

EFFECTS OF HIGHWAY DE-ICING SALTS ON GROUNDWATER AND WATER SUPPLIES IN MASSACHUSETTS

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•RECENTLY, Boston area newspapers have carried articles and editorials with such titles as *Town Fights Road Salting to Protect Water Supply*, *Vermont Conservationists Attack Use of Road Salt*, and *Voters Ban Road Salt in Victory for Ecology*. Why is there such public awareness of the problems that can be caused by highway salting practices? The answer is that the concentration of chloride in some public water supplies has increased significantly during the last few years. This increase corresponds to the increased use of salts for de-icing highways, and this correspondence has not gone unnoticed.

In some localities, the concentration of chloride has increased beyond the 250 mg/liter recommended by the U.S. Public Health Service (3) as an upper limit for drinking water supplies. Where this has happened, local public health authorities have sometimes condemned the supply, and the practice of highway salting has thus received much criticism.

According to data furnished by the Massachusetts Department of Public Works, the use of highway de-icing chemicals, mainly sodium chloride and calcium chloride, on state highways in Massachusetts has increased nearly eightfold in the last 15 years. In the winter of 1954-55, 26,000 tons of sodium chloride and calcium chloride were applied to state highways at the rate of about 4.2 tons per lane-mile (Fig. 1). During the winter of 1970-71, a record high of 209,000 tons was applied at about 22.4 tons per lane-mile. In addition, de-icing salts were applied to local streets by most of the cities and towns in Massachusetts.

The U.S. Geological Survey and the Massachusetts Department of Public Works foresaw a need for data concerning the dispersion of salt in the environment. In 1965, a cooperative program was begun to monitor the concentration of chloride in groundwater along state highways.

In contrast to calcium and sodium, which may be sorbed by soils, chloride enters into solution in the hydrologic system and may act as a tracer of water movement (2, p. 23). As snow and ice on highways and snowbanks alongside highways melt, the de-icing salts dissolve and move with the meltwater. Some of the meltwater leaves an area as surface runoff, and some percolates to the water table. After reaching the water table, the salt-bearing water moves downgrade with respect to the water table. The concentration of chloride in groundwater may be responsive to many factors including (a) rate of application of de-icing chemicals, (b) type of soils and geologic materials, (c) type, intensity, and quantity of precipitation, and (d) highway drainage design.

Initially, 10 sites were selected to represent various types of geologic materials along old and new highways. At most sites, two wells were installed, one at 15 ft and one at 30 ft from the highway. At one site, 12 wells were installed at several depths and distances from the highway. All wells were on the downgrade side of the highway with respect to the water table. Samples were collected from each well periodically and analyzed for chloride.

Along with monitoring the chloride levels at the test sites, we set out to investigate complaints against the Department of Public Works alleging contamination of water supplies by de-icing chemicals, either from the highway or from the salt handling and storage areas. Five chloride contamination complaints of municipal and industrial water supplies were investigated between 1965 and 1969; in 1970, six complaints were investigated.

The concentration of chloride in normal, uncontaminated groundwater in eastern Massachusetts is about 5 to 15 mg/liter, based on published analyses of public water supplies by the Massachusetts Department of Public Health. Chloride concentration in the aquifers at the test sites near highways and analyses of water from wells near heavily salted highways and salt storage sites indicate that a significant part of the salt applied to roadways is entering the groundwater system.

The test site at Chelmsford is alongside Mass-3, which was opened to traffic in 1946. Well spacings of 15 and 30 ft from the highway were selected to detect any chloride percolating downward from salt-laden snowbanks. The water table is about 18 ft below land surface in sand and has a gradient of 0.1 percent from the road toward the wells. The wells are screened just below the water table (Fig. 2).

Before 1968, the concentration of chloride in all three wells at Chelmsford showed only a small increase. In early 1968, the concentration of chloride began to increase, and since then it has continued upward (Fig. 3). The following observations about Figure 3 may help to explain some of the apparent discrepancies between the increase in concentration of chloride and the application of chloride shown in Figure 1.

1. Before 1968, peak concentrations may have been missed because of infrequent sampling.
2. During the drought of 1963 to 1967, much of the chloride may have concentrated in the unsaturated zone. Increased groundwater recharge resulting from normal rainfall in 1967 may have flushed the salts from the unsaturated zone.
3. During 1968 and 1969 more frequent sampling shows that the peak concentration in water from well 389 (Fig. 2), which is 26 ft deep, lags a few months behind the peak concentration in water from well 387, which is 22 ft deep. Both wells are 15 ft from the highway, so this lag should represent vertical travel time in the saturated zone. We are not yet sure how long the travel time in the unsaturated zone may be. The peak concentration observed in 1968 may have been caused by salt applied during the winter of 1967-68 or perhaps during some previous winter.

Water from well 386 has a lower concentration of chloride because it is farther from the source and has been diluted by dispersion and by direct recharge from precipitation.

Another test site at Wenham shows the same general fluctuations in concentration (Fig. 4) of chloride in water from wells located 15 and 30 ft from Mass-128. Here, the materials are fill and swamp deposits over sand and gravel. The water table is about 3 ft below land surface.

Because the water table at the Wenham site is near the land surface, it may be safe to assume that salt from any winter application reaches the water table before the next salt season. However, if from the example at Chelmsford (Fig. 3) we can expect a vertical travel time of 3 to 4 months for peak concentrations between wells at depths of 22 and 26 ft, then at Wenham there may be a much longer time between the time the chloride reaches the water table and the time it reaches the well screens. The minimum travel time from application of de-icing chemicals to the highway and their appearance in the Wenham test wells is 6 to 12 months.

The rate at which chloride contamination moves is illustrated (Fig. 5) by changes in the concentration of chloride in samples from a Reading municipal well, which is located about 1,100 ft from a salt storage pile. The aquifer in which the well is screened apparently extends beneath the salt storage pile. Salt was first stored at Reading in 1959, the year the well was installed. From 1959 to 1966, large quantities of salt were stored outdoors, where precipitation could dissolve the salt and carry it downward to the water table. The salty groundwater moved through the aquifer from the storage area to the well in about 6 years or at a minimum rate of about 200 ft per year. This movement is probably much faster than at the test sites because the natural hydraulic gradient is increased by pumping in the vicinity of the wells.

Since 1967, when the salt pile was covered, the concentration of chloride has continued at a gradual increase. It will probably be several years before the salty water has passed the vicinity of the wells or is pumped from the aquifer, and the concentration will decrease significantly.

Figure 1. Amount of de-icing salts applied on state highways in Massachusetts.

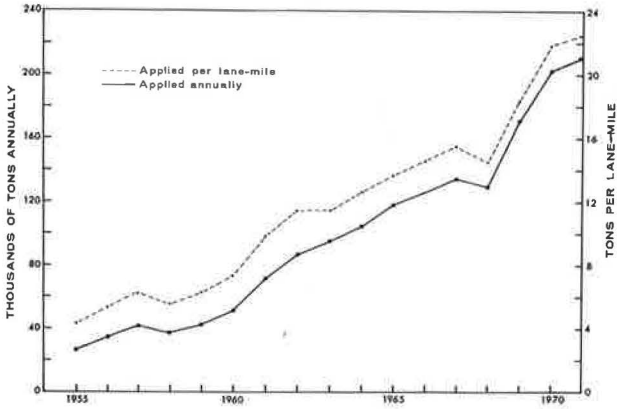


Figure 2. Cross section of test wells in Chelmsford, Massachusetts.

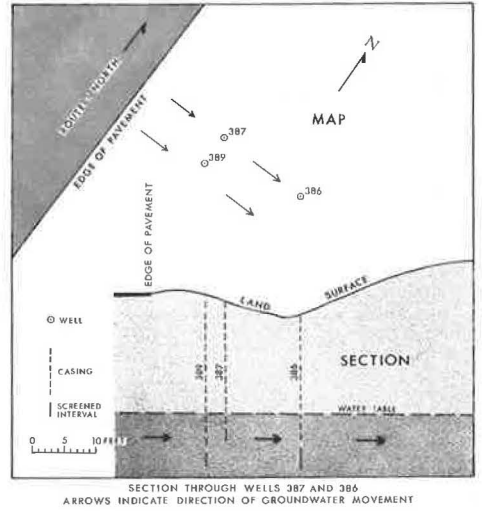


Figure 3. Chloride concentration in samples from Chelmsford wells.

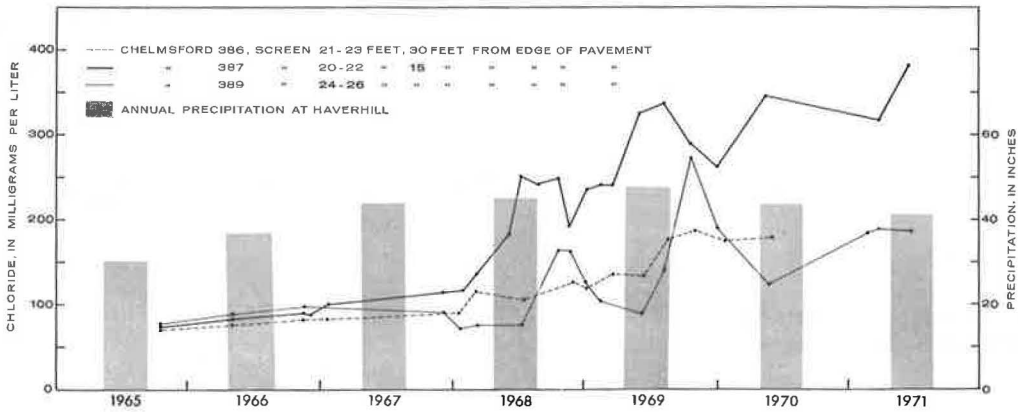


Figure 4. Chloride concentration in samples from Wenham wells.

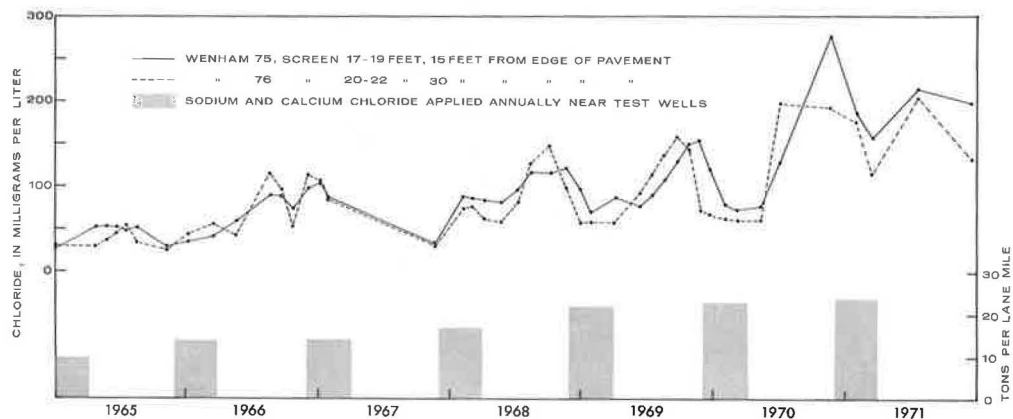


Figure 5. Chloride concentration in samples from Reading municipal well.

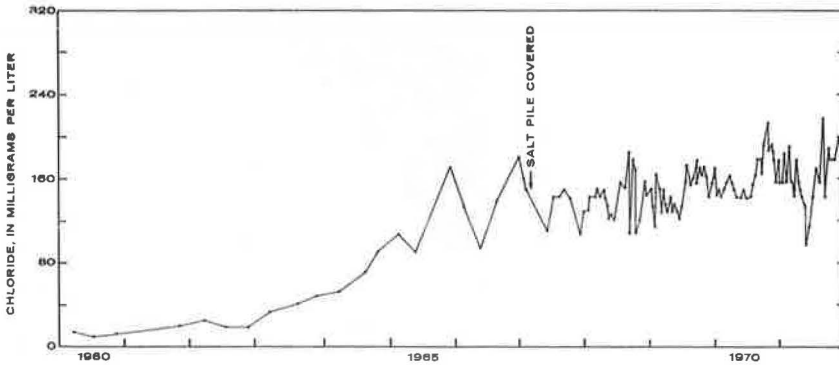


Figure 6. Chloride concentration in samples from main pumping station in Burlington.

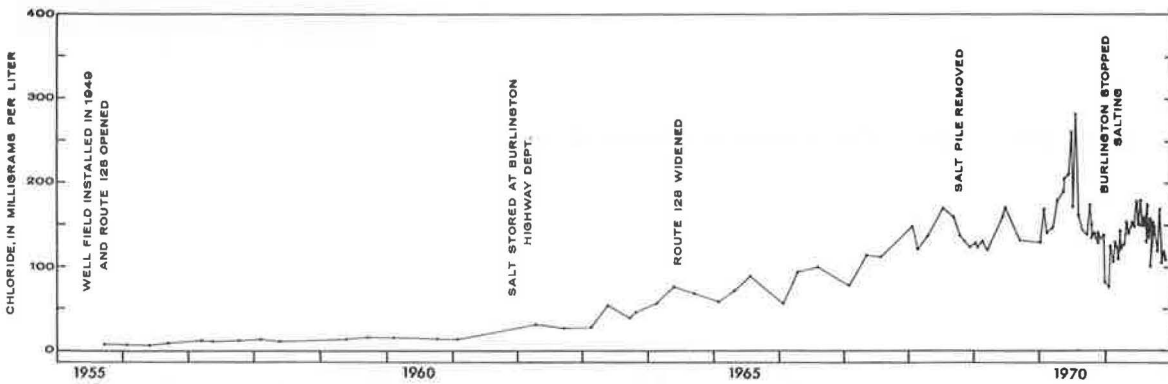
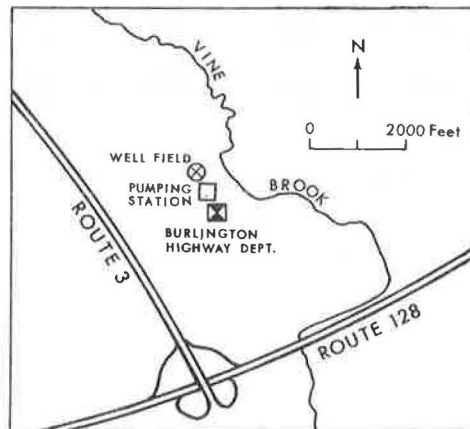


Figure 7. Location of main pumping station in relation to well field and Burlington Highway Department.



Increasing concentration of chloride (Fig. 6) has also been observed at the main pumping station in Burlington. This station pumps from a group of 70 interconnected wells in sand and gravel. In 1949 the well field was installed, and Mass-128, approximately 3,500 ft upgrade from the well field, was opened (Fig. 7). In 1961, when the Burlington Town Highway Department began storing salt, uncovered, approximately 400 ft upgrade from the well field, the concentration of chloride in water from the well field was less than 15 mg/liter. The concentration of chloride began to increase notably in 1963 during a period when sources of salt included that applied to Mass-3 and Mass-128, applied to town streets, and stored at the Burlington Highway Department. Remedial measures by Burlington included construction of a salt storage shelter in 1968, when the concentration of chloride reached 170 mg/liter, and banning the use of de-icing chemicals on town streets in 1970, when the concentration of chloride exceeded the 250 mg/liter upper limit recommended by the U S. Public Health Service.

To answer some of the problems associated with the release of highway de-icing chemicals in the environment requires more factual information on the dispersion of the chemicals after application to the highway. Toward this end, the U.S. Geological Survey, in cooperation with the Massachusetts Department of Public Works, in 1970 expanded its study of highway de-icing chemicals in the hydrologic environment.

One aspect of the study is to determine how much of the de-icing chemicals leaves the application site via surface runoff. Specific-conductance recorders have been installed at stream-gauging sites near highways. Analysis of water samples for chloride will be made to establish a relationship with specific conductance and the chloride load in the stream calculated from concentration and discharge. Kunkle (1) calculated that as much as 90 percent of salt applied to roads in a small drainage basin in Vermont leaves the basin in surface runoff.

Six sites will be selected for monitoring the movement of de-icing chemicals in the ground and will include a variety of hydrologic conditions and highway management practices. Fourteen wells will be installed at each site, at several depths, at distances ranging from 15 to 1,000 ft from the highway. At first, these wells will be sampled monthly and more or less frequently later, as determined by the results. The rate of application of de-icing chemicals and snow removal practices for each test site will be documented by the Massachusetts Department of Public Works.

Each of the test sites will provide data useful for analysis and understanding of the factors that influence the migration of de-icing chemicals under field conditions. From this information, it is anticipated that more knowledgeable decisions can be made regarding the following:

1. Location of highways to avoid areas of greatest potential danger to water supplies and the environment,
2. Design of highway drainage systems to divert de-icing chemicals along the least hazardous route,
3. Selection of optimum application rates of de-icing chemicals to ensure adequate de-icing with minimum deterioration of water supplies, and
4. Prediction of maximum or minimum effect on the environment under various conditions.

ACKNOWLEDGMENT

The authors gratefully acknowledge the cooperation of the Massachusetts Department of Public Works, Research and Materials Division. Special acknowledgment is given to John Lyons, Research and Materials Engineer, and Leo Stevens, Environmental Test Engineer. Acknowledgment, also, is given Francis Carr, State Snow and Ice Control Engineer, Massachusetts Department of Public Works, for supplying data on snow and ice control operations throughout Massachusetts.

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