SALT AND ROAD DEICING ON THE MICHIGAN STATE HIGHWAY SYSTEM

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Table of Contents

Tables

Figures

SECTION I.
EXECUTIVE SUMMARY

Michigan's Department of Transportation (MDOT) and its contractors presently maintain approximately 13,670 miles of 24-foot wide road surfaces (also called equivalent miles or "e-miles") in the state highway system. Emphasizing safety and efficient passage of vehicles, MDOT's winter maintenance forces are used extensively to blade snow and ice from the roads and apply deicing chemicals and sand (an abrasive). Salt is the preferred deicing chemical. Generally, these efforts are in response to popular demand and the "common wisdom" that winter maintenance activities reduce accidents.

There are numerous benefits gained by the use of sodium chloride (NaCl) or salt for deicing. Salt is both easy to handle and the most cost-effective deicer presently available. Such road deicing reduces the driving hazards of icy surfaces and aids in snow removal. Deicing practices may help reduce: worker lateness and absenteeism; production and shipping losses; increased fuel use caused by rough, snow-covered roads; fire and crime losses caused by delays of emergency vehicles; and injuries and property losses caused by vehicle accidents.

Detrimental effects caused by the release of sodium chloride salts into the environment through roadway deicing are also extensive. The corrosive effects of salt cause significant losses for vehicle owners and increased deterioration of roadways, bridges and other infrastructures. Small streams, ponds and other sensitive ecosystems can be damaged by road salt runoff. Road deicing salts have and are contributing to the gradual salinization of the Great Lakes (particularly Lakes Michigan and Erie). There are also indications of increasing levels of salt in groundwater supplies.

MDOT uses a three priority-level system of maintenance for snow and ice control on Michigan highways. In addition, MDOT trucks have calibrated salt flow controls which allow metering of the quantities of salt spread with each pass. Although the MDOT has tried to reduce salt use, there is no overall downward trend in salt use since the late 1960's. Michigan continues to have one of the highest levels of deicing salt use in the nation.

Efforts have been made in Michigan and many other states to find and use alternative deicing chemicals. In several states, deicing salts have been reduced by the use of mixtures of salt and abrasives, such as sand. In a few states, sensitive ecosystems and vulnerable groundwater areas have been identified and protected from salts. Recent research in Michigan and elsewhere suggests the chemical deicer calcium-magnesium acetate (CMA) holds promise for future use in areas where salt would be corrosive or harmful to water supplies. However, CMA is not being commercially produced at this time. In all cases, substances used to take the place of salt also pose significant problems either in increased maintenance (e.g., more frequent applications and cleanup of sand) or in increased purchase and handling costs, or both.

A simple elimination or arbitrary reduction in the use of salt for roadway deicing does not appear practical. However, some reductions in total salt used can be achieved through one of or a combination of the following: increased use of various mixtures of sand and salt or calcium chloride, exclusive use of sand/salt mixtures in sensitive areas, reduced driver speed and increased driver education, and more strict metering through spreader equipment. Future reductions of salt use may be gained through the use of less harmful, alternative chemicals like CMA.

SECTION II.
INTRODUCTION

As of 1982, Michigan's total highway system included 117,383 miles of interstate, state, county and local roads. The state has jurisdiction over about 9,500 miles of that system, translating to approximately 13,670 miles of 24-foot wide road surfaces (called "equivalent-miles" or "lane-miles"). According to the Department of Transportation, over 50 percent of the total vehicle miles traveled in Michigan are across these state-maintained roads. (Adams, 1983).

The maintenance of the state highway system is a responsibility carried out by the Michigan Department of Transportation (MDOT) and its contractors. In 62 of our 83 counties, MDOT contracts the county road commissions to maintain state trunklines within their boundaries. In addition, MDOT has contracts with about 150 municipalities to do maintenance work on state roads. In other areas state trunklines are maintained by MDOT employees. In all cases, the work is supervised and controlled by the Maintenance Division of MDOT (Williams, 1981).

In maintaining the state highways, MDOT must place a heavy emphasis on the safety and efficient passage of vehicles. During winter months, snow and ice can become the major impediments to safe, efficient travel. Therefore, the winter maintenance forces are used extensively to blade snow and ice from pavement surfaces and apply deicing chemicals and abrasives (e.g., sand).

The primary deicing chemical used in Michigan and nationally is sodium chloride (NaCl) or rock salt. Salt is the preferred deicer because it is inexpensive, easy to handle and, pound for pound, the most effective deicer presently available. The practice of road salting has been particularly beneficial to the road user. Therefore, increased traffic (including increasing suburban populations and truck transport) together with expanded highway systems has encouraged the 20 fold increase in the salt used on the nation's roads between 1950 and 1970 (Calabrese and Tuthil, 1978). In addition to the obvious beneficial effects, however, detrimental health and environmental effects have been noted.

SECTION III.
BENEFITS OF USING ROAD SALT

There are numerous tangible and intangible benefits to the use of salt in deicing road surfaces. Some benefits relate to the efficiency of the chemical. Other tangible benefits are related to the quick and efficient transport of people and goods in spite of adverse weather conditions. Less tangible benefits are related to the reduction of driving risks and anxiety.

As a mined mineral, salt is far lower in cost than man-made deicing chemicals such as calcium chloride (a DOW product). Further, there are large reserves available in Michigan. As a relatively hard, crystalline substance, rock salt is easy to store, handle and distribute through automatic spreaders. Salt works as a chemical deicer down to about 10° F by dissolving in the presence of water into separate sodium (Na^+) and chloride (Cl^-) ions. The resulting brine (or ionic solution) has a much lower freezing temperature than salt-free water. Salt can be mixed with sand abrasives to prevent freezing of sand into clumps. (In Michigan calcium chloride (CaCl) is mixed in sand to assure easy flow through spreaders.) However, in Michigan most salt is applied directly after a plow has removed loose snow. The brine that results helps loosen packed snow and ice as well as helping to prevent additional snow packing.

Generally, road salting can increase vehicle traction and reduce road roughness due to ice and snow buildups. Several studies have discussed the economic benefits accrued by individuals and commerce from a deicing, "bare-pavement" program (Brenner and Moshman, 1976; McBride, et. al., 1977; Massachusetts Department of Public Works, 1978). These studies indicate significant losses can occur without road deicing when storms cause lateness to work and absenteeism, reduced production of goods, and losses of goods shipped due to delays. It has also been reported that rough, icy roads can increase fuel consumption by as much as fifty percent (Brenner and Moshman, 1976). The true economic value of losses is difficult to calculate and continues to be debated. Actual production losses due to reduced mobility probably vary, depending on the ability of a business to reschedule production (McBride, et. al., 1977).

It is also pointed out that ice and snow can delay emergency response vehicles. Brenner and Moshman (1976) suggest that delays in emergency services can result in higher death rates from medical conditions and higher fire and crime losses. However, there is no comparison of winter storm delays under salt use maintenance versus any other maintenance programs.

All studies reviewed indicate that vehicle accident rates are highest for snow-packed roads, lower for wet pavements and lowest for dry roads. Generally, better traction provides safer vehicle travel. There is statistical confirmation that the likelihood of accidents for all vehicles is much higher during and immediately after snow storms. However, there is no confirmation of increased accidental deaths due to snow-covered roads in the literature reviewed. In addition, there is considerable dispute over the effectiveness of road salting during and after storms in reducing the severity of personal injury accidents. For example, a Federal Highway Administration report states that both property damage and personal injury accident rates "increase significantly during a storm". However, the report makes no comparison of road maintenance of any type to no maintenance during a storm (McBride, et. al., 1977, p. 33). Similarly, an EPA report found no data to differentiate accident rates based on the level and type of maintenance (Murry and Ernst, 1976). Instead, the EPA report suggests that salted surfaces increase traffic volumes during and after snow storms. That report also suggests that salting practices may give drivers a false sense of safety on wet pavement, increasing their willingness to take risks of speed. Statistics do show that greater speeds lead to increasing personal injury accidents. Apparently, there is a need for better research and statistical comparisons of types of maintenance programs and their applications in different parts of the state.

SECTION IV.
DETRIMENTAL EFFECTS OF USING ROAD SALT

Sodium chloride (salt) is a natural part of the environment. High concentrations of this and other salts are found in seawater, the water of arid regions, and in certain geologic deposits. The chloride ion (Cl^-) is particularly mobile in aquatic environments; that is, it tends to move freely with water, not being locked up in soils or sediments. (The sodium ion (Na^+) is far less mobile.) As a result, naturally occurring chloride is carried in rainfall (about 0.5 parts per million) as well as in streams, rivers and the Great Lakes (Hutchinson, 1957). However, McNabb and Tierney (1971) pointed out, "The addition of chloride to the environment above the level of background at which the ecosystem has historically developed will stress the system to some degree."

Human activities add salt to the environment in a number of ways. Sodium chloride is a basic raw material of several industries. In addition to road salts, large quantities of salt enter the environment through domestic and industrial sewage, fertilizers and pesticides.

A. Corrosion

Corrosion is most often caused by oxygen combining with metals when moisture is present. Due to the activity of the ions, the corrosion process is accelerated when the moisture includes salt. For this reason, deicing salts have been cited as a major cause of vehicle corrosion. The actual rate of corrosion is dependent on several environmental factors including, but not limited to: the presence of salty moisture, other corrosive pollutants (e.g., acids), temperature and the use of corrosion resistant materials.

Due to its humidity, Michigan has a naturally corrosive environment and deicing salts increase its corrosiveness. However, since the mid-1960s increasing amounts of corrosion-resistant materials have been used in the manufacture of trucks and automobiles. These improvements are expected to continue to reduce the extent and severity of vehicle corrosion.

Increased damage to road surfaces and bridge structures is also attributed to the corrosive effects of salty water (McBride, et. al., 1977, and others). Steel bridges and steel reinforced concrete bridges are corroded in the same way as vehicles, by general oxidation (rusting) and by pitting. Since concrete is porous and somewhat permeable, chloride ions enter with water and increase the corrosion of steel reinforcing rod, welds and joints. In addition, variations of the salt concentrations in water within the concrete can cause differential freezing. Such differential freezing promotes shallow chipping of concrete surfaces adding to the rapid deterioration of bridge decks (Brenner and Moshman, 1976). Overall, infrastructure damage has been reported to be substantial (Murry and Ernst, 1976 and others). Damage to bridges is particularly serious because of the costs of repair and the hazards and inconvenience to motorists during the repair (DeFoe, 1973). Due to the potential corrosion damage, the MDOT does not use salt on the Mackinac and Blue Water Bridges. (Murry and Ernst, 1976 and others).

In some cases, the effects of salt related corrosion can be reduced by design and construction techniques. For example, a minimum thickness of concrete in bridge decks may reduce corrosion of reinforcing rod. Sealants such as linseed oil have also been used. In addition, latex-modified concrete coverings are now being used by MDOT in new and rebuilt bridge decks to reduce the penetration of moisture.

B. Soils, Vegetation and Wildlife

When applied to roads, salt will runoff to drainage ways and soils nearby as well as spray off the roadway. Plows and wind can spray the salt more than 100 feet from the road. Salt in solution usually disassociates into separate ions allowing positively charged sodium ions (Na^+) to be adsorbed onto negatively charged soil particles, while negatively charged chloride ions (Cl^-) continue to move. As a result of this process, sodium ions may displace calcium ions (Ca^{++}) on the soil particles, making the soil less fertile, less permeable and more prone to erosion (Prior and Berthouex, 1967; Sucoff, 1975).

Road salt and salt spray can also damage plants near the roadway, particularly within 100 feet. Direct contact with salt spray can be damaging to twigs and new growth. Increases of sodium chloride ions in the soil water can also interfere with some plants' abilities to take up water. Sodium ions in solution can also move into some plants causing toxic damage. In addition, sodium can raise the pH (i.e., decrease the natural level of acidity) to levels harmful to plants within 45 feet of the highway (Sucoff, 1975). Generally, trees and woody plants are more susceptible to injury from salt contamination. The damage to plants from road salt is usually considered negligable since the effects are limited to near road areas. However, some concern has been expressed for the potential damage to wetlands due to salt's greater mobility in wet environments (Graham, 1984).

Concern for deer and other wildlife attracted to the highways for salt has also been noted. Although deer are attracted by salt deposits, no statistics have been developed relating road salting and vehicle/deer collisions.

C. Surface Water

Highway runoff from precipitation contains a number of environmentally harmful materials, including: heavy metals from fuels, oils and exhaust; oil, gas and hydrocarbons from petroleum leaks and exhaust; and substantial amounts of salt from deicing (Smith and Kaster, 1983). These materials may collect in the roadside snow and ice build-ups until a thaw and then flow, or flow immediately away from the road surfaces. Given the mobility of the chloride ion, most of this element of salt moves with the water down into the soils or along the surface to a ditch, stream, pond or other receiving water body.

Most investigators indicate that the increase of sodium and chloride ions in streams and rivers from road salt runoff does not pose a serious or immediate threat. Although numerous reports describe significant temporary increases in salt, particularly during the spring thaw periods, dilution appears to be enough to limit most problems (Scott, 1976; Smith and Kaster, 1983; and others). According to recent reviews by the Michigan Department of Natural Resources, fish and other aquatic animals are generally unaffected by salt (NaCl) concentrations of less than 1000 parts per million (Wuycheck, 1984). Concentrations of salts in water courses near major highways <u>have</u> been shown to exceed 1000 parts per million (Hawkins and Judd, 1972; and others). However, these high concentrations are usually only temporary and frequently part of controlled urban waterways or sewer systems. It should be noted that this urban runoff may be controlled away from sensitive streams, but must eventually be discharged somewhere (e.g., from sewage treatment plants). Therefore, road salt may have an indirect impact on water bodies through wastewater discharges.

Small lakes and ponds receiving salty road runoff pose more significant problems. If dilution and flushing actions are limited, salt may be concentrated in enclosed water bodies. This may be accompanied by exchange of sodium ions for toxic metal ions that were once tied up in lake sediments. In addition, incomplete mixing of salt ions entering lake bodies can cause layers of different water densities. This density stratification may interrupt normal mixing of water and cause a depletion of oxygen needed by plants and animals (Judd and Steggal, 1982). Research has also indicated that chloride concentrations as low as 250 parts per million can increase the production of aquatic plants and may be part of a chemically induced reduction of diversity in aquatic plants (McNabb and Tierney, 1971).

D. The Great Lakes

Chloride levels have been shown to be rising significantly in the Great Lakes. Lakes Michigan and Erie are of primary concern, together with some local problems in Lake Huron (Pringle, et. al., 1981). Data has been accumulated to show that chloride levels throughout Lake Michigan have increased by over 4 parts per million since the turn of the century. The current concentration of chlorides in Lake Michigan averages approximately 8 parts per million (Wuycheck, 1984). Chloride concentrations in Lake Erie have increased three fold in the last 50 years, now averaging about 26 parts per million (Pringle, et. al., 1981). It has been pointed out that chloride loadings to the Great Lakes were reduced in the mid-seventies by increased control of industrial and municipal waste water discharges through the National Pollution Discharge Elimination System. However, the chloride concentrations in the Lakes continue to increase. Presently, about 40 to 45% of the contribution of chlorides to Lake Michigan and about 11% of the contribution of chlorides to Lake Erie are directly attributed to road deicing salt (Kenaga, 1978 and Pringle, et. al., 1981).

The concentrations of chlorides in the Great Lakes are far less than the U.S. Environmental Protection Agency's recommended limit for drinking water, 250 parts per million. However, aquatics researchers have expressed concern over the apparent replacement of some freshwater species with less-desirable, salt-tolerant plants. According to at least one researcher, chloride levels of more than 7.5 to 10 parts per million will cause a major shift in the plant species of Lake Michigan toward nuisance, unpleasant taste and odor-causing blue-green algal populations (Wuycheck, 1984).

E. Groundwater

As discussed above, a portion of all road deicing salt eventually runs off the road surfaces and lodges in or on the soils nearby. Subsequent rainfall and/or snowmelt infiltrating the soils carries some of this salt down to where all pore spaces are saturated with water. The top of this water-saturated zone is usually called the water table. The waves or pulses of water infiltrating from the surface (i.e., groundwater recharge) contribute the salt to the groundwater flow system. Generally, the salt ions move laterally with the groundwater from areas of recharge (usually higher elevations) to discharge points such as streams, lakes, and wells.

Road deicing salts present the most direct threat to groundwaters of shallow, unprotected aquifers. In areas where rapid downward percolation can take place, the surges of salty water may increase sodium and chloride ion concentrations beyond acceptable limits for drinking water, interfering with water supply wells (Freeze and Cherry, 1982). Under some conditions, these salt concentrations will fluctuate annually in relation to the seasonal "salt recharge".

Investigations in Maine found numerous private wells along highways that had been contaminated by road deicing salts (Hutchinson, 1969). Some of the wells in that study exceeded the 250 parts per million chloride standard for drinking water as well as having high sodium concentrations (75 parts per million average). Similar, less severe problems of increasing salt ions in groundwater reserves have been reported in Massachusetts, New Hampshire, New York, and Wisconsin (Hawkins, 1976; Murry and Ernst, 1976; Buller, et. al., 1978; and others).

In Michigan, little information has been gathered about the impact of road salt on groundwater resources. However, in many places throughout the state a general increase of salt ions in groundwater used for drinking water has been documented. The immediate causes for many of these problems are unclear. Table 1 is a listing of sample results from a selection of municipal water wells which show a significant rise in salt ions over a period of years. In each case, state trunklines are nearby with no other obvious source of pollution in the vicinity. Road salt may or may not have a direct bearing on the community's water quality. These are only indicators of a generalized and complicated problem which will require further investigation.

In the past, there have been several instances of groundwater contamination by runoff from salt storage areas. According to a recent count, 88 salt storage areas in Michigan have caused unacceptable levels of chlorides in the state's groundwater (Houck, 1984). These problems resulted from the practice of storing salt in open areas, unprotected from rain and uncontained. Although the effects of these contamination problems linger, all storage facilities under MDOT control have been reconstructed to prevent any further problems (Williams, 1984).

F. Human Health

Generally, there is reason for concern whenever road deicing salts impact drinking water supplies. Both the sodium and chloride ions from salt can degrade drinking water beyond reasonably acceptable levels. Sodium has been shown to aggravate numerous medical conditions such as hypertension, congestive heart failure, renal diseases, cirrhosis of the liver and toxemias of pregnancy. Although no drinking water standard has been set for sodium by the U.S. Public Health Service, 100 milligrams sodium per liter of water (100 parts per million) is the recommended limit which would benefit about 40% of the population (Flaga, 1984). However, the above limit does not protect people on sodium-restricted diets. For that sensitive population, a limit of 20 milligrams sodium per liter of water is recommended.

Table 1

EXAMPLES OF INCREASING CHLORIDE (Cl) AND SODIUM (Ca) IN

GROUNDWATER

MDPH Analyses of Public Water Supplies
(From MDPH Data Center)

		Date	Cl (mg/l)	Na (mg/l)
Spring Lake, Ottawa County Roads: US 31 (code green) & M-104 (code yellow)	Well #3	3/51	8	6.0
	Well #3	11/58	14	4.6
	Well #3	4/68	34	11.0
	Well #3	12/73	46	17.0
Rogers City, Presque Ilse County Roads: US 23 (code red) & M-68 (code red)	Well #3	3/61	1	1.8
	Well #3	10/70	6	3.0
	Well #3	4/71	13	5.0
	Well #3	11/74	16	4.8
	Well #3	8/83	0	7
Beecher Area, Flint Metro District, Genesee County. Roads: I-475 M-54, I-69, I-75 (all code green)	Well #3	6/54	63	-
	Well #3	12/73	81	95.0
	Well #3	3/75	73	79.0
	Well #3	3/83	258	179
Linden, Genesee County North Bridge, Roads: US 23 (code green)	Well #1	1/51	13	19
	Well #1	1/59	16	28
	Well #1	4/71	19	26
	Well #1	3/74	18	29
	Well #1	2/84	31	23
Hillman, Montmorency County M-32 (code yellow)	Well #2	11/49	8	8.0
	Well #2	7/58	18	6.0
	Well #2	9/62	6	20.0
	Well #2	5/73	70	25.0
Hastings, Barry County Tyden PA, Roads: M-43 (code yellow), M-37 (code yellow), & M-79 (code yellow	Well #3	10/57	10	6.5
	Well #3	3/62	4	11.0
	Well #3	9/63	15	8.7
	Well #3	2/75	77	28.0
	Well #3	11/82	60	38

The chloride ion presents no known hazards to health in lower concentrations. However, most people can taste chloride in drinking water at about 200 parts per million. Therefore, the U.S. Public Health Service has set a "secondary maximum contaminant level" in drinking water at 250 parts per million (milligrams/liter) on the basis of taste considerations. In addition, Michigan Water Quality Standards protects public water supplies at the point of intake. For the Great Lakes and connecting waters, chloride (Cl) cannot exceed 50 parts per million (milligrams/liter) at the point of intake for a public water supply as a monthly average (Wuycheck, 1984).

G. Salt Additives

Many salt supply companies have mixed additives with the salt they sell for deicing. In the past, chromium was added to salts as a corrosion inhibitor. However, this highly toxic heavy metal, has been dropped by Michigan salt suppliers.

Recently, MDOT salt suppliers have indicated that they continue to add sodium ferrocyanide (approximately 35 to 125 parts per million) to the deicing salts. Domtar Industries and Morton Salt Company (2 of the 3 Michigan salt suppliers) also add equivalent amounts of ferric ferrocyanide (Prussian Blue) to their deicing salts (Schramm, 1984). These compounds are intended to prevent "caking". However, under the right conditions, these compounds will generate cyanide, a potent poison and pollutant. This literature review found no scientific assessment of the environmental hazards posed by these additives.

SECTION V.
MICHIGAN'S USE OF DEICING SALTS

In general, Michigan's use of salt on the state highway system increased through the 1950s and 60s. In the 1970s through the present, the total salt used by the MDOT and its contractors has remained in the same order of magnitude, with fluctuations apparently related to overall winter conditions. It should be noted that the road system is considerably different in the Detroit area than the rest of the state. The Detroit Metropolitan area has a higher density of major roadways as well as many below ground level roadways. Large quantities of salt are used on the below ground roadways to melt all snow and allow the sewer and pump system to remove the runoff.

Table 2 lists the total tons of salt used by the MDOT maintenance system for each winter between 1965 and 1984, and the average quantity of salt used for each equivalent ("E") mile or lane mile in the system. Since the Metro area consistently uses a much larger quantity of salt per lane mile, separate tables were also prepared for the state highway system without the Detroit Metropolitan area included and for the Detroit Metropolitan area alone (Tables 3 and 4).

Table 2

MDOT/CONTRACTOR ANNUAL SALT USE

State Wide with Metropolitan Detroit*

Year	Salt Usage in Tons	Tons/per "E" Mile
1965-1966	153,094	13.02
1967-1968	238,182	19.63
1969-1970	322,729	26.3
1972-1973	329,687	26.4
1973-1974	301,268	24.2
1974- 975	333,697	26.3
1975-1976	313,315	24.05
1976-1977	309,627	23.36
1977-1978	318,801	23.73
1978-1979	337,485	24.94
1979-1980	275,920	20.23
1980-1981	302,574	22.08
1981-1982	354,982	25.91
1982-1983	204,496	14.92
1983-1984	379,411	27.44

[*Figures obtained from data supplied by the Michigan Department of Transportation]

Table 3

MDOT/CONTRACTOR ANNUAL SALT USE

State Wide without Metropolitan Detroit*

Year	Salt Usage in Tons	Tons/per "E" Mile
1965-1966	113,227	11.41
1967-1968	170,158	16.8
1969-1970	219,970	21.46
1972-1973	262,068	20.98
1973-1974	228,119	21.41
1974-1975	268,906	24.85
1975-1976	234,409	21.10
1976-1977	221,121	19.7
1977-1978	216,948	19.30
1978-1979	243,631	18.00
1979-1980	192,739	16.99
1980-1981	212,911	18.68
1981-1982	217,372	19.07
1982-1983	158,687	13.92
1983-1984	252,853	22.02

[*Figures obtained from data supplied by the Michigan Department of Transportation]

Table 4

MDOT/CONTRACTOR ANNUAL SALT USE

Metropolitan Detroit*

Year	Salt Usage in Tons	Tons/per "E" Mile
1965-1966	39,867	21.71
1967-1968	68,024	34.39
1969-1970	102,759	51.66
1972-1973	67,619	37.97
1973-1974	73,149	40.94
1974-1975	64,791	35.13
1975-1976	78.906	41.16
1976-1977	88,506	43.42
1977-1978	101,853	46.38
1978-1979	93,854	42.01
1979-1980	83,181	36.29
1980-1981	89,663	38.82
1981-1982	137,610	59.67
1982-1983	45,808	19.86
1983-1984	126,557	54.01

[*Figures obtained from data supplied by the Michigan Department of Transportation]

In the 1960s, the MDOT began a program of controlled chemical spreading through the use of flow valves and salt calibration systems. This equipment allows the truck driver to meter the desired amount of salt onto the pavement according to prevailing conditions. The program was reported to have saved road commissions "thousands of dollars on their own road systems" (Woodford, 1981). Based on reported salt use, however, no overall downward trend in salt use is apparent on the state highway system.

According to MDOT policy, maintenance of the Michigan highway system during winter storms follows a priority system based on traffic volumes. This three-level system is intended to provide a "high degree of safety without practicing a 'bare pavement' policy" (Adams, 1983). Under the system, state trunklines are divided into three major categories for maintenance, as follows.

> <u>Category 1</u>, "Green" roads with high traffic volumes (over 3500 average daily traffic), receive continuous plowing and salting until the storm is over.
>
> <u>Category 2</u>, "Yellow" roads, which have moderate traffic volumes (1000 to 3500 average daily traffic), are plowed and salted sufficiently to attempt to keep the middle eight feet in a reasonably bare, wet condition. A bare condition is obtained during the next regular working day.
>
> <u>Category 3</u>, "Red" roads, or low-traffic-volume roads (less than 1,000 average daily traffic), are plowed during the winter storm and sand is applied to curves, hills and intersections. After the storm, during the next regular working day, salt is applied to these roads to remove the ice-pack and bring the pavement to a bare condition.

Table 5 is a compilation of the average number of tons of salt used per lane mile by district, from the winter of 1972-73 through 1981-82. Figure 1 is a map of the MDOT districts. As indicated on the table, the total salt used per lane mile varies significantly from district to district. Some variation can be expected due to different weather conditions. Additionally, the presence of numerous high priority, Category 1, road miles could be expected to increase the average salt use per lane mile. However, these numbers suggest significant inconsistencies between districts in either the salting policy or the rate of application or both, unrelated to weather and priority care highways. For example, compare Districts 1 and 2 or Districts 3 and 4.

For reference, Figure 2 provides a map of average snowfall in the state based on the period of 1940 through 1969. This map may be useful as a very general indicator of the need for roadway plowing and deicing. It should be pointed out, however, that the number of

Table 5

TONS OF SALT PER "E" MILE
District Average

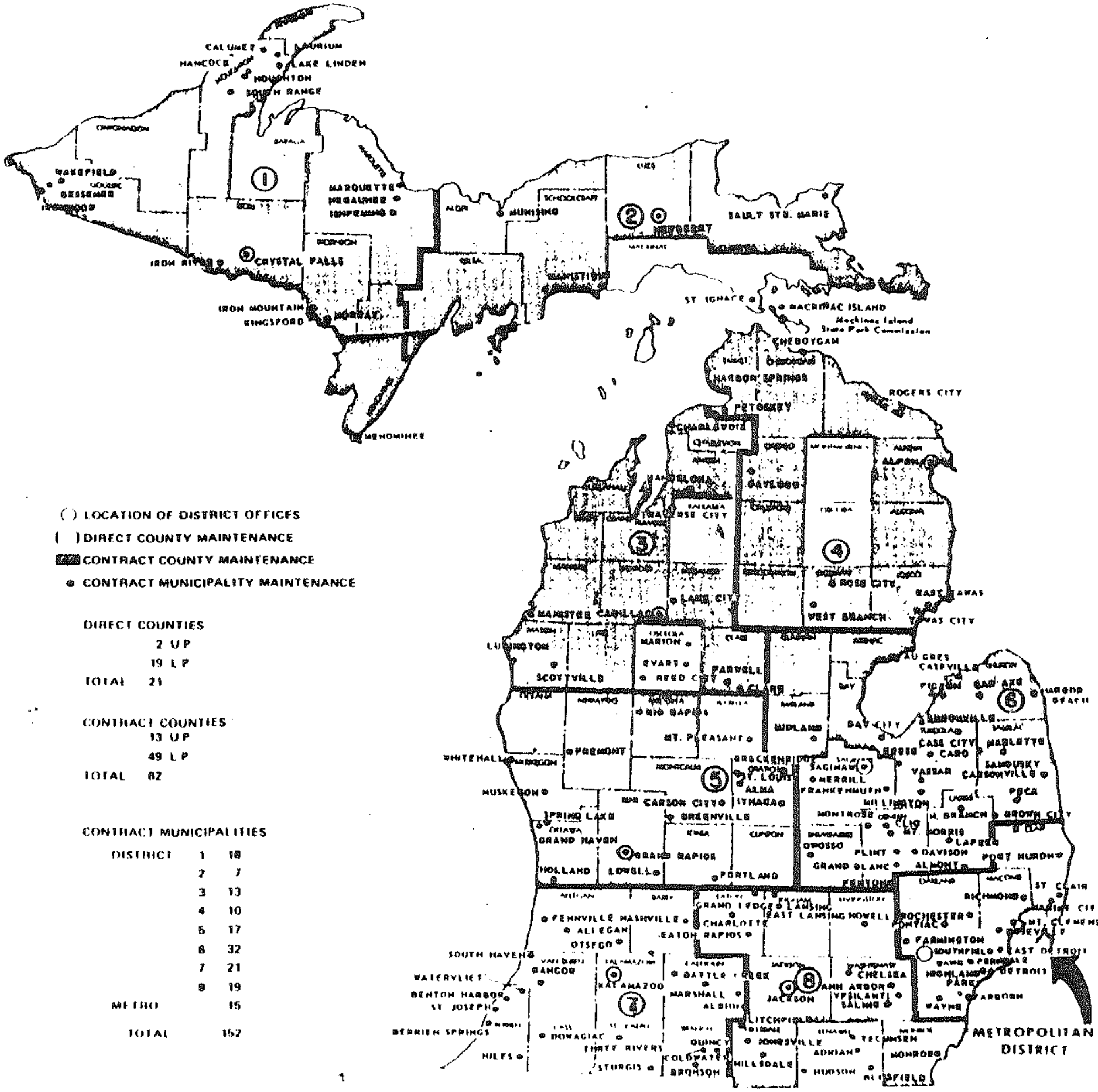
District	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82
1	26.3	26.4	25.6	23.0	24.5	22.9	23.1	21.6	23.0	22.7
2	20.8	24.8	20.9	15.2	11.4	15.2	16.8	12.7	11.6	14.1
3	18.2	16.5	19.2	17.8	18.1	13.8	17.5	13.4	15.7	14.1
4	19.7	21.7	24.8	19.4	19.8	16.8	19.7	15.5	17.5	16.9
5	25.1	18.0	24.7	23.4	22.9	19.4	21.6	15.5	20.1	20.5
6	25.1	23.2	23.9	23.9	18.9	18.2	20.9	15.1	16.4	17.6
7	28.4	21.4	31.0	22.8	24.3	27.3	28.7	24.0	25.4	20.4
8	28.1	21.2	25.6	19.5	15.9	18.2	20.6	16.7	17.2	22.3
metro	38.0	40.9	37.1	41.2	43.4	46.4	42.0	36.3	38.9	59.0

STATEWIDE AVERAGE	1977-78	1978-79	1979-80	1980-81	1981-82
	23.7	24.9	20.2	22.1	25.7

STATE OF MICHIGAN
DEPARTMENT OF TRANSPORTATION

Figure 1

LOCATION OF CONTRACT MUNICIPALITIES



( ) LOCATION OF DISTRICT OFFICES
( ) DIRECT COUNTY MAINTENANCE
CONTRACT COUNTY MAINTENANCE
• CONTRACT MUNICIPALITY MAINTENANCE

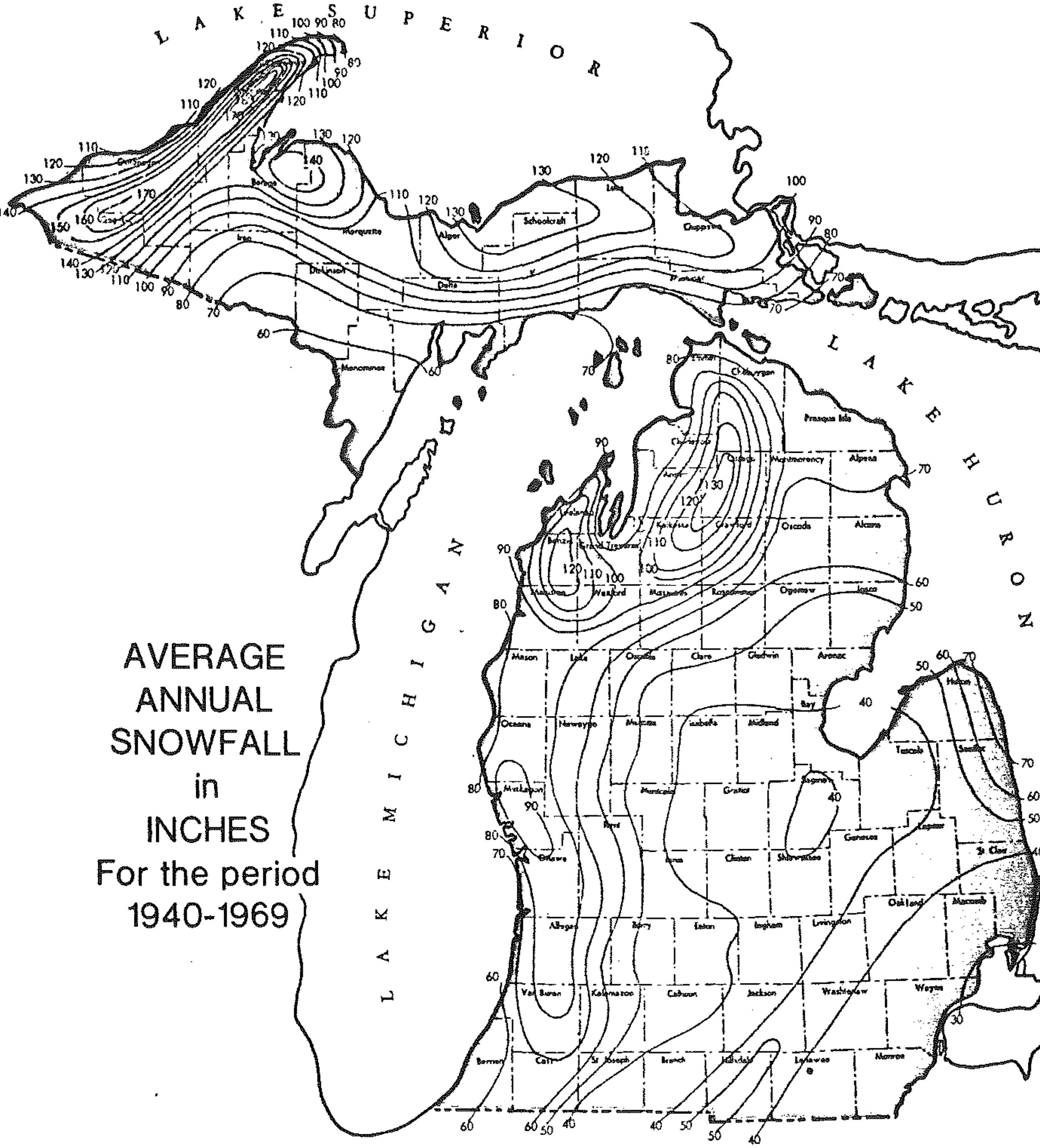
DIRECT COUNTIES	
	2 U P
	19 L P
TOTAL	21

CONTRACT COUNTIES	
	13 U P
	49 L P
TOTAL	62

CONTRACT MUNICIPALITIES

DISTRICT	1	18
	2	7
	3	13
	4	10
	5	17
	6	32
	7	21
	8	19
METRO		15
TOTAL		152

Figure 2



AVERAGE ANNUAL SNOWFALL in INCHES For the period 1940-1969 winter storms, their type, and severity are the primary factors determining highway deicing needs throughout most of the state.

Most salt used by the MDOT is purchased from three vendors: the International Salt Company in Detroit and Morton and the Domtar Salt Companies in Ontario, Canada. Over the past several years, their prices have averaged $21 to $22 a ton. For example, in 1980-1981, about 275,000 tons of salt were purchased at an average of $21 a ton and used on the state trunklines at an approximate total cost of $6 million. In addition, the MDOT uses a relatively small quantity of calcium chloride (CaCl) obtained from Dow Chemical Company. In 1980-1981 the MDOT mixed about 522 tons of CaCl at a cost of $139 a ton, with about 20,000 tons of sand at a cost of $3 a ton (Woodford, 1981). This sand-calcium chloride mixture is used only when temperatures are below salt's useful melting ability (less than 10° F) and on some low-traffic roads (Woodford, 1981).

SECTION VI.
USE OF DEICING SALTS IN OTHER STATES

As mentioned above, comparisons of total salts used can be misleading since the number and severity of winter storms can vary greatly between regions. However, a comparison of salt use averages indicates the relative importance of salt in the winter maintenance policies of other state transportation authorities.

Tables 6 and 7 provide lists of the 25 state highway departments reporting the greatest total quantities of salt used for road deicing in 1981-1982 and 1982-1983, organized in order from greatest to smallest. In each case, Michigan used the fourth largest amount of salt for road deicing in the nation. However, when expressed as tons used for each lane mile, Michigan is shown to have used the fifth largest amount in 81-82 and the seventh largest amount in 82-83 for each lane mile. According to the Salt Institute, Michigan uses far less abrassive material in winter maintenance than most other states. Comparison of licensed drivers and total reported lane miles per state (licensed drivers per lane mile) indicates that salt use policies do not necessarily relate to the number of in-state roadway users. Although some states use more, several states with similar climates and road use are using less salt than Michigan.

In preparing this report, the Science Office completed a brief phone survey of 16 states to determine salt use policies and recent changes in those policies. The Appendix provides a summary of the responses received. Apparently, most midwestern and northeastern states place a heavy emphasis on salt in their winter maintenance program. In many cases, however, some modification of salt use policies has occurred or is being attempted. In the west, sand and other abrasives are the primary methods of improving road surface traction. The western states contacted use salt primarily to keep the abrasives flowing freely. It should be noted that winter highway conditions

Table 6

SALT USE FOR SNOW AND ICE CONTROL BY THE STATE HIGHWAY AUTHORITIES 25 HIGHEST QUANTITY STATES FOR 1981-1982

State	Approx. Total Lane Miles	Bare Pavement Miles	Salt (tons)	Tons Salt/ Lane Mile	Abrassives	Licensed Driver/ Lane Mile
Pennsylvania	77,000	--	500,000	6.5	1,200,000	92
New York	29,780	29,780	443,000	14.9	899,000	310
Ohio	42,192	0	401,285	9.5	239,087	167
MICHIGAN	**27,334**	**4,695**	**397,000**	**14.5**	**17,000**	**234**
Indiana	31,036	14,559	313,365	10.1	278,193	117
Illinois	38,515	--	304,184	7.9	--	182
Massachusetts	12,000	--	262,000	21.8	184,000	303
Wisconsin	25,774	25,774	236,790	9.2	26,584	116
Virginia	112,814	17,350	178,500	1.6	400,000	31
Maryland	14,600	0	155,758	10.7	71,400	187
New Hampshire	8,630	8,406	138,692	16.07	210,135	76
Minnesota	28,724	4,162	118,587	4.12	291,204	81
Connecticut	10,160	0	103,201	10.1	18,000	214
Missouri	69,664	-	90,963	1.30	--	47
W.Virginia	70,000	21,000	90,636	1.29	239,655	22
Utah	22,000	--	79,540	3.61	125,000	38
Kentucky	53,846	4,966	73,275	1.36	--	38
Vermont	6,079	6,079	71,904	11.8	154,648	57
Iowa	24,300	0	64,000	2.6	145,000	87
Rhode Island	3,015	3,105	56,280	18.6	86,094	195
New Jersey	10,366	10,366	54,500	5.25	12,400	476
Maine	7,877	1,178	51,676	6.56	519,750	93
Tennessee	25,087	25,087	51,000	2.03	51,000	50
N.Carolina	76,200	23,342	45,264	0.59	--	50
Kansas	22,371	5,688	35,490	1.58	--	75

[Figures calculated (with corrections) from: Survey of Salt, Calcium Chloride and Abrassives Use in the United States and Canada, Salt Institute and the World Almanac.]

Table 7

SALT USE FOR SNOW AND ICE CONTROL
BY THE STATE HIGHWAY AUTHORITIES
25 HIGHEST QUANTITY STATES FOR 1982-1983

State	Approx. Total Lane Miles	Bare Pavement Miles	Salt (tons)	Tons Salt/ Lane Mile	Abrassives	Licensed Driver/ Lane Mile
New York	29,780	29,780	300,000	10.07	460,000	310
Pennsylvania	77,000	---	231,000	3.00	655,000	92
Wisconsin	25,774	25,774	229,803	8.91	25,913	116
MICHIGAN	**27,334**	**4,695**	**229,000**	**8.4**	**10,000**	**234**
Illinois	38,515	---	206,000	5.34	--	182
Ohio	42,192	---	184,341	4.36	128,975	167
Massachusetts	12,000	---	178,500	14.87	95,000	303
Minnesota	28,724	4,162	127,957	4.45	288,893	81
Indiana	31,036	14,559	116,650	3.75	108,619	117
Virginia	112,814	17,350	95,000	.84	255,000	31
New Hampshire	8,630	8,406	93,813	10.87	151,322	76
Maryland	14,600	0	82,499	5.65	30,859	187
Utah	22,000	---	79,720	3.62	125,000	38
Missouri	69,664	---	75,111	1.07	--	47
Vermont	6,079	6,079	65,647	10.7	106,654	57
Iowa	24,300	0	60,400	2.4	116,000	87
West Virginia	70,000	21,000	52,709	.75	178,642	22
Connecticut	10,160	0	51,934	5.11	169,598	214
Maine	7,877	1,178	49,202	6.24	472,500	93
N.Carolina	76,200	23,342	36,573	0.48	--	50
New Jersey	10,366	10,366	35,700	3.44	4,200	476
Kentucky	53,846	4,966	32,964	.61	--	38
Kansas	22,371	5,688	31,630	1.41	65,000	75
Rhode Island	3,015	3,015	29,297	9.71	45,000	195
Nebraska	22,000	---	24,899	1.13	86,734	50

[Figures calculated (with corrections) from: Survey of Salt, Calcium Chloride and Abrassives Use in the United States and Canada, Salt Institute and the World Almanac.]

are much different from those in Michigan for most western states, including less traffic and colder temperatures.

Several midwestern and northeastern states have attempted reductions of salt use in recent years. In Minnesota, a 1982 statute intended to reduce salt use requires all highway maintenance authorities to use salt only at "such places as upon hills, at intersections, or upon high speed or arterial roadways where vehicle traction is particularly critical," and only when other methods such as plowing and sanding cannot reduce the hazardous conditions (Minnesota Compiled Laws 760.215). The Wisconsin legislature is considering a simple across the board reduction by percentage in the total amount of salt used. The Iowa DOT has used and recommends a 50/50 blend of sand and salt to reduce the total salt applied (Salt Institute Highway Digest, 1984). Both Vermont and Massachusetts have on-going programs to identify sensitive areas and restrict road deicing with salt in those locations. In addition, the Massachusetts legislature is now considering a complete prohibition on the use of salt, calcium chloride, and other chemicals which may be harmful to water supplies. Similarly, the West Virginia legislature is considering a total ban on sodium and calcium chlorides.

SECTION VII. STATE LIABILITY

Under current state law, municipalities, political subdivisions and the State and its agencies can be sued for negligence (1964 PA 170). In the case of state highways, the MDOT has been the defendant in an ever increasing number of liability suits. The numbers and types of law suits as well as the size of monetary awards have increased radically in recent years. For instance, there were 272 cases pending at the end of 1979 and 426 cases pending at the end of 1983. In 1979, the state paid about $1,389,000 in judgments. In 1983, the judgments paid reached $14,919,000.

According to Carl Carlson, Chief of the MDOT Negligence Division, Office of Attorney General, most cases concern: problems with low shoulders; impacts into guard rails, signs, and other "road-side furniture"; and improper warnings. Although several suits have alleged government liability for slippery conditions on road surfaces, the courts have never agreed. According to Mr. Carlson, "It is the position of the State that there is no cause for action in those instances where the defect in the highway complained of is the natural accumulation of ice and snow....it would appear that the Court's view of liability for natural accumulation of ice and snow upon streets and highways has not changed in over 100 years and that view is that no liability attaches for natural accumulation of ice and snow" (emphasis added).

SECTION VIII.
ALTERNATIVES TO REDUCE THE EFFECTS OF SALT (NaCl)

Sodium and calcium chloride have been considered highly corrosive and damaging to highway structures and vehicles for many years (DeFoe, 1984, Dunn and Shenk, 1980, and others). More recent concerns have centered on degradation of water resources. One result is that transportation engineers have been looking for and researching a number of alternatives to sodium and calcium chlorides. Among the numerous alternatives considered, several deicer chemicals and structural changes have been suggested.

A. Structural Protection

As previously discussed, increased concrete scaling and metal corrosion of bridge structures are significant problems directly associated with the use of salt for deicing. Over the years, numerous engineering and structural methods of protection have been suggested and tried with varying degrees of success. Generally, these methods add to the cost of new structures and the maintenance of older ones. The following are the most notable structural protection methods.

"Air entrained" concrete can help reduce problems caused by the differential freezing of salty water mixtures. This method employs a concrete that has a percentage of tiny air bubbles throughout (entrained) together with a minimum thickness which allows greater expansion and contraction. Air entrainment and concrete thicknesses are part of MDOT's specifications for new bridges.

Many highway departments, including MDOT, use sealants on bridge decks to reduce the penetration of salt water. One coating used successfully for many years is linseed oil and mineral spirits. However, sealants usually require periodic reapplication.

In recent years, latex modified concrete has been used by MDOT as a bridge deck cover. Over two inches of this non-permeable material is applied to the top of new and rebuilt bridge decks to prevent the penetration of water and salt.

Another concrete cover that has received some attention is called "verglimit". This is a patented bituminous concrete with particles of calcium chloride encapsulated in the material. The calcium chloride dissolves to produce a thin deicing solution as the surface wears with traffic. MDOT has not experimented extensively with this material.

"Cathodic protection" has been suggested as a method for existing bridge decks. This approach protects the metal in a bridge from corrosion by treating it like the cathode or positively charged pole in a battery. Anodes (negatively charged poles) are placed in a bridge and a small electrical current is continuously applied to them. In this way, the metal of the anode is sacrificed to corrosion rather than the concrete reinforcing rods.

B. Glycol Liquids

Glycols are dihydroxy alcohols which are sometimes used in antifreeze. Submitted by several producers as a good roadway deicer, the MDOT researched the effectiveness of glycol products for use on roadways and bridges in the early 1970s (DeFoe, 1973 and DeFoe, 1974). A non-corrosive liquid, this material was shown to be an effective but short-lived deicer. Glycol products are also many times more expensive than salt and pose substantial environmental risks due to their high biochemical oxygen demands (BOD).

C. Urea

Urea, an organic compound, is used as a deicing agent on airport runways. This is because urea is far less corrosive on aluminum airplane bodies than sodium chloride. However, the widespread use of urea on roadways would have severe environmental impacts in streams and ponds due to its fertilizing effect. Urea is also very expensive.

D. Methanol

Methanol or methyl alcohol has been advocated for use as a roadway deicer. It works much more rapidly than NaCl and to a much lower temperature (as low as -120° F, -85°C). However, this benefit is short-lived and after only a few hours sufficient methanol evaporates to necessitate reapplication.

Like glycol, methanol is a liquid and would require different application equipment than is presently used for salt or sand. Methanol is toxic when sufficient vapors are encountered in an enclosed space (i.e., the interior of an automobile) or when consumed. Methanol is also important as a fuel source and much more expensive than salt (approximately 5.5 times).

E. Calcium Chloride

Generally, calcium chloride ($CaCl_2$) has more desirable attributes than salt. Calcium chloride can melt ice effectively down to temperatures of approximately -40°F. It is spread using the same technique and equipment as is presently used for salt. It is not as corrosive as NaCl. Calcium poses little health threat in drinking water. However, calcium chloride is about 6.6 times more expensive than salt.

As previously discussed, the MDOT has used calcium chloride for many years in combination with sand, particularly at low temperatures. In 1962, the MDOT performed research on enhancing the effectiveness of salt by combining it with calcium chloride. Had that proven effective, less sodium salt would have been required, reducing the total sodium released on the highways. However, the 3 to 1 salt and calcium chloride mixture proved to be no more effective than straight salt (DeFoe, 1962).

F. Sand

Sand or abrasives have been advocated as a viable supplement or replacement for sodium chloride in winter road maintenance. In some states they are used almost exclusively. In Michigan, the abrasives used for roadway traction are primarily silica sands rather than other abrasives such as limestone or cinders. As stated earlier, Michigan presently uses some sand in its winter maintenance operations. However, sand must be mixed with some salt or calcium chloride to prevent the sand from freezing into lumps which clog the spreading equipment. When sand is used, the maintenance truck plows the loose snow from the pavement and spreads the sand-chloride mixture on the remaining snow-pack to give traffic additional wheel traction. However, the benefits of this treatment may be short-lived. Continued traffic may press the sand into the snow-pack or more snow may cover it up. Therefore, it may be necessary to repeat the application many more times than salt. It should also be noted that excess abrasives on hard road surfaces may increase the potential for vehicle skidding.

Sand or abrasives have been used on low-traffic volume highways and at low temperatures when salt's melting action is poor. Many county road commissions use this on their secondary roads. In the past, MDOT has maintained that abrasives are not feasible on the state's main trunklines because traffic volumes are too great.

The present rate of sand usage causes no significant environmental impacts. However, if the use of silica sand were to rise dramatically, potential environmental problems could arise in obtaining and disposing of sand. Unlike salt, sand is usually mined in open pits. The availability of silica sand is limited due to the environmental protection of many coastal areas. Since it does not dissolve, sand accumulates alongside curbed roadways requiring cleaning or collection. This sand must be disposed of or used again, posing an economic and aesthetic problem. Sand may also enter the drainage systems of sewered areas and contribute to the filling of catch basins. However, these catch basins are designed to be cleaned regularly, regardless. Other potential impacts of increased sand use are silting of streams and ponds, increased sand particles in the air, and increased energy consumption (from increased plowing and application).

Sand is much cheaper than salt ($3/ton). However, it must be mixed with calcium chloride or salt. The increased cost in labor and fuel to spread the mixture more frequently and clean up the excess can also add substantially to the costs of increased sand use.

G. Calcium-Magnesium Acetate (CMA)

In 1980, the Federal Highway Administration (FHWA) released a study of alternatives to salt in which calcium-magnesium acetate or CMA was identified as a new chemical formulation worth pursuing (Dunn and Schenk, 1980). [CMA is a metal-organic salt which dissolves and lowers the melting point of ice.] In subsequent research efforts funded by FHWA and others, methods for economical production of the chemical were established and used to produce 200 tons for field trials. Generally, the production of CMA was identified as a simple process of reacting dolomitic limestone (a common sedimentary rock found in Michigan) with acetic acid (the acid found in vinegar).

Preliminary tests of CMA have shown it to be far less corrosive than salt. Additionally, the chemical constituents of CMA may be beneficial to some soils by contributing nutrients while having little or no impact on water quality (due in part to their limited mobility).

Last winter (1983-1984), the MDOT participated in a Pooled Fund Study administered by the FHWA. In the study, a dry-pellet form of CMA was compared to rock salt on a section of I-96 during winter storms. CMA was shown to be effective in melting ice and snow but more slowly than salt. Researchers concluded that CMA could be effective for ice and snow control on critical structures where chlorides should not be used (DeFoe, 1984) and in areas of possible water contamination by salt (Chollar, 1984).

Several problems must be overcome before CMA can be used extensively. Regular manufacture of the chemical near its point-of-use (e.g., Michigan) must be established to bring costs down. However, it should be noted that manufactured chemicals will continue to cost more than mined rock salt. Additionally, problems caused by clogging of standard salt spreading equipment must be corrected. Apparently the material is softer than salt and more likely to absorb moisture. Different CMA spreading methods may be needed such as mixing with sand for spreading or spraying in liquid or slurry form.

SECTION IX.
DISCUSSION

Given the large quantities of salt spread on Michigan trunklines, all the benefits and detriments discussed in this paper could be expected. Clearly, Michigan is a highly industrialized and populous state. Therefore, quick and efficient travel on state highways, regardless of weather conditions, is highly desirable. Over the years, salt has been considered the primary and most effective tool used to combat icy conditions on road surfaces. Although salt has been efficient, it has also been costly.

As described previously, salt runoff has had little obvious impact on Michigan rivers and streams. However, road deicing salts carried by streams and wastewater discharges are contributing to major changes in the Great Lakes ecosystem. There are indications that salts are contributing to a general degradation of groundwater quality, a concern for all its users. Additionally, sensitive environments such as specific wetlands, small streams, and ponds may be adversely affected by current salting practices. Finally, corrosion damage caused by the use of road deicing salts has had a significant impact on Michigan's vehicles and infrastructure.

The MDOT has pointed out that salt is the most effective method of increasing traction for vehicles during and after winter storms above 15° F. Although a less harmful replacement chemical is in development (i.e., calcium-magnesium acetate or CMA), no manufactured chemical can be expected to rival the price of mined rock salt. Therefore, it is highly unlikely that the practice of deicing roads with salt will be discontinued. However, a comparison of other state salting practices suggests significant reductions can be achieved in Michigan.

There appears to be no single answer to the problems posed by the use of deicing salts. In addition, there is a need for information concerning the effectiveness of various winter road maintenance policies and the locations of sensitive areas including groundwater recharge areas.

Several short and long-term options are available to reduce the impact of deicing salts on the environment and infrastructure. In the short-term, reductions in salt use can be sought through any one or a combination of the following: 1. more frequent calibration of salt metering equipment; 2. a small, overall reduction of salt flow established for each pass based on prevailing conditions; 3. greater reliance on plowing; 4. broader use of sand/salt mixtures at various ratios, particularly on non-curbed roads with lower traffic volumes; 5. reduced traffic speeds during winter months and increased driver education; and 6. some additional use of calcium chloride may be helpful.

Over a larger period of time, other options may become valuable in protecting the state's resources and infrastructure. For example, sensitive ecosystems and vulnerable groundwater recharge areas could be identified and specifically protected from deicing salts. Additional sealing and recovering of bridge decks could be helpful. Greater effort in and financing of the research, manufacture, and use of calcium-magnesium acetate (CMA) could also reduce salt use while protecting infrastructure.

APPENDIX

Summary of Sixteen States' Use of Deicing Salt

Minnesota

Deicing Method: Salts (NaCl and CaCl) and abrassives

Legislation: In 1982 a law (160.211) was passed limiting the use of salt in order to minimize the harmful or corrosive effects of salt (and other chemicals) upon vehicles, roadways, and vegetation, and reduce the pollution of waters. In 1983, legislation was introduced (Bill 386) to prohibit the use of salt. This bill did not pass.

Wisconsin

Deicing Methods: Salts (NaCl and CaCl) and abrassives

Legislation: In 1983 legislation was introduced (SB 180) to limit the use of salts on highways. It is still under consideration. Limit would be imposed by a mandatory reduction from a given "baseline" winter. No alternatives are suggested.

Washington

Deicing Methods: Salts (NaCl and CaCl) and abrassives

Legislation: In 1983, Senate Bill 3450 was introduced which would prohibit the use of salt on any street or highway in the state. It is still under consideration.

Massachusetts

Deicing Method: Salt and other chemicals and abrassives--Presently enforces restriction in sensitive areas.

Legislation: A 1984 bill (HB 4445) would prohibit the use of sodium chloride, calcium chloride or chemically treated abrassives which may be dangerous to water supplies. It is still under consideration

West Virginia

Deicing Method: Salts (NaCl and CaCl) and abrassives. (Salt is $30 per ton and calcium chloride is $123 per ton.)

Legislation: In January 1984, HB 1300 was introduced. This bill would prohibit the use of calcium or sodium chloride products on state roads and highways if passed. It is still under consideration.

New York

Deicing Method: Salts (NaCl and CaCl) and abrassives.

Legislation: In 1982 a bill was introduced which would regulate the storage and handling of road salts. It died in the Ways and Means Committee. In 1983, Assembly Bill 3742 was introduced which, again, would regulate the storage and handling of salt and sand used on the roads and highways as are necessary to protect and maintain the environmental quality of the waters of the state. It is still under consideration.

Virginia

Deicing Methods: Salts (NaCl and CaCl) and abrassives

Legislation: Virginia has some water contamination in drinking wells due to improper storage of road salts. However, no legislation has been introduced.

Idaho

Deicing Methods: 92% Sand mixed with 8% salt. (For the southern part of Idaho, salt cost $13-15 per ton, in the north $30-35 per ton.)

Legislation: There has been no legislation introduced to ban the use of salt. Sand is the major deicing substance used with a small percentage of salt mixed in to keep the sand from freezing. The Idaho Department of Transportation does not have any major environmental concerns with the use of salt mainly because the salt content is so low in the mixture. They are more concerned with the damage salt does to the roads and bridge structures.

Montana

Deicing Methods: Sand/salt mixture with sand comprising 97-99% of the mixture.

Legislation: No past or pending legislation. Because of the very small amount of salt used in the state, environmental concerns are minimal.

South Dakota

Deicing Method: Sand is the main substance with a very small percentage of salt to keep sand from freezing.

Legislation: There has been no legislation proposing to ban the use of salt on the roads. However, in 1981, South Dakota did eliminate the use of pure salt on the highways by order of the Highway Commission. Salt use was prohibited because of the deterioration of the roads, not for environmental reasons.

North Dakota

Deicing Method: Sand with salt mixed in to keep sand from freezing.

Legislation: No legislation to ban the use of salt. Have had no environmental problems from use of salt on the roads.

Vermont

Deicing Method: Salt with some sand mixed in for traction. (Salt cost: $33 per ton.)

Legislation: No legislation has been introduced to ban the use of salt. Vermont has experienced some water contamination problems. When a problem of this nature arises, the state Department of Transportation must replace the contaminated water supply, and decrease the amount of salt used in that area.

Ohio

Deicing Method: Salts (NaCl and CaCl) and abrassives (Salt cost $20.42 per ton average for the state of Ohio.)

Legislation: Possible ban or limiting of salt has been discussed often in Ohio, but no legislation has been introduced. However, state highway department is attempting to decrease salt use by increasing abrassives to reach a mixture of 50% salt and 50% abrassives.

Indiana

Deicing Method: Salts (NaCl and CaCl) and abrassives. (Average use of salt per year, 215 thousand tons.)

Legislation: No legislation has been introduced. There have been some well-water contamination problems from improper storage of salt. The highway department has changed storage habits to correct this problem.

Pennsylvania

Deicing Method: Salt and abrassives (limestone, sand, cinders). (Salt cost $25-30 a ton.)

Legislation: State has had well-water pollution problems from improper storage. The highway department is improving storage to solve problem.

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