Winter Design Storm Factor Determination for Airports

DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 81

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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.

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The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

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FOREWORD

By Marci A. Greenberger
Staff Officer
Transportation Research Board

ACRP Report 81: Winter Design Storm Factor Determination for Airports identifies the relevant factors in defining a winter design storm for use in sizing deicing runoff management systems and components and provides a decision support tool for identifying an appropriate winter design storm for the airport-specific project and the available data. Case studies illustrate how the support tool can be used with real-world examples of projects with different drivers and objectives for managing deicing runoff. While historical weather, facility, and operations data can be helpful in a rigorous analysis to define the winter design storm, it is more likely that partial data are all that will be available, and the case studies demonstrate how limited or partial data can be effectively used in moving forward. The guidebook includes a review of regulations as they pertain to deicing runoff and a discussion of target levels of service. *Target level of service* refers to the acceptable level of risk of the designed system not meeting performance standards. This guidebook will assist airport planners and engineers in developing an appropriate winter design storm event for their specific requirements. The guidebook will also assist airport operators in communicating their rationale for sizing their systems to environmental regulatory agencies that may have no experience with deicing systems.

Winter storms can be highly disruptive at airports and present significant operational challenges for airports and airlines that must ensure compliance with both safety and environmental standards. The development of a storm water management system to handle airport/aircraft deicing runoff is a balancing act between the demands of ensuring safety, operations, environmental compliance, and fiscal responsibility. If a system is designed to meet the worst-case deicing event, it will likely result in a high cost for the management of such rare events; conversely, if the system is designed so that it will allow frequent overflows, it raises concerns about the airport's ability to meet environmental standards.

There are a number of factors that are used in determining the winter design storm, and how these factors interrelate in the development of a deicing runoff management system is very complex. CH2M HILL, through ACRP Project 02-19, conducted research to identify these factors and prepare a guidebook and a decision support tool to help airport operators understand winter storm design factors and how they should be considered in determining a winter design storm for the purpose of sizing deicing runoff collection, conveyance, storage, and treatment system components. The decision support tool was developed to provide a structured process for defining the project, considering the relevant factors and data requirements, and applying the appropriate analytical approach to define the winter design storm.

The guidebook includes five case studies that demonstrate the application of the guidance and the decision support tool. These case studies illustrate that regardless of an airport's deicing management system objective(s), the airport can successfully utilize the decision support tool to help it understand the relevant factors and their interrelationships and define a defensible winter design event consistent with those objectives.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

Abbreviations and Acronyms

AAF	anti-icing fluid
AC	Advisory Circular
ACAA	Allegheny County Airport Authority
ACI-NA	Airports Council International, North America
ACRP	Airport Cooperative Research Program
ADF	aircraft deicing fluid
BMP	best management practice
BOD	biochemical oxygen demand
BOD5	5-day biochemical oxygen demand
BTU	biological treatment unit
BWI/Marshall	Baltimore/Washington International Thurgood Marshall Airport
CBOD5	5-day carbonaceous biochemical oxygen demand
CBWWTP	City of Portland's Columbia Boulevard Wastewater Treatment Plant
CMH	Port Columbus International Airport
COD	chemical oxygen demand
CRAA	Columbus Regional Airport Authority
CWA	Clean Water Act
DAC	deicing/anti-icing chemicals
DCA	Ronald Reagan Washington National Airport
DEQ	Oregon Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
GRV	glycol recovery vehicles
IAD	Washington Dulles International Airport
IDF	intensity-duration-frequency
LID	low-impact development
MAA	Maryland Aviation Administration
MBBR	moving-bed biological reactor
MWAA	Metropolitan Washington Airports Authority
NCDC	National Climate Data Center
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OD	oxygen demand
OTR	oxygen transfer rate
PaDEP	Pennsylvania Department of Environmental Protection
PDX	Portland International Airport
PIT	Pittsburgh International Airport
POTW	publicly owned treatment works

ppm	parts per million
SPDES	State Pollutant Discharge Elimination System
SWMM	Storm Water Management Model
TP	total phosphorus

SECTION 1

Introduction

This guidebook was prepared to provide standardized guidance for airports and their consultants to use in defining appropriate design storm event conditions for sizing deicing runoff control systems and associated components. This guidance is intended both to facilitate efficiency in the design process and help airports communicate the rationale for sizing their systems to funding authorities, regulatory agencies, and other interested stakeholders.

1.1 Background

Designers of systems managing airport deicing runoff must size system components to ensure adequate collection, conveyance, storage, and treatment capacity during peak winter events. Undersizing collection and drainage components can result in unacceptably frequent flooding, overflows, or bypasses of storage and treatment units, and exceedances of National Pollutant Discharge Elimination System (NPDES) permit limitations. Oversizing these components may avoid or at least reduce the occurrence of these conditions but at unnecessary cost.

The challenge of appropriate sizing is addressed by describing a set of meteorological, operational, environmental, and other conditions that define the upper bounds of what the system is designed to contain. In this research, the term *design storm event* is used to characterize this set of conditions. Design storm event characteristics can take the form of meteorological (snowfall, freezing precipitation, temperature), operational (total deicer usage), environmental (receiving-water quality, flow, or temperature), or performance (storage capacity) factors. Although these conditions are centered on winter storms, the design conditions often encompass periods when runoff processes continue beyond the time of the actual winter storm.

There are several aspects to describing the design storm event:

1. **Selecting the right factors to characterize the event.** Each airport project will present a unique set of circumstances and demands that require a specific set of factors to describe critical conditions. Design storm event factors relate to both winter storm conditions and how those conditions drive deicing operations, the generation of runoff from those operations, and the environmental responses to that runoff.
2. **Defining the acceptable frequency of occurrence of critical values for those factors.** The second consideration is specifying how often event conditions may be exceeded. The issue often becomes defining what is acceptable to the regulatory agency or agencies whose requirements and criteria are involved. There is no standard definition of this, and acceptability may hinge on many factors and divergent considerations, some of which may change over time. The answer ultimately depends on negotiations involving regulatory policy and considerations of cost versus capacity and incremental benefit. As discussed in Appendix A, this highlights the need for including regulatory factors in the definition of a design storm event.
3. **Estimating the expected frequency of design event conditions in the context of evaluating design alternatives.** Determining the expected frequency for which design conditions will be exceeded for a given design alternative involves the calculation of a recurrence interval. For deicing projects, this presents a complex problem because it requires consideration of storm events of varying duration and the weather conditions that precede and follow the storm and determine the volume and rate runoff. Thus, a statistical approach is needed that describes the probability of critical sequences of events (for example, warm rain following heavy snowfall) extending over variable periods of time.

In the absence of standardized guidance, airports have addressed the deicing design event issue in various ways—some of them successfully, others less so. This guidebook was prepared to provide standardized guidance for the selection of deicing design storm events or conditions for deicing runoff management systems.

1.2 Overview of a Winter Storm

The term *winter design storm* refers to a specific meteorological condition for which winter facilities (for example, deicing facilities) are designed. The concept of a design storm is used extensively in the design of storm water facilities. A winter design storm captures the unique seasonal factors affecting facility performance and objectives. Winter design storms necessarily address the fact that precipitation may fall as either a liquid or a solid (snow), and that snow may accumulate and run off later. Airport deicing facility designs, which are concentrated on aprons and deicing pads, must handle winter flows primarily in liquid form since the deicing rapidly converts snow and ice to liquid. Airport runway designs, on the other hand, necessarily address the accumulated snow, whose runoff characteristics are further complicated by the spatially varied accumulations in plowed snow piles. This current study focuses on design storms in the liquid phase since the primary interest is design storms for deicing runoff controls.

Conventional storm water facilities are commonly designed for two purposes: first, to rapidly convey storm water runoff away from busy areas, and second, to trap excess sediment and attached pollutants. Consequently, design storms for storm water controls focus on (1) meteorological factors contributing to peak flow rates that govern conveyance sizing and (2) first-flush storm volumes, which typically contain most of the sediment load. The characteristics of the storm water design storm (frequency, depth, and duration) are often specified by locally applicable drainage regulations in order to reduce the risk of flooding.

Winter design storms are similarly used to size peak-flow-related conveyance facilities but also to size whole systems that include treatment facilities and equalization storage facilities. Sizing of the latter involves determining optimum storage requirements to reduce peak flows to the cost-effective treatment rate. Winter storm water facilities also differ from conventional storm water controls in that the peak flow rates are a complex function of precipitation intensity and form (snow or liquid), and the treatment must deal with dissolved pollutants (principally deicers).

Storm water design storms are most commonly specified in terms of rainfall event volume falling in a given amount of time (for example, 1 in. of rainfall in a 24-hour period). That volume-duration pair can be associated with a recurrence probability using available depth-duration-frequency evaluations, such as those available in *Atlas 14: Precipitation-Frequency Atlas of the United States* (NOAA, 2004–2011). Designers often assign a distribution (the fraction of the storm volume that falls at each increment of the storm duration) to better define the temporal runoff pattern that must be handled in the conveyance, storage, or treatment facilities.

These common intensity-duration-frequency (IDF) evaluations and distribution functions are proven and appropriate for sizing deicing system components that are dependent on peak flow rates (for example, pipes and treatment) but inappropriate for sizing equalization storage where runoff from multiple storms may need to be stored prior to being treated. The U.S. Environmental Protection Agency (EPA) combined sewer overflow control policy (EPA, 1994) advises designers to address the conveyance/storage/treatment balance using continuous simulation of long-term precipitation time series rather than attempting to characterize the probability of inter-event dewatering periods. Several airports (Dayton International, Washington Dulles, O'Hare, Detroit Metropolitan, Portland International) have applied continuous simulation of the long-term wintertime precipitation time series and found doing so to be the most effective means of evaluating precipitation, runoff, storage, treatment, and discharge interactions. Thus, different approaches are needed to meet the requirements of the two different design situations: deicing system components where the timing and magnitude of flows correspond closely with precipitation, and system components (or even whole systems) where the timing and magnitude of flows occur as functions of sequences of individual winter storms and associated weather phenomena (for example, melt-off events).

1.3 Purpose and Objectives

This guidebook provides standardized guidance for airports and their consultants to use in understanding the technical and regulatory issues in defining design conditions and developing an appropriate design storm event for their specific requirements. This guidance is intended to both facilitate effectiveness and efficiency in the design process and help individual airports communicate the rationale for sizing their systems to stakeholders and environmental regulatory agencies that may have limited experience with deicing systems.

1.4 Structure of the Guidebook

The guidebook is structured as a series of four sections plus supporting information. Section 1 introduces the topic and objectives of the guidebook. Section 2 provides important background information required to understand the regulatory context of defining a winter design event, the various factors that should be considered in defining a design storm, and the concept of a multiday event. After this background, Section 3 describes a decision support tool that embodies a structured process for identifying an appropriate winter design storm. Section 4 presents five case studies that illustrate how the decision tool captures design decisions that airports have faced in different deicing management program situations. Supporting information is provided in the form of the references and Appendix A.

SECTION 2

Strategies for Selecting and Applying Winter Design Storm Factors

This section presents background information on key technical and regulatory aspects of characterizing design events.

2.1 The Importance of Risk and Controlling Drivers

The need to document the rationale in defining a winter design storm is driven by regulatory compliance requirements (see Appendix A). Regulatory agencies will assume that the deicing runoff management system is sized and operated to meet permit and other requirements under all conditions up to the severity of the design event. The frequency of the design event will generally correspond to the expected frequency of not achieving permit requirements such as effluent limitations, capture percentages, and treatment efficiencies. Often, the first response when encountering permit exceedance or noncompliance is to compare the conditions under which the exceedance occurred with the winter design event conditions. This is especially the case where permit upset and bypass conditions (discussed in Appendix A, Section A.3) specifically reference winter design event characteristics.

As a result, an intrinsic component in defining the design event is the expected frequency of meteorological and hydrological conditions that exceed it. Regulatory agencies implicitly or explicitly accept some frequency of exceedance of system capacity (and, by extension, permit compliance), and this frequency is critically important in defining the probability of a suitable design event. This concept is elaborated upon further in Section 3 in terms of level of service.

At some point in the process of determining the appropriate design storm event for constructing or implementing deicing controls, scientifically derived calculations must be compared with all of the regulatory standards that apply to the specific project to ensure compliance at an acceptable level of risk. Different drivers will apply in different cases. For example, if the Federal Aviation Administration (FAA) suggests that the 5-year, 24-hour precipitation event is appropriate for sizing storm water drainage conveyance, but the applicable Clean Water Act (CWA) permitting convention is to not exceed numerical limits more often than once every 10 years, then necessary adjustments must be made to the overall design to ensure CWA permit compliance. (Permit writer's guidance, often state-specific, commonly requires calculating allowable discharge concentrations that will not cause or contribute to a violation of receiving-water quality standards criteria during 7-consecutive-day low-flow conditions with a probability of occurring less than once in 10 years.) The opposite also could be true, in that the design event defined by drainage criteria may well exceed the regulatory minimums based on pollutant controls. Hence, an understanding of all applicable regulatory drivers must be factored into the overall design storm event analysis.

2.2 Overview of Factors Used to Characterize a Storm

Hydrologists and engineers commonly use seven distinct factors to define isolated storms: precipitation volume, precipitation intensity, precipitation temporal distribution, precipitation duration, temperature, probability, and inter-event period.

2.2.1 Precipitation Volume

Precipitation volume refers to the total amount of precipitation that falls during a storm event. Some of the precipitation volume may fall as snow or sleet. Snow or sleet is recorded as precipitation but will not result in the same amount of runoff as the equivalent amount of rain. A minimum precipitation volume is often specified, such as 0.1 in., for an event to be officially recorded as a storm event.

From an infrastructure design perspective, the volume of the winter design storm will have a direct impact on the size of the infrastructure needed to treat or store the runoff. This factor will also affect sizing of conveyance, but the conveyance sizing will be equally sensitive to the intensity (Section 2.2.2) and assumptions regarding temporal distribution (Section 2.2.3) of the precipitation.

2.2.2 Precipitation Intensity

Precipitation intensity refers to the volume of precipitation over time. A larger storm volume over a shorter period will be a more intense storm and have higher precipitation intensities. Alternatively, that same storm volume spread out over a much longer period will be a much less intense storm and will have lower precipitation intensities.

Peak intensities are usually critical factors in determining the conveyance system size, while volume is the more critical factor for end-of-pipe treatment or storage device design. The goal of conveyance systems is to carry runoff away from other critical infrastructure (such as a tarmac) to a device for treatment, storage, or release into waters of the United States. If a conveyance system is designed for a low-intensity storm event, then the chances are much higher of the runoff surcharging out of the piping and becoming a flooding problem.

2.2.3 Precipitation Temporal Distribution

Precipitation temporal distribution describes the resulting shape or variation of intensity of a storm throughout the whole event. If the precipitation falls evenly throughout the storm, the resultant runoff will be different from if it rains gently for the first period and then is followed by a cloudburst. Several different distributions, such as the SCS Type II, developed by the Soil Conservation District (now Natural Resources Conservation Services) in the 1960s, are commonly used in sewer design.

Understanding the typical temporal distribution of the region surrounding the airport will result in a design storm more representative of the locality and, therefore, in more efficient sizing of storm water facilities. *Atlas 14* (NOAA, 2004–2011) presents temporal distributions characteristic of most localities in the United States.

2.2.4 Precipitation Duration

Precipitation duration is the time elapsed between the first recorded precipitation and the last recorded precipitation in the storm event above a given threshold (for example, 0.1 in., as mentioned previously).

Recognize that volume, intensity, distribution, and duration are interrelated. A given volume in a given duration has a readily calculated average intensity (volume divided by duration). Different distributions can be applied within the parameters of the specified volume and duration, resulting in a variety of peak intensities.

2.2.5 Temperature

Temperature affects the volume and state (liquid or frozen) of what falls to the ground but not necessarily the overall precipitation volume (for example, 1 in. of rain may equal 10 in. of snow, but both equal 1 in. of equivalent precipitation).

Temperature becomes an important consideration in the design and operation of storm water facilities. For example, if the storm event is freezing rain or snow and then there is a warm-up and melt off, all these different aspects of the storm event need to be understood when considering the size of the system and the conveyance of the runoff.

2.2.6 Probability

The frequency or probability of a storm is defined by statistical calculation of the probability of a given volume of precipitation falling within a given duration. For the probability calculations to be meaningful, they must be calculated from a long series of reliable rainfall records representative of the location of interest. The statistical calculations will yield a table, or curve, defining the probability of a given rainfall intensity (inches per hour) occurring in a specific duration (hours). For a selected probability, the combination of precipitation depth and duration requires some distribution in time.

A 1% storm is a storm that has a 1% probability of being exceeded in severity in any one year and is expected to be exceeded an average of once every 100 years. A 10% storm is a storm that will be exceeded in severity an average of once every 10 years, or alternately, has a 10% chance of being exceeded in any one year. A 50% storm is a storm that will be exceeded in severity an average of once every 2 years, or alternately, has a 50% chance of being exceeded in any one year.

Choosing more frequent storms, such as a 50% storm, will result in smaller sizing of projects in design and a greater potential for those designs to flood if a larger storm does occur. Designing projects with a less frequent storm will result in larger projects (larger pipes, storage basins, etc.).

2.2.7 Inter-Event Period

Inter-event period distinguishes one storm from another and is defined as the period between individual storm events. Appropriate inter-event periods vary with geographic (or more specifically, hydrometeorological) regions and can be typically between 3 and 24 hours.

Understanding the inter-event period of the geography in question will aid in understanding the storage or conveyance time and size of the storm water facilities in question. For instance, short inter-event periods may mean that a facility needs to be sized large enough for several storms, since the inter-event period is short and the runoff cannot be conveyed away or treated that quickly before the next storm comes.

2.3 Multi-Storm Analyses

Individual storms are anomalies in a continuous time series of variable, interrelated meteorological features. Storm water studies, and consequently storm water control engineering, simplify the variability into definitions more manageable for discrete storm events. For several purposes—particularly for facilities that must operate continuously both during and between storms or for which storage must work within the boundaries of fixed conveyance or treatment outlets—engineers elect to investigate the entire time series of interrelated meteorological factors. The continuous analysis avoids a number of assumptions inherent in the definition of design storms (inter-event periods, storm event independence, joint probabilities of precipitation and temperature extremes, etc.). The analysis of continuous time series of numerous related meteorological factors can be extremely data intensive and hence is avoided except in those cases where the extra effort is necessary to refine conservative assumptions in the definition of design storms.

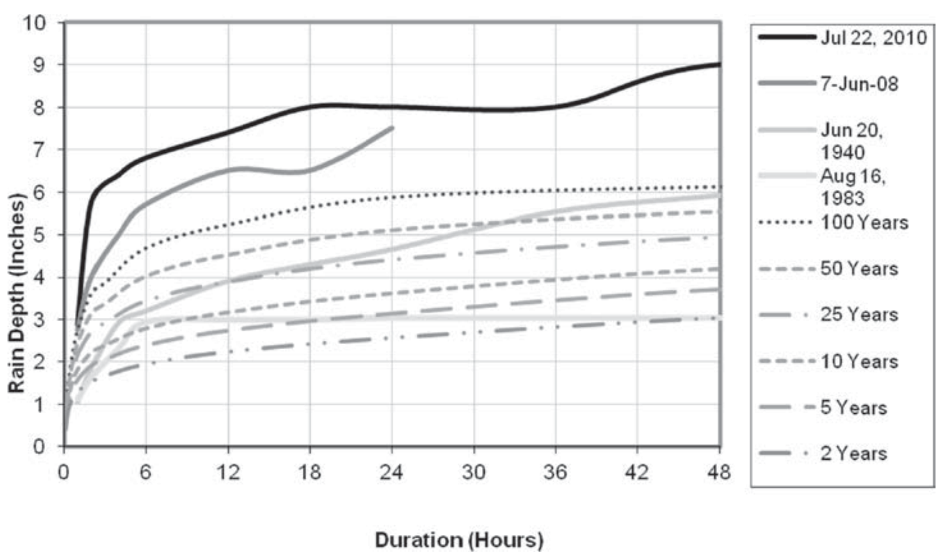
Figure 2-1 illustrates the difficulty inherent in evaluating individual events within the continuum of multiple precipitation events. The dashed lines in the figure show the duration (*x*-axis) of rainfall depth (*y*-axis) with the statistically projected recurrence interval (legend). The solid gray lines indicate the peak rainfall depths for the durations observed during the specific storms shown in the legend. Note that these storm curves are calculated by identifying the peak 1-hour period, the peak 2-hour period, and so forth, in the storm time series observed. The complexity increases exponentially with the number of variables (for example, temperature, dew point) considered.

In those cases where assumptions surrounding the design storm may result in extremely large or complex facilities, the designer may choose to refine the facility design criteria through the use of continuous simulation using multiple-year time series of several interrelated meteorological time series parameters. The use of such continuous simulation approaches is beyond the scope of this guidance document but is recommended for further investigation in those particular situations where continuous simulation may be required to refine the performance expectations of particular airport deicing facilities.

2.4 Applicability of Factors to Different Types of Deicing Projects

The users of this guidance document will discover early in their project that many of the winter design storm factors described in Section 2.2 will have some impact on their deicing project, whether their project requires implementing a simple block-and-pump collection system for a small regional airport or designing a centralized deicing facility at a major air carrier facility. What is also apparent is that different winter design storm factors are more or less applicable to different types of deicing projects.

Table 2-1 provides guidance regarding the factors to consider for different deicing project components. The list of types of deicing projects is based upon *ACRP Report 14: Deicing Planning Guidelines and Practices for Stormwater Management Systems* (CH2M HILL et al., 2009). The table provides the reader with an indication of the likely applicability of each



From SEWRPC (2000) with storm data from maximum gage reported to Milwaukee Metropolitan Sewerage District.

Figure 2-1. Depth-duration-frequency curves isolating design storms (gray) from continuous statistics (dashed).

Table 2-1. Matrix to determine applicability of design storm factors of various design project types.

DEICING PROJECT TYPE	Design Storm Factors: Regulatory/Environmental Factors	NPDES/SPDES Permit/Environmental	Operational Factors	Peak Departure Rates	Airfield Utilization/Flow Rate	Physical Factors	Storage Volume Restriction	Deicing Runoff Collection System Restriction	Land Constraints	Climatological Factors	Geographic Region	Hydrologic Factors	Precipitation Volume	Precipitation Intensity	Precipitation Temporal Distribution	Precipitation Duration	Temperature	Probability	Inter-Event Period	Precipitation Type
Aircraft Deicing Source Reduction																				
Infrared deicing technology		○		●	●		●	●	●		○		○	●	—	—	—	○	○	●
Deicing Runoff Containment/Collection Facilities																				
Apron collection system		●		—	—		●	●	—		●		●	●	●	●	—	●	●	○
Glycol collection vehicles		●		●	●		○	○	—		●		○	○	○	○	○	○	○	○
Block-and-pump system		●		—	—		●	●	—		●		●	●	●	●	○	●	●	○
Airfield drainage planning/design/retrofit		●		—	—		●	●	●		●		●	●	●	●	—	●	●	○
Centralized deicing facility		●		●	●		●	●	●		●		●	●	●	●	—	●	●	○
Deicer-laden snow management		●		—	○		○	—	●		●		●	—	—	○	○	○	○	○
Deicing Runoff System Components																				
Portable tanks		●		○	○		●	○	●		○		●	●	●	●	○	●	●	—
Modular tanks		●		—	—		●	○	●		○		●	●	○	●	○	●	●	—
Ponds		●		—	—		●	○	●		○		●	●	○	●	○	●	●	—
Permanent tanks		●		—	—		●	○	●		—		●	●	○	●	○	●	●	—
Manual and automated diversion valves		●		—	—		○	○	—		—		○	○	○	○	○	○	○	—
Real-time monitoring technology		●		—	—		—	—	—		—		—	—	○	—	○	—	○	—

DEICING PROJECT TYPE	Design Storm Factors																			
	Regulatory/Environmental Factors	NPDES/SPDES Permit/Environmental	Operational Factors	Peak Departure Rates	Airfield Utilization/Flow Rate	Physical Factors	Storage Volume Restriction	Deicing Runoff Collection System Restriction	Land Constraints	Climatological Factors	Geographic Region	Hydrologic Factors	Precipitation Volume	Precipitation Intensity	Precipitation Temporal Distribution	Precipitation Duration	Temperature	Probability	Inter-event Period	Precipitation Type
Catch basin inserts/valves		●		—	—		○	○	—		—		—	○	○	○	—	○	—	—
Deicing Runoff Treatment/Recycling																				
POTW discharge		●		—	—		●	—	○		—		○	—	○	—	—	—	○	—
Anaerobic fluidized bed reactor		●		—	—		●	—	●		—		○	—	—	—	●	○	○	—
Reciprocating subsurface treatment		●		—	—		●	—	●		●		○	—	—	—	●	○	○	—
Moving-bed bioreactor treatment system		●		—	—		●	—	●		—		—	—	—	—	●	○	○	—
Sequencing batch reactor		●		—	—		●	—	●		—		—	—	—	—	●	○	○	—
Natural treatment system		●		—	—		●	—	●		●		○	—	—	—	●	○	○	—
Membrane filtration		●		—	—		●	—	●		—		—	—	—	—	●	○	○	—
Glycol recovery (recycling)		●		—	—		○	—	○		—		○	○	○	○	○	○	○	—

LEGEND

Very applicable ●

Somewhat applicable ○

Not applicable —

deicing storm factor to those types of deicing projects. Applicability ratings were categorized as *very applicable, somewhat applicable,* and *not applicable,* defined as follows:

- **Very applicable.** The design storm factor is directly related to the deicing project type and needs to be considered when developing the project (e.g., precipitation volume directly affects the design of drainage infrastructure for apron collection systems, block-and-pump systems, or centralized deicing facilities).
- **Somewhat applicable.** The deicing storm factor could have some impact on the deicing project type and may need to be considered in the project design process [e.g., precipitation volume may have an impact on the discharge of deicer-laden runoff to a publicly owned treatment works (POTW)].
- **Not applicable.** There is most likely no interrelationship between the winter design storm factor and the deicing project type (e.g., precipitation duration has no impact on the handling of aircraft deicing materials).

For example, the design storm for sizing a storage facility and the design storm for assessing the ecological impact of deicing discharges would likely be described using different factors. For sizing a storage facility, the design storm factors could include hydrologic factors such as rainfall intensity, inter-event period, and storm recurrence interval, or physical factors such as existing storage capacity, piping infrastructure, discharge rates, and land availability. Storm factors for determining the ecological impact of deicing discharges could include environmental factors such as NPDES/SPDES (State Pollutant Discharge Elimination System) permit requirements as well as hydrologic and receiving-water factors.

Another example is the consideration of the frequency of the storm used to design a typical apron collection system to divert deicer-laden runoff to a storage tank versus designing an on-site treatment system for airport deicing runoff. Airfield drainage conveyance systems are typically sized for a 5- or 10-year design storm frequency, in accordance with FAA's Advisory Circular (AC) 150/5320-5C, "Surface Drainage Design" (2006). However, for a particular deicing project such as a centralized deicing pad, the design storm frequency is likely much less than the 5-year storm when historical weather records are taken into consideration.

Unlike warm-weather precipitation events, peak storms and intensities during deicing operations seldom correlate to periods when the full hydraulic capacity of the drainage system is needed. Therefore, consideration should be given to a lesser storm frequency, one that is suitable more for the typical winter storm used for sizing deicer-laden runoff diversion piping. This piping would be sized relative to the most likely design event that is supported by historical weather records evaluated for the deicing season. For example, analysis of the weather data should begin with isolating the period during which deicing activities normally take place (October through April, for instance). The number of precipitation events to be considered can then be further narrowed down by analyzing only those precipitation events that occur when the outside temperature is 38°F and falling or staying steady, because deicing activities related to precipitation events seldom occur above 38°F.

Another example is where an airport has stringent effluent limits in its NPDES permit that may require aggressive collection and treatment to maintain compliance. In this case, the NPDES permit limits could drive the system designer to size the runoff collection pipes for a larger storm recurrence interval than what might otherwise be required for managing wintertime storm water.

In some cases, even the relationship of the same winter design storm factors to different airport types will produce drastic differences in recommendations for deicing project components. One example of this can be seen in the type of precipitation that an airport experiences as a result of its geography. Airports in warmer geographies may be subject to deicing activities only when a freezing rain or light snow event occurs, while airports in northern geographies could base their deicing collection on their winter season being loosely defined as October through April. The deicing project solution to meet the particular drivers at each of these airports will be very different. An airport in a warmer climate may need to implement only a glycol recovery vehicle (GRV) or a simple block-and-pump system followed by a flushing to collect deicing runoff, whereas a snowbelt airport may be required to have a centralized deicing facility equipped with a sophisticated deicing collection system, storage tanks, and treatment systems.

SECTION 3

Decision Support Tool

This section describes a decision support tool in the form of a winter design storm identification process, shown in Figure 3-1. On the left side of the figure are data reflecting design storm factors discussed in Section 2. The balance of the figure illustrates the analyses and decisions required to identify an appropriate winter design event or multiday storm in the context of a specific project and its circumstances.

3.1 Nomenclature

Certain terminology in this guidance should be clearly understood before the reader applies the process shown in Figure 3-1.

3.1.1 Design Events and Storms

An important distinction is made between design conditions that are referenced to a single, isolated, peak event and those that reflect a multiday progression of weather and deicing activities. The terminology is as follows:

- **Winter event.** An isolated period of significant wet and/or freezing precipitation that requires applications of aircraft and pavement deicers/anti-icers. The duration of an event in this context is generally in the range of hours (for example, 6 hours, 24 hours). Isolated design events will be used most frequently where there is no significant storage requirement involved and the primary temporal criterion is time of concentration, operating day, or similar.
- **Multiday winter storm.** A prolonged (multiday) period of continuous or intermittent significant wet and/or freezing precipitation that requires applications of aircraft and pavement deicers/anti-icers. The multiday winter storm is relevant where the design of a project, such as a storage facility, must take into consideration the cumulative effects of the precipitation and runoff occurring during a prolonged period, often involving multiple back-to-back events. Multiday winter storms may encompass entire deicing seasons where, for example, processing of collected deicing runoff continues through, and even beyond, the deicing season.

3.1.2 Project

The project is the component, facility, or system that is driving the need to define a winter design condition. Examples of relevant projects are a deicing pad, an apron diversion and collection system with storage and treatment components, and a pond that stores dilute airfield runoff for controlled discharge via a NPDES-permitted outfall.

3.1.3 Factors at Risk

This term refers to what is at risk if facilities designed for the selected winter design storm fail. Examples are violation of NPDES permit requirements, flooding of areas of the airfield, or damage to airport infrastructure. Additional examples are given in the case studies in Section 4.

- **Regulatory factors.** Regulatory risk factors involve noncompliance with FAA and environmental (that is, EPA and/or state-level) regulatory requirements. For example, FAA Federal Aviation Regulation (FAR) Part 77 airfield contours might be at risk if deicer-affected snow piles were to be placed in certain locations or allowed to grow beyond a certain elevation. The most common environmental regulatory risk factor is noncompliance with discharge limits in an airport's NPDES permit. Other examples are violation of an airport's sanitary sewer discharge permit and failure to maintain downstream water quality standards as a result of airport deicing discharges.
- **Physical factors.** Other potential factors at risk are infrastructure features and safety features. Examples of the former would be risking the integrity of storm water pond containment structures if pond volumes reach overflow

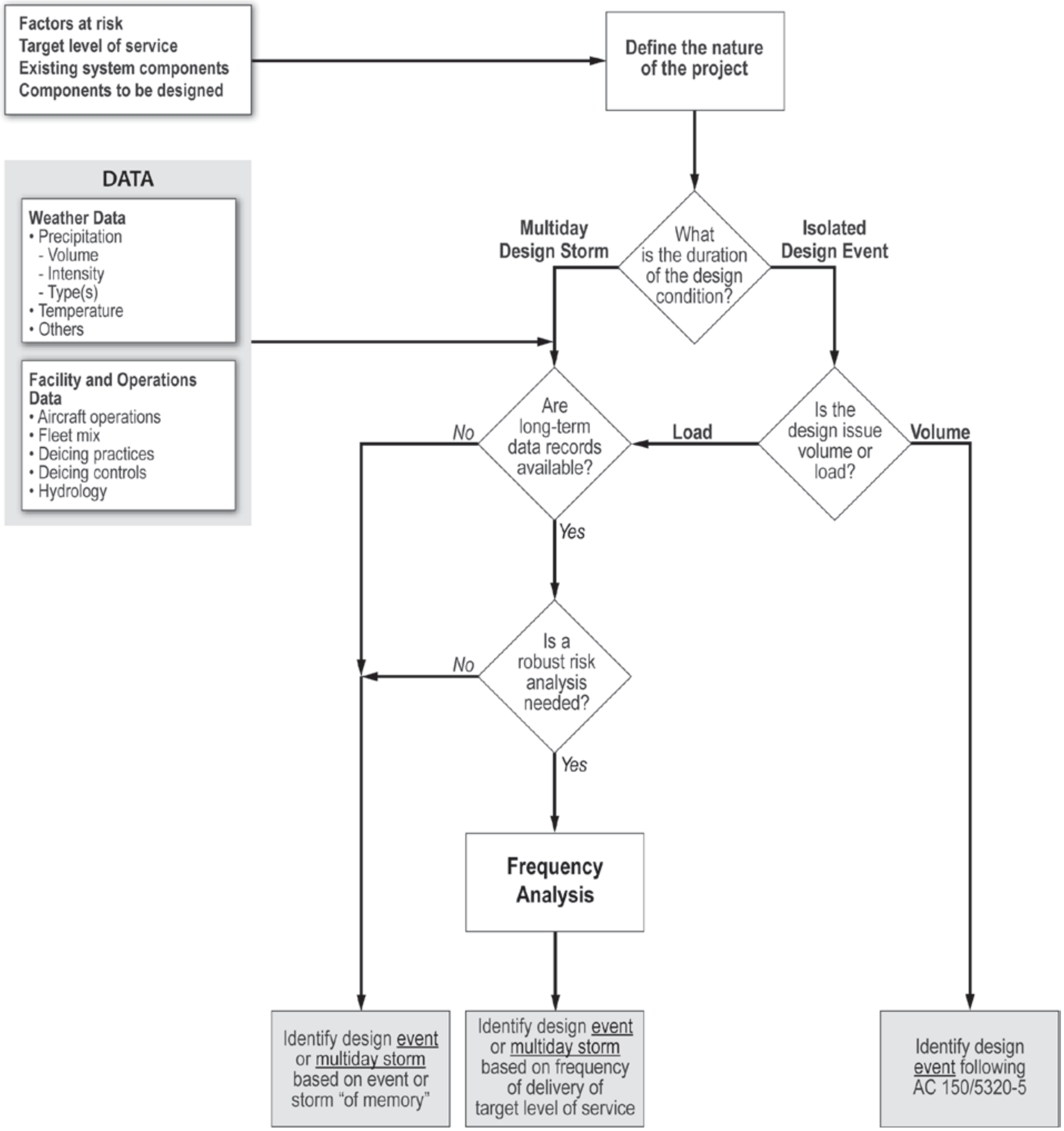


Figure 3-1. Winter design storm identification process.

levels, or the risk of flooding airfield pavements or airfield equipment infrastructure such as electrical vaults. An example of the latter would be increased wildlife hazard risk with flooded areas with standing water.

- **Operational factors.** Deicing infrastructure and operations must accommodate peak-hour departures under weather conditions that pose the greatest demands on effectively deicing and anti-icing the aircraft fleet mix at the airport. The risk factors associated with maintaining these operational levels include inadequate throughput capacity of the aircraft deicing pads and teams, inability to maintain snow- and ice-free airfield pavement, inadequate supplies of deicing products, and excessive amounts of ponded water in terminal apron areas.

Undersizing deicing system components will result in increased risk of not maintaining these regulatory, infrastructure, and/or operational factors.

3.1.4 Target Level of Service

Once the factors at risk have been identified, the critical question then becomes, "How much risk are we willing to accept?" This question is addressed through defining the target level of service or the level of risk the airport is willing to assume in its deicing facility design approach.

There are two distinct elements in defining the risk associated with each risk factor: severity and likelihood. If the risk factor is operational—for example, the risk that deicing facilities may not be adequate to serve all of the flights—then the severity of the risk might be associated with the number of flights delayed, and the likelihood might be associated with the probability of critical storm factors exceeding the selected design storm. The actual risk is a combination of the severity (one or 100 flights affected) and the likelihood (10 times a year or once in 10 years).

Often, regulatory agencies initially assume a very low risk tolerance. Commonly, this tolerance level is later balanced against the costs to achieve that initial low level of risk. For example, the environmental permitting agency may expect NPDES effluent limits to be met 100% of the time under the maximum historical deicing storm conditions. After estimating the cost and practicality of achieving that high standard, the airport may propose a compromise level of service that meets regulatory agency requirements at a marginally higher level of risk. Thus, the process of defining level of service often becomes an iterative one where the cost of achieving lower risk levels is balanced against the value of incremental reductions in risk.

3.1.5 Existing System Components

This term refers to the relevant components that make up the current system within which the project will be installed. Some examples of relevant system components are drainage basins, storm drainage networks, deicing runoff collection elements, storage facilities, permitted storm water outfalls, permitted sanitary sewer discharge points, and on-site treatment facilities. Definition of some or all of these components is needed to support modeling conducted as part of the frequency analysis, as discussed in Section 3.4.

3.2 Decision Points

Four decisions, represented by the diamonds in Figure 3-1, determine which of three possible approaches is used to identify the winter design event or multiday storm. The discussions that follow describe the nature of each decision point and the thinking that goes into each. It must be recognized that each airport and deicing project represents a unique set of circumstances, and it is not feasible to anticipate the details of every possible situation. As a result, the users of this guidance should be prepared to interpret the principles represented by each of these decision points and apply them to their specific project.

- **What is the duration of the design condition?** The nature of the project and the design criteria will determine if the design condition is a single, isolated, peak event or a multiday progression of weather and deicing activities. Typically, if conveyance capacity is the key design issue, then intense, short-duration events will define the critical condition because they represent the greatest challenge to runoff conveyance. An example is the inlets and pipes at a central deicing facility that must be sized to move runoff away from the facility quickly enough to avoid flooding under peak runoff conditions. On the other hand, if the project involves designing a storage tank for a deicing apron or central deicing facility, then typically it will be necessary to consider the dynamics of runoff flowing into and out of the tank from a series of events between which the tank cannot be completely emptied.
- **Is the design issue volume or load?** This question applies only to projects where the critical design condition is an isolated design storm. If the risk is associated with exceeding a parameter involving volumes of runoff resulting from wet precipitation, such as flooding an apron area, then short-term precipitation and runoff phenomena are the drivers, and conventional storm water design event definitions are applicable.

  On the other hand, if the risk is associated with exceeding a deicer load or concentration design criterion, such as a numerical effluent limitation in storm water discharges under a NPDES permit, then the sources and magnitudes of deicing loads must be incorporated into defining the design event or multiday storm.
- **Are long-term data records available?** At this junction in the process, the need for data to support modeling analyses must be addressed. Long-term historical records of weather parameters that affect deicing operations are generally available through the National Weather Service. The resolution of these data may be hourly or shorter periods, or daily totals and averages, depending on the reporting station and length of record. Where weather records are available for several decades or more, the representativeness of older data should be critically evaluated in light of local long-term trends in climate change (see Section 3.5).

  In addition, non-weather data—such as aircraft operations and fleet mix, deicer types and usage (see Box 3-1), deicing runoff collection performance, treatment and recycling volumes and concentrations, and outfall discharge records—are often needed to support the analyses. The exact data requirements will vary with the type of project, factors at risk, and target level of service. Typically, recent data on these aspects of airport operations are going to be the most representative of conditions of interest to the design objectives.

  Table 3-1 provides general guidance regarding the data that may typically be needed for different types of projects and the relative importance of the data in supporting analyses. It is rare for all of the data requirements to be met with available records, which is why skilled analysts and modelers with experience in conducting analyses with limited

Box 3-1. Obtaining deicer usage data.

Obtaining accurate data on deicer usage is often challenging but is essential where the project design requires consideration of deicer loads or concentrations. The data will typically be obtained from the entities that apply the deicers. It is advisable to obtain Material Safety Data Sheets or similar product specification documents for all deicers used.

Aircraft deicer usage. Aircraft operators and deicing service providers are the best sources for data on aircraft deicer (Type I ADF) and anti-icer (Type II/IV AAF) usage. Critical usage information includes whether the products are propylene- or ethylene glycol-based, the mixture strength or dilution (for Type I ADF), and the volumes applied at mixture strength. Mixture can be reported in different ways, so providing the reporting organizations with specific guidance (e.g., always report mixture strength as the ratio of neat ADF concentrate to water) will promote data consistency. Other useful information is time and location of application, and type of aircraft deiced. Daily or finer timescale usage data are typically best for modeling analyses.

Pavement deicer usage. Airfield pavement deicer usage is obtained from the airport department responsible for airfield pavement deicing. Critical data include the brand names of the products, the volumes or weights of each product applied, and the location of those applications. Normally, daily totals are adequate for pavement deicer usage data.

data records are normally required. If it is determined that the data needed to support a robust analysis do not exist, then a simplified default approach is recommended, as discussed in Section 3.3.1.

- **Is a robust risk analysis needed?** Developing a statistical frequency analysis of long-term weather and deicer usage can be a significant undertaking in terms of time and resources. As such, it is important to consider whether the investment is appropriate to the value of the information that the analysis will provide, even if the data to support an analysis are available. On projects where the factors at risk have a high value, and the consequences of over- or under-designing the system are significant and potentially costly, a robust frequency analysis will typically be valuable in supporting confident decision making and justifying costs. An example is the sizing of an on-site treatment facility where under-design risks noncompliance with regulatory permits and overdesign is unnecessarily costly. On the other hand, where the risk associated with under-designing a project, or the incremental cost of overdesigning it, is small, a sophisticated frequency analysis may not be needed to adequately define the winter design event or multiday storm. The Baltimore/Washington Thurgood Marshall International Airport (BWI/Marshall) case study (see Section 4.1) is an example of such a situation, where new storage volume was estimated on the basis of experience with system performance to estimate additional storage requirements.

3.3 Winter Design Event/Storm Outcomes

Applying the decision process outlined in Figure 3-1 will lead to three possible characterizations of the winter design event or storm. These outcomes are described in the following subsections, presented in order of increasing complexity. It should be emphasized here that in all cases the characterization of the winter design event or storm should be in the context of the deicing season months and conditions.

3.3.1 Design Storm or Multiday Event of Memory

In the absence of long-term, facility-specific records that support a frequency analysis, the default is to examine weather records as well as any supporting information (newspaper accounts, recollections of long-term airport staff, etc.) to identify an extreme winter season storm or multiday event in the past (i.e., a storm "of memory") that arguably represents appropriate design conditions. Commonly, the identification of such an event or storm is done as part of negotiations with a regulatory agency.

3.3.2 Design Event Based on AC 150/5320-5C

If it is determined that an isolated winter precipitation event is appropriate as the design event, then the design standards for airfield drainage systems in FAA's AC 150/5320-5C, "Surface Drainage Design," (2006) are used to identify the appropriate design event. Published precipitation records can be used to identify an event with the target frequency of occurrence (for example, 5-year/24-hour). The National Oceanic and Atmospheric Administration (NOAA) publishes

Table 3-1. Types of data records commonly needed for different types of projects.

						Facility and Operations Data				
	Weather Data					Deicing Practices		Deicing Controls		
Type of Project	Precipitation (Water Equivalent)	Precipitation Type	Air Temperature (Min/Max/Average)	Other	Aircraft Operations and Fleet Mix	Aircraft Deicing and Anti-icing Fluid Usage (Including Locations)	Airfield Pavement Deicer Usage (Including Locations)	Deicing Runoff Collection Volumes and Concentrations	Storm Water Runoff Discharge Volumes and Water Quality	Treatment and/or Recycling Volumes and Deicer Concentrations
Apron collection system	●	○	●	○	○	●	○	○	●	○
Glycol collection vehicles	○	○	—	—	●	●	○	●	●	○
Block-and-pump system	●	○	●	—	○	●	○	○	●	○
Airfield drainage planning/design/retrofit	●	●	●	—	—	●	●	○	●	○
Centralized deicing facility	●	○	●	○	●	●	—	○	○	○
Deicer-laden snow management	●	●	●	—	—	●	○	○	—	—
Storage for deicing runoff	●	○	—	—	—	●	○	●	○	●
Manual and automated diversion valves	—	—	—	—	—	●	○	●	●	—
Real-time monitoring technology	—	—	—	—	—	○	○	●	○	—
Catch basin inserts/valves	●	—	—	—	—	●	—	○	○	—
POTW discharge	—	—	—	—	—	○	—	●	○	●
On-site treatment facility	●	—	○	—	—	●	○	●	○	●
Recycling program	—	—	—	—	—	●	○	●	○	●

Legend:
● High priority
○ Potentially useful but not essential
— Not typically needed

precipitation frequency analyses that provide the frequency of precipitation depths associated with different durations (depth-duration-frequency analyses). The latest versions of NOAA's precipitation frequency analyses are available at http://hdsc.nws.noaa.gov/hdsc/pfds/index.html (accessed November 4, 2011).

The design event can be identified from the NOAA data with a definition of the critical duration and the target frequency of occurrence. For example, if a deicing apron is being designed for a 5-year/24-hour storm for an airport near Louisville, KY, the NOAA reference would indicate that the design event would have a rainfall depth of 3.9 in.

The frequency data published by NOAA seldom distinguish between seasons. Some site-specific studies have identified distinct differences between precipitation depth frequency statistics calculated for winter months and the annual statistics readily available from NOAA. This may be important where separate deicing runoff conveyance is being designed. In such cases, using the annual statistics may result in oversizing the project components. However, the procedures documented in NOAA's *Atlas 14* (2004–2011) can be applied to derive deicing season-specific depth frequency statistics from available long-term precipitation data. The deicing season would be defined by reviewing deicing records and identifying those months during which significant deicing is typically conducted. The procedure can be simplified by using only the local airport data and using a site-specific analysis not adjusted for regional patterns. The simplification might also use a less rigorous testing of the most appropriate extreme value frequency distribution, defaulting to the lognormal, log Pierson, or Gumble distributions.

One final note on this approach concerns the implications of snow removal. If the operation of the planned facility includes removing snow from within the project boundaries before it can melt, then some adjustment to the design event precipitation depth may be appropriate to account for removing the water equivalent of that snow.

3.3.3 Design Storm or Multiday Event Based on Frequency Analysis

The frequency analysis approach identifies a winter design storm or multiday event specific to the airport and project. This is accomplished by conducting a continuous simulation modeling of runoff and deicing operations and of deicer usage and loading over a relatively long period of historical winter weather conditions. The output of the simulation is in parameters that are relevant to the factor(s) at risk and that represent the performance of a current or planned deicing project or system under the full range of deicing season weather conditions in the historical record. Statistical determination of the frequency of conditions that correspond to failure of the factor(s) at risk is used to identify the characteristics of the winter design storm or multiday event.

This approach involves relatively sophisticated modeling and statistical techniques applied to the circumstances specific to the airport and project being evaluated. A significant amount of professional skill and judgment is involved in constructing the analysis to adapt to these factors, and the reality of available data and resources is also a concern. As a result, the guidance presented here cannot provide a cookbook approach for conducting these analyses. Rather, the guidance is intended to equip readers with a working familiarity with the concept and steps in the process, to serve as a basis for making informed decisions about its potential applicability to their situation, and to provide a foundation for understanding the results of its application.

3.4 Frequency Analysis

The steps in applying the frequency analysis approach are described in the following subsections and correspond to the process steps illustrated in Figure 3-2. It should be noted that the example tables and graphics that are shown in Figure 3-2 and accompany the following discussions are for illustrative purposes only and do not reflect actual data or analysis.

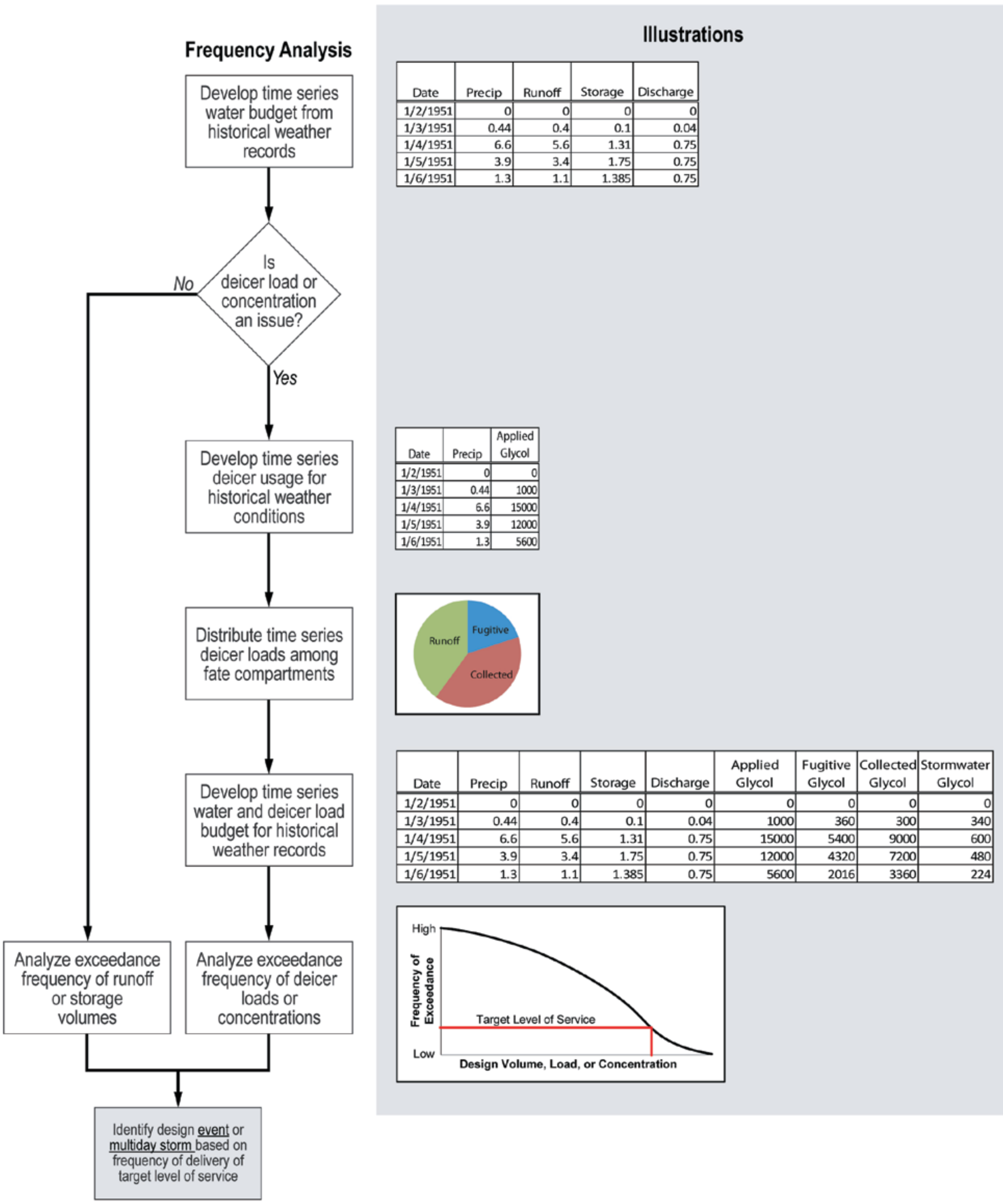
As noted in Section 3.2, the need to conduct a frequency analysis at the level of detail described will depend on the specific design issues and needs. If either the risk associated with under-designing the system or the incremental cost of overdesign is small, then the costs of conducting an analysis to precisely define the winter design event or storm may not be justified. Instead, a less rigorous analysis combined with professional judgment may be adequate in defining appropriate design conditions.

3.4.1 Develop Time Series Water Budget from Historical Weather Records

The first step is to construct a time series runoff model of the system that describes the relevant components of the water budget (see example water budget in Box 3-2) within the boundaries of the project. These may include the following:

- Precipitation inputs in the form of rain, freezing rain, and snow;
- Storage in the form of accumulated snow and ice pack, depression storage, storage of collected deicing runoff, and storm water pond, basin, or tank storage; and
- Outputs in the form of conveyance from a project area to the airport's storm water system, plowing of accumulated snow outside of a project area, permitted surface water discharges, discharges to sanitary sewers, and volumes of collected deicing runoff transported off site for treatment or recycling.

The complexity of the runoff model used for developing the water budget can range from a relatively simple spreadsheet model to one of the more sophisticated continuous hydrology and hydraulics models, such as the EPA's Storm Water Management Model (SWMM). Often, an existing storm water runoff model developed for general drainage at the airport may be adapted to this purpose. *ACRP Report 14* (CH2M HILL et al., 2009) provides an overview of various approaches that can be applied to modeling airport runoff quantity and quality.



Date	Precip	Runoff	Storage	Discharge
1/2/1951	0	0	0	0
1/3/1951	0.44	0.4	0.1	0.04
1/4/1951	6.6	5.6	1.31	0.75
1/5/1951	3.9	3.4	1.75	0.75
1/6/1951	1.3	1.1	1.385	0.75

Date	Precip	Applied Glycol
1/2/1951	0	0
1/3/1951	0.44	1000
1/4/1951	6.6	15000
1/5/1951	3.9	12000
1/6/1951	1.3	5600

Date	Precip	Runoff	Storage	Discharge	Applied Glycol	Fugitive Glycol	Collected Glycol	Stormwater Glycol
1/2/1951	0	0	0	0	0	0	0	0
1/3/1951	0.44	0.4	0.1	0.04	1000	360	300	340
1/4/1951	6.6	5.6	1.31	0.75	15000	5400	9000	600
1/5/1951	3.9	3.4	1.75	0.75	12000	4320	7200	480
1/6/1951	1.3	1.1	1.385	0.75	5600	2016	3360	224

Figure 3-2. Winter design storm frequency analysis process.

Box 3-2. Example of a time series water budget.

Date	Precip (inches)	Runoff (inches)	Storage (1,000 cf)	Discharge (1,000 cf)
1/2/1951	0	0	0	0
1/3/1951	0.44	0.4	0.1	0.04
1/4/1951	6.6	5.6	1.31	0.75
1/5/1951	3.9	3.4	1.75	0.75
1/6/1951	1.3	1.1	1.385	0.75

Two important considerations at this point in the process are selecting the timeframe and selecting the time step of the model simulation. The implications of climate change should be considered in selecting a simulation period that reflects current and anticipated future weather conditions. This topic is discussed further in Section 3.5. With respect to the time step for the analysis, although weather data may be available for intervals as short as 5 min., data on aircraft and deicing operations are typically available only for longer intervals; deicer usage is rarely reported per aircraft and is more commonly reported on a daily or less frequent basis. Also, short time steps may not be necessary to adequately represent the mechanisms and phenomena affecting the factor(s) at risk.

The product of this step is a description of the water budget at each time step over a simulation period that captures the full range of weather conditions experienced at the facility.

3.4.2 Determine if Deicer Load or Concentration Is a Factor

The complexity of the frequency analysis depends on whether deicer concentrations or loads in runoff affect the sizing of the project. If sizing is purely a function of runoff flows and volumes, then frequency analysis is conducted on the time series water budget record. An example is designing storage for high-strength runoff from a centralized deicing facility prior to transport off site for recycling. In this case, the constraining factor on emptying the storage facility is the rate at which stored runoff can be transported off site, regardless of the deicer concentration.

Conversely, where deicer concentration or load is a determinant in sizing the project, then the time series water budget must be expanded to include deicer concentration, as described in the subsections that follow. An example of this situation is sizing a facility to store deicing runoff prior to its discharge to a wastewater treatment plant where the discharge rate to the plant is limited by concentration in the runoff.

3.4.3 Develop Time Series Deicer Usage for Historical Weather Conditions

The next step is to develop a time series of deicer usage associated with the water budget time series over the simulation period (see example in Box 3-3). Deicer usage at each time step in the simulation period is estimated using defined relationships between weather parameters, airfield operations, and deicer usage. Typically, these relationships are developed empirically using historical weather, operations, and deicer usage records from the airport.

The expression of deicer usage relationships can take various forms, typically depending on the nature of available data. For example, if daily airport-wide deicer usage records are available, aggregate usage may be estimated as a function of weather. Figure 3-3 presents an example of a predictive relationship based on regression analysis of daily aircraft deicing fluid (ADF) usage and snowfall. The decrease in usage predicted after a critical snowfall amount reflects the point at which aircraft departures begin to decline with the increasing severity of the snow event.

Greater resolution and detail in estimated deicer usage may be possible where historical data include deicer application records by individual aircraft. Where adequate data are available, analysis of hourly weather data, aircraft type, and deicer usage can yield average application rates for different group size aircraft under different defined ranges of weather conditions. Table 3-2 illustrates how rates of Type I ADF usage might be expressed on the basis of these

Box 3-3. Example of time series estimated deicer usage.

Date	Precip (inches)	Applied Glycol (gals)
1/2/1951	0	0
1/3/1951	0.44	1,000
1/4/1951	6.6	15,000
1/5/1951	3.9	12,000
1/6/1951	1.3	5,600

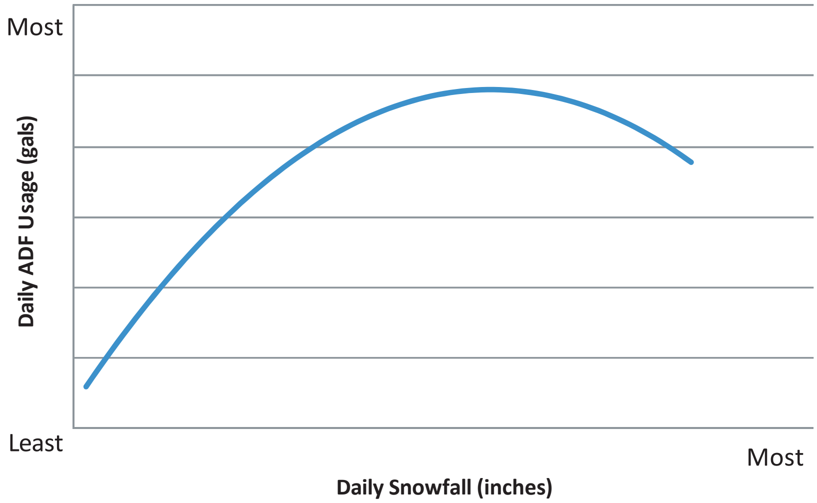


Figure 3-3. Example of how the relationship between daily snowfall and Type I ADF usage can be expressed.

types of records. Similar relationships can be developed to describe Type II/IV deicer usage and airfield pavement deicer usage.

The relationships describing deicer usage as a function of weather and operations are applied to each time step in the simulation period to generate a time series record of estimated deicer usage, or load generation.

3.4.4 Distribute Time Series Deicer Loads among Fate Compartments

The next step in the process is to develop a quantitative characterization of the distributions of applied deicers among the compartments shown in the material balance of deicers applied to aircraft and/or airfield pavement in Figure 3-4. (An example of the possible distribution of applied deicers is contained in Box 3-4.) Each compartment on the right side of the figure represents the fate of some portion of the applied deicers. It is difficult to generalize the quantitative distributions or extrapolate them from other airports because of the influence of facility-specific factors. The best approach is to conduct mass balance evaluations of monitoring data to estimate facility-specific distributions for aircraft and pavement deicers. Guidance on approaches for these evaluations is provided in *ACRP Report 14* (CH2M HILL et al., 2009).

Not all of the compartments shown in Figure 3-4 will apply under all weather conditions, and the description of distributions must reflect that. For example, with freezing rain, there will be no "pink snow" compartment unless there is snowpack remaining from previous precipitation.

It is important to note that there should be a direct correspondence between compartments in the water budget and in the distribution of deicers, with the possible exception of fugitive losses.

Table 3-2. Example of how the relationship between weather, aircraft size, and Type I ADF usage can be expressed.

Weather Condition	Group I	Group II	Group III	Group IV	Group V
Frost					
Freezing rain					
Light snow	*[Gallons of Type I ADF concentrate for each combination of weather condition and aircraft group size]*				
Medium snow					
Medium-heavy snow					
Heavy snow					

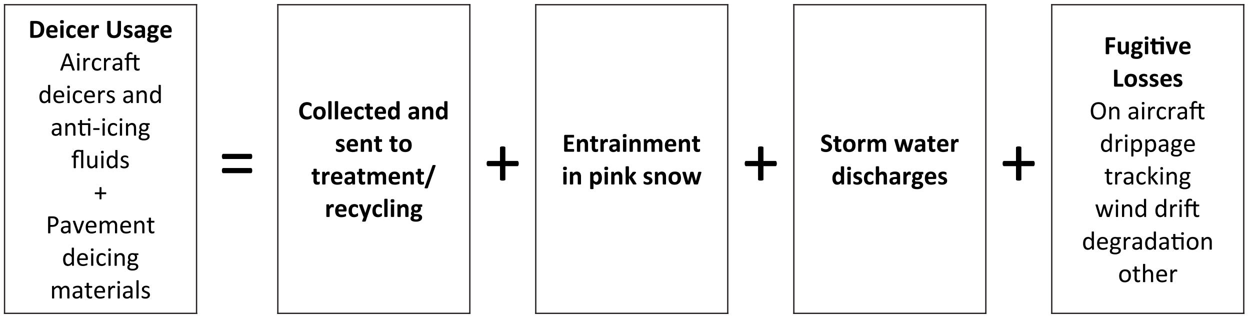


Figure 3-4. Material balance. Adapted from ACRP Report 14 *(CH2M HILL et al., 2009).*

3.4.5 Develop Time Series Water and Deicer Load Budget for Historical Weather Records

Once the distributions of applied deicers are defined, they are applied to the time series of deicer usage to describe deicer loads in each compartment at each time step. Where an existing storm water model has already been developed for an airport, the deicing functions can often be added as pollutant load sources.

The product of this step is a time series data set of weather parameters, distributed water volumes and deicer loads, and any other calculated parameters that directly relate to the factor(s) at risk. Some examples of the latter are deicer concentrations in collected runoff or discharges and storage facility volumes or surface elevations. Table 3-3 presents a conceptual example of what this data set might look like.

3.4.6 Analyze Exceedance Frequency

The event or multiday storm conditions associated with the target level of service relative to the factor(s) at risk are identified by statistically evaluating the time series data set.

Assuming for simplicity's sake that the data set is based on a 1-day time step, the analysis can be described in the following steps:

1. Rank all days in the data set according to the parameter that reflects protection of the factor(s) at risk. An example is ranking the data set by daily outfall discharge concentration from lowest to highest because high concentrations represent risk to NPDES permit compliance.
2. Calculate the frequency of exceedance of each value in the data set (see Box 3-5).
3. Identify the day in the data set where the exceedance frequency corresponds to the target level of service. The conditions on this day reflect the threshold of the design condition, or the design event.
4. Evaluate the days immediately above and below the threshold to assess the variability in weather factors associated with the design condition. This is important because similar volumes of deicers may be used, or similar outfall concentrations may be observed under significantly different weather conditions. Insights gained through understanding the range of weather conditions that are associated with the target level of service will typically be valuable in the design process.

The same basic steps apply to identifying the multiday winter design storm, but the analysis becomes more complicated. The key complexity is that the duration of the storm must be defined. Storm duration will be specific to the airport and context of the project. Determining an appropriate duration involves examining the time series data set and possibly testing the implications of using different storm durations to identify the duration that best suits the needs of the design. Applying statistical techniques for time series analyses may be required, the details of which are beyond the scope of this document.

Box 3-4. Example of distribution of applied deicer.

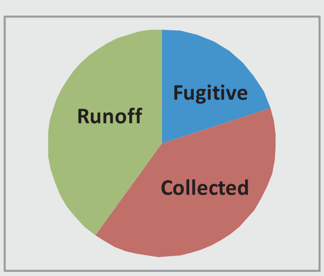


Table 3-3. Example of time series data set of water and deicer budgets.

Date	Precipitation (in.)	Runoff (in.)	Storage (000s ft^3)	Discharge (000s ft^3)	Glycol (Gallons)			
					Applied	Fugitive	Collected	Storm Water
1/2/1951	0	0	0	0	0	0	0	0
1/3/1951	0.44	0.4	0.1	0.04	1,000	360	300	340
1/4/1951	6.6	5.6	1.31	0.75	15,000	5,400	9,000	600
1/5/1951	3.9	3.4	1.75	0.75	12,000	4,320	7,200	480
1/6/1951	1.3	1.1	1.385	0.75	5,600	2,016	3,360	224
1/7/1951	0.5	0.4	0.775	0.75	275	99	83	94
1/8/1951	0	0	0.025	0.25	0	0	0	0
1/9/1951	0	0	0.025	0	0	0	0	0

3.4.7 Identify Design Event or Multiday Storm Based on Frequency of Delivery of Target Level of Service

The process described in the preceding subsections will result in the identification of a subset of individual events or multiday storms that reflect conditions that recur at the defined target level of service. These events or storms may be similar or dissimilar in terms of meteorological, operational, and environmental factors, depending on a myriad of site-specific characteristics and mechanisms that drive runoff volumes and rates, deicer loads and concentrations, discharge rates, and so forth. As a result, it is difficult to generalize the steps in precisely characterizing design conditions based on the events or storms identified through the frequency analysis. It is at this point in the process where the collaboration of designers, planners, compliance specialists, airport management, and other airport stakeholders will result in a suitable definition of the design event.

Box 3-5. Estimating frequency of exceedance.

The frequency of exceeding for a given level of a parameter (i.e., risk) can be estimated from historical data using the following Weibull formula:

$$T = (NYRS + 1)/M$$

Where:

T = return period in years,
$NYRS$ = number of years available in the data, and
M = rank of the given event (events are ranked in descending order).

3.5 Consideration of Climate Change

A detailed discussion of climate change and its implications to the design of storm water infrastructure is beyond the scope of this investigation. Nonetheless, a general overview of the issue is provided here.

There is clear evidence in the historical weather records from many airports that weather conditions have changed significantly over the period of record, and the implications of these changes should be considered in the process of defining a winter design storm. Depending on region, airports may experience changes in temperature regimes that affect the duration of the deicing season, necessitating more or less deicing product storage or more frequent deep freezing days that shift airport operations from defrosting aircraft to fully deicing aircraft and airfields. Temperature regime changes may also change the character and volume of deicing fluid-laden storm water that an airport needs to accommodate during storm events. Climate change may also result in an increase in the frequency or magnitude of intense precipitation events. Such an increase could result in more frequent exceedance of design conditions than those expected from use of the historic weather statistics.

A simplified approach to addressing climate change impacts may be taken by looking at the historic winter precipitation records in isolated periods, distinguishing recent decades from earlier periods. An example of how this might be accomplished in identifying the winter design storm is provided in the Portland International Airport (PDX) case study presented in Section 4.5. In this case, the full historical record showed significant climate change effects, with much more severe winter weather in Portland during the early part of the 20th century as compared to the latter decades of the century. With that recognition, the design storm was developed based upon just the most recent 22 years of weather data in order to more accurately represent current conditions.

The reader is directed to the growing body of work on the topic of climate change adaptation at airports for detailed information on the implications of climate change to airport infrastructure and design. In particular, the products of ACRP research on this topic (e.g., *ACRP Synthesis 33: Airport Climate Adaptation and Resilience* and research to come from ACRP Project 02-40) should be consulted.

3.6 Documenting the Basis for the Winter Design Event/Storm

Figure 3-5 presents a template that can be used to document the application of the decision process to identify a winter design storm/event.

Description of the project: ______________________________

Factors at risk: ______________________________

Target level of service: ______________________________

Duration of the design condition: ❑ One-day/short period ❑ Multiday period

Rationale: ______________________________

Key design driver: ❑ Volume of runoff ❑ Deicer load in runoff

Rationale: ______________________________

Nature of available long-term records (parameter, period of record, frequency, other):

Weather data:	
Aircraft deicer usage:	
Pavement deicer usage:	
Aircraft operations/fleet mix:	
Deicing runoff controls:	

Is a robust risk analysis needed? ❑ Yes ❑ No

Rationale: ______________________________

Frequency Analysis (if applicable)

Period of meteorological record analyzed, and rationale: ______________________________

Basis and rationale for water budget calculations: ______________________________

Basis and rationale for deicer usage estimates: ______________________________

Basis and rationale for distribution of deicer loads among fate compartments: ______________________________

Design condition/storm corresponding to target level of service: ______________________________

Figure 3-5. Template for documenting the basis for the winter design event/storm.

SECTION 4

Case Studies

This section presents five cases that illustrate the application of the guidance presented in Section 3 to different deicing management program situations requiring definition of a winter design storm event.

4.1 Baltimore/Washington International Thurgood Marshall Airport (BWI/Marshall)

The following describes design criteria used for all of the deicing projects at BWI/Marshall. The latest of these projects is to improve the collection system and pumping, add storage to meet peak needs, and provide redundant pumping capability.

4.1.1 Airport Overview/Project Definition

BWI/Marshall is located approximately 10 miles south of Baltimore, MD. Owned, operated, and managed by the Maryland Department of Transportation's Maryland Aviation Administration (MAA), BWI/Marshall is a medium-sized hub airport with approximately 22 million annual enplaned passengers and 276,457 annual operations (ACI-North America, 2010).

January is the coldest month in Baltimore, with an average temperature of 36.8°F. Snowfall occurs occasionally in the winter, with an annual average of 20.8 in. Freezing rain and sleet occur a few times each winter as warm air overrides cold air at the low to middle levels of the atmosphere. When the wind blows from the east, cold air gets dammed against the mountains to the west, and the result is freezing rain or sleet. The average date of first frost in Baltimore is October 29, and the average last frost is April 11. The Baltimore region experiences winter weather conditions that could require deicing runoff collection from November 1 through April 30.

Project Definition

MAA has worked closely with Maryland Department of the Environment and the EPA to develop a phased plan to reduce the amount of deicing runoff to the receiving waters surrounding BWI/Marshall. A consent order and decree was issued to MAA requiring a phased approach to provide progressive improvement in water quality. One of the requirements of the phased approach is that MAA must install deicing collection provisions at every newly constructed gate to capture gate deicing runoff.

The projects included in this case study represent two separate phases of improvements. The most recent project included the rehabilitation of the terminal aprons at Piers C, D, and E with provisions to add eight additional deicing gates (four additional diversion vaults) at Piers C and D. In addition, infrastructure was also installed for three new diversion vaults at Piers D and E for future gate deicing capability and a future redundant lift station and bypass piping to provide backup to the Runway 15R lift station. The existing collection, pumping, and storage systems are undersized to handle the additional flow generated by these additional terminal deicing gates when they are brought online, so additional infrastructure is needed to handle the additional volume of collected fluid.

The second project reviewed as part of this case study was the original construction of the Runway 15R and Runway 15L-33R deicing facilities and the implementation of GRVs around the terminal apron areas. These were the original phases of the deicing fluid collection system, and they provide a significant period of data for the performance of the system with respect to the original winter storm design criteria that have been used for all phases of the development of the program.

Existing (Pre-Project) System Components

Deicing operations at BWI/Marshall typically occur on dedicated aircraft deicing pads, and gate deicing typically occurs at Piers A, B, and C. Gate defrosting may also occur at any gate. Trench drains around each gate deicing position collect deicing runoff, which then flows to one of 34 diversion vaults on the airside. The diversion vaults then discharge deicer-laden runoff to the deicing fluid collection piping and clean runoff to the storm sewer system. The collected deicing runoff is pumped through force mains to aboveground storage tanks with a total capacity of approximately 1.8 million gallons. Deicing runoff is discharged from the tanks to a sanitary sewer for treatment at Baltimore's Patapsco Wastewater Treatment Plant. The permit for this discharge limits daily discharges to 10,000 gallons or 10,000 lbs of 5-day biochemical oxygen demand (BOD_5), whichever is most constraining.

Performance of Existing (Pre-Project) Facilities

The performance of the existing, pre-project facilities at BWI/Marshall was adequate for the number of deicing positions that were routinely used. The collection system, diversion vaults, force mains, and storage tanks appeared to provide adequate capacity for meeting the per-day limit of 10,000 gallons or 10,000 lbs BOD_5. A system limitation, however, was that all of the pre-project deicing runoff was pumped through a single lift station near Runway 15R, with no allowance for redundancy if the lift station were to be taken out of service. If that were to occur, aircraft deicing operations would be severely limited by an inability to control deicing runoff.

4.1.2 Application of Decision Support Process

Risk Factors (Consequences of Failure)

The primary risk factors for MAA at BWI/Marshall are noncompliance with the NPDES permit thresholds and exceedance of the collection system, pumping, and storage capacities (volume). The pre-project disposal conditions allowed for up to 10,000 gallons of glycol-water mixture or 10,000 lbs BOD_5 to be discharged to the sanitary sewer system per day. The allowable discharge volume depends on the combined fluid's glycol concentration and could be less than 10,000 gallons owing to BOD_5 levels. With the addition of a new central deicing pad and more deicing gates, it was necessary to expand the existing collection system so that the system volume would not be exceeded during winter storm deicing operations, when up to 30 aircraft could be departing per hour.

Target Level of Service

The target level of service at BWI/Marshall is to not exceed NPDES permit discharge limits and be capable of providing an aircraft flow rate of 30 departures per hour during a winter storm event with a snowfall rate of 1 in. per hour.

Performance Goals of New Facilities

The performance goals for the BWI/Marshall deicing runoff collection system, diversion vaults, pumping system, and storage tanks are to expand the deicing collection system to be able to accommodate additional gates and a centralized deicing pad for Runway 15R, thereby systematically reducing the impact of deicing runoff to receiving waters surrounding the airport. The goals further include designing a new system sized to accommodate the new gate deicing and remote deicing locations and to provide redundancy for the single pump station. The performance goals include the need to contain runoff from a storm of memory to allow disposal at the predetermined rate of 10,000 gallons per day. This requires construction of deicing infrastructure adequate to divert and pump the additional runoff to the storage tanks so that the deicing runoff mixture to the local treatment plant can be metered.

Assessing Existing Performance Relative to Target Levels

The performance of the existing system is adequate with respect to the existing, pre-project deicing facilities; however, the system capacity will be inadequate to accommodate the runoff from additional deicing positions without additional diversion vaults, force mains, and storage tanks.

Design Storm Features Critical to Performance Target

The design storm feature critical to target performance is either the volume or the rate of winter precipitation. All components of the deicing runoff collection system are based on either a design storm of record or a defined hourly precipitation rate. The collection piping and force mains were designed to accommodate the water equivalent of 1 in. per hour of snowfall. This snowfall rate was selected because it coincides with the rate at which the airfield snow removal equipment and air carrier ground support equipment can feasibly clear the airfield and maintain departure rates near 30 departures per hour. When the snowfall rate exceeds 1 in. per hour, the airlines typically go into a delay mode or begin canceling flights altogether, so this becomes the theoretical maximum rate at which deicing activities will occur. Exceeding these design storm assumptions could result in flooding or exceeding the storage capacity of the tanks, resulting in potential discharges to the storm sewer system and then to surface waters; however, the capacity of the collection pipes and pumps has never been exceeded.

Defining Duration of Design Condition (Multiday Storm or Isolated Event)

The design storm for this project is actually different for different deicing collection system components. For diversion structures, pumps, and force mains, the design basis is an isolated storm event with a 1-in.-per-hour snowfall rate. This design element also includes a percentage reduction in assumed flows, which is applied because not all of the deicing locations will be contributing to the collection and pumping system at the same time. The airlines do not often deice at the gates, and deicing location is somewhat dependent on the selected departure runway.

For overall deicing runoff storage volume requirements, the design condition takes into consideration cumulative effects from multiday or back-to-back events and is based on weather records and a storm of memory, although the record documents provided do not specify what design storm was actually used for that purpose. This storage design component is based on providing enough storage so that the daily rate of disposal (10,000 gallons) to the local treatment plant is not exceeded. The total storage volume capacity was derived over a number of years whereby MAA evaluated the system performance at the end of the deicing season to determine if storage capacity had been adequate. Additional tanks were added as new deicing gates or the Runway 15R deicing facility came online or as MAA determined were necessary from evaluating the prior season's performance.

Frequency Analysis

Are long-term records available? Long-term weather records are available for BWI/Marshall and were used by MAA in their initial storage tank sizing analysis; however, the storm used in the evaluation is not identified in the literature provided for evaluation. The use of long-term weather records has been discontinued because MAA evaluates storage volume on the basis of the previous season's actual performance.

Is a robust risk analysis required? A robust risk analysis was not required for BWI/Marshall because the design solution is dependent on runoff volume and only indirectly on load. Using this approach, MAA used the weather records to select a design storm of record for sizing the initial storage tank capacity but has since abandoned that approach and has based its storage requirements on actual system performance.

Summary of the Decision Support Process Results

The decision support process was applied to MAA's collection system improvements and is shown in Figure 4-1. The path taken is mapped by the arrows, and the decisions made are further explained in the following.

Duration of design condition: Two different requirements were identified corresponding to the different system components being designed: (1) multiday design storm for tank sizing, and (2) isolated design event (water equivalent of 1 in. of snowfall) for conveyance piping and pump sizing. These resulted in two different paths:

Path A—(Storage Tank Sizing)

- Are long-term data records available? Decision = Yes
- Is a robust risk analysis needed? Decision = No. After initial sizing of storage tanks, BWI/Marshall changed its approach to evaluating storage adequacy at the end of each deicing season and has incrementally added volume as needed.

Path A outcome: Storage tanks designed based on event or storm of memory.

Path B—(Pump/Pipe Sizing)

- Is the design issue load or volume? Decision = Volume. At BWI/Marshall, the pipes/pump needed to be sized for the water equivalent of 1 in. of snowfall per hour, the maximum rate of precipitation before the airfield and airlines start delaying/canceling flights.

Path B outcome: Size pumps/piping in accordance with FAA guidelines for a maximum snowfall rate of 1 in. per hour.

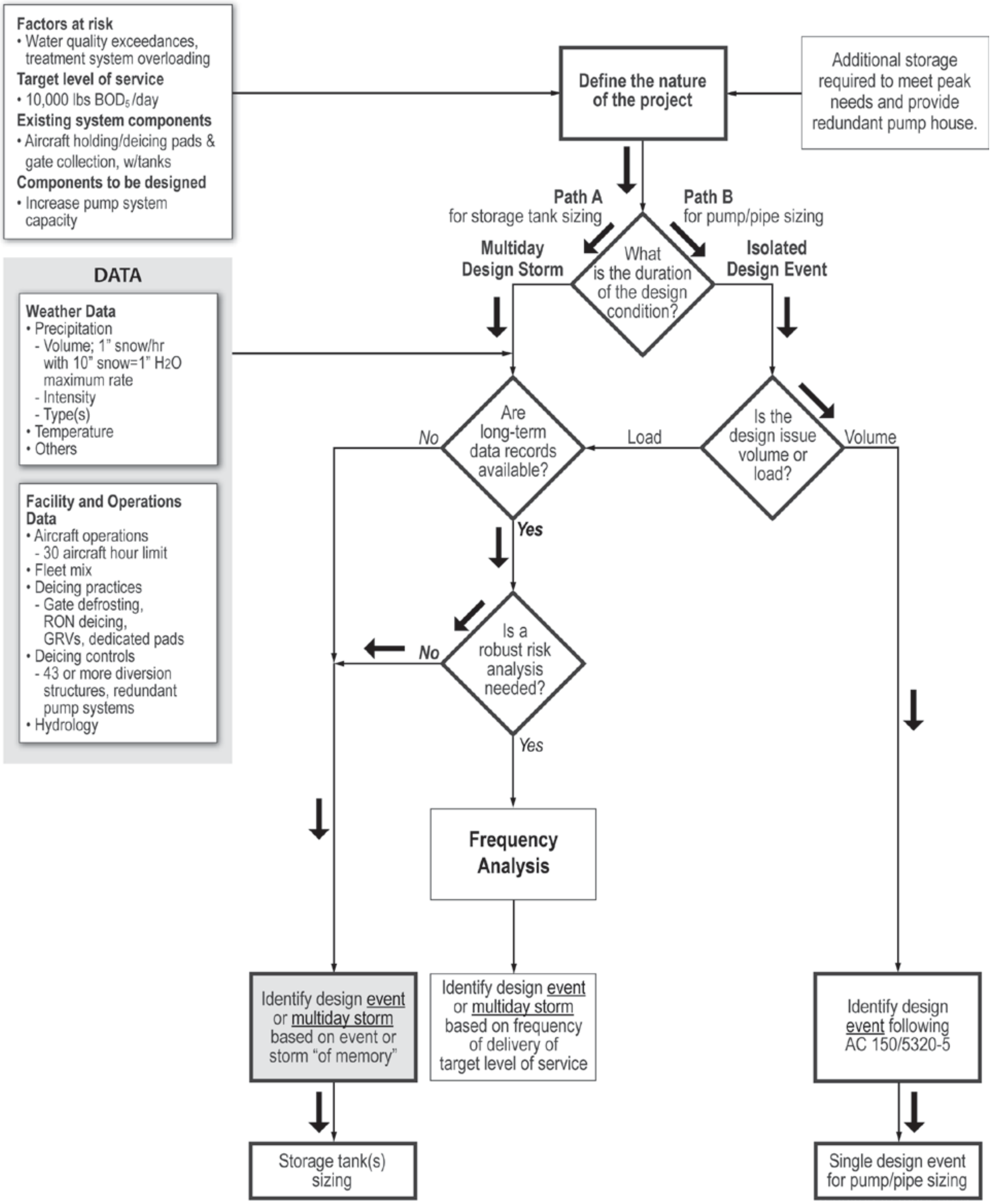
While not all of the suggested features of the process were followed in this example, the decision support process represents BWI/Marshall's identification of a winter design event based on the frequency of delivering the target level of service. Based on the selected storm and the addition of storage tanks as new facilities came online, MAA is able to provide adequate storage to allow a disposal rate of 10,000 gallons of fluid per day to the local treatment plant.

4.2 Port Columbus International Airport (CMH)

This section describes a case study of the application of the decision support process to the design of a retrofit of drainage, collection, and containment infrastructure at CMH to achieve necessary control of deicing runoff.

4.2.1 Airport Overview/Project Definition

CMH is located approximately 8 miles from downtown Columbus, OH. The airport is owned and operated by the Columbus Regional Airport Authority (CRAA). CMH is a medium-sized hub airport with approximately 6.4 million annual enplaned passengers and 136,081 annual operations (ACI-North America, 2010).



Note: RON = remain overnight.

Figure 4-1. Baltimore/Washington International Thurgood Marshall Airport.

At CMH, aircraft are deiced primarily on the terminal apron around Concourses A, B, and C and on the east remain-overnight apron. Storm water runoff from these deicing areas drains to Outfall 6, east of Sawyer Road and just south of the intersection of Sawyer Road and Bridgeway Road, eventually flowing to Big Walnut Creek. On rare occasions, aircraft are deiced at the Runway 10R hold pad located on Taxiway C at the approach end of Runway 10R. Storm water runoff from this area drains to Turkey Run on the south side of the airport.

The Columbus region experiences winter weather conditions that could require deicing runoff collection from October through April. Though Columbus rarely receives snow in October or April, October marks the beginning of freezing temperatures that require defrosting of aircraft that have been parked overnight on the terminal apron. The heaviest deicing activities occur from December through February.

Project Definition

The design component evaluated in this case study is a retrofit of the drainage, collection, and containment infrastructure that was in place prior to this project.

Existing (Pre-Project) System Components

Prior to this project, deicing runoff drained to the drainage infrastructure in the terminal apron and discharged to Outfalls 2 and 6, from which it flowed eventually to Big Walnut Creek.

The deicing collection project includes the construction of dual-trench drains behind the aircraft gate positions at the outer edge of the terminal apron. These trench drains are connected by drainage pipes to diversion structures. Normal wet-weather, nondeicing flows are diverted to the storm sewer outfalls around the airport. During deicing periods, a pump station transfers deicer-laden runoff to aboveground storage tanks, where it is held prior to being transferred to and disposed of at the local treatment plant. The design also includes snowmelt-collection areas where glycol-laden snow plowed from the terminal apron is held until it melts and eventually drains to the collection system and storage tanks.

Performance Limits of Existing (Pre-Project) Facilities

Under pre-project conditions, runoff from aircraft deicing was discharged directly to the storm drainage system.

4.2.2 Application of the Decision Support Process

Risk Factors (Consequences of Failure)

The primary risk factor associated with failing to adequately control the release of deicing fluid runoff to the surrounding streams is noncompliance with the airport's NPDES permit and associated possible fines and enforcement actions. Other risks associated with exceeding the design storm collection capacity include damaging the diversion piping, damaging the pumps, and exceeding the storage tank capacity. The consequences of exceeding the design storm capacity include potential flooding of the terminal apron and overflows of contaminated deicing runoff to streams, with potential exceedances of NPDES and industrial permit limits.

Target Level of Service

The target level of service for CMH is defined by the Ohio Environmental Protection Agency's NPDES permit and City of Columbus's industrial permit. The industrial discharge permit limits for CMH are a BOD_5 maximum of 30,000 lb/day for discharge to the POTW, with a monthly average of 12,000 lb/day. The NPDES permit limits for CMH outfalls related to deicing discharge are a daily maximum of 640 mg/L for propylene glycol for Outfall 2 and a daily maximum of 1,300 mg/L for propylene glycol for Outfall 6, with a monthly average not to exceed 71 mg/L and 950 mg/L for Outfalls 2 and 6, respectively. Maximum monthly 5-day carbonaceous biochemical oxygen demand ($CBOD_5$) for Outfalls 2 and 6 are 200 mg/L and 1,300 mg/L, respectively. Furthermore, the NPDES permit stipulates the following regarding design storm overflows:

> The Airport's containment system is designed based on collecting runoff equivalent to a 10-year winter storm event. Storm water flows above these design criteria will generate a bypass event resulting in the direct discharge of storm water to Big Walnut Creek. Computer modeling indicates the assimilative capacity of Big Walnut Creek during such a storm event is greater than the potential impact of aircraft deicing operations. Bypasses of this containment system according to the conditions of an approved Permit-to-Install are not violations of this permit as long as the maximum concentration limits for ammonia and glycol parameters are attained. (Ohio Environmental Protection Agency, 2011)

Ammonia levels in Big Walnut Creek are no longer an issue since the airport has discontinued urea usage for pavement deicing.

Performance Goals of New Facilities

The goal behind installing the new deicing collection, storage, and disposal facilities at CMH was to dispose of glycol-laden runoff so that the NPDES permit discharge limits are achieved with only limited (and permitted) exceedances for storms that exceed the 10-year design storm, providing that maximum concentration limits for glycol parameters are not exceeded. The original objective of the design process was to develop a collection and storage system with a deicer-runoff disposal rate to ensure that deicing tanks are empty after 24 hours of metered disposal to the local POTW or within 7 days for back-to-back events.

Assessing Existing Performance Relative to Target Levels

Pre-project deicing procedures did not include any provisions for collecting and disposing of deicer-laden runoff; therefore, the pre-project system did not meet the target levels.

4.2.3 Apply Decision Support Process

Design Storm Features Critical to Performance Target

Design storm features, including a combination of the total runoff generated by precipitation and deicing fluids sprayed, are critical to achieving the target of not exceeding the runoff equivalent to a 10-year winter design storm. Exceeding the 10-year storm could result in overflows to the storm water system with the potential of exceeding the maximum glycol parameters identified in the NPDES permit.

Defining Duration of Design Condition (Multiday or Isolated Event)

CRAA used two different approaches to defining design conditions relative to weather. The drainage infrastructure was sized on the basis of a single-day event, whereas a statistical analysis of weather records was used to size the storage tanks for deicing runoff.

Storm drainage design at commercial airports is required to comply with FAA guidelines, which stipulate that surface drainage and collections systems must be designed for at least the 5-year design storm and a 10-year storm if surface ponding could affect aircraft traffic areas (FAA, 2006). The design storm for drainage system sizing at CMH was not specifically mentioned in the *Deicing Study Final Report* (Camp Dresser & McKee, 1998); however, it is specified in the July 2011 NPDES permit as a 10-year design storm. The deicing runoff collection, conveyance, and storage system was designed for a peak event, and it was anticipated (and permitted) to bypass the collection system when the precipitation event exceeded the design storm runoff volumes. The assumption was made that if flows were great enough to bypass the collection system, then glycol and ammonia concentrations in the runoff would be sufficiently low during such an event and would not exceed permit limits. Thus, the drainage infrastructure portion of this project followed the isolated design event path through the decision process.

The need for an analysis of long-term weather records was identified to define the critical multiday storm that would be used for sizing the storage tanks. The airport used a model to determine the maximum required containment volume.

Availability of Long-Term Data Records

Forty-seven years of precipitation data for the months October through April (i.e., the winter period) were analyzed for the purpose of characterizing a winter design storm. The average precipitation during the period from October through April is 19.4 in. Most deicing activities occur below 37°F, and the weather records analysis was limited to those days in the record where temperatures were below this level.

Is a Robust Risk Analysis Needed?

A robust risk analysis was required for the CMH project in order to size the deicing-runoff storage tanks. The tank sizing was based on the rate of discharge to the local POTW, so a robust analysis was required to determine the maximum daily storage volume.

4.2.4 Frequency Analysis

Develop Time Series Water Budget from Historical Records

Statistical programs were used to characterize storms that occurred during the winter period for the 47 years of available data. The average storm duration for each month of the winter period was found to range between 5.5 and 12.8 hours, although occasional longer-duration events have occurred. The study showed that the greatest deicer usage coincided with the smallest precipitation events. However, occasional high-volume, high-intensity storms mandated that the storm water collection system be sized to handle large volumes and peak flows to minimize glycol-contaminated runoff during severe storm conditions. The water budget was therefore developed using the 10-year design storm frequency for sizing the drainage infrastructure.

Develop Time Series Deicer Usage for Historical Weather Conditions

Aircraft and airfield deicer usage has been tracked at CMH since 1992. However, at the time of the 1998 deicing study, only 7 years' worth of data was available. More recently, the airport hired a consultant to assess the potential effect of a proposed deicing treatment system on the existing storage system. The consultant used a storm water model to simulate deicer system performance based on weather data from the historical period of record. The 2006 flight schedule was used as the basis for simulating the runoff collected for 57 seasons of complete seasonal historical weather data (Gresham, Smith and Partners, 2009).

Distribute Time Series Deicer Loads Among Fate Compartments

It was assumed that 65% of the applied aircraft deicers would be captured in the storm sewer system and that this percentage would increase to 95% if the airport added GRVs for surface collection (optimistic, but conservative). The fate of the remaining fraction of applied deicers was not relevant to the design analysis. The basis for these assumptions was not described in any of the documents reviewed.

Develop Time Series Water and Deicer Load Budget for Historical Weather Conditions

The combined water and deicer load budget was used to support application of the STORM model, which allows for fate variables such as precipitation, fugitive glycol, applied glycol, and collected runoff. The generation, storage, and discharge of collected deicing runoff across the time series was modeled, and this provided the basis for sizing the storage. In simple terms, the model provided an estimate of daily storage volumes over the simulation period. These daily estimates were then analyzed to identify a storage volume that met the performance and target level of service criteria.

The modeling analysis concluded that roughly 8 million gallons of aboveground storage tank capacity would be required to match the planned waste disposal rate. The design included snowmelt-collection areas that drain to the collection system and storage tanks.

Evaluation of Results

The goal of the deicing collection, storage, and disposal system is to maintain compliance with the industrial and NPDES permits without exceeding its total storage capacity. With the construction of 8 million gallons of storage with an additional 500,000 gallons in storage capacity in the pump wet well, the airport does not need to empty the tanks within 24 hours or 7 days for back-to-back events. To date, this storage volume has never been exceeded. One winter storm in recent years that started as ice and turned to rain nearly filled the storage tanks to capacity and depleted the airlines' supply of glycol; however, the tanks did not overtop and the system did not overflow. To date, the glycol collection, containment, and disposal system has adequately served its purpose and has successfully met the industrial and NPDES permit limits.

Summary of the Decision Support Process Results

The process followed by CRAA mapped closely to the decision support tool.

Were all features in the suggested process covered by the airport? The decision support process was applied to CRAA's collection system improvements and is shown in Figure 4-2. The path taken is mapped by the arrows, and the decisions made are further explained in the following.

Duration of design condition: Two different requirements were identified corresponding to the different system components being designed: (1) multiday design storm for tank sizing, and (2) isolated design event for conveyance piping and pump sizing. These resulted in two different paths.

Path A—(Storage Tank Sizing)

- Are long-term data records available? Decision = Yes. Available data included 47 years of weather data, including hourly precipitation.
- Is a robust risk analysis needed? Decision = Yes. The tank sizing was based on the rate of discharge to the local POTW, so a robust analysis was required to determine the maximum daily storage volume requirement.
- Is deicer load or concentration an issue? Decision = Yes.
  - Develop time series deicer usage for historical weather conditions. CMH assumed captured deicing fluid volume = 65% of applied fluid, or 95% when combined with GRV surface collection measures.
  - Distribute time series deicer loads among fate compartments. CMH's consultant used storm-water modeling software that accounted for these variables.
  - Develop time series water and deicer load budget for historical weather records—the water and deicer budgets were combined.
  - Analysis of exceedance frequency of deicer loads or concentrations. CMH looked at exceedance frequency of runoff/storage volumes.

Path A outcome: Storage tanks designed based on multiday storm based on frequency of delivery of target level of service (30,000 lb/day BOD_5 maximum discharge to POTW).

Path B—(Collection Infrastructure Sizing)

- Is the design issue load or volume? Decision = Volume. At CMH, the collection infrastructure needed to be sized for the ramp areas where deicing occurs in accordance with FAA AC 150/5320-5C.

Path B outcome: Size collection infrastructure in accordance with FAA guidelines.

As shown in Figure 4-2, the CMH project followed the process very closely. This project actually followed two paths

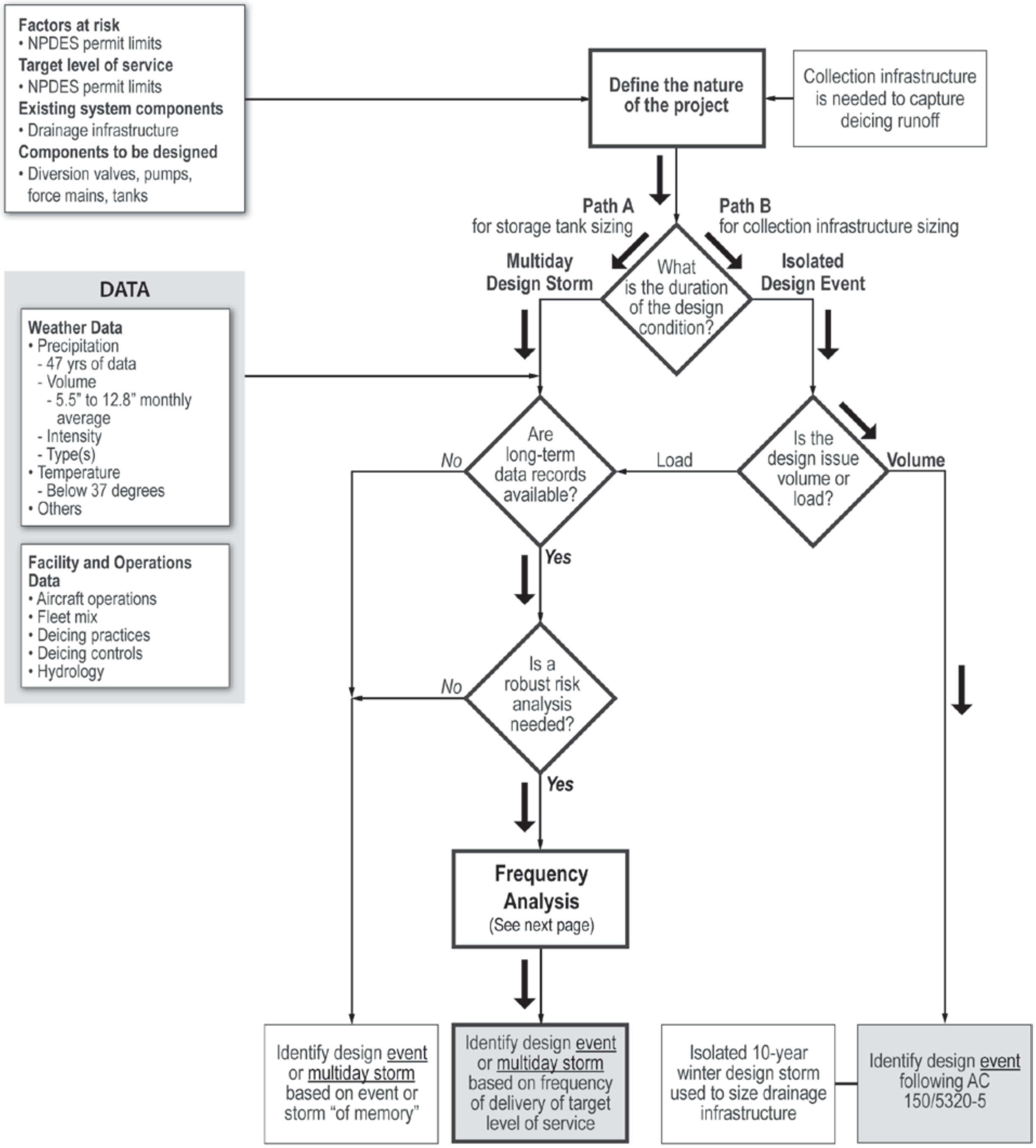


Figure 4-2. Port Columbus Regional Airport (CMH).

for determining the appropriate design storm, depending on the component of the deicing system being designed: (1) the multiday storm path was used for the deicing runoff storage tank design in order to capture multiday or back-to-back storm events, and (2) the isolated design event path was used to size the deicing runoff collection infrastructure. The use of the STORM model mirrored the development of a water and deicer load budget and how it was distributed to the various fate compartments. The result of the process was that a 10-year design storm was adequate for sizing the drainage infrastructure and conveyance to deliver the performance and service level required, while a multiday storm based on 47 years of historical weather records was suitable for sizing deicing runoff storage tanks suitable for storing fluid at a rate that complied with the requirements of the airport's NPDES permit.

Did the airport include any features or considerations not covered in the suggested process? No.

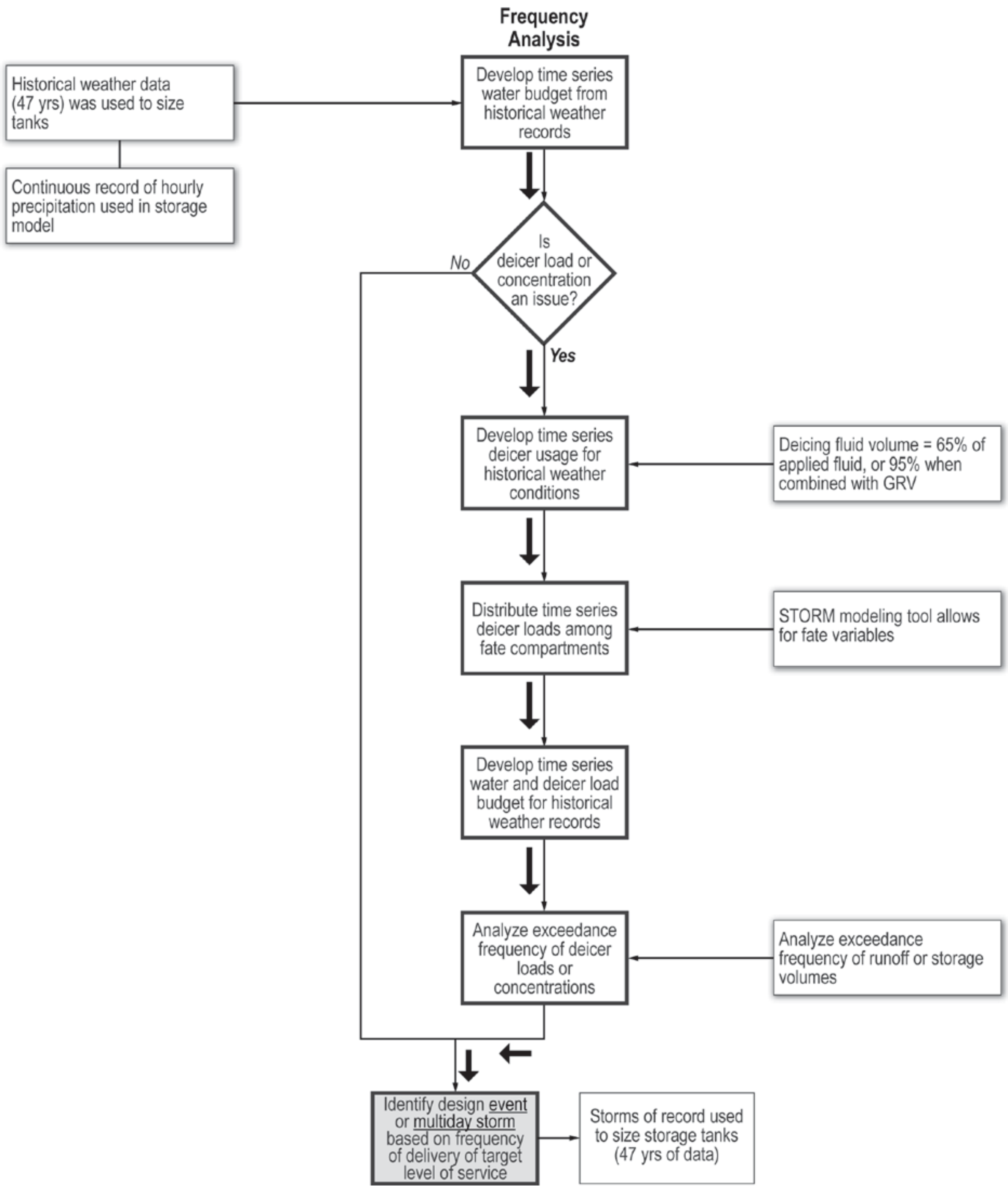


Figure 4-2. (Continued).

4.3 Washington Dulles International Airport (IAD)

This section describes a case study of the application of the decision support process to the Washington Dulles International Airport's Biological Treatment of De-Icing Agents and Stormwater for Runway 1L-19R and Associated Taxiways project.

4.3.1 Airport Overview/Project Definition

IAD is operated by the Metropolitan Washington Airports Authority (MWAA). IAD is situated on 11,830 acres in Chantilly, VA, approximately 26 miles from Washington, D.C. The IAD main terminal began operating in November 1962. IAD is a major hub for domestic and international air travel, serving 23.7 million passengers annually (2010).

IAD experiences average annual temperatures of 55.3°F (1981–2000). December, January, and February are the coldest months, averaging 36.6°F, 33.2°F, and 36.2°F, respectively. IAD averages 22.0 in. of snowfall each year (1981–2000), with the majority falling in January and February (7.3 and 7.6 in., respectively). Extreme monthly snowfalls occurred in January 1996 and in February 2010, when 30.9 and 46.1 in. were recorded, respectively (NWS, 2011a).

Project Definition

MWAA invested in the infrastructure at IAD through a major construction program called D2, Dulles Development, which included construction of a fourth, 9,400-ft runway, referred to as Runway 1L-19R. A storm water management plan that considered environmental resources, storm water regulatory requirements, and long-term airport operational needs was developed for the new runway and associated taxiways, service roads, and future deicing pad.

In order to meet Virginia Department of Environmental Quality water quality requirements, low-impact development (LID) concepts were incorporated into the storm water system plan. The principles of LID require that runoff be minimized by promoting infiltration and treatment on site or as near to the source as possible. This approach is increasingly advocated by regulators and reflected in changes in professional practice. In fact, the focus of the NPDES permit for IAD at the time of the design was on best management practices (BMPs), monitoring, and communication with Fairfax County Water Authority. (Fairfax County Water Authority manages drinking water in the area.) The permit provided MWAA with the opportunity to lead by example, apply innovative treatment techniques, and exhibit a cooperative good-neighbor approach to storm water management. MWAA also wanted to be proactive in terms of storm water management on this project because it recognized that the next several years were going to bring unknown changes in the regulatory environment. The airport was encouraged to implement biological treatment units (BTUs), as preferred by state and federal regulatory agencies, in order to comply with the permit's BMP requirement (CH2M HILL, 2002).

The storm water system plan featured BTUs, which are intended to treat storm water runoff not contained at centralized deicing pads. The BTUs detain storm water for treatment through passive biological systems, which remove BOD and total phosphorus (TP) from fugitive deicing material. A total of five BTUs and their associated water quality swales and detention systems were planned; an additional five water quality swales were planned in areas not served by BTUs. The number of BTUs was driven by existing topography, stream channel locations, and the proposed airfield geometry. Treated storm water discharges to the nearest existing stream, usually Stallion Branch or its tributaries.

Existing (Pre-Project) System Components

There were no preexisting system components.

Performance of Existing (Pre-Project) Facilities

No system components existed for performance evaluation.

4.3.2 Application of the Decision Support Process

Risk Factors (Consequences of Failure)

The primary risk factor for MWAA at the time was noncompliance with its NPDES permit. Because the permit did not contain direct water quality effluent limitations, risk took the form of potential impacts to the airport's relationship with local, state, and federal regulatory agencies and with the public rather than typical regulatory action, fines, and so forth, as one would expect with a water quality violation.

Target Level of Service

The NPDES permit was based on BMPs. The airport chose to implement BTUs in order to comply with the permit's BMP requirement (CH2M HILL, 2002). The targeted level of service was for the system to meet performance goals in the average rainfall year. The selection of the average rainfall year was driven largely by the BTUs' anticipated performance. A review of local dry-year and wet-year conditions concluded that BTUs designed for wet-year conditions would likely perform poorly during dry-year conditions. However, BTUs designed for average-year conditions were expected to perform adequately during both dry and wet years.

Performance Goals

As mentioned earlier, performance limits were not included in the existing NPDES permit. However, it was anticipated that effluent limits might be specified during the next (2008) permitting cycle. The design team reviewed literature and case studies to determine appropriate performance goals for the selected treatment method, and it was decided to limit BOD concentration in storm water discharges to 100 mg/L or less. In the context of assumed storm water runoff water quality characteristics, this is equivalent to a concentration reduction of 91% for inflow concentrations of 1,140 mg/L and 80% for inflow concentrations of 500 mg/L. In addition, it was determined that the treatment system must reduce total phosphorus concentrations by 50%. (The assumed water quality values were based on BOD concentrations measured in storm water samples collected from various locations at the airport.)

Assessing Existing Performance Relative to Target Goals

The proposed storm water management plan was for new development; no system components existed for performance evaluation.

Design Storm Features Critical to Performance Target

The primary design features critical to the performance target are the storm volume and the expected water quality characteristics, specifically BOD and TP concentrations of storm water runoff in the collection area.

Define Duration of Design Condition (Multiday Storm or Isolated Event)

The selected BTU treatment method requires that the collection and treatment capacity be sufficient for a variety of potential storm events. As a result, the design requires a continuous simulation (multiday) approach.

Availability of Long-Term Data Records

Hourly meteorological data from Ronald Reagan Washington National Airport (DCA) are collected and reported by the National Climate Data Center (NCDC). More than 50 years of detailed precipitation data were available. These data were compared to a shorter data set (5 years) collected at IAD. Appropriate adjustment factors were applied to generate a long-term synthetic precipitation record for IAD. The synthetic weather data set was reviewed by the design team, and representative dry, average, and wet precipitation years were identified.

Need for Robust Risk Analysis

Statistical analysis of historical weather data was required because the design is based on the long-term average annual storm volume. This analysis qualifies as a form of frequency analysis, the frequency in this case being an average.

Frequency Analysis

The frequency analysis approach to identifying a design event differed in detail from that shown in the process flow chart, but the approach generally followed the process, as outlined in the following steps:

Develop Time Series Water Budget

1. The precipitation data set at DCA was reviewed to identify dry, average, and wet rainfall years. The year 1995 was selected as average on the basis of its comparison with the long-term annual average of approximately 45.7 in. Precipitation volumes at DCA were adjusted by a factor of 15% to estimate precipitation volumes at IAD. This is based on comparisons of available data that showed annual totals at IAD being between 9% and 17% greater than those at DCA.
2. Continuous flow simulation using the XP-SWMM software package was conducted to estimate surface runoff and system losses, including infiltration for dry, wet, and average rainfall years.
3. Runoff volumes to the BTUs, duration of storm events, and inter-event periods were determined from the continuous simulation output. The average rainfall year (1995) was selected as the basis of design. The annual average storm runoff volume was calculated by dividing the volume of storm water runoff entering a given BTU during the year by the total number of storm events.

Establish Deicer Concentrations in Storm Water Runoff

4. BOD in runoff to BTUs was assumed to be at anticipated maximum average concentrations of 1,140 mg/L near future Deicing Pad B and 500 mg/L for the remaining collection system areas, which are farther from deicing operations. (The assumed water quality values were based on BOD concentrations measured in storm water samples collected from various locations at IAD.) The range of inflow concentrations is consistent with concentrations treated by other systems receiving airport storm water with deicing agents, such as the Pearson Airport treatment system in Toronto and the Westover Air Force Base system.

Apply Frequency Analysis Results to the Design and Sizing of Treatment Units

5. BTU sizing was based on water quality targets and accomplished using empirical equations (Van der Tak et al., 2005). The independent (i.e., input) variables in the sizing equation consisted of the oxygen demand (OD) for nitrification, BOD, chemical oxygen demand (COD), and the oxygen transfer rate (OTR). Observed ranges of oxygen supply per unit area [as taken from literature, including Kadlec (2000), Platzer (1999), Green et al. (1997), and Cooper and Green (1998)] were combined with an estimate of oxygen demand (OD) to determine the BTU bed area as:

$$A = \text{OD}/\text{OTR} \qquad (\text{area in m}^2)$$

Oxygen demand is, in turn, a function of water quality (NH_4, N, and BOD) and flow rate. Oxygen demand is estimated as follows (Cooper and Green, 1998):

$$OD = 4.3\,\Delta(NH_4 - N) + \Delta(BOD) \quad (\text{oxygen demand in g } O_2/\text{day})$$

For example, for Runway 1L-19R System A, an OTR of 50 g $O_2/m^2 \cdot$ day was assumed, based upon literature values. The OD was estimated as follows:

$$(4.3 \cdot 0.1\ g/m^3 - 0\ g/m^3) \cdot 221\ m^3/day + (1{,}140\ g/m^3 - 100\ g/m^3) \cdot 221\ m^3/day = 229{,}935\ g/day$$

Dividing this OD by an OTR of 50 g $O_2/m^2 \cdot$ day yields 4,599 m^2, or 1.1 acres.

6. Once the BTU design capacity was determined, the system performance was evaluated given the 24-hour, SCS Type II synthetic storms for standard return periods of 1 to 100 years. The intensities and depths for these storm events were based on data provided in the *Loudoun County Design Manual.*

Steps 1 through 3 developed the time series water budget. Step 4 established assumed deicer concentrations without needing to go through the process of estimating deicer usage or distributions, and steps 5 and 6 involved the analysis of frequency of runoff volumes to establish the design sizing.

Summary of the Decision Support Process Results

The storm water management design approach for the Runway 1L-19R and associated taxiways project at IAD maps to the decision support process as shown in Figure 4-3. The path taken is mapped using the arrows, and the decisions made are further explained:

Define the nature of the project: Implement a biological treatment unit system to reduce discharged BOD to 100 mg/L and TP concentrations by half in accordance with Virginia Department of Environmental Quality NPDES permit requirements.

Duration of design condition: Decision = Multiday design storm. A multiday storm was chosen because the collection and biological treatment system must work for a variety of storm events in order to comply with NPDES permit limits.

- Are long-term data records available? Decision = Yes. Fifty-seven years of meteorological data were available for analysis.
- Is a robust risk analysis needed? Decision = Yes. A robust risk analysis was needed because the design is based on the long-term average annual storm volume. This analysis qualifies as a form of frequency analysis, the frequency in this case being an average. A continuous flow simulation was performed using storm-water modeling software to determine runoff volume, event duration, and inter-event periods for the dry, average, and wet rainfall years. The average rainfall year was selected for design purposes, and average storm runoff volume was calculated for each BTU.
  - Is deicer load or concentration an issue? Decision = Yes. BOD in runoff diverted to biological treatment units was assumed to have a concentration of 1,140 mg/L near Deicing Pad B and 500 mg/L at remote facilities.
  - Develop time series deicer usage for historical weather conditions. Deicer usage at IAD was assumed, not calculated using historic records.
  - Distribute time series deicer loads among fate compartments. MWAA made assumptions regarding how much of the applied deicer would reach each BTU (for example, maximum BOD concentration of 1,140 mg/L in runoff flowing to the BTU closest to Deicing Pad B).
  - Develop time series water and deicer load budget for historical weather records. MWAA used a storm-water modeling software for this purpose.
  - Analysis of exceedance frequency of deicer loads or concentrations: This step was not specifically conducted in this example.

Path outcome: The analysis conducted by MWAA was consistent with the decision support process outlined in this guidebook. In this case, the risk analysis included a simplified frequency analysis that focused on average event runoff volumes during a representative precipitation year. The output of this analysis was combined with literature and applied empirical equations regarding pollutant removal to size the BTUs. While not all of the suggested features of the frequency analysis process were followed in this example, the structured approach of the decision support process leads to a winter design event based on the delivery of the target level of service.

4.4 Pittsburgh International Airport (PIT)

This section describes a case study of the application of the decision support process to the design of a deicing storm water treatment plant at PIT.

4.4.1 Airport Overview/Project Definition

PIT is approximately 17 miles west of Pittsburgh. Owned, operated, and managed by the Allegheny County Airport Authority (ACAA), PIT is a medium-sized hub airport with approximately 8.2 million annual enplaned passengers and 144,563 annual operations (ACI-North America, 2010).

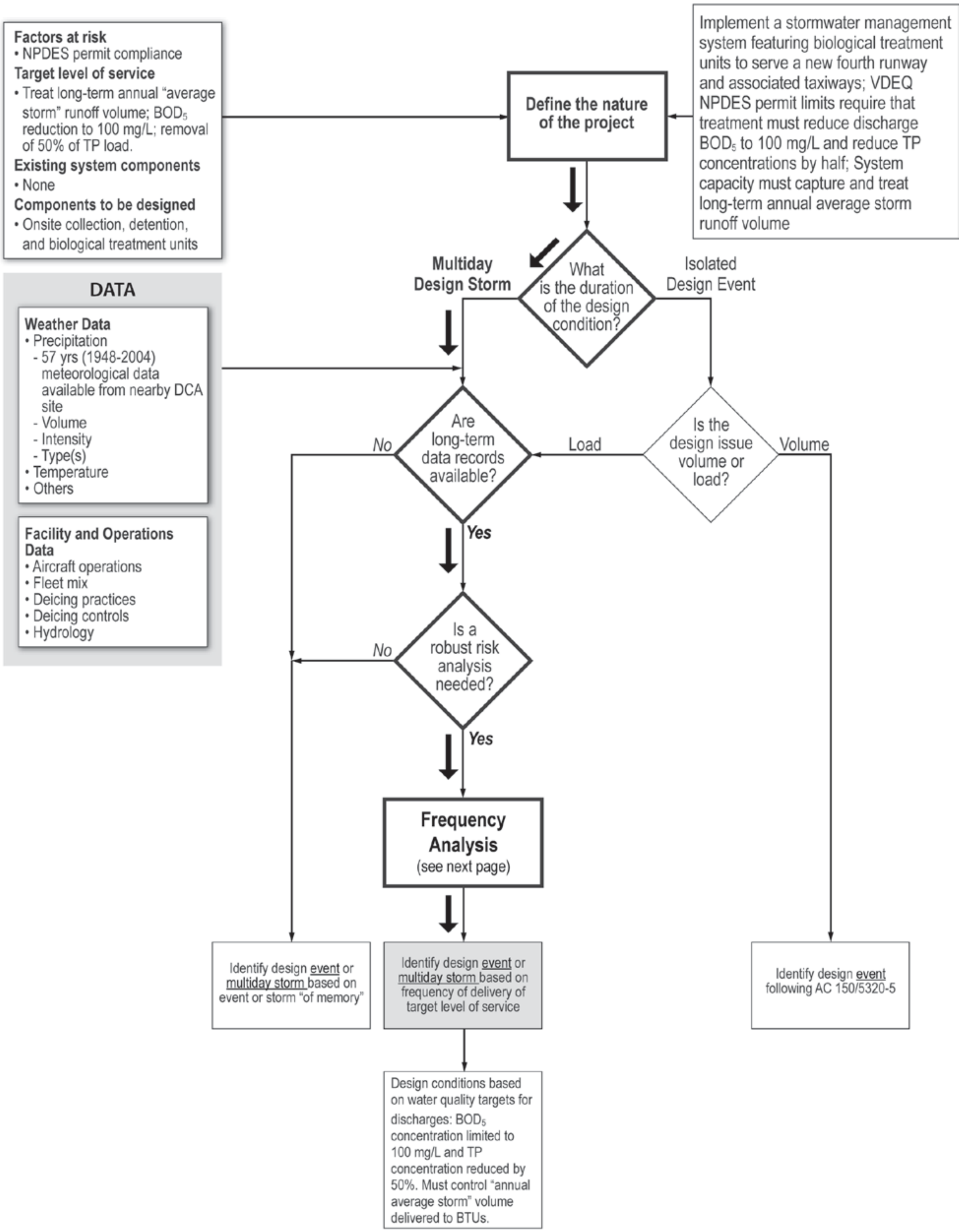


Figure 4-3. Washington Dulles International Airport.

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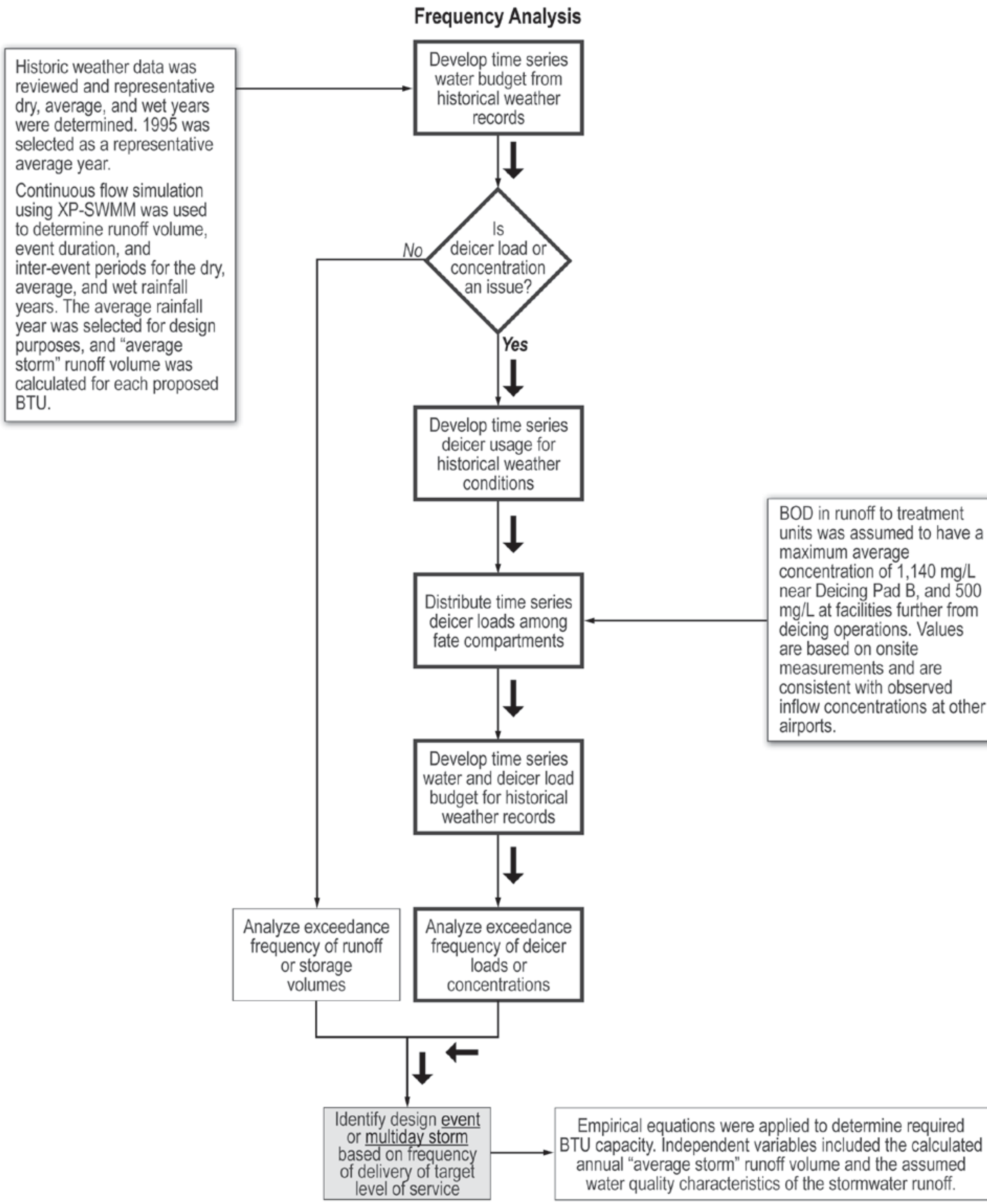

Note: VDEQ = Virginia Department of Environmental Quality

Figure 4-3. (Continued).

The coldest month of the year in Pittsburgh is January, when the 24-hour average temperature is 27.5°F (–2.5°C), and subzero lows (below –18°C) can be expected on an average of 3.9 nights per year. Annual snowfall is 40.3 in. (102 cm). Although Pittsburgh generally experiences moderate weather, a few extreme weather events occurred between 1990 and 2010. The blizzard of 1993 deposited over 23 in. (58 cm) of snow in under 24 hours, and the first North American blizzard of 2010 deposited nearly 2 ft (60 cm) of snow in less than 24 hours.

The Pittsburgh region experiences winter weather conditions that could require deicing runoff collection from

October 1 through May 31. Though Pittsburgh rarely receives snow in October or May, October marks the beginning of freezing temperatures that require defrosting of aircraft that have been parked overnight on the terminal apron.

Deicing operations at PIT typically occur on one of three centralized deicing pads: Deicing Pad Charlie ("C"), constructed in 1992, serves aircraft departures on Runways 10L-28R and 14; Deicing Pad Echo ("E"), constructed in 1992, serves aircraft departures on Runways 10C-28C and 10R-28L; and Deicing Pad Sierra ("S"), constructed in 2001, was built primarily to serve wide-body aircraft such as the Airbus A330 and Boeing 767 but was also sized to serve as a temporary backup to either Deicing Pad C or E. Deicing Pad S now serves not only as the deicing pad for wide-body aircraft but also as a deicing location for aircraft with winglets.

Project Definition

ACAA was issued three administrative orders and a consent order and decree by the Pennsylvania Department of Environmental Protection (PaDEP) to cease the "unauthorized discharge of industrial wastes such as aircraft deicing fluid into waters of the Commonwealth of Pennsylvania." ACAA is addressing these orders through a comprehensive storm water management program for the airport that is designed to (1) improve water quality so that these streams experience a decrease in nuisance bacterial growth (*Spaerotilus*) and odor observations, and (2) slow peak runoff rates to some extent, thereby potentially improving the morphologic condition of the streams (Camp Dresser & McKee, 2004). It should be noted that the receiving streams, including the East Fork of Enlow Run and the West Fork of McClaren's Run, have a very small drainage area above the deicing operations areas and offer minimal assimilative capacity (6 ft^3/s and 4 ft^3/s, respectively).

ACAA has implemented available and practicable technologies as well as known BMPs, including the construction of centralized deicing pads and the use of forced-air application technologies, collection structures, storage tanks, and surface collection measures (GRVs). The full employment of these technologies and practices has not and cannot sufficiently prevent deicing/anti-icing chemicals (DACs) from reaching and negatively affecting the receiving waters, including through point source and nonpoint source discharges. As a result, further control measures are required to reduce DACs in PIT discharges while maintaining the safe and efficient operation of the airport. Therefore, ACAA is proceeding with the design and installation of a deicing storm water treatment plant that uses a three-stage moving-bed biological reactor (MBBR) system. The design is based on collecting 90% of the average annual surface and subsurface runoff containing DACs in quantities sufficient to contribute to water quality impairment in Enlow and McClaren's Runs during the deicing season (October 1 through May 31). This capture level will prevent the capacity of the deicing runoff collection and treatment system from being exceeded more than five times during the deicing season, on average. This capture level will also satisfy the water-quality-based requirements of the Pennsylvania Clean Streams Law.

Existing (Pre-Project) System Components

Current aircraft deicing practices at PIT consist of limited defrosting/deicing at the gates and deicing/anti-icing at the centralized deicing pads. The airlines, deicing pad operators, and spent-deicing-fluid-recycling/disposal contractor currently use a variety of BMPs to capture deicer-laden runoff, including the following:

- Use of GRVs around the gate areas when defrosting activities occur;
- Use of forced-air deicer application equipment at the deicing pads to reduce applied quantity;
- Collection of deicing runoff from the centralized deicing pads via subsurface and surface collection, as well as storage of runoff in low- and high-concentrate tanks; and
- Recycling of spent deicing fluid by a recycling contractor and treatment using a reverse osmosis process.

Performance of Existing (Pre-Project) Facilities

Pre-project BMPs resulted in the collection of approximately 60% of the applied DACs, which correlated to approximately a 55% reduction in $CBOD_5$ load. The annual sampling and monitoring program indicates that while the BMPs have drastically reduced the amount of DAC found in the receiving waters around PIT, nuisance bacterial growth in the streams has not been eliminated, and further reductions in DAC in airport discharges are needed.

4.4.2 Application of Decision Support Process

Risk Factors (Consequences of Failure)

The primary risk factor for the ACAA at PIT is noncompliance with its NPDES permit. A draft NPDES permit was issued in August 2010 with specific discharge limits imposed by PaDEP to meet water quality standards; however, the draft permit has yet to be finalized. The discharge pipe from the treatment plant will have specific limits, including for $CBOD_5$ a maximum instantaneous value of 20 mg/L and a monthly average of 10 mg/L. The draft permit further stipulates for propylene glycol a maximum instantaneous value of 3.4 mg/L and a monthly average of 1.7 mg/L.

Target Level of Service

The target level of service has been defined as not exceeding the capacity of the collection and treatment system more than five times per year. In addition, in-stream dissolved oxygen standards must be maintained 99% of the time, as required by PA Title 25 Chapter 96.3(c), and the draft NPDES permit thresholds must be met.

Performance Goals of New Facilities

The draft performance goals for the PIT treatment plant will be to achieve a total 93% $CBOD_5$ load reduction to achieve less than 10 mg/L of BOD and less than 1.7 parts per million (ppm) of propylene glycol in the receiving waters of PIT. Water quality modeling studies show that a 93% $CBOD_5$ load reduction will require collection and treatment of approximately 75% of the affected runoff.

Assessing Existing Performance Relative to Target Levels

The existing performance of the system is characterized by BOD_5 concentrations on the order of 25 ppm to 30 ppm, with propylene glycol concentrations approaching 2,200 ppm. These levels do not meet the performance goals and lead to the conclusion that additional measures are necessary.

Design Storm Features Critical to Performance Target

The design approach for the MBBR treatment plant is based on continuous hydrologic simulation, yielding a percent load factor reduction similar to a wet-weather total maximum daily load (TMDL) or combined sewer overflow approach. This approach defines exceedance frequencies and recurrence intervals using runoff statistics, as opposed to traditional design storm hydrology (e.g., a 2-year design storm), which assumes that rainfall and runoff recurrence intervals are identical. The analysis resulted in a design storm with an approximate 3- to 4-month 24-hour recurrence interval. As previously mentioned, the percent load factor reduction is based on a treatment system design capacity that is exceeded no more than five times, on average, during the deicing season. This is in contrast to a point source industrial wastewater discharge, which typically uses the design storm approach.

Defining Duration of Design Condition (Multiday Storm or Isolated Event)

Continuous hydrologic simulation, coupled with deicing season receiving-water quality modeling of $CBOD_5$ loading and the resultant in-stream dissolved oxygen concentration, was used to determine that a total $CBOD_5$ load reduction of 93% would satisfy the water-quality-based requirements of the Pennsylvania Clean Streams Law. ACAA further determined through modeling of the 2000 through 2006 deicing season flows and loads that the 2003–2004 deicing season and its use of DACs represented a conservative time period to be used for establishing the design capture volume. The 2003–2004 deicing season records are characterized by one of the highest uses of DACs at PIT since the start of their record keeping in the early 1990s. Also, there were significantly more aircraft departures in 2003–2004 than currently because of PIT's status then as a hub for US Airways, so operations levels are believed to be very conservative. Thus, while a robust analysis of the storm water flow component of the design storm was performed, the deicing load component of the storm water runoff is actually a storm of memory, the 2003–2004 deicing season in this case.

Another defining climatological factor was minimum temperature with respect to deicing collection operations. The efficiency of the MBBR treatment process will decline when influent temperatures are below 37°F, and ACAA is requesting PaDEP to take this fact into consideration when developing the limits in the new NPDES permit.

Frequency Analysis

The frequency analysis begins with developing a time series water budget, which is a tracking of runoff over a specified duration. For PIT, a knee-of-the-curve analysis determined the point at which additional storage and treatment would require significant additional investment for incrementally small environmental gains. The analysis concluded that treatment to achieve a 93% load reduction in $CBOD_5$ was the optimal level of storage/treatment necessary and that it would meet dissolved oxygen standards 99% of the time, satisfying the water-quality-based requirements of the Pennsylvania Clean Streams Law.

Because deicer load is not a factor, no further time series analysis was required in this case. The treatment system has adequate storage capacity and sufficient runoff volume to allow the treatment process to work efficiently regardless of deicing runoff load. At this point in the decision process, an analysis of the frequency of exceedance of the runoff or storage volume is the only remaining step in identifying the winter design storm. As mentioned earlier, ACAA determined the anticipated frequency of exceedance of dissolved oxygen standards to be four or five times a year, based on those times when the temperature during the treatment process dips below 37°F and/or the volume of the treatment system is exceeded.

Summary of the Decision Support Process Results

The decision support process was applied to the ACAA MBBR treatment system's design approach, as shown in Figure 4-4. The path taken is mapped using the arrows, and the decisions made are explained in the following.

Duration of Design Condition: Multiday Design Storm for Storage Volume Sizing

Flow path:

- Are long-term data records available? Decision = Yes. Historic meteorological data, flow, historical deicing usage, and water quality data were available for the analysis.

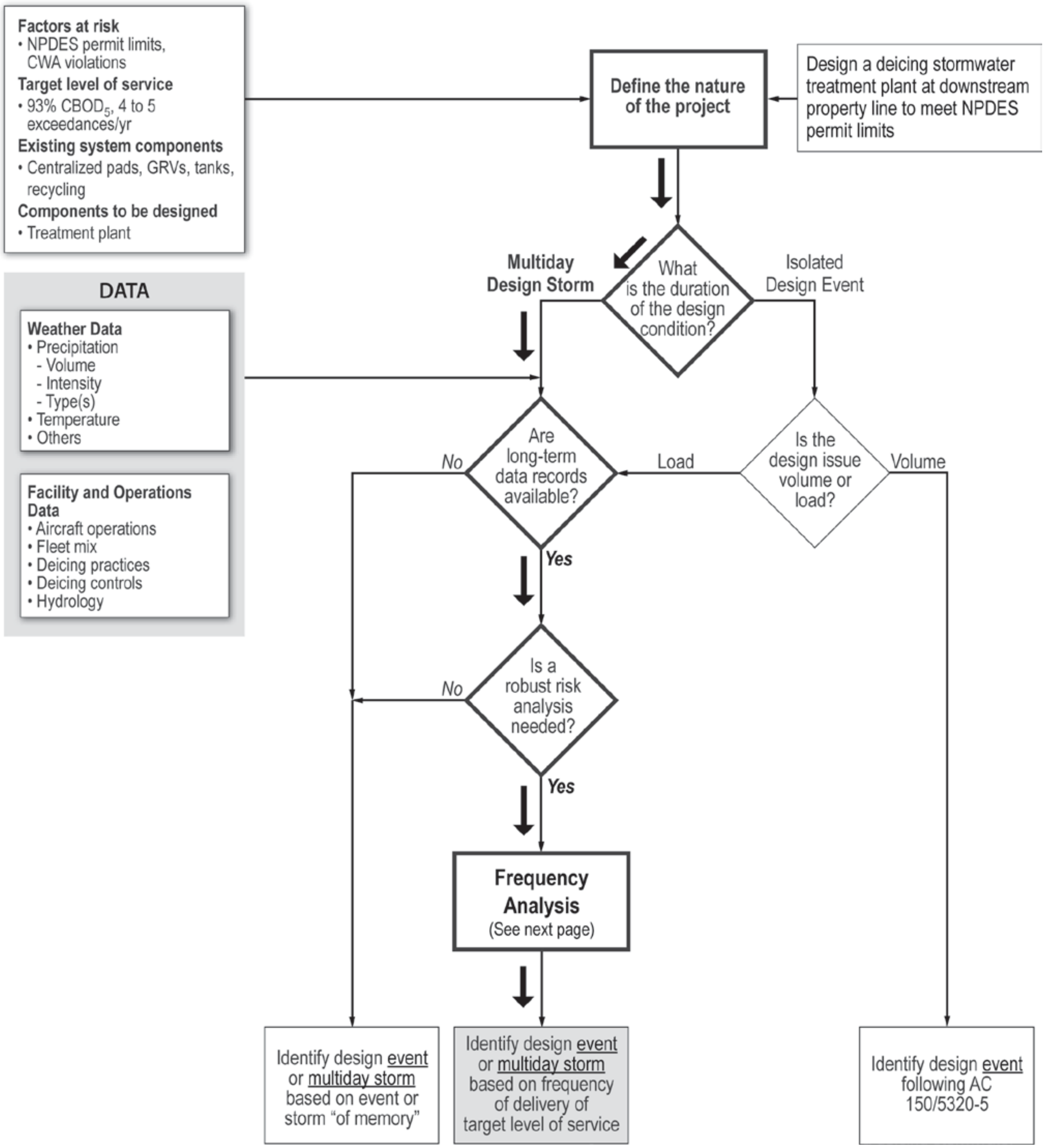

Figure 4-4. Pittsburgh International Airport.
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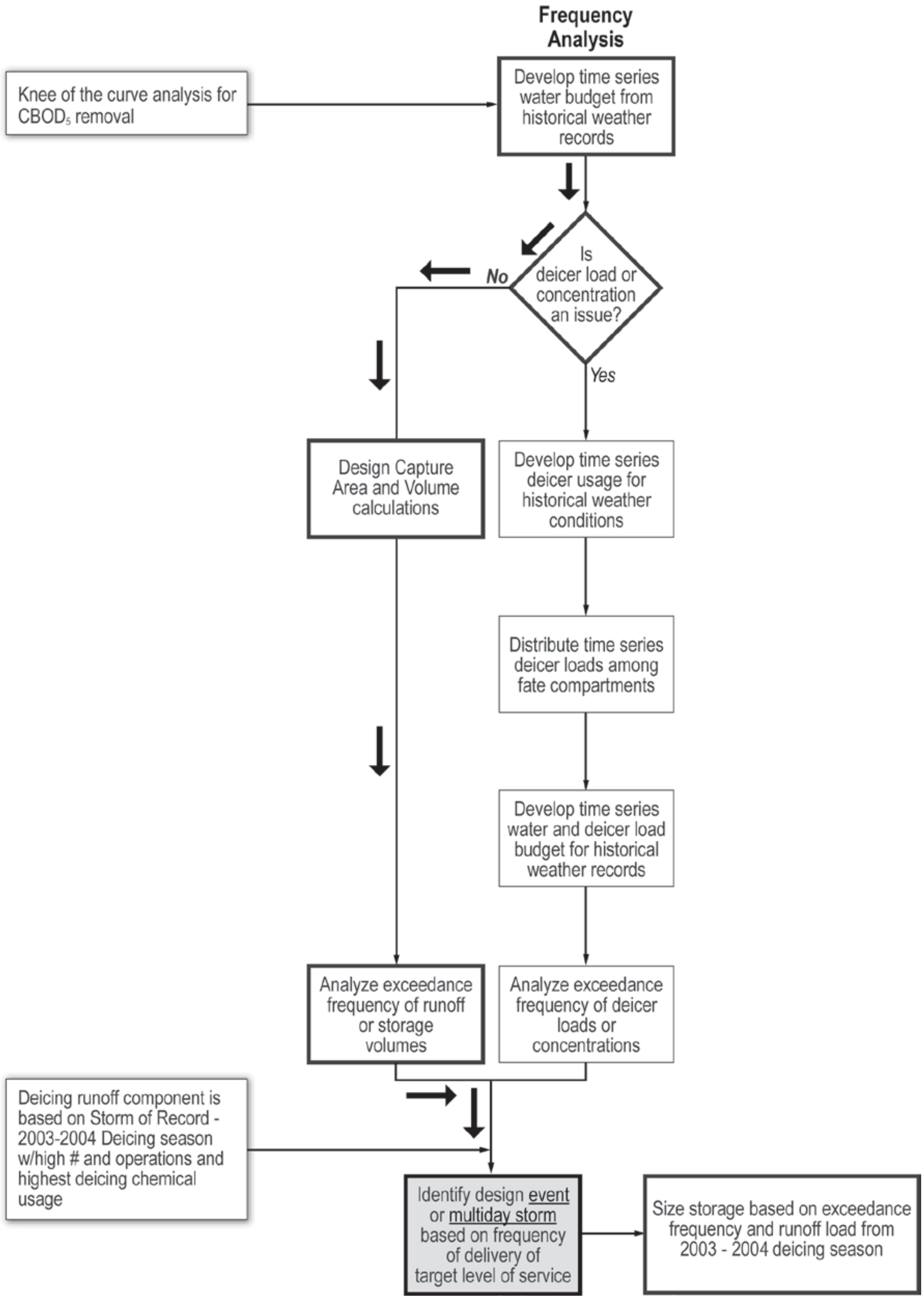

Figure 4-4. (Continued).

- Is a robust risk analysis needed? Decision = Yes. A robust risk analysis was required to determine the design treatment plant's hydraulic capacity.
  - Develop time series water budget: A knee-of-the-curve analysis was performed to determine the point at which additional storage and treatment would require significant additional investment for incrementally small environmental gains. The analysis further determined that a 93% reduction in $CBOD_5$ would satisfy the water-quality-based requirements of the Pennsylvania Clean Streams Law.
- Is deicer load or concentration an issue? Decision = No. In PIT's case, calculating the design capture area and volume were sufficient to develop the treatment plant model. However, the deicer usage from the 2003–2004 deicing season was used in the storm water model to be conservative. The 2003–2004 deicing season represented a season with high deicer usage and correspondingly high aircraft departures prior to PIT losing its airport hub status.
  - Determine design capture area and perform design capture volume calculations. Separate design capture area and design capture volume reports were performed for this purpose.
  - Analyze exceedance frequency of runoff or storage volumes. The exceedance frequency at PIT was the number of times the temperature during the treatment process fell below 37°F (four or five times per season).

Flow-path decision outcome: For PIT, the design solution was to identify a design event or multiday storm based on frequency of delivery of the target level of service (93% reduction on $CBOD_5$ with an exceedance frequency of 4 to 5 times per year).

While not all of the suggested features of the process were followed in this example, the decision support process led to an equivalent winter design event based on the frequency of delivery of the target level of service.

4.5 Portland International Airport (PDX)

This section describes a case study of the application of the decision support process to PDX's Deicing System Enhancement Project.

4.5.1 Airport Overview/Project Definition

PDX is operated by the Port of Portland and provides both domestic and international passenger and cargo services. The airport has 14 passenger airlines that serve over 14 million travelers each year. The airport is also served by 11 all-air cargo carriers. PDX is the 34th largest passenger airport and the 24th largest cargo airport in the United States. In addition, PDX houses the 142nd Fighter Wing of the Oregon Air National Guard.

Located in Portland, OR, PDX enjoys a moderate climate with average annual temperatures of 53.6°F and average deicer season (October through April) temperatures of 53.7°F. Portland typically sees 151 days of precipitation each year, but only 2.1 days per year with snow, ice, or hail exceeding 1.0 in. (NWS, 2011b).

The PDX deicer management system that existed prior to the case study project collected, stored, and discharged deicer-laden runoff from Basins 2, 4, 6, and 7 to the Columbia Slough and to the City of Portland's Columbia Boulevard Wastewater Treatment Plant (CBWWTP).

Discharges into the Columbia Slough are subject to the conditions of a NPDES permit issued by the Oregon Department of Environmental Quality (DEQ). Discharges to the CBWWTP are subject to the conditions in an industrial pretreatment discharge permit with the City of Portland.

Project Definition

In 2003, the port undertook modifications to the then-existing deicing system in order to improve its performance and comply with the terms of its NPDES permit. However, the installed system was found to have limitations, and more significant infrastructure enhancement was determined to be needed. In 2006, the DEQ issued a Mutual Agreement and Order (MAO) to the port to bring the deicing system into compliance with environmental requirements. The port agreed to a larger project to enhance the existing system and committed to having it fully operational by April 2012.

The targeted deicing system improvements include:

- Collection: Expansion of collection system to capture storm water runoff containing deicing materials from the western airfield. Approximate collection area to be contained is 2,100 acres (S. Aha, personal communication, Feb. 24, 2011).
- Storage: Increase storage capacities for concentrated and diluted runoff. Approximate storage capacities are 25.8 million gallons diluted and 5 million gallons concentrated (S. Aha, personal communication, Feb. 24, 2011).
- Treatment: Addition of an on-site anaerobic treatment facility for treating concentrated effluent prior to discharge to the Columbia River or the sanitary sewer.
- Discharge: Addition of a Columbia River outfall, which was completed in January 2010.

Existing (Pre-Project) System Components

In 2003, PDX completed construction of a $31 million deicing system designed to monitor, collect, treat, and discharge deicing storm water runoff to the Columbia Slough and to the City of Portland sanitary system. The system includes the use of GRVs that capture concentrated runoff from aircraft deicing and anti-icing operations. All other runoff is collected by the storm water drainage system. Within the collection system, runoff is tested for BOD concentrations to determine if it is concentrated (1,000 mg/L or more) or diluted (800 mg/L or less). Concentrated runoff is diverted to an on-site storage tank, the contents of which are discharged to the sanitary sewer for treatment at CBWWTP. Diluted runoff is diverted to one of several dilute detention basins and eventually discharged to the Columbia Slough.

Performance of Existing (Pre-Project) Facilities

PDX exceeded its NPDES permit limits during each winter season from 2003 to 2006 (i.e., 2003–2004, 2004–2005, and 2005–2006). In general, the system was judged to be effective at collecting deicing runoff from runways, taxiways, and terminal areas. However, the collection system did not collect runoff from Basin 1, which serves the western half of the airfield. In addition, flows in the receiving waters (Columbia Slough) were much lower than anticipated, and as a result the allowable discharge loads under the NPDES permit, which vary with flow in the slough, were often very low. These conditions contributed to the failure of the deicing system to consistently perform in compliance with the NPDES permit requirements.

4.5.2 Application of the Decision Support Process

Risk Factors (Consequences of Failure)

In conjunction with its Deicing System Enhancement Project, PDX obtained from DEQ a revised NPDES permit, which was approved in June 2009 (Port of Portland, 2010). The primary risk factor for PDX is noncompliance with this new NPDES permit.

Target Level of Service

The terms of the NPDES permit require that the system be able to handle all runoff from storm events up to the 5-year recurrence level. PDX may claim an *upset* if the system is insufficient for a given storm event, such that runoff bypasses the collection and treatment systems. However, the frequency of recurrence of upsets should not exceed once every 5 years, on average.

Performance Goals

Discharges to the Columbia Slough are to be limited to dilute runoff with BOD concentrations of 20 mg/L or less. Runoff with BOD concentrations in the range of 20 mg/L to ≤200 mg/L is either diverted to the dilute detention basins or discharged to the Columbia River via the dilute storage tanks. Runoff greater than 200 mg/L is diverted to the concentrated storage tanks. PDX has an operational goal to collect and store concentrated runoff with BOD concentrations of 200 mg/L or greater and to then treat the runoff on site or deliver it to the CBWWTP for off-site treatment.

In addition to regulatory compliance, the objectives of the PDX Deicing System Enhancements Project are as follows (CDM, 2008a):

- Reduced reliance on outside agencies for compliance;
- Efficient operation, cost-effective implementation, minimized ongoing maintenance costs, and a 20-year minimum project life;
- Increased confidence that the system will maintain compliance with current regulatory requirements and flexibility to respond to potential changes such as effluent limit guidelines or potential changes in the Columbia Slough's TMDL allocation;
- Allowance for PDX growth, both in terms of BOD loading and changes in airport infrastructure;
- Use of proven technologies that complement the existing system infrastructure; and
- Meeting the milestones of the DEQ–Port MAO compliance schedule.

Finally, to accomplish these goals over the long-term, PDX considered future conditions as part of their analysis. A design year of 2022 was selected to represent airfield operational levels. In addition, climate change impacts were incorporated into the analysis.

Assessing Existing Performance Relative to Target Goals

The existing deicing system collects and treats runoff with BOD concentrations of 1,000 mg/L or greater—a lower limit that is five times the new concentration collection goal (200 mg/L). The performance of the existing system was not sufficient to meet water quality limits specified in the 2004 PDX NPDES permit.

Design Storm Features Critical to Performance Target

The design approach for the PDX system expansion is based on providing system capacity sufficient to capture and treat all runoff with BOD concentrations above 200 mg/L, with a recurrence interval for upsets of not less than 5 years.

Defining Duration of Design Condition (Multiday Storm or Isolated Event)

The permit requirement of a 5-year recurrence interval for system upsets required a multiday storm approach.

Availability of Long-Term Data Records

Hourly meteorological data are collected and reported by the NCDC at PDX. Over 50 years' worth of detailed meteorological data are available. Available parameters include ambient air temperature, dew point temperature, and precipitation depth. These data were used by PDX to derive the precipitation type for each winter weather event, such as frost, ice, and snow.

Historical, current, and projected facility and operations data are available for PDX. Historical flight schedule data from 2003 to 2007 are available from the PDX noise department, while individual airlines have provided current (2007–2008) flight schedules. Future flight schedules through 2022 are available from the Terminal Area Forecast prepared for PDX by the FAA. Data regarding the number and type of aircraft used at PDX are available as provided by the airlines.

Data regarding deicing practices, such as type (I or IV) and volume, are available as a function of weather conditions and aircraft type. Similarly, information related to the existing deicing runoff control system, including GRV operations, water quality thresholds for runoff diversion and discharge, and storage capacities, are also available.

Hydrologic and water quality data are available to PDX for the Columbia Slough receiving waters. Continuous flow data are collected when discharge pumps are operating, and the data are available from 2003 to present. In addition to historical data, slough discharge equations and flow assumptions are provided by the port (CDM, 2007a). The city has collected water quality data in the slough, including dissolved oxygen, temperature, and TMDL pollutant levels, for more than a decade (S. Aha, personal communication, Feb. 24, 2011).

Data available for PDX are summarized as follows:

- Over 50 years' worth of hourly meteorological data
  - Observed temperature and precipitation
  - Derived precipitation type (frost, ice, snow)
- Historical, current, and predicted future flight schedules (2003–2022)
- Current and future fleet mix
- Current deicing practices
- Current deicing controls
- Limited hydrologic and water quality data for the receiving water (Columbia Slough and Columbia River)

Need for Robust Risk Analysis

A robust risk analysis was needed to evaluate system design sizing to achieve the permit requirement of a 5-year recurrence interval for system upsets.

Frequency Analysis

A simulation model was used to develop detailed representations of the existing and proposed PDX deicing management systems and to evaluate sizing and other design considerations in terms of risk (i.e., frequency) of upsets. This analysis consisted of a long-term, continuous simulation using historic, current, and projected conditions. Historic meteorological data driving the analysis were constrained to the most recent 22 years (i.e., 1985 to 2007) in order to account for climate change effects observed in the older data. Fate compartments were characterized based on a Transport Canada study on the fate and transport of deicer after it is applied to aircraft. The PDX analysis assumed that 90% of applied Type I and 23% of applied Type IV deicers are available for capture.

Summary of the Decision Support Process Results

The decision support process was applied to PDX's enhancement project design approach, as shown in Figure 4-5. The path taken is mapped using the arrows, and the decisions made are explained in the following.

Define the nature of the project: PDX collects and discharges deicing runoff to the Columbia Slough. In response to repeated exceedances of NPDES permit limits, PDX began designing and implementing deicing collection and treatment system enhancements in 2006 to achieve a BOD of less than 200 mg/L.

Duration of the design condition: Decision = Multiday storm. A multiday storm evaluation was required to determine the event that would result in a system upset no more frequent than once every 5 years.

- Are long-term records available? Decision = Yes. Fifty years of historical meteorological data were available; however, PDX limited the analysis to the last 22 years to account for climate change.
- Is a robust risk analysis needed? Decision = Yes. Compliance with the NPDES permit required a design that would result in a minimum recurrence interval of 5 years for exceedance of permit limits.
  - Develop time series water budget from historical weather records. PDX limited weather time series to 22 years (1985–2007) to account for climate change effects observed in the historical record.

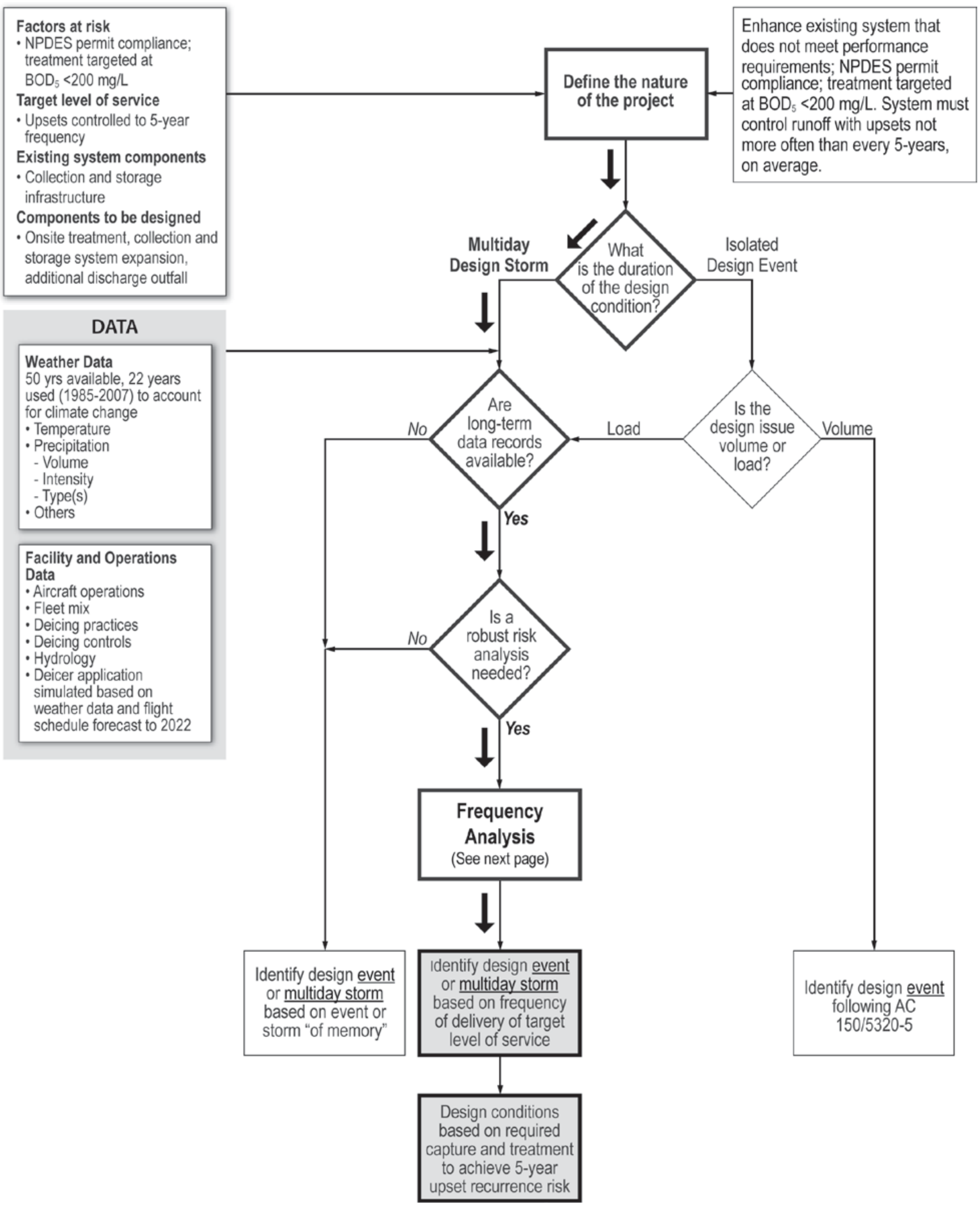

Figure 4-5. Portland International Airport.

(continued on next page)

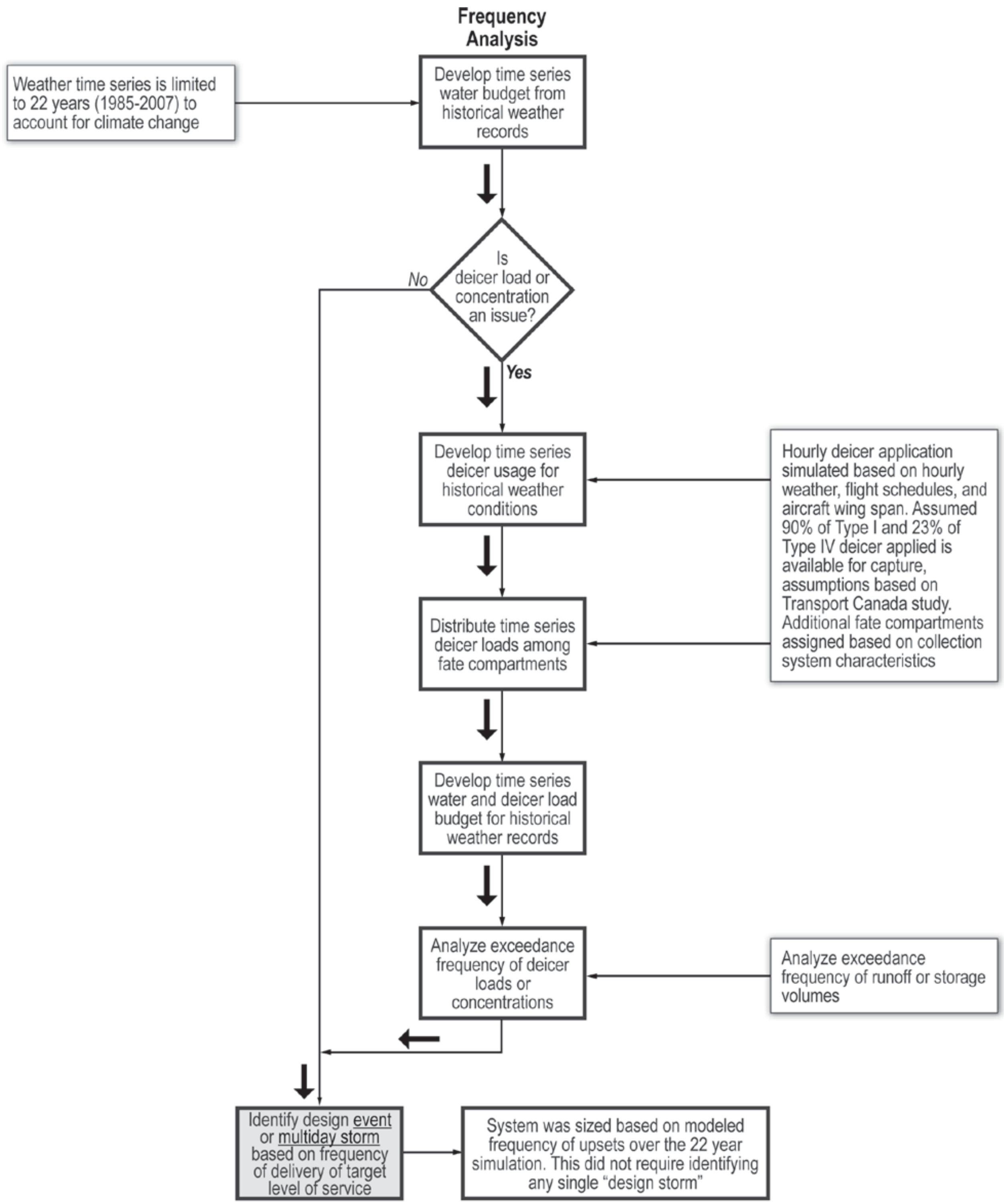

Figure 4-5. (Continued).

- Is deicer load or concentration an issue? Decision = Yes. Load or concentration is an issue at PDX and is driven by the risk factor of exceeding NPDES permit limits.
  – Develop time series deicer usage for historical weather conditions. In its analysis, PDX used simulated hourly deicer application on the basis of hourly weather, flight schedules, and aircraft wing span.
  – Distribute time series deicer loads among fate compartments. PDX assumed that 90% of applied Type I and 23% of applied Type IV deicer are available for capture based on a Transport Canada study. Additional fate compartments were then assigned on the basis of collection system characteristics.
  – Develop time series water and deicer load budget for historical weather records. PDX considered only the most recent 22 years of historic meteorological data to adjust for the effects of climate change. PDX then considered future aircraft operations with a selected design year of 2022 to estimate the deicer load budget.
  – Analysis of exceedance frequency of deicer loads or concentrations: PDX determined the number of upsets over the 22-year simulation and sized the system to yield a 5-year upset-recurrence frequency.

After exploring a number of design storm approaches (CDM, 2007b; CDM, 2008b), PDX targeted a system-performance-level approach to guide the design of the enhanced deicing system.

The analysis conducted by PDX was consistent with the decision support process outlined in this guidebook. However, rather than selecting a specific design storm, PDX defined an acceptable system performance level based on a selected recurrence frequency of 5 years. Slight modifications were made to the decision process to allow for future conditions, including operations and climate change. While not all of the suggested features of the process were followed in this example, the decision support process worked in leading to a winter design event based on the frequency of delivery of the target level of service.

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APPENDIX A

Regulatory Implications of Defining Winter Design Storms

Typically, a winter design storm or event is defined to ensure that the capacity of a facility or system component will ensure compliance at an acceptable service level (i.e., risk) with one or more regulatory requirements. This appendix provides an overview of the relevant FAA and EPA regulations that may apply to deicing runoff management system designs.

A.1 FAA Regulatory Drivers

The FAA provides guidance on design criteria for airport storm water drainage projects that can include deicing controls in the following ACs:

150/5300-14, "Design of Aircraft Deicing Facilities." This AC discusses the sizing of deicing facilities in terms of the physical configuration of deicing pads and apron deicing areas to accommodate aircraft and in providing enough deicing positions to ensure adequate traffic capacity under severe weather conditions. No specific guidance is provided regarding the design basis for runoff management systems beyond a discussion of factors that affect sizing and the acknowledgement that "the state or local authority having jurisdiction generally sets construction and design standards."

150/5320-5C/Unified Facilities Criteria 3-230-01, "Surface Drainage Design." This combined Unified Facilities Criteria document and FAA AC provides comprehensive and practical guidance to engineers, airport managers, and the public for the design of storm drainage systems associated with transportation facilities. Criteria are provided for the design of storm drainage systems that collect, convey, and discharge storm water on and around pavements and other transportation facilities. The updated criteria in this document are considered standard practice and allow users to take advantage of drainage design concepts and methods that are widely understood and accepted throughout the industry today.

150/5300-13, "Airport Design." This document serves as the foundation of airport project design and establishes the basic criteria the designer must adhere to when designing airport deicing facilities. This AC discusses general airport design practices such as runway and taxiway safety and object-free areas, longitudinal and transverse grading criteria, geometric design criteria, and other pertinent criteria that must be considered by the designer when siting and designing an aircraft deicing facility.

A.2 Environmental Regulatory Drivers

A variety of environmental regulations and permitting programs authorize storm water (or other appropriate) discharges associated with airport deicing and anti-icing operations. As noted at the end of this section, federal, state, and local wet-weather permits and regulatory obligations are expanding in scope and complication, and entirely new programs are on the horizon. Therefore, the most current regulatory requirements must be considered in any evaluation.

Federal Acts Affecting Airport Wet-Weather Discharges

CWA Section 402 creates the NPDES program, through which all nonexempt facilities that discharge pollutants from a point source directly into a water of the United States must obtain a permit. The terms "pollutant," "point source," and "waters of the United States" are very broadly defined. Point-source discharges include, for example, sanitary and industrial wastewater that is treated at POTWs before being discharged to surface waters, treated wastewater from industrial facilities that is discharged directly to surface waters (with no POTW involved), and certain designated wet-weather flows that have been identified by Congress or the EPA for treatment prior to their discharge to surface waters. In most cases, storm water that is discharged to the receiving waters via a constructed system (pipe, culvert, channel) is considered a point source necessarily subject to permit.

Airports (and other regulated entities at airports) may have NPDES direct-discharge permits for storm water or other treated industrial wastewaters that flow directly to receiving water bodies. Airports that capture deicing operation runoff for treatment or recycling (or that have other on-site 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 system. Finally, airports that collect storm water or other wastewater in tanks may truck those wastes to a centralized waste treatment facility for subsequent treatment generally governed by the terms, conditions, and prices set by an agreement with the centralized waste treatment entity.

Federal Storm Water Program

Currently, there are three principle storm water regulatory programs in the United States: the industrial storm water permit program regulating discharges from a specific list of industrial operations, the municipal storm water program that controls discharges from most municipal separate storm sewer systems (MS4s), and the construction storm water program that applies to all active construction that disturbs a threshold quantity of land at a site. An airport could be subject to all three of these programs.

Under EPA's industrial storm water permit program, 11 categories of industrial operations are required to obtain NPDES storm water permits. These categories are denoted by narrative descriptions and industrial classification codes, including Sector S "transportation facilities" that conduct vehicle or aircraft maintenance, equipment cleaning, or airport deicing operations [see 40 CFR § 122.26(b)(14)(viii)]. The industrial storm water program regulates only those discharges associated with industrial activity and otherwise unregulated storm water discharges that are commingled with those industrial storm water discharges. Purely administrative buildings, administrative parking lots, and storm water discharges from "nonindustrial" areas at the airport may not be covered by the industrial storm water program.

The EPA created a municipal storm water program that requires most operators of MS4s to obtain NPDES storm water permits. Under the EPA's MS4 storm water 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, gas station, food service, etc.). Because these areas generally are designed to drain away from the industrial or active construction areas at an airport (and into the MS4, obviously), the municipal storm water program may not be a significant factor in winter design storm analyses.

The EPA also established a storm water permit program for any construction activity that disturbs 1 acre or more of land or is part of a common plan of development that would exceed 1 acre. While applicable to construction operations at airports, the construction storm water program generally would not apply to airport deicing activities, with the exception of initial construction of certain management practices, drainage systems, or other controls. Nevertheless, as described previously, if that construction storm water drained into ponds or other drainage systems dedicated to the industrial storm water program, it would be regulated regardless of its designation as "construction-related storm water." These overlapping aspects are important considerations for appropriately sizing collection and drainage structures and the overall consideration of a design storm.

In summary, the CWA requires that airports obtain a NPDES permit for any direct discharges of process wastewater and most storm water. Storm water can be regulated either through the industrial, construction, or municipal storm water programs. Indirect discharges of deicing or other industrial wastes sent to a POTW require authorization and often a permit from the POTW's authority. Finally, any other wastewater may be trucked to a centralized waste treatment site if it cannot be managed in any other way on the airport property.

Airport Storm Water Discharge Permits

The NPDES program generally is implemented through two types of permits: *general permits* that reflect the permitting authority's recognition that many similar types of facilities and operations may be covered under a more universally applicable permit, and *individual permits* that are issued specifically to the regulated facility. The following discussions describe these two permitting devices.

General industrial storm water permits. Because of the volume of regulated entities subject to the storm water program, the EPA has used general permits to ease its administrative burden, and states with delegated permitting authority 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 they are completed, facilities that wish to comply with the general permit typically must file a Notice of Intent form that certifies that the permittee will comply with the terms and conditions contained in the permit.

Individual industrial storm water permits. Unlike general permits, individual permits are tailored to the actual physical and operational characteristics at the permittee's facility and require a thorough analysis of site-specific conditions. For this reason, individual permits are preferred by some regulators over general permits for complex facilities or where specific environmental concerns exist. While the EPA and most states have developed general permits that are broadly applicable to industrial storm water discharges, there has been a departure from this trend with 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 rationale behind this requirement is that general permits provide limited site-specific controls, and while they may provide sufficient environmental protection for small or medium-sized airports, they are unlikely to do so for large airports.

There are several fundamental differences in the development of general versus individual permits. General permits tend to provide more narrative approaches to fundamental permitting issues (for example, compliance with water quality standards and implementation of BMPs). Individual permits require a two-part analysis that first mandates implementation of appropriate technology standards (typically BMPs in storm water permits) and next requires that the permit writer assess receiving waters 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. These requirements may be expressed as numeric limits either on the concentrations or mass loadings associated with the discharges or 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).

Industrial pretreatment permits. Not all deicing runoff is discharged directly to waters of the United States through general or individual storm water 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 that 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. For the most part, deicing runoff is well suited to treatment at POTWs because it has high 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 numeric limits that ensure compliance, or it may rely on BMPs to ensure that waters sent to the POTW are acceptable. As with direct-discharge permits, numeric limits may be expressed as concentration or mass-based limits, and usually both daily maximum and monthly average restrictions are provided.

Co-Permittees

Either general permits or individual permits may allow airports to include major tenants as co-permittees. Whether to include tenants as such, 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 with tenants and manage significant interactions with them to ensure that appropriate controls are in place, functioning, and lead to permit compliance. This may require relatively detailed collaboration on the airport's storm water pollution prevention plan, deicing runoff management plan, and other compliance mandates in the permit.

A.3 Considering Probability in Permit Compliance

There are no regulatory standards for defining the frequency of the deicing design event. While the building blocks of NPDES permits described provide the framework, permit-writer discretion fills in many of the specific aspects of the final NPDES permit, including the design event criteria.

The probability of design event occurrence is one of the issues that can be discussed and negotiated by an airport during the permit drafting and negotiation process. Airports can engage permit writers to gain an understanding of the design conditions and other factors that the permit writer may be considering and to offer alternative approaches that might meet the permit writer's needs while addressing key design storm factors that the airport may desire or that need to be addressed in a final permit. For example, the permit writer may want to apply a storm design criterion of some type but may not necessarily understand how deicing events differ from ordinary precipitation events. That lack of understanding may lead to the permit being developed based on conventional storm water approaches, such as collecting the first ½ in. of precipitation or the 2-year, 24-hour storm event, neither of which may be an appropriate design basis for a system that manages meltwater from snowfall that has accumulated over several days or even weeks of freezing precipitation.

Finally, the NPDES permit program provides certain protections for situations that may arise during permit compliance, particularly with regard to excessive precipitation or flooding conditions. Standard NPDES permit conditions include two particular safe harbors—one referred to as an "upset," the other as a "bypass"—each of which may include reference to threshold conditions beyond which system capacity is acknowledged to be exceeded. The negotiation of these conditions should take into consideration the expected frequency of upset and bypass conditions.

A.4 Looking Forward

A challenge in defining an appropriate design storm event lies in the uncertainty of future environmental standards. NPDES requirements are certain to change, acceptable frequency of permit exceedances may change, and permit writers' level of discretion is an unknown variable. How does the likelihood of more stringent environmental standards and aggressive enforcement affect the effectiveness of a design storm event using current regulatory requirements?

There are several programmatic developments ongoing at the EPA that may affect storm water permitting and determinations relating to design storm factors for airports in the future. First, the EPA is assessing whether to change its basic storm-water permitting philosophy from a BMP-based approach to one that relies more heavily on end-of-pipe numeric effluent limits. A numerical approach will increase the risk and liability for noncompliance and is likely to require many airports to revisit the design basis for existing controls to confirm that they will comply with NPDES permits.

Next, the EPA has initiated a major expansion of the NPDES storm-water permitting program. The EPA has indicated that it will expand the number of MS4s subject to the storm-water permit program as well as place more strict mandates on regulated MS4s regarding controls on discharges *into* the MS4. This may force MS4s to place greater emphasis on regulating any entity that discharges into the MS4, such as an airport, as opposed to focusing on controlling the discharges at the point where the MS4 discharges into a U.S. water. The EPA also wants to expand the storm water program to control "post-construction" storm water discharges for the life of a building project. As of the date of this report, the EPA has indicated that it may require every developed or redeveloped site to control the first inch of precipitation on site (no discharge) or mandate that the developed site mimic the predevelopment hydrology of that site. While it is not possible to predict what the EPA ultimately may mandate, these issues are critical for factoring into future design storm analyses.

The EPA also is proposing to refine its guidance for determining what constitutes a "water of the United States" for permitting purposes. As currently stated, the current draft guidance would significantly expand the scope of regulated water bodies and how the NPDES permits described previously would be implemented and designed. For example, an airport that currently uses naturally created ponds on its property for controlling flows and obtaining on-site treatment prior to discharge off site may have to treat those ponds as "waters of the United States" and add new treatment devices before any water can drain into those ponds, even though they are fully contained on airport property and not subject to any public use or enjoyment. The EPA also may regulate drainage ditches that drain to waters of the United States as if those ditches were natural water bodies. No resolution is imminent, but these are issues that should be looked into before design storm factors are finalized for an airport.

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	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
HMCRP	Hazardous Materials Cooperative Research Program
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
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
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