FEASIBILITY OF ALTERNATIVE SALT STORAGE STRUCTURES IN SASKATCHEWAN - NEILBURG CASE STUDY

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Abstract

The focal point of an efficient winter maintenance program is to provide safe driving conditions by breaking the bond between snow/ice and the road to enable traction between tires and the road surface during operating and braking. In regards to Saskatchewan Department of Highways and Transportation (DHT), the primary winter maintenance objective is to provide snow and ice free conditions on the provincial highway network. This is generally achieved by applying salt and other de-icing materials in the right place at the right time. To achieve this objective it is important to have salt stored in strategic locations where it can be easily accessed when needed. In the past DHT has primarily utilized wooden salt storage facilities to ensure adequate salt storage. Over the past several years the department has incorporated other storage devices to ensure good access to salt when required. One of the more recent cases involves the assessment for road salt storage at Neilburg, located in west central Saskatchewan.

DHT typically uses two different types of salt storage facilities: one, wooden salt sheds and two, steel salt silos. Most wooden salt sheds are wooden structures with a concrete base consisting of 1.2 meter high pony walls and either a concrete or an asphalt treated floor. Salt silos, the second alternative, are made of a steel bins suspended above the ground and supported by a concrete pad or concrete pilings. This raised type structure enables trucks to load directly under the silo. The truck's hydraulic system is hooked to the salt silo control box to open and close a gravity feed chute allowing quick and efficient salt loading. This type of setup does not require the utilization of a separate loader or conveyor system.

To ensure that DHT minimizes salt storage costs a software analysis, Decision Programming Language (DPL), is used to perform life cycle benefit cost analysis and evaluate different performance indicators in the selection of the appropriate salt storage facility. The main purpose of this paper is to describe different salt storage facilities utilized by DHT's Central Region and what performance indicators influence the decision-making process. Recent analysis work, completed for a site located at Neilburg in west central Saskatchewan, will be used to demonstrate the process.

Key terms: efficient winter maintenance program, snow and ice free conditions, storage facilities, salt material, salt sheds, salt silos, Decision Programming Language, life cycle benefit cost analysis.

1.0 Introduction

The Central Region of Saskatchewan Department of Highways and Transportation (DHT) is located in the central southern part of the province and extends between the town of Davidson in the south and the hamlet of McDowell in the north and also between the Alberta border in the west and the Manitoba border in the east. This extensive area is intersected by numerous provincial and rural highways that support economic and social activities within this region of the province. The Central Region maintains approximately 8 560 km of highways consisting of: 335 km of gravel surface; 2 425 km of thin membrane surface (TMS) or oil treated aggregate dust free roads; and approximately 5 800 km of structural pavements (DHT 2003).

Saskatchewan has a vast and relatively low population density that is heavily reliant on roads that are considered one of the more important public assets. Providing a safe and reliable road network is vital to the well being of the province. As a land-locked province the Saskatchewan economy depends on an efficient road transportation system for moving goods and people. Ensuring adequate and timely mobility is important not only for the economy, but crucial for tourism, provides recreational access, supports social activities, and ensures timely emergency response. During the winter months ensuring adequate mobility is important for the people of Saskatchewan.

Considering that Saskatchewan is exposed to harsh winter conditions for almost six months of the year, in order to maintain this essential transportation system in a safe operating mode DHT needs an effective winter maintenance program. The effectiveness of the road winter maintenance activities is a balancing act between supporting the economy by providing sound and safe roads and at the same time, minimizing possible adverse effects that salt may have on the natural environment. Proper winter maintenance can "lower accident rates through safer roads, lower associated insurance and liability claims, generate time savings from faster (and safer) travel, generate fuel savings as a result of better traction and less congestion, reduce productivity losses due to late days and absenteeism by employees, reduce productivity losses due to unavailability of material inputs to production, ensure that emergency and security services can operate efficiently, ensure mobility for Canadians to engage in social activities, etc." (Transportation Association of Canada 1999). These positive aspects are directly applicable to the province of Saskatchewan.

Saskatchewan being a prairie province receives colder and drier winters compared to other coastal regions in Canada. Saskatchewan does receive varying amounts of snow and precipitation depending on various locations throughout the province. Given various snow events throughout the winter, snow and ice accumulates on the road surface consequently reducing traction between vehicle tires and the road surface. The primary objective of DHT's winter maintenance program is to provide bare pavement by breaking the bond between snow/ice and the road to enable traction during operating, maneuvering and braking. This can be achieved through anti-icing and de-icing activities through the use of salt and other materials. To be effective and efficient it is essential to place salt in the right place at the right time. Hence, it is important to have salt stored in strategic locations where it can be easily accessed when needed. Minimizing haul distance and dead time for salt spreading equipment is important in timely application of material, which invariable improves mobility and safety.

The main purpose of this paper is to describe different salt storage facilities utilized by DHT's Central Region and what performance indicators influence the decision-making process. Recent analysis work, completed for a site located at Neilburg in west central Saskatchewan, will be used to demonstrate the process.

2.0 Current DHT Practices and Procedures

2.1 Winter Maintenance Practices and Procedures

DHT's primary winter maintenance objective is to "maintain the highway system in a snow and ice free condition, as economically as possible, within the limits of the approved policy for snow and ice removal" (DHT [1]). DHT's winter maintenance policy is to treat and remove all ice and snow from its major arterials and other highways with Average Annual Daily Traffic (AADT) > 1500 vehicles as soon as practical but within a 24-hour period. Collector and other highways with AADT < 1500 should be treated as soon as conditions are favourable to ensure removal on at least the center 1/3 of the driving lanes with danger spots treated within 48 hours (DHT [2]).

DHT's Maintenance Practice and Procedures Manual (DHT [3]) recognizes the need to provide reasonably safe roads for winter travel through effective ice and snow control measures. It specifies that a minimum amount of salt should be used to achieve necessary ice and snow control. In cases where temperatures are too cold for the effective use of salt, other measures involving other types of chemical treatment or sand are applied to improve traction between vehicles and the road surface.

2.2 DHT Salt Storage Facilities

DHT basically uses two different types of salt storage facilities to store salt material: one, wooden salt sheds and two, steel salt silos. Most of the salt sheds are wooden structures with a concrete basis consisting of 1.2 m high pony walls and either a concrete or asphalt treated floor. Figure 1 represents a typical salt shed used by DHT. In some cases, newer buildings are circular or dome shaped to provide increased capacity. DHT operates only a few of these buildings with no current plans to build additional dome structures. Figure 2 illustrates a dome shaped structure utilized by DHT. In regards to wooden salt sheds, salt is controlled or moved around by mechanical means typically using loaders.

Salt silos are made up of a steel bin raised above ground level and supported on a concrete pad or concrete pilings. This raised type of structure enables trucks to load below the structure by utilizing the truck's hydraulic systems to open and close a chute that allows salt to gravity flow into the truck box. Over the years the department has built two different size silos: 140-tonne and 90-tonne capacity structures as shown in Figure 3 and Figure 4, respectively.

Geotechnical testing is undertaken before a salt silo is constructed and installed. A soil analysis is performed to determine the soil characteristics so that proper foundation design can be completed along with determining if there are any potential environmental issues associated with the site. Figure 5 illustrates pre-construction drilling analysis. In Figure 6, a concrete pad foundation based on a foundation design is shown. The concrete pad, shown in Figure 7, supports the silo structure and provides limited containment if salt spills during loading operations.

3.0 Salt Storage Life Cycle Benefit Cost Analysis

To determine which type of salt storage facility to construct DHT undertakes an evaluation to determine which type of salt structure should be constructed at the proposed site. Three different storage systems are considered in the analysis:

1. Salt sheds with loaders
2. Salt silos – 90-tonne capacity
3. Salt hopper with conveyor – 90-tonne capacity

The three options are outlined in more detail, below.

3.1 Salt Sheds With Loaders

Historically, DHT has built two different sizes of wooden salt sheds: 9.0 m x 12.0 m and 10.8 m x 15.0 m. It was found that 10.8 m x 15.0 m structures posed a problem, since 2x4 boards and rafters with sufficient span were challenging during construction. Analysis costs of constructing these types of structures are hard to determine since the department hasn't built any of these types of storage facilities in the last few years. The cost to build these structures was estimated to be $35,000 for the smaller salt shed and $45,000 for the larger facility. Either structure can easily hold up to 8 or 9 B-train semi-loads or approximately 400 tonnes. It needs to be noted that salt sheds provide the largest storage capacity of the three options. They are typically located at section headquarters that have good access to larger loaders and generally service a larger road network.

Construction methods and service life for salt sheds vary depending on site conditions and other variables. Most of the salt sheds have an asphalt treated floor consisting of 100 to 150 mm of hot mix asphalt. In a few cases, as outlined in Figure 8, salt sheds were constructed with a 150 mm concrete floor treated with epoxy seals or with cut back asphalt. In regards to service life, salt sheds are generally depreciated over either a 10 or 20 year period. At the end of the service life there is a minimal salvage value with structures sold to the highest bidder.

Typically salt sheds don't require any special annual maintenance. Throughout their 20-year life cycle outside walls may be painted, roof singles replaced after 10 to 15 years, and other minor maintenance requirements undertaken. In most cases concrete walls and inner walls are usually sprayed with asphalt oil before salt is initially stored (this process might be repeated once throughout the shed's life, if required). For most salt sheds, inside wooden walls are treated with wood preserver before commissioned into service. Most sheds have aprons in front of the entrance consisting of locally available granular material with some of the newer sheds having asphalt concrete pads as illustrated in Figure 9. Other minor maintenance requirements may typically involve door rollers replacements approximately every 2 years.

The dome shaped salt shed structures that were built are either 30 m (Saskatoon and Regina) or 24 m (Moose Jaw) in diameter. The cost of building a dome shaped salt shed would be approximately $110,000. They are treated in a similar manner as other wooden structures. Figure 10 illustrates the interior of a dome shaped salt shed.

3.2 Salt Silos

DHT owns and operates four 140-tonne type salt silos located at Oungre, Sheho, Blaine Lake, and Wilkie. They all have a 4.8 m diameter – 8 leg hopper bin supported by the salt storage bin support structure residing on concrete pilings. In addition, DHT also owns and operates eight 90-tonne salt silos at Meacham, Loreburn, Delisle, Bresaylor, Wadena, Weyakwin, Balgonie, and Neilburg. Similar to the larger 140-tonne bins, these smaller structures have a 4.8 m diameter – 8 leg hopper bin supported by the salt storage bin support structure residing on a concrete pad.

The total cost of constructing a 90-tonne salt storage facility is approximately $76,000, including the foundation and above ground structure. The following is the breakdown of costs: hopper bin and auxiliary structure - $27,000, support structure - $30,000, and foundation structure $19,000. An additional $2,000 should be allowed for the soil drilling, depending on the location. It is estimated that salvage value of the salt silo would be approximately $3,000 after it's utilized for 20 years. In regards to salt silo maintenance a number of steps are taken to preserve the silo. To protect the concrete pad from negative impacts from salt it is recommended to have it sealed every 3 years at a total cost of $1,500 per sealing. The salt bin should be painted with epoxy paint at least once during its 20-year life at an estimated cost of $10,000. In addition, the bin vibrators have to be serviced every spring adding $200 in additional annual expenditures.

In regards to salt storage capacity and potential limitations, the 90-tonne and 140-tonne facilities have considerably less storage than the wooden salt sheds. However, in most cases salt silos are located in remote areas that typically service a smaller road network and do not require large storage capacity. In some cases the salt silo is located in an area where trucks can re-load without returning to their initial section yard and continue further along the road network. Although the salt silos are limited in capacity they are sufficient in providing enough salt to typically go through two or three snow/ice events prior to being re-stocked with salt from salt suppliers.

3.3 Salt Hopper Bin With Conveyor Belt (Auger System)

A third alternative being considered by DHT involves a salt hopper bin with a conveyor belt auger system to load trucks. This type of structure avoids having high standing structures that require additional steel and pneumatic loading requirements. There are several advantages associated with this type of layout. This option consists of the same type of hopper bin support with a very low support structure that resides on a concrete pad relatively close to the ground. Salt is loaded onto the truck through the use of a conveyor belt running underneath the bin. The capacity of the bin could vary, but for analysis purposes a 90 tonne silo was considered.

Costs associated with this type of storage facility would be slightly higher by approximately $2,000 in annualized costs compared to the gravity feed salt silo option outlined in Section 3.2. It is estimated that the foundation for the structure would cost $19,000, the same as the overhead bin. The cost of constructing the bin and support structure would be approximately $37,000. It is estimated that the conveyor belt or auger system with hydraulic motor would cost $20,000, which would be powered by the trucks' hydraulics system. The salvageable value after 20 years is estimated to be approximately $3,000. Similarly to the overhead silos, to protect the concrete pad from negative impacts from salt it is recommended to have it sealed every three years at a total cost of $1,500 per sealing. The salt bin should also be painted with epoxy paint at least once during its 20-year life at estimated cost of $10,000. Minor maintenance to the bins would also require that the bin vibrator system would have to be serviced every spring adding an additional $200 in expenditures annually.

The capacity limitations for salt hopper bins would be the same issues as outlined for salt silos in Section 3.2.

3.4 Analysis Input - Costs

To ensure that the analysis is undertaken properly DHT tries to capture all the associated costs for the different options. In regards to the site the following costs are considered: site modifications that may include fencing around the structure to protect access and prevent unauthorized personnel entry and possible abuse, ground preparation for the foundation construction, construction of an apron in front of the storage, building an approach to access the site, soil drilling and lab analysis, etc. These costs can vary widely from no cost in case where a structure is being built at an existing yard site to costs as high as $10,000 where high fencing might be required.

In regards to construction and equipment costs, initial capital cost for the various options involve the following: 90-tonne salt silo including foundation - $76,000; salt shed 30x40 ft ($35,000) and new large loader ($110,000); salt hopper with conveyor belt system - $76,000. Material cost implications are also taken into consideration. It is estimated that fine salt costs $30/tonne and coarse salt approximately $60/tonne. The difference in cost is primarily associated with additional haul costs for coarse salt material. Annual operating costs are also considered. For the salt silo: estimated $5,000 annually to account for concrete pad treatment, servicing vibrators, painting with epoxy paint and other maintenance activities. For the salt sheds: estimated $10,000 annually to account for building the concrete pad, spraying walls with asphalt (typically MC 30), replacing shingles and door rollers, loader annual expenditures and repair costs and other maintenance activities. The salt hopper: estimated $5,000 annually to account for concrete pad treatment, servicing vibrators and conveyor pad, painting with epoxy paint and other maintenance activities.

It is important to try to capture all applicable costs to ensure an accurate comparison is made between the three alternatives.

3.5 Analysis Inputs – Benefits

There are various benefits associated with undertaking the three different options. One of the stronger benefits for salt silos is strategic location. These silo structures can be built in isolated areas and are powered by trucks hydraulics; therefore, it is estimated that DHT would benefit $15,000 annually by having silos built in the right locations to provide adequate service to the traveling public. Salt sheds, on the other hand, need access to electrical power in order to keep loaders warm so they will start in cold temperatures. It is estimated that their slightly limited strategic location benefits to DHT would be approximately $5,000 annually. Finally, salt hopper structures can be built in isolated areas and are powered by trucks hydraulics like salt silos. It is estimated that DHT would benefit $15,000 annually by having salt hoppers built in the right locations to provide adequate service to the traveling public.
With technological advances it is estimated that in the near future salt silos and salt hoppers could provide storage and mixing capabilities in mixing and producing salt brine and anti-icing mixes. This benefit to DHT is estimated to be approximately $5,000 annually. With material requirements it is estimated that by using coarse salt that supposedly stays better on the road and is more effective in treating snow pack, benefits can be estimated as $10,000 annually.

Summary of all costs and benefits for the three available options is presented in Table 1.

4.0 <u>Example Case Study – Neilburg Salt Storage Facility Analysis</u>

An analysis was done to determine the best salt storage alternative for the Neilburg area located in West Central Saskatchewan approximately 250 kilometers west of Saskatoon. It is located on the provincial Highway No. 40 with several other highways located in close proximity. Several years ago DHT sold its salt storage facility in the town and had the opportunity to reallocate the facility to a more optimal location. An out of town limits option was only considered in this analysis since there was no opportunity to buy any property within the town limits.

4.1 Analysis Process

As part of the analysis an analytical methodology involving a Life Cycle Cost Analysis (LCCA) was used to evaluate overall cost efficiency of the proposed alternatives. The process takes into account all costs and benefits associated with alternatives over the entire life cycle. The Net Present Value (NPV) is used as a preferred evaluation method. NPV measures the net contribution to wealth of each alternative. It is calculated as the present value of the future cash flows minus the initial investment.

Decision Programming Language (DPL) software was chosen for modeling purposes. This software enables modeling in two different graphical methods: decision tree and influence diagram. In regards to the decision tree, “A decision tree is a graphical method of expressing, in chronological order, the alternative actions that are available to the decision maker and the choices determined by chance" (Hiller and Lieberman 1990). Squares represent decisions to be made and circles chance events. The branches leading out of a square are alternatives available and the branches leading out of a chance node are the possible outcomes of an uncertain event. The third element of the decision tree specified at the end of the branch is the consequences. Clemen (1996) and Winston and Albright (1997) have excellent detailed instructions and examples on how to use decision trees in decision analysis. Similarly, since decision trees can be very detailed another graphical method, called influence diagram, was developed. It is a preferred method to use when dealing with many decisions and chance nodes. Clemen (1996) provides an excellent overview of the method. In addition, a DPL manual (1998) provides very good practical examples using influence diagrams.

A complete step by step analysis of the Neilburg salt storage analysis is outlined in Appendix A.

4.2 Results of the Neilburg Analysis

The Life Cycle Cost Analysis revealed that the best alternative was the construction of an overhead salt silo. However, through a sensitivity analysis it is evident that even slight changes in the values of some performance indicators would yield a different result. It is therefore crucial to closely examine all performance indicators associated with the selection of a salt storage structure in order to obtain the most reliable result. This requires good knowledge of all costs and benefits of each alternative over its entire useful life.

This paper suggests that the cost of site modification, initial capital cost, material cost, operating costs as well as benefits expressed in term of dollar value such as strategic location, technological advances and material requirement be considered in the evaluation of salt storage facilities. However, since the performance indicators can be numerous their selection should depend on an agency's preferences and the type of analysis performed.

5.0 Conclusion

Over the past decade considerable more attention has been given to the importance of proper salt management and the positive impacts that it can have on the environment and potential cost reductions for road salt users. DHT continues to try to minimize salt usage by implementing various strategies that reduce salt requirements. By minimizing salt storage costs and ensuring that salt is available for timely application during winter snow/ice events this goal can be achieved. The following analysis procedures, outlined above, allow the department to consider different salt storage options and try to implement the best overall solution. The Neilburg case study is one example of how the department is trying to ensure a good level of service by minimizing costs and potential environmental impacts.

6.0 References

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7.0 <u>Figures</u>

Figure 1 – Salt Shed at Kindersley

Figure 2 – Dome Shaped Salt Shed at Saskatoon

Figure 3 - 140-tonne Salt Silo on Highway No. 16 at Sheho

Figure 4 - 90-tonne Salt Silo on Highway No. 19 near Loreburn

Figure 5 - Drilling at the Meacham Salt Silo Location

Figure 6 - Concrete Mat for 90-tonne Salt Silo at Meacham

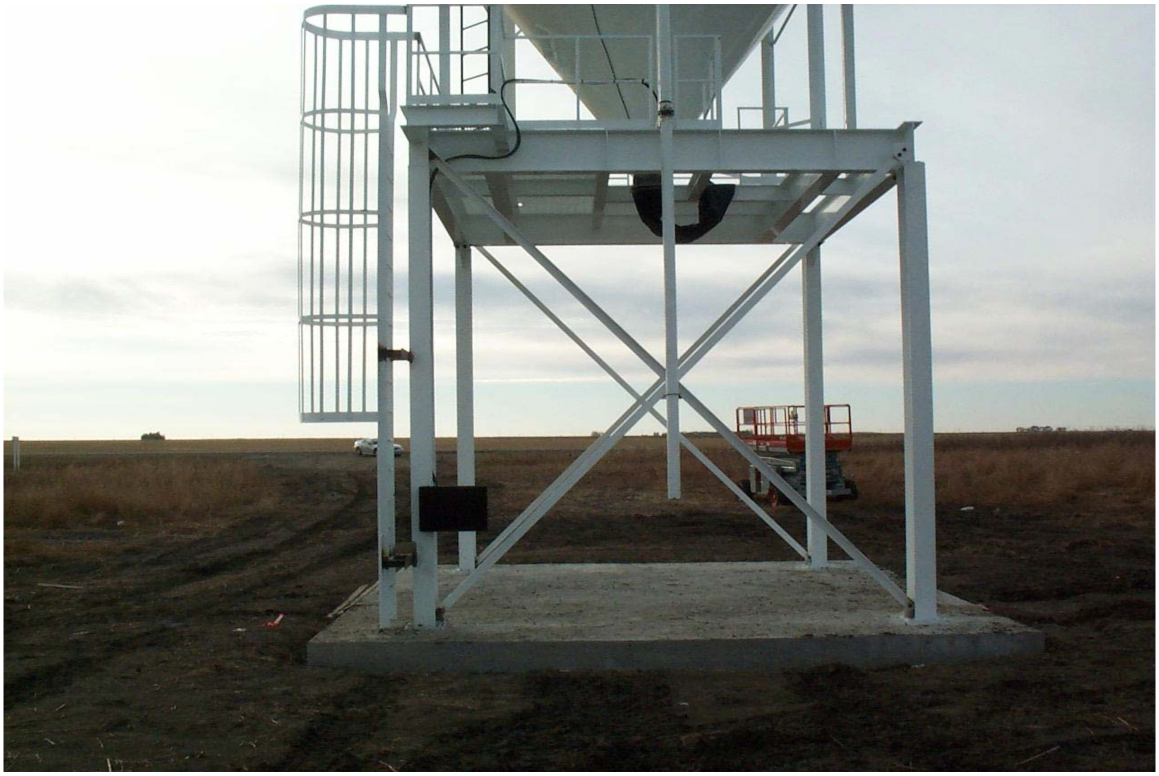

Figure 7 - Support Structure for a 90-tonne Salt Silo

Figure 8 – Salt Shed at the Saskatoon West Shop

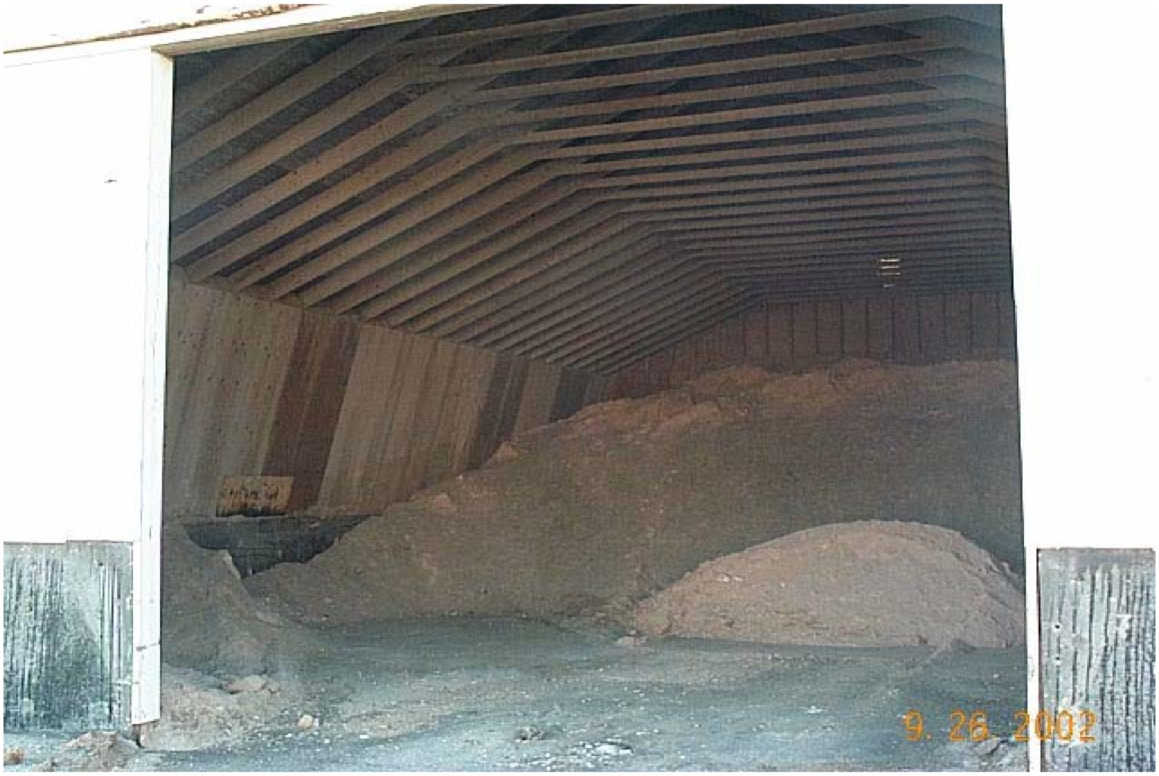

Figure 9 – Inside of the Salt Shed at the Saskatoon West Shop

Figure 10 – Interior of a Dome Shaped Salt Shed

8.0 Tables

Table 1 – Benefits and Costs of Each Alternative

Decisions, Costs and Cash Flow Diagrams (Best Estimates):

Interest Rate:	3.0%	(rr)
Planning Horizon (yrs):	20	(time)

Overhead Salt Silo

1) Costs	**Costs**	**Remaining Life**	**Annualized Costs**	**Annual Operating/Maintenance Costs**		
Storage Purchase	76,000	20	-5,108	Service vibrators	200	annual
Site Modifications	3,000	20	-202	Seal concrete pad	1,500	every 3 years
Annual Operating/Maintenance Costs	5,000		-5,000	Paint bin	10,000	in year 10
Material Costs	24,000		-24,000	Others		
Accessibility/Strategic Location	5,000		5,000			
Technological Advances	500		500			
Material Requirements	3,000		3,000			
		Total Annualized Costs of Overhead Salt Silo:	**-25,810**			

Salt Shed + Loader

1) Costs	**Costs**	**Remaining Life**	**Annualized Costs**	**Annual Operating/Maintenance Costs**
Storage and Equipment Purchase	150,000	20	-10,082	Concrete pad
Site Modifications	5,000	20	-336	Replacing shingles
Annual Operating/Maintenance Costs	12,000		-12,000	Replacing door rollers
Materail Costs	12,000		-12,000	Loader Operating/Repair Costs
Accessibility/Strategic Location	2,000		2,000	Others
Technological Advances	0		0	
Materail Requirements	0		0	
		Total Annualized Costs of Salt Shed + Loader:	**-32,418**	

Hopper Bin + Auger (Conveyor)

1) Costs	Costs	Remaining Life	Annualized Costs	Annual Operating/Maintenance Costs
Equipment Purchase	76,000	20	-5,108	Service vibrators
Site Modifications	3,000	20	-202	Seal concrete pad
Annual Operating/Maintenance Costs	7,000		-7,000	Paint bin
Material Costs	24,000		-24,000	Others
Accessibility/Strategic Location	5,000		5,000	
Technological Advances	500		500	
Materail Requirements	3,000		3,000	
		Total Annualized Costs of Hopper Bin + Auger Configuration:	**-27,810**	

Conversion to Chance Nodes:

	Low	Nominal	High
Interest Rate	0.02	0.03	0.05
Storage Purchase			
Overhead Salt Silo	70,000	76,000	82,000
Salt Shed + Loader	145,000	150,000	160,000
Hopper Bin + Auger (Conveyor)	70,000	76,000	85,000

Appendix A

Figure A-1 illustrates the Neilburg salt storage facility decision model built as an influence diagram in DPL. Similarly, Figure A-2 is the same problem presented in a decision tree graphical format. The developed model is probabilistic because of the inherent risk associated with some future events. For example, the initial capital costs are not known until the selected salt storage facility is tendered. However, based on historical costs and knowledge of the problem, probability can be assigned to different event outcomes as illustrated for initial capital costs in Figure A-3. The decision at hand is which type of salt storage to select for the Neilburg area. Three alternatives are presented:

1. 90-tonne capacity salt silo
2. existing salt shed with a large loader
3. 90-tonne capacity salt hopper with conveyor system.

The yellow decision node contains the three alternatives. Green chance nodes represent uncertain inputs where probabilities are used to represent different possible event outcomes. Blue value nodes contain certain decision events as well as calculated values. Costs and benefits are evaluated for each of the observed alternatives (Table 1) and entered as either certain or uncertain values.

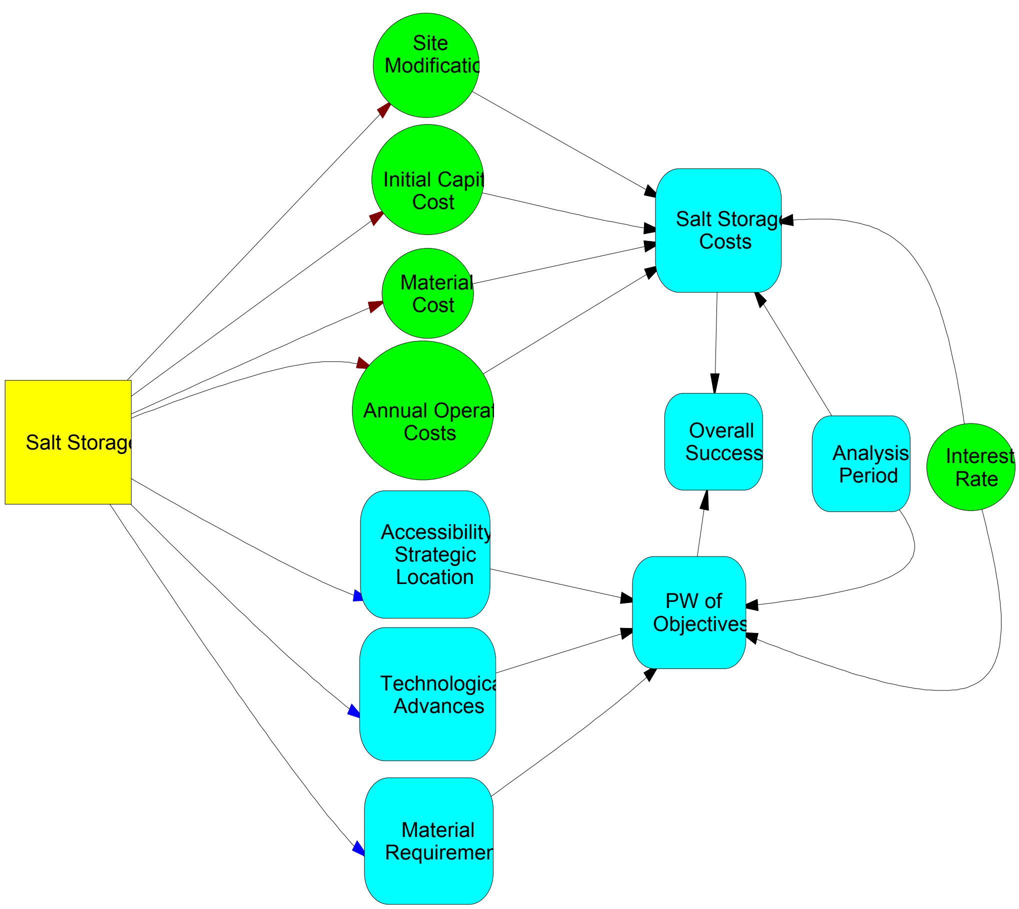

Figure A-1 – Influence Diagram for Salt Storage Decision Problem at Neilburg

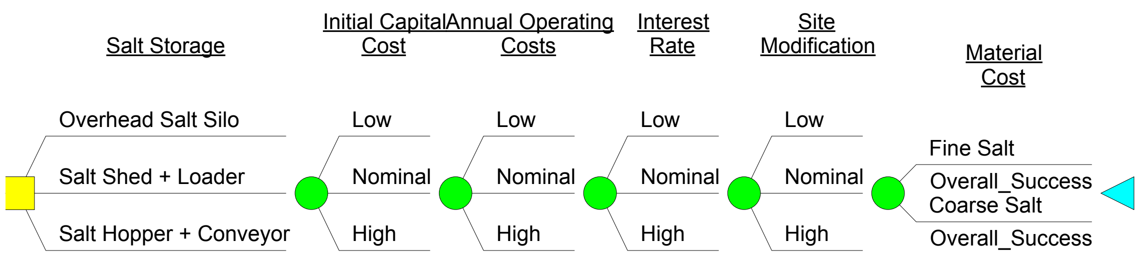

Figure A-2 – Decision Tree for the Neilburg Problem

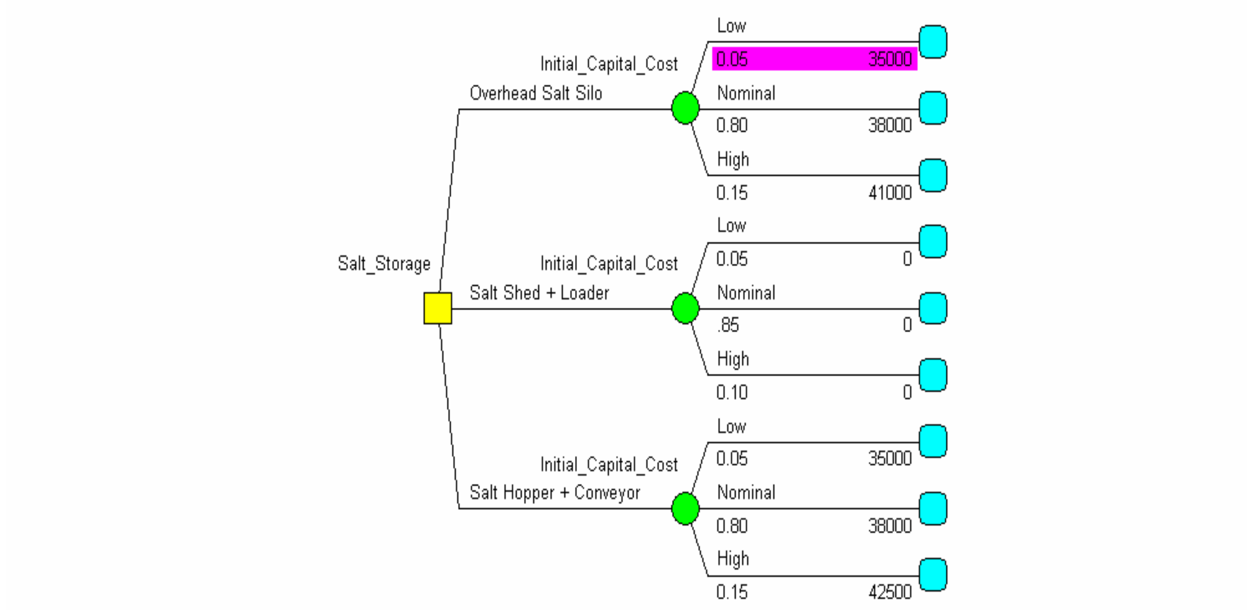

Figure A-3 – Initial Capital Costs and Event Probabilities

With all inputs entered and decision sequencing determined the model is run. It is set to do Net Present Value (NPV) analysis of the observed alternatives over a 20-year life cycle. The results are presented in Figure A-4. The analysis results show that the overhead salt silo is the best alternative. Once the analysis is complete it is important to evaluate the impact of each input on the final result. This is achieved by performing a sensitivity analysis. This analysis provides the analyst with information how sensitive the final result is to the changes in input values. If it is revealed that the final result might indeed call for a different alternative, if input values are changed over a certain range of possible values, it is an indication to pay closer attention to that input. It might be required that the analyst should go back and closely re-evaluate that particular input or obtain a second opinion from a different expert. Figure A-5 illustrates Expected Value Tornado diagram for the salt silo option. Only a few inputs were considered in the diagram. Whenever there is a change in colour on a bar representing the range of values for a specific input it is an indication that the choice of an alternative would also change.

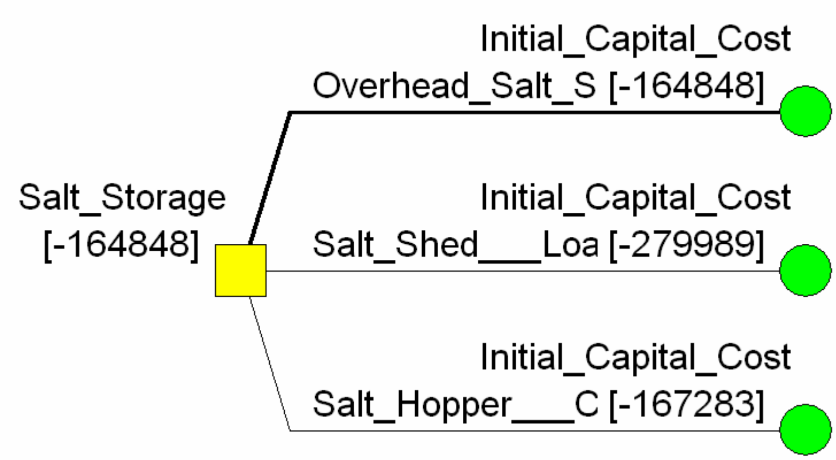

Figure A-4 – Analysis Results

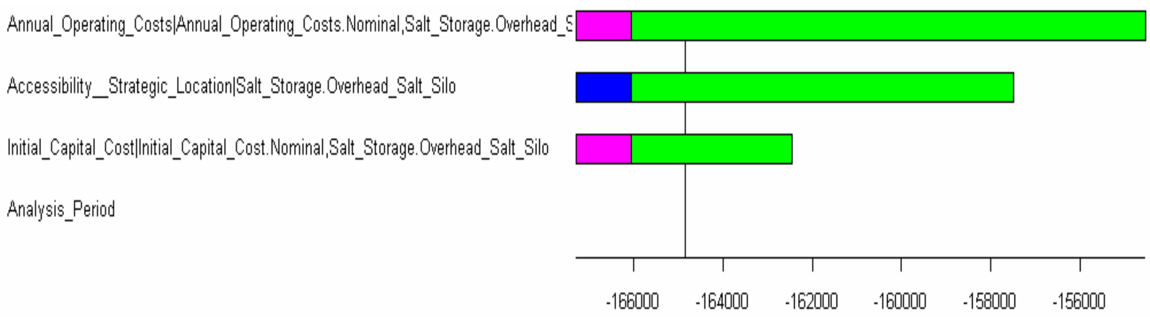

Figure A-5 – Expected Value Tornado Diagram