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Estimate of National Use of Aircraft- and Airfield-Deicing Materials

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CH2MHILL
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Project Panel

Our Project team would like to thank the members of the Project Panel for providing the opportunity to work on this important project.

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Airport Representatives

The project team would also like to thank the following airport representatives, who provided data and information valuable to the development of this document:

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ACRONYMS AND ABBREVIATIONS

ACAIS	Air Carrier Activity Information System
ACRP	Airport Cooperative Research Program
ADF	aircraft deicing fluid
ANC	Anchorage International Airport
BMP	best management practice
BOD	biochemical oxygen demand
CWA	Clean Water Act
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
NCDC	National Climatic Data Center
NPDES	National Pollutant Discharge Elimination System
PCS	Permit Compliance System
POTW	publicly owned treatment works
RAD	Reach Address Database
SAE	Society of Automotive Engineers
SIC	Standard Industrial Classification
TMDL	Total Maximum Daily Load
UAF	Unit Application Factor
WATERS	Watershed Assessment Tracking and Environmental Results

SECTION 1

INTRODUCTION

Introduction

The CH2M HILL research team was contracted by the Airport Cooperative Research Program (ACRP) to develop a national assessment of aircraft and pavement deicer use and describe the extent of existing Clean Water Act regulatory requirements that directly regulate potential discharges of runoff from that use.

Nature of the Problem

There is a significant amount of ongoing work (government and private) that involves some aspect of addressing potential environmental impacts associated with the use of airfield and aircraft deicers. For the most part, however, none of this work assesses or characterizes the total use of deicing materials. In 2000, the U.S. Environmental Protection Agency (EPA) published a study that relied upon limited data it had collected (scaling that to the industry at the time) and concluded that perhaps 35 million gallons of working strength aircraft deicing and anti-icing fluids where applied annually in the United States (EPA, 2000). Despite the fact that airports and other industry experts have questioned the accuracy of this value, nobody has collected appropriate data and performed a robust analysis, which in part would substantiate or rebut EPA's estimate. In addition, EPA's previous work did not include airfield pavement–deicing materials, which contribute to airport stormwater discharges.

The current investigation was initiated by ACRP to provide the airport industry with a key tool for future research by developing a robust estimate of what potential deicing chemical use may be today and how it may vary by geographic location or seasonal weather characteristics. In addition, ACRP sought to summarize information on the existing Clean Water Act regulatory programs that directly address the potential discharge of deicing runoff because full implementation of these existing programs has the potential to greatly reduce the potential environmental impacts of these discharges.

Structure of This Report

The following sections of this report are organized as follows:

- Section 2. Estimate of Current National Aircraft and Airfield Deicer Use
- Section 3. Existing Regulatory Requirements
- Section 4. Summary and Conclusions
- Section 5. References Cited

Comprehensive data tabulations and descriptions of technical analyses are presented in Appendices.

SECTION 2

ESTIMATE OF CURRENT NATIONAL AIRCRAFT AND AIRFIELD DEICER USE

Introduction

The objective of this analysis was to evaluate deicer use at airports where regularly scheduled commercial air carrier operations are conducted. The criterion selected for identifying this population of airports was possession of a Part 139 Certification, which is required for airports that (14 CFR Part 139):

- Serve scheduled and unscheduled air carrier aircraft with more than 9 seats, and
- The Federal Aviation Administration (FAA) Administrator requires to have a certificate.

Military aircraft–deicing operations were explicitly excluded from the analysis because no use data were available for those activities. Military aircraft operations are significantly different from commercial operations, and extrapolation using unit application factors (see below) based on commercial carrier deicing data would be inappropriate.

Data used in this analysis are limited to the 2002-2003, 2003-2004, and 2004-2005 deicing seasons, to be consistent with the three deicing seasons for which EPA collected data for their 2006 Airport and Airline Deicing Questionnaires. The deicing season was assumed to extend from October through April, and the data analysis reflects just these months within each deicing season. Airports represented here are believed to encompass most (i.e., over 99 percent) of deicing operations within the United States.

Data Collection

Data collection efforts spanned a range of sources, reflecting the diverse types of data sought for the analysis. Information on basic airport characteristics was obtained from the following sources:

- FAA's Airport Data (5010) and Contact Information web page provided a list of 480 Part 139 certificate holders, average annual operations, contact information, and the location (latitude/longitude) of each airport used in the spatial analysis. (http://www.faa.gov/airports_airtraffic/airports/airport_safety/airportdata_5010/).
- FAA's Air Carrier Activity Information System (ACAIS) provided information on the hub type and service level for most of the airports in the analysis. Hub type categories were large, medium, small, and nonhub. Service types included primary, commercial service, and general aviation.
- FAA staff provided total monthly operations data for 494 airports from 2003 through 2005 by operator type, including air carrier, air taxi, general aviation, military, local military, and local general aviation.

- The National Climatic Data Center (NCDC) website provided annual snowfall totals (in inches) for locations near most of the airports in the analysis (http://www.ncdc.noaa .gov/oa/climate/online/ccd/snowfall.html).

Deicer use data were obtained from the following sources:

- EPA Office of Water, Engineering and Analysis Division, staff provided copies of responses to their 2006 Airport Deicing Questionnaire. These data included responses from 150 airports, 78 of which reported some types and amounts of pavement-deicing materials used during one or more of the three deicing seasons (2002–2003, 2003–2004, and 2004–2005).
- Aircraft deicing and anti-icing fluid use data was collected through three primary sources: (1) existing data within the project team's libraries and databases; (2) responses to an ACI-NA request to its membership for aircraft deicer data to be shared with the project team; and (3) direct outreach by the project team to airports deemed critical to project objectives. The use data were requested to be broken out into SAE Type (i.e., Type I and II/IV), glycol type (i.e., propylene and ethylene glycol), and reporting concentration (i.e., as applied, concentrated product, or pure glycol).

The three-letter FAA airport designation was used as the "primary key" to associate airport-specific information within the project database. A list of airport codes, their full names, hub type, average annual snowfall, and average annual deicing season operations are provided in Appendix A.

Data Analysis Methods

Airports with Deicing Operations

A cutoff of 9,000 commercial operations per year was chosen as the threshold for including airports in the analysis. This threshold was based on a combination of data availability on very small airports and professional judgment of the research team regarding the size of airports with potentially significant deicing operations. For comparison, in a previous evaluation EPA concluded that "airports with less than 10,000 total operations per year perform an insignificant number of aircraft deicing/anti-icing operations and, therefore, use minimal amounts of ADF [aircraft deicing fluid]" (ERG, 2000). The two criteria are roughly equivalent, especially when it is considered that EPA's threshold included military operations, whereas the current investigation does not.

Two hundred and sixty-eight U.S. airports were identified as being Part 139 Certificate holders with average annual operations above the 9,000 operations per year threshold. A subset of these airports was identified as being likely to actually conduct deicing operations, based on an airport meeting one or more of the following criteria:

- Provided the research team with a nonzero estimate of annual aircraft glycol use for any of the three deicing seasons examined;
- Reported nonzero annual pavement deicer use for any of the three deicing seasons examined;

- Located in an area with an average annual snowfall greater than zero; and
- Located near other airports where deicing operations are conducted or within regions where deicing operations are typically conducted.

A total of 210 airports met one or more of these criteria and were included in subsequent analyses.

Operations Data

Operations data are classified by FAA into four basic categories: air carrier, air taxi, general aviation, and military.[1] Only air carrier and air taxi operations were considered in the analysis. These two categories encompass virtually all commercial passenger and cargo aircraft operations. General aviation operations, which typically avoid flying during winter weather events and are often hangared, were excluded because they are considered to be insignificant users of deicing fluids. Military aircraft operations were also excluded for reasons mentioned in the introduction to this section.

Available Aircraft and Pavement Deicer Use Data

Figure 2-1 shows the locations of the 268 Part 139 Certificate holder airports, the nature of aircraft and pavement deicer use data that were available (shown in degrees of shading), and the average number of deicing season operations (indicated by the size of each airport's circle). It should be noted that Figure 2-1 includes many airports in southern regions where the absence of deicer use data reflects the absence of deicing operations.

Aircraft deicer use data were obtained from 74 airports, including most of the larger airports in the United States. The use data were reported in various forms and then normalized to gallons of pure propylene and ethylene glycol used at each airport during each deicing season. The average reported total annual glycol use for the three seasons was used as the basis for most of the analyses in this study.

Pavement deicer use data were obtained for 45 airports. Use was reported in terms of amount applied per deicing season for the products and materials approved for use on airfields, including urea, potassium acetate, sodium acetate, sodium formate, ethylene glycol–based fluids, propylene glycol–based fluids, and sand.

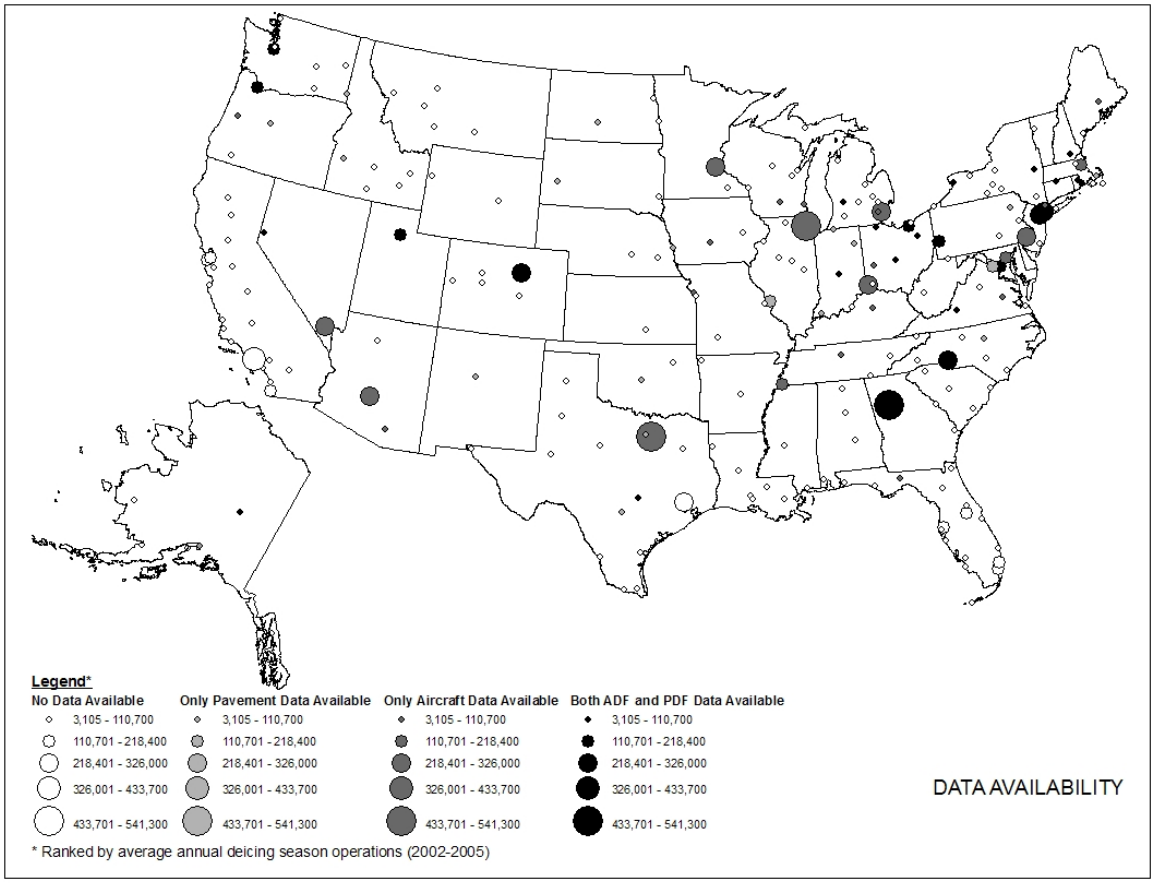
Analysis of Pavement Deicer Use

The analysis of pavement deicer use data was constrained by the fact that data were not available from the entire population of airports. Pavement-deicing practices vary significantly from one airport to the next. For example, two airports in the same region may have similar levels of deicing season operations, but site-specific factors such as airfield configuration and airfield maintenance preferences can result in selection and use of entirely different pavement-deicing products. Thus, it would be inappropriate to extrapolate data to airports for which no data were available. As a result of these considerations, the analysis of

[1] These categories are described in FAA ORDER JO 7210.3V, "Facility Operation and Administration" (February 14, 2008). http://www.faa.gov/airports_airtraffic/air_traffic/publications/atpubs/fac/INDEX.htm

pavement deicer use was limited to the characterization of reported use from the EPA survey data set.

FIGURE 2-1
Availability of Deicer Use Data from 268 Part 139 Certificate Holder Airports



Estimation of Aircraft Deicer Use

Actual reported aircraft deicer use data were used wherever available to estimate average annual glycol use for individual airports.

A method was sought to estimate total average annual glycol use for the airports where data were not available. The initial investigation focused on trying to identify "off-the-shelf" climatology protocols or products that could be used to characterize geographic areas with similar intensities of aircraft- and airfield-deicing requirements. The intent was to use this information to develop and apply a methodology for correlating meteorological parameters such as temperature and precipitation with the magnitude of deicer usage at airports. After extensive research and personal communications with the top experts in the United States on aircraft icing, airline industry winter operations, and icing climatology, it was determined that an existing product to meet this project objective does not currently exist, and that significant effort beyond the resources of this project would be required to develop

such a methodology. The details of the investigation into a meteorological protocol are presented in Appendix B.

In the absence of an existing meteorological protocol to estimate total average annual glycol use for the airports where data were not available, a modified version of the Fluid Use Factors method was employed (ERG, 2000). For the current analysis, FAA hub type was used to classify the scale of operations, and total annual snowfall was represented by categories similar to those used in the ERG analysis, except a larger number of snowfall categories was defined and it was assumed that deicer usage at any airport with less than 0.1 inch of average annual snowfall would be insignificant for the purposes of this investigation. The resulting coefficient describing glycol usage as a function of deicing season operations is called the Unit Application Factor (UAF). Full details of the computational derivation of the UAFs are provided in Appendix C-1.

Table 2-1 presents the UAFs developed for each hub type–snowfall code combination. It should be noted that there were no usage data available for some of the hub–snowfall combinations, so the factors from adjacent combinations were assigned as reasonable estimates. The estimated UAFs and the UAFs on which the estimations are based are shaded; the estimated UAFs are footnoted.

TABLE 2-1
Unit Application Factors

Snowfall		Hub Type			
Code	**Range (Inches)**	**Large**	**Medium**	**Small**	**Non**
1	> 60	2.37 *n* = 1 s.d. = n/a	3.00 *n* = 2 s.d. = 0.439	2.40 *n* = 3 s.d. = 0.504	2.40[a]
2	30.0–59.9	2.43 *n* = 4 s.d. = 1.00	2.83 *n* = 6 s.d. = 2.83	1.22 *n* = 4 s.d. = 0.861	1.22[a]
3	15.0–29.9	1.44 *n* = 6 s.d. = 0.182	1.41 *n* = 3 s.d. = 0.307	1.20 *n* = 3 s.d. = 0.408	0.40 *n* = 1 s.d. = n/a
4	1.0–14.9	0.16 *n* = 4 s.d. = 0.048	0.24 *n* = 5 s.d. = 0.219	0.16[a]	0.16[a]
5	0.1–0.9	0.07[a]	0.07 *n* = 1 s.d. =n/a	0.07[a]	0.07[a]

s.d., standard deviation.
[a] Estimate based on others in snowfall group.

The UAFs in Table 2-1 were multiplied by the average deicing season operations to obtain an estimated average annual glycol usage for each airport where usage data were not available.

Estimation of Uncertainty on Aircraft Deicer Usage

An estimate of the uncertainty in the national average annual glycol usage calculation was developed using standard statistical methods, as described in Appendix C-2.

Results

The results of the analyses are presented separately for pavement and aircraft deicer usage.

Pavement Deicer Usage Results

Table 2-2 summarizes the pavement deicer usage data for the three deicing seasons examined during this investigation; Appendix D lists all the data.

TABLE 2-2
Summary of Reported Airfield Pavement Deicer Usage

	2002–2003		2003–2004		2004–2005	
Pavement Deicer	**Airports Reporting Usage (*n* = 74)**	**Total Amount Reported**	**Airports Reporting Usage (*n* = 77)**	**Total Amount Reported**	**Airports Reporting Usage (*n* = 77)**	**Total Amount Reported**
Urea (lbs)	24	5,909,148	26	7,611,376	26	8,054,134
Potassium acetate (gal)	60	6,913,639	63	6,051,737	64	5,897,977
Sodium acetate (lbs)	21	8,315,269	21	7,086,107	25	7,353,266
Sodium formate (lbs)	9	650,883	9	690,813	9	549,073
Ethylene glycol–based fluids (gal)	3	410,269	3	175,828	3	279,997
Propylene glycol–based fluids (gal)	9	2,824,126	9	3,238,526	10	9,636,565
Sand (lbs)	43	78,240,700	44	59,858,917	46	58,890,027

The following observations may be drawn from the pavement deicer usage data:

- Potassium acetate–based products were used by about 82 percent of the airports included in the EPA survey that reported any pavement deicer usage.
- Sand, although it is not technically a deicer, was used by approximately 58 percent of the respondents who reported pavement deicer usage as part of their toolkit of products used to maintain safe airfield wintertime operations.

- Urea was being used by about one-third of the airports that reported any deicer usage.
- Relatively few of the airports in the EPA survey used glycol-based pavement deicers.

Because there are particular concerns about the potential environmental impacts of urea in stormwater runoff, the distribution of urea usage was examined by airport hub category (Table 2-3). The distribution of the urea usage among the hub size categories varies between the deicing seasons. In any season, more than 80 percent of the urea usage is accounted for by five or six airports covering the spectrum of hub sizes. As might be expected, the greatest individual use was reported by large and medium hub airports. It should be noted that the *n* count in Table 2-3 represents the total number of airports in that hub category that reported urea usage during any of the three deicing seasons; some airports did not report urea usage in all seasons examined.

TABLE 2-3
Distribution of Pounds of Urea Used by Hub Size Categories (Percentage of Deicing Season Total)

	Season		
Hub Size	**2002–2003**	**2003–2004**	**2004–2005**
Large (*n*=4)	391,850 (7%)	2,486,050 (33%)	1,244,400 (16%)
Med. (*n*=6)	2,458,950 (42%)	1,438,750 (19%)	3,940,250 (49%)
Small (*n*=9)	1,686,148 (29%)	2,347,611 (31%)	1,295,404 (16%)
Non (*n*=9)	1,372,400 (23%)	1,338,965 (18%)	1,574,080 (20%)
Total	**5,909,148**	**7,611,376**	**8,054,134**

It should also be noted that a few airports reported using ethylene or propylene glycol-based pavement deicers. Some of these glycol-based products contain urea, although the available data do not allow an estimate of this potential additional use of urea.

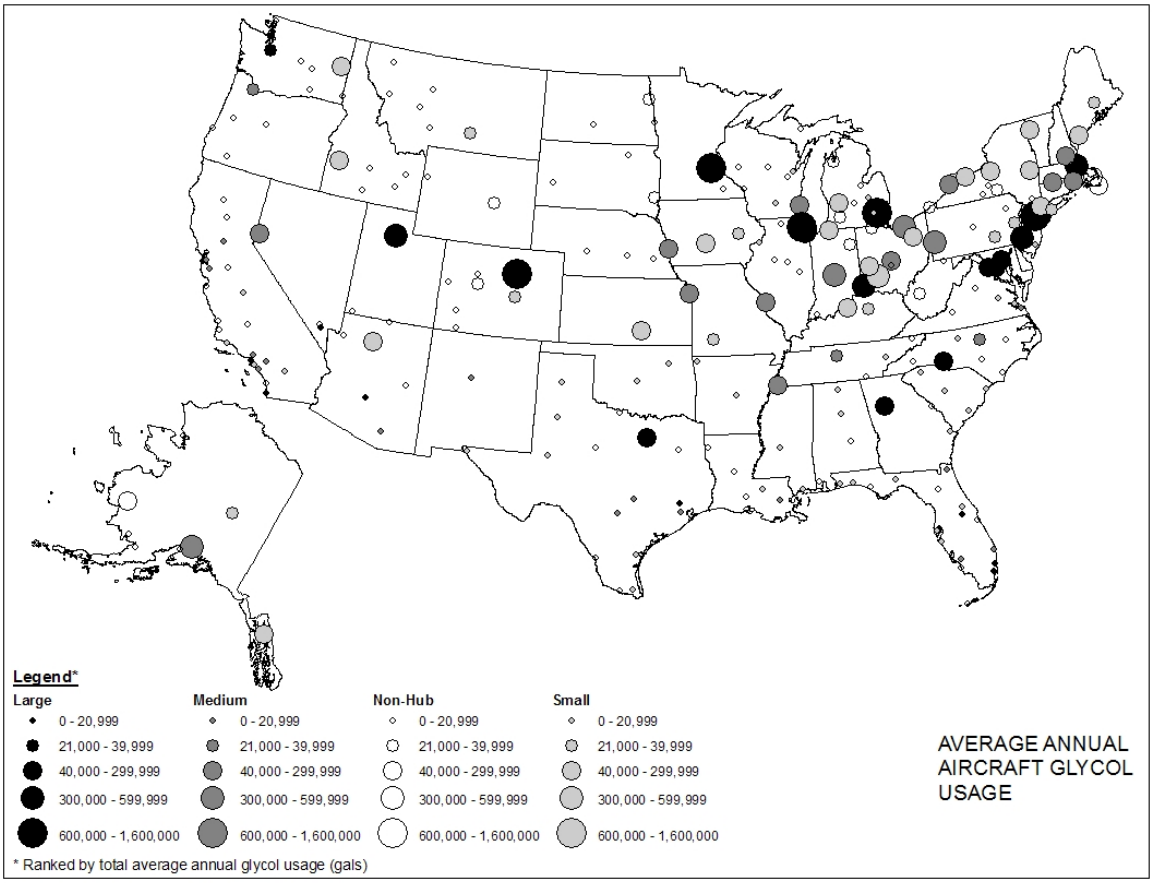
Aircraft Deicer Use Results

Appendix E summarizes relevant operational and other characteristics for the 184 airports with likely deicing operations identified in this analysis. The airports are ranked in order of estimated average annual glycol use. Figure 2-2 shows the geographic distribution of estimated average annual glycol use at airports across the United States.

The data analysis yielded an estimated average of approximately 15,103,044 gallons of pure glycol (propylene and ethylene) being used annually for aircraft deicing and anti-icing operations at 184 airports in the United States. Of this total, approximately 12,019,032 gallons (or 80 percent) is based on actual reported-use data; only 20 percent of the national total was based on estimation using the UAF approach. Uncertainty analysis indicates upper and lower 99 percent confidence intervals of approximately 13,909,444 gallons and 16,296,643 gallons, respectively, for this estimated national average. Based on the reported use data for 2003–2004 and 2004–2005, approximately 10 percent of total average annual glycol use is ethylene glycol–based fluids. The ethylene glycol use for 2002–2003 was

significantly lower than these subsequent two seasons, at approximately 6 percent of the total.

FIGURE 2-2
Geographic Distribution of Annual Average Aircraft Deicing Glycol Use



The relative contribution of airports by size to total glycol use is shown in the distribution of use among hub size categories (Table 2-4). Large- and medium-hub airports represent approximately 80 percent of the total national average annual glycol use.

TABLE 2-4
Distribution of Average Annual Aircraft Deicer Glycol Use Among Hub Size Categories

Hub Size	Total Glycol Use (Gallons)	Fraction of National Total (%)
Large	8,655,239	57
Medium	3,412,824	23
Small	2,117,407	14
Non	917,574	6

Figure 2-3 presents individual and cumulative distributions of average annual glycol use estimates for all airports with predicted glycol use, ranked from highest to lowest. Upper and lower 99 percent confidence intervals are shown for the cumulative use estimates. It can be seen from this figure that 30 airports represent approximately 12,000,000 gallons (or about 80 percent) of all aircraft deicer glycol use in the nation.

FIGURE 2-3
Ranked Individual and Cumulative Average Annual Glycol Use for 184 Airports Where Aircraft Deicing is Conducted

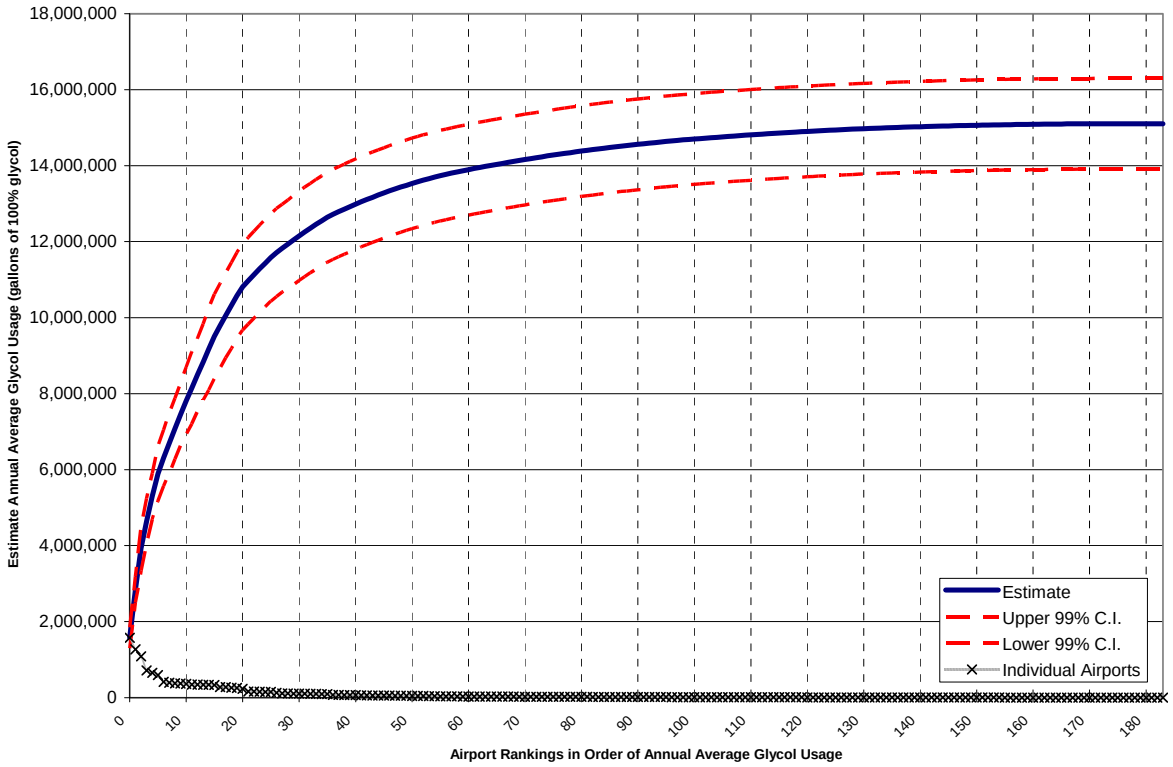
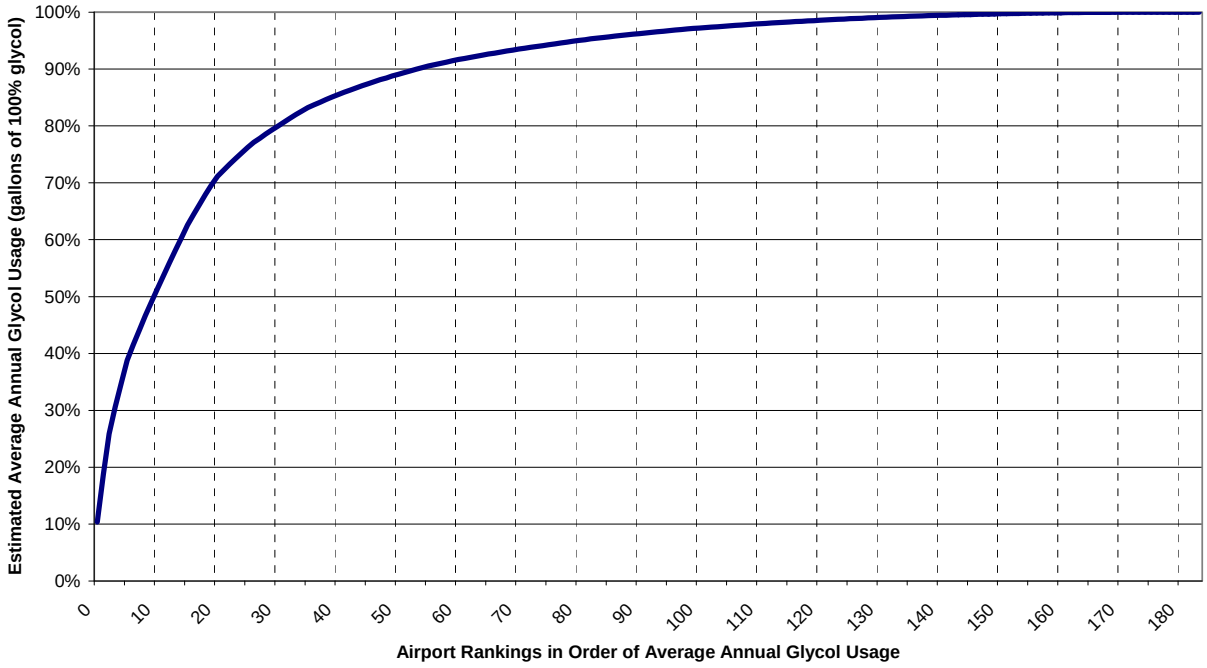


Figure 2-4 provides additional insight into the percent contribution of each airport to the national average total annual estimate. For example, the top 10 deicing airports account for approximately half of all glycol used for aircraft deicing in the nation. The diminishing contribution of smaller airports is illustrated by the observation that approximately one-third of the airports in the analysis account for about 92 percent of the total annual glycol use.

FIGURE 2-4
Ranked Cumulative Percent Contribution from 184 Airports to the Total National Average Annual Glycol Use



SECTION 3

EXISTING REGULATORY REQUIREMENTS

The objective of this component of the project was to identify and describe the various environmental regulatory mechanisms currently in place to control the impacts of deicing-runoff discharges on the environment. This identification effort focused on the National Pollutant Discharge Elimination System (NPDES) permit and total maximum daily load (TMDL) programs.

Regulatory Drivers

The following discussion identifies and describes the various Clean Water Act regulatory mechanisms that control or limit the discharge of pollutants to the environment associated with deicing-related runoff. The major program that limits pollutant discharges from regulated sources is the National Pollutant Discharge Elimination System (NPDES) permit program. In addition, the Clean Water Act requires that total maximum daily load (TMDL) limitations supplement or enhance the NPDES permit program for certain "impaired" waters. This following overview of these two Clean Water Act programs will help provide some context relative to efforts to assess the impacts of existing and future controls that prevent deicing-related pollutants from reaching the nation's waterways.

Federal Acts Affecting Airport Water Quality Regulations

The CWA Section 402 creates a permitting system, known as the NPDES program, through which all facilities that discharge pollutants from a point source into a water of the U.S. must obtain a permit. The terms "pollutant," "point source," and "waters of the U.S." are all very broadly defined. Point source discharges include, for example, those from publicly owned treatment works (POTWs), those from industrial facilities, and those associated with stormwater runoff.

Pollutant contributions to U.S. waters may come from direct or indirect sources. Direct sources discharge pollutants directly into receiving water bodies. Indirect sources discharge pollutants to POTWs, which in turn discharge into receiving water bodies. NPDES permits are issued only to directly discharging facilities, while indirect discharges are regulated by the CWA's National Pretreatment Program. Airports and individual lease holders may have NPDES direct discharge permits for stormwater or for discharges of other industrial wastewaters that flow directly to receiving water bodies.

There is an additional regulatory program that pertains to airports that capture deicing operation runoff for treatment or recycling (or that have other onsite operations that generate wastewater that is captured and sent to POTWs). These facilities may have pretreatment permits or agreements with their local POTW for handling those wastewaters sent for treatment through the sewer. This regulatory program is not of specific relevance to the current analysis, but is mentioned for completeness.

It should be noted throughout these discussions that the airport operator generally will be held responsible for compliance with limitations on discharges that leave the airport property. However, this responsibility may be shared with aircraft operators and other tenants through facility-specific arrangements that include these parties as co-permittees, or otherwise establish formal responsibilities.

Federal Stormwater Program

Currently, there are three main categories of regulated stormwater discharges: industrial, municipal, and construction. EPA includes within the term "industrial" a variety of discharges, most of which are designated by narrative descriptions and Standard Industrial Classification (SIC) codes, including SIC code 45, "transportation facilities" that conduct vehicle maintenance, equipment cleaning, or airport deicing operations (40 CFR part 122.26(b)(14)(viii)). The industrial stormwater program regulates only those discharges associated with industrial activity and those otherwise unregulated stormwater discharges that are commingled with those industrial stormwater discharges.

Neither the construction nor the municipal stormwater programs focus on aircraft deicing. Hence, our focus here is on EPA's NPDES industrial permit program.

Implementation of Regulations in Different Types of Airport Discharge Permits

The NPDES permit program is implemented through two types of permits. The permitting authority may develop broader permits that allow specified groups of regulated entities to obtain NPDES permit coverage—"general" permits — or permits can be issued directly to the facility that discharges pollutants to U.S. waters—an "individual" permit. The following discussions describe these two permitting devices.

General Industrial Stormwater Permits Because of the volume of regulated entities subject to the stormwater program, EPA has used general permits to ease its administrative burden, and states have followed suit. General permits are issued for specific groups of regulated entities and thus must be drafted rather generically to ensure that they are applicable to as many of those entities as possible. General permits go through a notice and comment rulemaking process and once completed, facilities that wish to comply with the general permit typically must file a Notice of Intent (NOI) form that certifies that the permittee will comply with the terms and conditions contained in the permit.

EPA's current general permit covering airport industrial stormwater discharges is the Multi-Sector General Permit (MSGP), which was promulgated in 1995 (and revised in 2000). [Note that a revised MSGP 2008 should be promulgated by the time of this document's publication.]

EPA developed the "air transportation" portions of the MSGP predominantly from information submitted through the AAAE Group Stormwater Permit Application in the early 1990s. Although authorized states retain discretion regarding their own general permitting approaches, (providing they meet minimum NPDES requirements), many states have adopted general permits based on EPA's MSGP, particularly with regard to airport discharges.

Individual Industrial Stormwater Permits Unlike general permits, individual permits are tailored to the actual activities occurring at the site and require a thorough analysis of site-specific conditions. For this reason, individual permits are preferred by some regulators over general permits for complex facilities or where specific environmental concerns exist. While EPA and most states have developed general permits that are broadly applicable to industrial stormwater discharges, one departure from this trend has been with regard to major hub airports, specifically due to their complexities. Several states prohibit complex sites, including some larger airports, from seeking coverage under the state's general permit, requiring instead that such sites obtain individual permits.

There are several fundamental differences in the development of general vs. individual permits. General permits tend to provide more narrative approaches to fundamental permitting issues (for example, compliance with water quality standards and implementation of BMPs). Individual permits require a two-part analysis that first mandates implementation of appropriate technology standards (typically BMPs in stormwater permits) and next requires that the permit writer assess receiving water bodies and determine if additional compliance requirements should be imposed to maintain water quality standards. Airports that discharge to smaller, more-sensitive water bodies will generate the more-stringent analyses and requirements (larger water bodies generally assimilate conventional pollutants that are discharged from airports—including BOD and total suspended solids (TSS)—with less chance of impacting water quality of those water bodies). These requirements may be expressed as numeric limits either on the concentrations or mass loadings associated with the discharges, or in the alternative as performance metrics associated with the deicing runoff control system (for example, percent of total applied deicers either collected and treated, or contained in permitted discharges).

Either general permits or individual permits may allow airports to include major tenants as "co-permittees." Whether to include such tenants as co-permittees, cover tenant operations through the airport's permit without co-permittee status, or require tenants to obtain their own permits is an airport-specific decision. In both individual and general permit scenarios, airports may have to engage and manage significant interactions with tenants to ensure that appropriate controls are in place, are functioning, and lead to permit compliance. This may require relatively detailed collaboration with regard to the airport's stormwater pollution prevention plan, deicing runoff management plan, and other compliance mandates in the permit.

In sum, one could argue that individual stormwater permits issued to airports generally would provide, at least incrementally, more specific and measurable protection for local receiving waters than general permits. For this reason, more weight may be given to those permits in this report's overall assessment of deicing usage and related environmental exposure.

Industrial Pretreatment Permits. Not all deicing runoff is discharged directly to waters of the U.S. via general or individual stormwater permits. Deicer-laden runoff may be collected and then sent to POTWs for treatment. POTWs are allowed to accept industrial waste along with sanitary waste provided they are designed to treat the type of wastewaters entering their systems and they comply with their own NPDES direct discharge permits. Industrial users (in this case, airports) must comply with the POTWs pretreatment regulations and cannot discharge pollutants that would "pass through" or "interfere" with the POTWs treatment

works. Again, this regulatory program is not addressed in the current analysis and mentioned here for completeness.

Total Maximum Daily Load (TMDL) Program Protections

The CWA also sets forth special requirements for pollutants that are discharged to "impaired" waters. States are responsible for determining whether any of its waters are "impaired" through a process in which it first assigns a "designated uses" for each water body or segment of a water body. The most common (and one of the more protective) "designated uses" is commonly referred to as "fishable/swimmable," because it requires both protection of human health as well as aquatic species. When a water body contains sufficient pollutant levels that it cannot meet its designated use, it is deemed to be "impaired" for whatever pollutant(s) prevents it from meeting its use.

States are required periodically to prepare and submit lists of "impaired waters" to EPA, and states must initiate efforts to ensure that the waters ultimately will meet their designated use (or actually change the use in special circumstances). In most cases, the CWA's TMDL program mandates that the state develop a program (or TMDL) that limits the total amount of the target pollutants discharged into the impaired water body. TMDLs specifically allocate the total allowable quantities of pollutant discharges to various regulated and unregulated sources.

Unlike the NPDES program, TMDLs set allocations not only for point source discharges (termed waste load allocations or WLAs), but also for non-point sources (termed load allocations). But because there are no direct regulatory mechanisms for forcing non-point sources to limit their discharges, such sources may end up consuming all of the allowable pollutant discharges, leaving zero allocations for NPDES permit holders. In any event, WLAs (whatever is left) then are allocated to point source discharges and incorporated into their NPDES permits. Hence, TMDLs can force regulated sources to meet more stringent permit standards than a similarly situated source on an unimpaired water body.

As is the case with other discharge restrictions contained in permits, TMDL restrictions may take the form of concentration or mass-based limits or performance requirements; or in certain circumstances, they can be expressed as BMPs. The latter are more commonly found in stormwater permits, like those that may be issued to airports. BMPs are particularly applicable when numeric limits are hard to calculate or justify. In any event, TMDLs help to serve as a useful tool for this report in assessing environmental exposure of pollutants found in deicing fluids because we can predict that waters listed by states as impaired for related pollutants eventually will drive airport discharge limits to ensure recovery of that water body.

Data Collection

Data collection consisted of the following:

- The EPA's Permit Compliance System (PCS) database was searched for information on airport permits and associated discharge compliance requirements. Existing project team files, knowledge, and professional networks were also employed to address gaps or inaccuracies in the database's coverage of airports known to perform deicing activities.

- A method was developed to identify airports within close proximity to water bodies either previously subject to TMDLs or on states' Impaired Waters (303(d)) lists, and thus subject to TMDL development. This included information on the nature of impairment and any identified potential sources.

Further details are provided below. The analysis was limited to the Part 139 certificate-holding airports that had been previously identified as being likely to have significant deicing operations.

NPDES Permits Issued to Airports

The EPA maintains numerous databases that are accessible through their Web site. One such database is the Permit Compliance System (PCS), which, according to the EPA, "…provides information on companies which have been issued permits to discharge waste water into rivers." Although the EPA uses the word "companies," note that municipal dischargers and other public-sector entities are included. Information available from this database includes the following:

- Facility name
- Geographic location
- Standard industrial classification
- Constituents limited in the discharge
- Permit issue date
- Permit expiration date
- Permitted discharge flow
- Monitoring data

There are some noteworthy limitations to the PCS system. First, the database is subject to the quality standards employed by each state's environmental regulatory agency. These agencies summarize the data and submit their summaries to the EPA. The methods used in preparing these summaries may differ among states. For example, a state may add extra digits to the basic permit number to denote a subcategory or other characteristic of importance. These additional digits, though, may cause the permit number to exceed the allowable size in the corresponding field in the EPA database. As a result, there can be significant variability among states in the completeness and accuracy of their reported information. Additional potential for error is introduced when the received data are combined and entered into the PCS database. Finally, the database is only as current as this data exchange and updating procedure occurs. As an example of the types of delays that may occur, the following is posted to the EPA's PCS query form: "As of June 6th, 2006, pending migration to a new system, the data for the Permit Compliance System (PCS) will remain frozen in Envirofacts for the following states: MA, NH, RI, VI, PR, DC, MD, IN, NM, UT, HI, AK, ID." In spite of these limitations, this database is the best available source for countrywide, existing discharge permits.

Through the PCS query form, the following queries were submitted to develop a list of the nation's commercial airports and any information associated with corresponding NPDES permits:

- Facilities with a Standard Industrial Classification (SIC) Code of 4581 (airports, flying fields, and airport terminal services);
- Facilities with an SIC Code of 4512 (air transportation, scheduled);
- Facility names containing the word "airport";

- Permits with ethylene or propylene glycol parameter codes associated with them; and
- Airport facilities known to have at least 10,000 total annual operations but that were not found in the above searches.

Once the initial compilation of permit information was developed, the information was reviewed to identify any questionable entries. All such entries were researched further to resolve the apparent discrepancy. This process revealed a number of PCS listings that were found to be in error, and the corresponding project database entries were updated to reflect the most accurate information.

Impaired Water Listings and Developed TMDLs

A method was sought to identify those airports that are subject to TMDLs. Unfortunately, there is no national list or database of dischargers associated with either 303(d)-listed waters or issued TMDLs. As an alternative, a GIS-based approach was developed to identify airports in close proximity to either a 303(d)-listed water body or a water body with an issued TMDL.

The EPA's Watershed Assessment Tracking and Environmental Results (WATERS) tool was employed to identify water bodies associated with an existing TMDL. To identify current 303(d)-listed waters, the EPA's Reach Address Database (RAD), a subset of the WATERS tool, was used. Note that, again, while these databases are the best available sources for this information, the information in these databases is neither necessarily complete nor up to date. These sources of information were supplemented with existing knowledge and queries using the WATERS Expert Query Tool. For example, the Ted Stevens Anchorage International Airport (ANC) discharges to a water body for which an official TMDL has not been developed. However, a Water Body Recovery Plan has been developed for this water body and, for the purposes of this investigation, is functionally equivalent to a TMDL.

To further reduce the list of potentially relevant water bodies, the identified water bodies were filtered to include only those where sources of impairment might be associated with deicing operations. The relevant sources of impairment consisted of the following database codes:

- Ammonia
- Ammonia-nitrogen
- Ammonia (unionized)
- Aquatic toxicity
- Biochemical oxygen demand
- Biological
- Biological oxygen demand
- BOD
- BOD_5
- CBOD
- Deicing agents
- Dissolved oxygen
- Dissolved oxygen saturation
- Low dissolved oxygen
- NH_3-N
- Nonpriority organics
- Organic enrichment/low dissolved oxygen
- Organics
- Oxygen demand
- Priority organics
- Propylene and ethylene glycols
- Total toxics
- Toxics
- Unionized ammonia
- Unknown toxicity

Location information for all Part 139 certificate-holding airports was obtained from FAA. A radial search was conducted using GIS to identify all such airports located within 3 miles of any water body that is either on the 303(d) list or for which a TMDL has been issued. The 3-mile radius was selected based on the assumption that an airport within this proximity to an impaired water body would be subject to regulatory scrutiny to ensure adequate environmental protection.

The result of the search is a list of airports with deicing operations located within three miles of a water body that is subject to an existing TMDL or on the current 303(d) list and slated for TMDL development, and where pollutants potentially associated with deicing operations have been identified as a concern.

Results

This section presents the results of the above analyses.

NPDES Permit Coverage of Deicing Discharges

Figure 3-1 presents the numeric distribution of types of NPDES permits authorizing stormwater discharges from airports with deicing operations; permit information was unavailable for almost half of the 184 deicing airports examined. An unusual observation occurred. One of these airports does not have an NPDES permit for surface water discharges because it does not discharge to a water of the state; all stormwater runoff is sent to a publically-owned treatment works (POTW). That airport's permit status has been defined as "none."

FIGURE 3-1
Distribution of NPDES Permit Types among 184 Deicing Airports

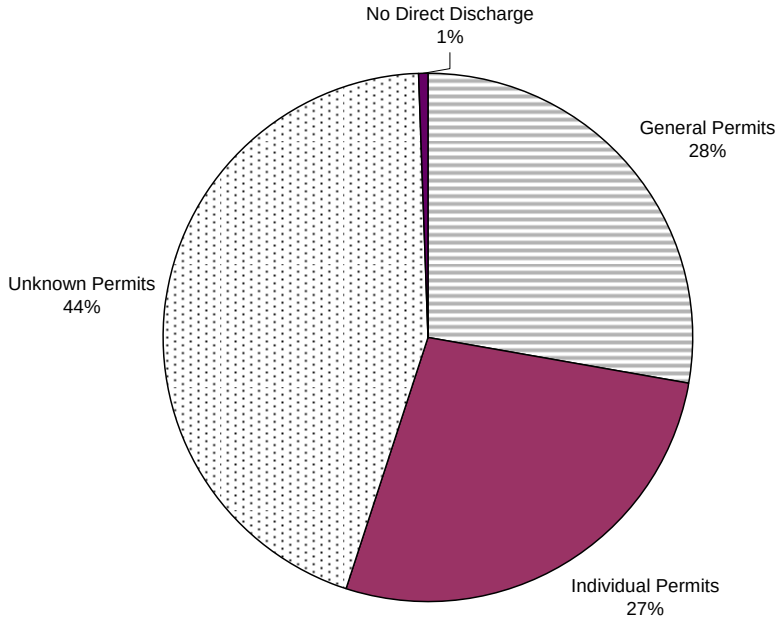


Figure 3-2 presents the geographic distribution of types of NPDES permits authorizing stormwater discharges from airports with deicing operations, along with estimated average annual total glycol use. It can be seen from this figure that most of the largest users of aircraft-deicing glycol discharge impacted runoff pursuant to individual NPDES permits.

Appendix E lists the NPDES permit type found for each airport along with the water quality parameters for which any numerical limits were found associated with each permit. Of those permits found with numerical limits, 33 percent specifically name biochemical oxygen demand (BOD) as a limited parameter. The next most common limited constituent is ammonia, found in 21 percent of the permits with any limits. Ethylene glycol, chemical oxygen demand, and dissolved oxygen cumulatively occur in 36 percent of the permits with effluent limits.

Table 3-1 presents the distribution of permit types further divided by airport hub size. All but one discharge from northern tier large hub permits are covered by individual permits (the exception is Ronald Reagan Washington National Airport), as are the majority of large- and medium-hub types.

FIGURE 3-2
Geographic Distribution of Permit Types among 184 Deicing Airports

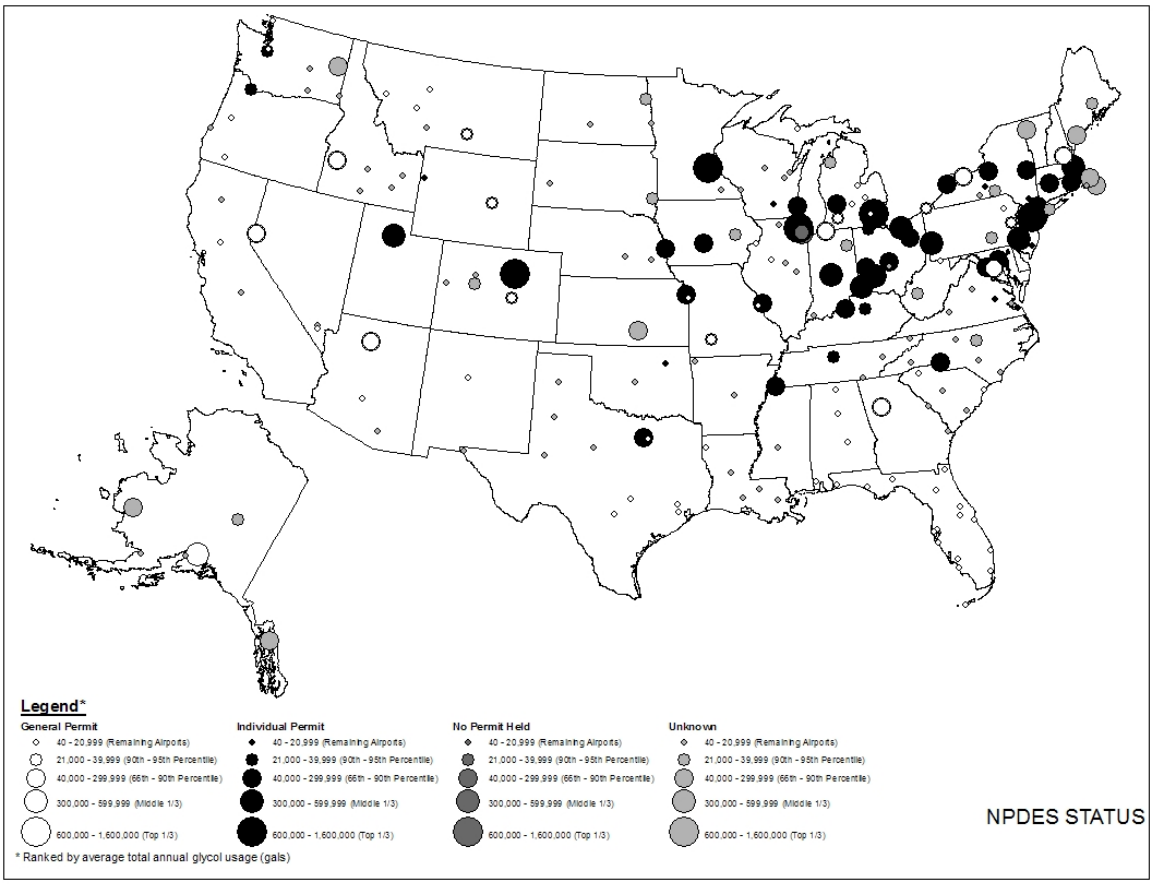


TABLE 3-1
Permit Type Versus Hub Type

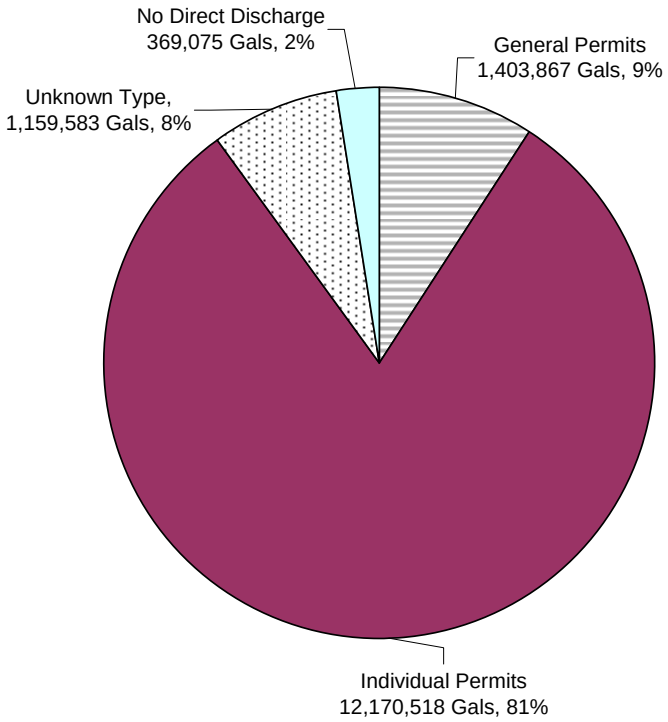
Hub Type	No. of General Permits	No. of Individual Permits	No. of Unknown Permit Type	No. without NPDES Permit	Total Glycol Use (gals)
Large	5	16	0	1*	8,655,239
Medium	10	15	3	0	3,412,824
Small	17	14	27	0	2,117,407
Non-	19	5	52	0	917,574

* Does not have an NPDES permit because there is no direct discharge to a water of the state.

Figure 3-3 presents total glycol use distributed among NPDES permit categories. The associated glycol use and percent of the total annual average glycol use are shown. Comparing Figures 3-1 and 3-3, it is apparent that, although the airports with individual permits only constitute 27 percent of the total permits, they represent roughly 80 percent of the total glycol use. Thus, the data indicate that the stormwater discharges affected by at

least 80 percent of the deicing glycol use in the country are controlled by individual NPDES permit requirements that have been developed specifically to protect the water quality of receiving waters. Although permit type was unidentified for 45 percent of the airports examined, these facilities represent only 8 percent of the total glycol use in the nation. Airports operating under general permits represent 28 percent of the permits and 9 percent of the total glycol use, and the remaining fractions are associated with the one deicing airport that does not have an NPDES permit because it does not discharge to a water of the state.

FIGURE 3-3
Distribution of Glycol Use Among NPDES Permit Types at Deicing Airports



Deicing Discharges Subject to the TMDL Program

A listing of airports with deicing activities that are likely to be subject to TMDL program regulation is contained in Appendix F. This listing includes the nature of the impairment(s) indicated by available data, as well as the potential source of impairment, if it is specifically mentioned in a TMDL.

Table 3-2 presents a summary of the distribution of airports subject to the TMDL program regulation among the two different conditions (i.e., 303(d) listed or TMDL issued) and hub sizes. It can be seen that about 44 percent of the total average annual glycol use in the nation is subject to regulation under the TMDL program.

Low dissolved oxygen issues are the most common type of impairment reported, with 16 of the 20 issued TMDLs and 25 of the 41 303(d) listed water bodies involving some sort of

oxygen-related impairment. Of the few listings with potential sources indentified, all included some mention of airport runoff. Toxicity, organics, and ammonia were the next most often found impairments.

TABLE 3-2
Distribution of Airport Subject to Regulation Under the TMDL Program

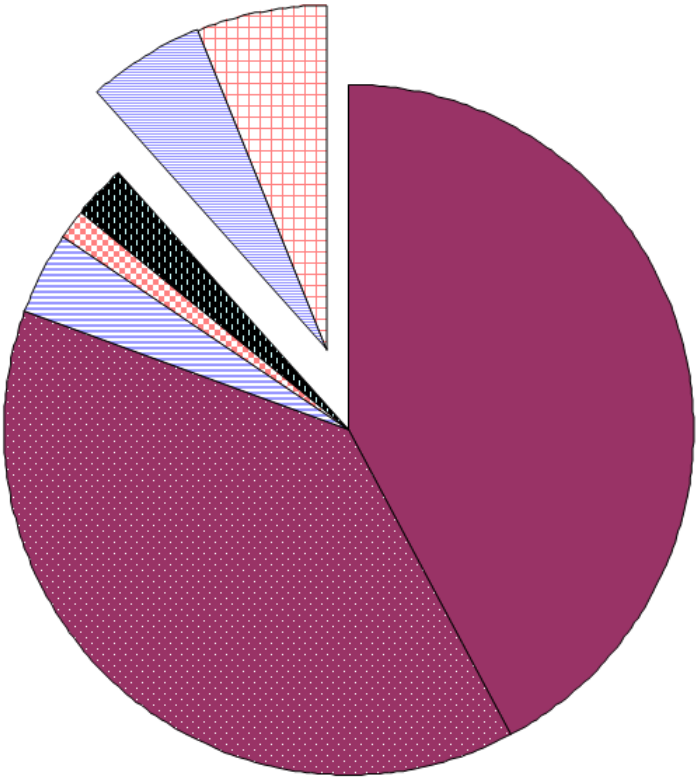
Hub Size	Data	303(d) Listed	TMDL Issued	Total
Large	Number of airports	7	3	10
	Estimated average annual glycol use (gal)	1,969,636	1,734,065	3,703,701
Med	Number of airports	9	6	15
	Estimated average annual glycol use (gal)	1,507,301	701,528	2,208,829
Small	Number of airports	8	2	10
	Estimated average annual glycol use (gal)	767,616	74,885	842,501
Non	Number of airports	17	9	26
	Estimated average annual glycol use (gal)	186,197	59,840	246,037
Totals	**Number of airports**	**41**	**20**	**61**
	Estimated average annual glycol use (gal)	**4,430,750**	**2,570,319**	**7,001,069**

Deicing Discharges Regulated by Individual NPDES Permits and/or Subject to TMDL Program

Figure 3-4 combines the information above to present the distribution of glycol use among permit types and TMDL program coverage. The data show that airport stormwater discharges associated with approximately 86 percent of all glycol use in the nation are regulated by individual NPDES permits and/or the TMDL program, both of which impose site-specific limits based on maintaining water quality standards in receiving waters. The one facility without an NPDES permit is not included in this group. However, if the current strategy were changed to allow surface water discharges, this facility would be subject to the TMDL program because it is within 3 miles of a water body currently on the 303(d) list.

It is likely that some fraction of the facilities where the permit type is unknown and the permit is not potentially associated with the TMDL program actually are controlled under individual permits. Thus, conservatively, no more than 14 percent of the glycol used in the nation is *not* controlled under either of these two stringent regulatory programs.

FIGURE 3-4
Distribution of Glycol Use among NPDES Permit Types and TMDL Program Coverage.



Permit Type	Covered Under TMDL Program?	Annual Glycol Use (gal)
Site-Specific Water Quality-Based Regulatory Controls		
Individual	No	6,412,451
Individual	Yes	5,758,026
General	Yes	642,451
Unknown	Yes	231,517
No Direct Discharge to Surface Waters	If discharge became necessary	369,075
BMP-based or Unknown Regulatory Controls		
General	No	761,416
Unknown	No	928,066

SECTION 4

SUMMARY AND CONCLUSIONS

Airfield Deicer Use

This analysis of pavement deicer use was limited to the use data available from EPA's 2006 Airport Survey Questionnaire. Among the 150 airports responding to that survey, 77 reported using airfield pavement deicers during one or more of the three seasons examined. Potassium acetate–based products were the most popular, with about 82 percent of the airports that used airfield deicers reporting its use. Sand was the second most commonly used product for maintaining safe airfield wintertime operations. Approximately one-third of the airports that used airfield pavement deicers reported using urea, with use occurring across a broad range of airports. Finally, it appears that relatively few airports use glycol-based pavement deicers.

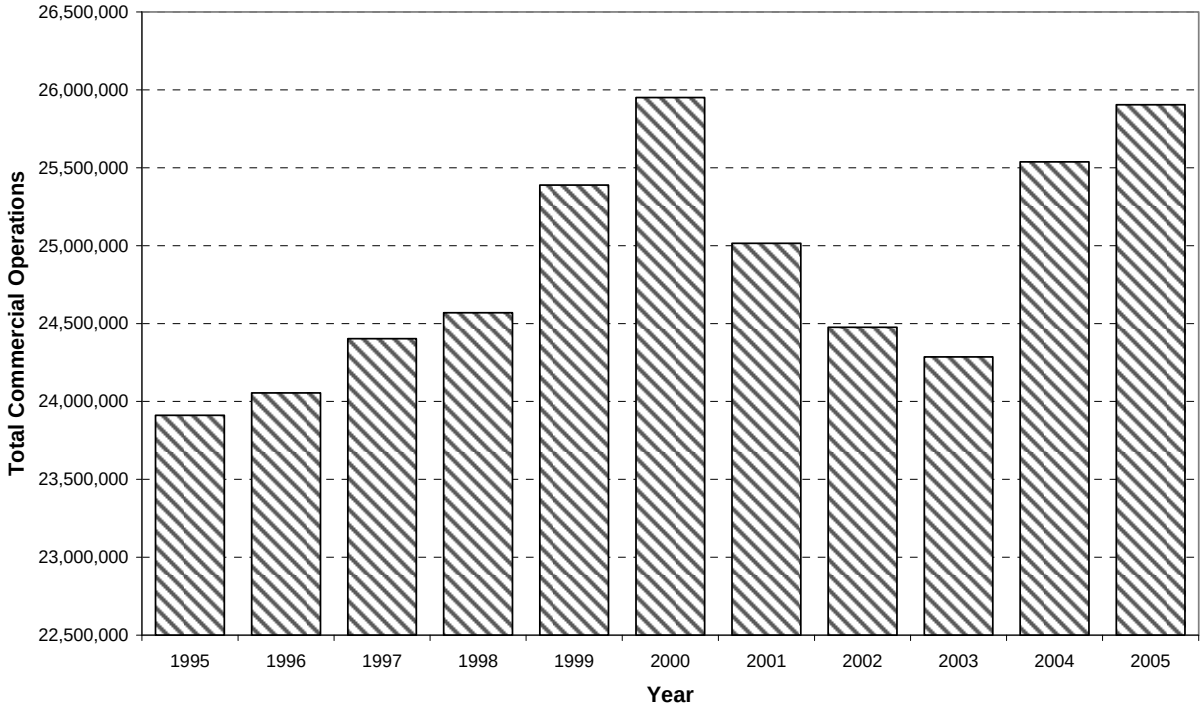
Aircraft Deicer Use

An estimated average of 15,103,044 gallons of pure glycol was used annually during the three deicing seasons between October 2002 and April 2005. Of this estimated total, approximately 12,019,032 gallons (or 80 percent) are based on actual reported use data, while only 20 percent of the national total was generated using the UAF approach. The upper and lower 99 percent confidence bounds on this national estimate are approximately 13,909,444 gallons and 16,296,643 gallons, respectively.

The vast majority (i.e., 80 percent) of the aircraft deicer glycol use in the nation occurs at large- and medium-hub airports. Just 10 of these airports account for more than half of all glycol used for aircraft deicing in the nation.

EPA previously estimated that 35,000,000 gallons of 50 percent concentration ADF was applied annually (EPA, 2000). Assuming that concentrated ADF is 88 percent glycol, this translates to approximately 15,200,000 gallons of pure glycol, which is remarkably similar to the estimate developed in the current study. However, some aspects of this earlier estimate must be considered in assessing its comparability to the results in the current report. The data used to develop EPA's estimate were collected in a 1999 survey of 23 airports and reflected a variable number of previous deicing seasons at each of these airports. As such, reported use reflected a much smaller sampling of airports than the current analysis and operating conditions, which may have been significantly different from the 2002–2005 period. Perhaps more significantly, air traffic volumes were notably lower in the mid- to late-1990s than during the 2002–2005 period (Figure 4-1). In conclusion, although the two estimates appear consistent, it is likely that the previous EPA analysis overestimated actual use for the period examined.

FIGURE 4-1
Annual Commercial Aircraft Operations Reported by FAA for the Years 1995–2005



Existing Regulatory Requirements

Existing regulatory requirements control the vast majority of deicing discharges in the nation. Stormwater discharges associated with approximately 86 percent of all aircraft deicer glycol use are covered by either an individual NPDES permit or the TMDL program or both.

Of the 34 airports using an average of more than 100,000 gallons of glycol annually, all but five are operating under individual NPDES permits. Of these five, one does not have an NPDES permit at all, and two others must manage their stormwater discharges to meet the requirements of local TMDLs. The remaining two airports are operating under general NPDES permits.

Nationally, environmental regulators are beginning to focus more attention on the impacts of nutrients and sediment, particularly as a result of stormwater pollution. For this reason, many more water bodies are likely to become designated "impaired" under the 303(d) program in the relatively near future. Because nutrient-related impairments typically include dissolved oxygen, as do impairments associated with deicing discharges, additional airports are likely to come under the scrutiny of the TMDL development process, and be subject to more stringent permit requirements in the future.

Future Trends

The data analysis presented in this report represents a snapshot in time of industry practices that are subject to change as a result of two significant factors: technological developments and climate change.

Over the past decade, aircraft and airfield pavement dicing operations and formulations have seen dramatic technological advances. While safety is always the overriding factor for deicing operations, new deicer application technologies (e.g., forced air in combination with low flow deicing fluid nozzles), and practices (e.g., blending aircraft deicing fluid mixtures to ambient temperatures) are reducing the amounts of glycol required for safe aircraft operation under a range of winter conditions. In addition, ongoing research into alternatives to the glycols by ACRP, the Department of Defense, and the private sector is resulting in new deicing products with reduced environmental impacts being introduced to the market on a regular basis. Hence, we now are witnessing reduced environmental impacts from these operations while still meeting flight safety standards.

Global climate change is starting to be considered by individual airports. Local changes are expected to vary by geographic location. Global climate change experts predict significant variations in precipitation patterns across the country. In those areas with warmer winters and less precipitation, significant reductions may occur. However, modest temperature variation coupled with significantly increased winter precipitation could result in some airports increasing deicer usage. The implications to national usage of deicers are unclear at this time.

Although a quantitative assessment of the implications of these trends is beyond the scope of the present investigation, these factors should be born in mind when interpreting the results presented herein.

SECTION 5

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Appendix A

TABLE A-1
List of Airports Examined in the Analysis

Airport Code	State	Facility Name	Average Deicing Season Relevant Operations	Hub Size	Average Annual Snowfall (inches)	Snowfall Group
1G4	AZ	Grand Canyon West	-	N	-	1 *
ABE	PA	Lehigh Valley Intl	22,462	S	32.1	2
ABI	TX	Abilene Rgnl	6,923	N	4.6	4
ABQ	NM	Albuquerque Intl Sunport	71,396	M	10.8	4
ABR	SD	Aberdeen Rgnl	-	N	36.5	2
ACK	MA	Nantucket Memorial	47,607	N	-	2 *
ACY	NJ	Atlantic City Intl	13,349	S	15.7	3
AEX	LA	Alexandria Intl	6,199	N	-	5 *
AFW	TX	Fort Worth Alliance	6,233	-	-	na *
AGS	GA	Augusta Rgnl At Bush Field	8,289	N	1.1	4
AKN	AK	King Salmon	8,783	N	46.1	2
ALB	NY	Albany Intl	52,557	S	63.8	1
AMA	TX	Rick Husband Amarillo Intl	13,233	S	15	3
ANC	AK	Ted Stevens Anchorage Intl	104,312	M	70	1
APF	FL	Naples Muni	9,402	N	-	na
ARA	LA	Acadiana Rgnl	9,443	-	-	na
ASE	CO	Aspen-Pitkin Co/Sardy Field	9,830	N	-	1 *
ATL	GA	Hartsfield - Jackson Atlanta Intl	536,869	L	2	4
ATW	WI	Outagamie County Rgnl	12,698	N	-	2 *
AUS	TX	Austin-Bergstrom Intl	68,453	M	0.9	5
AVL	NC	Asheville Rgnl	11,898	N	14.9	4
AVP	PA	Wilkes-Barre/Scranton Intl	13,199	N	-	2 *
AZO	MI	Kalamazoo/Battle Creek Intl	11,112	N	-	1 *
BDL	CT	Bradley Intl	63,673	M	47.9	2
BED	MA	Laurence G Hanscom Fld	13,060	N	-	2 *
BET	AK	Bethel	54,969	N	49.4	2
BFI	WA	Boeing Field/King County Intl	36,954	N	6.8	4
BFL	CA	Meadows Field	15,462	N	-	na
BGM	NY	Greater Binghamton/Edwin A Link Field	9,205	N	82.8	1
BGR	ME	Bangor Intl	13,893	S	-	1 *
BHM	AL	Birmingham Intl	43,808	S	1.5	4
BIL	MT	Billings Logan Intl	28,643	S	56.3	2
BIS	ND	Bismarck Muni	7,648	N	42.7	2
BKF	CO	Buckley Afb	-	-	-	1 *
BKL	OH	Burke Lakefront	9,733	-	-	2 *
BLI	WA	Bellingham Intl	8,082	N	-	4 *
BMI	IL	Central Il Regl Arpt At Bloomington-Normal	7,844	N	-	2 *
BNA	TN	Nashville Intl	99,790	M	9.9	4
BOI	ID	Boise Air Terminal/Gowen Fld	39,942	S	20.7	3
BOS	MA	General Edward Lawrence Logan Intl	209,301	L	41.7	2
BTR	LA	Baton Rouge Metropolitan, Ryan Field	13,870	S	0.2	5
BTV	VT	Burlington Intl	22,905	S	78	1
BUF	NY	Buffalo Niagara Intl	54,861	M	91.8	1
BUR	CA	Bob Hope	52,063	M	-	na
BWI	MD	Baltimore/Washington Intl Thurgood Marshal	152,407	L	20.4	3
BZN	MT	Gallatin Field	9,396	N	-	2 *
CAE	SC	Columbia Metropolitan	36,097	S	1.7	4
CAK	OH	Akron-Canton Rgnl	20,027	S	47.4	2
CHA	TN	Lovell Field	13,511	N	4.3	4
CHO	VA	Charlottesville-Albemarle	12,619	N	-	4 *
CHS	SC	Charleston Afb/Intl	29,529	S	0.7	5
CIC	CA	Chico Muni	3,386	N	-	na
CID	IA	The Eastern Iowa	20,301	S	-	2 *

TABLE A-1
List of Airports Examined in the Analysis

Airport Code	State	Facility Name	Average Deicing Season Relevant Operations	Hub Size	Average Annual Snowfall (inches)	Snowfall Group
CLE	OH	Cleveland-Hopkins Intl	138,244	M	55.7	2
CLT	NC	Charlotte/Douglas Intl	245,352	L	5.4	4
CMH	OH	Port Columbus Intl	98,620	M	27.9	3
CMI	IL	University Of Illinois-Willard	7,176	N	-	2 *
COE	ID	Coeur D'Alene Air Term	-	N	-	2 *
COS	CO	City Of Colorado Springs Muni	28,043	S	42.3	2
CPR	WY	Natrona County Intl	9,766	N	79.1	1
CRP	TX	Corpus Christi Intl	12,539	S	-	na
CRQ	CA	Mc Clellan-Palomar	7,743	N	-	na
CRW	WV	Yeager	23,274	N	33.1	2
CVG	KY	Cincinnati/Northern Kentucky Intl	287,189	L	23.4	3
CWA	WI	Central Wisconsin	10,289	N	-	2 *
DAL	TX	Dallas Love Field	74,821	M	2.5	4
DAY	OH	James M Cox Dayton Intl	49,675	S	27.7	3
DCA	DC	Ronald Reagan Washington National	150,793	L	16.4	3
DEN	CO	Denver Intl	301,738	L	60.3	1
DFW	TX	Dallas/Fort Worth Intl	438,595	L	2.5	4
DLG	AK	Dillingham	-	N	-	2 *
DRO	CO	Durango-La Plata County	-	N	-	1 *
DSM	IA	Des Moines Intl	37,552	S	33.3	2
DTW	MI	Detroit Metropolitan Wayne County	284,203	L	41.3	2
EAT	WA	Pangborn Memorial	-	N	-	3 *
EAU	WI	Chippewa Valley Rgnl	-	N	-	2 *
EGE	CO	Eagle County Rgnl	7,801	N	-	1 *
ELM	NY	Elmira/Corning Rgnl	7,406	N	-	1 *
ELP	TX	El Paso Intl	37,603	S	5.3	4
ENA	AK	Kenai Muni	8,607	N	-	2 *
ERI	PA	Erie Intl/Tom Ridge Field	9,245	N	86.5	1
EUG	OR	Mahlon Sweet Field	15,606	N	6.3	4
EVV	IN	Evansville Rgnl	14,070	N	13.6	4
EWR	NJ	Newark Liberty Intl	236,820	L	27.5	3
EYW	FL	Key West Intl	22,186	N	0	na
FAI	AK	Fairbanks Intl	30,997	S	69.5	1
FAR	ND	Hector Intl	11,789	N	38.9	2
FAT	CA	Fresno Yosemite Intl	28,358	S	0.1	5
FAY	NC	Fayetteville Rgnl/Grannis Field	5,519	N	-	4 *
FLL	FL	Fort Lauderdale/Hollywood Intl	145,289	L	-	na
FNT	MI	Bishop Intl	15,977	S	45.2	2
FSD	SD	Joe Foss Field	21,249	N	40.1	2
FWA	IN	Fort Wayne Intl	22,832	N	32.8	2
GCN	AZ	Grand Canyon National Park	42,685	S	-	1 *
GEG	WA	Spokane Intl	36,709	S	49.5	2
GFK	ND	Grand Forks Intl	23,226	N	-	2 *
GJT	CO	Grand Junction Regional	11,915	N	24.7	3
GNV	FL	Gainesville Rgnl	5,910	N	-	na
GPI	MT	Glacier Park Intl	-	N	63.9	1
GPT	MS	Gulfport-Biloxi Intl	9,016	S	-	na
GRB	WI	Austin Straubel Intl	14,755	S	46.7	2
GRI	NE	Central Nebraska Rgnl	3,105	N	30.5	2
GRR	MI	Gerald R. Ford Intl	33,656	S	71.8	1
GSN	CQ	Francisco C. Ada/Saipan Intl	19,236	S	-	na
GSO	NC	Piedmont Triad Intl	42,943	S	-	4 *
GSP	SC	Greenville Spartanburg Intl -	30,024	S	-	4 *

TABLE A-1
List of Airports Examined in the Analysis

Airport Code	State	Facility Name	Average Deicing Season Relevant Operations	Hub Size	Average Annual Snowfall (inches)	Snowfall Group
GTF	MT	Great Falls Intl	13,105	N	58.4	2
GUM	GU	Guam Intl	14,452	S	-	na
HLN	MT	Helena Rgnl	9,151	N	47	2
HNL	HI	Honolulu Intl	131,331	L	0	na
HOM	AK	Homer	-	N	57.7	2
HOU	TX	William P Hobby	90,235	M	0.4	5
HPN	NY	Westchester County	40,938	S	-	3 *
HRL	TX	Valley Intl	8,704	S	-	na
HSV	AL	Huntsville Intl-Carl T Jones Field	21,277	S	2.7	4
HYA	MA	Barnstable Muni-Boardman/Polando Field	43,080	N	-	2 *
IAD	DC	Washington Dulles Intl	217,263	L	22.3	3
IAH	TX	George Bush Intercontinental/Houston	279,238	L	0.4	5
ICT	KS	Wichita Mid-Continent	34,286	S	15.7	3
IDA	ID	Idaho Falls Rgnl	8,077	N	-	3 *
ILM	NC	Wilmington Intl	11,905	N	1.9	4
ILN	OH	Airborne Airpark	-	N	-	3 *
IND	IN	Indianapolis Intl	103,350	M	22.9	3
ISP	NY	Long Island Mac Arthur	20,269	S	20.5	3
ITH	NY	Ithaca Tompkins Rgnl	5,547	N	-	1 *
ITO	HI	Hilo Intl	38,504	S	0	na
JAC	WY	Jackson Hole	7,409	N	-	1 *
JAN	MS	Jackson-Evers Intl	18,189	S	0.9	5
JAX	FL	Jacksonville Intl	50,102	M	-	5 *
JFK	NY	John F Kennedy Intl	178,959	L	22.9	3
JNU	AK	Juneau Intl	24,555	S	100.7	1
KOA	HI	Kona Intl At Keahole	23,294	S	-	na
KTN	AK	Ketchikan Intl	-	N	-	2 *
LAN	MI	Capital City	17,232	N	49	2
LAS	NV	Mc Carran Intl	268,780	L	1.2	4
LAX	CA	Los Angeles Intl	361,472	L	-	na
LBB	TX	Lubbock Preston Smith Intl	19,055	S	9.9	4
LBF	NE	North Platte Rgnl Airport Lee Bird Field	-	N	-	2 *
LCK	OH	Rickenbacker Intl	-	N	-	3 *
LEX	KY	Blue Grass	21,878	S	15.8	3
LFT	LA	Lafayette Rgnl	16,191	N	-	5 *
LGA	NY	La Guardia	220,887	L	25.8	3
LGB	CA	Long Beach /Daugherty Field/	20,238	S	-	na
LIH	HI	Lihue	42,559	S	-	na
LIT	AR	Adams Field	35,581	S	5.1	4
LNK	NE	Lincoln	11,277	N	26.8	3
LRD	TX	Laredo Intl	8,959	N	-	na
LSE	WI	La Crosse Muni	5,697	N	42.5	2
LUK	OH	Cincinnati Muni Airport Lunken Field	9,237	-	-	3 *
LWS	ID	Lewiston-Nez Perce County	6,127	N	15.8	3
MAF	TX	Midland Intl	13,458	S	4.2	4
MBS	MI	Mbs Intl	10,900	N	-	2 *
MCI	MO	Kansas City Intl	93,281	M	19.9	3
MCO	FL	Orlando Intl	176,517	L	-	na
MDT	PA	Harrisburg Intl	27,731	S	35	2
MDW	IL	Chicago Midway Intl	152,058	L	-	2 *
MEM	TN	Memphis Intl	207,735	M	5.1	4
MFE	TX	Mc Allen Miller Intl	5,017	N	-	na
MFR	OR	Rogue Valley Intl - Medford	12,991	N	7.2	4

TABLE A-1
List of Airports Examined in the Analysis

Airport Code	State	Facility Name	Average Deicing Season Relevant Operations	Hub Size	Average Annual Snowfall (inches)	Snowfall Group
MGM	AL	Montgomery Rgnl (Dannelly Field)	7,355	N	0.4	5
MGW	WV	Morgantown Muni-Walter L. Bill Hart Fld	5,089	N	-	2 *
MHT	NH	Manchester	41,554	M	-	2 *
MIA	FL	Miami Intl	216,937	L	0	na
MKC	MO	Charles B. Wheeler Downtown	11,035	-	-	3 *
MKE	WI	General Mitchell Intl	107,433	M	47.2	2
MKK	HI	Molokai	15,206	N	-	na
MLB	FL	Melbourne Intl	3,462	N	-	na
MLI	IL	Quad City Intl	15,453	S	30.4	2
MOB	AL	Mobile Rgnl	9,574	N	0.4	5
MOD	CA	Modesto City-Co-Harry Sham Fld	6,041	N	-	na
MRY	CA	Monterey Peninsula	12,665	N	-	na
MSN	WI	Dane County Rgnl-Truax Field	24,728	S	43.9	2
MSO	MT	Missoula Intl	10,985	N	45.5	2
MSP	MN	Minneapolis-St Paul Intl/Wold-Chamberlain	281,693	L	49.5	2
MSY	LA	Louis Armstrong New Orleans Intl	75,409	M	0.2	5
MVY	MA	Marthas Vineyard	7,336	N	-	2 *
MWH	WA	Grant Co Intl	8,496	N	-	3 *
MYR	SC	Myrtle Beach Intl	14,447	S	-	5 *
OAK	CA	Metropolitan Oakland Intl	116,668	M	-	na
OGG	HI	Kahului	72,885	M	-	na
OKC	OK	Will Rogers World	34,275	S	-	4 *
OMA	NE	Eppley Airfield	48,218	M	29.8	3
OME	AK	Nome	-	N	58.8	2
ONT	CA	Ontario Intl	69,182	M	-	na
ORD	IL	Chicago O'Hare Intl	541,287	L	38.2	2
ORF	VA	Norfolk Intl	45,145	M	7.4	4
OTH	OR	Southwest Oregon Rgnl	-	N	-	4 *
OTZ	AK	Ralph Wien Memorial	-	N	47.6	2
PBI	FL	Palm Beach Intl	62,193	M	-	na
PDX	OR	Portland Intl	128,008	M	6.5	4
PFN	FL	Panama City-Bay Co Intl	9,762	N	-	na
PGA	AZ	Page Muni	-	N	-	na
PGV	NC	Pitt-Greenville	-	N	-	4 *
PHF	VA	Newport News/Williamsburg Intl	13,992	S	-	4 *
PHL	PA	Philadelphia Intl	256,841	L	20.8	3
PHX	AZ	Phoenix Sky Harbor Intl	286,001	L	-	4 *
PIA	IL	Greater Peoria Rgnl	13,775	N	24.8	3
PIE	FL	St Petersburg-Clearwater Intl	10,587	S	-	na
PIH	ID	Pocatello Rgnl	7,626	N	42.7	2
PIT	PA	Pittsburgh Intl	177,382	M	43.5	2
PNS	FL	Pensacola Rgnl	19,131	S	0.2	5
PPG	AS	Pago Pago Intl	4,138	N	-	na
PSC	WA	Tri-Cities	14,712	N	-	3 *
PSG	AK	Petersburg James A Johnson	-	N	-	2 *
PSP	CA	Palm Springs Intl	23,493	S	-	na
PTK	MI	Oakland County Intl	9,486	-	-	1 *
PVD	RI	Theodore Francis Green State	47,109	M	35.9	2
PWM	ME	Portland Intl Jetport	24,118	S	70.8	1
RAP	SD	Rapid City Rgnl	8,548	N	39.4	2
RDD	CA	Redding Muni	7,670	N	2.9	4
RDM	OR	Roberts Field	8,330	N	-	na
RDU	NC	Raleigh-Durham Intl	103,224	M	6.9	4

TABLE A-1
List of Airports Examined in the Analysis

Airport Code	State	Facility Name	Average Deicing Season Relevant Operations	Hub Size	Average Annual Snowfall (inches)	Snowfall Group
RFD	IL	Chicago/Rockford Intl	9,083	N	35.9	2
RIC	VA	Richmond Intl	50,634	S	13.7	4
RKD	ME	Knox County Rgnl	-	N	-	1 *
RNO	NV	Reno/Tahoe Intl	46,786	M	24.4	3
ROA	VA	Roanoke Rgnl/Woodrum Field	20,428	N	22.5	3
ROC	NY	Greater Rochester Intl	42,774	S	90.3	1
RST	MN	Rochester Intl	8,493	N	48.6	2
RSW	FL	Southwest Florida Intl	43,988	M	0	na
SAN	CA	San Diego Intl	111,258	L	-	na
SAT	TX	San Antonio Intl	69,145	M	0.7	5
SAV	GA	Savannah/Hilton Head Intl	22,766	S	0.4	5
SAW	MI	Sawyer Intl	4,961	N	130.6	1
SBA	CA	Santa Barbara Muni	24,010	S	0	na
SBN	IN	South Bend Rgnl	19,150	S	70.9	1
SBP	CA	San Luis County Rgnl	9,000	N	-	na
SDF	KY	Louisville Intl-Standiford Field	87,582	S	16.1	3
SEA	WA	Seattle-Tacoma Intl	195,663	L	11.3	4
SFB	FL	Orlando Sanford Intl	5,631	S	-	na
SFO	CA	San Francisco Intl	185,365	L	-	na
SGF	MO	Springfield-Branson National	18,522	S	17.2	3
SGU	UT	St George Muni	-	N	-	3 *
SHV	LA	Shreveport Rgnl	18,367	N	1.5	4
SIT	AK	Sitka Rocky Gutierrez	-	N	-	2 *
SJC	CA	Norman Y. Mineta San Jose Intl	90,677	M	-	na
SJU	PR	Luis Munoz Marin Intl	100,253	M	-	na
SLC	UT	Salt Lake City Intl	191,268	L	57.7	2
SMF	CA	Sacramento Intl	70,355	M	-	5 *
SMX	CA	Santa Maria Pub/Capt G Allan Hancock Fld	7,021	N	-	na
SNA	CA	John Wayne Airport-Orange County	64,494	M	-	na
SOW	AZ	Show Low Rgnl	-	N	-	na
SPS	TX	Sheppard Afb/Wichita Falls Muni	-	N	5.7	4
SRQ	FL	Sarasota/Bradenton Intl	14,372	S	-	na
STL	MO	Lambert-St Louis Intl	182,827	M	19.5	3
STT	VI	Cyril E King	37,091	S	-	na
STX	VI	Henry E Rohlsen	20,797	N	-	na
SUN	ID	Friedman Memorial	7,288	N	-	2 *
SUS	MO	Spirit Of St Louis	6,436	-	-	3 *
SWF	NY	Stewart Int'L	10,409	N	-	3 *
SYR	NY	Syracuse Hancock Intl	38,742	S	114.7	1
TEX	CO	Telluride Rgnl	-	N	-	1 *
TLH	FL	Tallahassee Rgnl	20,071	S	-	5 *
TNI	CQ	Tinian Intl	-	N	-	na
TOL	OH	Toledo Express	21,801	N	37	2
TPA	FL	Tampa Intl	122,270	L	-	na
TRI	TN	Tri-Cities Rgnl Tn/Va	13,539	N	15.4	3
TUL	OK	Tulsa Intl	30,081	S	9.4	4
TUS	AZ	Tucson Intl	35,472	M	1.2	4
TVC	MI	Cherry Capital	11,286	N	-	1 *
TWF	ID	Joslin Field - Magic Valley Rgnl	7,283	N	-	3 *
TYR	TX	Tyler Pounds Rgnl	5,494	N	-	na
TYS	TN	Mc Ghee Tyson	35,496	S	11.6	4
UNV	PA	University Park	-	N	-	2 *
VGT	NV	North Las Vegas	24,212	N	-	4 *

TABLE A-1

List of Airports Examined in the Analysis

Airport Code	State	Facility Name	Average Deicing Season Relevant Operations	Hub Size	Average Annual Snowfall (inches)	Snowfall Group
VIS	CA	Visalia Muni	-	-	-	na
VPS	FL	Eglin Afb	-	S	-	na
VQS	PR	Antonio Rivera Rodriguez	-	N	-	na
XNA	AR	Northwest Arkansas Rgnl	19,055	S	-	4 *
YIP	MI	Willow Run	13,020	S	41.3	2

na - Not applicable (i.e., below minimum snowfall to be assigned a snow group code)

* Extrapolated based on code from nearby locations where snowfall data were available.

Appendix B

Deicing Study

PREPARED FOR: Dean Mericas

PREPARED BY: Lucille Olszewski

DATE: January 29, 2008

Summary

Off-the-shelf climatological products to support geographic categorization of airports for the ACRP 11-02: National Deicer Usage Estimates Project do not exist. Extensive research and personal communication with leading experts in the country was conducted with limited results. A database could be compiled using sounding and surface observation data provided by the National Climatic Data Center's Solar and Meteorological Surface Observation Network Dataset, however, the substantial work to provide this level of support is beyond the scope of this task. Though there are many drawbacks and caveats, the least costly information that could be used for nationwide station data is that provided in the EPA Study, " Final loadings in Wastewater Discharges from Aircraft Deicing/Anti-icing Operations" (Eastern Research Group, 2000).

Discussion

The task to support the ACRP 11-02: National Deicer Usage Estimates Project consisted of trying to identify off the shelf climatology products that could be used to accurately characterize geographic areas with similar intensities of aircraft and airfield deicing requirements. Such a methodology would represent an improvement over the relatively simplistic previously applied in the EPA Study, "Final loadings in Wastewater Discharges from Aircraft Deicing/Anti-icing Operations" (Eastern Research Group, 2000).

It was determined that a reasonable basis for such as categorization scheme is the likelihood of snow/ice /temperature (and relative humidity) events that would trigger the need for deicing fluid application to aircraft. The ideal product would have been a GIS database of the annual percent of time or frequency of hours that sufficient atmospheric conditions occurred that would trigger aircraft deicing. The task proved to be significantly more difficult than anticipated for the following reasons:

- A simple atlas of icing is not readily available because ice may be defined in different ways. Icing conditions occur in three forms: freezing drizzle, freezing rain, ice pellets (sleet). Further, in order to equate snow fall with icing events the parameter needed is the "snowfall liquid equivalent" (SLE). The SLE is not a parameter that is collected at many observation stations and there seem to be data quality issues with the data that has been collected.
- The Airforce 14th Weather Squadron does have an icing atlas from 1986 and is available in hard copy only. Several contacts with the organization indicated that there might have been an update to this atlas, but it could not be obtained for this project. The

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justifications given were that CH2M HILL is not a government contractor on this particular job, and this request would be given a low priority because the Squadron is busy supporting the war efforts in Iraq and Afghanistan.

- The main focus of the icing observations collected in recent years has been on in-flight icing conditions rather than at ground level. Pilots report the conditions as they fly through various levels in the atmosphere, especially on take-off and landing.
- Researchers working on aircraft icing are focused on the formation of supercooled large droplets. This parameter is not directly measured, but is empirically derived from sounding measurements. There were no easily accessible maps or databases of super cooled large droplets.

There are also many triggers that are not directly or easily correlated with observed weather data. For example:

- Pilots can request to be deiced based on their observations of the atmospheric conditions. "Estimation of Snowfall Rate Using Visibility" Rasmussen, Vivekarnandan, Cole, Meyers and Masters1
- Freezing fog typically occurs in the morning hours before and at sunrise.
- Frost build-up from condensation overnight.
- Some planes have different deicing requirements than others. Ex: MD80's can still be deiced when surface temperatures are near 50 degrees F.
- Deicing can occur on quick turn-around when the temperatures are above freezing and no precipitation is occurring at the surface. For example: a plane descends through the atmosphere where temperatures can be anywhere between -50 degrees F to – 10 degrees F. The moisture in the lower atmosphere will condense particularly near the surface of the super-cooled fuel tanks. The plane will often be deiced before its next flight.

After much research and personal communication with the top experts on aircraft icing, airline industry experts and icing climatology experts in the U.S., it was determined that the product that was desired was not readily available and that significant effort would be required to get the information to develop such a product. The information would have to be compiled from hourly observation data for over 200 stations from the National Climatic Data Center for a 15 – 20 year time record. The volume of data needed to accomplish this task is beyond the level of effort authorized and included in the scope of work.

The research did lead to some graphically summarized data that offered at least partial information. Below are four graphs compiled by Ben Berstein[2] that show the average number of hours that freezing precipitation potentially occurred over the period 1961 – 1990. These graphs were based on sounding data (data collected via weather balloons launched twice daily) and where the event based on surface observations lasted within +/- 3hours of the sounding launch time. The time resolution of this data is not exactly what is needed but over the 30 year period trends can be seen. Graph A represents on an annual basis, a composite of all freezing precipitation types (freezing drizzle – FZDZ, freezing rain

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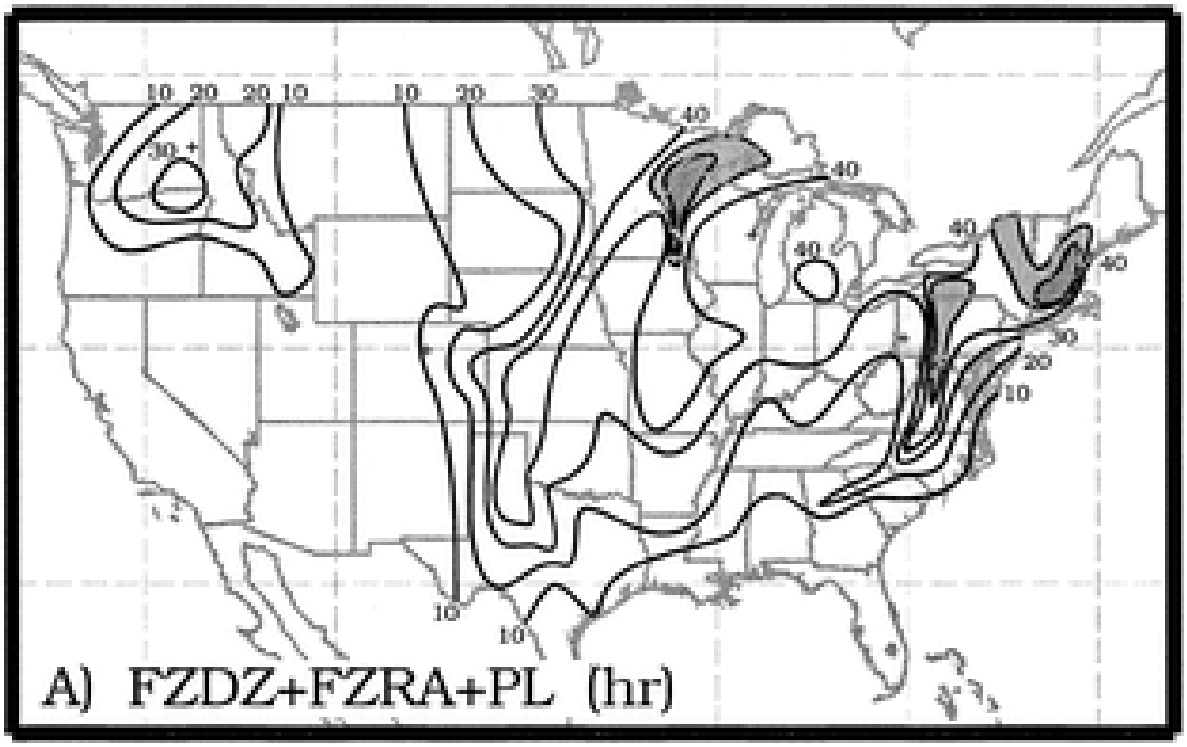
– FZRA and ice pellets - PL. The grayest shading represents >60 hours of freezing precipitation.

There is a noticeable blank area in Pacific South West. Freezing precipitation is very rare in the region. There is the rare freezing drizzle event, but freezing rain is essentially non-existent. In general, the Southwest is less cloudy and has less precipitation, with the exception of the mountains. There, the precipitation is typically in the form of snow or rain, depending on the elevation. Freezing fog events happen at times, both in the mountains and lower elevations, but its not nearly as common as it is elsewhere in the U.S.



Separately this graph can be broken down into the individual precipitation categories. Figure B represents the percent of time that freezing drizzle may occur. For example: in Figure A, Denver represented approximately 20 total hours of freezing precipitation, greater than 80 percent of those hours were in the form of freezing drizzle – shown in Figure B.

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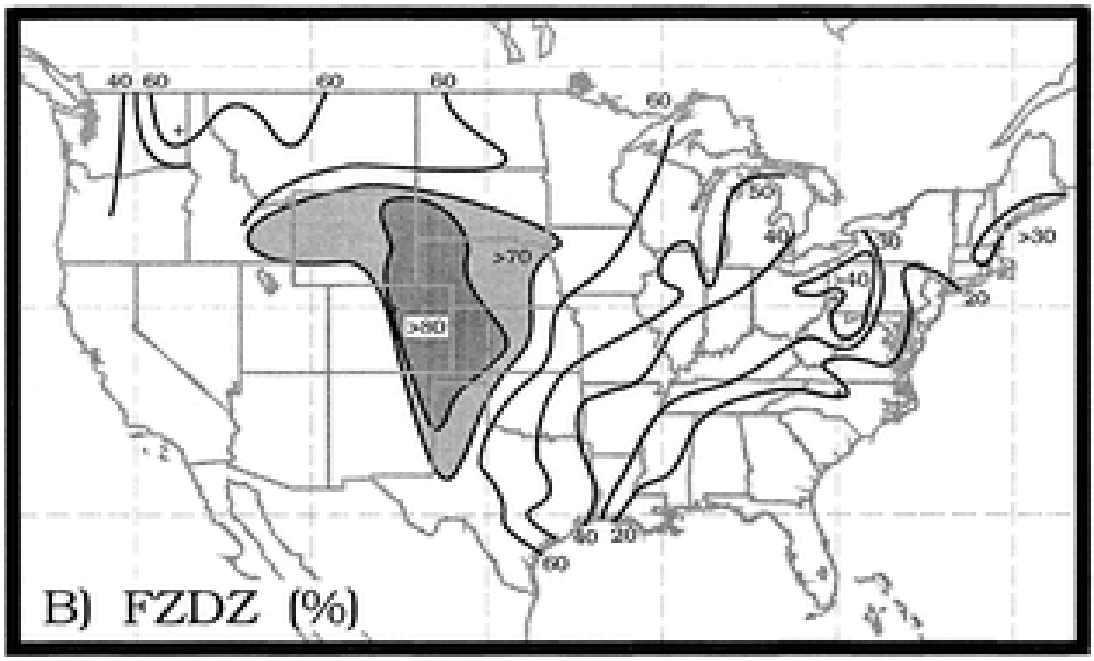

Figure C represents the percent of time that freezing rain may occur. In the northwest of all freezing precipitation that occurred > 80 percent occurred as freezing rain in Portland and Spokane, WA while greater than 50 percent occurred throughout the southeast. The particular band of freezing rain in the southeast is known to shift westward to include portions of Texas, Oklahoma and Kansas based on observations by T. Riley[3]

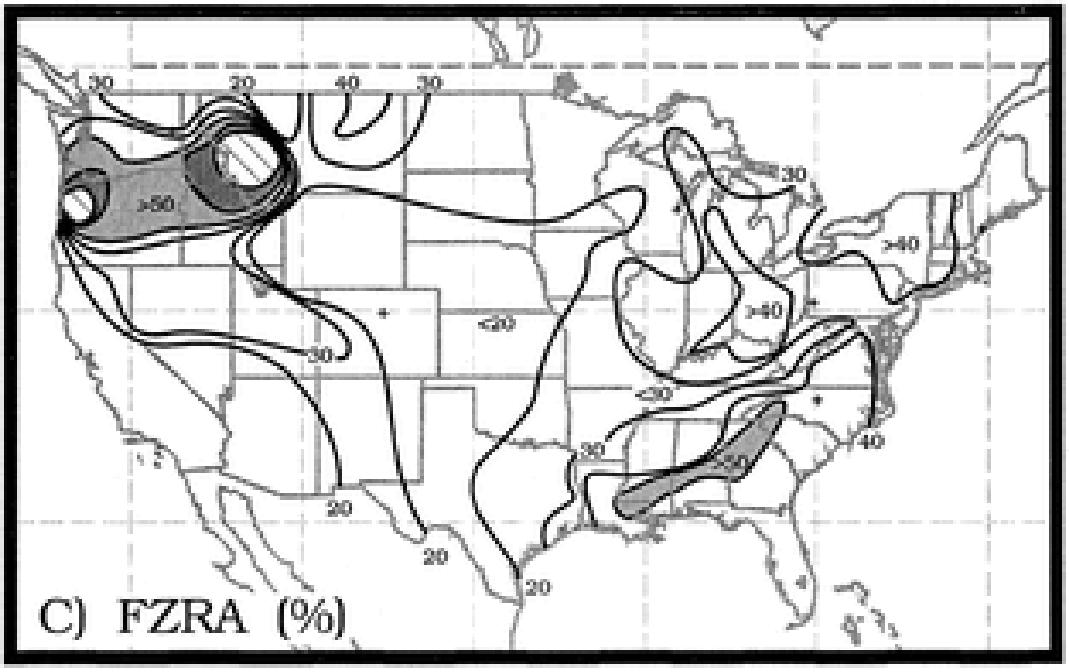

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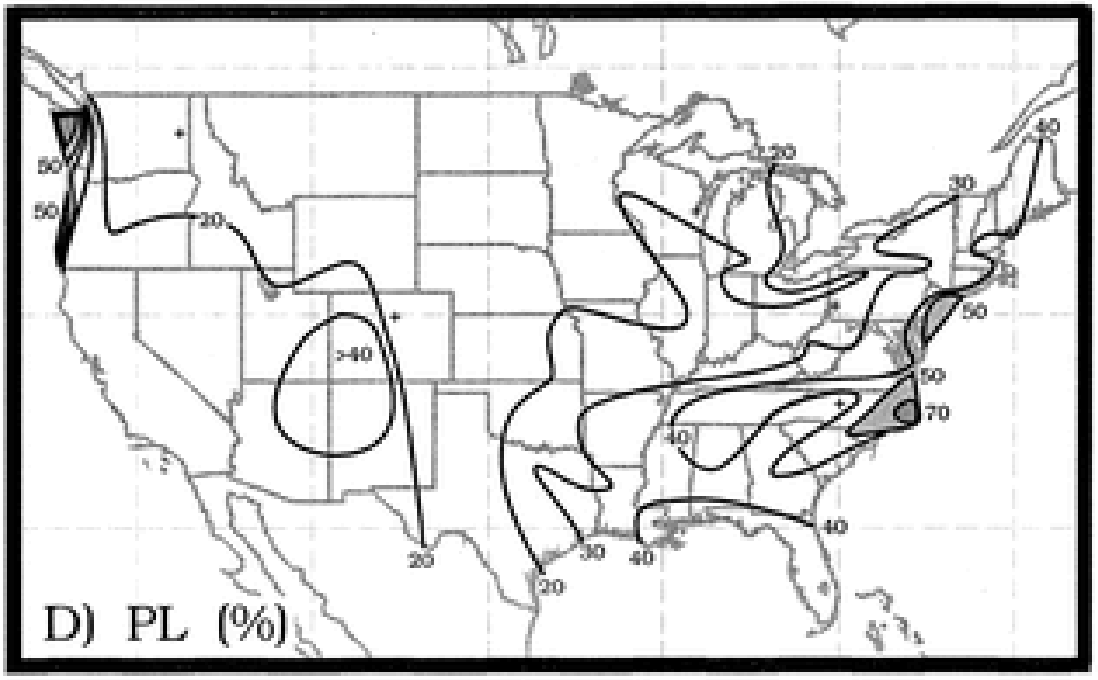
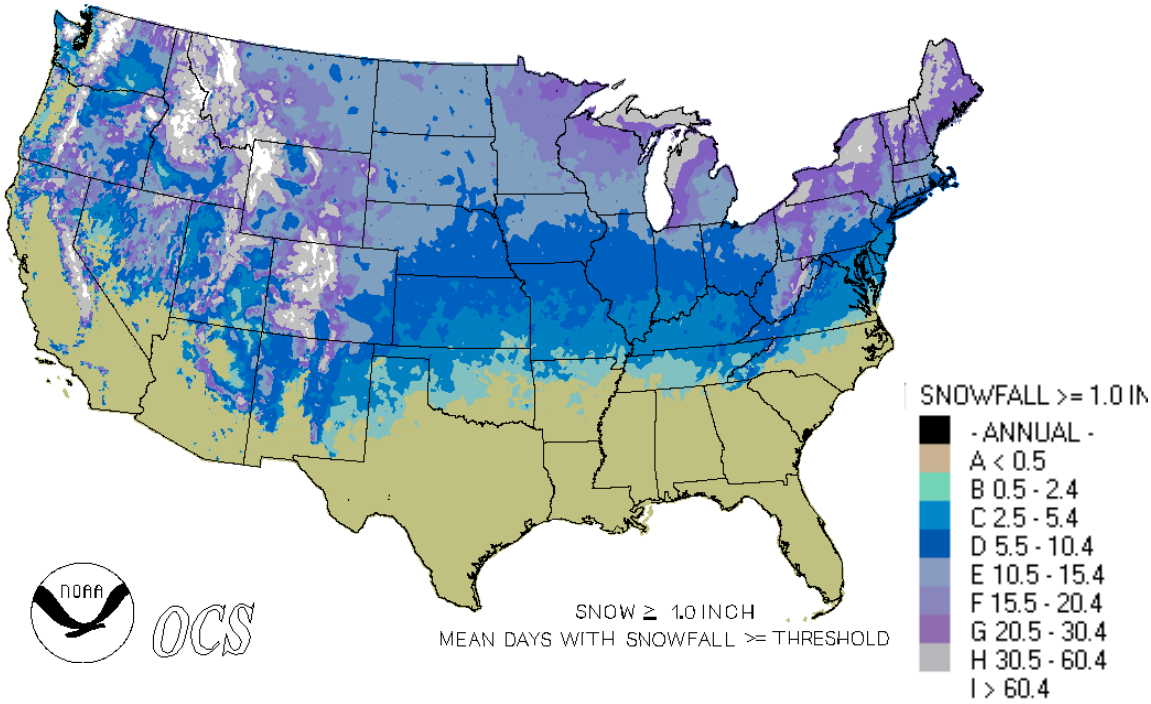
Figure D represents the percent of time that ice pellets may occur. In the northwest and central east coast – Massachusetts south to North Carolina, of all freezing precipitation that occurred > 70 percent occurred as freezing pellets or sleet.



Although snowfall liquid equivalent is not readily available, the number of mean days with snow falls greater than 1.0 inch as shown below is the best composite that was available from NOAA- OCS. Again, this does not incorporate snow fall intensity or liquid water equivalent, the two important parameters.



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Conclusion

There are no off-the-shelf climatology products or readily available databases that contain the information needed for categorizing airports relative to deicing conditions and requirements. Although there are drawbacks and caveats, the least costly information to use for nationwide station data appears to be that provided in the 2000 EPA Study, "Final loadings in Wastewater Discharges from Aircraft Deicing/Anti-icing Operations" prepared by the Eastern Research Group, January 6, 2000, Section 8.0 DCN T11074.

1 Rasmussen, R, M., Vivekarnandan, J., Cole, J, Meyers, B and Masters , C., "Estimation of Snowfall Rate Using Visibility" Journal of Applied Meteorology, Vol. 38, No. 10, 1999, pp 1542 – 1563.

2 Bernstein, B. C. "Regional and Local Influences on Freezing Drizzle, Freezing Rain, and Ice Pellet Events" Weather and Forecasting, Vol. 15, October 2000, pp 485 – 508.

3 Eastern Research Group, 2000. Final loadings in Wastewater Discharges from Aircraft Deicing/Anti-icing Operations. Section 8.0 DCN T11074.

4 Riley, James T. Ph.D. Federal Aviation Administration William J. Hughes Technical Center Atlantic City, NJ 08405, Personal Communication, 12/03/07, 12/28/07.

5 Underwood, Warren. Federal Aviation Administration. Atlanta, GA, Personal Communication, 12/03/07.

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Appendix C

APPENDIX C

Computational Methods

C.1 Unit Application Factors

In order to estimate total average annual glycol use for the airports where data were not available, a modified version of the 'Fluid Use Factors' method was employed (ERG 2000). For this analysis, hub type was used to classify the scale of operations, and total annual snowfall was represented by categories similar to those used in the ERG analysis, except it was assumed that deicer usage at any airport with less than 0.1 inches of average annual snowfall would be insignificant for the purposes of this investigation. For clarity, the coefficient describing glycol usage as a function of deicing season operations is called the "Unit Application Factor" (UAF).

A Unit Application Factor (UAF) was first determined for each airport with reported usage data using the following equation:

$$UAF_x = Average\left[\frac{G_i}{O_i}\right]$$

Where:

UAF_x = Unit Application Factor for Airport x

G_i = Glycol usage in season i (gallons)

O_i = Total operations in season i (operations)

The airports were then aggregated into Group Codes representing combinations of hub size and ranges of average annual snowfall amount, as illustrated in the following matrix:

TABLE C-1
Unit Application Factor Group Codes

		Hub Type			
		L	**M**	**S**	**N**
Snowfall Code and Range (inches)	1, >60"	L1	M1	S1	N1
	2, 30.0 - 59.9"	L2	M2	S2	N2
	3, 15.0 - 29.9"	L3	M3	S3	N3
	4, 1.0 - 14.9"	L4	M4	S4	N4
	5, 0.1 - 0.9"	L5	M5	S5	N5

A UAF was then calculated for each Group Code, as follows:

$$UAF_z = Average[UAF_1 \cdots UAF_n]$$

Where:

UAF_z = UAF for Group Code *z*

UAF_i = UAF for airport i in Group Code *z*

n = Number of airports in Group Code *z*

There were two adjustments that were required by lack of data or apparently anomalous results:

- There was no usage data available for some of the hub/snowfall groups, so the factors from adjacent groups were assigned as reasonable estimates.
- A few airports were censured from the analysis because their UAFs were inconsistent with the rest of the airports in their Group. The criterion used for this decision was a UAF that varied from the average for the rest of the group by a factor of two or more.

Table C-2 presents the UAFs developed in the analysis. Numbers of airports that contributed to each UAF value are shown, along with the standard deviation of the data. Boxed groups of cells indicate where UAFs from adjacent Groups were assigned as reasonable estimates. The shaded cells in each cluster have been extrapolated from the unshaded cell. Aircraft usage data for LAS and PHX was received after the unit application factor analysis was complete and thus not included in the calculation.

TABLE C-2
Unit Application Factors

Snowfall		Hub Type			
Code	**Range (Inches)**	**Large**	**Medium**	**Small**	**Non**
1	> 60	2.37 *n* = 1 s.d. = n/a	3.00 *n* = 2 s.d. = 0.439	2.40 *n* = 3 s.d. = 0.504	2.40[a]
2	30.0–59.9	2.43 *n* = 4 s.d. = 1.00	2.83 *n* = 6 s.d. = 2.83	1.22 *n* = 4 s.d. = 0.861	1.22[a]
3	15.0–29.9	1.44 *n* = 6 s.d. = 0.182	1.41 *n* = 3 s.d. = 0.307	1.20 *n* = 3 s.d. = 0.408	0.40 *n* = 1 s.d. = n/a
4	1.0–14.9	0.16 *n* = 4 s.d. = 0.048	0.24 *n* = 5 s.d. = 0.219	0.16[a]	0.16[a]
5	0.1–0.9	0.07[a]	0.07 *n* = 1 s.d. =n/a	0.07[a]	0.07[a]

s.d., standard deviation.
[a] Estimate based on others in snowfall group.

C.2 Estimation of Uncertainty in Aircraft Deicer Usage

This subsection describes the method used to estimate the uncertainty in the national average annual glycol usage calculation.

The calculated UAFs are based on a subset of airports in the United States where deicing is conducted. For a variety of reasons, these airports tend to be those with the largest number of operations and greatest snowfall totals, and therefore represent the greatest portion of the total national glycol usage. There is inherent year to year variability in both operations and weather that introduces uncertainty into the calculated average annual glycol usage at each airport where usage data were available. This uncertainty in calculated average glycol usage for each such airport can be described as the standard error:

$$SE = \frac{SD}{\sqrt{n}}$$

Where:

SD = Standard Deviation

n = sample size

After the UAFs were calculated for each airport within a given Group Code (e.g. L1, L2, L3, etc…), an average UAF was determined as the average of the calculated UAFs in each group. The error associated with a Group UAF based on the average of individual airport UAFs, $X_1, X_2, X_3, \ldots, X_n$, is calculated as:

$$E_z = \frac{1}{m}\sqrt{\frac{SE_{X_1}{}^2}{n_1} + \frac{SE_{X_2}{}^2}{n_2} + \ldots + \frac{SE_{X_m}{}^2}{n_m}}$$

Where:

E_z = statistical error in UAF for Group Code *z*

m = number of airports in Group Code *z*

n = number of airports with usage data in Group Code *z*

The uncertainty in the estimated average annual glycol usage for each airport where data were not available can then be calculated as:

$$E_{Glycol_Estimate} = UAF_z * t_{Ops}\sqrt{\left[\left(\frac{E_z}{UAF_z}\right)^2 + 1\right]\left[\left(\frac{E_{t_{Ops}}}{t_{Ops}}\right)^2 + 1\right] - 1}$$

Where:

t_{Ops} = number of deicing season operations

E_{tOps} = Standard deviation of number of deicing season operations

With the uncertainties in the estimated annual average glycol use each airport defined, the error in the nationwide estimate can be calculated as:

$$E_{National_Estimate} = \sqrt{E_{Airport_1}{}^2 + E_{Airport_2}{}^2 + \ldots + E_{Airport_n}{}^2}$$

Appendix D

TABLE D-1
2002 - 2003 Pavement Deicer Usage

Airport	Hub/Snowfall Group Code	Urea Usage (lbs)	Potassium Acetate (gal)	Sodium Acetate (lbs)	Sodium Formate (lbs)	Ethylene Glycol Based Fluids (gal)	Propylene Glycol Based Fluids (gal)	Sand (lbs)
ABQ	M4	-	700	-	-	-	-	-
ABR	N2	-	4,009	-	-	-	-	-
AFW	N5	-	900	-	-	-	-	600
ALB	S1	-	15,000	150,000	-	-	-	1,600,000
ANC	M1	2,377,200	85,442	-	-	-	-	4,613,280
ASE	N1	-	-	15,000	-	-	-	-
ATL	L4	-	48,000	-	-	-	-	-
ATW	N2	-	17,500	-	-	-	-	81,000
AUS	M5	-	7,756	-	-	-	-	-
AVP	N2	-	-	-	-	-	10,000	-
AZO	N1	-	-	-	-	-	-	100,000
BDL	M2	50,250	85,500	255,000	-	-	-	3,860,000
BET	N2	178,000	-	-	-	-	-	30,000
BIS	N2	-	-	-	-	-	-	307,340
BOI	S3	131,888	1,295	-	-	-	-	-
BOS	L2	7,500	-	-	-	373,185	-	4,664,000
BUF	M1	-	-	-	-	-	-	589,200
BWI	N	-	221,299	234,000	360,000	-	-	558,000
CAK	S2	-	5,521	-	-	-	-	-
CLE	M2	-	350,000	-	1,433	-	-	1,100
CLT	L4	60,350	-	10,000	-	-	-	-
CMH	M3	-	69,980	-	9,620	-	-	5,587,160
COS	S2	-	40,800	-	-	-	-	4,000
CRW	N2	35,000	-	-	-	-	3,983	-
CVG	L3	-	561,400	-	4,000	-	-	10,396,100
CWA	N2	115,700	8,903	-	-	400	-	962,400
DAL	M4	-	100	-	-	-	-	-
DAY	S3	-	21,568	-	6,600	-	-	2,000,000
DCA	L3	124,000	57,100	57,000	-	-	-	298,000
DEN	L1	-	480,205	-	-	-	-	2,750,000
DFW	L4	-	-	-	-	-	-	900,000
DSM	S2	-	40,000	75,000	-	-	-	-
DTW	L2	-	368,000	-	-	-	-	50,000
EVV	N4	-	4,400	-	-	-	-	-
EWR	L3	-	489,500	-	-	-	-	300
FAI	S1	574,000	40,180	-	-	-	-	4,782,500
FWA	N2	373,500	42,870	-	-	-	-	1,346,000
GEG	S2	296,000	-	-	-	-	110	-
GRB	S2	56,260	-	-	-	-	-	780,000
GRR	S1	-	11,370	-	13,230	-	-	-
GSO	S4	140,000	11,500	-	-	-	-	-
HTS	N2	48,000	-	-	-	-	-	-
HYA	N2	-	-	-	-	-	-	7,000
IAD	L3	-	558,000	379,020	-	-	-	-
ILM	N4	-	-	4,400	-	-	-	-
ILN	S3	-	390,528	2,762,000	-	-	-	-
IND	M3	-	222,733	894,000	-	-	-	-
JFK	L3	-	39,000	3,252,600	-	-	39,000	-
JNU	S1	452,000	-	-	-	-	-	-
LCK	N3	-	18,660	-	24,000	-	-	-
LGA	L3	-	175,300	1,602	-	-	175,300	4,482,000
MCI	M3	-	20,000	5,880	-	-	-	1,122,000
MDW	L2	-	190,397	-	-	-	-	-
MEM	M4	-	47,422	29,767	-	-	-	-
MHT	M2	25,500	45,133	-	-	-	-	1,676,000
MKE	M2	-	251,000	-	-	-	-	-
MSP	L2	-	83,640	114,000	-	-	-	16,262,000
OKC	S4	-	6,500	4,000	-	-	-	-
OMA	M3	-	20,312	10,000	-	-	-	102,600
OME	N2	-	6,000	-	-	-	-	3,000,000
ORD	L2	-	12,702	-	-	-	1,103,233	-
OTZ	N2	10,000	7,500	-	-	-	1,350,000	-
PHL	L3	-	-	-	-	-	141,000	-
PIT	M2	-	204,000	40,000	200,000	-	-	-
PVD	M2	-	24,000	-	-	-	-	1,462,120
RAP	N2	-	-	-	-	-	1,500	600,000
RDM	N4	-	-	-	-	-	-	4,000
RDU	M4	-	100,000	-	-	-	-	480,000
RFD	N2	488,000	50,460	-	-	-	-	-
RIC	S4	-	30,203	-	-	-	-	20,000
RNO	M3	6,000	3,000	-	-	-	-	-
ROA	N3	-	17,935	-	-	-	-	-
ROC	S1	-	45,000	-	-	-	-	40,000
SDF	S3	-	107,760	18,000	-	-	-	-
SLC	L2	200,000	1,600	-	-	-	-	278,000
STL	M3	-	1,100,256	-	-	-	-	454,000
SWF	N3	120,000	12,000	4,000	-	-	-	300,000
SYR	S1	-	1,800	-	-	-	-	1,190,000
TOL	N2	4,000	30,000	-	-	-	-	-
XNA	S4	36,000	-	-	32,000	36,684	-	-
YIP	S2	-	-	-	-	-	-	500,000

TABLE D-2
2003 - 2004 Pavement Deicer Usage

Airport	Hub/Snowfall Group Code	Urea Usage (lbs)	Potassium Acetate (gal)	Sodium Acetate (lbs)	Sodium Formate (lbs)	Ethylene Glycol Based Fluids (gal)	Propylene Glycol Based Fluids (gal)	Sand (lbs)
ABQ	M4	-	700	-	-	-	-	-
ABR	N2	-	3,000	-	-	-	-	-
ALB	S1	-	15,000	150,000	-	-	-	1,600,000
ANC	M1	1,317,500	73,526	-	-	-	-	6,661,220
ASE	N1	-	-	23,000	-	-	-	-
ATL	L4	-	48,000	-	-	-	-	-
ATW	N2	-	17,500	-	-	-	-	81,000
AUS	M5	-	250	-	-	-	-	-
AVP	N2	-	-	-	-	-	12,000	-
AZO	N1	-	-	4,000	-	-	-	1,000,000
BDL	M2	250	67,600	202,000	-	-	-	1,650,000
BET	N2	10,000	-	-	-	-	-	30,000
BFI	N4	-	2,835	-	-	-	-	-
BIS	N2	-	1,700	-	-	-	-	147,780
BNA	M4	-	25,000	-	-	-	-	-
BOI	S3	542,571	13,991	-	-	-	-	-
BOS	L2	4,800	-	-	-	151,118	-	1,334,000
BUF	N	-	-	-	-	-	-	596,800
BWI	L3	-	152,928	362,000	120,000	-	-	660,000
CAK	S2	22,000	1,703	-	-	-	-	-
CLE	M2	-	499,988	-	1,393	-	-	1,100
CLT	L4	319,250	17,039	-	-	-	-	-
CMH	M3	-	90,665	-	4,720	-	-	2,385,120
COS	S2	-	25,051	-	-	-	-	2,000
CRW	N2	44,000	-	-	-	-	2,710	-
CVG	L3	-	327,400	-	4,000	-	-	4,000,000
CWA	N2	68,740	8,983	-	-	400	-	836,400
DAY	S3	-	24,000	-	-	-	-	2,000,000
DCA	L3	32,000	52,400	40,000	-	-	-	162,000
DEN	L1	-	526,958	-	-	-	-	3,486,000
DFW	L4	-	-	-	-	-	-	-
DSM	S2	-	28,500	88,000	-	-	-	-
DTW	L2	-	221,600	-	-	-	-	50,000
EVV	N4	-	4,400	-	-	-	-	-
EWR	L3	-	429,780	7,000	-	-	-	288
FAI	S1	288,000	30,030	-	-	-	-	6,527,500
FWA	N2	227,625	35,390	-	-	-	-	2,980,000
GEG	S2	810,000	-	-	-	-	110	-
GRB	S2	34,180	-	-	-	-	-	484,900
GRR	S1	-	8,610	-	1,000	-	-	-
GSO	S4	78,000	7,500	-	-	-	-	-
HTS	N2	70,000	4,135	-	-	-	-	20,000
HYA	N2	-	-	-	-	-	-	6,500
IAD	L3	-	367,483	736,860	-	-	-	-
ILN	S3	-	226,353	714,000	-	-	-	-
IND	M3	8,000	80,948	312,000	-	-	-	-
JFK	L3	-	57,000	4,269,600	-	-	57,000	-
JNU	S1	536,000	-	-	-	-	-	3,000
LCK	N3	-	7,350	-	24,000	-	-	-
LGA	L3	-	155,700	1,901	-	-	155,700	2,049
MCI	M3	-	128,300	1,960	-	-	-	940,000
MDW	L2	-	193,263	-	-	-	-	-
MHT	M2	21,000	50,270	-	-	-	-	1,600,000
MKE	M2	-	149,088	-	80,000	-	-	-
MSP	L2	-	214,100	40,000	-	-	-	9,300,000
OKC	S4	-	6,500	-	-	-	-	-
OMA	M3	-	47,206	2,000	-	-	-	85,600
OME	N2	-	6,000	-	-	-	-	3,000,000
ORD	L2	-	56,154	-	-	-	1,554,506	-
OTZ	N2	10,000	5,300	-	-	-	1,350,000	-
PDX	M4	-	77,595	17,632	385,700	-	-	-
PHL	L3	-	-	-	-	-	105,000	-
PIT	M2	-	253,000	-	70,000	-	-	-
PVD	M2	-	20,350	-	-	-	-	771,840
RAP	N2	-	-	-	-	-	1,500	600,000
RDM	N4	-	-	-	-	-	-	1,000
RDU	M4	84,000	-	-	-	-	-	-
RFD	N2	738,600	52,599	-	-	-	-	-
RIC	S4	-	13,000	14,000	-	-	-	20,000
RNO	M3	8,000	4,500	-	-	-	-	-
ROA	N3	-	21,150	-	-	-	-	-
ROC	S1	-	45,809	-	-	-	-	40,000
SBN	S1	36,860	-	-	-	-	-	1,000,000
SDF	S3	-	117,227	94,000	-	-	-	-
SEA	L4	-	44,838	2,154	-	-	-	5,420
SLC	L2	2,130,000	57,600	-	-	-	-	2,734,000
STL	M3	-	783,092	-	-	-	-	247,400
SWF	N3	170,000	12,000	4,000	-	-	-	300,000
SYR	S1	-	1,800	-	-	-	-	2,006,000
TOL	N2	-	30,000	-	-	-	-	-
XNA	S4	-	-	-	-	24,310	-	-
YIP	S2	-	-	-	-	-	-	500,000

TABLE D-3
2004 - 2005 Pavement Deicer Usage

Airport	Hub/Snowfall Group Code	Urea Usage (lbs)	Potassium Acetate (gal)	Sodium Acetate (lbs)	Sodium Formate (lbs)	Ethylene Glycol Based Fluids (gal)	Propylene Glycol Based Fluids (gal)	Sand (lbs)
ABQ	M4	-	700	-	-	-	-	-
ABR	N2	-	1,000	-	-	-	-	-
AFW	N5	-	300	-	-	-	-	200
ALB	S1	-	15,000	150,000	-	-	-	1,600,000
ANC	M1	3,850,000	131,000	-	-	-	7,400,000	-
ASE	N1	-	10,700	13,000	-	-	-	-
ATL	L4	-	48,000	-	-	-	-	-
ATW	N2	-	17,500	-	-	-	-	81,000
AVP	N2	-	-	-	-	-	14,000	-
AZO	N1	-	-	8,000	-	-	-	200,000
BDL	M2	250	49,899	215,000	-	-	-	2,600,000
BET	N2	14,000	-	-	-	-	-	30,000
BFI	N4	-	1,861	-	-	-	-	-
BIS	N2	-	5,679	-	-	-	-	282,180
BOI	S3	135,244	7,286	-	-	-	-	-
BOS	L2	18,350	-	-	-	261,887	-	5,062,000
BUF	M1	-	-	-	24,000	-	-	276,000
BWI	N	-	165,614	208,000	-	-	-	898,000
CAK	S2	42,000	1,968	500	-	-	-	-
CLE	M2	-	275,000	-	1,985	-	-	1,100
CLT	L4	70,050	8,000	-	-	-	-	-
CMH	M3	-	125,002	-	7,580	-	-	4,011,780
COS	S2	-	37,000	-	-	-	-	4,000
CRW	N2	48,000	-	8,000	-	-	3,844	-
CVG	L3	-	508,000	-	4,000	-	-	5,000,000
CWA	N2	185,880	9,324	-	-	400	-	1,292,400
DAY	S3	-	34,530	-	-	-	-	2,000,000
DCA	L3	78,000	36,740	5,000	-	-	-	211,000
DEN	L1	-	607,836	-	-	-	-	3,970,000
DFW	L4	-	2,775	-	-	-	-	40,000
DSM	S2	-	87,500	267,000	-	-	-	-
DTW	L2	-	258,100	-	-	-	-	50,000
EVV	N4	-	4,510	-	-	-	-	-
EWR	L3	-	297,470	2,000	-	-	-	282
FAI	S1	134,000	20,014	-	-	-	-	7,770,000
FWA	N2	282,000	44,820	-	-	-	-	2,144,000
GEG	S2	388,000	110	-	-	-	110	-
GRB	S2	44,140	-	17,457	-	-	-	1,242,000
GRR	S1	-	10,400	-	12,000	-	-	-
GSO	S4	60,000	5,700	-	-	-	-	-
HTS	N2	50,000	-	-	-	-	-	-
HYA	N2	-	-	-	-	-	-	8,000
IAD	L3	-	187,546	743,725	-	-	-	-
ILN	S3	-	260,923	2,120,000	-	-	-	-
IND	M3	-	54,899	20,600	-	-	-	-
JFK	L3	-	60,000	3,181,400	-	-	60,000	-
JNU	S1	446,000	-	-	-	-	-	1,500
LCK	N3	-	6,924	-	67,660	-	-	274,240
LGA	L3	-	181,037	1,680	-	-	181,037	1,841
MCI	M3	-	125,300	5,880	-	-	-	1,952,000
MDW	L2	-	256,200	-	-	-	-	-
MEM	M4	-	104,215	123,480	-	-	-	-
MHT	M2	64,000	87,212	-	-	-	-	2,000,000
MKE	M2	-	183,796	-	180,000	-	-	-
MSP	L2	-	285,219	94,000	-	-	-	5,700,000
OKC	S4	-	9,715	2,000	-	-	-	-
OMA	M3	-	64,957	17,300	-	-	-	134,664
OME	N2	-	6,000	-	-	-	-	3,000,000
ORD	L2	-	231,221	-	-	-	591,074	-
OTZ	N2	10,000	5,000	-	-	-	1,350,000	-
PDX	M4	-	39,855	13,244	247,848	-	-	-
PHL	L3	-	-	-	-	-	35,000	270,000
PIT	M2	-	91,800	-	4,000	-	-	-
PVD	M2	-	29,163	-	-	-	-	823,440
RAP	N2	-	-	-	-	-	1,500	600,000
RDM	N4	-	-	-	-	-	-	1,000
RDU	M4	6,000	-	-	-	-	-	600,000
RFD	N2	814,200	39,777	-	-	-	-	-
RIC	S4	-	22,000	20,000	-	-	-	20,000
RNO	M3	20,000	12,000	-	-	-	-	-
ROA	N3	-	10,850	-	-	-	-	-
ROC	S1	-	44,114	-	-	-	-	40,000
SBN	S1	28,020	-	-	-	-	-	1,000,000
SDF	S3	-	123,968	112,000	-	-	-	-
SLC	L2	1,078,000	20,100	-	-	-	-	960,000
STL	M3	-	461,048	-	-	-	-	35,400
SWF	N3	170,000	12,000	4,000	-	-	-	360,000
SYR	S1	-	1,800	-	-	-	-	1,842,000
TOL	N2	-	50,000	-	-	-	-	-
XNA	S4	18,000	-	-	-	17,710	-	-
YIP	S2	-	-	-	-	-	-	500,000

Appendix E

TABLE E-1

Estimated Average Annual Aircraft Deicer Usage

Ranking	Airport	Hub Type	Average Annual Deicing Season Operations	Estimated Average Annual Glycol Usage (Gals)	Percent of All Glycol Usage Nationwide	Cummulative Percent of All Glycol Usage Nationwide	Permit Type G = General I = Individial R = General Stormwater N = No Direct Discharge U = Unknown	Permit Parameters of Interest
1	DTW	L	284,204	1,575,769	10.4%	10.4%	I	DO, BOD, ammonia, CBOD
2	ORD	L	541,287	1,270,083	8.4%	18.8%	I	BOD, ammonia
3	MSP	L	281,693	1,085,858	7.2%	26.0%	I	
4	DEN	L	301,738	713,773	4.7%	30.8%	I	
5	EWR	L	236,820	656,038	4.3%	35.1%	I	COD
6	PIT	M	177,383	593,629	3.9%	39.0%	I	
7	CLE	M	138,244	414,248	2.7%	41.8%	I	DO, ammonia, ethylene glycol
8	CVG	L	287,190	391,252	2.6%	44.4%	I	DO, BOD, ammonia
9	LGA	L	220,887	379,441	2.5%	46.9%	I	BOD
10	MDW	L	152,058	369,075 *	2.4%	49.3%	N	
11	SLC	L	191,268	360,645	2.4%	51.7%	I	BOD, ethylene glycol, CBOD
12	ANC	M	104,312	345,166	2.3%	54.0%	G	
13	IND	M	103,350	342,170	2.3%	56.3%	I	ammonia, COD, propylene glycol monobuty ether
14	BOS	L	209,302	339,507	2.3%	58.5%	I	No parameters of interest
15	PHL	L	256,841	337,675	2.2%	60.7%	I	
16	ILN	S	N/D	333,713	2.2%	63.0%	I	
17	BDL	M	63,673	279,280	1.9%	64.8%	I	COD
18	IAD	N	217,263	276,653	1.8%	66.6%	I	
19	STL	M	182,827	258,257 *	1.7%	68.4%	U	BOD, COD, ammonia
20	JFK	L	178,959	257,009 *	1.7%	70.1%	I	BOD, BOD % removal
21	BWI	L	152,407	230,508	1.5%	71.6%	I	
22	DAY	S	49,676	160,352	1.1%	72.6%	I	
23	MCI	M	93,282	158,863	1.1%	73.7%	I	BOD and COD
24	ALB	S	52,557	156,515	1.0%	74.7%	I	BOD, ammonia, UOD
25	MKE	M	107,433	150,086	1.0%	75.7%	I	
26	BUF	M	54,861	147,505	1.0%	76.7%	I	BOD, ammonia, ethylene glycol
27	CLT	L	245,352	129,616	0.9%	77.6%	I	
28	MEM	M	207,736	113,172	0.8%	78.3%	I	
29	PVD	M	47,109	111,731	0.7%	79.0%	I	No parameters of interest
30	CMH	M	98,620	107,607	0.7%	79.8%	I	DO, ammonia, ethylene glycol, CBOD
31	SDF	S	87,582	105,247 *	0.7%	80.5%	I	DO, BOD, ammonia, ethylene glycol
32	MHT	M	41,555	103,961	0.7%	81.1%	G	
33	ROC	S	42,775	102,501 *	0.7%	81.8%	G	
34	GCN	S	42,686	102,288 *	0.7%	82.5%	G	
35	SYR	S	38,743	92,839 *	0.6%	83.1%	I	BOD. ammonia
36	DFW	L	438,596	91,631	0.6%	83.7%	I	
37	DCA	L	150,793	72,732	0.5%	84.2%	G	
38	GRR	S	33,657	70,114	0.5%	84.7%	I	
39	OMA	M	48,219	68,113 *	0.5%	85.1%	I	BOD
40	RNO	M	46,786	67,538	0.5%	85.6%	G	
41	BET	N	54,970	66,980 *	0.4%	86.0%	U	
42	ATL	L	536,870	61,433	0.4%	86.4%	G	
43	JNU	S	24,555	58,841 *	0.4%	86.8%	U	
44	ACK	N	47,608	58,010 *	0.4%	87.2%	U	
45	PWM	S	24,118	57,795 *	0.4%	87.6%	U	
46	HPN	S	40,939	55,099	0.4%	87.9%	I	BOD, ethylene glycol, CBOD
47	BTV	S	22,905	54,887 *	0.4%	88.3%	U	
48	HYA	N	43,080	52,493 *	0.4%	88.6%	U	
49	CAK	S	20,027	48,834	0.3%	89.0%	I	DO, ammonia, ethylene glycol
50	BOI	S	39,943	47,999 *	0.3%	89.3%	G	
51	SBN	S	19,150	45,890 *	0.3%	89.6%	G	
52	DSM	S	37,552	45,324	0.3%	89.9%	I	Ethylene Glycol
53	GEG	S	36,709	44,730 *	0.3%	90.2%	U	
54	ICT	S	34,286	41,201 *	0.3%	90.5%	U	
55	PDX	M	128,009	38,208	0.3%	90.7%	I	
56	BIL	S	28,643	34,902 *	0.2%	90.9%	G	
57	COS	S	28,043	34,171 *	0.2%	91.2%	G	BOD
58	MDT	S	27,732	33,791 *	0.2%	91.4%	U	
59	SEA	L	195,664	33,453	0.2%	91.6%	I	

*Glycol usage estimated using EPA method outlined in *Preliminary Data Summary Airport Deicing Operations (Revised)* EPA-821-R-00-016

** Estimated

N/D No Data

TABLE E-1

Estimated Average Annual Aircraft Deicer Usage

Ranking	Airport	Hub Type	Average Annual Deicing Season Operations	Estimated Average Annual Glycol Usage (Gals)	Percent of All Glycol Usage Nationwide	Cummulative Percent of All Glycol Usage Nationwide	Permit Type G = General I = Individial R = General Stormwater N = No Direct Discharge U = Unknown	Permit Parameters of Interest
60	BGR	S	13,894	29,562	0.2%	91.8%	U	
61	BNA	M	99,790	28,628	0.2%	92.0%	I	DO, BOD, COD, ammonia, CBOD
62	CRW	N	23,274	28,359 *	0.2%	92.2%	U	
63	GFK	N	23,227	28,302 *	0.2%	92.4%	U	
64	FWA	N	22,833	27,822 *	0.2%	92.6%	U	
65	ABE	S	22,462	27,370 *	0.2%	92.7%	G	
66	TVC	N	11,286	27,045 *	0.2%	92.9%	U	
67	AZO	N	11,112	26,628 *	0.2%	93.1%	G	
68	TOL	N	21,802	26,565 *	0.2%	93.3%	I	
69	FSD	N	21,249	25,892 *	0.2%	93.4%	U	
70	CID	S	20,301	24,737 *	0.2%	93.6%	U	
71	ISP	S	20,269	24,357 *	0.2%	93.8%	U	
72	RDU	M	103,225	24,317 *	0.2%	93.9%	U	
73	ASE	N	9,831	23,557 *	0.2%	94.1%	U	
74	CPR	N	9,766	23,403 *	0.2%	94.2%	G	
75	LEX	S	21,879	23,137	0.2%	94.4%	I	DO, ammonia
76	SGF	S	18,522	22,258 *	0.2%	94.5%	G	BOD
77	ERI	N	9,245	22,154 *	0.2%	94.7%	G	
78	BGM	N	9,206	22,059 *	0.2%	94.8%	U	
79	FAI	S	30,997	21,492	0.1%	95.0%	U	
80	LAN	N	17,233	20,998 *	0.1%	95.1%	G	
81	IAH	L	279,238	19,797 *	0.1%	95.2%	G	
82	FNT	S	15,978	19,469 *	0.1%	95.4%	G	
83	MLI	S	15,454	18,830 *	0.1%	95.5%	G	
84	EGE	N	7,801	18,694 *	0.1%	95.6%	U	
85	GRB	S	14,755	17,979 *	0.1%	95.7%	U	
86	JAC	N	7,409	17,755 *	0.1%	95.9%	I	
87	ELM	N	7,406	17,748 *	0.1%	96.0%	U	
88	ABQ	M	71,396	16,819 *	0.1%	96.1%	G	
89	MSN	S	24,728	16,455	0.1%	96.2%	I	
90	AVP	N	13,199	16,083 *	0.1%	96.3%	G	
91	ACY	S	13,349	16,042 *	0.1%	96.4%	I	
92	GTF	N	13,105	15,969 *	0.1%	96.5%	G	
93	BED	N	13,060	15,914 *	0.1%	96.6%	I	
94	AMA	S	13,233	15,902 *	0.1%	96.7%	U	
95	ATW	N	12,699	15,473 *	0.1%	96.8%	U	
96	FAR	N	11,789	14,365 *	0.1%	96.9%	U	
97	MSO	N	10,985	13,385 *	0.1%	97.0%	G	
98	ITH	N	5,548	13,294 *	0.1%	97.1%	I	BOD and ethylene glycol
99	MBS	N	10,900	13,282 *	0.1%	97.2%	G	
100	CWA	N	10,290	12,538 *	0.1%	97.3%	U	
101	SAW	N	4,961	11,889 *	0.1%	97.4%	G	
102	BZN	N	9,396	11,449 *	0.1%	97.4%	U	
103	RIC	S	50,635	11,405	0.1%	97.5%	I	
104	HLN	N	9,151	11,151 *	0.1%	97.6%	G	
105	RFD	N	9,084	11,068 *	0.1%	97.7%	U	
106	AKN	N	8,783	10,702 *	0.1%	97.7%	U	
107	ORF	M	45,145	10,635 *	0.1%	97.8%	I	
108	ENA	N	8,608	10,488 *	0.1%	97.9%	U	
109	RAP	N	8,548	10,416 *	0.1%	97.9%	U	
110	RST	N	8,493	10,349 *	0.1%	98.0%	U	
111	LCK	N	N/D	10,056	0.1%	98.1%	U	
112	BHM	S	43,808	9,868 *	0.1%	98.1%	G	No parameters of interest
113	GSO	S	42,943	9,673 *	0.1%	98.2%	U	
114	BMI	N	7,845	9,559 *	0.1%	98.3%	U	
115	BIS	N	7,648	9,320 *	0.1%	98.3%	U	
116	PIH	N	7,626	9,292 *	0.1%	98.4%	U	
117	MVY	N	7,336	8,939 *	0.1%	98.4%	U	
118	SUN	N	7,289	8,881 *	0.1%	98.5%	U	

*Glycol usage estimated using EPA method outlined in *Preliminary Data Summary Airport Deicing Operations (Revised)* EPA-821-R-00-016

** Estimated

N/D No Data

TABLE E-1
Estimated Average Annual Aircraft Deicer Usage

Ranking	Airport	Hub Type	Average Annual Deicing Season Operations	Estimated Average Annual Glycol Usage (Gals)	Percent of All Glycol Usage Nationwide	Cummulative Percent of All Glycol Usage Nationwide	Permit Type G = General I = Individial R = General Stormwater N = No Direct Discharge U = Unknown	Permit Parameters of Interest
119	CMI	N	7,176	8,744 *	0.1%	98.6%	U	
120	ELP	S	37,604	8,470 *	0.1%	98.6%	U	
121	CAE	S	36,097	8,131 *	0.1%	98.7%	U	
122	ROA	N	20,428	8,079	0.1%	98.7%	U	
123	LIT	S	35,582	8,015 *	0.1%	98.8%	U	
124	TYS	S	35,496	7,996 *	0.1%	98.8%	U	
125	OKC	S	34,275	7,721 *	0.1%	98.9%	U	
126	YIP	S	13,020	7,333	0.1%	98.9%	G	
127	LSE	N	5,697	6,942 *	0.1%	99.0%	U	
128	TUL	S	30,081	6,776 *	0.0%	99.0%	I	
129	GSP	S	30,024	6,763 *	0.0%	99.1%	G	
130	HOU	M	90,235	6,398 *	0.0%	99.1%	G	
131	MGW	N	5,089	6,201 *	0.0%	99.1%	G	
132	BFI	N	36,955	5,920 *	0.0%	99.2%	G	
133	PSC	N	14,712	5,818 *	0.0%	99.2%	U	
134	PIA	N	13,776	5,448 *	0.0%	99.3%	G	
135	TRI	N	13,540	5,355 *	0.0%	99.3%	U	
136	MSY	M	75,409	5,347 *	0.0%	99.3%	U	
137	SMF	M	70,356	4,988 *	0.0%	99.4%	G	
138	SAT	M	69,145	4,903 *	0.0%	99.4%	G	
139	AUS	M	68,453	4,853	0.0%	99.4%	G	
140	HSV	S	21,277	4,793 *	0.0%	99.5%	G	No parameters of interest
141	GJT	N	11,915	4,712 *	0.0%	99.5%	U	
142	LNK	N	11,277	4,460 *	0.0%	99.5%	U	
143	XNA	S	19,055	4,292 *	0.0%	99.5%	U	
144	LBB	S	19,055	4,292 *	0.0%	99.6%	U	
145	SWF	N	10,409	4,117 *	0.0%	99.6%	I	Ethylene Glycol
146	VGT	N	24,212	3,879 *	0.0%	99.6%	U	
147	GRI	N	3,105	3,784 *	0.0%	99.7%	U	
148	JAX	M	50,103	3,553 *	0.0%	99.7%	G	
149	MWH	N	8,496	3,360 *	0.0%	99.7%	U	
150	IDA	N	8,077	3,195 *	0.0%	99.7%	U	
151	PHF	S	13,993	3,152 *	0.0%	99.7%	U	
152	MAF	S	13,458	3,032 *	0.0%	99.8%	U	
153	SHV	N	18,367	2,943 *	0.0%	99.8%	G	
154	TWF	N	7,283	2,881 *	0.0%	99.8%	U	
155	LAS	L	268,780	2,860	0.0%	99.8%	G	
156	EUG	N	15,607	2,500	0.0%	99.8%	G	
157	LWS	N	6,127	2,423 *	0.0%	99.9%	U	
158	EVV	N	14,070	2,254 *	0.0%	99.9%	U	
159	DAL	M	74,821	2,219	0.0%	99.9%	G	
160	CHA	N	13,512	2,165 *	0.0%	99.9%	U	
161	MFR	N	12,991	2,082 *	0.0%	99.9%	G	
162	CHO	N	12,619	2,022 *	0.0%	99.9%	U	
163	ILM	N	11,905	1,908 *	0.0%	99.9%	U	
164	AVL	N	11,898	1,906 *	0.0%	99.9%	U	
165	AGS	N	8,290	1,328 *	0.0%	100.0%	U	
166	BLI	N	8,082	1,295 *	0.0%	100.0%	G	
167	RDD	N	7,670	1,229 *	0.0%	100.0%	U	
168	ABI	N	6,923	1,109 *	0.0%	100.0%	U	
169	FAY	N	5,519	885 *	0.0%	100.0%	U	
170	TUS	M	35,473	642	0.0%	100.0%	U	
171	PHX	L	286,002	440	0.0%	100.0%	G	
172	CHS	S	29,530	195 *	0.0%	100.0%	U	
173	FAT	S	28,358	187 *	0.0%	100.0%	U	
174	SAV	S	22,767	150 *	0.0%	100.0%	U	
175	TLH	S	20,072	132	0.0%	100.0%	G	
176	PNS	S	19,131	126 *	0.0%	100.0%	G	
177	JAN	S	18,190	120 *	0.0%	100.0%	U	

*Glycol usage estimated using EPA method outlined in *Preliminary Data Summary Airport Deicing Operations (Revised)* EPA-821-R-00-016

** Estimated

N/D No Data

TABLE E-1

Estimated Average Annual Aircraft Deicer Usage

Ranking	Airport	Hub Type	Average Annual Deicing Season Operations	Estimated Average Annual Glycol Usage (Gals)	Percent of All Glycol Usage Nationwide	Cummulative Percent of All Glycol Usage Nationwide	Permit Type G = General I = Individial R = General Stormwater N = No Direct Discharge U = Unknown	Permit Parameters of Interest
178	LFT	N	16,191	107 *	0.0%	100.0%	U	
179	MYR	S	14,448	96 *	0.0%	100.0%	G	
180	BTR	S	13,870	92 *	0.0%	100.0%	U	
181	OTH	N	N/D	80	0.0%	100.0%	U	
182	MOB	N	9,574	63 *	0.0%	100.0%	G	No parameters of interest
183	MGM	N	7,355	48 *	0.0%	100.0%	G	No parameters of interest
184	AEX	N	6,199	41 *	0.0%	100.0%	U	

*Glycol usage estimated using EPA method outlined in *Preliminary Data Summary Airport Deicing Operations (Revised)* EPA-821-R-00-016

** Estimated

N/D No Data

Appendix F

APPENDIX F

Deicing Airports Subject to TMDL Regulations (on 303(d) Listed Water or Water Body with Issued TMDL)

Airport	Estimated Average Annual Glycol Use (gallons)	Nature of Receiving Water Impairment	Potential Sources Related to Impairment?	303(d) Listed or Issued TMDL
ORD	1,270,082	Ammonia-Nitrogen, BOD (TMDL) Dissolved Oxygen (303(d) Listed)		Issued TMDL and 303(d) Listed
PIT	593,629	Nonpriority Organics, Unionized Ammonia, Organic Enrichment/Low Do		303(d) Listed
CLE	414,247	Unknown Toxicity, Organic Enrichment/Low Do, Unionized Ammonia		303(d) Listed
CVG	391,251	CBOD, NH3-N (TMDL) Organic Enrichment/Low DO (303(d) Listed)	Deicing fluid contamination	Issued TMDL and 303(d) Listed
LGA	379,440	Oxygen Demand		303(d) Listed
SLC	360,644	Dissolved Oxygen		303(d) Listed
ANC	345,166	Dissolved Oxygen	Deicing runoff	Issued TMDL
BOS	339,506	Priority Organics		303(d) Listed
ILN	333,712	Unknown Toxicity, Organic Enrichment/Low Do, Unionized Ammonia		303(d) Listed
BDL	279,279	Ethylene Glycol	Deicing agents	Issued TMDL
JFK	257,009	Oxygen Demand		303(d) Listed
BWI	230,508	Biological		303(d) Listed
DAY	160,352	Priority Organics, Organic Enrichment/Low Do		303(d) Listed
MKE	150,085	Aquatic Toxicity		303(d) Listed
MEM	113,172	Dissolved Oxygen		303(d) Listed
PVD	111,731	Low Dissolved Oxygen		303(d) Listed

Deicing Airports Subject to TMDL Regulations (on 303(d) Listed Water or Water Body with Issued TMDL)

Airport	Estimated Average Annual Glycol Use (gallons)	Nature of Receiving Water Impairment	Potential Sources Related to Impairment?	303(d) Listed or Issued TMDL
SDF	105,247	Organic Enrichment/Low Do		303(d) Listed
MHT	103,961	Dissolved Oxygen, Dissolved Oxygen Saturation		303(d) Listed
DCA	72,732	BOD (TMDL) Organics (303(d) Listed)		Issued TMDL and 303(d) Listed
BTV	54,887	Toxics		303(d) Listed
CAK	48,834	Organic Enrichment/Low Do		303(d) Listed
BOI	47,998	Dissolved Oxygen		303(d) Listed
DSM	45,324	Priority Organics (TMDL) Deicing Agents, Priority Organics (303(d) Listed)	"Airport"	Issued TMDL and 303(d) Listed
PDX	38,208	Dissolved Oxygen, Biological Oxygen Demand	"…diurnal swings in dissolved oxygen during the summer months are most likely the result of algal growth, while winter violations are likely due to storm water runoff, including de-icing fluid."	Issued TMDL
SEA	33,453	Dissolved Oxygen		303(d) Listed
BGR	29,561	Propylene and ethylene glycols	"Deicing Agents"	Issued TMDL
BNA	28,627	Organic Enrichment/Low DO (TMDL) Dissolved Oxygen (303(d) Listed)	"Ethylene glycol (de-icer) runoff from Nashville airport impacts Sims Branch."	Issued TMDL and 303(d) Listed
CRW	28,359	Biological		303(d) Listed
TOL	26,565	Total Toxics		303(d) Listed
FSD	25,891	Ammonia, BOD		Issued TMDL

Deicing Airports Subject to TMDL Regulations (on 303(d) Listed Water or Water Body with Issued TMDL)

Airport	Estimated Average Annual Glycol Use (gallons)	Nature of Receiving Water Impairment	Potential Sources Related to Impairment?	303(d) Listed or Issued TMDL
LAN	20,998	Dissolved Oxygen		303(d) Listed
EGE	18,694	Unionized Ammonia		Issued TMDL
MSN	16,455	Aquatic Toxicity, BOD, Dissolved Oxygen		303(d) Listed
BED	15,914	Organic Enrichment/Low Do		303(d) Listed
FAR	14,365	Ammonia		303(d) Listed
MSO	13,385	Organic Enrichment/Low Dissolved Oxygen		303(d) Listed
HLN	11,150	Unionized Ammonia		303(d) Listed
RFD	11,068	Dissolved Oxygen		303(d) Listed
ORF	10,635	Dissolved Oxygen		303(d) Listed
RAP	10,416	Ammonia, CBOD, Dissolved Oxygen		Issued TMDL
LCK	10,055	Unknown Toxicity		303(d) Listed
CMI	8,744	Dissolved Oxygen		303(d) Listed
ROA	8,078	Biochemical Oxygen Demand		303(d) Listed
MGW	6,201	Biological		303(d) Listed
MSY	5,346	Organic Enrichment/Low DO (TMDL) Dissolved Oxygen (303(d) Listed)		Issued TMDL and 303(d) Listed
SMF	4,988	Unknown Toxicity		303(d) Listed
SAT	4,902	Dissolved Oxygen		Issued TMDL
AUS	4,853	Low Dissolved Oxygen		303(d) Listed
SWF	4,116	Unknown Toxicity		303(d) Listed

Deicing Airports Subject to TMDL Regulations (on 303(d) Listed Water or Water Body with Issued TMDL)

Airport	Estimated Average Annual Glycol Use (gallons)	Nature of Receiving Water Impairment	Potential Sources Related to Impairment?	303(d) Listed or Issued TMDL
EUG	2,500	Biological Oxygen Demand		Issued TMDL
LWS	2,423	Dissolved Oxygen		303(d) Listed
EVV	2,254	Dissolved Oxygen		303(d) Listed
MFR	2,081	Ammonia-Nitrogen, BOD5		Issued TMDL
BLI	1,295	Dissolved Oxygen		303(d) Listed
RDD	1,229	Unknown Toxicity		303(d) Listed
TLH	132	Dissolved Oxygen		303(d) Listed
LFT	106	Oxygen Demand		Issued TMDL
MOB	63	CBOD (TMDL) Organic Enrichment/Low DO (303(d) Listed)		Issued TMDL and 303(d) Listed
MGM	48	CBOD (TMDL) Organic Enrichment/Low DO (303(d) Listed)		Issued TMDL and 303(d) Listed
AEX	41	Oxygen Demand		Issued TMDL