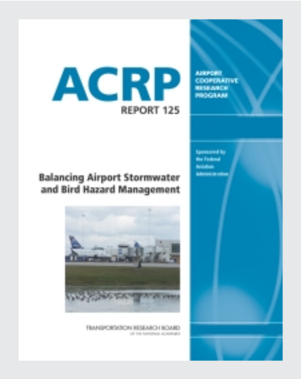

Balancing Airport Stormwater and Bird Hazard Management

DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 125

Balancing Airport Stormwater and Bird Hazard Management

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AIRPORT COOPERATIVE RESEARCH PROGRAM

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

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

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), Airlines for America (A4A), and the Airport Consultants Council (ACC) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

Research problem statements for the ACRP are solicited periodically but may be submitted to the TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

Once selected, each ACRP project is assigned to an expert panel, appointed by the TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

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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.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

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FOREWORD

By Joseph D. Navarrete
Staff Officer
Transportation Research Board

ACRP Report 125: Balancing Airport Stormwater and Bird Hazard Management and the accompanying CRP-CD 159, *Bird Strike Risk Analysis and Stormwater Management Decision Tool* provide valuable guidance to help airports identify and evaluate stormwater management and bird mitigation practices. The tool uses the FAA's familiar safety management system (SMS) approach to assess potential risks to minimize hazards posed to aviation by birds attracted to bodies of water as well as to evaluate alternative stormwater management options. The report and tool can be used to foster interaction between airport industry practitioners and environmental regulators and help them reach implementable solutions that meet their respective objectives and missions.

Airports are required to manage the quantity and quality of stormwater on site while ensuring the safety of aircraft operations; however, many stormwater management options can create potential aviation bird hazards. In addition, airports are faced with potentially conflicting federal, state, and local stormwater and wildlife management regulations and guidance. Research was therefore needed to develop proactive tools and guidance to assist airports in making decisions that balance stormwater management and bird hazard management.

The research, led by Environmental Resource Solutions, Inc., began with a review of applicable regulations, guidance documents, and relevant research. Next, the research team identified airport stormwater management options and assessed the potential effect these options could have on wildlife (specifically, waterfowl) behavior. Using this analysis, a matrix was developed that considered the likelihood and severity of a bird strike given various stormwater design characteristics. A draft tool was then developed using a SMS framework. Two airport case studies were conducted to obtain input from initial users and to see how the tool performed at airports of different sizes and activity levels and with differing amounts of available data. The research team used the results of research and the case studies to prepare the final tool and to prepare the report.

The report documents the research objectives, details the research approach, presents the findings and conclusions, and suggests areas of future research. The report also features appendices, including a summary of the case studies and references.

The decision tool provides a five-step process for identifying improved airport stormwater management practices. In the first step, users enter the bird species most relevant to their airport, strike history, and other observational data. Users then input existing bird mitigation measures and the design elements of existing or planned stormwater facilities and practices. Based on these inputs, the tool identifies the potential risk based on current conditions. In subsequent steps, the tool enables users to identify alternative mitigation strategies and/or stormwater designs to see their potential benefit in terms of reducing bird strike risk. The tool also features valuable resources, including a list of hazardous water-dependent bird species, bird mitigation definitions, USDA-recommended landscaping vegetation for use at airports, definitions, and the references and assumptions used to develop the tool. Lastly, the CD-ROM includes a summary sheet describing the research and tool that is suitable for outreach material.

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.

SUMMARY

Balancing Airport Stormwater and Bird Hazard Management

Airports are subject to a variety of environmental requirements that drive the need for stormwater best management practices (BMPs) to control the quantity and quality of stormwater discharging from their property. The U.S. Federal Clean Water Act of 1972 (with its subsequent amendments) identified the need to address water quality issues, which led to the implementation of federal, state, and local regulatory programs requiring the management of stormwater quality and quantity. Airports have historically incorporated BMPs to comply with these requirements, such as stormwater detention ponds and vegetated swales, many of which have exposed open water, vegetation, and other design characteristics that attract wildlife. Research shows that 10 of the 15 bird species most hazardous to aircraft are highly attracted to these types of water features (DeVault et al. 2011).

To address this hazardous wildlife concern, the FAA has established guidelines for airport stormwater management to provide for aircraft safety. These guidelines promote drainage of water away from movement areas as quickly and efficiently as possible, minimizing the attraction of hazardous wildlife species. Airports are challenged with implementing required stormwater BMPs while ensuring the safety of aircraft operations in accordance with FAA advisory circulars (ACs) and Federal Aviation Regulations (FARs). Bird Strike Risk Analysis and Stormwater Management Decision Tool is available on the accompanying CD and is intended to assist airports with evaluating opportunities to balance stormwater management and bird strike hazard management for water-dependent bird species.

Each airport is unique and highly variable in operations, land availability, and local regulatory requirements for stormwater management. Airports need to balance aviation growth and development with resource management while minimizing public safety risk. This tool provides airport personnel with a means of assessing the potential risk of a bird strike associated with a current or proposed stormwater BMP following the FAA protocols for Aviation Safety Management Systems (SMS).

The tool assesses risk as a product of severity and likelihood. The risk of a bird strike is assumed to increase if the severity (extent of aircraft damage) or likelihood of a strike increases. Strike severity is affected by the size or number of birds struck. Research indicates that the following factors affect severity: relative hazard score of a particular species, the perimeter irregularity of the stormwater design, the slope to the water's edge, the proximity of water bodies to each other, and the percentage of vegetation coverage within the stormwater pond. The likelihood of a strike is affected by the history of bird observations, the proximity of those sightings to the movement areas, the species strike history, and the proximity of the stormwater BMP to the movement areas.

This tool also examines how existing mitigation strategies and additional techniques may be used to mitigate bird strike risk. The risk analysis portion of the tool takes the above data and calculates an overall risk. The stormwater management decision portion of the tool provides a framework for considering wildlife risk, along with other influential factors, into the decision-making process when managing existing BMPs and selecting new BMPs.

CHAPTER 1

Background

Problem Statement

ACRP Project 09-08 “Balancing Airport Stormwater and Wildlife Hazard Management: Analysis Tools and Guidance” was established to address the following problem statement:

> Airports are required to manage the quantity and quality of stormwater on site while ensuring the safety of aircraft operations. Many stormwater management options can create potential aviation wildlife hazards. In addition, airports are faced with potentially conflicting federal, state, and local stormwater and wildlife management regulations and guidance. Research is therefore needed to develop proactive tools and guidance to assist airports in making decisions that balance stormwater management and wildlife hazard management.

Objective

The objective of the research performed for ACRP Project 09-08 was to develop a tool and associated guidance to assist airports with identifying and evaluating stormwater management BMPs and wildlife mitigation practices that may be used to minimize hazards posed to aviation by wildlife.

Project Scope

The research team developed the Bird Strike Risk Analysis and Stormwater Management Decision Tool to provide airport personnel with a qualitative means of assessing the potential risk of a bird strike associated with a current or proposed stormwater BMP. The tool is designed following a SMS risk assessment methodology to aid in the integration of bird strike risk into an airport’s existing (or future) SMS plan. Based on the problem statement’s emphasis on the contribution of stormwater BMPs to an airport’s strike risk, the tool development focused on water-dependent birds that are attracted to stormwater BMPs. Other wildlife species were assumed to pose strike risks that are independent from stormwater management decisions.

Airports are unique and differ in location, local environmental regulations, wildlife, users, and/or funding. Therefore, the research team investigated a variety of subjects to help in the development of the tool and instructions, including the following:

- Existing stormwater management options, their potential to impose an aviation wildlife hazard, and possible mitigation techniques to reduce these hazards;
- Federal guidance and regulations pertaining to stormwater management, wetlands, aviation wildlife hazards, and natural resource conservation including ambiguities/conflicts among them; and
- Potential state and local stormwater management requirements and conflicts with airport wildlife hazard management objectives.

In addition to the research listed above, the research team tested the tool with two airports. The resultant case study data aided the research team by demonstrating the tool’s performance and providing valuable feedback regarding the tool before presenting the draft final tool to the project panel.

CHAPTER 2

Findings and Applications

Research Findings

The research team reviewed documents on bird strike risk and stormwater BMP design and used factors identified in the research and from the research team's experience to develop a draft Bird Strike Risk Analysis and Stormwater Management Decision Tool. As a result of the research, feedback from the case studies, project panel teleconference, and panel meeting, the research team identified the research findings described in the following paragraphs. Conclusions and recommendations from these findings are included in Chapter 3.

Scope and Applicability

Tool Use at Airports with Limited Data

Because the tool provides a risk analysis based on bird hazard data from an airport, and the risk and mitigation options are species-dependent, airports without significant bird strike data or bird observation records may find the tool less predictive. In addition, airports experiencing fewer operations and reporting few strikes, and airports without concerns about water as a bird attractant may find this tool less predictive. Some airports may not possess the appropriate staff, knowledge, or funding to evaluate bird strike risk in regard to stormwater management. The tool is most effective when used by a team of airport personnel and/or consultants, ideally consisting of an airport engineer, airport wildlife biologist, and airport operations specialist. This may result in limited use of the tool among airports lacking significant bird hazard data, extensive stormwater management systems, or a large staff. The research team considered this limitation and identified ways to make the tool more functional to airports with these restrictions.

To begin, the user must select species data and input strike data. If the user does not select a species of concern or does not enter any strike data for the airport, the user cannot proceed. The tool provides ranges to increase options when estimating factors such as distance to nearest water body, number of species observations, number of strikes, etc. While the tool provides a more accurate risk analysis when actual bird strike data from an airport are entered, these additional tool functions will expand the use of the tool to include airports that have limited bird strike data. Although users may select "Other" for bird species data, this can reduce the accuracy of the risk assessment. The research team will emphasize that the quality of results depends on the quality of inputs in the guidance contained within the tool. It will be the responsibility of the user to input the most accurate and specific data available.

Weighting Factors

Weighting factors are one aspect of a risk assessment that can increase or decrease the influence a risk factor has on the math calculations. Originally, weighting factors ranged from 0 to 10 and the research team provided default weighting factors for each risk factor in the risk matrix. For example, the "hazard ranking" of each species (or species selection) factor was given a default weighting factor of 10, while the "history of observations" factor was given a weighting factor of 2 and the "history of strikes" factor was given a weighting factor of 1. The rationale for the weighting of the species selection factor was that it is the most important factor when determining bird strike risk, and, therefore, it was given the highest weight. Based on research team experience with wildlife management, species selection was estimated to be 5 times as influential as the "history of observations" factor, therefore "history of observations" was assigned a default weighting factor of 2. The "history of observations" data is important, although it can be highly variable, and thus it was assigned a reduced weight. Species identification and corresponding hazard score was estimated to be 10 times as influential to risk as the "history of strikes" factor, therefore "history of strikes" was assigned a default weighting factor of 1. Although the strike data can be revealing, the shortage of species identifications in the database and the general absence of data for many airports can provide misleading information. The goal was to make the species identification and the corresponding relative hazard scores from DeVault et al. (2011) the most significant wildlife risk factor.

Through discussions with the panel, the research team decided to change the approach for assigning importance to the species relative hazard score. As opposed to using the experience-based factor of 10, the tool now calculates an average of the severity factors other than hazard score, and then this score is averaged with the hazard score to estimate the overall severity. The weighting factors of 2 and 1 were retained to differentiate the relative importance of likelihood factors in estimation of the overall likelihood.

The tool also originally allowed users to define additional weighting factors to be applied on top of the default weighting values to further adjust the importance of each risk factor to severity or likelihood. Through discussions amongst the research team and with the project panel, the research team decided to replace this approach with confidence levels. Confidence levels allow users to adjust the relative influence that individual wildlife risk factors have on the overall risk if they have particularly low confidence in the quality of a particular type of wildlife data. For example, if the user indicates low confidence in the quality or completeness of their strike data, then the history of strikes input will have less significance in determining the overall risk. To simplify user input, the user will simply select "High" or "Low" confidence, and factors that are associated with "Low" confidence will have their weighting values reduced by one-half compared to default weighting values. Factors with "High" confidence will retain the non-adjusted default weighting values. If the user has equal confidence in the quality of strike data, history (frequency) of observations, and proximity of bird sightings, they may select equal weighting for all three and keep the default weighting as originally designed. This approach simplifies a difficult concept for users to understand and allows the overall risk to be tailored to airport-specific data quality.

Other Wildlife Hazards and Attractants

The scope of this project was to develop a tool addressing bird strike risk associated with stormwater, and explicitly excluded other wildlife (mammals and herpetofauna) and attractants not related to stormwater. This clearly represents only one component of wildlife hazards at an airport and, as such, the tool will not be able to provide an airport with an overall wildlife hazard risk assessment. While the research team recognizes the benefit of developing a risk assessment tool that addresses other wildlife species and non-stormwater related hazards, those are outside of the scope and budget of the current project. The research team recommends that these species and their attractants be further characterized as part of a separate research effort. Therefore, the species that may be analyzed in the tool are limited in accordance with the project scope. The research team will indicate in the guidance that the risk analysis is specific to water-dependent bird species and does not quantify all wildlife hazard risks or attractants.

Assessment of Overall Risk

The tool is designed to assess the wildlife attractant risk for bird species individually and does not provide a cumulative assessment of risk for all bird species of concern. The research team considered developing a calculation of cumulative risk, but determined that an overall assessment could prove more complicated than beneficial. If cumulative risk was calculated based on the average risk for all species considered, high risk for an individual species might be masked by low risk for multiple other species or vice versa, potentially giving the user a false sense of risk. Additionally, mitigation measures are species-specific, and both risk and mitigation should be considered by airports on a species-specific basis. The research team intends that airport staff mitigate their stormwater designs based on their riskiest species.

Species Definition and Birds Not Affected by Stormwater

The initial list of species included in the tool was based on a list of 77 wildlife species gathered by DeVault et al. (2011) based on national wildlife strike data. The species listed are the most frequently reported wildlife species to cause damaging strikes to aircraft and/or cause a negative effect on flights (aka "adverse effect" strikes) from 1990 to 2009; however, not all of these species are birds or are attracted to stormwater BMPs. Per the scope, the risk assessment produced by the tool is focused on the attraction of birds to stormwater BMPs, and the tool allows users to mitigate for this risk by modifying the design of potential stormwater BMPs. At the case study visit, PMP staff identified the turkey vulture as a species of concern for their airport to be analyzed in the tool. Although turkey vultures are not attracted to stormwater, the inclusion of this and other non-water-dependent species in the tool suggested that changes to the stormwater BMP design would affect the species-specific bird strike risk, when this is not scientifically accurate. The initial and residual risks produced by the tool integrate species and stormwater characteristics. They cannot be analyzed independently of one another.

As a result, the list of species included in the tool was modified to include only water-dependent birds that pose an aircraft strike risk (i.e., included on the list of 77 hazardous wildlife species). This will prevent users from selecting a bird not affected by stormwater and attempting to reduce bird strike risk through stormwater management decisions. The research team recognizes that many users may not be aware of which species are attracted to water and may be frustrated when they see that their species of concern is not on the list. See Appendix G for a list of species included in the tool with their associated hazard rankings.

Cost and Other Non-Avian Decision Factors

The research team was tasked with identifying other factors, beyond bird strike risk, that may affect stormwater management decisions at airports. The research team referred to their own stormwater management experience to develop a list of considerations that typically play a role in selecting an airport-specific stormwater management approach:

- Construction cost
- Operations and maintenance requirements
- Performance and regulatory acceptance
- Constructability
- Footprint and space requirements

In developing the list of these non-avian factors, the research team recognized that many of these factors are highly specific to each airport, the particular site selected for the BMP, and the associated regulatory requirements. The importance of these factors compared to each other and compared to the level of bird strike risk may vary depending on an airport's resources, priorities, and other unique perspectives. Although the scope and budget of this project did not allow for the tool to provide the user with an assessment of these factors, it was important that the tool facilitate the user being able to perform these assessments based on outside resources. Thus, a BMP alternatives analysis worksheet was incorporated into the tool to allow the user to document these assessments for each BMP alternative, rank the importance of the factors based on the airport's specific priorities, and select a BMP alternative that best meets the airport's stormwater management objectives.

Microsoft Excel 2010

The Bird Strike Risk Analysis and Stormwater Management Decision Tool is designed to allow users to enter and/or read local information (e.g., FAA strike data, local stormwater BMPs) as an Excel spreadsheet does. Tool users are not expected to see or modify the software, and they will not have to purchase expensive software to use the application (other than basic Microsoft Office-type software). The research team was tasked with making the tool available to airport personnel with varying degrees of background in wildlife hazards and risk analysis, thus the Excel platform was determined to be the most appropriate for this project.

Through the development of the tool, the research team decided to use dropdown selection lists in Excel to simplify input selection. The use of these particular dropdown lists is a feature of Microsoft Excel 2010 that does not convert to earlier versions of Microsoft Excel. The research team weighed the benefits enabled by the drop-down lists (streamlining inputs, reducing confusion, and prohibiting inappropriate inputs) with the potential limitation of the tool for users with older versions of Microsoft Excel. The research team determined that most airports are likely currently using Microsoft Office 2010 or will be upgrading in the near future. Therefore, Excel 2010 is required to operate the tool.

Bird Strike Risk

Incorporating Airport-specific Strike Data

The severity risk factors include the relative hazard score of an individual species, which was derived based on the number of adverse effect strikes reported for that species within the airport environment (below 500 feet above ground level) (DeVault et al. 2011). The percentage of reported strike history for water-dependent birds for a specific airport associated with a specific species is included as a likelihood factor for each species and is titled, "Percentage of Total Airport Bird Strikes Associated with Species." The "Percentage of Total Airport Bird Strikes Associated with Species" risk factor is a calculation of total strikes reported for that species divided by the total strikes reported for all water-dependent birds at the airport.

Levels or "banding" is a common SMS risk assessment method and the research team developed five levels for each risk factor outlined in the risk matrix. The banding categories describing the "Percentage of Total Airport Bird Strikes Associated with Species" risk factor are listed in Table 2-1.

Strikes that are not linked to a specific aircraft (e.g., carcass recoveries) are often reported to the FAA Wildlife Strike Database and should be included in an airport's strike history

Table 2-1. Likelihood levels for percentage of total airport bird strikes associated with species.

Likelihood	Percentage of Total Airport Bird Strikes Associated with Species
Frequent	>75
Probable	50–75
Remote	10 to <50
Extremely Remote	5 to <10
Improbable	<5

when calculating the rate of overall strikes. Unfortunately, species data may be absent when only partial carcasses are recovered. If species data is known and reported, it is incorporated into the above calculations.

The comparison of total bird strikes per operation at an airport compared with the national average is also included as a likelihood factor titled, "History of Total Bird Strikes per Operations Compared to National Average." This risk factor is a calculation of the total strikes reported for all water-dependent birds at the airport divided by the total operations for the airport for the period of bird strike record compared with the national average airport strikes of water-dependent bird species per airport operation. The national averages were calculated using the number of strikes for water-dependent bird species per airport, from 1990 through 2012 (Dolbeer et al. 2013) and the total national aircraft operations for the same time period for airports with operations data reported in the FAA air traffic control database (ATADS 2014).

The banding categories describing the "History of Total Bird Strikes per Operations Compared to National Average" likelihood factor are listed in Table 2-2. If the user's airport has a strike rate within one standard deviation of the national average, the likelihood will be remote (Level 3) for this risk factor. If the user's airport strike rate is greater than one standard deviation from the national average, the likelihood will be either probable or frequent (Levels 4 or 5) for this risk factor. If the user's airport strike rate is less than one standard deviation from the national average, the likelihood will be either extremely remote or improbable (Levels 2 or 1) for this risk factor.

Strikes that are not linked to a specific aircraft (e.g., carcass recoveries) are often reported to the FAA Wildlife Strike Database and should be included in an airport's strike history when calculating the rate of overall strikes. Unfortunately, species data may be absent when only partial carcasses are recovered. If species data is known and reported, it is incorporated into the above calculations.

For the two strike data factors, the user must enter the number of strikes per species for each identified species of concern within a specified time period (e.g., 22 years or 5 years, etc.), the total strikes for other water-dependent bird species not identified as a species of concern, and the number of aircraft operations at the airport for the same time period. The tool will calculate the percentage of strikes associated with each species of concern at that airport for the "Percentage of Total Airport Bird Strikes Associated with Species" likelihood factor, and the rate of strikes per operations to compare with the national average for the "History of Total Bird Strikes per Operations Compared to National Average" likelihood factor.

Bird Strike Mitigation Measures

The research team identified various mitigation measures that would reduce bird strike risk at an airport by managing the hazard itself. The SMS framework categorizes risk mitigation measures by relative effectiveness at reducing risk. The research team decided to adopt the SMS framework or "Hierarchy of Controls" to reduce risk and organized the mitigation measures by each control. This is also a standard function of Failure Modes and Effects Analysis (FMEA) widely used in the safety profession to classify the effectiveness of controls (ISO 2009).

The SMS Hierarchy of Controls or "defense in depth model" implies that additional levels of mitigation equate to an increase in risk reduction. However, there appears to be an intrinsic diminishing return on risk reduction with implementation of additional mitigation measures. That is, the risk reduction associated with implementing five measures is not the same as five times the risk reduction associated with implementing one measure. The research team determined that the tool needed to address the concept of decreased risk with increased mitigation while incorporating diminishing returns from implementing numerous mitigations. In order to account for diminishing returns for implementation of multiple mitigation measures, the tool quantifies a risk reduction for zero, one, or more than one measure in each category. The research team recognizes there may be some additional risk reduction with implementation of additional mitigations, but that it would be less effective and difficult to quantify that risk.

The research team decided to include the mitigation measures described in Table 2-3, which are grouped by SMS categories (categories are listed in decreasing order of effectiveness).

Table 2-2. Likelihood definitions for history of total bird strikes per operations compared to national average.

Likelihood	Strike Rate for Species in Question Compared to National Average
Frequent	> 2 standard deviations above national average
Probable	Between 1 and 2 standard deviations above the national average
Remote	Within 1 standard deviation of the national average
Extremely Remote	Between 1 and 2 standard deviations below the national average
Improbable	< 2 standard deviations below national average

Table 2-3. Bird strike mitigation measures.

SMS Hierarchy of Control	Mitigation Measures
Elimination	Not Applicable (N/A)
Substitution	Not Applicable (N/A)
Engineering	Falconry Harassment with dogs Toxicants; fumigants Anti-perching devices Capture and lethally take Lethal take (shooting) Install wire grid across/around BMP Alter mowing regime Capture (trap) and relocate Dead bird effigies Install bird balls Pyrotechnics Nest destruction Other
Warnings	Bioacoustics (distress calls) Propane cannons Vehicle harassment Visual deterrents Warnings from ATC Other
Administrative	Maintain a wildlife management log (data collection) Signage Wildlife hazard management training WHA/site visit Wildlife strike reporting Wildlife control permits Wildlife patrols/inspections Wildlife hazard management plan Other

The research team included the "Elimination" and "Substitution" Hierarchy of Control categories here as conceptual SMS components, but does not include realistic wildlife mitigation options. The user will not be permitted to select a mitigation option under these categories. The user may select a mitigation option under Engineering, Warnings, and/or Administrative controls. The research team further assessed the effectiveness of each mitigation measure by allowing the user to indicate whether the measure is ongoing or only conducted when a species is observed, i.e., upon sighting. If the measure is "ongoing," the user receives a greater risk reduction than if the measure only took place "upon sighting." Safety science literature outlined in International Standards Organization (ISO) 31010 (2009) suggests that the level of risk will depend on the adequacy and effectiveness of existing and proposed controls. Factors to consider when addressing the efficacy of controls include: current mitigation options available, whether the existing mitigation options have proven to reduce risk to a more tolerable level, whether the mitigation options are being implemented in the manner intended, and whether they can be continuously evaluated for effectiveness if required. These factors can only be satisfied with confidence if there are proper documentation and assurance processes in place (e.g., annually auditing a wildlife hazard control program). The level of effectiveness for a particular control, or suite of related controls, may be expressed qualitatively, semi-quantitatively, or quantitatively. It is valuable to express and record a measure of risk control effectiveness so that judgments can be made on whether effort is best expended in improving a current mitigation or implementing a different mitigation option.

Numeric Definition of Risk

Originally, the tool was designed so that the higher the risk output number, the lower the risk. For example, a Canada goose was assigned a hazard ranking of 2, while a swallow was given a hazard ranking of 5. The justification being that the hazard rankings were akin to mitigation/management priorities. A goose is a higher priority than a swallow, so it would be assigned a lower number (higher priority). Similarly, a risk score less than 10 was high risk (or red) and a risk level higher than 21 indicated low risk (or green). Throughout the case studies, it was determined that this approach was counter-intuitive for the user. The research team reversed the order so that a higher number indicates greater risk.

Stormwater BMPs

Definition of Stormwater BMPs

The Amplified Research Plan specified that the tool would allow the user to select the size and type of stormwater management options. The research team determined that there are many different types of BMPs. Different names are often used for similar BMPs which could lead to confusion if the user does not see the specific name for their BMP on the list. Also, for some BMP types, there could be wide variations in the characteristics of a specific BMP that may greatly influence its attractiveness to birds, making a risk assessment based on a specific BMP type difficult. For example, a swale can have steep slopes or gradual slopes, a dry detention pond can have vegetation or not, or an infiltration basin can be close or far from another water body in the area or from the air operations area (AOA). All of these characteristics are associated with varying risk levels, regardless of the BMP type. Assigning default characteristics to BMPs by type would ignore the variations in design approaches between airports, and would also limit the tool to a set list of BMPs that may not consider emerging approaches for stormwater management.

To account for site-specific design variations and maintain flexibility for a variety of BMP types, the research team decided to define the BMPs by the basic characteristics affecting their attractiveness to birds, potentially shared by several types of BMPs. Guidance is provided in the tool to inform the user on the characteristics with the potential to affect wildlife attraction, and recommended values for these characteristics. A copy of a list of recommended wildlife-resistant plants developed by USDA is also included with the tool as an example to help the user identify plant species for their BMP, although users are encouraged to consult with local resources for additional species that may be appropriate within their geographic region. The research team identified the following BMP characteristics related to wildlife attraction, which will require determination by the user based on their selected existing BMP, proposed BMP, or potential BMP modification:

- Water exposure
  - Is water fully enclosed?
  - Does the BMP draw down water within 48 hours?
- BMP geometry
  - BMP—perimeter irregularity
  - BMP—apparent slope to water's edge
  - Is the length:width ratio (aspect ratio of the BMP) 3:1 or greater?
- BMP Location
  - BMP—proximity of water bodies (from each other)
  - Proximity of BMP to airport movement areas
  - Is there less than 12 acres of combined standing water (6,500 feet) of the AOA?
- BMP Vegetation
  - BMP—percentage of stormwater vegetation coverage
  - Do all vegetation species appear on the USDA recommended plant list?
  - Is BMP vegetation a monoculture?

BMPs with no open water surface, such as underground detention, initially were not addressed in the tool calculations. Although they have no associated wildlife risk, the research team decided to include them (i.e., is water fully enclosed?) so that they could be evaluated based on the non-wildlife factors and compared with open-water BMPs in the overall assessment.

Quantification of Stormwater BMP Risk Factors

The research team used published literature as a starting point for which factors could most influence the severity risk (i.e., increase the size or numbers of birds attracted to the airport) of a bird/aircraft strike in regards to stormwater management systems or BMPs. Blackwell et al. (2008) studied the avian use of stormwater management ponds considering the following factors: pond surface area, ratio of the area of open water to area of emergent and woody vegetation, perimeter irregularity, and geographic isolation. Previous research also suggested that species richness increases in wetland complexes versus large, isolated wetlands (Brown and Dinsmore 1986) and also increases in those wetlands with an intermediate level of emergent cover (Gibbs et al. 1991). The research team deduced that an increase in species richness leads to an increase in strike risk (i.e., increasing diversity could lead to an increase in the size or number of birds attracted to the airport). Further, Blackwell et al. (2008) found two of the 30 ponds they surveyed to have a particularly high average of individuals utilizing the pond. Mean usage throughout the other 28 ponds in the study was 2.0 individuals with a standard deviation of 1.6 individuals. The two outlier ponds had an average usage of 23.3 individuals and 15.3 individuals, respectively. These averages are substantially higher than the overall average of 2.0 individuals. These ponds had two characteristics that were interesting to note: (1) they had little to no emergent vegetation and (2) they had a high perimeter irregularity. These results seem reasonable as this mimics what our team's biologists often observe in the field. Therefore, an intermediate level of vegetation was determined to be the most attractive to birds (i.e., the most risky, Level 5, Appendix A, Table A-2), while 100% vegetative cover with no open water exposed was the least attractive (Level 1). No vegetative cover (Level 2) was determined only slightly more attractive than 100% coverage.

In addition, Blackwell et al. (2008) illustrate that the more irregularly shaped a pond is, the higher the probability of use by birds. Therefore, having a perimeter greater than that of a perfect circle is more attractive (i.e., risky) than having a pond perimeter equal to that of a perfect circle (Level 1). With regards to the tool, if the ratio value of the pond perimeter to the perimeter of a circle of equal area is less than 1.1, that implies a negligible level of risk. Conversely if the ratio value is greater than 6.4, we consider that to be most risky (Level 5) for that factor. The other levels fall between those two extremes and are based on demonstrated probabilities of use. Blackwell et al. (2008) also found that the more geographically isolated a stormwater pond is, the lower the probability of use by birds. Thus, being part of a wetland complex is more attractive (risky) than being an isolated pond as previously concluded by Brown and Dinsmore (1986). Therefore, the research team incorporated geographic isolation into the tool. The probability of use is near zero when the water bodies are 8 km or greater from one another (Blackwell et al. 2008), therefore 8 km (approximately 5 miles) was determined the minimum for the least risky level of that severity factor. All of the findings in Blackwell et al. (2008) mirror the anecdotal observations biologists continuously see in the field.

Regulatory Requirements for BMPs

One of the objectives of the tool is to provide guidance on BMP selection to meet regulations while minimizing wildlife attraction in accordance with FAA requirements. Although there are a variety of BMP types to choose from (e.g., infiltration basin, vegetated swale, detention basin, etc.), many of the BMP types have similar design features with the potential to contribute to their attractiveness to wildlife (e.g., vegetation, open water surface, side slopes, etc.). The team turned to industry guidance with consideration for what characteristics make BMPs more or less attractive to wildlife. FAA AC 150/5200-33B *Hazardous Wildlife Attractants On or Near Airports* identifies specific BMP design criteria that minimize the attraction of wildlife. These criteria include the exposure of the water surface (FAA recommends a 48-hour drawdown time with no standing water between storm events, or use of physical covers such as bird balls), vegetation (FAA recommends eliminating vegetation), and length-to-width or aspect ratio (FAA recommends a "narrow" shape). Additional resources were used to further define these criteria, including the Washington DOT Aviation Stormwater Manual and USDA vegetation guidance. Rather than evaluate these regulatory requirements with banding levels (like the risk factors outlined above), they were incorporated into the tool as priority impact factors, which are input as answers to yes or no questions. The risk calculations are affected negatively or positively based on whether the design criterion complies with industry recommendations for minimizing the attraction of wildlife (where a "Yes" response indicates a design characteristic that complies with industry recommendations and leads to reduced strike risk). The tool originally included a factor for the linearity of the water surface edge, in accordance with BMP guidance in FAA AC 150/5200-33B *Hazardous Wildlife Attractants On or Near Airports.* However the research team removed this factor after it was determined that it may be redundant with the perimeter irregularity factor from DeVault et al. (2011). Both factors are assumed to represent the similarity of an irregular BMP perimeter to a natural water body, which has the potential to increase wildlife attraction.

Vegetation Attractiveness

There are additional variables including climate (Zhao et al. 2006) and immigration accessibility (Daniels 1992) that can affect species richness; however, there is a general positive correlation between animal diversity and plant diversity, particularly when comparing homogeneous habitats (MacArthur 1964; Recher 1969). Studies have shown that aquatic macroinvertebrate communities are at least as rich and diverse in highway stormwater retention ponds as surrounding ponds, suggesting that stormwater ponds can contribute to biodiversity on a regional scale and provide crucial landscape connectivity (Le Viol et al. 2009). For example, mean nesting success for red-winged blackbirds in highway stormwater ponds was found to be comparable to nesting success recorded in natural wetlands (Sparling et al. 2007). Therefore, just because a stormwater BMP is man-made, does not mean that it necessarily lacks in diversity. Decreasing plant diversity in an airport's BMP will help facilitate an overall sterile environment. In the tool, the user's risk is affected by his or her response to the question, "Is BMP vegetation a monoculture?"

Although not all vegetation has the same attractiveness to birds, existing research does not definitively indicate that one plant species is better over another in every situation, and species vary significantly across the United States. For example, research shows that certain kinds of grasses are more attractive than others to Canada geese (Washburn and Seamans 2012), but this same information is not available for all hazardous wildlife species. The USDA has developed a recommended plant list for use on airports. Although originally intended for use in Ohio, it is rather all encompassing, applicable across the country, and provides a long list of vegetation options. USDA/FAA generally prefers to have BMPs constructed containing those species and considers them to reduce wildlife attractiveness.

Greater vegetative diversity increases the diversity in wildlife species; however, there is no mathematical equation that relates plant diversity directly to animal diversity as there are additional factors influencing diversity (Zhao et al. 2006; Daniels 1992). That is, biologists cannot say that an increase by a factor of 10 in plant diversity translates to an increase by a factor of 2 in animal diversity, etc. The research team is also concerned with an airport's ability to correctly identify and count all of the species in the BMP. Thus, the USDA plant list is included in the tool to assist users with identification of species, provide the user with a way to assess their confidence in the identification of their plant species, and as a recommendation of plant options that are less attractive to wildlife.

Proximity of BMP to Movement Areas/Other Water Bodies

The tool includes separate inputs for the proximity of the BMP to airport movement areas (a likelihood factor) and the proximity of water bodies to each other (a severity factor). The "proximity of water bodies" severity factor includes any other water body, lake, ocean, natural wetland, etc., and is not exclusive to only stormwater BMPs or only other water bodies within the AOA. There is research that suggests that the closer water bodies are located to one another, the more attractive those water bodies become to birds. This may appear counterintuitive; however, as noted above, research shows that "wetland complexes" are more attractive than single water bodies to birds (Brown and Dinsmore 1986). Also as previously mentioned, Blackwell et al. (2008) found that if the water bodies are farther than 8 km apart, the level of attractiveness (due to proximity) drops dramatically. [We converted 8 km to miles (approximately 5 miles) and defined 5 miles as a "negligible" severity level (Level 1)].

At the CLE site visit, the airport suggested adding a tool parameter that would account for the synergistic effect of having attractants located on opposite sides of the airfield, allowing potential bird flight paths to conflict with aircraft flight patterns due to an increased likelihood of birds crossing the runway to travel from one BMP to another. The research team acknowledged that there isn't an easily-defined parameter that would accurately assess this situation, which is extremely complex and unpredictable in nature. The research team decided that the current tool parameters indirectly address this risk and that the addition of another parameter could make the tool overly complex. As such, the research team did not add this additional parameter to the tool.

Application

It is the research team's intent that the tool be integrated into the overall BMP planning and selection process to help bring bird strike risk considerations to the forefront amongst competing BMP selection factors. When applied during the BMP planning phase, the tool may be useful to explore the bird strike risk associated with conceptual BMP design characteristics, and allow for changes to reduce risk with minimal project cost impacts. The tool may also be used to demonstrate the potential bird strike risk impacts of particular BMP regulatory requirements, therefore facilitating discussion and negotiation with regulators during the planning process. Outreach materials associated with the tool will include a broad overview of the conflict between stormwater design and wildlife hazard management at airports, and provide guidance on how and when to most effectively use the tool to reduce risk. The outreach material will also provide brief instructions on how the tool works (conceptually). Ultimately, these materials, along with the tool, should be incorporated into the stormwater design process. The tool allows for documentation of potentially acceptable alternatives, and will prompt airports to incorporate these other non-wildlife factors to allow the selection of a preferable alternative that meets airport constraints and priorities.

The research team anticipates that the following entities are stakeholders in this project:

- Airport planning departments
- Airport safety managers
- Airport engineering departments
- Airport operations staff
- Environmental compliance staff
- Airport facilities managers
- FBOs/airport tenants
- Planning, engineering, and environmental consultants working for airports
- Airport wildlife biologists or managers
- Local government representatives that manage/operate airports
- Local, state, and federal government agencies that regulate stormwater design criteria on airports

The tool developed as a result of this research project will be introduced to the aforementioned stakeholders through outreach materials, webinars, and presentations designed for airport personnel, wildlife regulators, stormwater regulators, and/or the general public given at aviation associated conferences and/or committee meetings.

CHAPTER 3

Conclusions and Suggested Research

Conclusions

Drawing on the research tasks (described in Appendix A) and associated findings presented in Chapter 2, the research team has developed a single tool that allows for the management of bird strike risk associated with the attraction of water-dependent birds to stormwater management BMPs at airports. The tool allows users to assess initial risk given species and stormwater design data, reduce that risk by incorporating initial (i.e., current) wildlife mitigations, and further manage bird strike risk through the selection of BMP design alternatives and additional wildlife mitigation measures. Finally, the tool allows users to evaluate BMP alternatives for other factors beyond bird strike risk, depending on airport-specific priorities. The content and format of the Bird Strike Risk Analysis and Stormwater Management Decision Tool, as shaped by the research findings, are described in further detail in the sections below.

Bird Strike Risk Analysis and Stormwater Management Decision Tool

Tool Design

The Bird Strike Risk Analysis and Stormwater Management Decision Tool is designed in Microsoft Excel 2010 to allow users to enter information (e.g., FAA strike data, stormwater design criteria, etc.), into Excel. Tool users are not expected to see or modify the software, but they must possess Excel 2010 or newer to use the application. The tool is designed on various tabs in the Excel spreadsheet.

The research team designed the tool so that the user enters different categories of data (bird data vs. stormwater BMP data) on different tabs for clarity. This serves to simplify the inputs and help users understand the flow of the tool. The risk analysis portion of the tool is provided as a step-wise process (five steps in total), followed by a risk summary page. The risk calculations are contained on separate tabs and these tabs are hidden, so as not to confuse the user. The tool content is summarized here and detailed further in the following subsections:

- START: This sheet serves as a main menu with instructions and hyperlinks to all of the tool features.
- Tool Overview: This sheet provides guidance on tool objectives and disclaimers.
- Bird Strike Risk Analysis: The following sheets each summarize a step in the risk analysis.
  - Step 1: Identify Bird Species, History of Strikes, and Operations Data
  - Step 2: Identify Existing Bird Mitigations
  - Step 3: Define Initial BMP Characteristics
  - Step 4: Review Initial Risk and Identify Additional Bird Mitigations
  - Step 5: Develop Proposed BMP Options and Review Residual Risk
- Bird Strike Risk Summary: This sheet summarizes the initial risk associated with the data in Steps 1–3, and the reduced risk associated with Steps 4 and 5 of the risk analysis.
- BMP Alternatives Analysis: This tab allows the comparison of BMPs based on other BMP selection criteria.
- Risk Matrix: Illustrates the SMS framework that formed the basis for tool calculations.
- Additional Resources: Includes lists of the water-dependent bird species, mitigation options, recommended vegetation, definitions, references, and assumptions for informational purposes.

Each tab includes "hot buttons" to allow users to go from one step to the next, access relevant additional resources, and go back to the main menu to facilitate navigating through the tool. Each tab also includes an overview of the specific step, instructions for completing the assessment, important definitions, and notes, along with the data entry and risk results.

Risk Matrix

The "Risk Matrix" tab depicts the risk matrix, based on the SMS framework, which forms the basis for assigning scores to severity and likelihood factors and calculating overall risk. This tab is provided for informational purposes to illustrate how the banding of each risk factor corresponds to the severity or probability levels. The research team included this tab at the back of this tool to allow users to first gain an understanding of various risk analysis inputs on previous tabs before seeing how these inputs are integrated within the matrix. Risk is defined as the combination of the severity (potential for mass) and the likelihood that the bird will be attracted. The result of this combination is a risk rating. The risk matrix establishes the definitions and parameters for severity and likelihood used in the tool and serves as the foundation for all subsequent steps.

The concept of risk (Likelihood × Severity) allows us to independently evaluate each of these risk factors. Within each risk factor, there are multiple potential hazards that exhibit a variety of risk levels. All risk factors and their corresponding levels are outlined in the risk matrix and this forms the basis of the remaining risk assessment. The levels for all factors correspond to numerical values. These values are then combined to result in an overall risk, incorporating both severity and likelihood. By addressing risk factors, controls, and priority factors, the tool allows an airport to not only evaluate existing hazards independent of any additional efforts or controls, but provides a way to test the applicability of additional control efforts and truly measure potential risk reductions.

Step 1 Input Bird Observation and Strike Data

Step 1 includes four input tables whereby the user selects the species of concern and enters species-specific bird observation and strike data, identifies confidence in the bird data, tallies total strikes for water-dependent birds, and inputs airport operations. In the Bird Observation Data table, the user selects the water-dependent bird species of concern from the dropdown list of options, and the tool automatically populates the relative hazard score associated with each species. Then, the user must select the frequency of observations, proximity of observations to aircraft movement areas, and the number of strikes reported for each species of concern selected.

The Bird Data Confidence table allows the user to adjust the influence that species likelihood factors have on the overall risk equation if they have particularly low confidence in airport-specific bird strike or observations data. To simplify user input, the user will simply select "High" or "Low" confidence, and factors that are associated with "Low" confidence will have their weighting values reduced by one-half compared to default weighting values. Factors with "High" confidence will retain the non-adjusted default weighting values. If the user has equal confidence in the quality of strike data, history (frequency) of observations, and proximity of bird sightings, they may select equal weighting for all three and keep the default weighting as originally designed. This approach simplifies a difficult concept for users to understand and allows the overall risk to be tailored to airport-specific data quality.

In the Total Bird Strikes table, the user identifies if there is strike data for water-dependent bird species that were not identified as a species of concern, and then enters the total number of strikes for other water-dependent birds not already included. In the airport operations table, the user must enter the number of operations at the airport for the same time period used to assess the number of strikes reported. Once the strike and operations data are entered, the tool calculates the percentage of total airport bird strikes associated with each species of concern and the strike rate per airport operation compared to the national average.

The research team decided to expand the original tool design to allow for 10 species inputs based on feedback from the panel. This will allow a user to evaluate up to 10 different bird species of concern at a time, select different options for each risk factor for the same species, or choose up to 10 different mitigation options for the same species at once. In other words, if the user is not selecting 10 total species for analysis, the user can assess the same species with varying inputs. If the user is not confident in their assessment of their bird strike data or bird observations, the 10 available rows allow the user to compare the risk for a single species based on several estimates for frequency of observations and/or strikes. The user can then decide to manage for the "riskiest" result or not.

Step 2 Identify Existing Bird Mitigations

In Step 2, the user must select (from a drop-down menu) the current bird mitigations implemented at their airport. Mitigations can be selected for each species and each of the SMS Hierarchy of Controls categories as outlined in Table 2-3: engineering, warnings, and administrative. For each mitigation, the user must input the frequency with which the particular mitigation is implemented: upon bird sighting or ongoing. This step is for identifying existing bird mitigations only.

Step 3 Define Initial Stormwater BMP Characteristics

The next step in the risk assessment involves defining the initial BMP characteristics. As previously discussed, the user will define various BMP design elements instead of selecting a size and type of BMP. The tool allows the user to evaluate an existing or planned BMP. At this step, the user must select (from a drop-down menu) design characteristics in the following categories: water exposure, BMP geometry, BMP location, and BMP vegetation. Based on the user inputs, the tool automatically calculates the banding level assigned to each selection (e.g., Levels 1 through 5). Additional BMP characteristics are presented as yes/no questions representing priority impact factors.

Step 4 Additional Mitigations

Once the bird observation and strike data has been entered and the BMP characteristics defined, the user will have the opportunity to review the initial risk and the risk reduction associated with existing mitigation measures entered in Step 2. The left side of the table illustrates the initial risk associated with species selection, airport bird observations, strike data, and the initial BMP design characteristics, both with and without the existing mitigations. This presentation of the risk both with and without the existing mitigations allows users to see the impact and results of existing mitigation practices.

At this step, the user can input additional bird mitigations, if desired, to further reduce the risk of a bird strike. Entering the mitigations at this step is identical to entering the mitigations in Step 2. The tool then automatically totals the existing and proposed mitigations and reduces risk based on implementation of zero, one, or more than one measure in each category. There is no additional risk reduction for two (2) or more mitigations in each category.

Step 5 Reduce Risk Through Proposed Stormwater BMP Modifications

The research team recognized the benefit of being able to compare several BMP design options simultaneously and added the ability to compare up to three BMP design modifications in Step 5 to explore the effect of BMP characteristics on bird strike risk. The initial BMP characteristics (from Step 3) are displayed on this tab to allow the user to review the original BMP design while selecting design characteristics for the alternative options. This is useful for making decisions about design modifications to be examined. At the bottom of the worksheet, the existing risk for each species (including the existing BMP design and existing mitigations) is presented from the previous step, along with the proposed risk associated with each BMP design modification. This facilitates review of the impact of each design modification on bird strike risk.

BMP Alternatives Analysis

The BMP alternatives analysis allows the user to review the risk analysis results for each BMP alternative in context with other non-bird strike factors that typically affect airport BMP selection and design decision making. This tab is not a part of the risk analysis, but does incorporate results for a selected species from the risk analysis as one of many factors affecting BMP selection. For example, an underground detention facility might be most effective at reducing bird strike risk, but these types of BMPs tend to be less cost-effective than other options, which may reduce their practicality depending on available funding and airport-specific priorities. Users are asked to define the importance of various criteria to BMP selection, define objectives for these criteria, and then evaluate each of the BMP alternatives for how well it meets the user-defined objectives. The results of the risk analysis and BMP evaluations are then combined and scored to allow users to see how well each BMP alternative meets user-defined objectives. As such, this tab serves as a tool for the comparison and selection of stormwater BMP alternatives.

Additional Information Provided in the Tool

In addition to the matrix and tool steps, several other tabs are included to provide the user with additional information and clarify the process. The START tab provides a summary of the steps involved with implementing the tool and includes hot button links to navigate to each of the steps that are included on separate tabs. The Overview tab provides background information that may help the user to understand tool assumptions and caveats for use of the tool. This information does not feed into the risk analysis, but is provided solely for the benefit of documenting the tool assumptions and features for the user.

The tool will also include the following tabs for additional information and guidance:

- Species tab listing all of the species initially considered for inclusion in the tool (including those not attracted by stormwater);
- Mitigations tab defining all of the mitigation measures and providing examples of each;
- USDA tab defining the vegetation on the USDA list;
- Definitions; and
- References and assumptions.

Tool Features

During the case studies, the research team identified the need to clarify stormwater and bird strike terminology and user inputs in the tool. The research team decided to add some additional clarification to the tool to increase understanding of the stormwater and bird attractant concepts. The research team developed the following features in the tool:

- Clarifying instructions for selection of inputs from drop-down lists;
- Additional "pop up" instructions that appear when user hovers the mouse over a risk factor;
- Guidance explaining how different BMP design characteristics affect bird strike risk;
- Color-coding of data entry cells in Excel to indicate user-defined inputs, default values, and other information;
- Color-coding of the risk analysis steps;
- Calculation of BMP perimeter irregularity in the tool;
- Enhancement of the user interface to facilitate ease of use; and
- Reorganization of the START tab and steps of the tool to facilitate navigation.

Suggested Research

The research team has found that more research is needed to accurately quantify bird strike risk. As an industry, there is an accepted understanding that water on an airfield is a hazardous wildlife attractant. Additionally, there is some research that quantifies the parameters of this attractant, but more information is needed. Specifically, the industry would benefit from a greater understanding of stormwater BMP location in relation to the airport movement areas. It would be beneficial to quantify a distance from movement areas where risk of a strike becomes minimal or "acceptable," within the AOA. Airports rarely have a mechanism for regulating stormwater BMPs off of their properties. Also, it would be beneficial to know the effect on risk when manipulating the placement, not just distance, of stormwater BMPs on or around the AOA. For example, is it more or less risky to construct all ponds on one side of the movement areas, potentially reducing the number of birds crossing over? Or, would it be best to create ponds as far apart from one another as possible to create an isolation affect? These are questions that warrant further investigation, perhaps both on stormwater BMP placement and patterns in wildlife movements.

As previously addressed, this ACRP project focuses on the relationship between man-made stormwater BMPs and potentially hazardous water-dependent bird species to decrease the risk of a bird strike. The research needs to be expanded to include all hazardous birds, terrestrial vertebrates (or potentially hazardous wildlife), and more habitat types. More research is needed on the synergistic effects of numerous desirable habitat types located on or around airports. For example, how does placing a stormwater BMP between agricultural fields and an airport affect risk? In regards to quantifying the hazards of all wildlife, there are several published lists containing relative hazard scores for species involved in aircraft strikes. For the purposes of this ACRP project, the research team has utilized the list published by DeVault et al. (2011), which combines mammals and birds, comparing their risks to each other. There are other published rankings, with different relative hazard scores, that separate birds and mammals (Dolbeer et al. 2013). As an industry there is a need for relative hazard scores, which are universally accepted, and clearly defined. The methodologies resulting in the universally accepted scores also must clearly define hazard and risk. Does hazard incorporate both likelihood and severity, or should it be limited to severity only? Should the scores be based solely on wildlife biomass? If so, how do we quantify biomass for small species that commonly flock (e.g., European starlings)? In addition, there appears to be substantial research on the attractiveness of airport turf grasses to wildlife; however, there is a need for more research on the attractiveness of aquatic vegetation to hazardous wildlife. It would be beneficial to airfield managers and planners to have a generic list of aquatic vegetation that is least attractive to these water-dependent species.

There is some research on the design parameters of stormwater BMPs that are attractive to wildlife, but some of the language is potentially confounding. For example, AC 150/5200-33B recommends designing stormwater BMPs with a linear edge to decrease attractiveness, the WashDOT Manual recommends a length-to-width ratio of the BMP of 3:1 or greater to decrease attractiveness (WashDOT 2008), and research from Blackwell et al. (2008) and Fox et al. (2013) suggests that an increased perimeter irregularity (when compared to a perfect circle) leads to an increase in bird attractiveness. These sources are somewhat contradictory by implying a long, narrow, linear BMP is least attractive (WashDOT 2008) and also suggesting a BMP designed like a perfect circle is least attractive (Blackwell et al. 2008; Fox et al. 2013). The research team believes that perhaps one set of design criteria (long and linear) refers to reduced surface area whereas the Blackwell et al. (2008) definition of perimeter irregularity refers to the amount of available shoreline. Both increased surface area and increased shoreline are proven attractive characteristics in BMP design (Fox et al. 2013). However, these parameters need to be further investigated and specific recommendations should be made to determine which design is actually preferable from a wildlife hazard management perspective.

Finally, it would be most beneficial to eliminate the attractant all together. More research is needed to either develop alternative methods for mitigating stormwater for water quality purposes, etc., or to reduce the costs of existing systems that completely enclose the stored water. Some airports are converting to stormwater master plans that only include "overland flow" as the method of discharging stormwater, rather than proposing water storage. For example, North Carolina state legislature passed Senate Bill 229 in 2011, amending certain environmental and natural resource laws. Section 6 specifically directs the state Department of Environment and Natural Resources to accept alternative measures of stormwater control at public airports in accordance with AC 150/5200-33B. Per Section 6 of the bill, "the Department shall not require the use of stormwater retention ponds, stormwater detention ponds, or any other stormwater control measure that promotes standing water . . . at public airports . . . [or at any] development projects located within five statute miles from . . . an air operations area. . . ." The guidance continues, "The Department shall deem runways, taxiways, and any other areas that provide for overland stormwater flow that promote infiltration and treatment of stormwater into grassed buffers, shoulders, and grass swales permitted pursuant to the state post-construction stormwater requirements." These methods eliminate the attractant from airfields completely and make strides toward reducing overall wildlife strike risk.

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APPENDIX A

Research Approach and Data Library

Overview

The project was divided into 16 tasks based on the Request for Proposal (RFP). The research phase of the project was executed through the following tasks:

Task 1: Project Kickoff and Amplified Work Plan
Task 2: Document Collection, Review, and Summary of Applicable Regulations/Guidance
Task 3: Existing Stormwater Management Options Review and Summary
Task 4: Checklist of Potential State and/or Local Environmental Considerations for Stormwater Management that May Affect Wildlife Hazard Management
Task 5: Math and Logic of Bird Strike Risk Analysis Tool
Task 6: Factors to Be Considered in Stormwater Management Decision Tool
Task 7: Airports Selected for Case Studies and ACRP Conference Call
Task 8: Update Work Plan and Budget
Task 9: Prepare Interim Report
Task 10: Meeting with ACRP Project Panel
Task 11: Airport Case Studies
Task 12: Draft Final Tool Development
Task 13: Prepare Draft Final Report
Task 14: ACRP Panel Conference Call
Task 15: Final Tool Development
Task 16: Final Report

Tasks 1 through 13 are complete and are described in this appendix. Following Task 14 ACRP Panel Conference Call, the research team finalized the tool and this report, thus completing Tasks 14 through 16.

Task 1 Project Kickoff and Amplified Research Plan

As required by the research contract and as our first step, the research team submitted an electronic copy of an Amplified Research Plan (work plan) to the project panel. This plan provided an expansion of the approved Research Plan as outlined in our proposal.

The project panel reviewed the work plan and provided comments to the research team. The research team responded to the project panel comments, revised the work plan, and provided the response to comments and final work plan to the Program Officer.

Task 2 Document Collection, Review, and Summary of Applicable Regulations/Guidance

The research team compiled available and applicable documents relevant to this project including:

FAA Orders and Advisory Circulars
Federal water resource regulations
Water resource guidance documents
Regulatory compliance guidance documents
ACRP reports and syntheses
USDA NWRC publications and research
Bird Strike North America conference presentations
Aviation and non-aviation-related stormwater management literature

Our research team members, as practitioners in the aviation industry, already possessed or had ready access to most of these documents. ESIS and STAR personnel have been active in the FAA SMS testing and implementation efforts, participating with airports in each of the FAA pilot SMS studies, to include wildlife risk assessments. STAR also has the reputation for being an SMS expert, in general industry as well as airport operations. Additionally, GS&P recently completed ACRP Reports 43 and 53, which summarize water resources-related regulatory requirements and wildlife management requirements. Through the completion of these projects for ACRP, a significant amount of research was already completed and the effort to summarize critical information for evaluation, reference, and/or inclusion in the tools and associated guidance was streamlined.

A document library was maintained in electronic format utilizing Egnyte, a secure file sharing storage site, accessible by all of our team members, which currently contains over 80 documents or document links. A current listing of all documents contained in the data library is included in **Appendix A**.

Other project documents, databases, and project management tools obtained or developed during subsequent work plan tasks are maintained on this web site as well. Document control, data accessibility, and timely information sharing are critical to our ACRP team communication and coordination.

Based on the review of regulatory documents, the research team prepared a comprehensive matrix of federal stormwater and wildlife management regulations. The summary focused on those requirements that result in the need for an airport to implement a stormwater management option on or nearby an airport property. For those regulations with similar requirements for similar controls, the regulations were grouped to simplify the matrix. A copy of the summary matrix is included as **Appendix B**.

Task 3 Existing Stormwater Management Options Review and Summary

Task 3 included establishing a list of stormwater management BMPs that are typically required or recommended by stormwater management professionals to manage the quality or quantity of stormwater discharged from an airport property. These stormwater management BMPs typically provide for temporary on-site detention to facilitate treatment or the attenuation of peak flows, in an effort to minimize the effects of new or redevelopment and mimic pre-development discharge conditions.

Utilizing information from the document library, established in Task 2, the research team established a matrix of potential stormwater BMPs and characteristics that should be considered when determining the most appropriate BMP, included as **Appendix C**. The research team also reviewed the Water Environment Research Foundation (WERF) SELECT tool and the Washington Department of Transportation (WashDOT) *Aviation Stormwater Design Manual: Managing Wildlife Hazards Near Airports* to help develop the list of stormwater management options that were integrated into the tool.

Based on our knowledge about the attractiveness of stormwater management facilities to birds, the influence stormwater management options can have on bird behavior, various stormwater mitigation options, and published research, the research team developed a matrix that considered strike likelihood risk factors of BMP characteristics. The matrix is included as **Appendix D**.

Task 4 Checklist of Potential State and/or Local Environmental Considerations for Stormwater Management that May Affect Wildlife Hazard Management

The research team recognizes that environmental regulations driving stormwater management vary greatly among states and cities. To characterize the range of these diverse conditions while maintaining a realistic data collection initiative, we performed a review of stormwater management requirements in five states (Rhode Island, Pennsylvania, Minnesota, Washington, and Florida's Southwestern Water Management District) and five local municipalities (Columbus, Ohio; Portland, Oregon; Dallas, Texas; Roanoke, Virginia; and Memphis, Tennessee) in different FAA regions. We established a local environmental considerations matrix composed of regulated stormwater features and the potential effect on wildlife management, included as **Appendix E**.

Task 5 Math and Logic of Bird Strike Risk Analysis Tool

A risk assessment is the qualitative and/or quantitative value of a risk (a specific activity with an undesirable outcome) based on a specific situation or event and a recognized hazard. To quantify the risk associated with construction of potential wildlife attractants (stormwater management facilities on airport property), two parameters were evaluated:

The severity (or magnitude) of the potential loss
The likelihood (or probability) of the negative outcome

In October 2010, a proposed rule was published in the Federal Register that would require each Part 139 certificate holder to establish a SMS for the entire airfield environment (including movement and non-movement areas) to improve safety at airports hosting air carrier operations. The FAA describes SMS in AC 150/5200-37 as "The formal, business-like approach to managing safety risk. It includes systematic procedures, practices, and policies for the management of safety (including safety policy, safety risk management, safety assurance, and safety promotion)." Therefore, the research team took an SMS approach to quantifying the risk of a bird strike associated with the design of a stormwater management system on airports.

A common tool for risk decision making and acceptance in SMS is a risk matrix. The risk matrix forms the basis of the risk assessment. See **Appendix F** for the risk matrix developed for this project. **Table A-1** lists the nine risk factors included under either severity or likelihood in the risk matrix. Information pertaining to the probability of a bird strike was incorporated as likelihood factors and information pertaining to the magnitude of the potential strike was incorporated as severity factors. In an SMS, the risk matrix forms the basis of the risk assessment.

Table A-1. Severity and likelihood risk factors.

Severity Risk Factors	Relative Hazard Score by Species* Stormwater BMP – Perimeter Irregularity Stormwater BMP – Apparent Slope to Water's Edge BMP – Proximity of Water Bodies (from each other) BMP – Percentage of Stormwater Vegetation Coverage
Likelihood Risk Factors	History of Observations Proximity of Bird Sightings Percentage of Total Airport Bird Strikes Associated with Species History of Total Bird Strikes per Operations Compared to National Average Proximity of BMP to Airport Movement Areas

*See **Appendix G** for a complete list of species used in the tool.

The research team developed a standard 5 × 5 risk matrix (recommended by the FAA in AC 150/5200-37) that includes five levels for severity and five levels for likelihood as illustrated in **Table A-2** below. For each identified severity and likelihood risk factor, five possible input options were identified, correlating to each of the five banding levels. These input options are presented to the user in the form of dropdown menus. A numeric score (1 to 5) is assigned to the input based on the significance level (as shown in Table A-2).

An overall likelihood score is calculated as the average of the likelihood scores for all likelihood factor inputs. An overall severity score is calculated in a similar manner, as described further in Chapter 2. When these overall severity and likelihood scores are combined, they result in an overall risk:

Overall Risk = Overall Severity × Overall Likelihood

Overall Risk is categorized into three levels, which are represented by color banding in the risk matrix. These levels are described in **Table A-3**.

In addition to the nine severity and likelihood risk factors shown in Table 2-1, the tool incorporates "priority impacts." Severity and likelihood risk factors are used to directly calculate risk levels. Priority impacts are questions that modify the risk levels, either decreasing or increasing risk, depending on user response. The priority impact questions do not have five banding levels, like the risk factors. All of the questions require a "yes or no" response, where a "no" response correlates to an increase in risk and results in an increase in overall severity by 0.1, and a "yes" response correlates to a decrease in risk and results in a decrease in overall severity by 0.1. While there is no one industry standard for risk factors, their definitions, or impacts, risk assessment techniques are defined both in FAA practices and advisory circulars as well as safety industry best practices. Priority impacts are one method safety professionals use to balance factors that influence risk (Bullock and Ignacio, 2006).

We understand that the ACRP vision is for an electronic stand-alone application. This tool must be useful to airport personnel with varying degrees of background in wildlife hazards and risk analysis. Due to the fiscal and labor constraints

Table A-2. Risk factor levels.

Numeric Score	Severity	Likelihood
1	Negligible	Improbable
2	Minor	Extremely Remote
3	Major	Remote
4	Hazardous	Probable
5	Catastrophic	Frequent

Table A-3. Overall risk ratings.

Risk Rating	Score
Low (green)	Risk ≤ 5
Moderate (yellow)	5 < Risk < 15
High (red)	Risk ≥ 15

of developing a dynamic, web-based application, the research team developed a Microsoft Excel spreadsheet model. The model establishes the necessary mathematical relationships and logic outlined above. The research team used the research collected in preceding tasks to draw upon information that was incorporated into the tool.

Our team did not duplicate existing academic studies or embark on a new statistical research project, but rather utilized the information and statistical analyses that have already been developed to create an SMS-style, user-friendly tool that quantifies bird strike risk to aid airport operators in their stormwater management planning and design. The tool is designed so that airport users will be able to evaluate their existing or proposed stormwater management system and determine the potential bird strike risk associated with an alternative.

Task 6 Factors to Be Considered in Stormwater Management Decision Tool

Task 6 was originally predicted to be the development of a separate Stormwater Management Decision Tool, but after consultation within the research team and with the Program Officer and project panel, it was decided that wildlife and BMP characteristics were both required inputs to assess the bird strike risk associated with stormwater BMPs. In addition to the BMP inputs to the risk analysis, the research team decided to add an additional feature to the tool to facilitate stormwater management decision making about potential BMP design modifications, which would take into account both the anticipated bird strike risk as well as typical BMP selection factors that are not associated with bird strike risk. This BMP alternatives analysis feature is outside of the risk analysis portion of the tool and does not feed into the bird strike risk, but uses the risk analysis results as one of several factors affecting the comparison of the BMPs.

The BMP characteristics input tabs in the risk analysis portion of the tool allow the user to define existing or proposed stormwater BMPs for which to evaluate the risk of bird strikes, as well as changes to the stormwater BMP or mitigation options to manage the risk. The intent is for the tool to be used when evaluating and comparing the risk of several alternatives for stormwater BMP design or modifications.

Instead of allowing users to define the BMP by type (e.g., detention basin, infiltration trench, etc.), the research team recognized that the BMPs would need to be defined in the form of characteristics that may be attractive to birds, which may be common between types of BMPs. The definition of BMPs based on these characteristics in the tool would allow comparison to FAA guidance and industry recommendations for BMP design. The selected BMP characteristic severity and likelihood factors are listed in **Table A-1**. Beyond these characteristics, additional BMP characteristics were incorporated into the tool as priority impacts (non-banded, yes/no inputs).

For the BMP alternatives analysis, the research team considered factors other than bird strike risk that may affect the selection of a particular BMP design alternative, depending on airport-specific priorities. The non-avian decision factors were identified based on the research team's experience in airport stormwater management planning, design, and decision making at airports as well as input from the project panel.

Task 7 Airports Selected for Case Studies

The research team used various available resources to assemble data on two airports (one commercial service and one general aviation) featuring unique and diverse stormwater management systems or open water sources. The data collected from these airports was used to test the accuracy and effectiveness of the Bird Strike Risk Analysis/Stormwater Management Decision Tool in different scenarios. Members of the research team conducted site visits to the selected airports to gain additional insight into the tools' function and instruct airport personnel on how to properly apply the tool at their airport. A complete summary of the case studies can be found in **Appendix H**.

The research team selected two case study airports based on the following selection criteria:

- FAA wildlife strike data
- Completed Wildlife Hazard Assessment/Environmental Assessment
- Master Stormwater Management Plan
- Stormwater management features and/or water resources on or adjacent to the airport
- Previously utilized wildlife hazard management techniques in regards to stormwater systems

Cleveland-Hopkins International Airport (CLE) was selected as the representative Part 139 certificated case study airport. CLE is located in Cuyahoga County, Ohio and is included in the Great Lakes FAA Region. It is approximately seven miles south of Lake Erie and adjacent to Rocky River, part of regional Metro Park. CLE is moving forward with redevelopment activities that will require them to meet more stringent stormwater management requirements and is challenged with how to incorporate the required BMPs, most of which would necessitate surface detention. CLE has ample wildlife strike data (1,277 total reported strikes) and has experienced at least 15 significant strikes since 1990, involving gulls, swans, geese, and ducks. In 2003, they contracted with the U.S. Department of

Agriculture (USDA) to complete a wildlife hazard assessment (WHA), which has been supplemented with continued data collection and annual reports.

Pompano Beach Airpark (PMP) was selected as the representative general aviation case study airport. PMP is located in Broward County, Florida, approximately 12 miles north of downtown Ft. Lauderdale and is included in the Southeast FAA Region. It is approximately 1 mile west of the Atlantic Ocean and contains several stormwater ponds on site. PMP has limited wildlife strike data (14 total reported strikes), however the majority of species-identified strikes involved water-dependent species (6), including gulls and egrets. In addition, PMP recently finalized a master stormwater management plan.

Prior to conducting the case studies, the research team pre-tested our proposed tool with data readily available from Jacksonville International Airport (JAX). They have ample strike data as well as 5 years of wildlife data collection compiled and maintained by ERS. Revisions to the tool were made based on the results of the pre-test to ensure the accuracy of the tool prior to initiating the case studies.

Task 8 Updated Work Plan and Budget

Following the teleconference with the project panel, the research team prepared a revised work plan schedule to reflect the decision to conduct the case studies and receive and incorporate feedback from the participants into the draft tool before developing the Interim Report and meeting with the project panel.

Task 9 Interim Report

In October 2013, the research team submitted the Interim Report which presented the research and activities conducted under Tasks 1 through 11 (excluding Task 10). It included the research team's recommended uses for the tool along with an outline of tasks completed to date. At the request of the ACRP panel, the Interim Report also presented the results of the research team's case studies, which involved testing the tool in real-world settings and collecting feedback from airport personnel. Therefore, Task 11 was completed prior to Tasks 9 and 10.

Task 10 Meeting with ACRP Project Panel

The research team met with the panel in Washington, D.C. on 19 November 2013. The research team presented and discussed the tool along with the results of the research summarized in the Interim Report and obtained direction from the panel on how to proceed with the development of the Draft Final Tool.

Task 11 Airport Case Studies

The research team used various available resources (e.g., published research, wildlife strike data, and wildlife survey data from WHAs) to assemble data on CLE and PMP. The research team also reviewed design drawings and specifications for the BMPs at CLE. Members of the research team conducted site visits at the selected airports to gain additional insight into the tools' function and instruct airport personnel on how to properly apply the tool at their airport. The data collected from these airports was used to test the accuracy and effectiveness of the Bird Strike Risk Analysis and Stormwater Management Decision Tool in different scenarios. Lessons learned from the case studies are incorporated into the findings in Chapter 2. A complete summary of the case studies can be found in **Appendix H**.

Task 12 Draft Final Tool Development

The research team assembled the information collected and summarized in Tasks 2 through 11, including Task 10 (above), into the Draft Final Bird Strike Risk Analysis and Stormwater Management Decision Tool. The tool allows users to review the bird strike risk associated with an existing or planned BMP and identify preferred BMP design characteristics or bird strike mitigation measures to reduce risk. In addition, the research team developed a brochure explaining use of the tool and why the tool is necessary in the stormwater planning process.

Task 13 Prepare Draft Final Report

The research team prepared a Draft Final Report, documenting the background information and processes used to develop the tool. The Draft Final Report represents an update to the Interim Report (Task 9) and was provided to ACRP for review in March 2014.

Task 14 ACRP Panel Conference Call

The research team was provided written comments from the project panel in June 2014. In lieu of a web-enabled teleconference with project panel, the research team was instructed to provide a written response to the comments.

Task 15 Final Tool Development

Our research team prepared the Final Bird Strike Risk Analysis and Stormwater Management Decision Tool and Stakeholder Outreach Materials including revisions suggested by the project panel.

Task 16 Prepare Final Report

The research team revised the Draft Final Report to address review comments and submitted the Final Report to ACRP in August 2014.

Data Library

Wildlife-related Documents

Marine Mammal Protection Act of 1972
Fish & Wildlife Conservation Act
Migratory Bird Treaty Act
Endangered Species Act
Bald and Golden Eagle Protection Act
SO CFR 21.49 Control of Canada Geese on Airports
SO CFR 22.27 Removal of Eagles
FAA Website: Airport Wildlife Hazard Mitigation Research & Development (http://www.airporttech.tc.faa.gov/safety/wildlife.asp)
International Birdstrike Committee Recommended Practices No 1: Standards for Aerodrome Bird/Wildlife Control
Bird Strike Risk Assessment for Athens International Airport by Anastasios Anagnostopoulos
The development of birdstrike risk assessment procedures, their use on airports, and the potential benefits to the aviation industry J. Allan et. al. (2003)
Developing bird-strike risk assessment models for open-water restorations J. Hart et. al. (2009)
Bird-Aircraft Strike Risk Assessment at Commercial Airports Jinfeng Wang (2012)
Bird Strike Committee USA Website (http://www.birdstrike.org/)
FAA Certalert 06-07: Requests by State Wildlife Agencies to Facilitate and Encourage Habitat for State-Listed Threatened and Endangered Species and Species of Special Concern on Airports
FAA Website: Current Hazard Assessment Systems (http://www.faa.gov/airports/airport safety/wildlife/current/)
Interspecific Variation in Wildlife Hazards to Aircraft: Implications for Airport Wildlife Management T. DeVault et. al. (2011)
FAA Draft AC 1SO/S200-33C Hazardous Wildlife Attractants On or Near Airports
FAA Draft AC 150/5200-38 Protocol for the conduct and review of wildlife hazard site visits, wildlife hazard assessments, and wildlife hazard management plans
FAA Wildlife Strike Database Website (wildlife.faa.gov)
Memorandum of Agreement between FAA, US Air Force, US Army, EPA, USFWS, and USDA to address aircraft-wildlife strikes
Office of Inspector General Audit Report: FAA has not effectively implemented its wildlife hazard mitigation program (2012)
USDA National Wildlife Research Center—Animal Damage Aviation Safety Publications Website (http://www.aphis.usda.gov/wps/portal/banner/help?1dmy&urile=wcm%3apath%3a%2Fap his content library%2Fsa our focus%2Fsa wildlife damage%2Fsa programs%2Fsa nwrc%2Fsa research%2Fsa aviation%2Fct aviation publications)
Risk Assessment FAQs from Bird Strike Committee USA Website
Understanding and Reducing Bird Hazards to Aircraft: North American Fatal Accident Risk (BSC-USA Website)
Integrating Wildlife Hazard Management into SMS (Wayne Clifton & Amy Johnson)—Proceedings from BSC Conference 2011
Regional Memorandum of Understanding between the FAA, Southern Region and U.S. Army Corp of Engineers, US Air Force, EPA, USFWS, and USDA.
Bird use of stormwater-management ponds: Decreasing avian attractants on airports B. Blackwell, et. al. (2008)
Wildlife Strikes to Civil Aircraft in the US R. Dolbeer et. al. (2013)

Stormwater-related Documents

Department of Transportation (DOT) Order 5660.1a Preservation of the Nation's Wetlands
FAA AC 150/5300-13A Airport Design
FAA AC 150/5320-SC Surface Drainage Design
ACRP Report 53: A Handbook for Addressing Water Resource Issues Affecting Airport Development Planning
FAA AC 150/5210-22 Airport Certification Manual
Federal Water Pollution Control Act (aka Clean Water Act) Coastal Barriers Resources Act
Coastal Zone Management Act
Executive Order 13089 Coral Reef Protection (1998)
Guidance for Presidential Memorandum on Environmentally and Economically Beneficial Landscape Practices on Federal Landscaped Grounds
ACRP Report 14: Deicing Planning Guidelines and Practices for Stormwater Management Systems
ACRP Report 32: Guidebook for Addressing Aircraft/Wildlife Hazards at General Aviation Airports
ACRP Report 43: Guidebook of Practices for Improving Environmental Performance at Small Airports
ACRP Report 49: Collaborative Airport Capitol Planning Handbook
Parameters Affecting Bird Use of Stormwater Impoundments in the Southeastern United States: Implications for Bird-Aircraft Collisions B. J. Fox (2011)
Designing for Water Quality and Wildlife Hazards at Airports D. J. Kiker & H. W. Marotti (2011)
Stormwater Best Management Practice (BMP) Selection and Implementation (Florida Department of Environmental Protection)

Technical Memorandum: Guidance for Developing a Stormwater Management Manual for Washington State: Mitigating Hazards Due to Wildlife Attractants at Airports (Washington State Department of Transportation)

Wildlife Collisions with Aircraft: A missing component of land-use planning at airports B. Blackwell et. al. (2009)

Airport Stormwater Guidance Manual: Briefing Paper (Washington State Department of Transportation)

Aviation Stormwater Design Manual Task Force: Meeting Summary (2008); Washington State Department of Transportation

Wildlife Hazard Management at Airports: A Manual for Airport Personnel R. Dolbeer and E. Cleary (2005)

The Airport Runoff Manual: Stormwater Design to Avoid Wildlife Attractants (Presentation—Washington State Department of Transportation)

Aviation Stormwater Design Manual: Managing Wildlife Hazards Near Airports. Technical Manual. Washington State Department of Transportation (2008)

SMS and Risk Assessment-related Documents

FAA AC 150/5200-37 Introduction to Safety Management Systems (SMS) for Airport Operators

ACRP Legal Research Digest 19 Legal Issues Related to Developing Safety Management Systems and Safety Risk Management at US Airports

ACRP Report 74 Application of Enterprise Risk Management at Airports

ACRP Synthesis 37 Lessons Learned from Airport Safety Management Systems Pilot Studies

American National Standard for Occupational Health and Safety Management Systems (American Industrial Hygiene Association)

FAA Order 5200.11FAA Airports (ARP) Safety Management System

Failure Modes and Effects Analysis Fact Sheet

International Standard ISO 31000 Risk Management—Principles and Guidelines (2009)

SMS Implementation Study for Jacksonville Aviation Authority (JAA) Completed by ESIS (2011)

Risk Assessment Principles for the Industrial Hygienist M. A. Jayjock et. al. Example blank risk assessment model

Example risk assessment model using Canada Geese

Example risk management matrix

ICAO Safety Management Manual (2009)

ACRP Report 1 Safety Management Systems for Airports Volume 1: Overview

ACRP Report 2 Safety Management Systems for Airports Volume 2: Guidebook

A systematic review of the effectiveness of safety management systems M. Thomas (2012); Australian Transport Safety Bureau

Wildlife Risk Management. J. Ostrom; BSC-USA Conference Proceedings (2013)

APPENDIX B

Regulatory Matrix

Document Number	Document Name	Author and/or Administrator	Type of Document	Relevant Regulatory Criteria and Considerations for Hazardous Wildlife and Stormwater
001	DOT Order 5660.1A, Preservation of the Nation's Wetlands	Department of Transportation	Federal Regulatory Guidance	• DOT policy that facilities should be planned, constructed, and operated to assure protection, preservation, and enhancement of wetlands. • Wetlands may serve as hazardous wildlife attractants due to open water surfaces and attractive vegetation. Projects that are intended to enhance wetlands may conflict with FAA hazardous wildlife guidelines if they do not meet FAA separation criteria.
002	FAA AC 150/5200-33C DRAFT Hazardous Wildlife Attractants	Federal Aviation Administration	Federal Regulatory Guidance	<u>Establishes separation criteria between AOA and wildlife attractant:</u> • 5,000 ft. for airports with piston-powered aircraft • 10,000 ft. for airports with turbine-powered aircraft • 5 miles (26,400 ft.) at all airports if wildlife movement potential to interfere with aircraft approach/departure <u>Establishes criteria for existing and proposed stormwater management facilities:</u> • Comply with separation criteria where possible • Consult with Qualified Airport Wildlife Biologist • Avoid/Eliminate standing water (permanent pools) • Modify/Design to meet 48-hour drawdown requirement • Incorporate concrete pads to prevent nesting vegetation in permanently wet areas • Incorporate physical barriers and deterrents (bird balls, wires, etc.) where permanent pools remain • Steep-sided, rip-rap lined, narrow, linearly shaped water detention basins • Eliminate attractive vegetation that provides food or shelter to wildlife • Promote infiltration and incorporation of under drains <u>Establishes criteria for artificial marshes and wetlands</u> • Comply with separation criteria where possible • Monitor wildlife use and habitat changes at existing and restored wetlands • Coordinate with stakeholders to raise awareness of aircraft safety risks and develop mitigation plans that minimize hazards • Perform mitigation off-site or within mitigation banks where possible, unless on-site wetlands must be maintained • Avoid enhancing mitigation areas to intentionally attract wildlife <u>Assess wildlife hazard risks</u> • Perform Wildlife Hazard Assessment (WHA) when triggering events occur • If required, develop Wildlife Hazard Management Plan (WHMP) to identify measures to mitigate risks
003	FAA AC 150/5300-13 Airport Design	Federal Aviation Administration	Federal Regulatory Guidance	• Promote effective drainage and lower water table • Incorporate sub drains to improve drainage • Open channels or natural water courses are permitted only at the periphery of an airfield • Prevent water accumulation in runway safety area (RSA) and taxiway safety area (TSA) through grading and stormwater drainage • Locate drainage channels outside RSA and follow minimum slope requirements to promote drainage • References to drainage and wildlife circulars and local requirements for specifics
004	FAA AC 150/5320-5C Surface Drainage Design	Federal Aviation Administration	Federal Regulatory Guidance	• Establishes location of swales (outside TSA/RSA) • Refers to Haz Wildlife AC • Maximum channel side slopes 3:1 to allow mowing (possible conflict with Haz. Wildlife AC steep slope requirement) • Conveyance design storm: 5-year • Ponding: Minimize, no encroachment on taxiway/runway pavement or shoulders for 5-year storm, no ponding over central 50% of runways/taxiways/helipads during 10-year storm
005	ACRP Report 53: A Handbook for Addressing Water Resource Issues Affecting Airport Development Planning, Fact Sheet 4: Hazardous Wildlife Attractant	Gresham, Smith and Partners/ ACRP	Industry Guidebook	Federal Aviation Regulation (FAR) 14 CFR Part 139.337: As part of the NEPA process, FAA has ability to require Wildlife Hazard Assessments (WHAs) as well as Wildlife Hazard Management Plans (WHMPs) to investigate and address observed wildlife hazards. WHAs and WHMPs are required to be submitted to the FAA for review and approval, and incorporated into the Airport Certification Manual (ACM). The FAA established a separate Memorandum of Understanding (MOU) with the USDA Wildlife Services to establish the role of each agency in mitigating wildlife hazards. The USDA assists the FAA with performing WHAs, contributing to and reviewing airports' WHMPs, and also serving as a guidance resource for airports in the identification and mitigation of potential hazardous wildlife attractants. The agencies have jointly developed a manual to assist airports in these tasks, Wildlife Hazard Management at Airports: A Manual for Airport Personnel ("Wildlife Hazard Manual").

006	FAA AC 150/5210-22 Airport Certification Manual (ACM)	Federal Aviation Administration	Federal Regulatory Guidance	Airports certified under Part 139 must keep ACM current at all times. ACM must include a statement regarding wildlife activity at airport, and status/results of WHA or WHMP. If WHMP exists, should be included as an attachment to ACM.
007	Clean Water Act	Environmental Protection Agency	Act of Congress	• Established National Pollutant Discharge Elimination System (NPDES), which regulates discharges to waters of the U.S. associated with qualifying municipal, industrial, and construction activities. NPDES is implemented through authorized state agencies with the issuance of NPDES permits. Permits typically establish effluent limits that trigger the need for BMPs. Many state construction permits include a standard minimum post-development storm water treatment volume called the "Water Quality Volume". • Section 304(m) of the Clean Water Act (CWA) requires US EPA to develop biennial plans for Effluent Limitation Guidelines that regulate discharges of pollutants associated with particular industrial categories. • Section 303(d) of the CWA requires states to identify impaired waters and develop Total Maximum Daily Loads (TMDLs) as required to protect water quality. • Section 404 of the CWA regulates impacts to wetlands by prohibiting discharges of dredged or fill material into waters of the U.S. without a permit. Section 404 is administered by the U.S. Army Corps of Engineers (USACE). Section 401 of the CWA identifies the need for coordination with state regulatory agencies, and authorizes states to regulate wetland impacts through 401 water quality certification programs. • Aboveground controls with open water surfaces, such as detention basins, are often involved with achieving water quality and quantity requirements for site discharges, and present a potential risk for hazardous wildlife attraction. Similarly, wetland mitigation or restoration can present risks through open water surfaces and vegetation that may provide nesting habitat or food to hazardous wildlife.
008	Coastal Barrier Resources Act of 1982, as amended by the Coastal Barrier Improvement Act of 1990	U.S. Fish and Wildlife Service	Act of Congress	• Established a policy that coastal barriers, in certain geographic areas of the U.S. are to be protected by restricting Federal expenditures that have the effect of encouraging development of coastal barriers. A Coastal Barrier Resources System (CBRS) is managed by the Fish and Wildlife Service (FWS) and coordinated with the USACE on projects that involve restoration, stabilization, and development of wildlife habitat. • Coastal resources provide habitat for wildlife and may present a risk to airports in coastal areas. Projects that are intended to enhance wildlife habitat may conflict with FAA hazardous wildlife guidelines if they do not meet FAA separation criteria.
009	Coastal Zone Management Act, as amended	National Oceanic and Atmospheric Administration	Act of Congress	• Encourages states/tribes to preserve, protect, develop, and where possible, restore or enhance valuable natural coastal resources, as well as associated fish and wildlife habitats. • Coastal resources provide habitat for wildlife and may present a risk to airports in coastal areas. Projects that are intended to enhance wildlife habitat may conflict with FAA hazardous wildlife guidelines if they do not meet FAA separation criteria.
010	Executive Order 13089, Coral Reef Protection	Bill Clinton, President of the United States	Executive Order	• Specific orders for preserving, protecting, and enhancing the biodiversity, health, heritage, and social and economic value of U.S. coral reef ecosystems and the marine environment. • Coral reefs and associated marine environments provide habitat for wildlife and may present a risk to airports in coral reef areas. Projects that are intended to enhance wildlife habitat may conflict with FAA hazardous wildlife guidelines if they do not meet FAA separation criteria.
011	Marine Mammal Protection Act of 1972, as amended in 2007	U.S. Fish and Wildlife Service & National Oceanic and Atmospheric Administration	Act of Congress	• The MMPA prohibits, with certain exceptions, the “take” of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S. • This regulation does not appear to be relevant to hazardous wildlife requirements.
012	Magnuson-Stevens Fishery Conservation and Management Act of 1976, as amended by the Sustainable Fisheries Act	Senators Warren G. Magnuson (WA) and Ted Stevens (AK)	Act of Congress	• The act requires the identification and protection of essential fish habitat. • This regulation does not appear to be relevant to hazardous wildlife requirements, unless the protection of fish habitat creates a wildlife hazard through the attraction of birds.
013	DOT Order 5650.2, Floodplain Management and Protection	Department of Transportation	Federal Regulatory Guidance	• This order prescribes policies and procedures to ensure that consideration is given to the avoidance and mitigation of adverse floodplain impacts in agency actions, planning programs, and budget requests. • Floodplains may serve as hazardous wildlife attractants due to open water surfaces and attractive vegetation. Projects that are intended to enhance floodplains may conflict with FAA hazardous wildlife guidelines if they do not meet FAA separation criteria.
014	Executive Order 11988 Floodplain Management	Jimmy Carter, President of the United States	Executive Order	• This order provides guidance on avoiding or minimizing occupancy, modification, and development within floodplains whenever there is a practicable alternative. • Airport drainage improvements, such as the addition of under drains or re-grading of poorly draining areas may result in a reduction in hazardous wildlife attraction (by reducing the open water surface), while simultaneously reducing floodplains. It may be necessary to consider options for addressing hazardous wildlife that minimize impacts to floodplains.

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Document Number	Document Name	Author and/or Administrator	Type of Document	Relevant Regulatory Criteria and Considerations for Hazardous Wildlife and Stormwater
015	Executive Order 11990 Protection of Wetlands	Jimmy Carter, President of the United States	Executive Order	• This order provides guidance on avoiding or minimizing the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands, whenever there is a practicable alternative. • Airport drainage improvements, such as the addition of under drains or re-grading of poorly draining areas may result in a reduction in hazardous wildlife attraction (by reducing the open water surface), while simultaneously reducing floodplains. it may be necessary to consider options for addressing hazardous wildlife that minimize impacts to floodplains.
016	Executive Order 12088 Federal Compliance with Pollution Control Standards	Jimmy Carter, President of the United States	Executive Order	• This order identifies that the head of each Agency is responsible for ensuring that all necessary actions for prevention, control, and abatement of environmental pollution with respect to federal facilities and activities are under the control of the agency, and in compliance with federal pollution control statutes. USEPA may conduct reviews and inspections to monitor compliance for federal facilities/activities. • This regulation does not appear to be relevant to hazardous wildlife requirements, as long as airports are otherwise complying with environmental pollution control laws. If compliance poses a risk for hazardous wildlife attraction, that should be worked out with the regulating agency.
017	Executive Order 12856 Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements	Bill Clinton, President of the United States	Executive Order	• This order requires federal agencies to manage facilities so that toxic chemicals entering waste streams are reduced through source reduction, generated waste is recycled to the maximum extent practicable, and wastes are stored, treated, or disposed to protect public health and the environment. Incorporates reporting requirements and encourages clean technologies/safe alternatives to hazardous substances or toxic chemicals. • This regulation does not appear to be in conflict with hazardous wildlife requirements. The storage and treatment of wastes should be done in a manner such that it is not exposed to the environment and does not attract wildlife.
018	Oil Pollution Act of 1990	Environmental Protection Agency	Act of Congress	• This regulation was promulgated after the Exxon Valdez oil spill to provide provisions to regulate and respond to oil spills. • This regulation does not appear to be directly related to hazardous wildlife requirements.
019	Presidential Memorandum on Environmentally and Economically Beneficial Landscape Practices on Federally Landscaped Grounds	Bill Clinton, President of the United States	Federal Regulatory Guidance	• This memorandum states that for federal grounds, federal (or federally funded) projects, agencies shall to the extent possible use regionally native plants for landscaping, promote construction practices that minimize adverse effects on the natural habitat, minimize runoff and seek to prevent pollution, and implement water-efficient practices for landscape irrigation and management. • Compliance with this regulation should involve selecting vegetation and landscaping practices that also do not serve as wildlife attractants. For example vegetation should be selected and maintained such that it does not provide habitat or food for hazardous wildlife. Vegetation may be selected with the goal of limiting the attraction or access of wildlife to open water surfaces.
020	Fish and Wildlife Conservation Act of 1980, as amended	U.S. Fish and Wildlife Service	Act of Congress	• This act provides authority for the Fish and Wildlife Service (FWS) to evaluate impacts to fish and wildlife from proposed water resource development projects. Federal actions must involve consultation with the FWS and state fish and wildlife agency regarding impacts to fish and wildlife resources and measures to mitigate these impacts. • Water resources that provide habitat for fish and wildlife may also attract hazardous wildlife that presents a risk to nearby airports. Projects that are intended to enhance wildlife habitat may conflict with FAA hazardous wildlife guidelines if they do not meet FAA separation criteria.
021	Migratory Bird Treaty Act of 1918, as amended	U.S. Fish and Wildlife Service	Act of Congress	• Establishment of a federal prohibition, unless permitted by regulations, to "pursue, hunt, take, capture, kill, attempt to take, capture or kill, possess, offer for sale, sell, offer to purchase, purchase, deliver for shipment, ship, cause to be shipped, deliver for transportation, transport, cause to be transported, carry, or cause to be carried by any means whatever, receive for shipment, transportation or carriage, or export, at any time, or in any manner, any migratory bird, included in the terms of this Convention for the protection of migratory birds or any part, nest, or egg of any such bird." •Conducting wildlife hazard management on an airport is not possible without a Depredation permit, issued under this law, allowing airports to take migratory birds. Over 90% of all known-species bird strikes involved birds protected by MBTA, including vultures and cattle egrets.
022	Endangered Species Act of 1973, as amended	U.S. Fish and Wildlife Service	Act of Congress	•The ESA's primary goal is to prevent the extinction of imperiled plant and animal life, and secondly, to recover and maintain those populations by removing or lessening threats to their survival. •The provision of the law in Section 4 that establishes critical habitat is a regulatory link between habitat protection and recovery goals, requiring the identification and protection of all lands, water and air necessary to recover endangered species. •All federal agencies are prohibited from authorizing, funding, or carrying out actions that "destroy or adversely modify" critical habitats (Section 7(a) (2)). While the regulatory aspect of critical habitat does not apply directly to private and other non-federal landowners, large-scale development, logging, and mining projects on private and state land typically require a federal permit and thus become subject to critical habitat regulations. •The combined result of the amendments to the ESA have created a law vastly different from the ESA of 1973. It is now a flexible, permitting statute. For example, the law now permits "incidental takes" (accidental killing or harming a listed species). Congress added the requirements for "incidental take statements," and authorized an "incidental take permit" in conjunction with "habitat conservation plans." This provision allows airports to take listed species when public safety is at risk.

023	Bald and Golden Eagle Protection Act	U.S. Fish and Wildlife Service	Act of Congress	•BAGEPA currently prohibits anyone, without a permit issued by the Secretary of the Interior, from "taking" bald eagles. Taking is described to include their parts, nests, or eggs, molesting or disturbing the birds. The Act provides criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle (or any golden eagle), alive or dead, or any part, nest, or egg thereof." •The purpose of BAGEPA is not to agitate the bald and golden eagle to an extent of (1) not abusing an eagle; (2) not interfering with its substantial lifestyle, including shelter, breeding, feeding; or (3) nest abandonment. •Bald and golden eagles are large birds that are capable of causing significant damage to aircraft. Airports must be able to harass or remove eagles, and their nests, when necessary. •Bald eagles are particularly attracted to nesting in, or near, water and stormwater features could increase the risk of eagles nesting on airports.
024	50 CFR 21.49 - Control order for resident Canada geese at airports and military airfields.	Federal Government of the United States	Federal Regulation	•The airport control order authorizes managers at commercial, public, and private airports (airports) (and their employees or their agents) and military air operation facilities (military airfields) (and their employees or their agents) to establish and implement a control and management program when necessary to resolve or prevent threats to public safety from resident Canada geese. Control and management activities include indirect and/or direct control strategies such as trapping and relocation, nest and egg destruction, gosling and adult trapping and culling programs, or other lethal and non-lethal control strategies. •Resident Canada geese may be taken only within the airport, or the military base on which a military airfield is located, or within a 3-mile radius of the outer boundary of such a facility. Airports and military airfields or their agents must first obtain all necessary authorizations from landowners for all management activities conducted outside the airport or military airfield's boundaries and be in compliance with all state and local laws and regulations. •Canada geese are a large, flocking bird that pose a significant threat to aircraft. Geese are attracted to short grasses (e.g., airfields) and open water bodies, therefore, stormwater management features can increase the attractiveness of an airport to the geese.
025	50 CFR 22.27 - Removal of eagle nests	Federal Government of the United States	Federal Regulation	•A permit may be issued under this section to authorize removal or relocation of: (1) an active or inactive eagle nest where necessary to alleviate a safety emergency; (2) an inactive eagle nest when the removal is necessary to ensure public health and safety; (3) an inactive nest that is built on a human-engineered structure and creates a functional hazard that renders the structure inoperable for its intended use; or (4) an inactive nest, provided the take is necessary to protect an interest in a particular locality and the activity necessitating the take or the mitigation for the take will, with reasonable certainty, provide a clear and substantial benefit to eagles. •This CFR allows airports to remove eagle nests from their property (with a permit) when they pose a threat to public safety (e.g., the travelling public).

APPENDIX C

BMP Design Considerations to Minimize Wildlife Risk

Characteristic to Consider in Evaluating Wildlife Risk of BMP:		Detention/Retention				Infiltration Practices				Low-Impact Development			Vegetated Filters			Media Filters			Treatment Structures	
Potential BMPs:		Detention Basin	Detention Tank	Wet Vault	Wet/Detention Vault	Infiltration Basin	Infiltration Trench	Infiltration Vault	Dry Well	Permeable Pavement	Rain Garden	Direct Impervious Runoff to Pervious Areas	Vegetated Filter Strip	Media Filter Drain	Vegetated Swale/Bioswale	Media Filter Basin	Media Filter Vault	Submerged Gravel Biofilter	Oil Water Separator	Hydrodynamic Separator
BMP Purpose	Implemented to Meet Water Quality Criteria	Y	U	U	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Implemented to Meet Water Quantity Criteria	Y	Y	Y	Y	D	D	D	D	S	S	S	S	S	S	Y	S	S	N	N
Exposure of Water	Closed Vessel / Exposed Water surface	Open	Closed	Closed	Closed	Open	Open	Closed	Closed	Closed	Open	Open	Open	Open	Open	Open	Closed	Open	Closed	Closed
	Permanent pool / dry between rain events (Open water)	Y	N	N	N	Y	Y	N	N	N	Y	Y	U	U	U	Y	N	D	N	N
	Drain Time	Y	N	N	N	Y	Y	N	N	N	Y	Y	U	U	Y	Y	N	Y	N	N
	Media in BMP	Y	N	N	N	Y	Y	N	N	N	Y	U	U	Y	Y	Y	N	Y	N	N
	Wire/Birdball/Other Surface Obstruction	Y	N	N	N	Y	Y	N	N	N	U	U	U	U	U	Y	N	U	N	N
Pond Surface Area/Size	Surface Area of Open Water	Y	N	N	N	Y	Y	N	N	N	Y	Y	U	U	Y	Y	N	D	N	N
	Typical Water Depth (Open Water)	Y	N	N	N	Y	Y	N	N	N	Y	Y	U	U	Y	Y	N	D	N	N
	Max Volume of Water Stored (Open Water)	Y	N	N	N	Y	Y	N	N	N	Y	Y	U	U	Y	Y	N	D	N	N
	Average Volume of Water Stored (Open Water)	Y	N	N	N	Y	Y	N	N	N	Y	Y	U	U	Y	Y	N	D	N	N
Perimeter Shape	Length/Width Ratio (Open Water)	Y	N	N	N	Y	Y	N	N	N	U	U	U	U	U	Y	N	U	N	N
	Sideslopes (Open Water)	Y	N	N	N	Y	Y	N	N	N	U	U	U	U	Y	Y	N	U	N	N
	Perimeter type (Open Water)	Y	N	N	N	Y	Y	N	N	N	U	U	U	U	Y	Y	N	U	N	N
Hydrology	Soil Characteristics / Infiltration Rate	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	D	N	N
	Frequency of Rainfall	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	N
	Magnitude of Design Storms	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	N
Vegetation	Type of Vegetation Within BMP	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	D	N	N
	Pervious or Impervious Bottom	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	D	N	N
	Vegetation/Water Ratio	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	D	N	N
	Vegetation Consistency / Diversity Index	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	D	N	N
Geographic Location	Distance from AOA	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	N
	Vicinity to Water Features / Wildlife Habitat	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	N
	Location Relative to Wildlife Migration Pattern	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	N
	Location and Elevation of BMP Relative to Aircraft Movement Pattern	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	N

Y	Yes - Important consideration
D	Should be considered, depending on design/site characteristics
S	Applicable during small storm events only
U	Unlikely to be a major consideration
N	No/Not Applicable

APPENDIX D

Risk Factors of BMP Characteristics

Category	Characteristic	Increases Wildlife Risk	Reduces Wildlife Risk	Implementation Challenges/Considerations
Exposure of Water	Permanent pool/dry between rain events	Permanent pool or frequently ponded	Dry between storm events	Local stormwater regulations often require a permanent pool to enhance water quality treatment. If a pool is not provided, additional quality BMPs may be required.
	Closed vessel/exposed water surface	Exposed water surface	Closed vessel / underground or limited access to water surface	Closed vessels such as tanks or underground storage tend to be more costly per unit volume than excavated/graded features such as detention basins. They also provide reduced water quality benefits.
	Drain time	Drain time > 48 hours	Drain time <= 48 hours	FAA requires maximum 48-hour drain time, but local stormwater regulations may require longer drain time to enhance water quality treatment
	Media in BMP	No media or media height< typical water elevation	Media height > typical water elevation to discourage water access by wildlife	Media can be selected to provide a water quality filtration benefit, but will reduce BMP volume available for detention/quantity control.
	Wire/bird ball/other surface obstruction	No surface obstructions	Obstructions to block or discourage access to water by wildlife	Wildlife obstructions may be costly and may impact or increase BMP operations and maintenance
Pond Surface Area/Size	Surface area of open water	Larger area	Smaller area / zero between storms	Surface area is the least significant factor influencing species utilization of ponds, but should still be considered.
	Typical water depth	Intermediate depth (0.50 m to 1.0 m)	Shallow (<0.50 m) or deep (> 1.0 m)	Wildlife utilization is related to water depth indirectly. Research shows that wildlife prefer an intermediate level of emergent vegetation, which would require an intermediate depth of water: shallow ponds can become choked with vegetation, reducing the attractiveness to wildlife while deep ponds will not allow vegetation to grow (not enough sunlight exposure) and will also reduce the attractiveness to wildlife.
	Max volume of water stored (design storm)	Increased water volume	Minimized water volume	The maximum volume of water stored is generally driven by local regulatory requirements for flood control and stream protection (reduction in peak flows and volumes), as well as extent of development. Low-impact development can help to reduce post-development runoff at the source and result in smaller BMPs.
	Average volume of water stored (design storm)	Frequent and large volume of ponding	Dry between storm events or infrequently ponded	The average volume of water stored may be driven by design criteria (peak flow and volume restrictions, required design storms), extent of development, frequency of precipitation, and drain time.
Perimeter Shape	Length/width ratio	Irregular	Length:Width>>>1 Length:Width = 1	Airports may have limited space to implement, and available space may dictate length/width ratio.
	Side slopes (horizontal run: vertical rise)	Shallow (3:1 or flatter)	Steep recommended by FAA (assuming 2:1 or greater)	Shallow slopes recommended to facilitate maintenance.
	Perimeter type	Irregular	Linear or circular	Linear BMPs are also easier to construct.
Hydrology	Soil characteristics/infiltration rate	Waterlogged/hydric or poorly draining soils	Well-draining soils	Airports may not have mitigation sites available with preferred soil characteristics. Hydric soils could be indicator of wetlands and possible permitting implications.
	Frequency of rainfall	Frequent precipitation events	Infrequent precipitation events	Airports have no control over precipitation.
	Magnitude of design storms	Higher-magnitude precipitation depths	Lower-magnitude precipitation depths	Airports have no control over precipitation or selected design storms.

(continued on next page)

Category	**Characteristic**	**Increases Wildlife Risk**	**Reduces Wildlife Risk**	**Implementation Challenges/Considerations**
Vegetation	Type of vegetation within BMP	Vegetation with high wildlife value (provides food or shelter)	Vegetation with low wildlife value	Vegetation may be a requirement of local permitting agencies to enhance water quality treatment; best to use vegetation that serves as a structural habitat and not a food source.
	Pervious or impervious bottom	Pervious bottom	Impervious (or partially impervious) bottom or well-draining pervious bottom	Impervious BMP bottoms will reduce water quality benefits from vegetation, eliminate the stormwater volume benefits offered by infiltration, and may increase stormwater management requirements or BMP sizing overall. A paved low-flow channel can reduce perviousness for most inundation conditions as well as facilitate access and sediment removal/maintenance.
	Vegetation/water ratio	Vegetation << Water	Vegetation >> Water to discourage water access by wildlife	Selected vegetation should be drought and inundation tolerant to survive variations in BMP water levels.
	Vegetation consistency/diversity index	High Diversity Index	Low Diversity Index	
Geographic Location	Distance from AOA	Inside AOA or Within FAA Separation Criteria (<10,000 ft.)	Outside FAA Separation Criteria of 10,000 ft.	Airports may have limited access/ownership of land outside of FAA separation criteria to allow for off-site mitigation. Regulatory criteria may require a mitigation ratio to increase the volume/performance of BMPs that are implemented offsite. Regulators typically also restrict mitigation to options within the same sub-watershed as the project.
	Vicinity to additional water features	< 3 km	> 3 km	Location of stormwater BMPs relative to other wildlife attractants can have a compounding effect on wildlife risk. Other wildlife risks off-property may be outside of airport's control. Increasing the distance between water bodies to 3 km or more, decreases the probability of avian usage by 50%.
	Location relative to designated important bird area (IBA) along migration flyway	Within FAA-recommended 5 mi separation criteria	Outside FAA-recommended 5 mi separation criteria	Location of the BMP within the migration flyway can increase visibility and attractiveness of the BMP to wildlife.
	Location and elevation of BMP relative to aircraft movement pattern	< 1 km	> 1 km	Location of stormwater BMPs relative to aircraft movement patterns can significantly affect the likelihood of aircraft wildlife strikes.

APPENDIX E

Local and State Stormwater Criteria Summary Matrix

Source Information				Development Information		Water Quantity Control		
Municipality or State	FAA Region[1]	Regulating Entity	Documents Reviewed (Manuals, Permits)	Development Applicability	Definition of Pre-Development	Peak Flow Limits	Stream Protection Volume or Other Minimum Storage Requirements	Runoff Volume Control / Infiltration
LOCAL								
Columbus, OH	Great Lakes	City of Columbus Division of Sewerage and Drainage (DOSD)	Stormwater Drainage Manual (Aug 2012)	New and redevelopment, >10,000 SF disturbance or >2,000 SF added impervious	Existing Conditions (no detailed definition is available).	Restrict the 100-year post peak flow to the 10-year pre-peak flow. Restrict the Critical Storm (storm event determined based on increase in 1-year storm runoff) post peak flow to the 1-year pre-peak flow.	None	None
Portland, OR	Northwest Mountain	City of Portland Bureau of Environmental Services (BES)	Stormwater Management Manual (2008) Sewer and Drainage Facilities Design Manual (2011)	New or redevelopment > 500 SF of impervious surface. Existing development proposing new offsite discharges.	Undeveloped Land Use "Lewis and Clark Era."	Depends on where runoff is discharged. -Base Condition: Maintain peak flow rates at pre-development levels for the 2-year, 5-year, and 10-year, 24-hour events. -Combined Sewer: Limit the 25-year post-development peak runoff rate to the 10-year pre-development peak rate. -Columbia River, Willamette River, or Columbia Slough: None -All other drainage systems: 2-year post to one-half of the 2-year pre; 25-year, 10-year, 5-year post to corresponding pre.	None	Infiltrate to the maximum extent feasible. (1-9).
Dallas, TX	Southwest	City of Dallas, North Central Texas Council of Governments	Integrated Stormwater Management (iSWM) Criteria Manual (2010) Site Development Controls Technical Manual (2010)	Land disturbing activity of 1 acre or more OR land disturbing activity of less than 1 acre where the activity is part of a common plan of development that is one acre or larger.	Development and redevelopment are not specifically defined in this manual. If clearing and grubbing has been performed in the past 5 years, than assume clearing and grubbing has not occurred.	Common practice requires the designer to control peak flow at the outlet of a site such that the post-development peak discharge equals the pre-development peak discharge.	Provide on-site controlled release of the 1-year, 24-hour storm event over a period of 24 hours (Streambank Protection Volume, SPV) (ALTERNATIVES INCLUDE DOWNSTREAM STABILIZATION AND SW CONTROLS TO IMPROVE EXISTING DS CONDITIONS).	Storm Drain Design (pipes and culverts) 100-yr, 24-hour: Provide adequate controls onsite or downstream to maintain existing downstream conditions.
Roanoke, VA	Eastern	City of Roanoke, Department of Planning Building and Development	Stormwater Management Design Manual (2007)	Generally applicable to land development projects that disturb more than 5,000 SF.	Site conditions that have existed for the 5-year period before the site plan application and shall use the site condition that results in the lowest peak rate of runoff.	10 year post shall not exceed 10 year pre 2 year post shall not exceed 2 year pre	None	None
Memphis, TN	Southern	City of Memphis Division of Public Works and Division of Engineering Shelby County Public Works Department	Storm Water Management Manual (Volumes 1, 2, and 3) (2007)	All development and land disturbance activities one acre or greater shall be in compliance with capital improvement projects.	Pre-Development Conditions (no detailed definition is available).	25 year post shall not exceed 25 year pre 10 year post shall not exceed 10 year pre	Attenuate the post- development outflow from hour 11 to hour 18 of the 24-hour storm to a level not to exceed the pre-development mass outflow for the same time period for both the 2-year and 5-year, 24-hour storms.	The facility may be designed to infiltrate runoff to groundwater rather than transmit it downstream under conditions up to a 10-year, 24-hour storm event.
STATE								
Rhode Island	New England	Rhode Island Department of Environmental Management (RIDEM)	Stormwater Design and Installation Standards Manual (2010)	Development: The construction of new impervious areas on undeveloped land is subject to the requirements of this manual even if other portions of the site are currently developed, unless the site meets the definition for an infill project. Re-Development: Any construction, alteration, or improvement that disturbs a total of 10,000 square feet or more of existing impervious area where the existing land use is commercial, industrial, institutional, governmental, recreational, or multifamily residential.	The standard for characterizing pre-development land use for on-site areas shall be woods, meadow, or rangeland. For agricultural land, use a CN representing rangeland.	Control the post-development peak discharge rates from the 10-year and 100-year storms to the corresponding predevelopment peak discharge rates. Calculations must be provided that show how runoff from the 10- and 100-year storms reaches the proposed facilities.	Channel Protection Volume (CPv) = 24-hour extended detention of the volume of the post-development 1-year, 24-hour Type III storm event	Maintain pre-development annual groundwater recharge volume to the maximum extent practicable through the use of infiltration measures Rev = (1")(F)(I)/12 Rev = groundwater recharge volume (ac-ft) F = recharge factor, see Table 3-4 I = Impervious area (acres)
Pennsylvania	Eastern	Pennsylvania Department of Environmental Protection (PADEP)	Pennsylvania Stormwater Best Management Practices Manual (2006)	For regulated activities less than or equal to 1 acre VOLUME CONTROL GUIDELINE 1 or VOLUME CONTROL GUIDELINE 2 may be used. For regulated activities greater than 1 acre, VOLUME CONTROL GUIDELINE 2 may be used.	Existing non-forested pervious areas must be considered meadow (good condition) or equivalent. Twenty percent of existing impervious area shall be considered meadow (good condition) for existing conditions or redevelopment.	Do not increase the peak rate of discharge for the 1-year through 100-year events (at minimum); as necessary, provide additional peak rate control as required.	VOLUME CONTROL GUIDELINE 1: Do not increase the post-development total runoff volume for all storms equal to or less than the 2-year/24-hour event.	CONTROL GUIDELINE 2: If VOLUME CONTROL GUIDELINE 1 is not followed, and project does not require design of SW storage facilities. 1.) Stormwater facilities shall be sized to capture at least the first two inches (2") of runoff from all contributing impervious surfaces. 2.) At least the first one inch (1.0") of runoff from new impervious surfaces shall be permanently removed from the runoff flow. Removal options include reuse, evaporation, transpiration, and infiltration. 3.)Wherever possible, infiltration facilities should be designed to accommodate infiltration of the entire permanently removed runoff; however, in all cases at least the first one-half inch (0.5") of the permanently removed runoff should be infiltrated.
Minnesota	Great Lakes	Minnesota Pollution Control Agency (PCA)	Minnesota Stormwater Manual (2005). Construction General Permit (2008).	Projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger Common Plan of Development or Sale.	The Minnesota Pollution Control Agency (MPCA) uses land cover conditions immediately preceding the current development project as the Minnesota Construction General Permit (CGP) pre-development condition.	None.	Extended detention for WQv of 24-48 hours to minimize stream bed erosion from frequent small storms.	None required, although recharge and infiltration are strongly encouraged through better site design and stormwater credits.
Washington	Northwest Mountain	Washington State Department of Ecology Water Quality Program	Stormwater Management Manual for Western Washington (2012) Western Washington Phase II Municipal Stormwater Permit (2010)	Land development projects that disturb greater than 2,000 square feet, or greater, of new, replaced or new plus replaced impervious surface area, or has a land disturbing activity of 7,000 square feet or greater. Additional requirements exist for 5,000SF, or more of new impervious surface area, 3/4 acre or more of native vegetation to landscape, or converts 2.5 acres of native vegetation to pasture.	Forested or Plains	Stormwater discharges shall match developed discharge durations to pre-developed durations for the range of pre-developed discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow.	Infiltrate, disperse, and retain stormwater runoff onsite to the maximum extent feasible	Infiltrate, disperse, and retain stormwater runoff onsite to the maximum extent feasible.
Florida (Southwestern Water Management District)[2]	Southern	Southwest Florida Water Management District	Southwest Florida Water Management District: Environmental Resource Permit Applicant's Handbook Volume II - Design Requirements for Stormwater Treatment and Management Systems Water Quality and Water Quantity (2013)[3]	SW District complies with state requirement. State environmental resource permits and corresponding stormwater treatment are needed for all new or modified stormwater discharges and for all projects disturbing 4,000 square feet or more of impervious surface. The NPDES stormwater generic permit is required for all sites that disturb one or more acres of land. Sites that discharge to Open Water Sources (OWS) are not required to meet water quantity discharges but are required to meet water quality criteria.	Existing Land Use Condition	The post-development peak discharge rate will not exceed the pre-development peak discharge rate for a specific design storm. The design storm for the SWWMD is a 25 year, 24 hour design storm. No requirement for discharges to tidal water bodies.	For projects discharging within a closed drainage basin: The total post development volume leaving the site shall be no more than the total pre-development volume leaving the site for the design 100-year storm. The rate of runoff leaving the site shall not cause adverse off-site impacts.	Where practicable, systems shall be designed to maintain water tables, base flows and low flows at the highest practicable level.

Footnotes:

[1]Alaskan = AK; Central = IA, KS, MO, NE; Eastern = DC, DE, MD, NJ, NY, PA, VA, WV; Great Lakes = IL, IN, MI, MN, ND, OH, SD, WI; New England = CT, ME, MA, NH, RI, VT; Northwest Mountain = CO, ID, MT, OR, UT, WA, WY; Southern = AL, FL, GA, KY, MS, NC, PR, SC, TN, VI; Southwest = AR, LA, NM, OK, TX; Western-Pacific = AZ, CA, HI, NV, GU, AS, MH

[2] The Department of Environmental Protection is involved in managing the quality and quantity of water through its relationship with the state's five water management districts.

[3]The Southwest Florida Water Management District (SWFWMD) Stormwater Management Manual is under review for approval by the SWFWMD. The information provided here reflects the current draft format.

	Water Quality Control				BMP Requirements Pertinent to Hazardous Wildlife Risk				
Municipality or State	Water Quality Treatment Volume or Flow	Capture and Treat Requirements	Special Requirements for Habitat / Sensitive Watershed	Special TMDL Considerations	Permanent Pool	Vegetation	Sideslopes	Drawdown Time	Airport Considerations/Limitations on the Selection of BMPs/Controls
LOCAL									
Columbus, OH	Design Quality BMPs to treat minimum Water Quality Volume or Flow (0.75-inch rainfall runoff volume)	None	None	None	Required for water quality	Required for stabilization and water quality features. Native and tolerant species recommended	4:1 or flatter	24-48-hour minimum, depending on BMP (min. 48 for dry basins)	List of acceptable controls provided, can use alternative BMPs if demonstrate benefits.
Portland, OR	SBUH 0.83-inch 24-hour NRCS Type 1A.	Size BMP for capturing 90% volume and removing 70% TSS.	None	BMP must be capable of reducing the pollutant of concern, as approved by BES.	Required for water quality	Required to the maximum extent feasible. Minimize need for herbicides and mowing. Appropriate for soil and hydrologic conditions.	3:1 or flatter	Drawdown times only mentioned for 2 BMPs. 10-hr for soakage trench. <10min for Drywell	Vegetated BMPs required. Where vegetated BMPs are not feasible, manufactured BMPs may be approved by BES. Rooftops with UIC and Temporary SW Controls are exempt. A list of select BMPs and design criteria are provided.
Dallas, TX	Treat the Water Quality Protection Volume by reducing total suspended solids from the development site for runoff resulting from rainfall of 1.5 inches (85th percentile storm). (ALTERNATIVES FOR MEETING THE WQv INCLUDE OFFSITE MITIGATION AND APPROVED ONSITE MITIGATION PRACTICES)	WQ controls not specified in the manual may be used provided they can demonstrate removal of 70% to 80% of the annual average TSS.	None	Ability to provide bacteria removal may be of particular concern when meeting regulatory water quality criteria under the Total Maximum Daily Load (TMDL) program.	Required for water quality	Required in vegetative stabilization and some water quality features. Specified recommended tolerances are based on BMP application.	3:1 or flatter	Only required for Porous Paver Systems & Porous Concrete: 24-48 hours.	List of acceptable controls provided, can use alternative BMPs if benefits can be demonstrated.
Roanoke, VA	WQv design criteria is defined per BMP. The WQV is equal to the volume from the first ½ inch of stormwater runoff from all the impervious surfaces passing through the BMP.	BMP selection is based on a calculation of the total phosphorus that must be removed to provide post-development runoff pollutant levels that do not exceed pre-development runoff levels. The accepted calculation procedure for the determining the pre- and post-developed pollutant loads is the Simple Method.	None	None	Required for water quality	Required in vegetative stabilization and some BMPs (erosion resistant) . Specified vegetation maintenance is based on BMP application.	3:1 or flatter	All stormwater detention facilities shall be empty within 72 hours following the storm event.	List of acceptable controls provided, can use alternative BMPs if benefits can be demonstrated.
Memphis, TN	None identified.	The overall GOAL of WQ treatment is to capture 90% of annual SW runoff volume, using a design storm of 1.0 inch rainfall.	None	Only as it applies to animal waste and fecal coliform in Sanitary Sewer Overflows.	In place of a permanent pool, a wet detention basin can be enhanced with other storm water treatment BMPs such as a pretreatment sediment forebay, baffle box, or storm water quality inlet.	Preservation of existing vegetation in some circumstances. Required in vegetative stabilization and some BMPs. Vegetation is based on BMP application.	4:1 or flatter	Detention storage volume necessary to meet SWMM requirements shall be drained in 72 hours.	Underground detention is prohibited and open water surface vegetated BMPs encouraged for water quality.
STATE									
Rhode Island	WQv (ac-ft) = (Impervious Area in acres)/12 = I/12 WQf (cfs) = unit peak discharge (cfs/mi2/inch) * Drainage Area (acres) * WQv / A	Structural BMPs are generally required to achieve the following minimum average pollutant removal efficiencies: 85% removal of total suspended solids (TSS), 60% removal of pathogens, 30% removal of total phosphorus (TP) for discharges to freshwater systems, and 30% removal of total nitrogen (TN) for discharges to saltwater or tidal systems	Stormwater discharges from land uses with higher potential pollutant loads (LUHPPLs) require the use of specific source control and pollution prevention measures and the specific stormwater BMPs approved for such use.	On a case-by-case basis, applicants may be required to calculate potential stormwater pollutant loadings for projects for pre-development and post-development conditions. Using the Simple Method.	Required for water quality.	Required in vegetative stabilization and some water quality features. Specified tolerances and planting recommendations based on BMP application. Native plants are encouraged.	3:1 or flatter	Drawdowns only mentioned for two BMPs. Filtering systems should be cleaned if drawdown exceeds 36 hours. Infiltration practices have a maximum dewatering time of 48 hours.	Wet Ponds are not listed as a BMP option. Instead, Wet Vegetated Treatment Systems (WVTS) are listed. WVTS require a permanent pool and vegetation for WQ treatment. The WQv must be treated by one of the BMPs listed in the manual. However, a method for adding innovative and emerging BMPs to the manual is provided.
Pennsylvania	WQv = 2year 24 hour event.	The recommended control guideline for total water quality control is: Achieve an 85% reduction in post-development particulate associated pollutant load (as represented by Total Suspended Solids), an 85 percent reduction in post-development total phosphorus loads, and a 50 percent reduction in post-development solute loads (as represented by NO3-N), all based on post-development land use.	VOLUME CONTROL GUIDELINES may require modification, on a case-by-case basis, before they are applied to Special Management Areas around the Commonwealth.	In Areas Tributary to High Quality and Exceptional Value (Special Protection) Waters—there shall be no degradation of existing or designated stream quality through a change in post construction stormwater runoff volume, rate and quality	Required for water quality.	BMP Plant list with Plant type, Hardiness, Availability, Wildlife Value, Wetland Indicator Status, Inundation Tolerance.	3:1 or flatter	Retention and detention facilities should be designed to completely drain water quality volumes including both the permanently removed volume and the extended detention volume over a period of time not less than 24 hours and not more than 72 hours from the end of the design storm.	A series of flow charts and worksheets walks the designer through non-structural BMPs, VOLUME CONTROL GUIDELINES 1 & 2, and ultimately through WQ calculations and structural BMPs to determine if WQ requirements are met.
Minnesota	WQv = 1/2 inch of runoff from the new impervious surfaces created.	Reduce at least 80% of the average annual total suspended solids (TSS) load and floatable debris, including oil and petroleum products (Assumed to be achieved by water quality volume control standards alone or in combination with pretreatment).	Multiple and Various. Generally the Stormwater Manual Tables 10.2 and 10.4 defines the design criteria for Special Waters and other Sensitive Receiving Waters.	The local authority may adopt a "no net increase" The selection and design of specific BMPs to address impaired water pollutant reductions will be determined through the TMDL process.	Required by the Construction General Permit.	Required in vegetative stabilization and some water quality features. Specified tolerances recommended based climate and mitigating mosquito habitats.	3:1 or flatter	The REQUIRED drawdown time for bioretention practices is 48 hours or less from the peak water level in the practice	List of acceptable controls provided, can use alternative BMPs if demonstrate benefits.
Washington	WQv = 6 mo., 24-hour event	The requirement to provide phosphorous control is determined by the local government with jurisdiction (e.g., through a lake management plan), or the Department of Ecology (e.g., through a waste load allocation).	Enhanced treatment for reduction in dissolved metals is required for the following project sites that discharge to fish-bearing streams, lakes, or to waters or conveyance systems tributary to fish-bearing streams or lakes: Industrial project sites, Commercial project sites, multi-family project sites, and high AADT roads.	Specific TMDL requirements exist per identified TMDL. See Western Washington Phase II Municipal Stormwater Permit, Appendix II	Required for water quality.	Preservation of existing vegetation in some circumstances. Required in vegetative stabilization and some BMPs. Specific vegetation is based on BMP application.	3:1 or flatter	Infiltration basin/trenches have a maximum drawdown time of 48 hours. Sand filters should drawdown in less than 24 hours.	List of acceptable controls provided, can use alternative BMPs if demonstrate benefits.
Florida (Southwestern Water Management District)[2]	Drainage Areas Greater than 100 acres and all wet Detention Systems WQv = 1inch of runoff Drainage Areas Less than 100 acres WQv = 0.5 inch runoff.	(STATE REQUIREMENT) New stormwater discharges must achieve at least 80% reduction of the average annual load of pollutants that would cause or contribute to violations of State water quality standards. However, current rules are based on TSS load reduction. New rule under development is based on TN and TP reduction.	Projects discharging directly into Outstanding Florida Waters (OFW) shall be required to provide treatment for a volume 50% more than required for the selected treatment system	New stormwater discharges to impaired waters must achieve "net environmental improvement" which means that the loading from the site for the pollutant of concern must not increase above current levels.	Required for water quality.	Planting is not required although vegetation that becomes established requires maintenance.	4:1 or flatter	Total treatment volume shall be available within 72 hours. Only volume available within 36 hours is considered water quantity storage.	A series of BMP manuals, provided in the appendices, specify BMP's by land use. The Florida Airport Best Management Practices Manual is proposed as an appendix to the SWFWMD manual, and is awaiting approval.

APPENDIX F

Risk Matrix

RISK MATRIX

Severity Factors (hazard of birds volume/mass of birds attracted)								Likelihood (Frequency) Factors - (Proximity to aircraft)					
Severity Levels		Relative Hazard Score - Species Incorporates Mass of Bird and Flock Size by Reported Adverse Effects to A/C		BMP - Perimeter Irregularity	BMP - Apparent Slope to Water's Edge	BMP - Proximity of Water Bodies (from each other)	BMP - Percentage of Stormwater Vegetation Coverage	FREQUENT	PROBABLE	REMOTE	EXTREMELY REMOTE	IMPROBABLE	
		Weighted Hazard Ranking Severity	Relative Hazard Score (Adjusted to exclude mammals)					5 daily to weekly sightings (year round)	4 daily to weekly sightings (seasonal only)	3 weekly to monthly sightings	2 weekly to monthly sightings (seasonal only)	1 annual sightings	History of Observations
								on the runway or RPZ in flight	on the runway on the ground	on the AOA	within airport property	off airport property	Proximity of Bird Sightings
								>75%	50-75%	10-50%	5-10%	<5%	Percentage of Total Airport Bird Strikes Associated with Species
								> 2 SD above national average	Between 1 and 2 SD above national average	Within 1 SD of national average	Between 1 and 2 SD below national average	< 2 SD below national average	History of Total Bird Strikes per Operations Compared to National Average
								AOA	<5000 ft	5000 - 10,000 ft	10,000 ft - 5 mi	> 5 miles	Proximity of BMP to Airport Movement Areas
NEGLIGIBLE	1	1	< 12	Irregularity <= 1.1	1:1	None within 5 mi	100%	5.0	4.0	3.0	2.0	1.0	
MINOR	2	2	> 12 < 24	1.1 < Irregularity <= 2.8	2:1	3.75 - 5 mi	0%	10.0	8.0	6.0	4.0	2.0	
MAJOR	3	3	> 24 < 36	2.8 < Irregularity <= 4.6	3:1	2.5 - 3.75 mi	less than 16.5% OR greater than 83%	15.0	12.0	9.0	6.0	3.0	
HAZARDOUS	4	4	> 36 < 48	4.6 < Irregularity <= 6.4	4:1	1.25 - 2.5 mi	16.5% to 32.9% OR 66.1% to 83%	20.0	16.0	12.0	8.0	4.0	
CATASTROPHIC	5	5	>48	Irregularity > 6.4	>=5:1	< 1.25 mi	33% to 66%	25.0	20.0	15.0	10.0	5.0	

APPENDIX G

Table of Water-Dependent Species

List of Hazardous Water-Dependent Bird Species

(Source: The list of species included in this tool is based on a list of wildlife species that were most frequently reported as causing damaging strikes to aircraft or causing an adverse effect on flights between 1990 and 2009 (DeVault et al. 2011), based on national wildlife strike data. The data below reflects information from DeVault, as adjusted to remove species that are not birds, as well as birds that are not water-dependent.)

Hazardous Water-Dependent Bird Species	Relative Hazard Ranking	Weighted Hazard Ranking Severity Level 1–5	Number of Strikes (1990–2012) from Strike Database for 530 Airports with FAA Ops Data	Mean Strikes / 100,000,000 Operations (1990–2012) for 530 Airports with FAA Ops Data
All Species in the List Below			10808	664.8
Bald Eagle	36	3	90	6.9
Black-bellied Plover	15	2	91	3.3
Blackbirds	9	1	438	21.8
Brown Pelican	40	4	47	2.8
California Gull	22	2	101	3.2
Canada Goose	46	4	1156	82.4
Cattle Egret	23	2	270	11.0
Double-crested Cormorant	43	4	93	5.4
Franklin's Gull	19	2	80	4.7
Glaucous-winged Gull	39	4	70	2.6
Great Black-backed Gull	32	3	85	2.4
Great Blue Heron	31	3	296	13.1
Great Egret	28	3	63	2.6
Herring Gull	29	3	946	42.5
Killdeer	7	1	2827	213.6
Laughing Gull	18	2	333	15.5
Mallard	29	3	639	32.4
Mew Gull	19	2	51	2.2
Osprey	31	3	222	11.2
Other Ducks	48	5	536	22.8
Other Geese	61	5	153	7.4
Pacific golden-plover	2	1	723	50.2
Ring-billed Gull	23	2	1147	72.5
Sandhill Crane	37	3	92	10.2
Terns	2	1	59	9.2
Upland Sandpiper	13	2	147	6.1
Western Sandpiper	3	1	53	6.7
None	0	0	0	0

*Blackbirds - red-winged blackbird, brown-headed cowbird, common grackle
*Other Ducks - 23 species in the Family Anatidae (Mottled Duck, Northern Pintail, American Black Duck, Gadwall, American
*Other Geese - snow goose, brant, greater white-fronted goose
*Terns - common tern, arctic tern, Caspian tern, least tern, fairy tern

APPENDIX H

Case Studies Summary

Summary of Case Studies

The research team used various available resources (e.g., published research, wildlife strike data and wildlife survey data from wildlife hazard assessments) to assemble data on two airports (one commercial service and one general aviation) featuring unique and diverse stormwater management systems or open water sources. The data collected from these airports was used to test the accuracy and effectiveness of the Bird Strike Risk Analysis and Stormwater Management Decision Tool in different scenarios. Members of the research team conducted site visits to the selected airports to gain additional insight into the tools' function and instruct airport personnel on how to properly apply the tool at their airport.

The research team selected two case study airports based on the following selection criteria:

1) FAA wildlife strike data
2) Completed Wildlife Hazard Assessment/Environmental Assessment
3) Master Stormwater Management Plan
4) Stormwater management features and/or water resources on or adjacent to the airport
5) Previously utilized wildlife hazard management techniques in regards to stormwater systems

Cleveland-Hopkins International Airport (CLE) was selected as the representative Part 139 certificated case study airport. CLE is located in Cuyahoga County, Ohio, and is included in the Great Lakes FAA Region. It is approximately 7 miles south of Lake Erie and adjacent to Rocky River, part of regional Metro Park. CLE is moving forward with redevelopment activities that will require them to meet more stringent stormwater management requirements and is challenged with how to incorporate the required BMPs, most of which would necessitate surface detention. CLE has ample wildlife strike data (1,277 total reported strikes) and has experienced at least 15 significant strikes since 1990, involving gulls, swans, geese, and ducks. In 2003, they contracted with the USDA to complete a wildlife hazard assessment (WHA), which has been supplemented with continued data collection and annual reports.

Pompano Beach Airpark (PMP) was selected as the representative general aviation case study airport. PMP is located in Broward County, Florida, approximately 12 miles north of downtown Ft. Lauderdale and is included in the Southeast FAA Region. It is approximately 1 mile west of the Atlantic Ocean and contains several stormwater ponds on site. PMP has limited wildlife strike data (14 total reported strikes); however, the majority of species-identified strikes involved water-dependent species (6), including gulls and egrets. In addition, PMP recently finalized a master stormwater management plan.

Commercial Service Airport: CLE

The CLE case study was conducted on 11 September 2013. It was attended by the research team, CLE operations, planning, environmental, and safety/risk management departments, as well as USDA Wildlife Services. A total of 11 individuals participated in the CLE case study. The case study visit consisted of a tour of CLE stormwater basins and classroom instruction. Following a project overview, the group selected the newest stormwater BMP, currently under construction, to evaluate with the tool. This basin is located outside of the AOA and its purpose is to meet stormwater treatment and attenuation criteria, therefore it is designed to be wet detention. The research team walked through the process of entering airport bird species data, historical bird observations, basin design information, and existing bird mitigation measures with participants and reviewed the risk analysis results. During the course of the workshop, CLE representatives helped the research team identify areas where the tool could be improved. Following the workshop, the research team provided all participants with a questionnaire (Attachment A) to allow for additional anonymous comments. The case study session lasted approximately four hours and the research team received questions, comments, and very useful feedback from CLE staff.

CLE representatives reported they appreciated the detail and flexibility of the tool, the knowledge of the research team, and the applicability to SMS. Several participants reported the tool to be complex and time consuming. Given personnel limitations and fiscal constraints facing airports, they worried the draft tool may present additional duties to a potentially encumbered staff. CLE staff offered some changes to the tool for the team to consider. For example, they recommended allowing the user to choose more than one mitigation per hierarchy of control category (engineering, administrative, etc.) and to auto populate the tool with strike data or species data from the strike database. Participants were concerned that the factors referring to the location of the stormwater BMP being evaluated to other water bodies did not consider whether movement areas would be crossed by birds in transit between basins. The draft tool addresses the proximity of water bodies from each other within 5 miles; however, it does not take into consideration whether there is a movement area present between the BMP and other water bodies or not. CLE case study participants suggested the research team improve the tool's user-interface. The participants appreciated that the tool was flexible, allowing the user to look at risk reduction by changing different variables. Participants felt the tool would most likely be used by risk/safety, planning, engineering, environmental and wildlife staff at larger airports. Overall, the CLE case study participants felt that the tool would be most useful in emphasizing the need for investment in specific BMP design characteristics and/or mitigation measures.

General Aviation Airport: PMP

The PMP case study was conducted on 25 September 2013. It was attended by nine individuals including the research team, the airport manager, a representative of PMP's environmental consultant (Kimley-Horn & Associates), and two professional engineers representing Hanson, Inc. (PMP's stormwater engineering consultant). This case study site visit lasted approximately four hours and consisted of a tour of PMP basins and classroom instruction. PMP requested that the draft tool be utilized to evaluate an existing stormwater BMP that was designed to be a dry detention facility; however, it is predominately wet year-round. This particular BMP also serves as a water feature for an adjacent golf course. While none of the participants elected to fill out the anonymous questionnaire, valuable feedback was received during the exercise.

The PMP airport manager and consultants thought the draft tool was very comprehensive, but also complicated. Given the lack of available staff at many GA airports, the PMP participants expressed concern over the practicality of the tool to the smaller GA airports. They felt that it would require more than an individual GA airport manager to evaluate the risk factors and mitigation options. However, participants realized that with the input of consultants who specialize in wildlife and stormwater design on airports, a GA manager could navigate the draft tool. Also, consistent with CLE comments, PMP consultants recommended allowing the user to select more than one mitigation option per hierarchy of control category. The airport manager and stormwater engineers (who are both private pilots) were concerned about NOTAMs as a mitigation option. These pilots expressed that (in their opinion) NOTAMs are not effective in mitigating bird strikes. They concluded NOTAMs should be classified as an "Administrative" control, rather than a "Warning," which translates to less risk reduction.

Results

Based on the results of the CLE and PMP case studies, the research team made modifications to the draft tool. Because overwhelming consensus from the case study participants was that the tool needs to be user-friendly, we have endeavored to update the visual appearance and functional capability of the tool. The goal is to make the instructions more precise and the tool inputs more intuitive. Also, the research team changed the hierarchy of controls (mitigation) options to reflect the recommendations of participants from both case studies. The user will now select "0" (no mitigations in this category), "1," or "More than 1" for each hierarchy of control option. If an airport currently practices or plans to incorporate more than one engineering control (or mitigation), for example, they will receive increased risk reduction for selecting "More than 1," rather than having the ability to select only one mitigation option from the list.

The case studies also highlighted the potential problems with utilizing airport strike data alone to populate the species selection portion of the tool. Airports, admittedly, may not report all wildlife strikes and many reported strikes contain no species information. Even more importantly, airports may already be managing for their riskiest species, thereby, leading to fewer strikes in the database. Ultimately, any water-dependent species considered hazardous to the airport should be assessed regardless of presence or absence in the strike database. These indiscretions confirmed the research team's reservations about emphasizing an airport's strike data to draw conclusions about risk.

Additional Changes Made to the Tool Based on Case Study Results

- Adding a link to the "USDA recommended vegetation for airports" list within the tool as a quick reference

- Cautioning the user from selecting a mitigation option under the "Elimination" hierarchy of control category. This option will remain part of the tool as a conceptual SMS component, but it is not a realistic wildlife mitigation option.
- NOTAMs will be moved to an "Administrative" mitigation example to give it less influence in overall risk reduction. Although NOTAMs may not be highly effective in preventing bird strikes, they should not be completely discounted as a mitigation option.
- The team is removing all non-water-dependent bird species from the list (e.g., turkey vulture). During the PMP case study, the risk reduction for these species was falsely inflated considering stormwater mitigations may not actually reduce risk. The tool will only include species that depend on water for some portion of their life cycle (e.g., foraging, nesting, etc.)
- Originally, the tool was designed so that the higher the risk output number, the lower the risk. For example, a Canada goose was assigned a hazard ranking of 2, while a swallow was given a hazard ranking of 5. The justification being that the hazard rankings were akin to mitigation/management priorities. A goose is a higher priority than a swallow, so it would be assigned a lower number (higher priority). Similarly, a risk score less than 10 was high risk (or red) and a risk level higher than 21 indicated low risk (or green). Through the case studies, it was determined that this was too counterintuitive for the user. The research team reversed the order so that a higher number indicates greater risk.
- Quantified non-avian decision factors (e.g., cost, maintenance requirements, regulatory compliance, etc.).
- Changed distances to largest practical Imperial Units, rather than metric.
- If the user is not selecting 10 total species for analysis, the tool will "gray out" the unused rows so as not to cause confusion on subsequent steps. During both case studies, only 5 species were assessed.

Although the draft tool was initially viewed as complicated, all case study participants were impressed with the detail, risk analysis process, and final outcomes of the tool at the conclusion of the workshops.

Discussion

Weighting Factors

Weighting factors are one aspect of the tool that increases or decreases the weight given to a particular risk factor in the math calculations. The weighting factors range from 0 to 10 and the research team provided default weighting factors for each risk factor in the risk matrix. For example, the "hazard ranking" of each species (or species selection) factor was assigned a default weighting factor of 10, while the "history of observations" factor was assigned a weighting factor of 2 and the "history of strikes" factor was assigned a weighting factor of 1. The rationale is that species selection was the most important factor when determining bird strike risk, and, therefore, it was assigned the highest weight. Species selection was chosen to be 5 times as influential as the "history of observations" factor; therefore, "history of observations" was assigned a default weighting factor of 2. The "history of observations" data is important, however, can be highly variable, hence the decreased weight. Species selection was also chosen to be 10 times as influential to risk as the "history of strikes" factor, therefore "history of strikes" was assigned a default weighting factor of 1. The strike data can be revealing, however, the lack of species identification in the database and the general absence of data for many airports can provide misleading information. If the user did not agree with the research team's default weighting factors, they could change the default to whatever factor they deemed appropriate. For example, if an airport has no wildlife observation data, the user can assign "history of observations" a weighting factor of 0 or 1, meaning the tool will adjust the math to reflect a low level of confidence in the selections made regarding that risk factor. The goal was to prioritize species selection and the DeVault et al. (2011) relative hazard scores as the primary risk factor.

Explaining these weighting concepts during the case studies was a challenge, therefore, the research team decided to remove the option for user-defined weighting factors under species of concern. In other words, the research team assigned species a weighting factor of 10 and it cannot be changed by the user. The research team believes this is the ultimate factor and, therefore, must be weighted the highest with no exception. The user will still have the ability to change the weighting factors for all other risk factors, however, instead of selecting a number from 0 to 10, the user will simply select "High" or "Low" confidence and the math will be adjusted accordingly. This approach will likely simplify a difficult concept for users to understand.

Ultimate User and Applications

From the case studies, the research team concluded that the tool will likely be most utilized by airport planners, environmental coordinators, engineers, and risk/safety personnel, either on airport staff or hired as consultants. Input from airport operations staff, wildlife biologists, and airport managers may be required; however, they will likely not be the primary users. The final tool is not intended to be utilized by one person, but rather will require several areas of expertise. Extremely positive feedback was received from airport safety/risk managers that have experience with SMS. The research team believes the tool will fit effortlessly into an airport's SMS plan.

The tool appears to be most effective at highlighting bird strike risk to regulatory agencies that enforce stormwater design criteria. Although the tool may not effect changes in stormwater design in every case due to the non-wildlife decision factors and the rigidity of many regulatory agencies, it will (at a minimum) highlight potential risks and increase awareness. By quantifying risk and illustrating risk reduction, the tool allows stormwater regulators to visually interpret the risks associated with standing water on airports. The research team envisions the tool will also bring attention to stormwater regulations that may directly conflict with wildlife hazard management.

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ACRP 09-08
Case Study
Questionnaire

1. What did you like about the Bird Strike Risk Analysis/Stormwater Decision SMS-based Tool?

2. What don't you like about the Tool?

3. What changes would you like to see made to the Tool?

4. Do you think the Tool will be useful to airports? Will it be useful to airports of all sizes?

5. Who (within the airport environment) do you expect to use the Tool most frequently (e.g. planners, biologists, managers, operations staff, etc.)?

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
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
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
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