agencies compete with one another to resupply their stockpiles. Delivery from mines can also be affected during the season should waterways become impassable. Most salt is moved by barge or ship before being distributed locally by truck. A variety of weather conditions can hamper movement of waterway traffic but frozen waterways virtually cease any deliveries.

PROCUREMENT

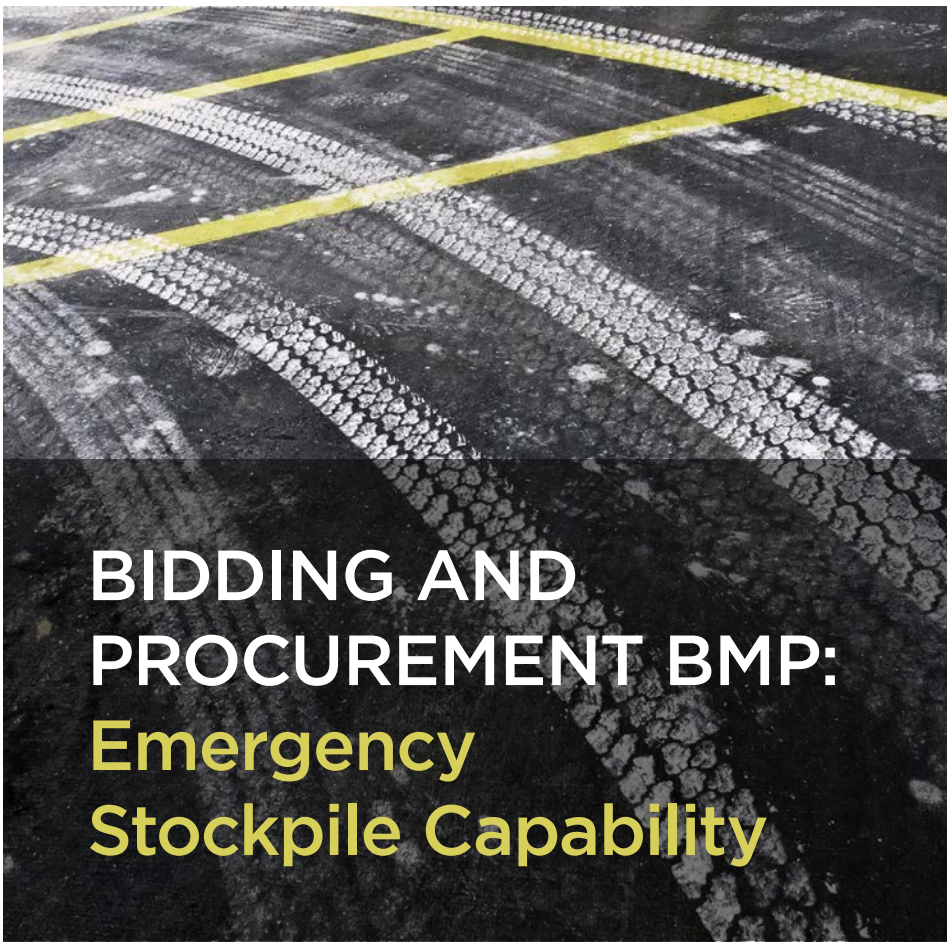
Agencies that can store 100% of their seasonal needs should have the salt in place prior to the beginning of the winter season. Agencies that do not have it in place are subject to the same delivery issues stated above. Agencies that have multiple sites need to consider if the storage they have is adequate for the area it serves. Having 100% of your salt stored is vital, but it also must be in the appropriate area. A number of agencies made the point that even if a state has storage statewide for more than 100% of their average annual salt needs that does not mean that the salt will be in the correct part of the state.

Having 100% of your seasonal needs means you will have enough material in a normal winter. Depending on the contract some agencies may purchase additional material but this may be subject to higher prices. In times of salt shortages price can be less of a factor than availability but higher prices are inevitable because salt must come from less traditional sources and shipping costs increase. Agencies that store 150% or more of their yearly needs rarely run out even in extreme winters. For those agencies, mid-winter deliveries will only be required during extremely severe winters, although as a matter of practice many agencies will take salt deliveries during the winter season to maintain their stockpile readiness.

PRACTICE IN SALT PROCUREMENT	POTENTIAL IMPACT OF PRACTICE
Having storage for 100% to 150% of average annual salt needs (AASN)	**Lowers costs**
Having emergency stockpile for 20% to 40% of AASN	Lowers costs
Specifying desired salt quantities as tightly as possible	Lowers costs
Requiring mid-winter delivery in short time period	Raises costs
Allowing salt deliveries at any given time (rather than during work hours)	Lowers costs
Requesting bids earlier in the year	Lowers costs
Having multi-year contracts	Lowers costs
Taking pre-season fills of salt	Lowers costs

- **THE NUMBERS:** Agencies with adequate storage are less likely to face shortages, less likely to be impacted by delivery issues and less likely to encounter higher costs.
- **THE ALTERNATIVES:** Implement a long term plan to increase storage. Consider shared facilities with other agencies. Consider vendor holding reserves for your agency.
- **THE NEEDS:** With many changes in the types of storage facilities more storage may be possible at reasonable costs. Additionally, many facilities have met their useful life and when replacing them today's needs may be addressed in additional storage and proper placement. Consider adding conveyor systems to maximize the full potential of any facility's capacity.
- **THE FUTURE:** More regional storage opportunities are being planned. Many States have plans to increase storage.

A best practice is agencies having storage for 150% of their average annual salt usage, appropriately placed throughout their region of operations. The greater the storage capacity that an agency has, the less their salt costs will be impacted by changes in demand for salt, especially after high salt usage.



BIDDING AND PROCUREMENT BMP: Emergency Stockpile Capability

According to the Salt Institute's Salt Storage Handbook, an agency should have at least 100% of a normal year's supply stored for its winter operations. A few states and some local agencies have in place emergency stockpiles of salt to supplement their annual seasonal supplies. These emergency stockpiles are for situations during severe winter events and when salt supplies become extremely low and resupply has become difficult or impossible.

Some of these emergency supplies are uniquely stored underground. The remaining emergency supplies are stored traditionally but generally in remote locations and are only used when the normal operating supplies run very low.

PROCUREMENT

Procurement for emergency stockpiles can be done during normal bidding, but often are done outside of the normal bid process when low-cost opportunities arise. Emergency stockpiles do more than just give an agency peace of mind. They give them great purchasing power. In some cases, agencies that have emergency stockpiles may have up to three years of their normal salt use. This gives them the flexibility to purchase salt when prices are low and to forgo the purchase of salt when prices are extremely high.

Another option, although not widely used, is to pay vendors to store an emergency supply in your state or area for you. Generally vendors do not want to store emergency supplies for agencies simply because in most cases they do not have the storage facilities to do this. If the vendor does store salt for an agency, the agency pays for the salt and a storage fee to hold the salt. There is also normally a timeline by which the agency will need to take this salt. It is not an indefinite storage option.

PRACTICE IN SALT PROCUREMENT	POTENTIAL IMPACT OF PRACTICE
Having storage for 100% to 150% of average annual salt needs (AASN)	Lowers costs
Having emergency stockpile for 20% to 40% of AASN	**Lowers costs**
Specifying desired salt quantities as tightly as possible	Lowers costs
Requiring mid-winter delivery in short time period	Raises costs
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- **THE NUMBERS:** Ideally the emergency stockpile should hold at least 20% of the average annual salt usage, with a recommended maximum of 40% of average annual salt usage.
- **THE ALTERNATIVES:** Implement a plan to include emergency storage capability. Consider shared facilities with other agencies to reduce the cost of emergency storage and reduce the need to help other agencies when supplies get low. Consider paying vendors to have emergency supplies for you.
- **THE NEEDS:** Emergency storage requires an agency to have an additional site, of some sort, in an area that should be easily accessible during a winter season. It also requires that an agency have a funding mechanism in place in order to purchase salt, in excess of its normal use, at a time when prices are optimal. The sites require the same regulations, equipment and maintenance as any normal site.
- **THE FUTURE:** Emergency storage may be one of the best options for agencies to increase the amount of salt they have available during severe winter seasons. Existing facilities are often very difficult to retrofit or may not have room to construct additional storage facilities. Emergency storage can also benefit many agencies, and that can sometimes make the option more palatable to elected officials and the public.

BIDDING AND PROCUREMENT BMP: Tightly Specified Quantities in Bid Documents

Bidding documents may be structured very differently depending upon the agencies needs and the procurement rules for the state. In these contracts the state requires the vendor to bid the required amount of salt. Some states put all the risk on the vendor and expect the vendor to supply as much or as little as a state needs for the winter season. Generally these contracts are for fairly small amounts of salt. Every state has an average seasonal usage and vendors are aware of this, especially when bidding this type of contract. Most states base their bid on this seasonal usage but most states also want flexibility in their contract. Flexibility in the amount of material needed results in a risk to the vendor and to the agency. The greater the flexibility the more risk the vendor incurs. Generally, the more risk the vendor incurs the more likely a state will see this reflected in the price the vendor bids.

Flexibility in the bid generally means the state will include a guaranteed minimum that the vendor will supply (and the state agrees to purchase) and a maximum that the vendor must supply, but the state is not required to purchase. This is commonly called the “over under” and is a percentage, both high and low, of the state’s normal seasonal use.

These percentages can vary greatly from 50% - 150% to 90% - 110%. Any local agency included on the state bid will have the same flexibility unless the contract allows them the opportunity to choose a tighter percentage or even a 100% guaranteed amount. Flexibility in the bid does not just affect vendors. It affects all agencies in every state. When a bid has great flexibility, such as a very low minimum but also a high maximum, the amount of salt "tied up" in that contract means it cannot be sold to any other agency locally or regionally. In years of great demand, salt promised, but not sold to an agency cannot be used to help another agency or an area that may be completely out of material.

There are states that feel that they need this flexibility and that the reduction in cost will not be significant compared to the risk that they incur. The risk is not only the up charge for the salt, it is also the concern that in a mild year they may not be able to take the required amount and incur penalties or storage fees for undelivered salt. However, agencies that have tightened their quantities, in most cases, have seen a reduction in price and felt it has been beneficial to their agency.

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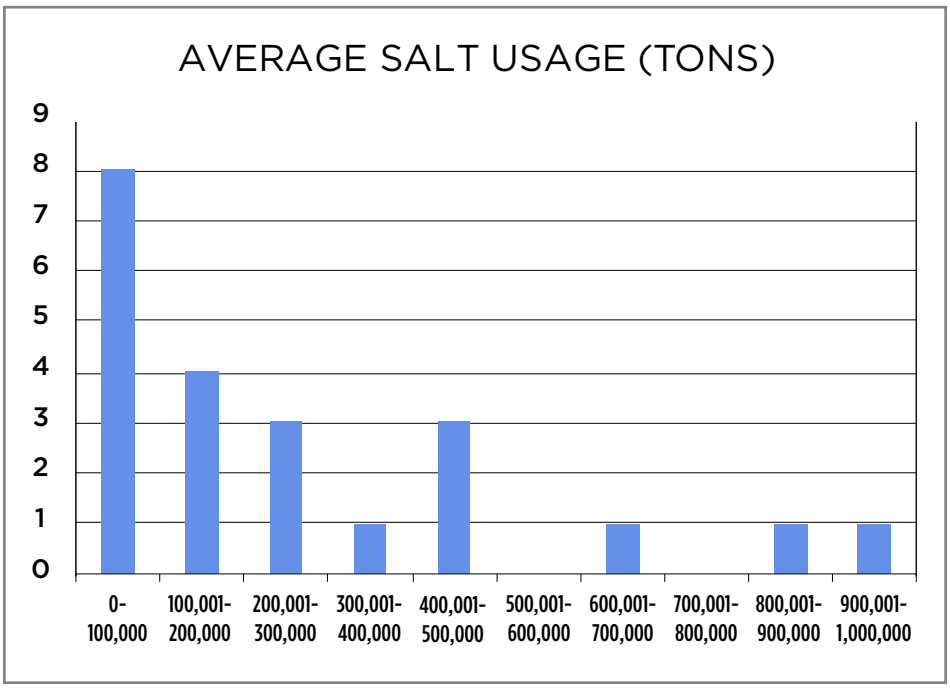
Having multi-year contracts	Lowers costs
Taking pre-season fills of salt	Lowers costs

- **THE NUMBERS:** Agencies with adequate storage can limit their risk, and therefore, possibly reduce the cost of salt by tightening the limits of their contract. When risk is put upon a vendor the cost of that risk is often reflected in the contract price. Salt dedicated in high percentage contracts cannot be sold to other agencies.
- **THE ALTERNATIVES:** The more flexibility for the agency, the higher the risk to the vendor. Therefore, the more an agency can limit that risk the lower the cost should be. Early season fills and seasonal guarantees almost eliminate this risk and help the agency and the vendors have what they need for any given season.
- **THE NEEDS:** Many agencies have adopted tighter quantity limits and seen some benefits. The risks associated with this are difficult for agencies to adjust to. Small changes may be a first step in adapting a contract that has tighter limits.
- **THE FUTURE:** It is extremely difficult to determine how implementing tighter quantities will affect the industry, but if more agencies adopt tighter limits then there would be more salt available for all agencies. It will be difficult for an agency to give up this flexibility, especially given the recent extreme events and winters that have been experienced all around the world.

BIDDING AND PROCUREMENT BMP: Multi-Year Contracts



State contracts for the procurement of salt must conform to the state's purchasing policies. This means that unless the state can enter into a multi-year contract it will have to annually bid its salt out. Multi-year contracts can offer some great advantages; however, not every state can have multi-year contracts. One of the great advantages to a multiyear contract is the certainty of knowing who that vendor or vendors are going to be over the term of their contract. This is also a benefit to the vendor because they know where they will be supplying salt in the coming years and they can work on long-term commitments for receiving and delivery of materials.

Most multi-year contracts have a provision to adjust prices after each year. The most common method seems to be a negotiation between the state and the vendor. If negotiations fail, then most contracts are void and salt is rebid. Some contracts have a set percentage or cap on increases each year. Some contracts include a fuel surcharge which can be an increase or decrease in the contract. Many of the multi-year contracts state they are for a single year, but may be renewed up to five years. Some contracts are for five years and may be renewed up to two additional years.

PROCUREMENT

Many state agencies enter into contracts with multiple vendors. Vendors can often bid on portions of the state or areas they feel they can serve based on where they have distribution points. Having multiple vendors, in a multiple year contract, can be a benefit should a vendor not be able to meet their requirements. Most contracts allow the state to procure salt from another qualified vendor that is under state contract and the primary vendor is obligated to make up the difference.

States and agencies that have yearly contracts may be subject to price fluctuations and the market. Multi-year contracts mean the vendor must supply the contract amount in the coming year and in some cases the amount can be increased. While the price is negotiable it often has a limit or a cap. In the case of a state that has a yearly contract everything is on the table. Depending on the timing of the bid and in years where salt is in short supply some states have seen extremely high prices and portions of their state receiving no bid all. Conversely in years where there is a salt abundance states with one year contracts may see greater reductions in price than those with multi-year contracts.

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- **THE NUMBERS:** While hesitant to suggest a best practice that some agencies may be legally unable to pursue, it is nonetheless a generally accepted best practice to use contract lengths of between 3 and 5 years, with options to extend up to an additional three years.
- **THE ALTERNATIVES:** Implement longer term contracts if State procurement policies allow. While 3-5 year contracts may not be possible, any form of multiyear contract is worth investigating.
- **THE NEEDS:** It may be necessary to work with the state legislature and the state procurement office to try and implement multi-year contracts. If long-term contracts cannot be implemented perhaps looking at options like emergency storage so states are less likely to be subjected to extremely high prices during years of high salt demands.
- **THE FUTURE:** Tighter limits, long-term contracts, and additional storage facilities will mean agencies are less likely to find themselves in salt shortages and high salt prices.

BIDDING AND PROCUREMENT BMP: Pre-Season Fills of Stockpiles

Some agencies' contracts allow for early season or pre-season deliveries of salt. These contracts can be structured in several different ways, some are a completely separate bid for early season salt, or it can be part of an annual bid with pre-season delivery included. Pricing for pre-season salt will vary depending upon the severity of the previous winter and the availability of salt to fill early season orders. In many cases a slight reduction in price is normal. There are some real benefits to the agency and to the vendor by utilizing preseason bidding and delivery. From the agency standpoint, there is the possibility of a slight reduction in price, and most importantly, material will be in the sheds prior to the start of the winter season. Pre-season fills also benefit vendors, because they may allow delivery right from the dock, and they deal with a fixed quantity of salt. This eliminates the need for the vendor to store the material over the summer months. This also can mean additional salt reserves may be stored at the vendor's stockpile. The dual benefit of the salt in the shed of an agency and a reduced amount of storage at the dock can have a positive environmental benefit as well.

PROCUREMENT

Delivery of pre-season materials during the summer months generally takes place during normal work hours and during a normal work week. This can mean delivery over several weeks but the benefits outweigh this slight drawback. Delivery of the material during the construction season may also be challenging at times due to the demand for trucks. On the other hand, ice covered roadways and ice covered waterways are not an issue making delivery much easier in the spring and summer months.

Cost for salt rises as risks increase. Early season fill has very little risk for the agency and almost no risk to the vendor. It is a way for agencies to secure their material and ensure they will have salt in the shed at the onset of the winter season.

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- **THE NUMBERS:** Pre-season filling tends to provide a known quantity of salt at a lower price than in-season deliveries, and under conditions that are typically less fraught than during the winter season.
- **THE ALTERNATIVES:** Instead of an agency using pre-season fills, they might be bidding salt for an upcoming season, and depending on delivery just prior to the season beginning. The agency also risks higher costs and the possibility of less salt available depending on when the bids are let.
- **THE NEEDS:** Early season delivery requires that the agency defines its needs during the on-going winter season, gets the bid out very early, and has the ability to take the pre-season fill as soon as the contract is let. It also requires that the agency have staff available during normal hours throughout the summer to handle the delivery of this material.
- **THE FUTURE:** The more agencies and vendors can find alternative ways to ensure agencies have salt when they need it, the better it is for the agency and traveling public. Early season deliveries should be part of contracts whenever possible and thereby benefit the agencies and the vendors.

STORAGE BMP:
Adequate Storage And Environmentally Safe Storage Facilities

The percentage of salt that an agency can store in relation to its seasonal usage is crucial to being successful in winter operations. Agencies that store less than 100% of their seasonal average will depend heavily on delivery to ensure they have the material they need throughout the winter season. Delivery of goods during winter can be hampered in a number of ways and in extreme conditions may cease altogether. Agencies that can store 100% or more of their seasonal needs have more flexibility and are less likely to be impacted by delays in delivery. Despite having adequate storage for 100% or more of their seasonal needs, agencies still may encounter problems if the stored material is not distributed appropriately across the state. Having adequate storage means having enough salt for an entire season, for every location throughout the state.

STORAGE

Having the appropriate amount of salt is extremely important, but that material must be stored properly as well. Salt can be stored in a variety of ways, but the best practice is to store salt on an impervious pad and ensure that the salt is covered. Salt that is not stored properly will lead to environmental issues and will not benefit the agency or its customers. The best environmental practice is to have salt stored inside a facility with a door where weather can not affect it in any way. If possible, it is better to load the facility using a conveyor system so it can be completely filled, and to avoid contaminants and lumps from being stockpiled. It is also beneficial if the door can face away from the predominate direction of incoming weather. Any runoff from the facility should be contained to avoid any negative environmental impacts as well.

- **THE NUMBERS:** Agencies with adequate storage are less likely to face shortages, and less likely to be impacted by delivery issues. Salt should be stored properly on an impervious pad in a facility or completely covered to reduce any environmental impact and avoid wasting material.
- **THE ALTERNATIVES:** Implement a long term plan to increase storage. Determine if the salt being stored is placed in the proper locations to serve the needs of the state.
- **THE NEEDS:** Environmental concerns grow stronger each year. It is vital that agencies that use salt store the salt properly. All runoff must be contained at the facility. Agencies that have less than 100% of their seasonal needs should look to increase their storage in order to meet that goal. If additional storage is to be added, consideration should be given as to the place for that salt to ensure that the agency has the right amount of salt for the right area.
- **THE FUTURE:** Salt use has seen a steady increase since the 1960s and has hit its highest points during the extreme winters in the past few years. Extreme winter events and changing weather patterns have affected much of the U.S. during the last decade, and have resulted in local and temporary material shortages. Agencies need to ensure that they have enough material for their operations and that the salt is stored properly.

State Agencies should have at a minimum 100% of their seasonal needs stored prior to each winter season. The more salt an agency has on hand the less it depends on delivery systems throughout the winter season. Storing this salt properly is critical. Best practices here require the salt is under cover and must be on an impermeable pad. Runoff must be contained. Facilities should be sited using the S.A.L.T.E.D guidelines from The Salt Institute.

STORAGE BMP:
Optimal Facility Layout

An agency's facility layout can be extremely important to the efficiency and safety of the agency, its employees and its vendors. Efficiencies can be realized in several different areas. In order for a facility to be filled to its entire capacity a conveyor system should be considered. Conveyor systems fill the facility from the highest point and it can be filled completely. This is unachievable when the material is simply pushed inside the facility. Not only is this the optimum way to fill the facility it is also a much safer way. Facilities should be designed to receive material, store the material and then distribute the material. The optimal layout allows delivery without the interruption of distribution.

It is also important that a flow pattern is established for the facility. Once again the optimal layout allows for delivery, with no opposing traffic, and does not interrupt loading of material for plows entering or leaving the facility. Additional considerations need to be given to level surfaces to load and unload, fueling equipment, liquid storage, liquid filling, snow clearing of the lot, runoff, runoff retention and employee parking.

STORAGE

The type and size of the storage facility will depend upon the agency's needs and budget. It should hold, at a minimum, 100% of the yard's seasonal needs. It is important in the layout to consider runoff and ensure it is contained at the site. If a new facility is to be constructed, consideration should be given to the future needs of the agency and the possibility of making the facility a shared site with other agencies.

- **THE NUMBERS:** Facilities that are filled using conveyor systems can be filled completely utilizing their total capacity. Efficient flow patterns will allow for vendors to dispense their loads quickly and leave the facility. It will also not interrupt the distribution of material to the agency's vehicles. A well designed flow pattern will also enhance the safety for everyone using the facility.
- **THE ALTERNATIVES:** Agencies that are unable to fill their facilities using some type of a conveyor system will not be able to optimize the full storage capacity of the facility. An inefficient flow pattern can mean delays in receiving and distribution of the materials due to conflicts. Employee and vendor safety may be compromised when these conflicts occur.
- **THE NEEDS:** Many facilities are pre-existing and while some retrofitting is possible, it may be very difficult to change flow patterns and existing facilities. Some efficiency can be gained by adding or renting a conveyor system. When any new facility is constructed consideration should be given to all the best practices listed above.
- **THE FUTURE:** As new facilities are constructed more unique designs for delivery and distributions of materials are being implemented. New types of facilities which include multiple access points, liquid brine making, liquid distribution and reuse of wash water are now being constructed.

The storage facility must be able to be filled completely to optimize its usage. It must provide for efficient loading and unloading. It must be safe for vendors and employees and flow patterns with no opposing traffic are critical. It should be well lit and have level loading areas. Good housekeeping around the whole facility is vital.

STORAGE BMP: Shared Facilities

A shared facility in Des Moines, Iowa

The purpose behind a shared facility is that a single site can be utilized by two or more different agencies. Shared facilities can offer some unique opportunities but also some challenges if responsibilities are not clearly defined. A shared facility may mean that the site houses material owned by two or more different agencies or that it houses material owned by one agency but serves other agencies. If a facility houses salt from more than one agency, how that salt is accounted for is an important consideration. This is often done by the utilization of some sort of a scale system (an onsite scale or a system on the end loader). If a scale system is not available then good documentation based on the number of buckets or the size of loads must be kept. Another option is to keep the material separate within the facility whenever that is possible. This may be difficult depending upon the way the facility is constructed. The same process is important if materials are to be supplied to other agencies and then be reimbursed or have materials returned to the parent agency.

STORAGE

Shared facilities may also offer other advantages, such as a refill spot. This may help optimize operations and eliminate the need for a truck to return to its home agency to refill. This can save time, fuel and is an environmental benefit to the agency and to its customers. Shared facilities may also offer the option of different materials than are housed at the home agency.

In order to avoid conflicts some sort of contract, mutual aid agreement or letter of understanding is often required. This is important to clearly specify the responsibilities with respect to site design, construction, and maintenance of the facility. It is also important in regards to the material taken and return policies of both agencies. It also is important if there are to be joint procurement practices for the site.

A facility in Washburn County in Wisconsin that houses state salt and county salt. A wall in the center divides the building.

- **THE NUMBERS:** Best practices for shared facilities include a location that is central for all users and owners of the facility, clearly specified responsibilities with respect to site design, construction, and maintenance of the facility, and appropriate written agreements that clarify all these responsibilities.
- **THE ALTERNATIVES:** Agencies with inadequate storage and no way to improve that storage are left with very few alternatives. One possibility would be to seek out other agencies in the area and try to develop a relationship where shared storage or the possibility of a remote refill site can be developed. State agencies that have adequate storage but are looking to optimize their operations may also consider agreements with other local agencies for remote site refill opportunities. State agencies that have adequate storage could perhaps offer these possibilities to local agencies that have inadequate storage for their operations.
- **THE NEEDS:** Developing sites that will serve as shared facilities require long-term planning and require that contracts or agreements are in place so all parties understand their responsibilities. The cost of constructing the sites can often be reduced when several agencies work together and contribute. The cost of maintenance should be included in the agreements as well.
- **THE FUTURE:** As roadway systems expand and with uncertain weather patterns, the need for more salt is a possibility for many agencies. Shared facilities can be one of the answers for these agencies.

Shared facilities may offer state agencies options to work with other agencies, have different material options, build facilities larger than they would on their own, build satellite facilities, and in general allow for efficiencies of scale by pooling resources among many agencies.

STORAGE BMP: Optimizing Facility Operations and Novel Ideas

The facility in Washburn, Indiana, has inside loading, liquid loading, brine production and truck washing all housed inside the facility.

The purpose behind optimizing facility operations is to incorporate other programs and best practices into one facility. One best practice already previously discussed is the ability to fill the dome completely utilizing conveyor systems. Other examples of this could be storing more than one type of material in one facility, the making and storing of salt brine within the facility, storing and dispensing liquids in or at the facility, and even treating the materials as they are placed inside the facility. Incorporating these types of operations into the facility will almost certainly improve the efficiency of the operation and are great examples of sustainable operations. Retrofitting existing facilities is possible, especially when adding a brine maker or liquid storage to an existing facility. However, the ability to drive through a facility, wash vehicles in the facility, and reuse that wash water for brine making will likely need to be incorporated into a new facility.

STORAGE

Along with methods to optimize facility operations came some very unique and novel ideas. One of these ideas is to build a regional facility that can serve more than one agency. These regional storage facilities can house additional material for agencies during extreme winter events or years where salt supplies become extremely low. These regional facilities also give agencies much more flexibility when purchasing salt. Regional facilities combined with an agency's normal supply of salt may give the agency multiple years of material for its operation. Other novel ideas that were discovered were facilities with multiple entrances and exits, and remote site facilities where an operator can load their own trucks without returning to the main yard.

Regional storage facility in Des Moines, Iowa.

- **THE NUMBERS:** To optimize facility operations, the goal is to consider all operations that will be conducted on site, and to ensure that each one can be done with minimal interference with other operations. Safety of operators and workers in the facility is a key concern but ease of operation for the operator is a great benefit. Adding remote storage facilities can benefit many agencies and give them multiple years supplies of materials. It can also give them great flexibility and purchasing power.
- **THE ALTERNATIVES:** Implementing plans to retrofit existing facilities and incorporate best practices and other operations into an existing facility if possible. Any new construction should consider incorporating these operations into it for efficiency and for environmental concerns. Agencies should look for opportunities to partner in regional storage facilities.
- **THE NEEDS:** Good planning and design is needed to incorporate other programs into a facility and have all the programs operate successfully. All local regulations must be followed for containment of any liquids at the site. In regional storage facilities agreements in contracts will need to be in place and maintenance of these facilities must be considered.
- **THE FUTURE:** More state agencies are adding proactive approaches to their operations, which include the use of liquids, brine making and truck washing. More regional storage opportunities are being planned.

Incorporating other operations into a facility is a good example of a best practice. The ability to drive through a facility, fill indoors with no spillage, incorporate truck washing inside, reuse the runoff in brine making that takes place inside the facility, and then loading those liquids or other liquids indoors is an incredible way to optimize the facility.

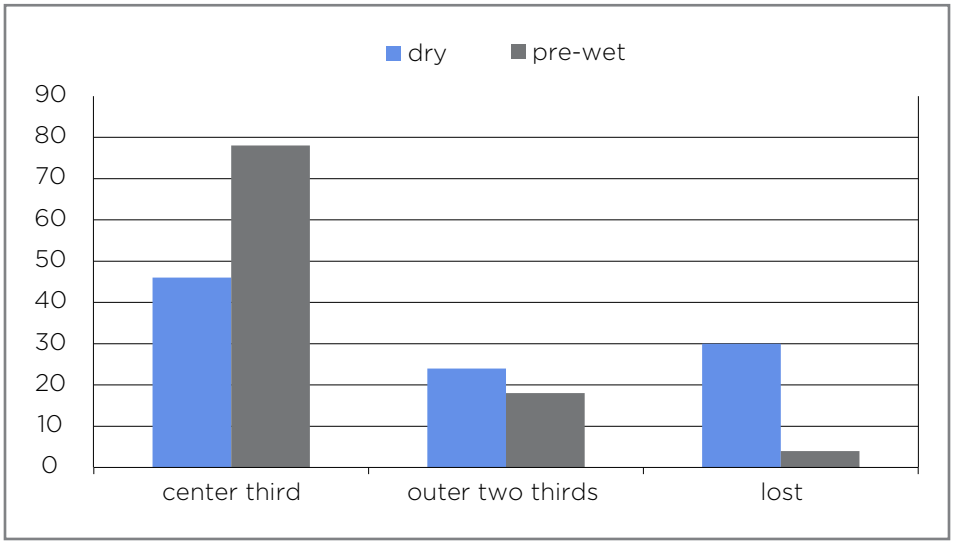
Application BMP: Pre-wetting

In the 1970s the Michigan Department of Transportation (MDOT) conducted a series of studies looking at how pre-wetting might impact the amount of salt left on the road after it was applied by a truck. In these experiments (which have been replicated and expanded upon many times since, with all the data confirming the benefits) they applied salt at a rate of 400 lbs per lane mile, and at a speed of 30 mph, while pre-wetting the salt at the spinner at a rate of up to 10 gallons of brine per ton of salt applied. They conducted tests on a closed three lane road, and drove down the center lane, collecting salt from that lane, and from the two lanes either side of the center lane, to determine dispersion. What they found was that when salt was placed dry (without pre-wetting) 30% ended up outside the three lane roadway (i.e. in the ditch) while when applied pre-wet, only 4% ended up in the ditch. This represented a significant potential saving in salt application rates. A second set of studies conducted in 2012 by MDOT essentially confirmed these findings.

APPLICATIONS

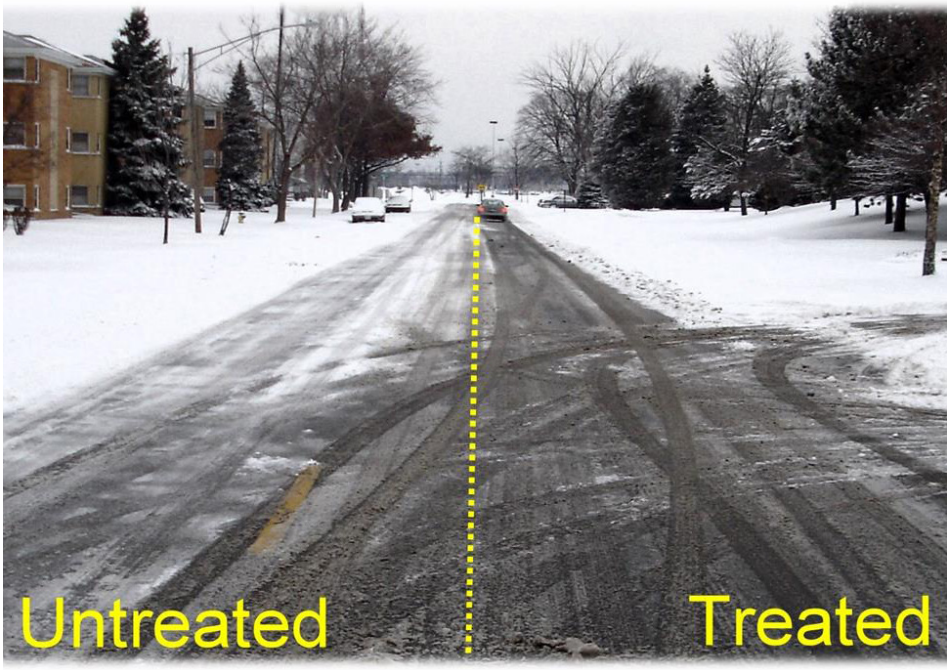
Simply put, pre-wetting requires that a brine should be added to the road salt prior to it being placed on the road. In practice, the brine can be added at the auger or at the spinner – no studies have indicated that one is better than the other in terms of performance. Typical application rates are in the 4 to 10 gallons of brine per ton of road salt. The brine used is typically one of either sodium chloride, calcium chloride or magnesium chloride. All three have been successfully used by agencies in pre-wetting, as have a variety of enhanced brines. The choice of brine for an agency should be a function of what they already have available, or if no brine is currently used by an agency, what they can most easily obtain.

The bottom line for pre-wetting is that it allows an agency to reduce salt application rates by up to 30% without a reduction in levels of service. Those sorts of savings ensure that any costs associated with implementing pre-wetting can be rapidly recovered by an agency, and experience suggests that many agencies will recover those costs within one or two winter seasons at most.



- **THE NUMBERS:** By applying 4 to 10 gallons of brine to each ton of salt applied on the road, an agency can save at least 30% of their salt usage compared with putting salt down dry.
- **THE ALTERNATIVES:** Two alternatives exist if you cannot get pre-wetting equipment on your trucks. You can pre-treat your salt stockpile with a liquid brine, typically at about 4 gallons per ton, or you can wet the whole load of salt in the back of the truck using a shower type of system. Drawbacks for the first are that the pre-wetting liquid may leach out of your stockpile over time. For the second, the load will not be wet evenly, and if you have to return some of the load at the end of a storm, you are putting partially wet material back into a dry stockpile, which may cause materials handling problems.
- **THE NEEDS:** To implement a pre-wetting program from scratch an agency will need: storage for liquid brine in the yard, storage for liquid brine on the truck, pumps to deliver brine on the truck to either the spinner or the auger of the truck to coat the road salt there, and appropriate rate controls for both road salt and pre-wetting liquid.
- **THE FUTURE:** There has been some very interesting work going on in Europe and in a few places in the US looking at using much higher rates of pre-wetting (from 30 to 70 gallons of brine per ton of dry material) to create a slurry of salt applied to the road. While this work is ongoing, it suggests that such higher pre-wet rates improve the retention of salt on the road, and enable it to act more effectively and efficiently to break the bond between snow and pavement and to prevent that bond from forming.

Pre-wetting allows an agency to reduce salt application rates by 30% without a reduction in level of service.



Anti-icing is defined as the process of placing chemicals on pavement surfaces prior to an event in order to prevent the formation of ice on the pavement, and also to prevent snow and ice from bonding to the pavement surface. Anti-icing may be accomplished using solid or liquid materials depending on the given circumstances and predicted weather conditions. The most common and widely accepted method of anti-icing is the application of salt brine to roadway surfaces prior to an event. However, anti-icing as a strategy also encompasses additional application of road salt (in either solid or brine form) after precipitation begins, to continue the prevention of bond formation.

Conditions must be correct in order to apply this liquid chemical to a roadway and be effective. In general three major conditions should be considered: whether the event will begin as rain, a minimum pavement temperature at which to apply, and the moisture in the air and on the roadway. Other considerations are loose and blowing snow and residual salt that may be on the roadway. The use of a decision chart for anti-icing is a best practice when using anti-icing as a strategy. (See flowchart on page 46),

APPLICATIONS

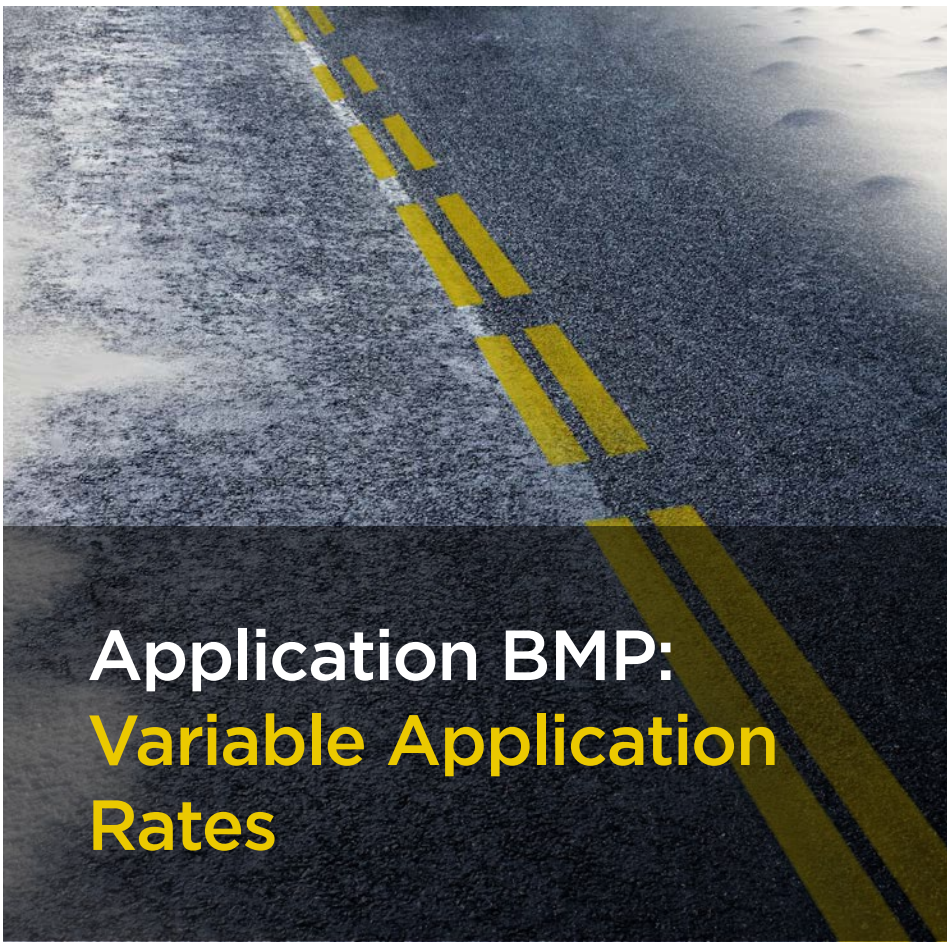
Application rates of salt brine of 30 to 50 gallons per lane mile are common for anti-icing applications. Done correctly there is little to no loss of material off the pavement, it dries very quickly and is effective in preventing frost from forming and snow and ice from bonding to the pavement at the inception of the event.

Rock salt in its solid form can also be used for anti-icing. There can be a variety of reasons to consider this. Should an event start as rain or freezing rain liquids may be diluted quickly and have little or no effect. Solids are likely to last somewhat longer and help prevent ice from forming. Solids are also a good choice when road and atmospheric conditions are damp and liquids are not recommended. The common drawback to using solids is that some of the applied material is likely to be lost off the surface due to traffic prior to the event beginning. When solids are used for anti-icing, they should be pre-wet to minimize this loss.

Anti-icing can result in huge savings to an agency and a safer roadway system for its users. Frost callouts can be reduced or eliminated. Ice-bond prevention can result in a 75% savings versus de-icing a roadway that has become ice bonded. Agencies that have implemented an anti-icing program have seen significant reductions in material use.

- **THE NUMBERS:** Studies suggest that anti-icing can reduce crashes by up to 85% compared to a de-icing strategy. Plus, bond prevention can result in a 75% savings versus de-icing a roadway that has become ice bonded.
- **THE ALTERNATIVES:** What if you cannot use liquids? You can still anti-ice using pre-wet solids, although the benefits may not be quite as strong. However, in some circumstances even if you have liquids you should use pre-wet solids. If a storm is going to start with rain rather than snow, for example, you should not pre-treat your roads with liquids, but rather use pre-wet solids.
- **THE NEEDS:** If you are changing to an anti-icing strategy, there are quite a few things you will need. You will need the ability to place liquids directly onto the road, which means liquid storage facilities, transfer facilities and trucks capable of direct liquid application (you can use trailers for this too). You will also need weather forecasts that provide you with enough information on storm types, pavement temperatures, and storm start times to allow you to have confidence in your pre-application program.
- **THE FUTURE:** Anti-icing may become even more refined in the use of chemicals as sensors are developed that allow the residual amount of salt on the road to be measured accurately. Also, salt spreading technology is advancing rapidly, so that application rates can be automatically adjusted to account for environmentally sensitive locations, changing pavement temperatures and road conditions, and forecast weather conditions.

An anti-icing strategy used throughout a storm allows level of service goals to be achieved while using only 25% of the salt required for a de-icing, reactive strategy.



Salt Application Rate Guidelines

	Surface Temperature (° Fahrenheit)	33-30	29-27	26-24	23-21	20-18	17-15
	Prewetted salt @ 12' wide lane (assume 2-hr route)						
lbs of salt to be applied per lane mile	Heavy Frost, Light Snow	50	75	95	120	140	170
	Medium Snow 1/2" per hour	75	100	120	145	165	200
	Heavy Snow 1" per hour	100	140	182	250	300	350
	Prewetted salt @ 12' wide lane (assume 3-hr route)						
lbs of salt to be applied per lane mile	Heavy Frost, Light Snow	75	115	145	180	210	255
	Medium Snow 1/2" per hour	115	150	180	220	250	300
	Heavy Snow 1" per hour	150	210	275	375	450	525

The Salt Institute implemented the concept of “sensible salting” in its snow fighters handbook a number of years ago, and this concept has been refined since that first notion. Specifically, the notion behind sensible salting is that salt application rates should be adjusted to account for a number of factors including pavement temperature, precipitation rate and type, level of service and cycle time. In other words, only use what you need for the circumstances with which you are dealing. A number of agencies have developed rates for a variety of storm conditions, often expressed in the form of a table, as for the Iowa DOT rates shown here. The Iowa DOT rates take into account the type of weather, the pavement temperature and the cycle time. Rates are shown in pounds per lane mile being applied in each instance. The chart shows a 2 hour cycle time and a 3 hour cycle time. The charts are intended to be used by operators, and thus, can be placed in trucks for ready reference. In order for these to be useful to an operator they must have pavement temperature data and be updated on the forecast conditions.

Having such a guideline for use during storms is a best practice for salt application. This does not mean that an agency should adopt "as is" the charts from Iowa, but an agency, if they wish to pursue best practices, should have some similar form of chart. It is worth noting that the Iowa chart has over thirty different application rates (not counting application rates for sand/abrasives). Clearly the use of such a chart operationally will require training and monitoring for the winter operations staff and will likely take time to implement.

Treatment recommendations can also be delivered in an automated format, normally through some sort of a decision support system or a contracted forecast service. These are useful because they can take into account both current observations and forecast conditions.

- **THE NUMBERS:** A look at the charts suggest that variation rates can be widely different for different storms, with a factor of seven between the highest and the lowest application rates. That is a big variation and indicates how much can be saved by using variable application rates. If you are only using a single application rate for your salt spreading, you may in the worst case be applying seven times more salt than you need to. That is an awful lot of salt!
- **THE ALTERNATIVES:** What if you are concerned that 18 different application rates are too many? Well, one application rate for every storm is certainly too few, so why not start out with two or three application rates, and grow them as needed. An incremental approach will work well, especially if it includes the checking process, where the agency winter operations team checks to be sure that recommended application rates are being followed and are providing the required level of service.
- **THE NEEDS:** On one level, all this BMP needs is the willingness to use different rates for different conditions, but in reality, it needs a few more things. First, trucks must have the equipment that allows them to apply at all the specified rates (and be calibrated too, but that is another BMP!). Then, you need ways of determining the pavement temperature in real time, so that you can adjust your application rates accordingly. Finally, you need a materials management system in place to measure how much material you applied, and to compare that with how much you should have applied according to your plan!
- **THE FUTURE:** Sensor technology and communication technology are improving all the time and so the ability to adjust the amount of material we place on the road with precision and according to detailed weather and road condition information is only going to improve. This is an important way to optimize material application rates, and so getting a start on implementing it now is a good thing.

By using a variable application rate approach, we acknowledge that every storm is different, and thus, every storm needs a different response. This approach can allow an agency to reduce their total salt application by up to 50% over a winter season.

Application BMP: Calibration

Equipment calibration has been one of the single most important methods that an agency can do to ensure it is not over-applying material. Equipment calibration is defined as determining the amount of material being dispensed in pounds per minute from any given unit. This value is then turned into a setting which is used by an operator to determine how many pounds per lane mile or grams per square meter actually are being applied at any given spreader setting.

The actual calibration of the equipment can be done by an operator or by the fleet facilities department in an agency. It is always desirable to have both parties present so the operator is aware of what is being dispensed at each setting and also so any adjustments can be made by the fleet department to ensure the settings are correct. Calibration can be done on both manual systems and on automated ground speed systems. The process of calibrating equipment is fairly easy, but is also time consuming. The Salt Institute has a step by step guide for calibrating equipment with manual systems installed in them. There are also several videos available that walk through this same process. Automatic systems generally have a test mode and a simple procedure to do the calibration. It is very important with automatic

systems to ensure, after calibration is completed, that the ground speed controller matches the speedometer speed of the vehicle.

Calibration of all agency equipment should be done prior to the beginning of the winter season. It should also be considered throughout the winter season especially if there is a change in the type of material that the unit was first calibrated with. This could be a change in material from a vendor or a change based on the type of winter conditions that the agency is facing. One example of this may be going from regular salt to a treated salt as pavement temperatures become extremely low. These two products will differ in the way they flow out of the vehicle and therefore units should be re-calibrated when switching from one to another.

While calibration is often thought of in terms of the application of solid materials, liquid dispensing systems should also be calibrated. The basic procedure is the same as for calibration with solid materials, but as noted above, different materials may be used under different winter conditions and so a liquid dispensing system should be calibrated for whatever liquids are being used by an agency.

The following two videos may be useful for agencies to use when training for calibration. There is also a detailed guide produced by Minnesota DOT that will be helpful:

https://www.youtube.com/watch?v=ilsHIuJW-9M

https://www.youtube.com/watch?v=kzTIOG3MxNw

http://www.dot.state.mn.us/maintenance/pdf/research/SaltSanderCalibrationGuide.pdf

- **THE NUMBERS:** Anecdotal evidence suggests that poorly or improperly calibrated (or in some cases, totally uncalibrated) dispensing systems may actually be applying twice as much material as intended. So, by implementing a regular and thorough calibration process, an agency can save as much as 50% of their total material applications.
- **THE ALTERNATIVES:** There really are not any alternatives to calibrating your material dispensing systems. The process is tedious, but a number of different guides are available and these typically include all the charts and forms needed as well as a step by step description of the process. The Minnesota DOT guide is one such example. Your material dispensing system manufacturer should also be able to provide detailed instructions on calibrations.
- **THE NEEDS:** The basic equipment needs for a calibration process (aside from the truck and spreader unit being calibrated) are a system to catch the material being dispensed and a system to measure the weight (or with liquids, the volume) of the dispensed material.
- **THE FUTURE:** As sensors on trucks become more sophisticated, it will be possible to measure in real time, in at least two different ways (to provide independence and verification of measurements), how much material is being dispensed by a spreader system. The electronics on the truck would then be able to perform an auto-calibration process, and thus, the truck would be self-calibrating in real time. However, we are not there yet, so in the meantime, you have to calibrate.

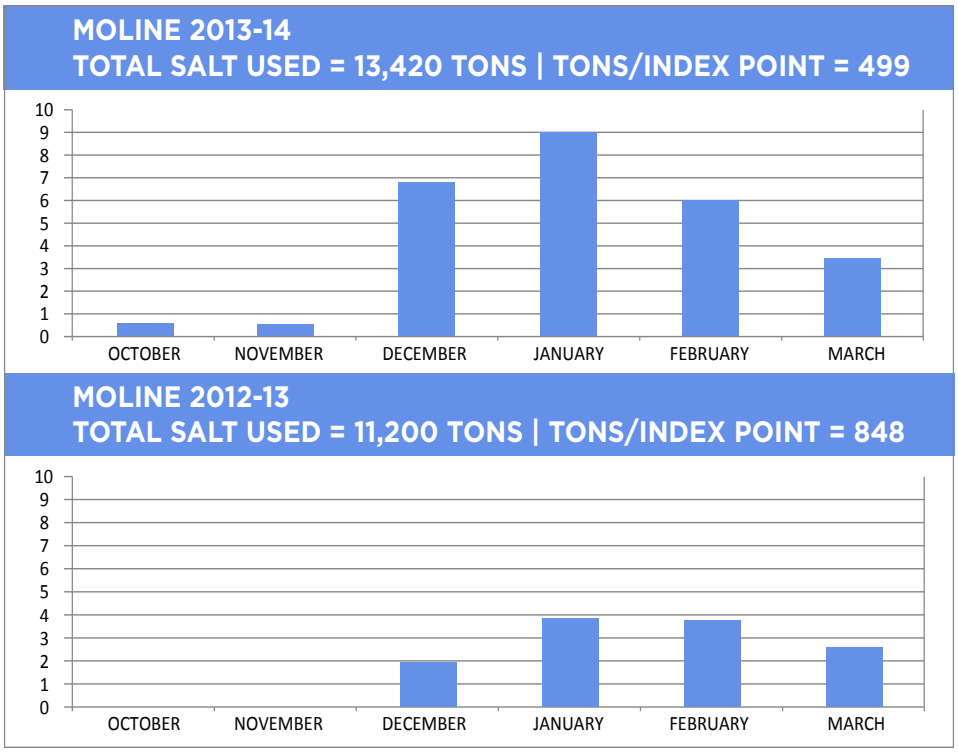
If spreaders and liquid dispensing systems are not regularly calibrated, then agencies do not know how much material they are applying – they are only guessing. Guessing is not good enough.

In regards to the best management practices for salt use, performance measurement is determined by the condition of the road throughout the event in relation to the severity of the storm and the treatments that have been applied. Under-treating a roadway will result in difficult driving conditions and possibly the formation of ice. Over-applying salt can result in wasting material and exceeding expected levels of service. If other application Best Management Practices are considered, it is evident that measurement must also be a BMP. For example, variable application rates are needed based on the severity of an event and the pavement temperatures during that event. Again, salt use in extremely cold situations may require that no salt be applied at all. Also, it is important to ensure that personnel are accountable for the decisions that they make in winter operations and material applications in particular. In order to verify if an agency is under-treating, properly-treating or over-treating a roadway, data must be collected and then must be evaluated and weighed against the recommended actions.

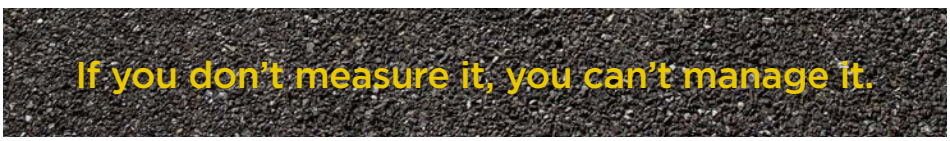
Measuring the performance of an agency in a winter event can be done in several different ways. When we consider that

we are discussing the use of salt it should start with an individual operator. Tracking their salt usage in each event and on a seasonal basis is important. This can be done manually by tracking how many buckets of salt are loaded on a vehicle or by weighing the vehicle but perhaps one of the best ways is using instrumentation. Computerized dispensing systems installed into vehicles can track the output of salt by the vehicle. On a larger scale some agencies look at salt use compared to the total snowfall for a season. Some agencies look at the average amount of salt used per lane mile for a given season. Many agencies now look at their salt use and include a storm severity index or a winter severity index to help normalize their actual use. Another method uses instrumentation to determine the grip of a roadway throughout an event and determine how they performed and what the mobility of the roadway was throughout the event.

These methods allow an agency to look back and determine if proper treatments were recommended, if those treatments were applied, if forecasts were accurate, if levels of service were achieved, and thus, how they could adjust their operations in future events.



- **THE NUMBERS:** It is hard to say exactly how much we can save by carefully measuring our winter maintenance actions and operations. For one thing, what would you compare your measurements to? The ones you did NOT make beforehand? Kind of tricky! But, management studies suggest that just by measuring what we do, we can cut down on waste by 10 to 30%.
- **THE ALTERNATIVES:** There really is no alternative to measuring what we do, unless it is not measuring, and that is not recommended.
- **THE NEEDS:** First you have to decide what you are going to track – for example, it might be how much salt you use on each lane mile. Then you have to figure out how to measure it – will you trust the spreader controller to be accurate? Will you tie in the spreader controller with GPS data? Finally, you have to collate all the information, see what it tells you and act upon that new knowledge by making appropriate changes.
- **THE FUTURE:** The key advance here is likely to be in the area of data collection and management. A system based on paperwork is much harder to handle than one that is fully automated, and the sensors to give us that fully automated data collection will be here soon if they are not here now.



Application BMP: Accountability

Accountability is something that should apply to all levels of operations in regards to winter maintenance. What this means is, there should be accountability at every level. Decisions about deployment, the number of personnel, the equipment used and how an agency will respond to an event are supervisory decisions. These policy decisions along with decisions about the type of material to use, the amount of material to apply, the level of service to be achieved and the route cycle time are also supervisory or policy decisions. Managers are held accountable for the decisions related to the planning of an event. It is an operator's duty to follow the decisions that have been made and to perform their operation safely. Understanding that each event is different, and operator experience plays into a successful operation is really important, but varying from policy and not following recommended guidelines is not appropriate. Operators that over-apply materials generally do so because they are trying to do a good job and provide a safe environment for roadway users, but the long term implications of continued over-application must be considered too.

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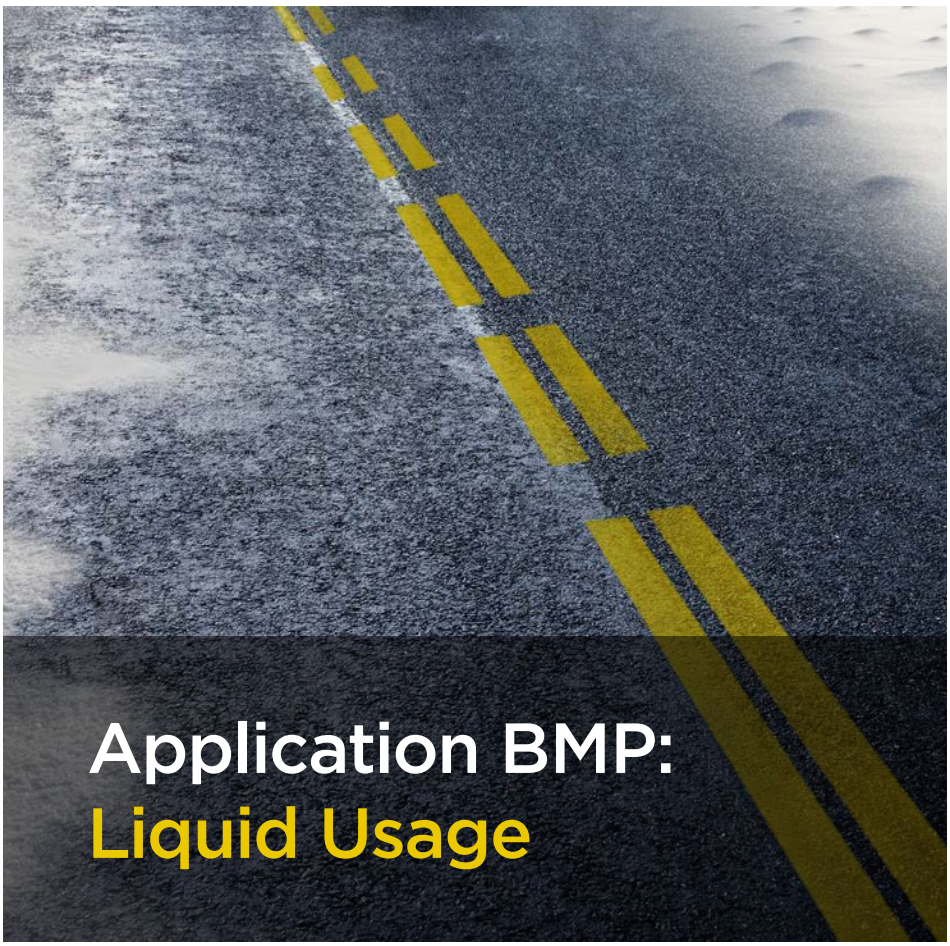
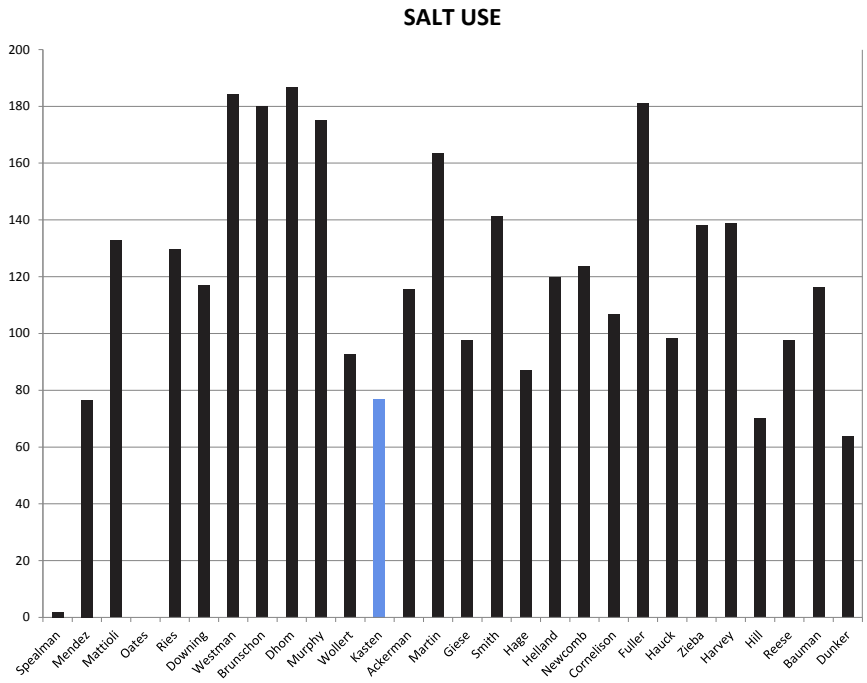
In regards to the best management of salt, both management and staff must have a successful plan in place and follow those guidelines to achieve the desired level of service. In order to determine if a plan was successful and if operators followed the guidelines, measurements and accountability must be applied. This is especially important in situations where only small amounts of material are needed or perhaps in extreme situations where no salt is recommended. Pre and post event meetings are vital for good communication and feedback. Data gathering and data review help determine if operators followed treatment recommendations and used the appropriate amount of material. Contracted weather services and programs like a maintenance decision support system (MDSS) can aid managers and operators in determining how to approach an event, the conditions they faced during the event, the type of treatments needed, the outcomes of those treatments and the duration of the event.

- **THE NUMBERS:** It is not easy to measure how much savings we could see from implementing an accountability plan, but management studies suggest there could be between a 10 to 50% improvement in performance, which in winter operations would translate to meeting our goals (our levels of service) with 10 to 50% less effort and less materials.
- **THE ALTERNATIVES:** On one level, accountability is just a word and there are other words out there that cover similar approaches (e.g. continuous improvement, quality circles, etc.). The key thing here is that, having set out goals and our methods to achieve those goals, we need to observe whether we are following our own procedures. It sounds simple, but change is always difficult, and without strong accountability, change will be slow and haphazard.
- **THE NEEDS:** What information do we need to be accountable? Clear goals are a must. Clear methods on how to achieve those goals are also vital. Finally, we need the measurements to tell us whether we are meeting our goals and what we are doing to meet those goals (are we doing what we should be doing?). Finally, and perhaps hardest of all, we have to follow through on what the data tell us about our operations.
- **THE FUTURE:** There will probably not be much change in this area over the next couple of decades, at least until we get fully autonomous snow plows!

Having plans is good, but carrying out those plans and being accountable for them being implemented is even better.



Application BMP: Liquid Usage

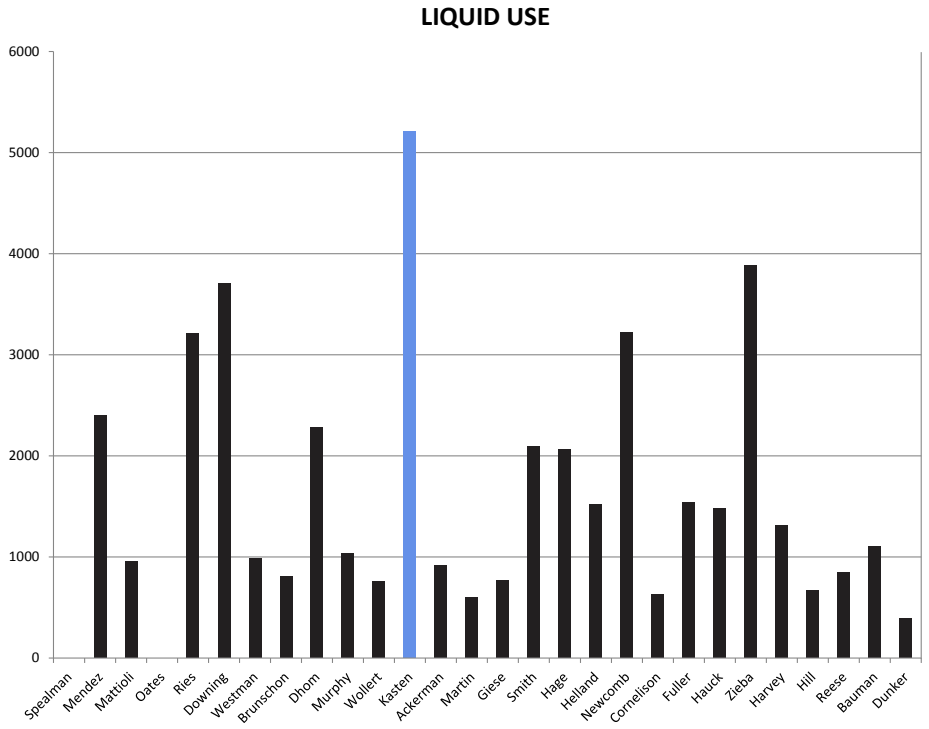


In regards to salt best management practices, liquid use can help reduce the amount of granular material used each season. Anti- icing, pre-wetting, treated salt, and slurries can all reduce the amount of material used by an agency. In the right conditions liquids can be used in place of granular material. Liquids can be used as a deicer in the right conditions as well. There are many different liquid deicers to choose from. Most commonly used in winter maintenance are liquid chloride deicers. There are also other liquids used in certain situations, but they are generally very costly. Liquid salt brine is the most commonly used product. Also widely used are liquid calcium chloride and liquid magnesium chloride. Just like common salt, salt brine, works to about 15° pavement temperatures. Liquid calcium chloride and liquid magnesium chloride work at lower temperatures. When choosing liquid chemicals it is important to look at the working temperature of the chemical, not just the eutectic temperature. It is also very important to know the properties of the chemical and how it will act when placed upon a roadway.

The use of liquids does require an agency to modify its equipment or have the versatility to change from liquids to solids. It also must have a secondary storage facility for its liquids and the ability to load the liquids into the vehicles. Liquid storage

facilities also must have some sort of containment system in case of a spill or rupture. Agencies can purchase liquids from vendors or in some cases produce liquids onsite (using, for example, a brine maker). An additional process, known as blending, can also be done on-site in order to produce enhanced salt brine. In order to produce salt brine or to start a program of in-house blending an agency should consult with vendors or other agencies to determine the appropriate program for the agency.

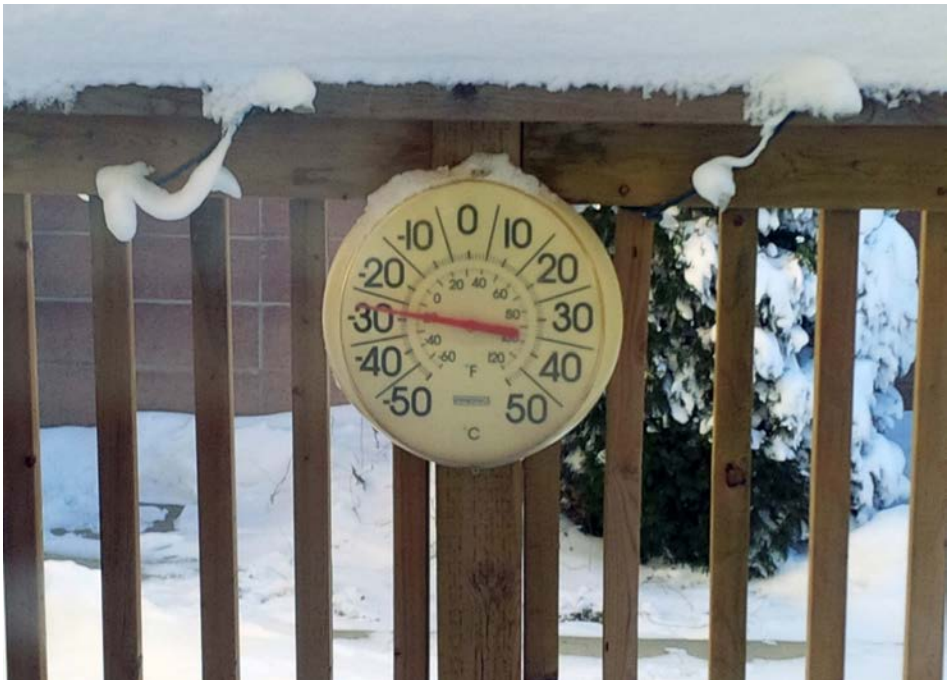
There are many agencies that serve as examples where liquid use has been implemented and the overall amount of granular material has been reduced. Iowa DOT is one good example of an agency that has implemented liquid use and has reduced their overall granular use. In the example shown here, McHenry County in Illinois tracked its operators' granular salt use against its operators' liquid use and found operators that used more liquid used less granular salt. The first figure shows solid salt usage by employees over a winter season, while the second figure shows liquid brine usage by those same employees. It is notable that the employee who used the most brine, used the least salt (excepting those employees who did not operate plows on a regular basis).



- **THE NUMBERS:** The most effective use of liquids is in frost prevention, where a suitable liquid program can reduce frost problems close to zero. Of course, liquids are also an effective method for anti-icing, and as the data shows, using liquids can reduce solid use by as much as 50% when done right.
- **THE ALTERNATIVES:** If you do not have the ability to store liquids, to make liquids and to dispense liquids, then the only sort of ice control material you can use is solids, which should be pre-treated in the stockpile so they can stick to the road.
- **THE NEEDS:** The first need is the ability to store liquids on site. They should be stored in tanks that are suitably protected in case of spillage or bursting. Also needed are spray units, which might be dedicated trucks, slide in units for regular plow trucks, or trailers to pull behind trucks (typically but not always, prior to a storm). Most agencies that make extensive use of liquids also make their own salt brine, using road salt, water, and some sort of brine making system. These systems can be enhanced with blending systems, allowing for the mixture of salt brine with other chloride brines and enhancing liquids (most typically carbohydrate based).
- **THE FUTURE:** There is a move toward using slurries for material placement, where very high levels of liquid (in the range of 50 gallons per ton and higher) are used to pre-wet materials being placed on the road. Also, additional work on blending and blending systems is leading to what might be termed "designer liquids" that can be specially tailored for given storm and weather conditions.

In the right circumstance, the use of liquids can save significant materials and operational effort, all while achieving excellent levels of service.

Application BMP: Use of Salt at Cold Temperatures



The best management practice for salt use under extreme cold conditions means an agency must optimize the use of its salt. The working temperature of salt ends at approximately 15° F pavement temperatures despite the fact that the eutectic temperature is -6° F. When pavement temperatures fall to 15° Fahrenheit or lower, untreated salt melts very little ice and takes hours to do so. During these extremely cold situations when pavement temperatures are below 15° F, untreated salt should not be used. During these situations alternatives should be considered. This could mean using salt that has been treated with a product like magnesium chloride or calcium chloride. It could also mean pre-wetting the salt with one of these liquid chemicals as well. It is important to note that if pavement temperatures should fall to 0 degrees Fahrenheit or lower, even these methods will be ineffective. In these situations materials that promote traction may be the only alternative to consider.

In order to manage its materials properly, agencies should consider "what is the optimum time to use treatments during extremely cold situations?" To do this, agencies should use instruments to determine the pavement temperature and, if possible, have a pavement temperature forecast. Pavement temperature forecasts can help an agency determine when its chemicals will be most useful and when is the appropriate time not to apply chemicals. It is vital that this information be made available to the operators in the vehicles. In many situations operators feel they must apply material when clearing roadways regardless of the pavement temperature. In all likelihood in extremely cold situations this material will be wasted because it will not go into solution and will subsequently be plowed off the roadway on the next round. Giving an operator access to pavement temperature in the vehicle or to the information coming from a roadway weather information system will help them make good educated decisions about when to apply deicing materials.

Pounds of Ice Melted Per Pound of Salt

Pavement Temp. ˚F	One Pound of Salt (NaCl) melts	Melt Times
30	46.3 lbs of ice	5 min.
25	14.4 lbs of ice	10 min.
20	8.8 lbs of ice	20 min.
15	6.3 lbs of ice	1 hour
10	4.9 lbs of ice	Dry salt is ineffective and will blow away before it melts anything.
5	4.1 lbs of ice	
0	3.7 lbs of ice	
-8	3.2 lbs of ice	

It is not cost-efficient to apply salt (sodium chloride) at a pavement temperatures less than 15˚F

- **THE NUMBERS:** It is not that salt does not work below 15° F, but that it works too slowly. If it will take more than two hours for salt to fully activate at cold temperatures, and your cycle time is two hours or less, you are just going to plow off the salt before it can help you. Instead of doing that, when the pavement gets really cold, stop spreading salt.
- **THE ALTERNATIVES:** If you are not going to use salt in these low temperature conditions, what should you do instead? If you have them available, either calcium chloride brine or magnesium chloride brine will work at these low pavement temperatures, although they have their limits too. If you do not have these other materials, then you should just plow, and where appropriate use abrasives for temporary local friction gains.
- **THE NEEDS:** The key need is for a pavement temperature sensor, either as part of an RWIS system or mounted on a truck. Either way, you need to know the pavement temperature. Then, you have to decide to stop using salt when that temperature gets too low.
- **THE FUTURE:** Regardless of climate change, it seems based on the last few years that we will still have some of these very cold storms from time to time. All we can do is recognize them when they happen and deal with them as best we can, without using salt in conditions that are not optimal for its use.

Application BMP: Forecasts

Using a weather forecast is certainly vital to best management practices for salt use. In a survey done by the Snow and Ice Cooperative Pooled Fund (SICOP) regarding the top 10 issues that make up a world-class snow and ice program, accurate forecasting is one of the top issues. In nearly every research request, better forecasting is always a major issue. Agencies use weather forecasting as a tool to help in their decision making process. Weather forecasting should always be seen as a prediction and predictions are always subject to change. Weather forecasting has certainly improved in recent years. Weather forecasters have better tools and better models than ever before. There are many sources for weather forecasts both free and value added services that an agency can choose to employ. There are also many different types of forecasts that agencies can use to help make decisions.

Perhaps one of the most critical components of a forecast that an agency needs to know is the beginning time of any given event. This is critical to the planning of a response and the staffing for an event. Other extremely important components will be the type of precipitation and the pavement temperatures. Wind speeds are also critical

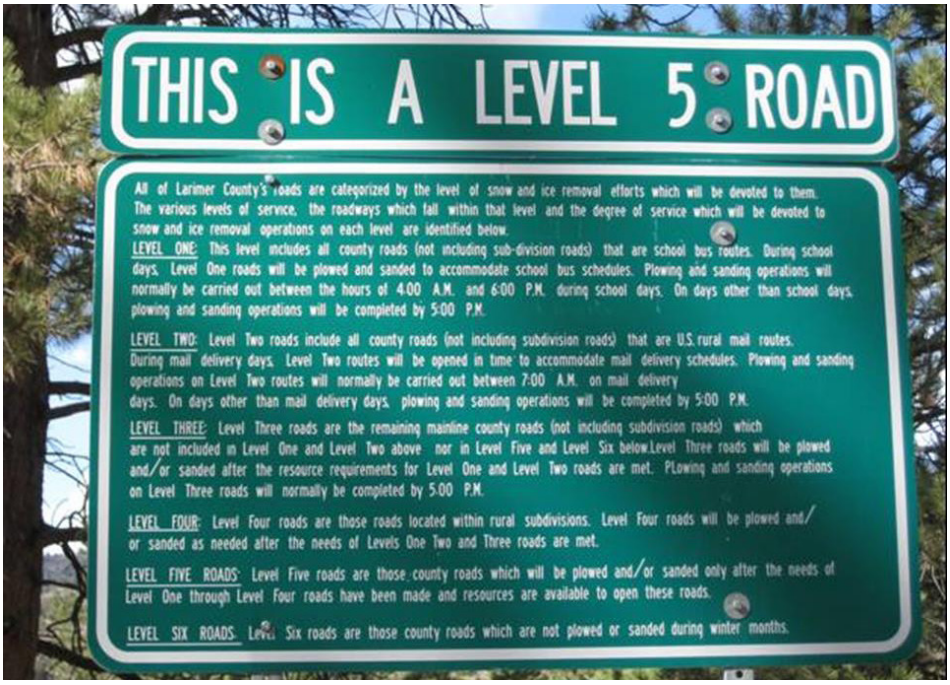
because they can lead to blowing snow and the duration of the event is also very important. Another critical component in forecasting is the frequency of events.

If you think about what the ideal winter operations forecast would contain, it might be something like the following: detailed start and end times for precipitation (ideally to an accuracy of 15 minutes); detailed information on precipitation types within a storm, with information on both where given precipitation types will be at given times, and when precipitation types will change at given locations; detailed pavement temperature forecasts; detailed information on post-storm weather that could have operational impacts (like wind speed increasing, or pavement temperatures dropping). There may well be other factors that you would like to see in your forecast, but at this point, it is probably worth remembering the wise words of Jagger and Richards (1968) "You can't always get what you want." But still, if you have a detailed list of what you need to get from your forecast, well you just might find, you get what you need.

- **THE NUMBERS:** A good forecast is absolutely critical for winter operations, especially if we want to be pro-active. Without it, we are in essence assuming every winter storm is the same, and we know that is not the case.
- **THE ALTERNATIVES:** To get a good forecast, you are likely to need to contract for a Value Added Meteorological Service (VAMS). The National Weather Service was not mandated to provide road related forecasts – their mandate was focused on aviation weather, and if your truck is flying, you have problems that will not be helped by a forecast.
- **THE NEEDS:** A good contract is a must for a satisfactory forecast. The Aurora pooled fund consortium (http://www.aurora-program.org/) has completed a number of projects that detail how good forecasting contracts can be obtained (see http://www.aurora-program.org/projects.cfm especially). It is also important to develop an ongoing relationship with your forecaster. Most contracts allow for daily discussions between the agency and the forecast provider, yet anecdotally most agencies do not make use of this feature. When agencies do use this feature, the end result tends to be an improved forecast experience that more fully meets the needs of the agency.
- **THE FUTURE:** Forecasting, especially of pavement conditions, has improved over the last decade, and as new sensors are deployed more widely, further improvements are to be expected. While you may not get everything on your forecast wish list, you might get enough to meet your needs.

The forecast tells us what type of storm we are dealing with. When we combine the forecast with our desired levels of service, we know what we need to do to achieve our goals. The forecast is critical.

Application BMP: Level of Service



In the realm of best management practices for salt use, setting the appropriate level of service is vital to the agency being successful. Levels of service are defined as the condition to which a roadway will be maintained during a winter season. These can vary from a bare pavement policy to a roadway that is closed during the winter season. In many cases level of service is based on the usage of the roadway and the traffic volume of that roadway. Generally, high volume roadways are maintained at a very high level, and lower volume roadways or secondary roadways are often maintained at a lower level. These varying roadway conditions can sometimes be confusing for roadway users and highway maintainers alike. Additionally, levels of service during a storm will differ from the condition that is trying to be achieved following a storm. An agency may want to achieve bare pavement following an event, but it does not necessarily mean it will try to achieve bare pavement throughout an event. Often, levels of service are pre-existing and set by policymakers or elected officials. Normally levels of service are not something that an agency can vary from or change without bringing policy changes forward. What agencies can do is help educate policymakers and elected officials on what levels of service should be and perhaps influence changes that make good sense.

Levels of service do not just vary from roadway to roadway but also from agency to agency. Each agency, whether it be state, county, or city, has the ability to set their own levels of service for the roads in their jurisdiction. This can cause a disparity because there is a lack of continuity along roadway systems. It also makes it difficult for operators to determine if they are achieving the level of service their agency is supposed to be providing. Public perception and complaints play a big role in setting the level of service initially but also in how an agency maintains a roadway throughout the winter. This can often lead to an agency exceeding the level of service for a roadway and thereby utilizing more salt.

Roadway users come to expect the level of service that is normally provided throughout the winter. An agency that exceeds its normal levels of service will find it very difficult to try and lower the expectations of its customers. Good communication is vital to roadway users and to agency operators to ensure they both understand how a roadway is expected to be maintained during and following a winter event. This should be clearly defined in the agency's policies on their website and even using roadway signing when possible. Visual aids are also a great tool to show a roadway and how it will be kept during the winter. This is especially useful when a roadway is only supposed to be partially cleared or snow packed.

- **THE NUMBERS:** When an agency conducts winter operations guided by its various levels of service, it will likely find that it can achieve those levels with a bit less effort than it has traditionally expended. The expected savings could be as high as 30%, but this will depend on how closely an agency is currently following its level of service.
- **THE ALTERNATIVES:** If you are not basing your operations on your levels of service, then first the old saying applies: If you don't know where you are going, how will you know when you have got there? And second, you are almost certainly using more material and time than you should, on at least some of your road system.
- **THE NEEDS:** The first need is an explicit statement of the level of service goals for your agency. This may already exist, but it may also need dragging into the light of day, dusting off, and then making sure that everyone (including the political authorities who typically set levels of service) knows what is in it. Then, you have to stick to it.
- **THE FUTURE:** This is not really an area that is very susceptible to technological advances, although a number of new sensors, that can measure road grip remotely, are in development and deployment. As these sensors become more accepted in the industry, it may be that grip level becomes a new measure of level of service, which would be a more quantitative measurement than at present.

Levels of service provide a roadmap for an agency in their winter maintenance work.

Application BMP: Training

A training program is vital to good salt management. Managers and operators need to understand how chemicals work, how much needs to be applied, when not to apply chemicals and how a proactive approach can help reduce their material usage. A comprehensive training program would teach managers and operators about agency planning and policies, understanding weather and weather tools, how materials work, what materials to choose, how to store materials properly, proper snow and ice removal, the use of proactive approaches, liquids use, calibration of equipment, equipment choices and maintenance. It would include both classroom and hands on training. It should test a manager and operator's knowledge and understanding.

APPLICATIONS

Training an operator to use good salt management is likely to be one of the best returns on investment opportunities that an agency can make. Operators make the decision of when to apply material and how much material to apply to the roadway. An operator that understands how materials work, the appropriate amount of salt to apply, and when not to apply any salt, is a great asset to an agency. On the other hand an operator that is not trained may use 10 times more salt than is necessary in a given situation. As was stated above for an operator to be successful they must be trained, and also have the necessary tools to make good decisions and utilize a proactive approach.

Also critical to best salt management practices is to train all seasonal personnel or contracted employees. Because these employees are not fulltime agency employees scheduling training may be more difficult. Seasonal employees and contract employees need the same training that any fulltime employee would receive. Seasonal and contracted employees are temporary and it is very important they buy into good salt management practices.

- **THE NUMBERS:** It takes time and consistent effort to develop a well-trained winter operations team. It is not something that is only done once. In the ideal, every worker should be trained before they even get to a plow, then should have detailed hands-on training with the equipment they will be using, and should continue to receive training throughout their working lives. Training is especially important when major changes in operations strategies and tactics are being implemented. Without such training, the innovations will likely fail.
- **THE ALTERNATIVES:** Training can be done in a number of ways: hands-on, classroom, computer-based, scenario-based. Ideally a training program should include a variety of methods, since everyone learns a little differently and using a one size fits all approach will inevitably leave some of your team less well trained than you would like.
- **THE NEEDS:** The primary need is an ongoing institutional commitment to providing appropriate training at all levels of the organization.
- **THE FUTURE:** As new technology is introduced it is likely that aspects of winter operations will change significantly. Given that, training is going to be even more important in the future than it is today.

Training is not an optional extra that is the first thing to be cut in a budget crunch. Comprehensive training is vital to a successful winter operations program.

EMERGENCY MANAGEMENT ASSISTANCE COMPACT (EMAC)

EMAC is a national interstate mutual aid agreement that enables states to share resources during times of disaster. EMAC acts as a complement to the federal disaster response system, providing timely and cost-effective relief to states requesting assistance from assisting member states who understand the needs of jurisdictions that are struggling to preserve life, the economy, and the environment. EMAC can be used either in lieu of federal assistance or in conjunction with federal assistance, thus providing a "seamless" flow of needed goods and services to an impacted state. EMAC further provides another venue for mitigating resource deficiencies by ensuring maximum use of all available resources within member states' inventories.

A SIMPLE SUMMARY OF HOW IT WORKS
1. EMAC Authorized Representative confirms declaration of emergency by Governor
2. State assesses needs for resources
3. State determines if they need an external EMAC A-Team
4. State determines best source for needed resource
5. EMAC A-Teams request resources
6. EMAC A-Teams determine cost and availability of resources
7. The EMAC REQ-A Form is completed by the EMAC Authorized Representatives
8. Resources are mobilized from the Assisting State to the Requesting State.
9. Resources check in at state staging areas and are deployment locations
10.Resources complete mission
11. Resources are demobilized
12. Assisting States complete reimbursement request
13. Requesting State reimburses the Assisting State

- **HOW EMAC WORKS:**
  Requesting and deploying resources is made at the discretion of the impacted (Requesting) state allowing them the ability to pick what they need and for what price. The responding (Assisting) state only has to offer assistance if they have the resources and can deploy it.
- **HOW EMAC IS COORDINATED WITH THE FEDERAL RESPONSE:**
  EMAC is first and foremost a state-to-state compact; however, DHS/FEMA and EMAC leadership have a long-standing agreement in which NEMA, through the NCG, facilitates requests to deploy a team to coordinate EMAC activities with federal personnel whenever requested by DHS/FEMA Headquarters. When requested, this results in EMAC moving from a Level 2 to a Level 1 operation.

For more information about EMAC visit www.emacweb.org, contact NEMA (www.nemaweb.org), or your state emergency management agency.

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

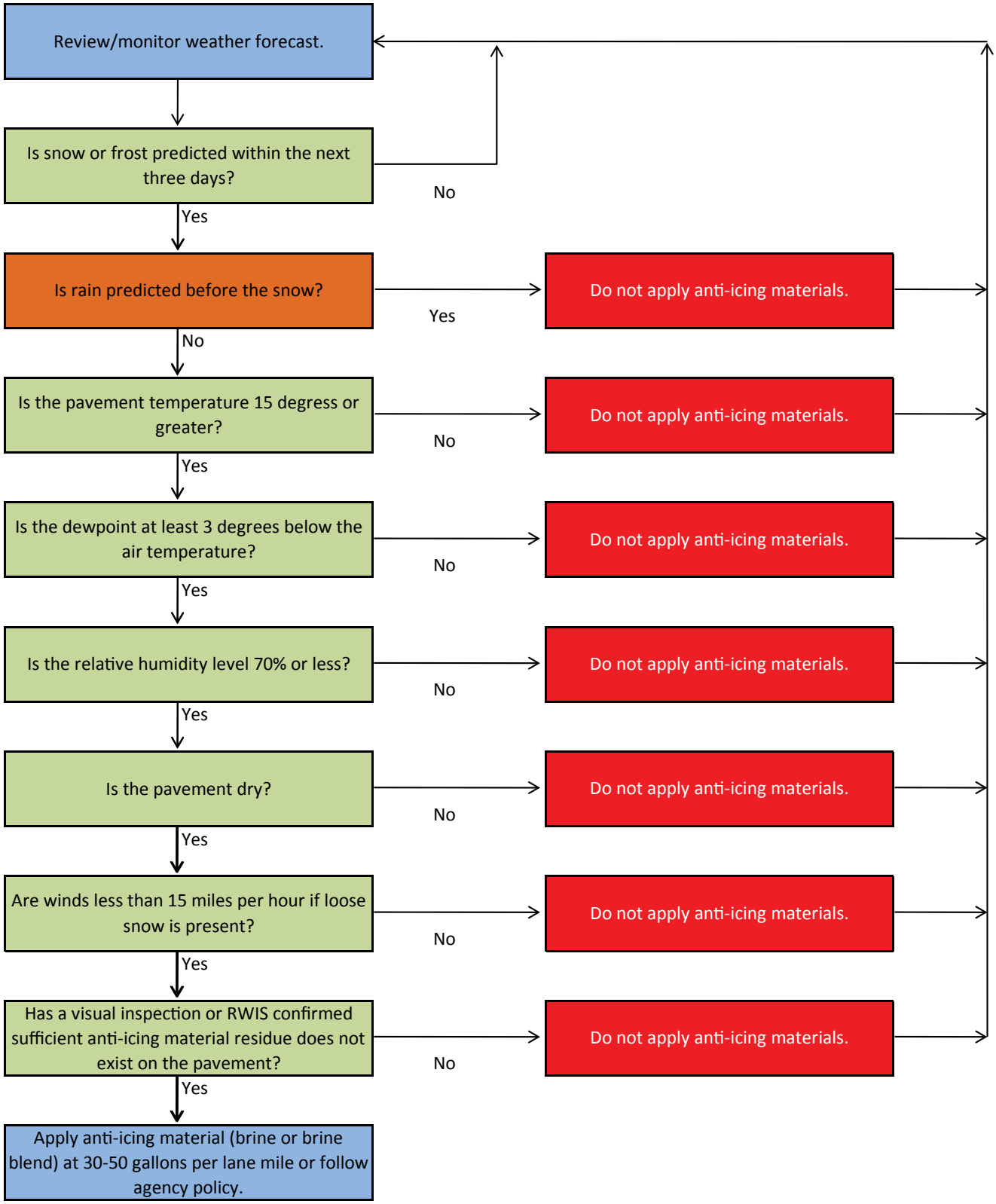
During and following extreme winter events the Governor of a State may declare a state of emergency and open the possibility of recovery of funds for State and Local agencies through the FEMA process if certain criteria are met. This process can be laborious and good documentation is required. Minimum money thresholds must be met and rates are predetermined for equipment. The length of the event is normally restricted to 72 hours. Contracted services may be included in the submittal. If the funds expended meet the minimum criteria for that area or the state then the submittal can be processed and the agencies may recover up to 75% of the submitted expenses for labor, materials and equipment use.

This process is often difficult to work through and some agencies choose not to submit. FEMA is currently working on some pilot programs utilizing different criteria to determine if there is a more simplistic approach while still requiring it to be an extreme or catastrophic event.

KEY POINTS ABOUT THE FEMA PROCESS:
Should an agency choose to pursue assistance from FEMA as a result of winter storms, the following key points may be of value:

- There must be a declaration of a disaster from the Governor. Without such a declaration there will not be any FEMA assistance available.
- FEMA assistance comes in the form of reimbursement for excess costs. FEMA cannot provide assistance or materials during an emergency – that is not their mission and they are not equipped to do this.
- A winter storm event does not have to be a record event. Near record events will be considered by FEMA as will heavy snowfall over a very extended period of time, severe winds and extraordinary drifting, extraordinary ice formation, and cumulative effect of snow on the ground. Additional information is available on the FEMA web site (http://www.fema.gov/public-assistance-archived-policies/snow-assistance-policy)

Anti-Icing Application Decision Flowchart



Dr. Wilfrid Nixon

Dr. Wilfrid Nixon received his Bachelor's and Doctorate degrees in engineering from Cambridge University, England, in 1981 and 1985 respectively. He moved to the United States in 1984, working first as a visiting professor at Dartmouth College in Hanover, NH. In 1987, he moved to the University of Iowa, and became a faculty member in the College of Engineering, rising to the rank of Professor in 1998. He worked at the University until June 2015, and is now Emeritus Professor there.

Dr. Nixon has conducted winter maintenance research for more than 20 years, and has covered topics relating to plow and cutting edge performance, optimal chemical usage, snow fence design, plow and truck instrumentation, optimal uses of novel technologies in winter maintenance, and information management and decision making in winter maintenance. He has written over 100 papers and reports on his research, and has made numerous presentations around the world.

THE UNIVERSITY OF IOWA

Dr. Nixon has worked on numerous committees and panels relating to winter maintenance at both the National and International level. He chaired the TRB committee on winter maintenance from 1998 to 2004, and is now an emeritus member of that committee. He has also chaired the TRB committee AH010: Surface Transportation and Weather (from 2008-2014). Dr. Nixon has served on the Winter Maintenance Sub-Committee of APWA for more than 10 years now.

Dr. Nixon is now the Vice President for Science and the Environment at the Salt Institute, a North American based non-profit trade association dedicated to advocating the many benefits of salt, particularly to ensure winter roadway safety, quality water and healthy nutrition.

R. Mark DeVries

Mark serves as an Application Expert for Vaisala Inc. In his new role he serves as a resource that is helping clients/agencies/etc. to improve their operations and works with them to solve problems, offers training opportunities and serves as customer support.

Previously, Mark was with McHenry County Division of Transportation (retired,) for 30 years. Past Chairman of the National APWA Winter Maintenance Sub-Committee. Previous member of the Winter Maintenance Technical Service Program. Member of the APWA Chicago Metro Chapter. Trainer for the Illinois Department of Transportation. Mark has presented at Snow and Ice seminars all across North American and abroad, many environmental seminars and various Municipalities across North America. Mark has also traveled several times to Europe, South America, Scandinavia and China.

VAISALA

Mark has been published in every major industry Magazine. Mark is the recipient of many awards including, the 2014 APWA Distinguished Service Award, the 2012 APWA Presidential Leadership Award, the 2010 APWA Top Ten Public Works Leader of the year, the 2007 APWA Donald C. Stone Award and the 2006 award of achievement from the APWA Chicago Metro Chapter. Mark and crew were the recipients of the 2006 APWA Technical innovation award and the National Association of Counties Achievement award for the County's Liquid De-icier Blending System.

CLEAR ROADS

research for winter highway maintenance