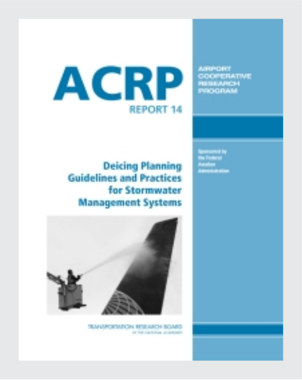

Deicing Planning Guidelines and Practices for Stormwater Management Systems

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 14

Deicing Planning Guidelines and Practices for Stormwater Management Systems

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), and the Air Transport Association (ATA) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

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FOREWORD

By Michael R. Salamone
Staff Officer
Transportation Research Board

ACRP Report 14: Deicing Planning Guidelines and Practices for Stormwater Management Systems represents one of the first references on deicing operations. This document provides practical technical guidance to airports; aircraft operators; consultants and designers; and local, state, and federal regulators. The guidelines address a wide array of practices for the practical, cost-effective control of runoff from aircraft and airfield deicing and anti-icing operations.

Under ACRP Project 02-02, CH2M Hill was asked to develop planning guidelines to assist airports and aircraft operators in identifying and selecting practices for controlling runoff from aircraft and airfield deicing operations.

A structured approach to developing an integrated deicing runoff management system is explained. This approach is based on the proven principles of adaptive management practices used in the field of watershed management/nonpoint source pollution control. Each step in the process is explained, along with special considerations that assist the reader in understanding how they may be applied to their specific facility.

The information in the document is organized in a top-down structure, leading the reader through the big picture issues and planning processes first, and then providing increasing detail on the how these processes might be implemented at an individual facility.

The discussion on drivers explains why deicing operations and control of the resulting runoff are required. Topics include why deicing is required for safe winter-time operations, the various FAA regulations and product specifications that ensure these operations are effective and the environmental concerns and regulations that result in requirements to control discharges of deicing runoff.

Overviews of the full range of available practices are described in a collection of fact sheets accompanying the report. They include guidance on how the reader can select from among various alternatives to identify which ones are potentially applicable at their facility. A master matrix identifying each fact sheet and comparing them in four categories: (1) source reduction, (2) containment/collection, (3) conveyance/storage, and (4) treatment/recycling. Characteristics covered include implementation and operation requirements; advantages, constraints, and keys to success; and relative costs and potential savings. Separate performance comparisons are presented in fact sheets for collection/containment practices and treatment/recycling technologies.

Detailed operational practices are provided on a comprehensive collection of fact sheets. These include source reduction techniques such as product selection and application and non-chemical deicing technologies. Fact sheets cover collection/containment practices, including centralized deicing facilities, glycol collection vehicles, and deicer-laden snow management. Descriptions of treatment and recycling alternatives cover options from discharge to a publicly owned treatment plant to natural treatment systems and glycol recovery. System component fact sheets describe different storage options, diversion controls, and monitoring technologies. Each fact sheet describes the nature and operating principles of each practice, factors that should be taken into account when considering its applicability at a particular facility, and capital and operating and maintenance costs.

CONTENTS

CHAPTER 1

Introduction

The Airport Cooperative Research Program (ACRP) funded the development of this document in response to a need for planning guidelines to assist airports and aircraft operators in identifying and selecting best management practices for controlling aircraft and airfield deicing runoff. Aircraft operators are included in this target audience because of their role as key participants and stakeholders in any decisions that may affect aircraft safety or operations.

This introductory section presents background on the origins and drivers behind this research project, describes the purpose and objectives of this document, and explains the structure of the planning guidance. Subsequent sections present guidelines for developing integrated deicing runoff management systems (Chapter 2), guidance for evaluating and selecting individual practices (Chapter 3), and Fact Sheets describing each of the practices (see Chapter 4).

For the purposes of this guidance document, best management practice is used in the most expansive sense and includes source reduction, collection, containment, storage, and treatment/disposal/recycling practices and technologies. Because the selection of deicing runoff management measures for each airport will be based on site-specific considerations and factors, the term should not be interpreted to mean that a particular practice identified in this document is the best for all situations. Instead, the collective group of practices identified generally is considered to represent potentially viable alternatives of managing deicing runoff. Other situation-specific practices or solutions outside the scope of this document also may be viable in certain situations.

Background

Deicing aircraft and airfield pavement is critical to ensuring safe flight operations during winter weather. The Federal Aviation Administration's (FAA's) "clean aircraft concept" and associated guidance require that all critical surfaces of an aircraft be free of contamination at takeoff. Achieving and maintaining these critical conditions during winter weather requires "deicing"—removing frost, snow, and ice—sometimes followed by "anti-icing"—preventing the development of further accumulations for a limited period of time (that is, holdover time). These processes are accomplished with a combination of physical removal techniques and application of specialized deicing and anti-icing products.

Similarly, airfield pavement surfaces must provide sufficient friction for safe landings, taxiing, and takeoffs during winter weather conditions. Approaches for deicing and anti-icing airfield pavement surfaces are distinctly different than those for aircraft, with physical removal playing a more prominent role and different deicing products being used. For simplicity, unless there is a reason to make a distinction, the term deicing in this document includes both deicing and anti-icing.

Deicing products and practices are standardized and implemented with the overriding priority of safe public travel. FAA standards for aircraft deicing and anti-icing include the use of products that meet stringent performance specifications defined and published by the Society of Automotive Engineers (SAE) Aerospace Council. To ensure deicing practices are appropriately and consistently implemented, they are described in an aircraft operator's FAA-approved Ground Deicing and Anti-icing Program, guidelines for which are provided in FAA Advisory Circular (AC) 120-60B. Reflecting the paramount focus on safety, pilots also have the discretionary power to demand supplemental deicing or anti-icing beyond the formal requirements if they believe it is needed.

FAA AC 150/5200-30B provides comparable guidance to airport operators in developing a snow and ice control plan, conducting and reporting runway friction surveys, and establishing snow removal and control procedures. These plans are required for all Part 139–certified airports and recommended for other airport operators. Guidance for airfield pavement deicing products is provided in the form of recommendations that they meet applicable SAE specifications.

Unfortunately, all of the SAE-certified aircraft and airfield pavement deicers have potential environmental implications when mixed with airfield runoff and discharged in airport stormwater. Concerns over these implications have led to regulation of deicing discharges under provisions of the Clean Water Act (CWA). Typically, this regulation is accomplished through a National Pollutant Discharge Elimination System (NPDES) permit authorizing deicing stormwater discharges and requiring that controls on deicing runoff be implemented. This situation can result in airports and aircraft operators facing the dual demands for flight safety and environmental compliance. Ultimately, flight safety cannot be impaired, and compliance with environmental laws must be maintained.

Environmental requirements on deicing runoff discharges vary from state to state and from airport to airport and may be driven by local environmental concerns associated with deicing pollutants (see "Environmental Concerns," in Section 2). Most larger airports and those on sensitive receiving waters already have implemented deicing runoff control programs designed to address site-specific needs for environmental protection. Currently, the U.S. Environmental Protection Agency (EPA) is engaged in effluent limitation guideline (ELG) rule making for airport deicing discharges. Should EPA determine that there are best available technologies that are both nationally applicable and economically achievable for most of the industry, it is expected to promulgate such standards, and they will become the "floor" for all future stormwater permits that address deicing.

Because many large airports already have been working to address the threats from deicing discharges, these potentially new regulatory developments may have their greatest affect on midsize and smaller airports, where deicing operations and runoff may have been previously considered to be too small by environmental regulators to be of significant concern. These facilities and their aircraft operator tenants face unique challenges in developing deicing runoff management programs, including limited staff resources, funding, and knowledge regarding the technical issues and best management practice alternatives. To date, gaining an understanding of this topic by airport staff required gathering information from a variety of government agency documents, communicating with other airports that have successfully developed deicing programs, attending national conferences to hear technical presentations, and hiring consultants experienced in this specialty area. With an increasing number of airports seeking this information, there is a clear need for a standard reference of essential information on the topic of deicing runoff management. ACRP Project 02-02 addresses this need.

Purpose and Objectives

The purpose of this document is to provide practical planning guidance describing best management practices for managing airport deicing runoff. The following objectives guided the development of this document:

- Develop the document as a practitioner's handbook that is useful to airports, aircraft operators, their consultants, and relevant regulatory agencies;
- Provide practical guidance to assist airports and aircraft operators in deciding what types of practices may be appropriate to meet their particular requirements and constraints (funding, operations, setting, etc.); and
- Present the guidance in a way that overlaps or overlays with the principal compliance considerations of the NPDES permit program and the CWA.

The purpose of this guidance is to assist airports and aircraft operators in gaining a basic understanding of the technical issues, screening the spectrum of deicing practices to identify those that may have potential benefits at their airport, and guiding the development of a deicing runoff management program. The guidance and information in this document are not intended to be a substitute for site-specific planning, permitting, engineering analysis, design, cost estimation, or operational procedures. Each airport presents a unique combination of physical, climatological, operational, funding, environmental, and regulatory characteristics that must be evaluated as a whole when an effective deicing runoff management program is being developed.

Rather, this document is intended to serve as a starting point. It is important to recognize that the technical and regulatory landscapes surrounding aircraft and airfield deicing are evolving, which may necessitate that this document be updated periodically to remain current.

Guidance Structure

The structure of the information in this document is top down, beginning with discussions of the issues and principles for developing integrated deicing runoff management systems, followed by overviews and guidance for selecting currently available deicing practices by category, and ending with a compilation of Fact Sheets that describe specific characteristics of each practice.

CHAPTER 2

Guidelines for Developing Integrated Deicing-Runoff Management Systems

This section provides an overview of technical and regulatory issues, site-specific factors to consider, and a generally applicable methodology for developing an effective deicing runoff control program for airport operators.

Aircraft and Airfield Requirements for Deicing

Safety Issues

Aircraft deicing is required to ensure flight safety. Even small amounts of snow and ice can seriously degrade the aerodynamic performance of an aircraft's lifting surfaces, with potentially catastrophic consequences. In addition, ice can impede the operation of control surfaces if it forms on mechanical joints or actuators. Achieving and maintaining safe flight conditions requires deicing, possibly followed by anti-icing, which is intended to provide sufficient holdover time to keep the critical aircraft surfaces free of ice-related contamination through taxiing and take off. Aircraft deicing is most often conducted by aircraft operators or their contractors, but pilots always will have the final responsibility regarding the adequacy of deicing relative to flight safety.

Similarly, airfield pavement surfaces should provide sufficient friction for safe landing, taxiing, and takeoffs during winter weather conditions. In most instances, deicing is conducted to maintain critical friction on the airfield pavement surfaces by keeping them free of snow and ice. Airfield deicing is conducted at the discretion of the airport operator. This discretion extends to closing the airfield if safe operating conditions cannot be maintained.

Applicable FAA Regulations

Deicing practices are regulated and implemented with an overriding emphasis on safety. No practice or system of practices should degrade or compromise flight safety. The FAA provides guidance on activities related to deicing in the form of advisory circulars (ACs), FAA orders, and engineering technical letters. The following key documents provide specific FAA technical and regulatory guidance to airport operators regarding deicing facilities and controls:

- **AC 150/5300-13, Airport Design.** Provides standards and recommendations for the design of civil airports. To ensure aircraft safety, the location and operation of deicing facilities must follow these clearance and separation standards, which involve airspace, aircraft separations, FAA Technical Operations facilities critical areas, and Airport Traffic Control Tower line-of-sight criteria.
- **AC 150/5300-14B, Design of Aircraft Deicing Facilities.** Provides standards, specifications, and guidance for designing aircraft deicing facilities. Airport managers can construct, within FAA standards, deicing facilities at terminals, on apron areas and taxiways, and near departure runways. Aircraft deicing facilities are recommended at airports where icing conditions are expected, including airports that serve aircraft that can develop frost or ice on critical surfaces even if the airport itself does not experience ground-icing conditions.
- **AC 150/5220-18A, Buildings for Storage and Maintenance of Airport Snow and Ice Control Equipment and Materials.** Provides guidance for site selection and design of buildings used to store and maintain this equipment, approved materials, and personnel areas required to support the requirements under the airport operator's winter storm management plan. Specific maintenance building with appropriate storage areas are needed to help protect and service the costly pieces of complex and technologically sophisticated equipment for the control of snow, slush, and ice on the nation's airports.
- **AC 150/5200-30B, Airport Winter Safety and Operations.** Provides guidance to assist airport operators develop a snow and ice control plan, conduct and report runway friction

surveys, and establish snow removal and control procedures. For airports certified under 14 CFR Part 139, "Certification of Airports," the Snow and Ice Control Plan is referenced in section 139.313, "Snow and Ice Control." This AC also provides guidance on aircraft and airfield deicing source controls and snow clearing operations (deicing activities).

Aircraft deicing facilities funded under federal grant assistance programs must follow these guidelines.

In addition, FAA provides extensive guidance regarding all aspects of aircraft operations under winter conditions. The following selected ACs are especially relevant to the objectives of this guidance document:

- **AC 120-60B, Ground Deicing and Anti-icing Program.** Provides an industrywide standard means of obtaining approval of a ground deicing/anti-icing program. In addition, it provides a means for a certificate holder to deice/anti-ice aircraft using another certificate holder's personnel and procedures or contract personnel who have been trained by the other certificate holder.
- **AC 135-16, Ground Deicing and Anti-icing Training and Checking.** Provides guidance regarding ground deicing and anti-icing training requirements that should be incorporated into an approved training program for certain aircraft operators; ground deicing and anti-icing guidance for those aircraft operators that are not required to have an approved training program; and pretakeoff contamination aircraft checks required of certain aircraft operators.
- **AC 120-58 Pilot Guide Large Aircraft Ground Deicing.** Provides recommendations for the safe operation of large aircraft during icing conditions and guidelines for the development of adequate procedures for deicing large aircraft.
- **AC 120-89, Ground Deicing Using Infrared Energy.** Provides guidelines and recommendations for pilots, certificate holders, and operators of deicing facilities regarding the use of infrared technology for deicing aircraft.

A comprehensive library of ACs may be found on the FAA's online Regulatory and Guidance Library: www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgWebcomponents.nsf/HomeFrame?OpenFrameSet.

Deicing Products

There are a limited number of products that meet SAE standards and are recommended by the FAA for use in aircraft and airfield deicing. For aircraft, the predominant deicing and anti-icing fluids are based on one of two freezing-point depressants (FPDs): propylene glycol (PG) and ethylene glycol (EG). (There are commercially available aircraft fluids that are based on other FPDs. At the time of this writing, at least one aircraft deicing product based on glycerin has been recently introduced to the U.S. market, but plans for its use by commercial aircraft operators is unknown.) The fluids contain the glycols as the main ingredient, along with water and an additives package. The additives package represents a relatively small fraction (less than 2 percent) of the total fluid volume, and includes corrosion inhibitors, surfactants, dyes, thickeners, flame retardants, pH buffers, and defoamers. The specific constituents vary greatly by product and manufacturer, and are proprietary formulas known only to the manufacturers.

There are several SAE types of aircraft fluid, categorized on the basis of their use and properties:

- Type I fluids are typically diluted with water and heated before application to remove frost, ice, and snow from aircraft. Type I fluids are relatively thin-bodied and may provide some nominal anti-icing protection, depending on the ambient weather conditions. These fluids are grouped as aircraft deicing fluids (ADFs). SAE publication AMS 1424, "Deicing/Anti-Icing Fluid, Aircraft," contains the specifications for these fluids.
- Type II and IV fluids are relatively viscous and are typically applied directly to a clean aircraft surface without dilution. Type IV fluids have improved holdover times and have largely replaced Type II fluids used by commercial aircraft operators. These fluids are grouped as aircraft anti-icing fluids (AAFs). SAE publication AMS 1428, "Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV," contains the specifications for these fluids.
- Type III fluids are intended for anti-icing protection on aircraft with lower rotation speed at lift off. The use of Type III fluids is relatively limited. SAE publication AMS 1428, "Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV," contains the specifications for these fluids.

Airfield pavement deicing material (PDM) options are much more varied and include sand as well as liquid and solid-form deicing chemicals. The FPDs in these products include ethylene or propylene glycol, urea, potassium acetate, sodium acetate, sodium formate, and potassium formate. Prior to 1990, glycol and urea products were the primary airfield pavement deicers used at airports. Since then, alternative pavement-deicing products with reduced environmental impact [for example, lower biochemical oxygen demands (BODs) and toxicity] have been introduced to the market. These new products are available in both solid (for example, sodium formate and sodium acetate) and liquid (for example, potassium acetate) forms. Limited information is available on the contribution of the acetate- and formate-based PDMs to toxicity and BOD in airport stormwater discharges relative to those from aircraft deicers, but research to better define these issues is ongoing. Recently, concerns have been raised regarding the compatibility of these formulations with pavement and certain aircraft materials. These issues are described and summarized in the ACRP synthesis 11-03/Topic S10-03 report, *ACRP Synthesis 6: Impact of Airport Pavement Deicing Products on Aircraft and Airfield Infrastructure.*

Ongoing research and development of aircraft and airfield deicers is being driven by both environmental considerations and materials compatibility issues. These efforts are resulting in continual improvement of existing products and the introduction of new products.

Environmental Concerns

Deicing runoff can contribute to a number of adverse environmental impacts from the deicing products used. There also may be environmental impacts from nondeicing-related pollutants that appear in deicing runoff, but are unrelated to the deicers themselves.

Typical Deicing Runoff Pollutants

All chemical formulations currently approved for aircraft and airfield pavement deicing can have environmental implications when they become entrained in stormwater runoff and are discharged to receiving waters, such as streams, lakes, or rivers.

The FPDs in aircraft and pavement deicing products are highly biodegradable by bacteria in the environment. Discharges containing deicers may contribute to or result in reduced dissolved oxygen concentrations in receiving waters as a result of the consumption of oxygen by bacteria as they break down the biodegradable matter.

Product additives, and to a lesser extent the FPDs required to meet SAE specifications, may result in exposure of aquatic organisms to toxic pollutants. The toxicity of individual products varies, depending on the proprietary additive packages unique to each formulation. PG and EG can be toxic to aquatic organisms at elevated concentrations, but the toxicity of aircraft deicing runoff is typically driven by the additives in ADF and AAF. The FPDs in acetate- and formate-based PDMs are the primary source of aquatic toxicity in these products (unpublished data; ACRP Project 02-01 “Alternative Aircraft and Airfield Deicing and Anti-Icing Formulations with Reduced Aquatic Toxicity and Biochemical Oxygen Demand”). Where urea is used for pavement deicing, ammonia toxicity to aquatic organisms is typically a significant concern. Further discussion of the variability in environmental profiles of deicers may be found in the product selection Fact Sheets (Fact Sheets 1 and 16).

Other potential impacts of deicers in runoff can include odor problems and growth of nuisance attached bacteria, typically *Sphaerotilus sp.* Occasionally, aircraft-deicing runoff has been implicated as contributing to foaming problems at stormwater outfalls.

Nondeicing Runoff Pollutants

Stormwater runoff from deicing operations is regulated pursuant to federal and state industrial stormwater permitting programs. Other airport operations may contribute additional pollutants to these stormwater discharges, including fuels, suspended solids, and oils/greases.

Regulatory Drivers

This subsection provides an overview of the environmental regulations and permitting programs that authorize discharges associated with airport deicing and anti-icing operations. The airport owner generally holds the primary responsibility for compliance with these regulations. However, as new permits are issued, some airport operators are including airlines on their permits. Compliance responsibility also may be shared with aircraft operators and other tenants under facility-specific arrangements that include these parties as co-permittees, or otherwise establish formal responsibilities through lease agreements or mechanisms outside the scope of any environmental regulation (i.e., that may indemnify the airport owner for activities outside of its control but occurring on airport property).

Federal Acts Effecting Airport Water Quality Regulations

CWA Section 402 creates a permitting system, known as the National Pollutant Discharge Elimination System (NPDES) program, through which all facilities that discharge pollutants from a point source into waters of the United States must obtain a permit. The terms “pollutant,” “point source,” and “waters of the United States” 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 discharge into receiving water bodies. NPDES permits are issued only to directly discharging facilities; indirect discharges are regulated by the CWA’s National Pretreatment Program. Airports and individual leaseholders may have NPDES direct discharge permits for stormwater or for discharges of other industrial wastewaters that flow directly to receiving water bodies. 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) may have pretreatment permits or agreements with their local POTW for handling those wastewaters sent for treatment through the sewer.

Federal Stormwater Program

Currently, there are three main categories of regulated stormwater discharges: industrial, municipal, and construction. Congress established the current NPDES stormwater program in 1987; EPA implemented it in 1990. EPA now requires that 11 categories of industrial operations obtain NPDES stormwater permits. These categories are denoted 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 otherwise unregulated stormwater discharges that are commingled with those industrial stormwater discharges. Purely administrative buildings, administrative parking lots, and stormwater discharges from nonindustrial areas at the airport may not be covered by the industrial stormwater program. Such discharges may be part of another stormwater program under EPA's NPDES stormwater program, or they may not be regulated in any way.

Besides the industrial stormwater program, EPA administers two other stormwater programs that may provide federal jurisdiction over nonindustrial stormwater discharges. First, EPA has created a NPDES permit program for any construction activity that disturbs 1 acre or more of land. (This program is further subdivided into one for sites 5 acres and larger and one for sites between 1 and 5 acres; these requirements also apply to smaller sites that are part of a common plan of development that would exceed either 1 or 5 acres.) While applicable to construction operations at airports, the construction stormwater program generally would not apply to airport deicing activities, with the exception of initial construction of certain management practices, drainage systems, or other controls.

Second, EPA has created a municipal stormwater program that requires operators of Municipal Separate Storm Sewer Systems (MS4s) that meet minimum size thresholds to obtain NPDES stormwater permits. EPA distinguishes MS4s for NPDES permit obligations on the basis of the density and size of the population being served by the system. Under EPA's MS4 stormwater permit program, MS4 operators are responsible for meeting certain minimum permit requirements and may in turn require those entities that discharge into the MS4 to meet certain conditions or implement practices to minimize the pollutants entering the MS4 system. Typical areas at airports that may not be subject to the industrial program but may otherwise be regulated by the MS4 program include public parking facilities, access roads, and commercial operations accessible by the public (car rental agency, gas station, food service store, etc.).

In summary, the CWA requires that airports obtain an NPDES permit for any direct discharges of process wastewater and most stormwater. Stormwater can be regulated either through the industrial or municipal stormwater programs. Indirect discharges of deicing or other industrial wastes sent to a POTW require authorization and often a permit from the POTW's authority.

In addition to CWA permit obligations, many airports also are subject to regulations that require them to develop programs to prevent and immediately clean up spills of oil or other chemicals. The Spill Prevention Control and Countermeasure (SPCC) program overlaps with many aspects of an airport's stormwater program and should be addressed in a way that ensures consistency and integration (see 40 CFR part 112). EPA encourages this integration by allowing airports and other regulated entities to combine their Stormwater Pollution Prevention Plan (SWPPP) and SPCC plans. Other spill and reporting requirements for hazardous substances are found at 40 CFR part 117.

There are specific reporting requirements associated with the use of EG-based deicers. The Comprehensive Environmental Response Compensation and Liability Act (CERCLA or Superfund) requires that releases of certain chemicals in certain quantities must be reported to the National Response Center (NRC). Ethylene glycol (but not propylene glycol) is on the list of chemicals covered by these regulations, and has a reporting threshold (called reportable quantity or RQ) of 5,000 pounds. Technically, this means that any release (deicing event) that involves 5,000 pounds of EG during a 24-hour period may be subject to reporting obligations. EPA provides a somewhat streamlined three-step reporting methodology for facilities (such as airports) that meet a "continuous release" definition. Continuous releases are those that are routine, anticipated, and intermittent during normal operations or treatment processes, and that are predictable and regular in amount and rate. Compliance with the reporting requirements is one reason some airports go to PG-based aircraft deicers only. Additional information on the RQ program can be found at: http://www.epa.gov/superfund/programs/er/triggers/haztrigs/rqover.htm

Beyond the CWA and CERCLA requirements already discussed, certain projects, including expansion and large capital projects that use federal-funding mechanisms, may trigger compliance obligations with other federal environmental laws, including the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), and the National Historic Preservation Act (NHPA). Activities that have the potential to release pollutants to soil that will reach groundwater also must consider the federal Safe Drinking Water Act (SDWA). All of these statutes could affect an airport's ability to discharge pollutants to local waters or groundwater. Finally, airports also should check with their state and local authorities to determine if there are state and local environmental or health laws that require authorizations in addition to the federal programs identified above.

Implementation of Regulations in Different Types of Airport Discharge Permits

The NPDES program discussed in the previous section 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 issued its first NPDES general permit for industrial stormwater discharges, including airport deicing operations, in 1992. Baseline General Permit is no longer available, and today, EPA remains the permitting authority in only a handful of states that have not been approved to run their own programs (Alaska, Idaho, Massachusetts, Maine, New Hampshire, and New Mexico) and in certain other states only with regard to federal facilities and certain Indian lands. It was used as a model for states with authorized permitting programs, and some Baseline General Permit–like state permits still exist today. For the most part, however, the Baseline General Permit was superseded by EPA's Multi-Sector General Permit (MSGP), which was promulgated in 1995 (and revised in 2000). As of this writing, EPA is preparing to promulgate a new MSGP; the most recent version of the MSGP is considered in interpreting this information.

EPA developed the air transportation portions of the MSGP predominantly from information submitted through the AAAE Group Stormwater Permit Application in the early 1990s. Because the MSGP relied on the "latest" industry information during its development, it was seen as far superior to the Baseline General Permit. As such, although authorized states retain discretion regarding their own general permitting approaches (providing they meet minimum NPDES requirements), more states have adopted general permits based on EPA's MSGP than any other "model" permit.

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 for complex facilities or where specific environmental concerns exist are preferred by some regulators over general permits. While EPA and most states have developed general permits that are broadly applicable to industrial stormwater discharges, one specific departure from this trend has been with regard to airports that are more complex. Several states prohibit complex sites, including some airports, from seeking coverage under the state's general permit, requiring instead that such sites obtain individual permits. The theory behind this requirement is that general permits provide limited site-specific controls and may provide sufficient environmental protection for small or medium-sized airports that lack significant operations that might present environmental risks but are unlikely to do so for large airports.

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 practices). Individual permits require a two-part analysis that first mandates implementation of appropriate technology standards (typically practices 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 to the airport's stormwater pollution prevention plan, deicing runoff management plan, and other compliance mandates in the permit.

Industrial Pretreatment Permits. Not all deicing runoff is discharged directly to waters of the United States 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. For the most part, deicing runoff is well-suited to treatment at POTWs because it contains high amounts of BOD, which can serve as "food" for bacteria used in the biological treatment process. POTWs charge fees to airports to offset the costs of treatment and generate income for the POTW.

In many ways, pretreatment permits are similar to NPDES direct discharge permits. The pretreatment permit may contain a numeric limit that ensures compliance, or it may rely on practices to ensure that waters sent to the POTW are acceptable. Like direct discharge permits, numeric limits may be expressed as concentration or mass-based limits and usually provide both daily maximum and monthly average restrictions.

Permit Development Process

The following discussion is specific to individual permits. The general NPDES permit process is similar, but it is not done with any specific site in mind. Nevertheless, both processes include opportunities for the public (and airports) to get involved, file comments, and, if necessary, challenge the final permit in federal court.

NPDES permits issued by EPA or authorized states contain two levels of effluent limitations to control pollutant discharges: the first is technology-based and is set by EPA on the basis of a category or type of discharge; the other is water-quality based (that is, a site-specific assessment as to whether the technology-based controls are sufficient to protect the water quality of receiving water body). EPA also establishes "new source performance standards" for certain categories of new dischargers.

Technology-based controls are mandated by the CWA and are set either on an industry-specific basis through the development of ELGs or by the permit writer's use of best professional judgment in the absence of industry-specific ELGs. Although there are no current ELGs for aircraft and runway deicing activities, EPA currently is engaged in an ELG rule making for airport deicing discharges. ELGs typically establish minimum national technology-based requirements to control discharges from the target industry. Should EPA determine that there are best available technologies that are nationally applicable and economically achievable for most of the industry, it is expected to promulgate such standards, and they will become the "floor" for all future stormwater permits that address deicing. EPA's current regulatory calendar shows that draft ELGs (if appropriate) would be proposed by late 2008 and then not finalized until late 2009, at the earliest. In the mean time, permit writers must use best professional judgment to determine specific technology-based standards for NPDES permits for the industry.

Water quality–based effluent limits are site-specific, determined on the basis of the specific characteristics and needs of the receiving water body. These standards are employed to protect the designated uses of that particular water body. In some cases, these limits are more stringent than technology-based limits and in some cases they are not. Water quality–based effluent limits are more difficult to apply to general permits, but they are addressed in those permits.

The CWA also sets forth special requirements for pollutants that are discharged to impaired waters. States are required to establish designated uses for their water bodies. The most common (and one of the more protective) use is commonly referred to as fishable/swimmable, because it requires both protection of human health as well as aquatic species. When a water body is not meeting its designated use, it is considered impaired. States are required to periodically prepare and submit lists of impaired waters to EPA, and states must initiate efforts to ensure that the waters will ultimately meet their designated use, or change the use. The CWA tool that states use to improve impaired waters is called a total maximum daily load, or TMDL. TMDLs limit the total amount of pollutants causing the impairment that are allowed to enter a water body. TMDLs allocate the total allowable quantities of pollutant discharges to various regulated and unregulated sources. For regulated point sources, these waste load allocations (WLAs) are 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 best management practices. The latter is more commonly found in stormwater permits, like those that may be issued to airports. Best management practices are particularly applicable when numeric limits are hard to calculate or justify.

New or increased discharges to unimpaired waters also must meet certain standards. The CWA contains antidegradation standards that prevent waters that currently meet standards from becoming impaired. Therefore, new sources or even increased discharges from existing sources must meet antidegradation standards.

In some cases, airports may have permits that have existed for many years and that contain limits or requirements that may be outdated or unnecessary to protect water quality. In certain circumstances, incomplete information, past errors, or wrong assumptions that led to unnecessarily stringent requirements can be corrected. However, the CWA contains antibacksliding provisions that may prohibit less stringent permit limits than currently exist, unless it can be shown that specific antibacksliding exceptions and/or considerations apply. This applicability must be demonstrated on an individual site-specific basis.

Technology-based effluent limits set the floor or minimum requirements for NPDES permits. As mentioned above, EPA currently is conducting a rulemaking to develop industry-specific ELGs for aircraft and airfield deicing and anti-icing operations that will set the minimum permit conditions and limitations for airports designated by EPA for regulation. Water quality-based effluent limits and TMDLs may establish even more stringent requirements in the final NPDES permit to account for site-specific receiving water concerns that are not addressed through the requirements of the ELG.

Practices, Numerical Limitations, or Other Performance Metrics. To meet the technology- and water quality–based standards in its stormwater general permits, EPA typically requires permittees to develop a SWPPP that names the responsible parties, describes the site and receiving waters, identifies potential sources of pollution, summarizes monitoring data, and lists existing and planned stormwater practices (including the timeline for implementing and maintaining practices). Hence, most stormwater permits are practice-based permits; they rely on a series of structural and nonstructural practices to ensure compliance with the CWA. This approach is based on the assumption that implementation and maintenance of these practices will reduce pollutant runoff sufficiently to comply with the CWA.

As discussed above, some individual permits contain numeric limits upon which compliance is determined. In these permits, the permitting authority has determined to ensure compliance with technology or water quality mandates of the CWA and protect local receiving streams, the airport must monitor its discharges to ensure they meet certain standards, expressed in these limits. Exceedances of numeric limits are permit violations.

The process for developing individual NPDES permits is set forth at 40 CFR Part 124. The major actions are the following:

1. Receive application from permittee.
2. Review application for completeness and accuracy.
3. Request additional information as necessary.
4. Develop technology-based effluent limits using application data and other sources.
5. Develop water quality-based effluent limits using application data and other sources.
6. Compare water quality–based effluent limits with technology-based effluent limits and choose the more stringent of the two as the effluent limits for the permit.
7. Develop monitoring requirements for each pollutant.
8. Develop special conditions.
9. Develop standard conditions.
10. Consider variances and other applicable regulations.
11. Prepare the Fact Sheet, summarizing the principal facts and the significant factual legal, methodological and policy questions considered in preparing the draft permit including public notice of the draft permit, and other supporting documentation.
12. Complete the review and issuance process.
13. Issue the final permit.
14. Ensure permit requirements are implemented.

Both the individual and general permitting processes include opportunities for the public (and airports) to get involved, file comments, and if necessary, challenge the final permit in federal court.

Permit Development and Compliance Considerations

The following generalized guidance is provided to airports undertaking NPDES permit development, renewal, and compliance efforts. These considerations encompass general stormwater management, not just discharges associated with deicing operations.

- Characterize and quantify runoff.
- Establish proactive interactions with regulators and determine their specific concerns.
- Establish proactive interactions with aircraft operators and other stakeholders and identify their specific concerns.
- Identify a stormwater pollution prevention team and allocate time and resources to address permit compliance issues.
- Program the NPDES compliance budget into operating expenditures and capital improvements.
- Have the pollution-prevention team reevaluate the SWPPP periodically and maintain good records of progress.

- Establish whether water bodies receiving airport stormwater discharges are in the state's (or EPA region's) 303(d) list and whether airport operations are associated with the listing criteria—for instance, BOD, COD, ammonia, pH, temperature, or chlorides. Ask the environmental regulators whether a TMDL has been or is about to be determined.
- If there are 303(d) and TMDL issues associated with the receiving waters, early involvement and consideration of alternatives can significantly influence the outcome as it relates to the airport's NPDES Permit requirements. The issues are often complex and the technical analyses can be fraught with uncertainty due to the water quality computer models applied and the common lack of robust data. As a result, this involvement typically requires specialized legal and technical expertise.

NPDES permits have a 5-year life cycle. For individual permits, the permittee must reapply at least 180-days prior to its expiration date. EPA or authorized states typically start working on revising and reissuing general permits 1 to 1.5 years prior to expiration. In both cases, if the airport wants to obtain the best possible permit, with the least impact on operations, budgets, and other important considerations, the airport must engage in the permit revision and reissuance process. Doing so requires a basic knowledge about the CWA permitting process, airport operations, and local politics, and is best addressed by experienced individuals. This guidance document cannot detail the steps and strategies necessary for a successful permit renewal other than to indicate that the best advocate for developing a permit respectful of both airport operations and complex tenant/community relationships, while protecting the environment, is the airport itself. Permit writers are not experts in airport operations and will appreciate the engaged, respectful involvement that results from the airport's active participation in the permitting process.

Framework for Planning Deicing Runoff Control Programs

This subsection describes a conceptual framework for developing and implementing a deicing runoff management system to comply with environmental regulatory requirements. Some of the elements of this framework coincide with components of an SWPPP, but by no means should these discussions be considered a comprehensive source of material for developing a fully compliant SWPPP. Also, this framework represents one approach to addressing the component issues and activities. Other approaches may be available and appropriate. (The primary source for information about SWPPP requirements is found in your permit. Although somewhat dated, the 1992 document "Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices," EPA 832-R-92-006, provides general guidance regarding SWPPP requirements for industrial activity under the NPDES Stormwater Program. The publication includes a set of worksheets, a checklist, and a sample SWPPP. The California Stormwater Quality Association also provides generalized guidance in their *Industrial and Commercial Handbook,* www.cabmphandbooks.com/Industrial.asp).

The material is organized according to the steps generally recognized for developing an effective deicing runoff management system for an airport. These steps are depicted in Figure 2-1. It should be noted that this framework is described as an overall process. Some of these steps may not be applicable at an airport with an existing deicing runoff management plan in place. It should also be noted that aircraft operators should be represented and involved as active participants in this process.

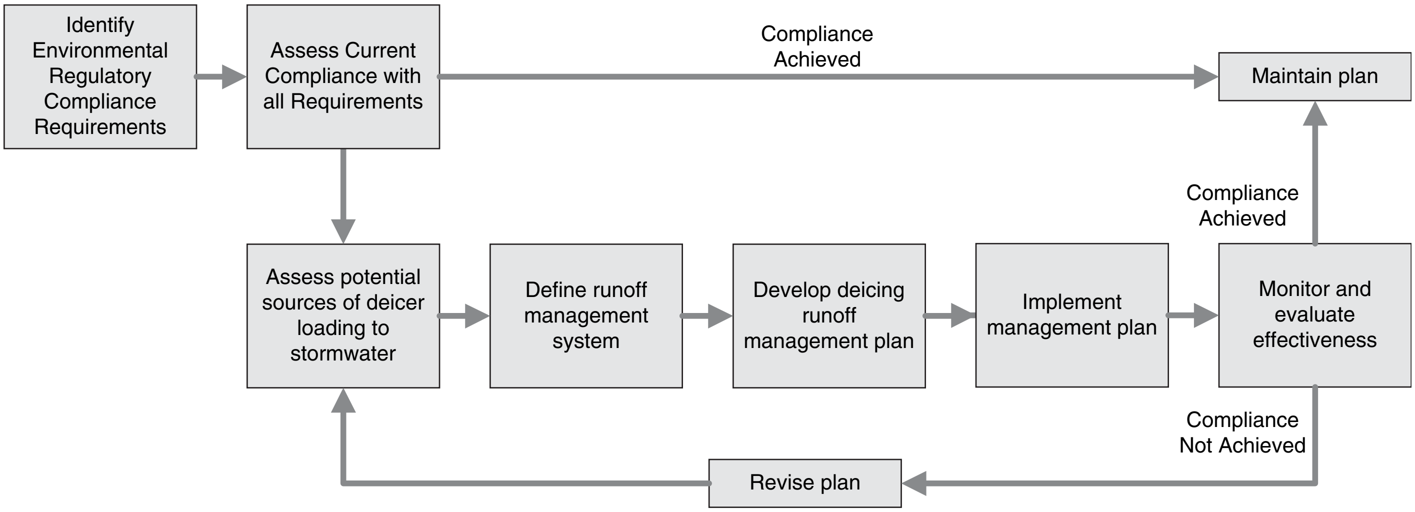

Figure 2-1. Framework for development and implementation of a deicing runoff management strategy.

Identify Environmental Regulatory Compliance Requirements

Compliance with environmental regulatory requirements is a primary objective and metric of success for deicing runoff management, as well as being a legal obligation. Requirements related to permitted deicing discharges will generally fall into the following categories, although these are not necessarily present in every permit:

- **Narrative/qualitative.** These requirements typically involve implementing practices such as handling and storing materials, selecting deicing products (for example, prohibiting urea), and encouraging conservation practices. Commonly, compliance requires that these practices be described in a SWPPP, Deicing Runoff Management Plan, or similar document.
- **Numerical/quantitative.** These requirements establish specific quantitative performance levels that must be achieved. Typically, they are expressed as concentrations or loads in permitted discharges. However, numerical limits may also express the performance of collection efforts in terms of fraction of applied deicers either collected or contained in stormwater discharges.
- **Reporting.** These requirements include routine reporting related to deicing activities and associated stormwater discharges. In some cases, compliance reporting may include some form of demonstration that the practices and other elements of an airport's SWPPP or Deicing Runoff Management Plan have been implemented and are working.

An inventory of all compliance requirements establishes the performance requirements for the deicing runoff management system.

Assess Current Compliance with All Applicable Requirements

Once all applicable regulatory requirements have been defined, the current status of compliance with those requirements can be assessed. If compliance is being achieved with current practices, then normally no further action will be needed. On the other hand, deficiencies in achieving compliance under existing conditions will set the context focus for activities described in subsequent steps.

Assess Potential Sources of Deicer Loading to Stormwater

This subsection describes the fundamental step of understanding the sources and mechanisms that may cause deicers to become entrained in stormwater. The first component is to understand the drainage patterns at the airport. The second is to identify and inventory deicing activities that contribute to runoff.

Some of the information presented below addresses runoff control beyond deicing operations. However, it is presented to emphasize the need to integrate deicing into an airport's overall stormwater management strategy.

Assess Airport Drainage System. An airport drainage system is typically a complex combination of natural systems and constructed infrastructure covering multiple drainage areas that discharge to different receiving waters. Comprehensive knowledge of the layout and function of the drainage system is needed to understand where runoff originates, how it flows, and what activities may contribute pollutants to stormwater, as it flows towards a receiving water body. At a minimum, understanding the drainage system requires the following information:

1. Site boundaries and tenant facilities (buildings, roads, access, etc.).
2. Pervious and impervious surfaces and flow directions.
3. Layout of the airside and landside storm drain systems including catch basins, pipes, connections, and outfalls.
4. Location, configuration and design data for all stormwater controls; these would include ponds, collection vaults, oil–water separators, infiltrators, filters, flow splitters, etc.
5. Receiving water bodies.
6. Location of materials exposed to precipitation.
7. Location of deicing activities and support functions that may impact stormwater, such as aircraft deicing or anti-icing, airfield deicing, ground support equipment operations, deicer storage and handling, snow disposal, etc.

Inventory Potential Sources of Deicing Runoff. Potential sources of aircraft and pavement deicing runoff must be identified, quantified, and prioritized. Data on types, volumes, and concentrations of aircraft deicers and anti-icers used, along with the locations of those uses should be compiled from all aircraft operators and fixed base operators that conduct deicing. Other elements of the aircraft deicer inventory should include the locations of storage tanks and transfer stations for deicing fluids, and types of equipment used for aircraft deicing. Performance data on existing aircraft-deicing practices also may be helpful.

Data that describes the types and amounts of airfield pavement deicers used also should be compiled, along with the areas where they are applied. Pavement deicer storage and handling areas should be identified, along with descriptions of any existing pavement deicing practices that may be in place.

Available data on discharges of deicing runoff to stormwater outfalls and treatment systems should be compiled. The critical information here will be flow and volume measurements and associated concentrations of deicing-relevant parameters (glycols, BOD, chemical oxygen demand, total organic carbon, ammonia, acetates, formates, etc.). Information regarding deicing season weather conditions (for example, typical conditions and extreme events) also should be developed during this step.

The goal of this exercise is to characterize the flow of deicing chemicals through the airport stormwater system by constructing an approximate material (that is, mass) balance. This analysis will provide an understanding of available data, reveal the spatial distribution of deicing activities and use, and indicate whether the material balance needs to be broken down into distinct areas within the airport. The material balance can be depicted as in Figure 2-2.

The material balance is an approximate calculation due to inherent uncertainty in the fate of deicers once they become exposed to wind, soil, and water. Deicer use records are useful to evaluate the maximum amounts that could potentially mix with precipitation and runoff. This information is likely to be the most accurate element of the material balance, provided that good recordkeeping practices are in place. Concentrations and volumes of runoff captured by collection efforts and sent to treatment and recycling can be used as a conservative estimate of how much material was not released to the environment. Outfall-monitoring data can provide an estimate of how much material reaches receiving waters, provided that the data are of sufficient quality and temporal resolution. Outfall monitoring may not be a reliable source of information because of the cost and technical difficulties of obtaining reliable data. In addition to these three quantities, an estimate of fugitive losses is necessary to complete the mass balance. Fugitive losses occur as a result of fluid adhering to aircraft after takeoff, dripping, tracking on the wheels of ground support equipment, being carried off as wind drift, or biodegrading on pavement surfaces and in soils (Revitt and Worral, 2003). These fugitive losses are typically estimated "by difference." It is not uncommon to see this fugitive fraction constitute as much as 20–60 percent of the total deicing materials used (Skjefstad, 2005; Williams, 2006; Wagoner, 2006; Corsi, 2006).

Despite the uncertainties, a simple material balance establishes a basis for understanding the magnitude of the potential sources of deicing runoff and their geographic distribution. This information can be used to prioritize management measures.

Define Runoff Management System

A deicing runoff management system is an assemblage of practices that, as an integrated whole, achieves environmental regulatory compliance within the context and constraints of safety, as well as operational and cost requirements and objectives. As discussed previously, practices for controlling deicing runoff can be arranged in three categories:

1. Source reduction;
2. Containment/collection; and
3. Discharge/treatment/recycling.

This step in the framework involves identifying and evaluating different system configurations to determine which one will best meet the diverse needs of safety, operational feasibility, regulatory compliance, and cost-effectiveness.

The process of formulating a system of runoff controls consists of four steps:

1. Identify potentially suitable practices;
2. Select practices;
3. Identify constraints on system design; and
4. Design and evaluate system alternatives.

Identify Potentially Suitable Practices. Deicing runoff practices are identified based on their suitability to address an airport's compliance requirements, usually specified in the NPDES permit (see "Implementation of Regulations in Different Types of Airport Discharge Permits"). Depending on these facility-specific requirements, controls may need to be identified from one or more of the three categories: source controls, containment/collection, and treatment/recycling. Generally, if source control practices are not going to be adequate for meeting compliance, then both containment/collection and treatment/recycling practices will be required.

An initial screening of practices will identify those that have potential within the specific context of an individual airport. Potentially suitable practices should meet the following criteria:

- Meet all applicable safety requirements;
- Applicable to the geographic, operational, and climatic context of the airport;

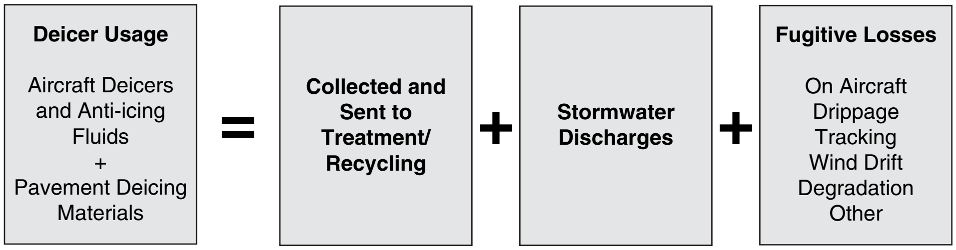

Figure 2-2. Material balance.

- Suited to addressing the sources and pollutants of specific concern; and
- Have order-of-magnitude costs consistent with the scale of the deicing operations, the nature of compliance requirements, and the economics of the facility.

Information that will be useful in evaluating these criteria is provided in Chapter 3 and the individual Fact Sheets.

The resulting list of candidate practices will serve as the basis for a more detailed assessment and selection of practices that can serve as the building blocks of a deicing runoff management system.

Select Candidate Practices. Once the subset of potentially applicable practices has been identified, further evaluation will lead to selection of those practices that are best suited to the facility. This evaluation may reveal the need to subdivide the facility into areas where different practices are appropriate. Chapter 3 provides guidance in the technical aspects of the practices selection process.

The selection of suitable practices should involve all relevant stakeholders, especially aircraft operators, to ensure that facility-specific issues are thoroughly considered and stakeholders who could be responsible for implementing or operating individual practices have input in the selection process. Many practices are implemented and under the control of aircraft operators, making their participation in the consideration and selection of those practices essential. Similarly, aircraft operators should be consulted regarding any practices that may have a significant and direct impact on aircraft operations. The importance of this involvement applies throughout the process of developing and implementing a deicing runoff management strategy.

The resulting list of candidate practices will serve as the basis for subsequent development and evaluation of alternative practice system configurations.

Identify Constraints on System Design. Before assemblages of candidate practices can be arranged into runoff control system alternatives, constraints on system design that may not have been apparent when individual controls were being evaluated must be considered. For example:

- Maintenance of aircraft/airfield safety.
- Assurance of efficient aircraft operations at present and planned demand levels.
- Design conditions, such as deicing event size or frequency of system capacity exceedances, associated with compliance requirements.
- Available POTW or other existing treatment facility capacity, policies on discharge concentrations and loads, and discharge fee structures.
- Pretreatment requirements.
- Airport master plan, airport layout plan, navigation aids, and other constraints on space availability.
- Environmental factors (wetlands, floodplains, sensitive ecosystems, nondeicing pollutants of compliance concern, air emissions).
- Anticipated growth that may affect deicing activities and controls.
- Special flight operations requirements.
- Accessibility of candidate practice installations on the airfield.
- Funding sources and cost constraints.
- System operation complexity.
- Acceptance by tenants and other stakeholders.
- Constructability.
- Utility conflicts.
- Aesthetics.

These factors may lead to adjustments in the system configuration but also could require the introduction of practices that were not initially in the list of preferences and that may call for further stakeholder involvement. At this stage in the design process, these factors serve primarily as criteria to evaluate conceptual system alternatives.

Assemble and Evaluate Practice System Alternatives. Practices are assembled into configurations that are realistically anticipated to meet the regulatory compliance requirements. Potentially applicable source reduction practices are typically defined first to establish a basis for deicer usage expectations, followed by containment/collection and treatment/recycling practices. Generally, the objective will be to take advantage of source reduction opportunities to the extent possible within the requirements of safety and efficient operations and then optimize the other two categories of practices to reduce the size and cost of the system.

Developing conceptual system alternatives includes the placement of practices. Runoff collection practices may need to be arranged in a configuration that provides containment, diversion controls, conveyance, storage, pretreatment, and onsite or offsite treatment or recycling, while also facilitating aircraft operations. It often will be feasible to arrive at more than one system configuration.

After the conceptual system is laid out, individual practices may be sized using design parameters and performance requirements. Sizing for conveyance, storage, and treatment practices requires characterization of the hydrology and deicer loading in runoff to develop peak flows and runoff volumes that the practices must handle. Hydrologic, hydraulic, or water quality models are used to estimate these quantities from data on weather, aircraft and pavement deicer use, flight operations, basin surface characteristics, and storm sewer system features. The effect of individual practices on deicing runoff is estimated using a variety of tools specific for each control, ranging from empirical equations to separate computer models. In practice, simple computations and rules of thumb may be used to perform preliminary sizing as the system is conceptually designed. The configuration of the system needs to be modified if the estimated performance does not meet compliance criteria; this introduces iterations in the design process. More sophisticated tools to evaluate the range of options related to system sizing and performance may be needed with complex configurations.

It is important to recognize the sources and impact of sources of uncertainty in sizing collection, storage, and treatment practices. Typically, model estimates of flow and runoff volumes are more accurate than those of deicer application rates and resulting runoff concentrations. In addition, the actual performance of practices often does not reflect ideal conditions, and practice performance may decline with age and with poor maintenance. Models may be used to evaluate the significance of those uncertainties when looking at the range of options and sensitivities to a variety of conditions. Engineering judgment needs to be applied in defining the input parameters and interpreting the output of models.

Cost estimates for the alternative systems are estimated once the individual components are defined, located, and sized, including ancillary features for access and maintenance. Construction cost elements include engineering design, permitting, and all of the expenses for installation and startup of the system. Operations and maintenance (O&M) cost elements include inspection and periodic tasks, labor, materials, replacement parts, and repair activities to maintain the performance of the individual controls. Life cycle costs are estimated using a suitable discount rate to enable comparison of systems with different capital and O&M cash flows, and useful lives.

The final step in the process is to decide which conceptual deicing runoff management system best meets the diverse requirements of safety, compliance performance, efficient aircraft operations, practicality, reliability, and affordability. The system requirements and constraints identified earlier are used along with the performance and cost to make this decision. Often, as the design progresses, a clear choice becomes apparent. If not, a scoring and ranking process may be applied to assist the decision-making process.

Develop Deicing Runoff Management Plan

The preferred runoff control system will typically undergo a process of refinement during which configurations, sizes, and cost estimates are refined. A deicing runoff management plan is developed around the selected conceptual system specifying the following:

- Purpose and objectives for the system (including compliance criteria);
- Identification of responsible parties;
- Description of the runoff control system components and configuration;
- Schedule and budget for phased implementation;
- System operational rules;
- Schedule of O&M activities;
- Metrics of system performance;
- Data collection and analysis to evaluate performance;
- Strategies for addressing performance deficiencies; and
- Procedures for recordkeeping.

These elements can be defined in a stand-alone document or folded into the airport's SWPPP.

Implement Management Plan

For implementation, the runoff management plan should be fully integrated with the airport's SWPPP. Because the plan usually involves significant expenses and resources, implementation is typically achieved in phases. The scheduling of these phases should be vetted by the regulators before it becomes part of the SWPPP.

A detailed implementation schedule should be developed to take into account procurement processes, construction activities, and airport operations. Similarly, a detailed annual cash flow needs to be projected. Tenants and other stakeholders must be involved in the development of the implementation schedule so that they can have input and begin planning for and implementing any adjustments in their practices and operations that may be involved.

The review process (described in "Revise Deicing Runoff Management Plan") marks the time to plan the activities for the coming year.

Monitor and Evaluate Effectiveness

The performance of the runoff management plan should be assessed on a regular basis to allow for adaptive management. Typically, this review will coincide with the end of the deicing season.

The metrics used to assess system performance will be specific to the compliance requirements within the airport's NPDES permit. The most common NPDES metrics associated with deicing runoff are collection performance and concentrations of pollutants in stormwater discharges associated with deicing. It may be useful to consider additional metrics for each of the practices to provide greater insight into system operation. In addition to concentrations at outfalls, the following are examples of metrics to measure progress towards meeting the goals in the deicing runoff management plan:

- Deicer use (correlated to weather);
- Deicing runoff treated;
- Recycled quantities of glycol;

- Number of aircraft operators implementing source control practices; and
- Estimate of annual BOD removed by the runoff control system.

If compliance requirements are not being met, the cause should be investigated. It is possible that one or more deicing practices are not functioning as expected, or that extreme weather conditions outside of the conditions assumed when the system was designed have occurred. Examining the metrics may reveal these problems and help isolate underperforming components. Appropriate corrective actions may need to be implemented, as discussed in the next section.

It also will be important to assess the performance of the system with respect to nondeicing metrics, such as safety requirements, efficiency of aircraft operations, and compliance with other environmental requirements.

Revise Deicing Runoff Management Plan

At most airports, the airport's SWPPP will be reviewed annually as part of compliance with its NPDES industrial stormwater permit. This is an opportunity to review the deicing runoff management plan and identify the infrastructure modifications and maintenance activities that will be accomplished during the coming year. The annual review is also an opportunity to adjust the implementation schedule based on the previous year's accomplishments and delays, which will affect the current year's activities.

The evaluation described in the previous subsection will indicate whether the deicing runoff management plan is meeting its objectives. If the performance is below the target, corrective measures will need to be implemented. These measures may involve maintenance actions, enhancement, or replacement of practices with more-effective controls, or modifications to the overall system. If an upgrade to the system is indicated, the monitoring plan may need to be adjusted to reflect the new configuration.

This task completes the cycle shown in Figure 2.1, illustrating the application of principles of adaptive management to deicing stormwater management. It is important that the stakeholders be involved as the management program evolves. It is also often advisable to keep regulators informed and appropriately involved in the process.

Role and Application of Modeling Tools

Computer models are powerful tools for simulating quantity and quality aspects of stormwater pollution, provided that they are appropriately matched to the problem being analyzed and properly constructed and interpreted. A simple materials balance, which is itself a model, may not adequately describe the complexities and dynamics of deicing runoff generation, transport, and discharge to support the characterization of sources of deicing runoff, and the subsequent identification and evaluation of alternative practice system configurations. An example of a situation where this might be the case is a permit that establishes maximum loads to receiving streams, perhaps based on a TMDL determination. In those instances, the basic materials balance data may be subsequently used to support a variety of computer modeling tools that provide a more sophisticated representation of the airport, deicing activities, and associated runoff.

The selection of a model is guided by two basic principles:

1. Choosing a model that fits the problem to be addressed. A model should represent the physical processes critical to the characterization of the problem. The essential nature of the problem should not be modified to meet the capabilities of a particular model—or the expertise of the modeler.
2. Selecting the appropriate level of model complexity consistent with goals and available data. A model should be as simple as possible while addressing the needs of the analysis. It should also be selected to make effective use of the data available, without incorporating complexity that data cannot support. The output from the model only can be as accurate as the input data and parameters used to drive it.

Models can be used for characterization of conditions as well as system design. A pollutant-loading model can be used to characterize the loads generated by each of the drainage areas in an airport. A hydraulic model of the stormwater conveyance system that simulates rainfall-runoff processes can be used to size inlets, pipes, treatment facilities, and other stormwater infrastructure.

Precipitation-runoff models may be designed to evaluate the response to individual events or simulate long periods of weather. Single-event models are useful in preliminary sizing of conveyance and treatment infrastructure under an assumed "design" event condition. On the water quality side, single-event models can provide estimates of pollutant removal under assumed conditions. Continuous simulation models describe the response of a system to a time series of weather conditions. Continuous simulation models tend to be more complex than single-event models but are useful in revealing temporal trends and evaluating risk over a wide range of conditions.

Models are approximate representations of the physical world and this imperfect knowledge introduces uncertainties in the output. This statement is more critical for water quality–modeling efforts than for water quantity. The issue of data availability and data requirements should be carefully considered in determining an appropriate modeling approach. Available data representing critical factors, such as deicer use and associated weather (for example, ice and snow), are often very limited. Without site-specific measurements over a representative range of conditions, extrapolation from other parameters or other facilities may be required, which introduces a potentially significant source of uncertainty. Whenever possible, models should be calibrated using site-specific data, and a sensitivity analysis should be conducted to understand the implications that the variability in model parameters has on the output.

At times, the accuracy of model output may not be as important as representativeness when it is used to make management decisions. For example, a modeling effort that compares alternative management scenarios does not need to focus on the absolute values of output variables but on the relative differences among scenarios under the same set of underlying assumptions and parameter inputs.

There are no commercial, off-the-shelf or public domain models specifically designed for comprehensively modeling all of the processes involved in deicing stormwater flow and quality at airports. Modeling is often performed piecemeal using several separate models, each suited to a particular aspect of the system. Table 2.1 summarizes potential approaches to modeling airport stormwater processes. It should be noted that many of the processes relevant to deicing runoff management could be modeled using spreadsheet tools. It also should be noted that models range in level of sophistication required for operation, and advanced training in the use of many of the more-sophisticated modeling tools is required for their application.

Table 2-1. Modeling approaches for airport runoff quantity and quality processes.

Process	Approach
Hydrology	
Runoff generation	Several commercial and public-domain models are available to simulate the generation of runoff from rainfall (e.g., SWMM,[a] TR-55,[b] HEC-HMS[c]). These models are useful to size conveyances and treatment facilities for hydrologic control (e.g., peak flow attenuation), and to withstand severe events. However, for deicing, runoff generation typically involves snow or ice melt and many models do not have this capability. SWMM and HEC-HMS can simulate snow processes, but not ice. It should be noted that meteorological measurements of snow, and especially ice, are often sparse or unavailable. Models based on the “curve number” methodology (e.g., TR-55) are appropriate for extreme events but not for the small storms that make up most of the annual runoff. The Rational Method can be used for design of relatively simple drainage configurations, and for pipe sizing for more complex systems. However, a continuous simulation hydrologic and hydraulic model (e.g., SWMM) is recommended to obtain an optimized final design and realize cost savings.
Infiltration	Infiltration is not a significant component in extreme events. For small events, infiltration can play a major role in reducing runoff volume. For snowmelt flow, infiltration is greatly reduced if the ground is often frozen, if the soil is still saturated, or most of the flow comes from paved areas. There are numerous approaches to simulating infiltration, for instance the Green-Ampt[d] and Horton[e] empirical formulas. Some of these are included in existing hydrologic models like SWMM and HEC-HMS
Evapotranspiration	Similar to infiltration, evapotranspiration can be significant for small rain storms. In the winter months when deicing is required, evapotranspiration is very small. Evapotranspiration data are not widely available and a common method is to derive them from mass or energy budgets such as the Bowen Ratio and Penman methods,[f] or empirical equations such as the Thornthwaite method.[g]
Hydraulics	
Conveyance	Hydraulic models are the strongest component in the modeling process. At airports, hydraulic modeling addresses flow in pipes and open channels conveying runoff from paved and unpaved surfaces to treatment facilities and outfalls. Suitable models are SWMM for pipe flow and HEC-RAS[h] for open channel flow.

Table 2-1. (Continued).

Process	Approach
Water Quality	
Pollutant loading	There are no standardized models to simulate the uses of aircraft and airfield deicers, and the subsequent generation of BOD loads from de/anti-icing operations. A variety of approaches to modeling the pollutant load associated with aircraft and pavement deicing may be taken. These range from discrete models which attempt to estimate application rates on a per-aircraft basis to empirical/statistical-based models. All approaches require site-specific information regarding historical deicer usage, weather conditions during deicer application, and airport flight schedules. The availability of information for these models will affect model accuracy and validity.
Pollutant wash-off	Pollutants become mobile when they come in contact with runoff. The hydrodynamic, chemical, and biological processes involved are extremely complex and fraught with uncertainty. Simulation of runoff quality is still an evolving field of science and, credibility of the results depends heavily on accurate field data for calibration and verification. For many applications, simpler, event-based methods can be effective where a finer temporal distribution is not required. One method is to develop a rating curve that relates flow to concentration. A second method uses the concept of Event Mean Concentration (EMC), which is the flow-weighted average concentration of a pollutant during an event. EMCs are typically lognormally distributed (Huber and Dickinson, 1992). Regardless of the method, adequate field data are needed to arrive at reliable representations. The SWMM model can be used for this purpose but a custom model can also be programmed in a spreadsheet. Methods have been developed to quantify the fugitive loss mechanisms in a way that would support inclusion in a mechanistic model.[i] This is an area where much research is still needed.
Pollutant decay	Many pollutants undergo a series of physical, chemical, and biological processes that begin as soon as they come in contact with the environment. The BOD in deicers begins to degrade on pavement surfaces, and degradation continues as deicing runoff travels through the stormwater conveyance system (Revitt and Worrall, 2003; Revitt et al., 2002). These processes are very complex and depend on a number of environmental factors, including temperature, which is typically low during deicing events. A common approach to modeling pollutant transformation as it is transported by runoff is to assume a lumped loss factor that includes all fugitive mechanisms, estimated from available mass balance monitoring data. Decay may be important for flow in swales and other natural conveyances, where a more explicit representation may be required. In either case, reliable field data are needed to derive the model parameters. These processes are available in models like SWMM, but can also be programmed in a custom spreadsheet.
Pollutant removal in runoff controls	Both collection and treatment practices reduce the pollutant loads generated by deicing operations and released to the environment. Collection practices may be characterized as a fraction of applied deicers removed by collection activities. Representation of treatment/recycling will depend on the nature of the process and the destination of the effluent stream relative to the objectives of the modeling analysis.

(continued on next page)

Table 2-1 (Continued).

Process	Approach
Receiving water quality	This modeling component may be critical where the need for permit limitations to protect receiving water quality must be determined or discharge limits must be developed in response to that need. Receiving water quality models take the pollutant inputs at outfalls and simulate their fate as they move in natural systems. Besides dilution, the processes in natural streams, lakes and estuaries are complex and their representation again depends on reliable field data. Simple models, such as the Streeter-Phelps dissolved oxygen model can be constructed and implemented in spreadsheets. More complex models that have been applied to simulate the impact of deicing discharges on surface waters include the WASP[j] model, QUAL2K[k] and CE-QUAL-W2,[l] and HSPF.[m] These are progressively complex programs, and extensive modeling experience is typically required for their application.

[a] Rossman (2004).
[b] USDA (1986).
[c] USACE (2006a).
[d] Mein and Larson (1973).
[e] Bedient and Huber (1989).
[f] Bras (1990).
[g] Singh (1989).
[h] USACE (2006b).
[i] APS Aviation Inc. (2005).
[j] Wool et al. (2001).
[k] Chapra et al. (2007).
[l] Cole and Buchak (1995).
[m] Bicknell et al. (1997).

CHAPTER 3

Guidelines for Selecting Individual Practices

This section provides an overview of the range of practices currently available to address airport deicing stormwater management needs and guidance for the review, interpretation, and use of the Fact Sheets.

Overview and Screening Process for Deicing Practices

Assessing the Need for Practices

Factors that would prompt an airport to pursue the implementation of new or additional practices include the following:

1. Concerns arise regarding potential impacts of deicing discharges on receiving-water quality, such as reduced dissolved oxygen, aquatic toxicity, nuisance odors, bacterial growth, or other evidence of possible impairment.
2. Physical or analytical monitoring results at airport outfalls indicate permit exceedances or potentially significant increases to the volume or concentration of deicing stormwater discharges.
3. Significant changes occur in aircraft fleet mix, size, and total number of flights that potentially increase the volume of deicer applied and thus the volumes or concentrations of deicing stormwater.
4. Changes occur in the airport drainage system that includes the size or location of deicing areas.

The spectrum of available deicing practices represents the toolbox from which the airport planner or manager can select the most appropriate tools for their requirements. Not every practice will be appropriate for an individual airport's deicing runoff management program. There is significant variation among airports in many aspects of deicing operations and runoff management, including nature, scale, and complexity of aircraft operations; climate; deicing materials and methods; existing stormwater collection and conveyance systems; regulatory permit requirements; and availability and access to resources such as publicly owned treatment works. The Fact Sheets are intended to help the reader understand the breadth of available options for constructing a deicing runoff management system and serve as an aid in the initial screening of practices.

Deicing Practice Categories

After an airport has determined that deicing practices are needed, they will need to assess the type(s) of practice(s) that are most appropriate to meet their deicing management needs. For the purposes of this document, the Fact Sheets have been divided into five functional categories:

1. Aircraft deicing source reduction;
2. Airfield pavement deicing source reduction;
3. Deicing runoff containment/collection;
4. Deicing runoff treatment/recycling; and
5. Deicing runoff system components.

Each practice category will not necessarily be represented in any given airport system, and some airport systems may incorporate multiple practices under a single category or multiple categories. A given type of practice also may be implemented at one or multiple points in an airport's drainage system.

Distinctions among practice categories are summarized in the following paragraphs:

- **Aircraft Deicing Source Reduction.** These practices reduce the amount of aircraft-deicing materials available to mix with precipitation and become deicing stormwater or reduce the amount of potential environmental contaminants within applied deicing material. This category includes high-efficiency application equipment, alternative deicing materials, procedures, and information systems. Typically, these practices are implemented by aircraft operators, and their feasibility is greatly dependent on the nature of aircraft operations and potential impacts on aircraft operations and safety. Thus, the airport authority and the aircraft operators need to work cooperatively in the consideration of these practices. Where source reduction is feasible, it may reduce the downstream requirements for collection, storage, and treatment/recycling.

- **Airfield Pavement Deicing Source Reduction.** These practices reduce the amount of airfield pavement deicing materials available to mix with precipitation and become deicing stormwater or reduce the amount of potential environmental contaminants within applied airfield pavement deicing materials. This category includes high-efficiency application equipment, alternative deicing materials, procedures, and information systems. Because of the significant difficulties in practical collection and treatment of airfield runoff, these practices represent the primary strategy for managing airfield deicing runoff.
- **Deicing Runoff Containment/Collection.** These practices consist of technological approaches to isolating and capturing deicing stormwater before it reaches receiving waters. This category includes specialized collection equipment, deicing area runoff collection systems, and drainage isolation and diversion systems. Implementation of a containment/collection practice will usually require associated storage and treatment/recycling practices. As a result, selection of practices from these categories tends to be very interdependent.
- **Deicing Runoff Treatment/Recycling.** These practices consist of process systems used to remove or recover deicing chemicals from collected deicing stormwater. This category includes both onsite and offsite treatment and recycling systems. Some form of treatment/recycling is usually required for any deicing runoff management system that includes containment/collection practices, and the availability of treatment/recycling capacity is often a constraining factor on the choice of containment/collection practices.
- **Deicing Runoff System Components.** Deicing stormwater system component practices are specific technologies (for example, hardware) that may be used in multiple locations within a deicer runoff management system. Examples in this category include various types of storage facilities, monitoring technologies, and diversion equipment for routing deicing stormwater to storage or treatment.

Screening Approach for Selecting Individual Deicing Practices

Practices should be assessed within the context of the development of an overall integrated deicing management strategy. An important step in this process is the initial screening of individual practices for applicability to a particular airport. As discussed in "Implement Management Plan," in Chapter 2, airports, in conjunction with key stakeholders, should perform their initial screening process by reviewing the Fact Sheets, identifying potentially applicable practices, and reviewing the practices with the airport's pollution prevention team and/or other stakeholders. It is important to review potential practices with the pollution prevention team and other stakeholders early so that consensus about which practices to pursue further can be obtained. Because of the many factors described in Chapter 2, the process of selecting and reaching consensus on appropriate practices will take time, typically several months to several years, depending on the complexity of the facility, operations, regulatory requirements, and required management controls. Screening of individual practices can be performed using the Fact Sheets. Guidance for use and interpretation of those Fact Sheets is provided in "Guidance on Use and Interpretation of the Fact Sheets." This subsection describes the order practice categories should be screened and selected, to facilitate the development of a cost-efficient, high-performance integrated deicer management system.

In general, practices nearest the source should be screened first for applicability. The analysis should then proceed outward in the drainage system toward the end-of-pipe practices, until all deicing management needs can be met. Controls implemented near the source can have a significant impact on the scale, complexity, and cost of practices that are implemented farther downstream from the source. Concentrated deicing runoff is subject to dilution as it moves away from the application areas and has the opportunity to mix with progressively larger volumes of stormwater. The result is a larger volume of deicing stormwater that must be managed downstream.

Computer models will often facilitate the screening process where environmental objectives are quantitative and include numerical discharge limits or performance requirements. These models provide a mathematical representation of the key physical, meteorological, operational, and environmental components and processes, and allow "what if" evaluations of different practice selections and progressively aggressive combinations of practices. Such modeling tools can be as simple as a spreadsheet balance sheet or as complicated as a detailed process model of the entire deicing system. The level of model complexity should be tailored to match the specific needs of the analysis as well as the availability of data for calibration. This quantitative analysis need not be complicated in the initial screening of practices, but can lay the foundation for more sophisticated modeling in subsequent design phases.

The overall approach for screening the practice categories is described below.

- Source reduction practices (Categories 1 and 2) should be considered first as a means to reduce the quantity of pollutants generated by deicing activities. The practices included in this category generally require modifications to an airport's deicer application protocols and equipment, which may not be practicable for some aircraft operators. Thus, only partial implementation of source reduction practices may be possible at any given airport.

The primary concerns with many source reduction practices are the risk of interference with airport or aircraft operations and the potential aircraft safety hazard posed by an inappropriate reduction in the amount of deicing materials applied. Specific safety concerns or potential operational issues are discussed further on the individual Fact Sheets. Review of each source reduction alternative should include consideration of the conditions under which the practice may be implemented safely and whether the practice would be appropriate given site-specific operations, deicing conditions, and safety concerns.

- The next tier of control beyond source reduction is the implementation of collection and containment practices close to the sources (Category 3). These practices serve to minimize the dilution of deicing runoff with stormwater by physically isolating deicing runoff from nondeicing stormwater. Examples of containment/collection practices include glycol recovery vehicles and catch basin inserts. Review of containment/collection practices that may be implemented near airfield pavement should include consideration of the potential for interference with airport or aircraft operations, as well as ways to minimize theses interferences.

  Options for containment/collection practices farther downstream in the airport drainage system should be considered if "near-source" practices are not adequate to meet environmental goals. Some airports may implement containment/collection practices within the drainage system if it is not feasible to implement them at the source, while other airports may implement containment/collection practices at various locations, including both at the source and at locations downstream in the storm sewer system. Implementation locations should be chosen to optimize overall system performance. An example of containment/collection practices within the drainage system is the use of diversion valves to route deicing runoff from aprons and taxiways directly from a storm sewer toward storage, treatment, or recycling. It should be noted that as collection and containment practices are implemented farther downstream, options for disposal are more limited and costly as volumes and dilution increase.
- Finally, storage, treatment, recycling, or disposal practices should be assessed last in the process (Category 4). The required capacity and costs for these practices is highly dependent on the types and level of deicing source reduction and containment/collection controls implemented. Capital costs for these practices have the potential to be very significant if the volume and concentration of deicing stormwater is not restricted by upstream controls. As the Fact Sheets are reviewed, opportunities to optimize the balance between storage and treatment/recycling/disposal should be sought along with additional practices that may be added upstream to reduce costs for end-of-pipe controls.
- In addition, deicing stormwater system component practices (Category 5) should be assessed each step of the way as they may be used in conjunction with practices in other categories.

Factors for Evaluating Practices

A variety of factors should be considered during the initial screening to identify potentially applicable practices for meeting an airport's long-term deicing runoff management needs. Table 3.1 summarizes these key characteristics (other than performance, which is addressed separately) and an assessment of each of the practices described in this guidance document. The matrix provides subheadings within each of the characteristics to facilitate finer-scale comparisons between similar practices. Numeric ratings associated with the practice characteristics are defined in the key at the bottom of Table 3.1. These ratings represent a synthesis of information from reports and data, where available, combined with the experience and best professional judgment of the authors, and are presented as relative ratings. The fundamental characteristics presented in Table 3.1 are defined as follows:

1. Proven and Demonstrated Application. Items under this heading provide measurements of how established the practice is within the deicing industry.
   a. Emerging Technology. Practices are described as either a proven technology at airports, demonstrated outside of the airport industry, or currently in the research-and-development phase.
   b. Industry Application. Frequency of occurrence in deicing runoff management systems is expressed with a relative ranking of 1 to 5, with 5 being standard practice in the industry.
2. Implementation and Operational Requirements. Items under this heading describe aspects of responsibility, implementation, and operation of the practice.
   a. Responsibility for Implementation. Implementation is described as responsibility of either airports or aircraft operators/fixed base operators (FBOs) or both.
   b. Responsibility for Operation. Operation is described as responsibility of either airports or aircraft operators/FBOs or both.
   c. Ease of Implementation. This expresses how readily the practice can generally be implemented. A relative ranking of 1 to 5 is used, with 5 being easiest to implement.

Table 3-1. Summary of characteristics of best management practices for runoff from aircraft and airfield deicing and anti-icing operations.

	Proven and Demonstrated Application		Implementation and Operational Requirements					Advantages, Constraints, and Requisite Factors for Success			Costs and Savings	
Fact Sheet #	**Emerging Technology**	**Industry Application**	**Responsibility for Implementation**	**Responsibility for Operation**	**Ease of Implementation**	**Labor Requirements**	**Training Requirements**	**Advantages**	**Constraints**	**Keys to Success**	**Relative Costs**	**Potential Savings**
Source Reduction												
Aircraft Deicing												
Product selection (#1)	N	5	Carriers/FBOs	Carriers/FBOs	4	**5**	**3**	No special equipment requirements May offer opportunity to reduce toxicity	Must conform with FAA-approved deicing plan Limited choice of products	Gaining aircraft operator acceptance	—	—
Storage and handling (#2)	N	5	Carriers/FBOs	Carriers/FBOs	4	**5**	**3**	Addresses sources outside of containment areas Saves money on wasted product	Depends on adoption of practice by carrier and FBO staff	Incorporation of practices into Standard Operating Procedures Education of employees who handle deicers	4	2
Proactive anti-icing (#3)	N	4	Carriers/FBOs	Carriers/FBOs	4	**5**	**2–3**	Reduces delays Reduces Type I use under certain weather conditions	May require extra deicing crew shift Must be incorporated into FAA-approved deicing plan	Suitable climate Accurate weather forecasting Suitable flight schedule	4	3
Blending to temperature (#4)	N	3	Carriers/FBOs	Carriers/FBOs	3	**4**	**2**	Optimizes use of aircraft deicers Reduces overall Type I use with certain weather conditions	Logistically complicated for FBOs serving multiple carriers with different FAA-approved deicing plans May require specialized equipment May undermine recycling efforts	Predominance of milder temperatures where lower glycol ratios can be used Ready source of water for blending Deicing equipment designed to facilitate blending Effective training and quality assurance	2–4	3–4
Forced air/hybrid deicing (#5)	N	2	Carriers/FBOs	Carriers/FBOs	3	**5**	**1**	Potentially significant reductions in ADF use	Reduced effectiveness with ice and heavy wet snow Specialized and extensive training required Equipment is more complex than conventional trucks May reduce amounts of recyclable glycol Significantly higher capital cost than conventional trucks	Extensive operator training and skill development Operator understanding of effectiveness under different conditions Climate that is suited to the technology's strengths Procurement as part of regular deicing truck replacement schedule	2–3	3–5
Infrared deicing technology (#6)	N	1	Carriers/FBOs	Carriers/FBOs	1	**—**	**1**	Potentially large reductions in glycol use Potentially lower operating costs compared to conventional deicing	Land requirements for structure(s) Some glycol required for shadowed areas and holdover protection Location and configuration of structures must conform to Part 77 requirements May reduce amounts of recyclable glycol	Available suitable land on the airfield Commitment by airport management Acceptance by aircraft operators Effective routing and control of aircraft traffic through the unit(s)	1–2	4–5
Physical removal (#7)	N	2	Carriers/FBOs	Carriers/FBOs	4	**4**	**3**	Reduces use of glycol to remove accumulated snow	Only works on loose precipitation May be dangerous or impractical on larger aircraft Care must be taken to avoid damage to aircraft surfaces, sensors, etc.	Smaller aircraft that can be easily "broomed" Dry powdery snow Non-time-critical departures	5	2–3

	Proven and Demonstrated Application		Implementation and Operational Requirements					Advantages, Constraints, and Requisite Factors for Success			Costs and Savings	
Fact Sheet #	**Emerging Technology**	**Industry Application**	**Responsibility for Implementation**	**Responsibility for Operation**	**Ease of Implementation**	**Labor Requirements**	**Training Requirements**	**Advantages**	**Constraints**	**Keys to Success**	**Relative Costs**	**Potential Savings**
Hangared parking (#8)	N	2	Carriers/FBOs	Carriers/FBOs	5	**5**	**4**	May eliminate the need for deicing Generally protects aircraft from the elements	Requires adequate hangar space Anti-icing may still be required Not suited to passenger operations or situations where aircraft are loaded outside of hangar	Adequate hangar space. Operating schedules that allow for transit directly from hangar to takeoff.	1–2 (new hangars)	4–5
Hot water deicing (#9)	N	2	Carriers/FBOs	Carriers/FBOs	4	**5**	**3**	Reduces the need for glycol under some weather conditions (i.e., frost)	Requires suitable climate No holdover protection against refreezing May require anti-icing	Suitable climate	5	2–3
Enclosed deicing buckets (#10)	N	3	Carriers/FBOs	Carriers/FBOs	3	**5**	**3**	Protects operator from spray Allows closer proximity of application to aircraft Facilitates greater attention to optimum deicing by operator	Requires purchase of new equipment	Procurement as part of regular deicing truck replacement schedule	2–3	2–3
Enhanced weather forecasting (#11)	N	3	Airport and Carriers/FBOs	Airport and Carriers/FBOs	3	**4**	**2**	Supports optimized use of deicers	Coordination efforts can require substantial effort Potential for error based on timing of delivery of information to the applicators	Availability of service	4	2–3
Holdover time determination systems (#12)	R	None	Airport and Carriers/FBOs	Airport and Carriers/FBOs	—	—	—	Supports optimized use of deicers Improves accuracy of holdover time determination Ensures that aircraft are deiced consistent with actual conditions	Still in the R&D phase	Commercial availability Acceptance and financial commitment by airport and carriers	—	—
Deicer use tracking (#13)	N	3	Carriers/FBOs	Carriers/FBOs	4	**4**	**3**	Supports optimized use of deicers Supports an understanding of the relationships between weather, operations, and deicer use Provides needed data if modeling used to simulate deicer application Can be used to identify inefficient operators or equipment	Requires commitment by aircraft operators and FBOs to maintain and report accurate data	Adoption by aircraft operators and FBOs Effective communication and data tracking system	3–4	2–3
Reduced operations (#14)	N	1	Carriers/FBOs	Carriers/FBOs	4	**5**	**5**	Reduces deicer use when system capacity is reached Improves ability to avoid environmental noncompliance during severe winter storms	Likely to create significant traffic delays Traffic delays may affect other airports, regional, and national traffic Likely to result in significant costs to aircraft operators	Acceptance of delays by traveling public Acceptance by aircraft operators and FAA	1–2 (incl. delays)	1
Tempered steam technology (#15)	R	None	Carriers/FBOs	Carriers/FBOs	3	5	2	May significantly reduce glycol use	Still in the R&D phase Maneuvering steam application heads in high winds may be challenging May be limited to certain types of weather or deicing activity May reduce amounts of recyclable glycol	Demonstration at an operational level. Adoption by aircraft operators and FBOs	—	—

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Table 3-1. (Continued)

	Proven and Demonstrated Application		Implementation and Operational Requirements					Advantages, Constraints, and Requisite Factors for Success			Costs and Savings	
Fact Sheet #	**Emerging Technology**	**Industry Application**	**Responsibility for Implementation**	**Responsibility for Operation**	**Ease of Implementation**	**Labor Requirements**	**Training Requirements**	**Advantages**	**Constraints**	**Keys to Success**	**Relative Costs**	**Potential Savings**
Airfield Pavement Deicing												
Product selection (#16)	N	4	Airport	Airport	4	**5**	**3**	May offer opportunity to reduce toxicity	Must conform with FAA-approved deicing plan Limited choice of products Concerns with catalytic oxidation, cadmium corrosion, airfield infrastructure complicate selection of acceptable deicers New application equipment may be required	Acceptance by airfield maintenance staff Acceptance by aircraft operators Acceptance of new operating procedures	3–4	3–5
Storage and handling (#17)	N	4	Airport	Airport	4	**5**	**3**	Saves money on wasted product Addresses sources outside of containment areas	New handling and storage equipment may be required	Education of front line staff who handle deicers	5	2
PDM application technology (#18)	N	3	Airport	Airport	3–4	**4**	**2**	Optimizes deicer use and airfield friction	Requires specialized application equipment and instrumentation Equipment investment may not be worthwhile at small airports	Accurate and timely data on airfield pavement conditions Adoption of the process by airfield maintenance	2–3	3–4
Heated pavement (#19)	R	None	Airport	Airport	1	**—**	**–**	Theoretically eliminates pavement deicer use	Still in R&D phase	Demonstration at an operational level.	1–2	—
Physical removal (#20)	N	5	Airport	Airport	5	**4-5**	**5**	Optimizes deicer use Already a common industry practice	Effectiveness in reducing PDM use is limited to certain types of weather or deicing activity	Education and training of airfield maintenance staff and equipment operators Most effective with dry snow	5	1-2
Containment/Collection												
Centralized deicing facilities (#21)	N	2	Airport or Carriers	Carriers/FBOs	1	**1**	**1**	Highest reported performance of available glycol collection practices Improves availability of gates Opportunity to collect relatively high concentration runoff Reduces volumes of deicing runoff that must be stored and treated. Eliminates deicing impacts on loading operations Removes deicer traffic from terminal and ramp areas. Facilitates glycol recycling	Reduces operational flexibility afforded aircraft operators by at-gate deicing Requires adequate space in appropriate location(s) on the airfield Requires coordination among different deicing crews operating at the same facility Unpopular among many aircraft operators at nonhub locations Typically involves a large airfield construction project	Acceptance by major aircraft operators at the airport Aircraft operator appreciation of benefits of improved gate availability Opportunities for retrofitting existing pavement areas Adequate sizing to ensure capture of runoff driven by jet blast and overspray Control of subsurface drainage from pad Effective traffic and queue management system Coordination among users of the deicing facility Motivation for glycol recycling	1–3	—

	Proven and Demonstrated Application		Implementation and Operational Requirements					Advantages, Constraints, and Requisite Factors for Success			Costs and Savings	
Fact Sheet #	Emerging Technology	Industry Application	Responsibility for Implementation	Responsibility for Operation	Ease of Implementation	Labor Requirements	Training Requirements	Advantages	Constraints	Keys to Success	Relative Costs	Potential Savings
Apron collection systems (#22)	N	3	Airport	Airport	2	**3**	**2**	Minimizes impact of collection on existing operations Allows operational flexibility of at-gate deicing May be implemented selectively to supplement other collection practices Land requirements are minimal	Requires storm sewer system modifications May not work well where storm sewers are “leaky” May require large storage capacity for collected runoff May increase traffic around ramps May result in lower collected deicer concentrations than other collection practices	Suitable storm sewer layout Adequate room for storage facilities Practical disposal/treatment of collected runoff Opportunity to incorporate collection system components in planned apron construction projects	1–3	1
Glycol collection vehicles (#23)	N	2	Airport, carriers, or FBOs	Airport, carriers, or FBOs	3	**1**	**1**	Adaptable to existing deicing locations and operations Only requirements are storm sewer inlet blocks and storage facility Collects runoff at relatively high concentrations May be used to supplement other collection practices Capable of “scrubbing” pavement to meet stringent environmental requirements	Require effective blockage of storm sewer inlets to achieve reasonable collection efficiency Increase traffic on the ramp May be susceptible to clogging with snow and slush Collected runoff must be hauled to storage and treatment	Blocking storm sewer inlets to facilitate runoff collection Operator training with a focus on the runoff collection objectives Sufficient number of vehicles for the deicing area(s) and operations Sufficient hauling and storage capacity to prevent flooding or overflows Sealing of apron pavement joints	3	1
Block-and-pump systems (#24)	N	2	Airport, carriers, or FBOs	Airport, carriers, or FBOs	3	**1**	**1**	Adaptable to existing deicing locations and operations Simple to implement using sewer balloons May be used to supplement other collection practices	Layout of storm sewers must be suitable May require storm sewer system modifications May not work well where integrity of storm sewers is poor May require large storage capacity for collected runoff Must have equipment to pump out blocked sewers Must have adequate pumping and hauling capacity to prevent flooding Collected runoff must be hauled to storage and treatment	Suitable storm sewer serving deicing areas Availability of adequate storage Availability of adequate treatment capacity for dilute runoff	3–4	1
Airfield drainage planning/design/retrofit (#25)	N	3	Airport	Airport	1	**5**	**4**	Potential opportunity to reduce fugitive deicing runoff loads May provide reduction in some non-deicing runoff pollutants	Typically only practical as an element of an airfield construction project Must be consistent with all FAA requirements for airfield design Opportunities depend on local facility layout and drainage patterns	Consideration of possibilities early in the planning and design phase of airfield projects	1 – 3	—

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Table 3-1. (Continued)

	Proven and Demonstrated Application		Implementation and Operational Requirements					Advantages, Constraints, and Requisite Factors for Success			Costs and Savings	
Fact Sheet #	Emerging Technology	Industry Application	Responsibility for Implementation	Responsibility for Operation	Ease of Implementation	Labor Requirements	Training Requirements	Advantages	Constraints	Keys to Success	Relative Costs	Potential Savings
Deicer-laden snow management (#26)	N	2	Airport	Airport or FBOs	2–3	**3**	**2**	Improves collection/containment performance Reduced transport of deicers out of containment areas	Increases complexity of snow plowing and management operations Requires separate area for deicer-laden snow storage May require snow melters where space is limited Requires change to Airport Snow Management Plan	Acceptance and adoption of practices by airfield maintenance staff Suitable area for storage of deicer-laden snow Capacity for treating deicer-laden snowmelt from storage area	2–3	1
Conveyance/Storage												
Portable tanks (#27)	N	3	Airport	Airport	3–4	4	4	Small footprint Storage can be placed where it is needed Can be mobilized on short notice Additional storage can be readily added as needed	Height restrictions may limit acceptable locations Tanks are typically limited to ~20,000 gallons	Storage requirements can be met with small units	4	1
Modular tanks (#28)	N	2	Airport	Airport	2–3	4–5	4	Can be sized to meet needs Less expensive than permanent tanks Construction time is relatively short	Height restrictions may limit acceptable locations May require covers Suitable location required	Suitable location	3	1
Ponds (#29)	N	3	Airport	Airport	1	**5**	**3**	Relatively cost-effective storage Can also serve stormwater detention function	Land requirements FAA discourages open water features near airfields Odors may be an issue Can pose wildlife attraction hazard Subject to storage volume increases and dilution from direct precipitation	Suitable land available Wildlife attraction issues fully addressed Address FAA concerns Appropriate site specific containment to address groundwater infiltration and deicer exfiltration Provisions for period maintenance (solids removal)	2–3	1
Permanent tanks (#30)	N	2	Airport	Airport	1	5	4	No odor issues No wildlife attraction issues Reduced potential for dilution from precipitation Contents may be mixed for uniform discharge concentrations Lower maintenance than ponds	Most costly form of non-portable storage Land requirements Height restrictions Geotechnical restrictions More difficult to remove solids than open storage	Suitable land available Accurate sizing Evaluating potential process advantages of multiple tanks Provisions for mixing contents	2–3	1
Manual diversion valves (#31)	N	3	Airport	Airport	3	4	3	Simple operation and maintenance	Requires operator during potentially busy periods	Appropriate valve selection Reliable and effective valve seals Well defined standard operating procedures	2–3	1
Automated diversion valves (#31)	N	2	Airport	Airport	4	5	2–3	Reduced manpower requirements Can be integrated into SCADA system for centralized operation of diversions throughout system	Increased complexity Capital costs can be high for large pipe diameters	Appropriate valve selection Reliable and effective valve seals Cost-benefit analysis for capital versus operating cost	3–4	1

	Proven and Demonstrated Application		Implementation and Operational Requirements					Advantages, Constraints, and Requisite Factors for Success			Costs and Savings	
Fact Sheet #	Emerging Technology	Industry Application	Responsibility for Implementation	Responsibility for Operation	Ease of Implementation	Labor Requirements	Training Requirements	Advantages	Constraints	Keys to Success	Relative Costs	Potential Savings
Real-time monitoring technology (#32)	N	3	Airport	Airport	2	4	2	Provides real-time information on BOD, or surrogate parameters Can be interfaced with automated diversion valves to achieve fine-scale separation of higher and lower concentration flows Allows operation of collection, diversion, or treatment when facility is not staffed May reduce storage and treatment requirements Recording capabilities provide fine-scale data record of runoff characteristics, including flows and loads	Instrumentation is sophisticated Installations require protective housing and utilities Use for compliance monitoring requires gaining acceptance by regulators	Clear need to detect BOD in real time Experienced or trainable operator with troubleshooting skill Clearly defined operating conditions and ranges Clear understanding of instrument accuracy Regular maintenance and calibration	3-4	3–4
Catch basin inserts/valves (#33)	N	3	Airport	Airport	3	4	3	Prevent deicer-laden runoff from entering storm sewers prior to be picked up by glycol collection vehicles	Must be custom fabricated for each catch basin Depend on manual operation Can promote flooding on the apron if not operated correctly Requires catch basin structures be in good condition Requires adequate collection and hauling capacity	Well-defined drainage patterns in deicing areas Proper sizing to suit catch basin and drainage area Effective operator training Incorporation of practices into Standard Operating Procedures	3–4	1
Treatment/Recycling												
POTW discharge (#34)	N	3	Airport	Airport (treatment operation by POTW)	2	**4**	**2**	Simplest treatment alternative Relatively low capital cost	Requires POTW with adequate available treatment capacity Requires separate industrial discharge permit Likely to require onsite storage and metering of discharges to sewer Annual discharge fees may be high Long-term cost effectiveness dependent upon projected increases in discharge fees Discharge authorization may be rescinded in the future	POTW with adequate available treatment capacity Address all POTW operator concerns regarding treatability of deicing runoff POTW operating problems may cause reduction or elimination of discharge authorization Understanding POTW's projected long-term increases in discharge fees	3–4	1
Anaerobic fluidized bed reactor (#35)	N	1	Airport	Airport	1	1	1	Low operating costs Treats deicer additives Excess methane can be used for other purposes Can be shut down and started back up in as little as 5 days Relatively small footprint Independence from outside market forces or costs	Not well suited to produce effluent with BOD concentrations less than 100 mg/L Some solids dewatering and annual disposal is required Startup time may be too long for applications where very intermittent treatment is needed Anaerobic degradation of additives has potential to generate endocrine disruptors	Requirement for treatment of relatively concentrated runoff Segregated and collection of concentrated runoff Motivated, trainable operator Clearly defined operating conditions and ranges prior to design considering deicer use and weather conditions Design for flexibility in management of influent flows	1–2	1

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Table 3-1. (Continued)

	Proven and Demonstrated Application		Implementation and Operational Requirements					Advantages, Constraints, and Requisite Factors for Success			Costs and Savings	
Fact Sheet #	Emerging Technology	Industry Application	Responsibility for Implementation	Responsibility for Operation	Ease of Implementation	Labor Requirements	Training Requirements	Advantages	Constraints	Keys to Success	Relative Costs	Potential Savings
Reciprocating subsurface treatment (#36)	N	1	Airport	Airport	2	2	1	Low effluent BOD concentrations Low initial capital and operating costs Can operate at ambient temperatures No biosolids processing or disposal typically required Relatively straightforward operational requirements	Large footprint Efficiency depends on operating within limited ranges of water temperature and influent BOD concentrations and loadings If solids buildup occurs, it requires significant effort to clean or replace the media	Requirement for high level of treatment Available land Moderate winter temperatures Experienced or trainable operator Clearly defined operating conditions and ranges prior to design considering deicer use and weather conditions	2–3	1
Moving bed bioreactor (#37)	N	1	Airport	Airport	1	2	1	Effluent BOD is 20 mg/L or less Relatively small footprint	Relatively high operating costs Requires oxygen inputs and sludge disposal Requires heating of influent if the system is used as primary treatment	Requirement for high level of treatment Best suited for steady BOD load, but accommodates variable influent loads Experienced or trainable operator Clearly defined operating conditions and ranges prior to design considering deicer use and weather conditions	1–2	1
Sequencing batch reactor (#38)	N	1	Airport	Airport	1	1	1	Effluent BOD is 20 mg/L or less	Relatively high operating costs Requires oxygen inputs Requires sludge disposal Limited airport application Requires heating of influent	Requirement for high level of treatment Best suited to situations with steady long-term BOD load Experienced or trainable operator Clearly defined operating conditions and ranges prior to design considering deicer use and weather conditions	1–2	1
Natural treatment systems (#39)	N	1	Airport	Airport	1	4	2	Low maintenance Lower operating costs and energy requirements than other treatment systems No routine biosolids processing Straightforward operating requirements Can operate at ambient temperatures Viewed favorably by public	Significant land requirements To avoid pumping, location must be down-gradient from sources of runoff to be treated May pose wildlife attraction hazard Not well suited to high influent BOD concentrations	Available land Best suited to low strength runoff Pilot testing Minimize wildlife attraction through proper design and choice of vegetation Experienced or trainable operator Clearly defined operating conditions and ranges prior to design considering deicer use and weather conditions	2–3	1
Membrane filtration (#40)	N	1	Airport, carriers, or FBOs	Airport, carriers, or FBOs	2–3	2–3	3	Low effluent concentrations of glycols and potentially of additives Can readily operate intermittently Relatively small footprint	Pretreatment required Concentrate stream requires disposal or onsite treatment Solids disposal from pretreatment system May require heating of stormwater	Pilot testing Cost-effective means for disposal of concentrate Understanding pretreatment requirements Experienced or trainable operator Clearly defined operating conditions and ranges prior to design considering deicer use and weather conditions	2–3	1

	Proven and Demonstrated Application		Implementation and Operational Requirements					Advantages, Constraints, and Requisite Factors for Success			Costs and Savings	
Fact Sheet #	Emerging Technology	Industry Application	Responsibility for Implementation	Responsibility for Operation	Ease of Implementation	Labor Requirements	Training Requirements	Advantages	Constraints	Keys to Success	Relative Costs	Potential Savings
Glycol recovery (#41)	N	2	Airport, carriers, or FBOs	Airport, carriers, or FBOs	2–3	2–3	3–4	Productive use of spent glycol Value of recovered glycol can help offset collection program costs Reduced requirements and costs for biological treatment Typically contracted out to specialty provider Potential single source provider of equipment and system operation	Requires collection of runoff containing only PG-based ADF Cost-effectiveness generally requires glycol concentrations greater than 3–5% Cost-effectiveness requires some minimum glycol use May require onsite processing to facilitate economics of offsite transport Requires access to ultimate processing/reuse facility May require pretreatment and solids disposal May require heating of stormwater.	Use of PG-based aircraft deicing fluids in collection areas targeted for recycling Consistent volume of runoff with 3–5% glycol concentration. Proximity and access to processing facility Understanding of need for pre-treatment Understanding effect of market value of recycled glycol on cost effectiveness Well-thought out contract provisions with service provider.	1–3	2–3

Key:

Emerging Technology
N Proven technology at airports
D Demonstrated outside of the airports industry
R In research & development phase

Industry Application
5 Standard practice
4 Widespread
3 Common
2 Limited
1 Rare
— Unknown

Ease of Implementation
5 Immediate
4 Administrative requirements
3 Capital equipment required
2 Infrastructure required
1 Major infrastructure required
— Unknown

Labor Requirements (During Deicing Periods)
5 No additional labor
4 <1 day per week
3 2–3 days per week
2 1 FTE
1 >2 FTEs
— Unknown

Training Requirements
5 No additional training
4 Basic orientation
3 Short training session
2 Multiple training sessions
1 Extensive training
— Unknown

Relative Capital Costs
5 Negligible
4 < $100,000
3 $100,000–$1,000,000
2 $1,000,000–$10,000,000
1 >$10,000,000
— Unknown

Potential Savings
5 Significant savings
3 Modest savings
1 No savings
— Unknown

   d. Labor Requirements. This provides information on the labor required to operate the practice using a relative ranking of 1 to 5, with 1 being greatest labor requirements.
   e. Training Requirements. The amount of specialized training required for implementation is expressed using a relative ranking of 1 to 5, with 1 being the most demanding training requirements.
3. Advantages, Constraints, and Requisite Factors for Success. Items under this heading are specific considerations that may help the reader differentiate between practices and determine whether a practice would be appropriate for a particular application.
   a. Advantages. Describes key advantages of practice relative to other practices.
   b. Constraints. Describes key limitations of practice relative to other practices.
   c. Keys to Success. Describes specific considerations and requirements cited by airports with successful implementations for achieving optimum performance of the practice. This information may help determine applicability for a particular airport.
4. Costs and Savings. Items under this heading provide the means to perform a relative economic cost-benefit comparison among practices.
   a. Relative Capital Costs. Practices are provided a relative ranking of 1 to 5, with 1 being highest relative potential capital costs.
   b. Potential Savings. Practices are provided a relative ranking of 1 to 5, with 5 being the most significant potential savings.

In interpreting Table 3.1, it must be recognized that generalizations have been required to facilitate direct comparison in this summary. The characteristics of a practice may vary significantly among different implementations, depending on site-specific conditions. Further detail and discussion of these site-specific considerations and factors is provided within individual practice-specific Fact Sheets.

Reported performance data for various practices are summarized in Tables 3.2 and 3.3. Because the performance metrics are very different, available performance information for source control, collection, and containment practices is summarized in Table 3.2, while performance information for treatment, recycling, and disposal practices are summarized in Table 3.3.

Typical metrics for quantifying the performance of source control, collection, and containment practices are mass balance–based and consist of percent reduction in deicer application, percent capture of applied deicers, or percent discharge of applied deicers. (A practical metric of practice performance is compliance with regulatory requirements, but because requirements are very site-specific and not necessarily tied to a single practice, this metric is not suitable in this generalized discussion.) Computationally, these can be described as follows:

$$\begin{array}{c}\text{Percent reduction in}\\ \text{deicer application}\end{array} = \frac{\begin{array}{c}\text{Deicer usage with}\\ \text{source reduction BMP}\end{array}}{\begin{array}{c}\text{Deicer usage without}\\ \text{source reduction BMP}\end{array}} \times 100$$

$$\begin{array}{c}\text{Percent capture of}\\ \text{applied deicer}\end{array} = \frac{\begin{array}{c}\text{Deicer in collected}\\ \text{runoff}\end{array}}{\text{Deicer usage}} \times 100$$

$$\begin{array}{c}\text{Percent discharge}\\ \text{of applied deicer}\end{array} = \frac{\begin{array}{c}\text{Deicer in stormwater}\\ \text{discharges}\end{array}}{\begin{array}{c}\text{Deicer usage in}\\ \text{stormwater drainage areas}\end{array}} \times 100$$

The accuracy of performance characterizations is limited by a variety of factors, including the inherent variability in the conditions surrounding the deicing process. In many cases, available data is representative of an airport's deicing stormwater management system as a whole, rather than of a single component of the system. It is especially challenging to assess performance of source control practices, which often requires comparing how much deicer was actually used with the new practice against estimates of how much would have been used if past practices had still been in place.

Available performance data on individual deicing practices are generally very limited, and for most of the practices in Table 3.2, the information is based on data from just a few airports. In some cases, the data represent practice operations at multiple facilities over multiple seasons, while in other instances performance is based on a limited number of tests or a narrow range of deicing, weather, or operational conditions. The table provides minimum and maximum reported performance purely as the limits of reported data. There is no statistical basis for the source data, and under no circumstances should this information be interpreted as what could confidently be achieved at another airport. Instead, the information is intended to reflect the general magnitude of performance that has been reported at airports where performance data have been collected and provided. Any comparisons should be made with this understanding.

The performance of treatment, recycling, and disposal practices is expressed in inherently different metrics than source control, collection, and containment practices, as reflected in Table 3.3. Performance of these technologies is expressed in terms of operational characteristics, such as influent and effluent concentration ranges, which reflect both applicability and pollutant removal; waste generation; and resilience to influent shock loading.

Table 3-2. Summary of reported mass balance performance metrics for source control and containment/collection practices.

Fact Sheet #	Performance[a]	Comments
Source Controls	**% Load Reduction**	
Aircraft Deicing		
Product selection[b] (#1)	~15	Based on product literature on the BOD_5 of Type I ADFs currently used in the U.S.
Storage and handling (#2)	—	No data
Proactive anti-icing (#3)	—	No data
Blending to temperature (#4)	18–50	Very dependent on local climate
Forced air/hybrid deicing (#5)	45–90	High end only attainable under ideal conditions
Infrared deicing technology (#6)	70–90	Based on manufacturer's data of individual aircraft deicings
Physical removal (#7)	—	No data
Hangared parking (#8)	≤90	Based on estimated Type IV requirements
Hot water deicing (#9)	≤90	Based on estimated Type IV requirements
Enclosed deicing buckets (#10)	—	No data
Enhanced weather forecasting (#11)	—	No data
Holdover time determination systems (#12)	80 (Type IV only)	Applies only to Type IV use; based on limited testing in Montreal
Deicer use tracking (#13)	80 (Type IV only)	Based on limited testing in Montreal
Reduced operations (#14)	—	No data
Airfield Pavement Deicing		
Product selection[b] (#16)	60–84 (fluids) 60–90 (solids)	Based on product literature on COD expressed as g O_2/g product. Consideration of possibly reduced application rates is not included.
Storage and handling (#17)	—	No data
PDM application technology (#18)	≤20	Based on reports from Munich Airport
Heated pavement (#19)	—	No data
Physical removal (#20)	—	No data
Containment/Collection	**% Capture**	
Centralized deicing facilities (#21)	44–86	High end attainable only under ideal conditions
Apron collection systems (#22)	10–65	Very dependent on local climate and apron drainage infrastructure
Glycol collection vehicles (#23)	23–48	Very dependent on local climate
Block-and-pump systems (#24)	20–35	Very dependent on local climate and apron drainage infrastructure
Airfield drainage planning/ design/retrofit (#25)	—	No data
Deicer-laden snow management (#26)	0–11	Based on USGS report from one airport (Corsi et al., 2006). Very dependent on local conditions and operations.

[a] Values shown represent extremes of reported or estimated performance from available information from a limited number of airports. No assumption should be made regarding the distribution of performance metrics between these extremes.

[b] Benchmarked against available products with the highest BOD content: propylene glycol-based Type I ADF and urea-based pavement deicer.

Table 3-3. Summary of performance metrics for treatment/disposal/recycling practices

Fact Sheet #	Influent Concentrations (BOD_5 mg/L)	Effluent Concentrations (BOD_5 mg/L)	Treatment Temperature Range	Resilience to Shock Loading	Waste Residuals Generation	Comments
POTW Discharge						
Aerobic (#34)	100–10,000	5–30	0–40°C to sewer (32–105°F)	L–M	Biosolids	Treatment by others
Anaerobic (#34)	1,000–30,000	50–500	0–40°C to sewer (32–105°F)	M–H	Biosolids (low)	Treatment by others
Onsite Treatment						
Anaerobic fluidized bed reactor (#35)	1,000–30,000	50–500	26–38°C (80–100°F)	M–H	Biosolids (low)	Small area
Reciprocating subsurface treatment (#36)	100–1,000	30–60	7–35°C (45–95°F)	M	Biosolids (intermittent)	Large area required
Moving bed bioreactor (#37)	100–2,000	10–50	7–35°C (45–95°F)	M	Biosolids	Media retains biomass
Sequencing batch reactor (#38)	200–2,000	10–50	10–35°C (50–95°F)	M	Biosolids	Supports intermittent flows
Natural treatment systems (#39)	100–1,000	30–60	7–35°C (45–95°F)	L–M	Biosolids (intermittent)	Large area required
Membrane filtration (#40)	100–30,000	10–100 Concentrate 7–15%	4–29°C (40–85°F)	M–H	Pretreatment wastes, i.e., solids, hydrocarbons	Potential modular design and recycling
Glycol recovery (#41)	3–10% glycol	Effluent <100 ppm Concentrate 50–99%	4–29°C (40–85°F)	M–H	Pretreatment wastes, i.e., solids, hydrocarbons	Concentrate value varies by location

L=low; M=medium; and H=high.

Guidance on Use and Interpretation of the Fact Sheets

Use and Limitations of the Fact Sheets

Deicing Fact Sheets described in Chapter 4 describe the essential characteristics of the spectrum of available "tools" in the deicing runoff management toolbox and facilitate initial consideration and screening. The information included within these Fact Sheets was compiled from a variety of sources, including published literature and research, unpublished "grey-literature," surveys from a cross-section of airports and vendors, and the research team's collective experience in developing and implementing deicing runoff management systems.

The Fact Sheets should be used with a clear understanding of the following:

- Aircraft Safety. The purpose of deicing is to ensure safe aircraft operations. Safety is paramount and will always take precedence over other considerations in practice selection, implementation, and operation. This guidance document and the Fact Sheets are presented from an environmental compliance perspective, with the explicit assumption that the predominant priority is understood to be safety, and that this topic is thoroughly described in various facility and operator-specific policy and procedures documents.
- Deicing personnel must make deicing decisions and implement deicing procedures that are conservative with respect to aircraft safety and that sometimes require overriding deicing practices. The reader is encouraged to recognize and weigh the benefits of particular practices with respect to aircraft safety risks, and to understand that conservative deicing procedures required to ensure safety have the potential to reduce the performance levels of certain practices. As such, it may be advisable to incorporate a margin of safety in planning analyses to allow for the likelihood of less-than-optimal performance.
- Site-Specific Challenges. Site-specific conditions tend to define the applicability, implementation, performance, and cost of deicing practices. The significant variation in approaches taken among successful airport deicing runoff management programs illustrates the challenge in providing generally applicable guidelines for airports. For this reason, the Fact Sheets should be viewed as a supplement to, rather than a substitute for, detailed site-specific analysis of deicing runoff management needs and solutions.

  The reader is cautioned that an attempt to develop a deicing runoff control system based solely on the information in the Fact Sheets and without a detailed analysis of site-specific conditions by an analyst with aviation experience in this specialized technical area will almost certainly lead to significant errors.
- Emerging Technologies. The available information for practices still in the development or field-testing phases and are not commercially available is necessarily limited. Fact Sheets for practices under development have been included to provide information on emerging technologies and the direction that innovation is taking within the deicer management field.

Interpretation of the Fact Sheets

An outline of the general Fact Sheet format is provided below, with a description of the information provided in the Fact Sheet and guidance for interpretation of that information.

1. Description. The first section of the Fact Sheet introduces the practice and provides general information about what the technology or practice is and how it works. The information is presented in the following subsections.

   Purpose. Describes the function of the practice with respect to deicing stormwater management, including source control, collection, containment, storage, or treatment.

   Technology. Provides details on the principles and technologies surrounding the practice, including concepts and mechanisms, and design or implementation options.

   Documented performance. Presents reported performance data, if available, or describes means for assessing the performance of the practice at an individual airport. Where relevant, examples of known installations at airports are provided. The reader is encouraged to review the performance data in context with the following qualifying information:
   - Performance data from manufacturers may be based on ideal conditions and may represent an upper estimate of the practice's performance capability.
   - Performance data from individual airports may reflect highly site-specific conditions.
   - Performance data from field tests may represent a limited range of deicing and operational conditions. Field test data may not reflect performance of the practice at an operational level.
   - Performance of practices is not additive; the aggregate performance of a system of practices will not be the sum of the expected performance of the individual elements.
2. Implementation Considerations. This section of the Fact Sheet provides guidance to help airports assess whether a practice may be appropriate for its deicer management system and presents challenges and keys to success associated with implementing the practice. This section may not encompass all of the site-specific challenges and considerations that can impact selection of a practice, but it does discuss general considerations for screening purposes. The

implementation considerations are presented in the following subsections.

Applicability assessment. Presents information to help assess whether a practice is potentially appropriate for a particular site or deicer management system

Regulatory considerations. It should be explicitly recognized that all of the practices described are intended to support reductions in discharges of deicing-related pollutants to achieve compliance with facility-specific CWA requirements. This heading addresses other regulatory requirements or implications associated with the practice.

Planning and design considerations. Presents specific guidelines, suggestions, and requirements for the successful design and implementation of the practice. This subsection is intended to provide key considerations and is not representative of the complete design process.

Integration with other practices. Provides examples of how the practice may be coordinated and used together with other practices as part of an overall deicing stormwater management system.

Operation and maintenance considerations. Presents general maintenance issues and operational requirements associated with use of the practice.

3. Costs. This section of the Fact Sheet discusses primary cost elements associated with each practice, including capital cost items and operations and maintenance cost items. This section is intended not to be all-inclusive but to give airports an idea about the primary cost elements that could be expected if the practice were to be implemented. In most instances, relative cost descriptions have been provided. Where specific costs of equipment and other well-defined elements are available, representative ranges have been provided to give the reader as sense of the magnitude of costs. *These cost numbers should not be used for planning purposes without verifying current local costs.* The following issues should be recognized in interpreting the cost information in the Fact Sheets:
   - Costs are highly variable, even for similar practices and systems, depending on site-specific conditions, including nature and scale of flight and airfield operations, region, climate, existing stormwater collection system characteristics, opportunities for integration with other practices, treatment goals and effluent limits, and other compliance requirements.
   - Much of the available industry cost data is based on a limited number of individual airport reports or manufacturers' data, which may not be representative of conditions and costs incurred with the implementation of the same practice at another airport. Reported costs for practices are frequently combined with costs for packages of practices, or with overall costs of capital improvement projects (for example, ramp rehabilitation).
   - Specific cost data were available only for some practices or elements of practices, precluding a meaningful quantitative comparison among all potential practices.
   - The relative cost data indicated reflects the installation or incorporation of a particular practice under typical airport conditions. Airports may incur significantly higher or lower costs or efficiencies based on site-specific conditions.

CHAPTER 4

Deicing Fact Sheets

This section describes the accompanying compendium of Fact Sheets prepared for each of the identified deicing practices. They are organized into the five categories mentioned in “Deicing Practice Categories,” Chapter 3: aircraft deicing source reduction; airfield pavement deicing source reduction; deicing runoff containment/collection; deicing runoff treatment/recycling; and deicing runoff system components.

Special note on costs: Where available, specific costs of equipment and other well-defined elements are provided in the Fact Sheets to give the reader a sense of the magnitude of costs. These estimated cost numbers should not be used for planning purposes without verifying current local costs.

Aircraft Deicing Source Reduction

The purpose of these practices is to reduce the amount of pollutants generated by aircraft deicing activities, either by using products with reduced environmental impacts or by reducing the amounts of deicing products required to achieve and maintain safe flight operations. It should be noted that U.S. aircraft operators must obtain FAA Flight Standards approval for certain proposed source reduction Fact Sheets prior to selection and implementation

Fact Sheet 1. Aircraft-Deicing Product Selection
Fact Sheet 2. Storage and Handling of Aircraft-Deicing Materials
Fact Sheet 3. Proactive Anti-Icing
Fact Sheet 4. Blending to Temperature
Fact Sheet 5. Forced Air/Hybrid Deicing
Fact Sheet 6. Infrared Deicing Technology
Fact Sheet 7. Physical Removal
Fact Sheet 8. Hangared Parking
Fact Sheet 9. Hot Water Deicing
Fact Sheet 10. Enclosed Deicing Bucket
Fact Sheet 11. Enhanced Weather Forecasting
Fact Sheet 12. Holdover Time Determination Systems
Fact Sheet 13. Aircraft Deicer Use Tracking
Fact Sheet 14. Aircraft Reduced Operations
Fact Sheet 15. Tempered Steam Technology

Airfield Pavement Deicing Source Reduction

The purpose of these Fact Sheets is to reduce the amount of pollutants generated by airfield pavement–deicing activities, either by use of products with reduced environmental impacts or by reduction in the amounts of deicing products required to achieve and maintain safe flight operations.

Fact Sheet 16. Airfield Pavement-Deicing Product Selection
Fact Sheet 17. Storing and Handling of Airfield Deicing/Anti-Icing Agents
Fact Sheet 18. PDM Application Technology
Fact Sheet 19. Heated Pavement
Fact Sheet 20. Airfield Deicers—Physical Removal

Deicing Runoff Containment/Collection

The role of these Fact Sheets is to provide methods for isolating, collecting, and containing storm water runoff from deicing activities. In most instances, these practices are implemented to address aircraft deicing runoff.

Fact Sheet 21. Centralized Deicing Facilities
Fact Sheet 22. Apron Collection Systems
Fact Sheet 23. Glycol Collection Vehicles
Fact Sheet 24. Block-and-Pump Systems
Fact Sheet 25. Airfield Drainage Planning/Design/Retrofit
Fact Sheet 26. Deicer-Laden Snow Management

Deicing Runoff System Components

These technologies represent components of systems that may be implemented in various locations, and serving different purposes, in any given system.

Fact Sheet 27. Portable Tanks
Fact Sheet 28. Modular Tanks
Fact Sheet 29. Ponds
Fact Sheet 30. Permanent Tanks
Fact Sheet 31. Manual and Automated Diversion Valves
Fact Sheet 32. Real-Time Monitoring Technology
Fact Sheet 33. Catch Basin Inserts/Valves

Deicing Runoff Treatment/Recycling

These practices provide alternatives for disposing of deicing runoff that has been collected and contained, and is not suitable for controlled discharge to receiving waters.

Fact Sheet 34. POTW Discharge
Fact Sheet 35. Anaerobic Fluidized Bed Reactor
Fact Sheet 36. Reciprocating Subsurface Treatment
Fact Sheet 37. Moving Bed Bioreactor Treatment System
Fact Sheet 38. Sequencing Batch Reactor
Fact Sheet 39. Natural Treatment Systems
Fact Sheet 40. Membrane Filtration
Fact Sheet 41. Glycol Recovery

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Acronyms and Abbreviations

AAF	aircraft anti-icing fluid
AC	advisory circular
ACRP	Airport Cooperative Research Program
ADF	aircraft deicing fluid
AMS	Aerospace Materials Specifications
BASH	bird airstrike hazard
BMP	best management practice
BOD	biochemical oxygen demand
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
COD	chemical oxygen demand
CWA	Clean Water Act
EG	ethylene glycol
ELG	effluent limitation guideline
EMC	event mean concentration
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FBO	fixed base operator
FBR	fluidized bed reactor
FPD	freezing-point depressant
GRV	glycol recovery vehicle
HOT	holdover time
MBBR	moving bed biofilm reactor
MS4	municipal separate storm sewer systems
MSDS	material safety data sheet
MSGP	Multi-Sector General Permit
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NOI	notice of intent
NPDES	National Pollutant Discharge Elimination System
NRC	National Response Center
O&M	operations and maintenance
PDM	pavement deicing material
PG	propylene glycol
POTW	publicly owned treatment works

RQ	reportable quantity
SAE	Society of Automotive Engineers
SBR	sequencing batch reactor
SCADA	supervisory control and data acquisition
SDWA	Safe Drinking Water Act
SERDP	Strategic Environmental Research and Development Program
SIC	Standard Industrial Classification
SPCC	spill prevention control and countermeasure
SWPPP	Stormwater Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TOC	total organic carbon
TSS	total suspended solids
TST	tempered steam technology
WLA	waste load allocation

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation