Development of a Handbook of Best Management Practices for Road Salt in Winter Maintenance Operations

Final Report

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Development of a Handbook of Best Management Practices for Road Salt in Winter Maintenance Operations

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16. Abstract

Road salt is a critical material for effective winter maintenance operations in North America. This study has developed a short, accessible handbook presenting best practices for road salt in three areas: the bidding process, the storage of road salt, and the application of road salt. This final report presents the process by which the best practices were collected and included in the handbook. The handbook is a separate, stand-alone document.

To obtain a good sense of the current practice in the procurement processes for road salt, the contractors conducted phone interviews with a variety of personnel involved in winter maintenance. As part of this process, five best practices were identified: having adequate storage; creating emergency stockpiles; tightly specified quantities; longer contract lengths; and pre-season fills.

In the area of salt storage the four best practices that were identified and described were: adequate storage and storage facilities; facility layout; shared facilities; and optimizing facilities operations.

In the area of road salt application, there are a great number of possible best practices, and in total eleven were identified. The eleven best practices in salt application were: pre-wetting and treated salt; anti-icing; variable application rates; equipment calibration; measurement; accountability; liquid usage; salt usage under extreme cold conditions; use of forecasts; setting levels of service; and training.

In all the areas of the "road salt life cycle" (procurement, storage, and application) best practices have been identified and are fully described in the body of the report. Further, the best practices have each been summarized into a handbook, with each best practice comprising two pages (i.e. one sheet of paper) in the handbook, so that if the end user of the handbook wishes, the individual best practice information can be presented separately from all other best practices, thus making them more accessible, and more useful.

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Executive Summary

Road salt is a critical material for effective winter maintenance operations in North America. This study has developed a short, accessible handbook presenting best practices for road salt in three areas: the bidding process, the storage of road salt, and the application of road salt. This final report presents the process by which the best practices were collected and included in the handbook. The handbook is a separate, stand-alone document.

A driver for this study is that the winter of 2013-14, which was particularly severe in some parts of the country, resulted in salt shortages that negatively impacted winter maintenance operations in a number of locations. In turn, this resulted in significantly increased demand for salt during the spring, summer, and fall of 2014, as agencies strove to restock their salt supply in preparation for winter 2014-15. While the salt shortages during the winter were likely due to a number of transportation issues, those since the end of winter were due to the fact that salt production from mines cannot be increased rapidly and thus while transportation in summer is simple, the supply of salt is also limited. The result has been a shortage of product (again, although as noted for different reasons) and a concomitant increase in price (in some locations).

A literature review was conducted as part of the study. Since the key goal of the project was to produce a handbook of Best Management Practices for Road Salt, the review focused on documents that enhanced that key goal. Other more comprehensive reviews on these issues have been conducted elsewhere, and rather than repeat those reviews, the reader is simply referred to them. Findings from the literature review indicated that best practices for the procurement, storage, and application of road salt were available in the literature.

In order to obtain a good sense of the current practice in the procurement processes for road salt, the contractors conducted phone interviews with a variety of personnel involved in winter maintenance.

As part of this process, five best practices were identified: having adequate storage; creating emergency stockpiles; tightly specified quantities; longer contract lengths; and pre-season fills.

In the area of salt storage the four best practices that were identified and described were: adequate storage and storage facilities; facility layout; shared facilities; and optimizing facilities operations.

In the area of road salt application, there are a great number of possible best practices, and in total eleven were identified. The eleven best practices in salt application were: pre-wetting and treated salt; anti-icing; variable application rates; equipment calibration; measurement; accountability; liquid usage; salt usage under extreme cold conditions; use of forecasts; setting levels of service; and training.

In all the areas of the "road salt life cycle" (procurement, storage, and application) best practices have been identified and are fully described in the body of the report. Further, the best practices have each been summarized into a handbook, with each best practice comprising two pages (i.e. one sheet of paper) in the handbook, so that if the end user of the handbook wishes, the individual best practice information can be presented separately from all other best practices, thus making them more accessible, and more useful.

Chapter 1 Introduction

1.1 Purpose and Goals of Study

Salt (Sodium Chloride, but for the purposes of simplicity it will be referred to as salt throughout this report) is a critical material in most of the winter maintenance operations conducted in the United States. The quantities of salt used annually in winter maintenance activities are large and have varied over the past five years between 12 and 22 million tons. The implication of this is that there is a significant logistical challenge involved in mining, shipping, delivering, storing, and placing that much material annually. The purpose of this study is to develop a handbook that considers the "fate" of road salt from when it leaves the mine to when it is placed on the road, with a view to providing best management practices that allow the various stages of the journey to be conducted as efficiently and effectively as possible.

Of importance in this endeavor is understanding that seemingly innocuous changes (for example, if an agency requires delivery with 2 days' notice throughout the winter season instead of three days' notice) may have substantial impacts on the price of the product to the end agency. This is not to say that an agency cannot or should not reduce the time within which they require salt to be provided – of course they can do this – but that the agency should understand the scale of the cost changes incurred when such changes are made.

The logistics supply chain for salt is complex, and there are a number of bottlenecks within it that may limit suppliers abilities to meet bids and thus to respond positively to such bids. Again, an understanding of such bottlenecks and how to avoid them may allow agencies to obtain their required supplies at a lower price, to the degree that they can change their own logistics practice to work with the supply chain limitations of the salt companies.

A driver for this study is that the winter of 2013-14, which was particularly severe in some parts of the country, resulted in salt shortages that negatively impacted winter maintenance operations in a number of locations. In turn, this resulted in significantly increased demand for salt during the spring, summer, and fall of 2014, as agencies strove to restock their salt supply in preparation for winter 2014-15. While the salt shortages during the winter were likely due to a number of transportation issues, those since the end of winter were due to the fact that salt production from mines cannot be increased rapidly and thus while transportation in summer is simple, the supply of salt is also limited. The result has been a shortage of product (again, although as noted for different reasons) and a concomitant increase in price (in some locations).

However, the shortages of salt are not all due to supply issues. As noted above, the 2013-14 winter was in many places severe and one aspect of the severity was unusually low temperatures, including unusually low pavement temperatures, especially during snow storms. When pavement temperatures are very low (typically below about 15° F) salt provides little to no benefit during winter maintenance operations. Yet, albeit anecdotally, many agencies used substantial amounts of road salt during such low pavement temperature storms and this inappropriate use undoubtedly contributed to the reduction of salt stockpiles for many agencies. Furthermore, it should be noted that using road salt under conditions when it provides little to no benefit, is inherently unsustainable.

The handbook can thus be thought of as a “soup to nuts” review of best practices for road salt. It will consider each step along the way, and provide rational and well-presented explanations of actions that agencies can take to manage their efficient, effective, and sustainable use of road salt as a central tool in their winter maintenance operations tool box.

Information for the study was obtained in three ways. A traditional literature review was conducted (see Chapter 2), interviews were conducted with a number of (primarily state) transportation agencies (see Chapter 3), and personal knowledge of the contractors was collected, supported with suitable data.

1.2 Organization of Report

This report comprises six chapters (including this one). Chapter 2 presents a review of the literature, including references. Chapters 3 through 5 examine respectively the state of the practice in the area of bidding, storage, and application of road salt. These chapters identify the best practices in each of these areas. Chapter 6 presents these best practices and presents the conclusions of the study. The appendix includes the questions that were asked during the interview process.

1.3 Creation of Handbook

The primary purpose of this study was not solely to collect the best practices for road salt, but primarily to collect that information into a short (twenty pages has been suggested as a suitable length) and accessible handbook of best practices. This handbook is a separate document from the final report. The final report is a summary of the process by which the best practices were collected and documented. While the final report serves as a supporting document for the handbook, the handbook is designed to stand alone without any reference to the final report being needed. The thinking behind this is that a handbook, by being much more accessible, will be much more likely to be used than a final report.

1.4 Conclusions

Road salt is a critical material for effective winter maintenance operations in North America. This study has developed a short, accessible handbook presenting best practices for road salt in three areas: the bidding process, the storage of road salt, and the application of road salt. This final report presents the process by which the best practices were collected and included in the handbook. The handbook is a separate, stand-alone document.

Chapter 2 Literature Review

2.1 Introduction

This literature review is presented in three parts. First, information relating to procurement and bidding of road salt is presented. Then information of salt storage is presented. Finally, information on road salt usage is presented.

Since the key goal of the project is to produce a handbook of Best Management Practices for Road Salt, the review focuses on documents that will enhance that key goal. Other more comprehensive reviews on these issues have been conducted elsewhere, and rather than repeat those reviews, the reader is simply referred to them.

2.2 Literature on Procurement and Supply Issues

Ciarallo et al. (2009) conducted a study of winter maintenance material ordering and inventory (with emphasis on the Ohio Department of Transportation) that developed guidelines for managing inventory based upon the significant and voluminous literature on that topic. The report provides a complete review of inventory management literature. It also noted that "*In practice it is difficult to track inventory when the supply is not carefully monitored*."

Hanneman (2009a, 2009b) provides a review of the salt shortage concerns that arose during the 2008 salt bid season. He identifies one major reason for these concerns: agencies dramatically increased their bid quantities after the severe 2007-08 winter. Some of the bid quantities were as much as 50% or more higher than in previous years. The difficulty from a supplier standpoint of such bids stems from the simple fact that while the total supply of salt is (almost) limitless, the rate of that supply is limited by mine capacities. When salt demand exceeds the annual supply, a shortage will ensue and prices will rise.

Hanneman also noted that the purpose of a contract is, at least in part, a process for assigning risk between the buyer and the seller. He discusses the issues of risk raised by what he terms 80/120 contracts, in which the buyer has to take 80% of the bid quantity, and the seller must guarantee to provide up to 120% of the bid quantity. This latter requirement essentially reduces the amount of salt available to the vendor to offer in response to bids.

Amsler (2008) has a number of suggestions for reducing salt costs during the bidding process. Key among these is having sufficient storage for a typical year of usage which allows an agency to make use of opportunity pricing. He also suggested structuring contracts for “early, main season, and late deliveries,” and further suggests not overburdening the contract with penalties and disincentives. He additionally suggests making use of shared storage facilities (he specifically mentions the shared storage facility developed in Central Iowa, which is discussed further in the Storage chapter of this document) and having contingency stockpiles which are not used except in situations where salt supply is threatened.

A somewhat unusual but useful source of information for the review is the report by the Office of the Michigan Attorney General (2015). This report was written in response to high prices during the 2014 salt procurement season, as the result of requests by participants in the MiDEAL purchasing program for road salt. While the report focused on investigating potential anti-competitive practices, their findings were more generally applicable. These included:

- No evidence of illegal price-fixing was found.
- There were legitimate explanations for price variations observed between locations in and around Michigan.
- The relatively late timing of the bid may have contributed to the higher prices observed.

The report found that some state bids were opened as early as April while others were as late as July. Michigan's bids are opened in mid-June and the report suggested that moving to an earlier timeframe for the bidding process might be beneficial. There are of course some potential drawbacks to this approach, not least of which is that not everybody can be first in line, as it were.

While there were a number of other reports and papers that addressed the issue of salt procurement in general, these were either superseded by later studies referenced herein or had a focus that was not pertinent to this study (e.g. Quack et al., 2010) and have not been included.

2.3 Literature on Salt Storage Issues

A useful starting point on all issues related to salt storage is the Salt Institute (2013) Safe and Sustainable Salt Storage Handbook. The handbook, although brief, touches upon all major aspects of salt storage, using the simple acronym "*SALTED*" as a guide for areas of consideration. The six areas covered by the acronym are:

- Safety – should be a major concern both for workers and the general public.
- Accessibility – the storage site should be easily accessed by trucks even in conditions of low visibility such as winter storms.
- Legality – in the sense that appropriate zoning and permits must be obtained.
- Tidiness – to ensure safety and avoid possible contamination due to salt spillage.
- Economics – the location of a storage site should be such that dead head time is in general minimized.
- Drainage – all storage structures should have good drainage away from the stockpile and should be on impermeable pads. The drainage should be properly contained and managed.

In addition to the SALTED guidelines, the Safe and Sustainable Salt Storage Handbook makes three other key recommendations. Salt should be stored on an impermeable pad, with appropriate slopes, away from wells, reservoirs and groundwater supplies. Stockpiles should if at all possible be covered by a permanent structure or if not by such a permanent structure by a waterproof cover. And, ideally, there should be enough storage to hold an average winter's needed salt. The handbook provides guidance on estimating annual salt needs, if historic data are not available.

Public Works Magazine (Public Works, 2012) provides a useful guide to selecting a salt storage building. The guide considers the various types of building materials (fabric, metal, or wood) and discusses what each of these material types requires in terms of foundations and structure, as well as likely lifetime and other issues (such as permitting). In a related topic, there is an ongoing research program by the South Dakota Department of Transportation entitled "Methods to Protect Salt Stockpiles." While this project has apparently not yet been completed, it may in time provide useful information pertinent to the Best Management Practices for Road Salt. As with all such activities, ongoing monitoring of new findings will be necessary to ensure the BMPs remain up to date.

Two other issues of import have been considered in the area of salt storage. First, there is the concept of shared salt storage facilities (Barbaccia, 2010), in which typically a number of smaller communities may pool resources to create a shared storage structure. This allows for economies of scale in purchasing as discussed briefly above and in more detail in the salt storage chapter of the report.

Second, there is the issue of optimally locating salt storage facilities to best serve the operations of an agency during winter maintenance activities. Studies such as Yang et al. (2011) explore how best to locate such facilities, often using sophisticated algorithms and detailed Geographical Information Systems (GIS). While these studies may be of value to agencies when new stockpile locations need to be selected, their application is often limited. One reason for this is that best practices in winter maintenance now require that agencies adjust their application rates of road salt depending on the pavement temperature and storm type. If the application rate used by a truck varies, then it is unlikely that any single geographic location is going to be ideal for all application rates. At the present time, the probability distribution of application rates for a given agency over a number of winter seasons has not been readily established, and until such time as this has been done, geographic optimization of stockpile locations will have limited utility for most agencies.

2.4 Literature on Salt Application Issues

The issue of how best to apply road salt to highways to ensure safe travel during and after winter weather events has been studied extensively over the past several decades. Accordingly this literature review will not attempt to recreate the reviews conducted elsewhere, but will rather touch on what might be considered the high points in the understanding of what constitutes best management practices in road salt application.

As a follow on from the first Strategic Highway Research Program (SHRP) there was an FHWA Test and Evaluation program conducted in the early 1990's. The result of this program was the FHWA Manual for an Effective Anti-Icing Program (Ketcham et al., 1996). This established for the first time in the US appropriate application rates for pre-storm treatment and in-storm treatment for a variety of different storm conditions (six broad conditions were identified).

Following on from the FHWA Manual, there have been a number of other projects such as NCHRP Report 526 (Blackburn et al., 2004). This report provided a more detailed methodology than the FHWA report, with allowances for other variables such as traffic levels, and desired levels of service. Later, environmental concerns were addressed directly through NCHRP Report 577 (Levelton Consultants, Ltd., 2007).

Subsequent studies by the Clear Roads Pooled Fund Consortium and others have investigated a broad range of issues relating to road salt application rates. These include, but are not limited to, work correlating laboratory performance and field performance for deicing chemicals (Fay et al., 2010), which is important because new materials often have only laboratory results available, and so some form of correlation between lab and field is very helpful. Another study examined the toxicity associated with ice control materials (Pilgrim, 2013). All of these studies underscore the need for optimizing the application rates of road salt so as to apply enough material to prevent or break the bond between the road and the snow or ice on top of it, and no more.

Another important aspect of this need (getting the right amount of material in place and keeping it there) is the method of distribution of the material. Recent studies on this topic include the potential role of automation in such systems (Thompson and Thompson, 2014). The intent of such systems is to adjust application rates automatically so as to optimize such application without further taxing the snow plow operator.

While touched upon by many of these studies, one important aspect of application rate optimization is the pre-wetting of the solid material prior to it being deployed from the truck. Studies showing the effectiveness of pre-wetting date back to at least 1975 (Michigan Department of State Highways and Transportation, 1975) when studies in Michigan showed that pre-wetting could provide the same level of service with 30% less salt when compared with non-pre-wet salt application. These results have been confirmed in subsequent studies up to the present day (see, for example, Burtwell, 2004). It is clear from this that a key best practice for salt application is pre-wetting.

2.5 Snow Declarations

During and following extreme 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 of 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.

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)

In addition to the options made available through FEMA agencies may also pursue opportunities through the Emergency Management Assistance Compact (EMAC) program. 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.

The EMAC system works as shown in Table 2-1. 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.

Table 2-1 Steps in the EMAC Process

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

2.6 Conclusions

The above referenced works do not present a comprehensive literature review for road salt procurement, storage and application. However, they do comprise a representative sample of the literature in these fields and will serve to inform the guide for Best Management Practices appropriately for this project.

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Chapter 3 Procurement Best Practices

3.1 Introduction

This chapter presents the results of a phone interview process to determine current practices among (primarily) state departments of transportation used when requesting bids for road salt. On the basis of the interview findings, a series of best practices are presented. Additionally, indications are provided, in tabular form, of which practices tend to lead to lower salt prices, and which tend to result in higher salt prices. It should be noted that these findings are only general tendencies.

3.2 Phone Interview Process

In order to obtain a good sense of the current practice in the bidding processes for road salt, the contractors conducted phone interviews with a variety of personnel involved in winter maintenance. Table 3.1 lists those agencies that were interviewed. Appendix A provides the questions that were used during the interviews. As part of the interview process, many agencies provided copies of their bid documents, their specifications, and their contracts. These have been collected into an addendum to this project; an electronic compilation of the material. It is suggested that this be made available through the Clear Roads web site. Likewise, the complete answers to the interview questions are available in a spreadsheet which again it is suggested be made available on the Clear Roads web site.

Table 3-1 Agencies Interviewed on Procurement Processes

	Agencies Interviewed	
Virginia Department of Transportation (DOT)	New Hampshire DOT	New York DOT
Montana DOT	Wyoming DOT	Nebraska Department of Roads
Missouri DOT	Oregon DOT	Michigan DOT
South Dakota DOT	Maine DOT	Louisiana DOT
Illinois DOT	Kansas DOT	Minnesota DOT
Colorado DOT	New Jersey DOT	Utah DOT
Wisconsin DOT	Kentucky DOT	Ohio DOT

North Dakota DOT	Iowa DOT	City of Toronto
City of Farmington Hills Michigan		

3.3 Interview Responses

Section 3.3 presents a summary of the responses provided to the contractors during the interview process. The complete responses are available in a spreadsheet.

3.3.1 Salt Quantities

Most agencies noted that they do not purchase a fixed quantity each year, and thus provided a range of quantities. As an example, Virginia Department of Transportation (DOT) reported an average annual purchase of 400,000 tons of salt, with a range from 126,000 tons to 720,000 tons. The highest reported annual quantity was 960,000 tons for Ohio DOT; while the lowest reported amount was 322 tons for Oregon (although Louisiana may have ordered less – their order is delivered as a bagged product rather than as loose rock salt).

Figure 3.1 shows a frequency distribution of average annual salt usage (in tons) for state agencies. As might be expected, there is significant variation in the quantities of salt used by different agencies.

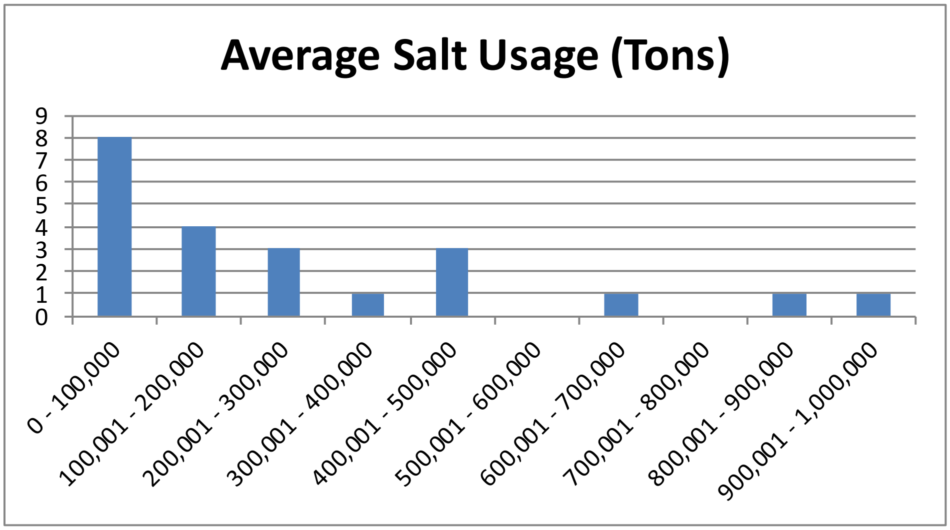

Figure 3-1 Average Annual Salt Usage Frequency Chart for State Agencies

3.3.2 Bid Responses

Interview respondents used some form of low bid process to select vendors. Most agencies let bids in different areas within the state (thus several different vendors might have salt contracts with each state agency, each vendor supplying certain areas and not others). In some cases, weighting may be applied to the responsive bids, depending on delivery methods or other factors detailed in the bid documents.

Most agencies receive multiple bids on all their bid offerings, although two agencies noted that in some cases over the past five years they had only received one responsive bid to at least one of their offerings. Some agencies had as many as nine bidders responding. A few noted that some of the responding bids included the import of salt from overseas. Some agencies (e.g. North Dakota DOT) require that bidders be salt producers, not trucking companies, because “we want to deal directly with those that are in charge of the stockpile.”

Nine of the twenty five agencies interviewed have received some of their salt from non-North American sources over the past five years. Five of these agencies indicated that it was normal to get at least some of their salt from such sources. Chile was the most frequently mentioned in this regard.

3.3.3 Contract Lengths

Fourteen agencies indicated they had one year contracts with a variety of options for renewal for up to four additional years. Five agencies had straight single year contracts (such that they always go out for new bids each year and re-let all contracts each year). The remaining agencies used contracts with initial lengths of between three and five years and all with the option to extend those contracts for additional periods of up to two more years. Some of these multi-year contracts included potential price changes each year.

Some agencies cited the convenience of not needing to go out to bid every year as being a good reason to consider multi-year contracts, although in most cases the multi-year aspect of the contract was contingent upon agreement between vendor and agency regarding price. Other agencies, conversely, indicated that rebidding every year simplified the process and ensured a uniform process for all contracts. One agency noted that multi-year contracts had caused problems for vendors with bonding agencies.

3.3.4 Upper and Lower Quantity Limits

Nine of the agencies reported no limits on quantities, specifically that the vendor had to provide as much salt as requested throughout the contract period. In one case (Montana DOT) the agency had investigated whether limiting the quantities in some way would have a beneficial impact on price, and were told by vendors that it would not. Note however that Montana uses a relatively small amount of salt each year (25,000 tons).

Of those states that do limit quantities, there was a broad range of limits. The broadest was 70% - 150% (New York DOT) although the vendor could increase price by 10% above 120% of the specified quantity and by 15% above 130%. New Jersey DOT has a 50% - 120% limit, which is the next broadest range. The tightest limit is a 90% - 110% limit for Ohio DOT although the agency can specify during the contract period where in the State the salt must be delivered.

Close to the tightest limits are those in use by Iowa DOT, which are 80% - 110% for the 2015/16 contract. In prior years, the limits had been broader – specifically in the 2014/15 contract the limit was 70% - 110%. Iowa found that by tightening the limits they saw a significant decrease in the per ton cost. Iowa bids their salt by garage, so there are different costs per ton for each of the DOT garages in the State. In some locations prices decreased by as much as $11 per ton. As a statewide average, the price of a ton of salt decreased from $75.01 to $72.48 (a 3.37% decrease). No other agency that had made changes in their limits was able to report on specific cost changes before and after the change.

3.3.5 Unusual Circumstances

Obviously there were a range of responses with regard to steps that agencies could take to deal with circumstances when a vendor fails to deliver salt in a timely manner. Some agencies structure their contracts so they could go to the second place vendor and charge the difference in price to the non-responsive vendor. Others imposed fees/fines on a per day basis (thus perhaps 1% of the price per ton per day for non-delivery). Still others require that their suppliers have bonds, and in cases of failure to deliver could collect on the bond.

For the most part, agencies reported that they try to work these issues out on a case by case basis, and they view the imposition of fines or going to the second place vendor to be actions of the last resort. There was no indication from any of the responders that the various processes included by the agencies in the contracts increased salt prices, with one exception. Montana DOT noted that the bonding process made the contracting process longer and added perhaps 0.5% to the price.

With regard to the need for the State agency to assist local agencies during times of emergency, for the most part agencies reported that this was not required or mandated, but was politically expected. The general sense was that this did not pose an undue burden on the operations of the State agencies.

3.3.6 Delivery Issues

Agencies typically have a time frame within which salt that is ordered must be delivered. The time varies from two days to fifteen days. Some agencies vary the time frame according to the quantity of salt that has to be delivered, with smaller quantities being on a tighter timetable. Other agencies have no penalties associated with pre-season (e.g. pre-October 31) deliveries, but do have time frames for in-season deliveries.

Deliveries are typically only accepted during normal working hours, except by prior agreement. Again, this is an area in which agencies are more than willing to work with vendors, especially in situation where supplies may be running low.

3.3.7 Storage Related Issues

Agencies reported a significant range of storage capacities. Capacities in this section are reported as a percentage of the reporting agency's average annual salt usage. One agency reported having storage for less than 20% of their average annual usage (which in this case was 475,000 tons per year). Clearly in such a case, mid-winter deliveries will be required and will have to be ongoing throughout the winter season. 44% of the responding agencies reported having storage for 100% or more of their average annual salt needs. Having storage for 100% of the average annual salt needs means that mid-winter deliveries will only be required in perhaps 50% of winters. Four agencies had storage capacities between

130% and 150% of their average annual usage. For those agencies, mid-winter deliveries will only be required during extremely severe winters, although as a matter of practice the four agencies all take salt deliveries during the winter season to maintain their stockpile readiness. It should be noted that for some agencies, located in areas where winter weather is more marginal, or where ice storms are more common, the annual variation in winter weather is such that more than 150% of average annual salt needs would be a prudent level of storage.

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. Four agencies reported that they had emergency stockpiles of salt that were not used in typical winters but were available in case of a severe shortage in the state. These stockpiles ranged in size from 2,000 tons to 160,000 tons. While this salt would obviously need to be trucked to locations where it is needed (and that trucking would need to be done by the agency itself, either directly or by means of a trucking contract) clearly such stockpiles mitigate the risks of mid-winter salt shortages. Of course, the excess storage (above 100% average annual use) serves a similar purpose. Further, such emergency stockpiles would ideally only be used when salt was not readily available through more usual means and therefore the extra costs associated with transportation from a central facility would be offset by typically much higher salt prices in such shortage situations.

Another benefit of having adequate storage was the ability to conduct a pre-season fill of salt stockpiles. This was accomplished in a number of different ways, sometimes using a separate contract for the pre-season fill and at other times using one contract for all supplies, but with different conditions (and sometimes a lower price) for the pre-season fill.

3.3.8 Overall Sense of Program Performance

Respondents were asked how they would rate their current salt purchasing program. All of them indicated they were happy with the current process. The lowest ranking on a scale of 1 to 10 was 6, indicating a general satisfaction with the status quo, although a few agencies had indicated they were making some minor adjustments to their processes.

3.4 Other Identified Practices

While the focus of the study is on State level organizations, a number of smaller agencies, at the City level, were interviewed. This section identifies those practices and shows how they would complement some of the State level practices described in Section 3.3 above.

For the most part, the information from these entities mirrored the information collected from the State Agencies. The most notable exception was for the City of Toronto, that bases its contract around essentially on-demand delivery during the winter season. The pertinent part of their contract reads:

> *During the period from October 15 to April 30 of each contract period, the bulk, crushed, coarse, common rock salt treated with non-caking agent shall be delivered as directed at any time, seven (7) days per week, Sundays and Statutory Holidays included. If required, the rate of delivery shall be 2,000 Mg[1] to the Scarborough District in a continuous forty-eight (48) hour period, starting after telephone notification to the Vendor. If the Vendor fails to deliver salt to the Scarborough District, then the Contract Administrator can request that suppliers from other Districts deliver salt to the Scarborough District at the expense of the Vendor.*

In short, the vendor must be able to deliver 2,000 tons in a 48 hour period. If the vendor fails to do this, the penalties are quite harsh:

[1] Note that 1 Mg = 1,000 kg or 1 metric ton.

Should the Vendor fail to deliver all the salt which was ordered within the forty-eight (48) hours after notification, then liquidated damages for the undelivered salt shall be assessed at $1.00 per Mg for each hour thereafter, against the Vendor.

The City of Toronto is aware that they pay significantly higher costs (about 30% more per ton in comparison with other agencies that have less stringent delivery requirements) but are willing to pay that premium for the benefit of this delivery clause in their contract.

A second example of a practice that has held costs in check is used by the City of West Des Moines. The City arranges a week for pre-season salt deliveries and during that period of time, salt deliveries are accepted 24 hours a day, seven days a week. Anecdotally, such a practice is preferable for vendors since it minimizes the trucking challenges involved with salt deliveries. Whether a practice such as this would be feasible for a state level agency is not clear, since all agencies reported limiting deliveries to normal working hours unless by prior arrangement.

3.5 Identified Best Practices

This section presents the summary of the identified best practices related to the bidding and procurement part of what is termed herein as the road salt life cycle. Not all of these practices are feasible for every agency, and for some agencies these practices may not be possible for regulatory reasons. Nonetheless, agencies would benefit from at least reviewing these practices and considering whether or not they might work in their own particular context.

In general, activities that reduce risks for the vendors will tend to reduce costs for the agency and vice versa. An example would be the Toronto contract mentioned above. Note also that not every practice that is identified as reducing cost has been identified as a best management practice, since the reduction of cost likely implies an increase in risk for the agency and as such would not necessarily be best practice.

3.5.1 Adequate Storage

The more salt an agency can store appropriately (see Chapter 4 for best practices on storage) the less the agency will require mid-winter deliveries which carry risk for the vendor. The best practice in this regard would involve agencies having storage for 150% of 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 winters.

3.5.2 Emergency Stockpiles

Having an emergency stockpile provides an agency with protection against salt shortages that can develop during severe winters. However, such stockpiles are in one place and as such methods must be available to deliver the salt to locations within the state where salt is needed. 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.

3.5.3 Tightly Specified Quantities

The more tightly an agency can specify the quantity of salt that they require under their contract, the less risk there is to the vendor and, all other things being equal, the cost of the salt will therefore be less. Of course, the ability to tightly limit the quantity of salt purchased is directly dependent upon the ability of an agency to store a year’s worth (or more) of salt. When an agency cannot store a full year of salt, the limits will of necessity have to be broader.

3.5.4 Contract Lengths

Often, state agencies are limited in the length of contract they can use, and the degree to which they can extend a contract beyond its original length. Notwithstanding this, the longer a contract term is, the lower the risk to the vendor and thus, all other things being equal, the lower the cost of salt to the agency. While hesitant to suggest a best practice which some agencies may be legally unable to pursue, it is nonetheless a best practice to use contract lengths of between 3 and 5 years, with options to extend up to an additional three years. Note, however, that such multi-year contracts should include a renegotiated price at the start of each year, and should also include a mechanism to account for significant changes in transportation costs.

3.5.5 Pre-Season Fills

If an agency can structure their contracts in such a way as to use the summer time period for many of the salt deliveries this is greatly beneficial for both the agency and the vendor. While some agencies identified issues with obtaining sufficient trucks for deliveries during the summer, for others this was a key part of their program. It tended to provide a known quantity of salt at a lower price than in-season deliveries, and under conditions that were typically less fraught than during the winter season.

3.6 Impacts of Practices

On the basis of the interviews and other information received, it is clear that some actions that an agency may choose to take in the bidding and procurement process will decrease prices and increase availability of salt, while other actions may do the opposite. In this section of the report, a summary of which practices cause what outcomes is presented in tabular form.

In creating this summary, the basis for the indicated impacts of each practice is the sharing of risk that the practice implies. If all the risk in a contract is taken by the vendor, the price will likely be higher for the commodity than if all the risk is taken by the purchasing agency. Thus by evaluating a given practice in terms of where it places the risk (or evaluating a change of practice, in terms of how it shifts risk) a reasonable judgement can be made about how prices would be impacted by the action or practice.

This is not to say that an agency should necessarily select the practices that tend to reduce costs the most. It is entirely appropriate for an agency to determine a level of risk with which they are comfortable, even though this may result in higher material costs for that agency. In particular, actions taken to ensure an adequate supply of salt during a winter (thus avoiding the risk of running out of salt in a particularly severe winter) will be actions that reduce the risk to the agency and will thus tend to increase the cost of the salt supply. Also, while table 3.2 shows impacts of the practice in terms of raising or lowering costs, that indication should always be considered within the context of "all other things being equal."

Table 3-2 Potential Impacts of Various Road Salt Procurement Practices

Practice in Salt Procurement	Potential Impacts
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
Having Multi-year contracts	Lowers 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

Chapter 4 Storage Best Practices

4.1 Introduction

This chapter presents the results of the information gathering process to determine current practices among transportation agencies used when storing road salt.

4.2 Information Gathering Process

Information for this section was gathered in several different ways. Much of the information about agencies' storage practices, delivery systems and storage capacities were gathered during the phone interview process. Additionally the contractors sought information on unique and regional storage facilities and this was achieved through an information request and phone discussions as well. Best practices in salt storage and siting a location were drawn from the Salt Institute's Safe and Sustainable Storage Handbook (Salt Institute, 2013). Additionally the contractor reached out to a storage vendor for additional information not gathered in the request for information.

4.3 Information Found

Section 4.3 presents a summary of the information collected as described in section 4.2 above. This section is broken into sub-topics

4.3.1 Basic Information

During the phone interviews much of the discussion centered on the percentage of salt that could be stored by an agency in relation to its yearly average usage. As stated in 3.3.7, most agencies only store a percentage of their yearly requirement and rely on winter delivery for the remainder or to restock as material is used. According to the Salt Institute's Salt Storage Handbook, which was first published in 1968 and updated 7 times to its current Safe and Sustainable Storage guide (Salt Institute, 2013), an agency should have at least 100% of a normal years supply stored for its winter operations. As was discovered in the interview process, even for agencies that actually had 100% of annual salt usage stored, it may not all be in the right location. Often the causes for this are out of the control of an agency – for example, if an area develops after a facility has been constructed, the facility may now be undersized due to growth in the area.

What was not discussed in the interviews, but is an important factor when considering best practices, is how the salt is stored. The handbook (Salt Institute, 2013) clearly states that good salt storage for transportation agencies requires that salt be stored on an impervious pad and that the salt be covered. While regulations vary, most state Environmental Protection Agencies (or their equivalents) will typically require amounts over 500 tons to be contained. They further typically require the prevention of salt from entering into freshwater sources or ground water wells. These limited guidelines give agencies great flexibility into what method they use when storing salt.

Salt storage can vary from a pile on a pad that is tarped to an elaborate building or dome. The most preferred methods are likely to be the most costly and the least costly methods may not always be the most operational and environmentally friendly. Improperly stored salt can lead to contaminated wells and waterways. This has brought forth lawsuits that required mitigation and restoration or settlements. This has resulted in better salt storage practices and realization that not only was good storage better for the environment but properly stored salt was easier to work with and results in little to no material being lost during the storage process.

The Safe and Sustainable Salt Storage handbook (Salt Institute, 2013) addresses these issues in a simple system that helps agencies that are evaluating, relocating or constructing a facility. The handbook gives these guidelines in a shorthand acronym; S.A.L.T.E.D. – comprising the topics of Safety, Accessibility, Legality, Tidiness, Economics, and Drainage. These simple areas are described in detail in the book and are great guidelines with which an agency can begin. Local regulations must also be examined for permitting and runoff containment. Deciding on the type of facility and size of the facility should be based on the layout of the yard, the 5 year average salt use and operational considerations.

4.3.2 Yard Layout

For most State agencies, their salt storage facilities are legacy structures. That is, they were typically built many years ago and funds are only rarely available for significant site improvements for these facilities. Nonetheless, preexisting facilities may be able to be modified or enhanced for better storage or operational efficiency. During the interview process issues pertaining to delivery of salt and filling the storage facilities were discussed. In every case salt was delivered by truck and almost always in Semi trucks. Some agencies did use rail at one time but it seems very limited today. The interview also included the type of equipment required and the type and size of trucks allowed. In several cases conveying salt was required, trucks with belly dumps were required in some cases and the size of the truck restricted due to the size of the agencies facility.

The Salt Institute handbook (Salt Institute, 2013) goes into great detail about how the size of the facility will vary depending on the amount of salt you need and the way in which you will store it. As discussed in the previous chapter, it is optimal to have the capability to store the average annual salt usage (typically a five-year average) on site, and the needed size of the facility can be calculated easily using this assumption. The handbook does address these issues and gives basic best practice guidelines.

Facility layout was not discussed in detail during the interviews but it is important to a safe and efficient operation. Consider the three main functions of these facilities, to receive salt, to store salt and to load salt. Facility layout should take all three of these operations into consideration. Thus facility design should make it easy for trucks to deliver salt to the loading location, and should also make it easy for plow trucks to load salt from the storage location. In this context, “easy” may be taken to include concerns about salt management i.e. minimizing any wastage of salt during either of these two transfer processes. Placing a storage facility in a corner may seem like a good idea and give more space for other operations but in fact such placement typically hampers all three of these operations. A flow pattern that allows all trucks to move in a similar manner with no opposing traffic is the best method. Besides taking delivery other important factors to consider in the layout are, level surfaces to load and unload, other operations like fueling equipment, liquid storage, liquid filling, snow clearing of the lot, runoff, runoff retention and employee parking.

One big consideration in site layout is the predominating weather pattern and ensuring the opening or openings are generally on the opposite side from the direction of the prevailing wind. Doors to keep weather and wildlife out and minimize material loss are also important. Good lighting for safety is vital.

Loading the facility can take place either inside or outside the storage structure. Salt can be dumped inside or dumped outside then pushed in or salt can be dumped into a pit and conveyed in. Determining how that will take place is key to facility layout. Using a conveyor can fill a facility completely. Pushing salt in generally cannot achieve this. Pit conveyors seem to be the best option for the agency and the trucking industry, but they are costly and require good maintenance. They help eliminate lumps and foreign objects. Furthermore, when using a conveyor system, salt free flows from the highest point filling the facility evenly. Above ground conveyors are a good option but these must be loaded (rather than using a pit) so the filling process can be more time consuming. Pushing salt inside a facility is common but does require care because walls and roofs can be pushed out, loaders can tip over and the salt can be compressed and contaminated during the process. Lumps and debris often get pushed in as well.

4.3.3 Shared Facilities

Constructing a salt storage facility is a long term decision and should be well thought out. Budget is always a concern and sites that have undersized sheds may be difficult to expand. If a new facility is to be built, how can it be built to accommodate future expansion? Several examples came out of the research of shared facilities. These are facilities where more than one agency operates out of a single site. These are generally different than situations where agreements are in place to obtain salt and return it following an event.

Shared facilities can offer some challenges: contracts or agreements must be established; maintenance of the facility and responsibility for this must be determined; procedures for material loading must be well defined; staffing requirements must be established; but most important, reliable and effective methods to track quantities used by each agency must be instituted.

Shared facilities offer some real benefits as well. Because the facilities are typically larger than those built by individual agencies, the cost per unit salt stored is usually reduced in comparison with individual agency structures. They may offer a secondary location which can help optimize operations. They can, in some cases, offer different material options not available at the original site. Two examples of shared facilities discussed during interviews are in Wisconsin and in Colorado.

In Wisconsin a facility was built that houses State salt and County salt. The County is contracted to perform winter maintenance for the State but State salt is to be used on State roadways and County salt on County roadways. To overcome the difficulties of tracking each, a shared facility was built to house both but a wall dividing the two was constructed so it separates each.

In Colorado the City of Fort Collins built a large facility that is shared by the City, the County and the State. It houses three different materials, rock salt, treated rock salt and brining salt. All three agencies are in very close proximity and the different materials give them flexibility and meet each of their needs. This incredible facility also supplies each agency with all types of liquid products and tracks each agencies material usage.

4.3.4 Optimizing Facility Operations

As discussed in 4.3.2, the layout of a yard can greatly affect the optimum performance of a salt storage facility and so can the way the facility is filled, like using conveyor systems (see figure 4.1). In the search for unique storage facilities the research was looking for ways agencies also optimized their facilities and their operations. Several examples were discovered. Most State agencies have employed more tools in their winter maintenance operations. These could include producing salt brine on site, the use of other liquid de-icing agents, treating stockpiles, treated or enhanced salt and the use of abrasives. To incorporate items such as these may mean adding additional buildings or tank farms. But several agencies found ways to incorporate these programs into one facility. As mentioned above some facilities can store multiple materials and have multiple access points (see Figure 4.2). This is important if more than one product is being stored because additional buildings add costs and require additional maintenance.

Figure 4-1 Conveyer Filling System in a Salt Storage Facility

Figure 4-2 Salt Storage Facility Showing Multiple Access Points for Different Materials

One agency that has incorporated all this into one facility is the Indiana DOT. Their Lebanon, IN unit is a large fabric covered barn like facility that serves several functions (see Figure 4.3). It has multiple access points. It stores 3700 tons of salt and all deliveries and loading is done inside. All truck washing is done inside as well and all rinse water is captured and used in Brine making. Brine making is done indoors and liquid filling is done undercover as well. This is a good example of an optimal facility that is extremely functional and sustainable. No salt is loaded or unloaded outdoors, no runoff occurs and any spillage is contained inside the facility. Wash water is reused and all loading and unloading is done in a well-lit safe environment. It has doors at either end so trucks enter, fill, and exit in a minimal amount of time and with no opposing traffic. A similar facility that houses 5000 tons of salt was built in the city of Charlotte NC.

Figure 4-3 Example of a Multi-Function Facility

Another way to optimize facility operations is by the actual type and placement of the facility. In Europe some agencies (Germany and Austria) use silos to house salt (see Figure 4.4). The salt has to be dry to be loaded and stored in these silos, but once it is, the operation becomes a one man loading facility. These silos are housed at the home facility but also on different routes as a refill site. The operator pulls their equipment under the silo and fills it themselves. This means the operator can make longer runs and refill without deadheading back to the yard. This concept is an important consideration if a State is considering adding a site and wishes to locate the new site optimally. Another way of achieving this is to work with other agencies through agreements to have trucks refill at their sites and return material after the event, or compensate the agency for the material. In Wisconsin they also added lean-to storage on each side of the barn to store equipment in the off season without need to build extra buildings (see Figure 4.5).

Figure 4-4 Silo Loading System from Europe

Figure 4-5 Additional Equipment Storage around Salt Barn

4.3.5 Novel Concepts

Regional storage was one of the novel concepts identified in the research. Several examples were shared and detailed information can be found in the appendix. Regional storage should be defined as additional stockpiled salt that is not part of the seasonal needs of an agency. We saw only a few State agencies that have done this although several cities that have done it. In Kentucky almost 170,000 tons of salt are in reserve in underground caves. The salt would need to be trucked from the two different sites but it gives the DOT nearly a year's supply in reserve. These underground caves keep the salt perfectly and it is not a contamination concern in any way.

Foreign and domestic examples of regional storage facilities were shared in the request for information. A newly constructed site in the United Kingdom holds 55,000 tons of salt, has 6 access doors and is the Country's biggest facility (see Figure 4.6). It was designed purposely in case of another shortage as was seen in previous years in Europe.

Figure 4-6 UK Salt Storage Facility

One of the best examples here in the States is in Des Moines. Here two sheds were erected on the same site, each holding 10,000 tons of salt. These were erected as a joint effort between 9 different public works agencies with the City of West Des Moines as the lead agency. These facilities serve as reserves for all these agencies to supplement their yearly salt requirements. A conveyor system is used to fill the storage structures completely. A scale to weigh incoming and outgoing trucks tracks each agencies usage. Agreements to maintain the facilities and the grounds are all in place for this site.

Reserves without having a facility are also possible. In the interview process the New Jersey DOT indicated that they have reserves (40,000 tons in the North and South parts of the State) that the DOT owns and has paid for that is stored by the vendor. This novel idea may not be possible everywhere due to limited storage areas where vendors keep supplies but it is in place in New Jersey.

4.4 Identified Best Practices

This section presents the summary of the identified best practices related to the storage part of what is termed herein as the road salt life cycle. Not all of these practices are feasible for every agency, and for some agencies these practices may not be possible for regulatory reasons. Nonetheless, agencies would benefit from at least reviewing these practices and considering whether or not they might work in their own particular context.

4.4.1 Adequate Storage and Storage Facilities

The Salt Institute Handbook indicates State Agencies should have at a minimum 100% of their seasonal needs. 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. While tarping is not recommended as a best practice (a permanent storage building is preferred), if the material is tarped it should be covered after each event to avoid environmental concerns.

4.4.2 Facility Layout

The size, shape and type of storage are important but it is critical to layout the facility correctly. It must provide for efficient loading and unloading. The storage facility must be able to be filled completely to optimize its usage. It must be safe for vendors and employees so 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.

4.4.3 Shared Facilities

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. Best practices for shared facilities include a central location to all users and owners of the facility, clearly specified responsibilities with respect to site design, construction, and maintenance, and appropriate written agreements that clarify all these responsibilities.

4.4.4 Optimizing Facility Operations

Incorporating other operations into a facility is a good example of a best practice here. 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 load those liquids or other liquids indoors is an incredible way to optimize the facility. Site placement and optimizing routes is another way to get the most out of a storage facility. In short, with regard to optimizing 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 operators is of great benefit (and the easier the operation, likely the safer the operation will also be).

4.4.5 Novel Ideas

Regional storage facilities or salt reserves are likely one of the biggest impacts a State agency could make. Placing reserves in areas that traditionally run low, have inadequate storage or commonly have delivery issues would likely have a great impact on winter operations. Best practices in this area are necessarily rather diverse, but the first step toward achieving best practice in this area is to consider ways in which salt reserves could be developed over a long time period. Creating a strategic stock pile of salt is not an overnight process, and inevitably requires a great deal of planning. One of the challenges with winter maintenance is that so much needs to be done “right now” that long term planning is often ignored.

Chapter 5 Road Salt Application Best Practices

5.1 Introduction

This chapter presents the results of the information gathering process to determine current practices among transportation agencies used when applying road salt.

5.2 Information Gathering Process

The information in this section has been gathered through previous studies, previous research, interviews and practical experience.

5.3 Information Found and Best Practices

Section 5.3 presents a summary of the information collected as described in section 5.2 above. This section is broken into sub-topics on pre-wetting, anti-icing, variable application rates, equipment calibration, measurement, accountability, liquid usage, salt usage under extreme cold conditions, the use of forecasts, training and the setting of levels of service. While this section deals with the use of salt and its best application practices, it should be noted that the underlying premise is that salt is used only to prevent or break the bond of ice to a roadway and mechanical methods remain the best method for removing snow from pavements.

In contrast with chapters 3 and 4, in this chapter, the "*information found*" section and the "*identified best practices*" sections have been combined since these practices are broadly known and were not identified by way of interviews or literature review.

5.3.1 Pre-wetting and Treated Salt

Pre-wetting is defined as the process by which material is wetted as it exits a vehicle. This is an onboard system with a tank or tanks holding de-icing liquids and applying it at the exit point of the vehicle. There are several different types and configurations of these systems but the theory is the same. As salt is augered out of the unit it is sprayed or flooded with liquid. The amount applied can also vary based on the configuration of the system, the capability of the pump and the type of liquid being applied. Early systems generally delivered between 7 – 14 gallons of liquid per ton of applied salt. More recent systems are capable of much higher amounts. Some studies and trials have shown benefits to higher amounts. Figure 5.1 shows a pre-wetting system at the spinner of a truck. Liquid can also be added to salt at the auger of the truck rather than at the spinner. No test results have been published yet as to whether one method or the other is conclusively better at ensuring the materials stay on the road.

Note that some agencies choose to pre-wet their salt by the truck load using a “shower type” system. In this process, a truck loads up with salt, and then moves under a series of nozzles which deposit liquid onto the salt load in the back of the truck. While this does provide some wetting of the salt load, the wetting is not uniform and it is not clear that all the benefits of the pre-wetting process will accrue to all the salt applied by that truck. Obviously this method requires less equipment modification than going to on-board pre-wetting systems, since a single system can serve many trucks. Nonetheless, this has not been identified as a best practice, although it is certainly a better practice than not pre-wetting salt at all.

Figure 5-1 Spinner Based Pre-wetting System

Pre-wetting of salt on board the truck is a best practice and has been proven to be effective. There are several benefits gained by pre-wetting salt. It reduces scatter when the salt is applied to a roadway. Studies done in Michigan have shown a reduction of up to 30% when liquids are applied versus dry salt being applied to a roadway. Applying liquids to dry salt also begins the process of transforming the solid salt into liquid brine. This results in the material working quicker on the roadway. It also has the potential to reduce the working temperature of the salt when a deicer liquid with a lower freezing point is applied.

Pre-wetting salt should not be confused with treated salt. Treated salt is defined as salt that has been treated and stockpiled. This means the salt has chemical placed upon it prior to storing it. Treated salt typically has between 2 and 7 gallons per ton of liquid added to it. Treated salt carries similar benefits to pre-wetted salt. It also scatters less (as a recent series of studies by Michigan DOT have shown) and generally has a lower working temperature than plain untreated salt. Treated salt may be purchased through vendors or some agencies treat the salt onsite before stockpiling it into storage.

Treated salt should always be kept unexposed to the elements. Again, it is not clear that using treated salt is as effective as using salt pre-wetted at the spinner or the auger, but again, it is clearly a better practice than not pre-wetting salt at all.

5.3.2 Anti-icing

For this research project 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. 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. A flow chart helps agencies determine if the conditions are correct to perform anti-icing (see Figure 5.2). It should be noted this chart is for salt brine or enhanced salt brine only and should be considered an example that can be adopted with changes by agencies if it is felt to be useful. Other liquid chemicals will require different conditions and different application rates. The parameters shown in the flow chart are a guide and agencies may have their own guidelines adopted and in place. However, the use of a decision chart of this type for anti-icing decisions should be considered a best practice when using anti-icing as a strategy. Application rates of salt brine may vary but in general a rate of 30 to 50 gallons per lane mile is common for anti-icing applications. Higher amounts are being used and this can be done without risk but each agency must determine what is appropriate for their climate, operation and level of service. 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. Solids are also a choice when the equipment the agency uses is not fitted with the appropriate items needed to apply liquids but the agency wants to apply something prior to an event. The common drawback to using solids is that a substantial amount 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 (see above) to minimize this loss.

There are other chemicals which can be and are used for anti-icing and the benefits would be the same. Following vendor recommendations will be vital to a successful program.

Anti-icing is a proven best practice and can result in huge savings to an agency and a safer roadway system for its users. Frost callouts can be reduced or eliminated. Ice prevention can result in a 75%[2] 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.

Salt brine can be enhanced by blending other materials with it. This can result in a longer residual retention on the roadway leading to less applications and the working temperature of the mixture can be depressed somewhat as well. Slightly lower application rates can generally be used with these

[2] This percentage comes from the Minnesota DOT Snow and Ice Control Field Guide, Operator's Version.

mixtures as well. Again, determining whether or not to use a blended salt brine will be a decision that an agency must make based upon climate, their operational capability, and their level of service goals.

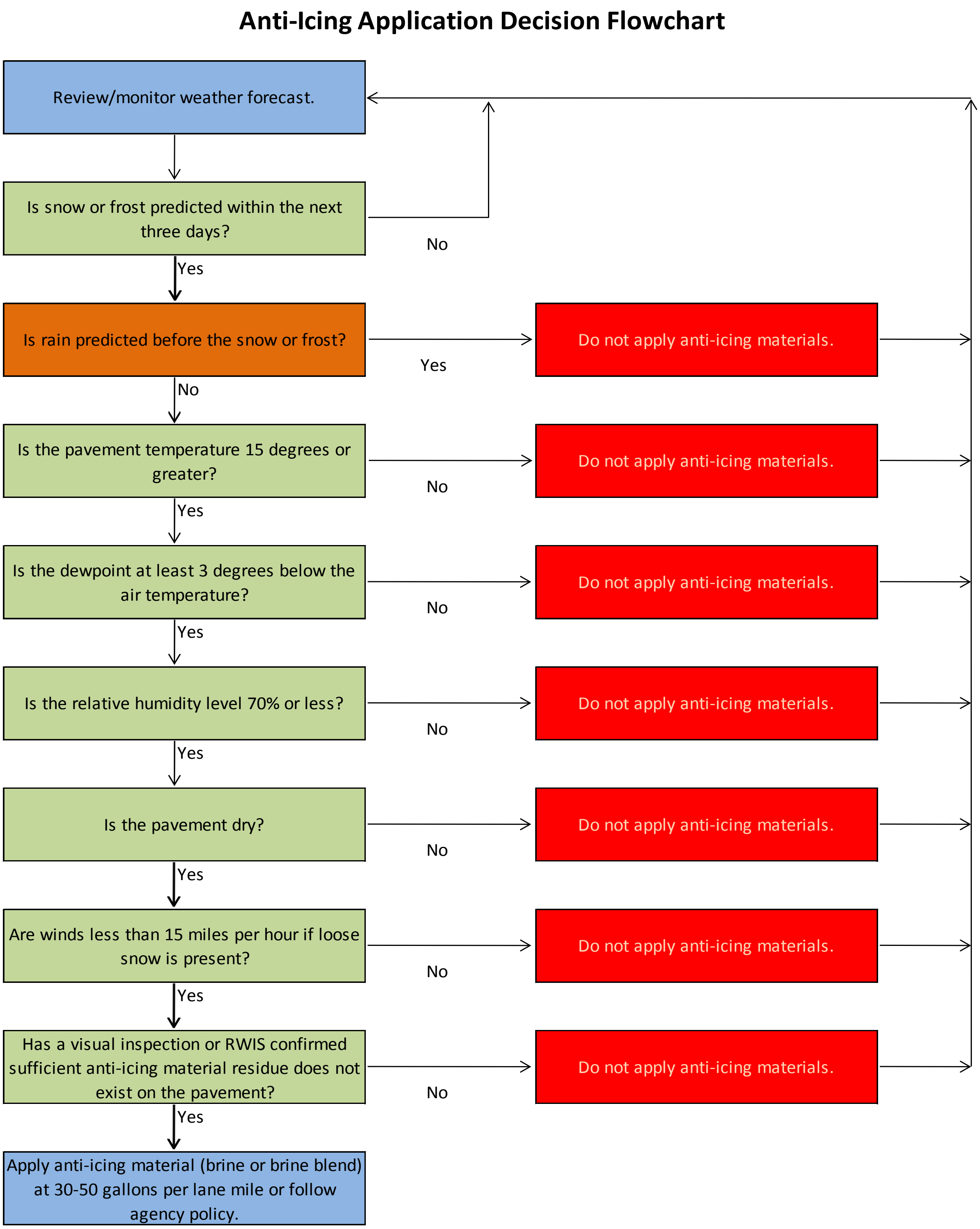

Figure 5-2 Example Flow Chart showing the Decision Process for Brine Based Anti-Icing

5.3.3 Variable Application Rates

The Salt Institute conceived 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. It recommends that only the appropriate amount needed be applied in any given situation. There are several good examples of internal application rates that have been developed. Below are examples of the Iowa DOT (Figure 5.3) and the Minnesota DOT (Figure 5.4) application rates. 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. It should be noted that these guidelines were developed internally. The Minnesota DOT guidelines are somewhat different in that they show single and multiple lane rates, salt, pre-wetted salt and even granular material. They were developed specifically to the DOT's operations. 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 either Iowa or Minnesota, but an agency, if they wish to pursue best practices, should have some similar form of chart which includes as a minimum the impacts of cycle time, pavement temperature, and storm type (or moisture content of the precipitation). It is worth noting that the Iowa chart has thirty different application rates, while the Minnesota chart has 48 different salt application rates (not counting application rates given 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.

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.

Salt Application Rate Guidelines							
Prewetted salt @ 12' wide lane (assume 2-hr route)							
Surface Temperature (º Fahrenheit)		***33-30***	***29-27***	***26-24***	***23-21***	***20-18***	***17-15***
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
	Freezing Rain, drizzle, sleet	140	185	250	300	350	400
Prewetted salt @ 12' wide lane (assume 3-hr route)							
Surface Temperature (º Fahrenheit)		***33-30***	***29-27***	***26-24***	***23-21***	***20-18***	***17-15***
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
	Freezing Rain, drizzle, sleet	210	275	375	450	475	600

Figure 5-3 Iowa Department of Transportation Salt Application Guidelines

Pavement Temp. (°F) and Trend(↑↓)	Weather Condition	Maintenance Actions	Lbs/two-lane mile			
			Salt Pre-wetted/Pre-treated with Salt Brine	Salt Pre-wetted/Pre-treated with Other Blends	Dry Salt	Winter Sand (abrasives)
>30° ↑	Snow	Plow treat intersections only	80	70	100-200	Not Recommended
	Frz. Rain	Apply Chemical	80-160	70-140	100-200	Not Recommended
30° ↓	Snow	Plow & Apply Chemical	80-160	70-140	100-200	Not Recommended
	Frz. Rain	Apply Chemical	150-200	130-180	180-240	Not Recommended
25-30° ↑	Snow	Plow & Apply Chemical	120-160	100-140	150-200	Not Recommended
	Frz. Rain	Apply Chemical	150-200	130-180	180-240	Not Recommended
25-30° ↓	Snow	Plow & Apply Chemical	120-160	100-140	150-200	Not Recommended
	Frz. Rain	Apply Chemical	160-240	140-210	200-300	400
20-25° ↑	Snow or Frz. Rain	Plow & Apply Chemical	160-240	140-210	200-300	400
20-25° ↓	Snow	Plow & Apply Chemical	200-280	175-250	250-350	Not Recommended
	Frz. Rain	Apply Chemical	240-320	210-280	300-400	400
15-20° ↑	Snow	Plow & Apply Chemical	200-280	175-250	250-350	Not Recommended
	Frz. Rain	Apply Chemical	240-320	210-280	300-400	400
15-20° ↓	Snow or Frz. Rain	Plow & Apply Chemical	240-320	210-280	300-400	500 for frz.rain
0-15° ↑↓	Snow	Plow, treat with blends, sand hazardous areas	Not Recommended	300-400	Not Recommended	500-750 spot treat as needed
<0°	Snow	Plow, treat with blends, sand hazardous areas	Not Recommended	400-600	Not Recommended	500-750 spot treat as needed

Figure 5-4 Minnesota Department of Transportation Salt Application Guidelines

5.3.4 Equipment 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 are actually being applied at any given setting. Calibration is not solely for solid materials either – liquid dispensing systems should also be calibrated regularly.

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 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. 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. The equipment should be calibrated at that time for all different material types that may be used during the winter season. 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 calibrated for both material types. A useful guide to when to recalibrate spreading equipment is given in the Clear Roads report "Calibration Guide for Ground-Speed-Controlled and Manually Controlled Material Spreaders[3]" which suggests equipment calibration when a unit is first placed in service, annually prior to the start of snow and ice operations, after major equipment maintenance, including replacement of hydraulic fluid and filters, when the controller unit is repaired or sensors are replaced, and when new material is delivered to the location.

Computerized dispensing systems, where units are controlled using ground speed, are the preferred method, especially at low traveling speeds. These units dispense the exact same amount of material at any given speed. An example of this would be that the unit dispenses 200 pounds per lane mile at 5 miles per hour and also dispenses 200 pounds per lane mile at 30 miles an hour. Providing these units are calibrated correctly they will always put a uniform amount of material down regardless of the speed the equipment is traveling. Manual systems are not capable of this. They do not put material down based on speed but only based on the setting number of the auger. What this means is, manual systems do not put out a uniform amount of material. This generally leads to over application at low speeds and possibly under application as speeds increase.

5.3.5 Performance Measurement

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. In section 5.3.3 it was stated that variable application rates are needed based on the severity of an event and the pavement temperatures during that event. In section 5.3.8 we

[3] Available at: http://clearroads.org/wp-content/uploads/dlm_uploads/05-02_WisDOT-0092-06-21_Calibration-Final-Calibration-Guide.pdf accessed on November 18, 2015.

discuss salt use in extremely cold situations where it may be recommended that no salt be applied at all. In section 5.3.6 we discuss the accountability of personnel following recommendations. In order to verify if an agency is under-treating, properly treating or over-treating a roadway, data must be collected and then that data must be evaluated and weighed against the desired level of service for that roadway.

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 the process 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. Figure 5.5 shows how such an index can be used. Data for this figure came from the Moline district of Illinois DOT. For each of the two winters show, salt use and weather conditions were recorded on a daily basis. Using a simple storm severity index, a cumulative monthly winter severity index was calculated, and is shown in the two graphs. By dividing the annual salt usage by the cumulative severity index, a measure of salt use efficiency can be gained by effectively normalizing the salt used with respect to the severity of the winter. 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.

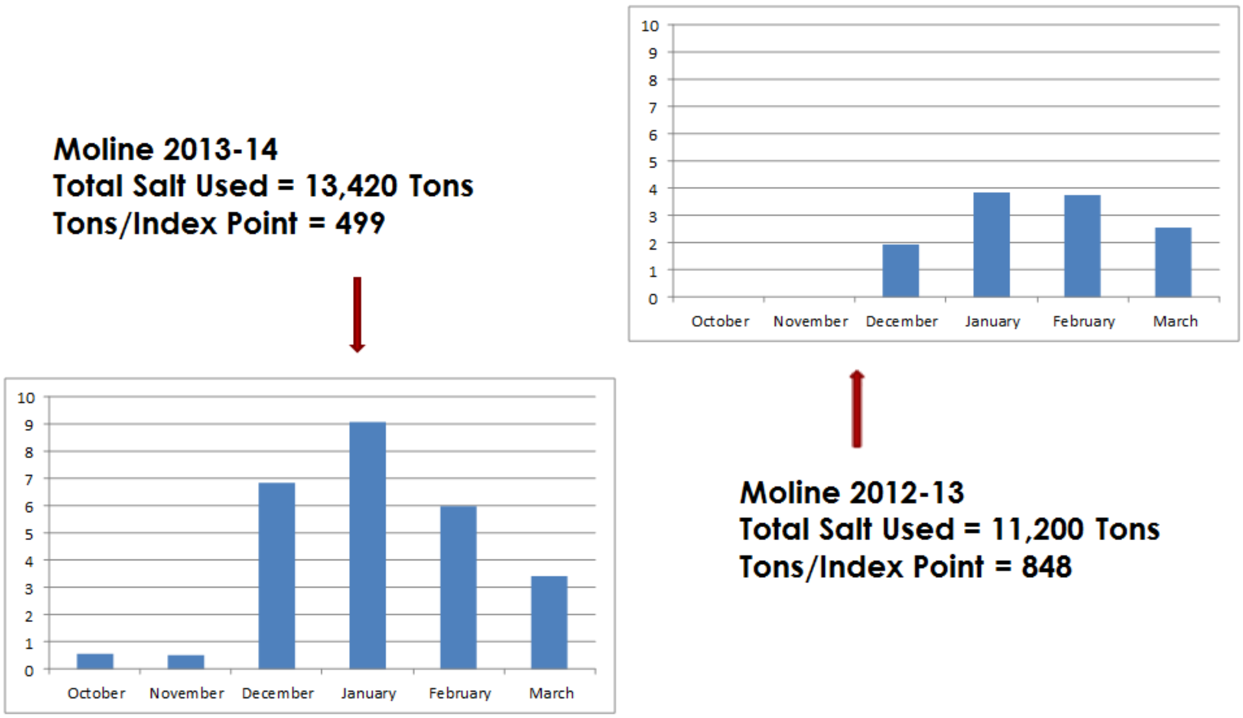

Figure 5-5 How a Storm Severity Index can be used to Compare Salt Usages

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.

5.3.6 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 that while operator experience plays a key role in a successful operation it needs to be recognized that varying from policy and not following recommended guidelines is usually 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.

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, what conditions will likely be faced during the event, what types of treatment are probably needed, what the outcomes of those treatments will be and finally how long the event will likely last.

5.3.7 Liquid Usage

In regards to salt best management practices, liquid use can help reduce the amount of granular material used each season. As described above, anti- icing, pre-wetting, treated salt and slurries can all contribute to reducing 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 de-icer 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 liquid acetates and glycols that are used in certain situations.

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 of the chemical. 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 to produce enhanced salt brine. In order to produce salt brine or to start a program of in-house blending and 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, resulting in the overall amount of granular material being 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 below McHenry County, Illinois tracked its operators' granular salt use against its operators' liquid use and found that operators who used more liquid used less granular salt. Figure 5.6 shows solid salt usage by employees over a winter season, while figure 5.7 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).

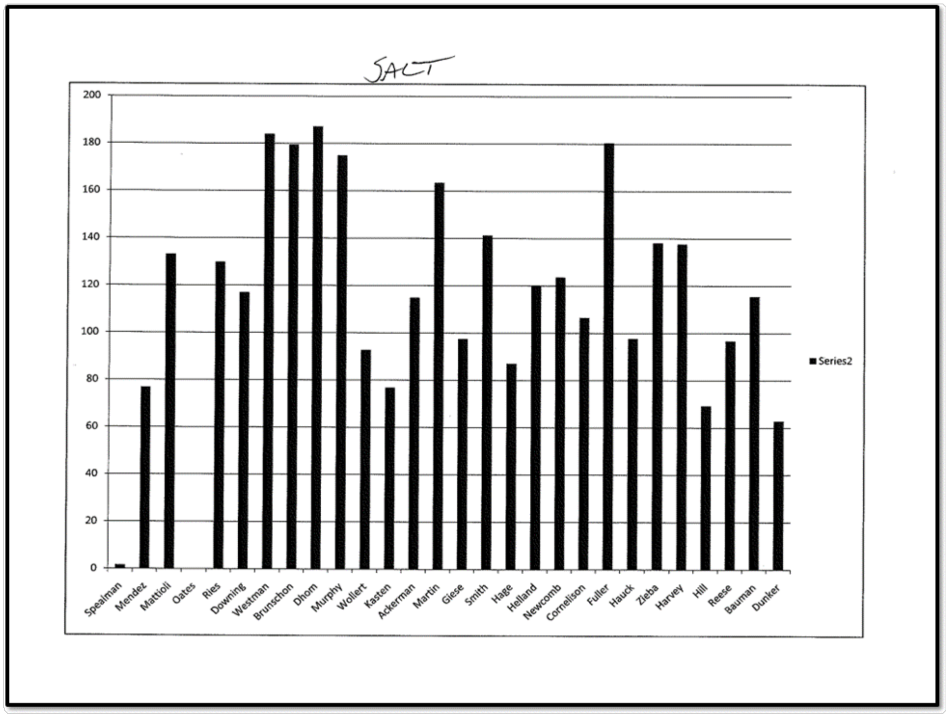

Figure 5-6 Annual Salt Usage by Employee

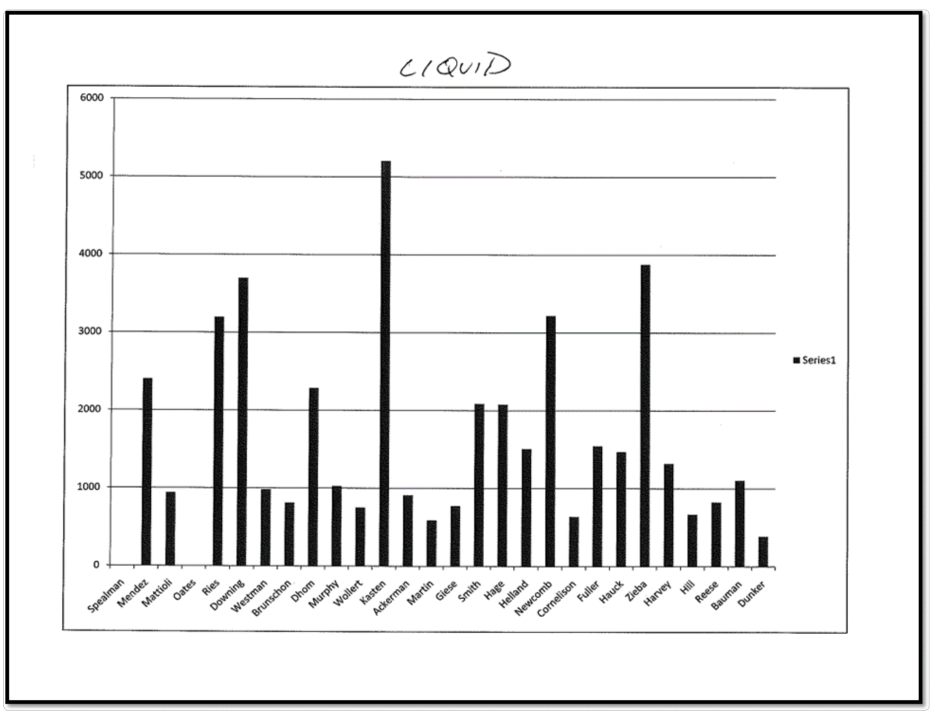

Figure 5-7 Annual Liquid Usage by Employee

Liquids have another advantage in that different liquids can be combined together to produce a better product. This is sometimes done by vendors where they combine different chemicals to produce a better product. One example of this is calcium chloride brine or magnesium chloride brine that has an inhibitor added to reduce corrosion. Another type of blending is to add some sort of organic product in order to increase the residual effect of the liquid thereby reducing the need to treat as often. There are also blends that include a base chemical with a lower working temperature in order to reduce the working temperature of the mixture. One example of this could be salt brine combined with a small percentage of calcium chloride to produce a product commonly known as hot brine. Many of these liquid combinations can now be made by an agency in house through the process of blending liquid chemicals together. There are both manual and automatic systems that an agency can build or purchase in order to accomplish in house blending.

In order for a liquid program to be successful an agency must follow very specific policies and have knowledge of the current weather conditions including pavement temperature, dew points, wind speeds and general road conditions. Nonetheless, the benefits of using liquids in the right circumstances clearly make liquid use a BMP for winter maintnenace.

5.3.8 Salt Usage under Extreme Cold Conditions

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°pavement temperature 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 an agency 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 during 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.

5.3.9 Use of Forecasts

Using a weather forecast is certainly vital to best management practices for salt use. In a survey done by 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 become increasingly better. 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 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.

5.3.10 Setting Levels of Service

In the role of best management practices for salt use, setting the appropriate level of service (LOS) is vital to the agency being successful. Levels of service are defined as the condition in which a roadway will be maintained during a winter event or even a winter season. LOS 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 desired 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 the appropriate 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 may be 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 not only 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.

5.3.11 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 usage of ice control materials. 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 select for the given conditions, 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.

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, what is 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 and 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 not only be trained appropriately but 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.

5.4 Conclusions

Not all of the practices identified above are feasible for every agency, and for some agencies these practices may not be possible for regulatory reasons. Nonetheless, agencies would benefit from at least reviewing these practices and considering whether or not they might work in their own particular context.

Some of the practices listed above require an agency to purchase or to modify its fleet. This is often difficult to do on a large scale. However it has been proven that the return on investment is worthwhile.

Agencies that are not currently using a liquid program should definitely consider it. Once implemented an agency should see a reduction of up to 30% in their annual salt usage. Using liquids in winter operations has been proven to be a best practice. In order for that to take place operators must understand how and when to use liquids. They must also understand its limitations. So it is vital that all operators, fulltime, seasonal or contracted receive training in liquid use and proper salt usage.

All state agencies should evaluate the levels of service they are striving to provide and whether they meet or exceed the expectations of their customers and the agencies goals. The only way this can be accomplished is to measure the agency's performance and to hold those that do the job accountable to the guidelines and policies that the agency has set. It is unrealistic to expect employees to be accountable if they are not properly trained or if the equipment they operate has not been properly calibrated. Given the right tools and training, operators should implement and follow treatment recommendations and sensible salting. These are proven best practices and will help an agency in its salt management.

State agencies should also evaluate their performance and the performance of each operator. They should also provide recommendations and decision support tools so managers and operators can make good informed decisions. The use of weather forecasts, decision support systems, roadway weather information systems, computerized dispensing systems and pavement temperature sensing devices are all proven technologies and should be considered best practices.

Chapter 6 List of Best Management Practices and Conclusions

6.1 Introduction

This chapter presents identified best management practices in the areas of bidding, storage, and application of what is termed herein as the road salt life cycle. Not all of these practices are feasible for every agency, and for some agencies these practices may not be possible for regulatory reasons. Nonetheless, agencies would benefit from at least reviewing these practices and considering whether or not they might work in their own particular context.

This chapter also describes the general format of the handbook of the best management practices which is being developed as a deliverable in this study.

6.2 Identified Best Management Practices in Bidding

The following actions represent the identified best management practices in the area of bidding and procurement of road salt. The best practices are listed here, and are more fully described in section 3.5 of this report, and in the best management practices handbook.

- Adequate storage capacity for road salt.
- Emergency stockpile capability.
- Tightly specified quantities in bid documents.
- Multi-year contracts.
- Pre-season fills of stockpiles.

6.3 Identified Best Management Practices in Storage

The following actions represent the identified best management practices in the area of road salt storage. The best practices are listed here, and are more fully described in section 4.4 of this report, and in the best management practices handbook.

- Adequate storage and environmentally safe storage facilities.
- Optimal facility layout.
- Shared facilities.
- Optimizing facilities operation.

6.4 Identified Best Management Practices in Applications

The following actions represent the identified best management practices in the area of road salt application. The best practices are listed here, and are more fully described in section 5.3 of this report, and in the best management practices handbook.

- Pre-wetting salt and/or treated salt.
- Anti-icing.
- Variable application rates.
- Equipment calibration.
- Measurement of application rates.
- Organizational accountability.
- Liquid usage.
- Salt usage under extreme cold conditions.
- Use of forecasts.
- Setting levels of service.
- Training.

6.5 General Format for Handbook

The purpose of the handbook is to serve as an accessible repository of information on the identified best practices that can be used in the field or the office and can provide immediately useful information to winter operations practitioners. To that end, the handbook will comprise no more than two pages (i.e. one sheet of paper) for each identified best practice. The handbook will be produced as an electronic document, so that agencies could, if they wished, print off a page with a best practice of interest, and distribute laminated copies of that best practice only to wherever they feel it would be of most value.

6.6 Conclusions

As a result of this study, twenty (20) best practices in the procurement, storage, and use of road salt in winter maintenance operations have been identified. Details of these best practices have been presented, and are further collected into a separate handbook designed to be an easily accessible repository of information on these practices that is immediately useful to winter maintenance practitioners.

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Appendix A

Questions asked of agencies about bidding process

The following presents the questions that were asked in the phone interviews as part of this project, to determine current practices used in the bidding and procurement processes for road salt. The questions are divided into four broad categories: Bid Structure, Unusual Circumstances, Delivery Issues, and Storage Issues. These were then followed by a closing question.

Bid Structure:

How much salt do you purchase annually?

What is the total average quantity of salt on the entire salt contract? How much is for your agency and how much is for local or municipal agencies? Example, a State agency takes roughly one million tons, while the contract total is roughly three million tons with multiple municipal customers.

What type of procurement approach do you use (low bid, multiple award, best value, reverse auction, other)?

How many suppliers typically bid on your requirements? Are any of those bidders International suppliers?

Does your salt typically come from North America or from overseas?

What date/month does your agency advertise bids, open bids, and when are contracts awarded?

Do you award contracts to more than one vendor?

What is the length of your contract? If it is multiple years, what percentage of increase is allowed each year. (follow up – what is your best contract length? Is two years better than three? Have you changed the contract length recently? If yes, why?)

Is there a price break for early season delivery? If so, how large is the price break?

What percentage of your requirement are you required to take and what percentage is the vendor required to provide. Example: the bid is for 100,000 tons and the vendor must supply a maximum of 120,000 tons at the bid price. Also, the agency must take a minimum of 80,000 tons at the bid price.

Are there quantity limits in the contract? For example, in NYS we see price escalations above 120% of our filed requirements, and we can be cut off at 150%.

What is done if a minimum quantity is not purchased by the end of the season? If you do not purchase a minimum of 70%, do you pay the vendor a certain amount per ton to store your remaining salt at their facilities until delivery is taken?

Do you anticipate, or have you experienced, significant cost savings when the min/max limits are tightened up? For example, we are currently at 70-120%; will prices be significantly better if that was tightened up to 80-110%, or 90-120%?

Are your bids only for salt, or is a percentage of the materials a premium product (e.g., treated salt). If so how do you store the different products?

Do you require a vendor to have a certain percentage of your yearly requirement on hand prior to the winter season? How do you verify it? Do you inspect vendor supplies prior to the season and if so, do you have a protocol for that inspection? Is the “salt on hand” just for “your” salt (state agency) or for all the salt on the contract (municipal agencies too)? If you do, can we get a copy?

Unusual Circumstances:

What does your contract specify when a vendor is unable to deliver for various reasons (too much demand, not enough trucking, stockpiles depleted, etc.)? Is there an emergency supply clause to hire another vendor, and how does that work? Does an “emergency” need to be declared before enacting that provision? Who approves the use of the emergency clause? If you have this, does it help?

Do your contracts contain a liquidated damage clause? Under what conditions does your state apply this clause? Are there times when your state has waived liquidated damage penalties? Example: You require delivery within five days. For every (work) day beyond five days you retain 10¢ per ton not delivered in a timely manner.

Do you restrict the use of *Force Majeure* as an excuse for late deliveries? Example: A contractor may claim *Force Majeure* if transportation along the Mississippi River system is not possible due to locks and dams being iced in.

If a vendors salt violates State specifications (too much moisture, incorrect gradation etc.) do you refuse delivery? Do you have a document describing how you determine such violations? If so, can we get a copy? Under what circumstances would you consider accepting salt that does not meet specifications?

In emergencies, is there a requirement for you to help local agencies (e.g. when salt supplies are low) by providing those agencies with salt from your supplies? If there is no requirement, is there nonetheless an expectation that you do this? Do you feel you are given priority (by suppliers) over local agencies in supply emergency situations? Is the priority structure formal or informal?

Delivery Issues:

If you require deliveries to be made year round, what time limit do you have for deliveries to be made within? Example: You require deliveries to be made within 5 working days of an order being placed.

If you accept early delivery (prior to the season), is trucking an issue due to construction? What dates define early delivery for you?

Do you restrict the times at which deliveries can be made to your storage locations? Example: Deliveries will only be accepted during the hours of 8 a.m. and 4:30 p.m. on Monday through Friday.

Do you adjust hauling prices to account for variation in the costs of diesel fuel? Example: If the price of fuel increases or decreases $ .10 per gallon the price of salt will increase or decrease $ .10 per ton accordingly. Adjustments will be made in $ .10 increments. The starting point is $ 3.875 per gallon**.**

Do you restrict the type of equipment that can be used to haul the salt to your storage locations? Example: No hauling equipment used for hauling bulk salt requiring unloading by scooping or requiring the use of a Drag Board will be allowed. Conveyer belts must be used.

Do you accept salt delivery by rail? If so, do you consider this delivery method to be more or less reliable than delivery by truck?

Do you require the vendor to provide the delivery of salt or do you contract with the trucking firms yourself? What cost savings have you seen if you do this? What issues arise from doing this?

Storage Issues

What proportion of your average annual salt use can you store when all your storage facilities are fully utilized? Example: If you use on average 10,000 tons of salt per year and you can store 7,000 tons of salt then you can store 70% of your annual salt use.

Do you use any of your salt storage facilities as equipment storage during off months?

Do you have emergency stockpile storage? If so, what percentage of your annual salt use is in emergency storage (e.g. 20% of average annual salt use)? If so, under what conditions can you make use of the emergency stockpile?

Closing Question: How would you rate your salt purchasing process?

CLEAR ROADS

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