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Abstract

Land development in the vicinity of airports often leads to land-use that can attract birds that are hazardous to aviation operations. For this reason, certain forms of land-use have traditionally been discouraged within prescribed distances of Canadian airports. However, this often leads to an unrealistic prohibition of land-use in the vicinity of airports located in urban settings. Furthermore, it is often unclear that the desired safety goals have been achieved. This paper describes a model that was created to assist in the development of zoning regulations for a future airport site in Canada. The framework links land-use to bird-related safety-risks and aircraft operations by categorizing the predictable relationships between: (i) different land uses found in urbanized and urbanizing settings near airports; (ii) bird species; and (iii) the different safety-risks to aircraft during various phases of flight. The latter is assessed relative to the runway approach and departure paths. Bird species are ranked to reflect the potential severity of an impact with an aircraft (using bird weight, flocking characteristics, and flight behaviours). These criteria are then employed to chart bird-related safety-risks relative to runway reference points. Each form of land-use is categorized to reflect the degree to which it attracts hazardous bird species. From this information, hazard and risk matrices have been developed and applied to the future airport setting, thereby providing risk-based guidance on appropriate land-uses that range from prohibited to acceptable. The framework has subsequently been applied to an existing Canadian airport, and is currently being adapted for national application. The framework provides a risk-based and science-based approach that offers municipalities and property owner's flexibility in managing the risks to aviation related to their land use.

Introduction

On August 1, 2001, after three years of consultation, a tract of land called the 'Pickering Lands' that had been previously expropriated by the Canadian federal government was declared an "airport site". There was need to identify areas surrounding the new airport site where the prohibition of certain forms of land-use could be specified in the airport zoning regulations. Initial stakeholders in the zoning process included Transport Canada (the federal government

department responsible for aviation safety), nine potentially affected municipalities, and numerous landowners situated in the urban and rural regions surrounding the future airport site. Many of the latter operate the lands commercially. Future stakeholders will include, *inter alia*, the airport authority, and the aviation industry operating to, from, and in the vicinity of the Pickering airport.

The safety-risk issues related to birds, land use and aircraft in the vicinity of the airport are complex. In recent years, there have been significant changes in land-use near the future airport site that have affected the behaviour of local and migrant birds. The concurrent pressure of increasing urbanization near Pickering and throughout Southern Ontario will lead to conflicting demands for land-use between the airport and the municipalities that surround the future site. Consequently, a project was commissioned by Transport Canada to conduct an up-to-date bird study to reflect the recent changes in land-use, and to develop a risk assessment process to support the restrictions that would need to be included in the zoning. The report of the study (ref. 1), which was completed in May 2002, serves a number of purposes, including:

- It is a principal reference document that can be used by current and future stakeholders;
- It provides a model by which the frequency and consequences of bird-related risks can be estimated;
- It provides a basis by which the risk control measures related to land-use can be formulated and later integrated with other mitigating measures that will be introduced by the airport authority and the aviation community; and importantly,
- It will provide the future basis to measure the effectiveness of the zoning in mitigating the risks related to bird activity.

This paper describes the framework that was developed to predict bird-related aviation risks and land-use. It concludes by examining the application of the framework at the Pickering airport site, and by assessing the benefits of employing a data-supported, performance-based approach when making decisions about sensitive public policy issues.

The Framework Described

General

The goal of the framework is to contribute to the reduction of the risk of bird-strikes to aircraft operating near an airport. The framework seeks to reduce the exposure to high-risk bird species by controlling land-use. It recognizes the various ways that aircraft and aero-engine manufacturers, airline operators and airport operators contribute to the goal by reducing the probability and severity of bird-related risks.

Components of the Framework

The framework measures three elements of risk:

- Categories of aircraft exposure and vulnerability (aircraft operations);
- Categories of relative risks of bird species (avifauna characteristics); and
- Categories of land-use (characteristics of land-use that attract bird species).

Aircraft Operations: Aircraft (particularly aircraft operated under Instrument Flight Rules) operate to, from and in the vicinity of airports with a high degree of predictability that enables

flight paths to be charted. In the case of the future Pickering airport, where all runways will be serviced by precision approach aids, and almost all aircraft will be transport-category aircraft powered by turbine engines, lateral and vertical "hazard" zones for departing and arriving aircraft can be projected. A traditional severity classification was adapted for the framework. The classification differentiates between catastrophic losses as a result of a bird strike event (Category A), major damage or the loss of no more than one of the aircraft occupants (Category B), and minor damage to the airframe, engines or aircraft systems (Category C).

The degree of risk to aircraft varies during different phases of the take-off, departure, arrival and landing. For example, the highest risk from a bird strike can occur just at take-off or while transitioning to the initial climb. The aircraft is low to the ground; it is usually being operated at or near the maximum performance limits; it has a large fuel load; and it is at a critical angle of attack. Crew activity is high and coordination is imperative. As the climb-out progresses and aircraft altitude increases, the risk of loss of control and collision with terrain (Category A) is reduced. However, the risk of serious damage to the airframe and engine (Category B) as a result of a bird strike event increases because of higher impact forces that result from the increased airspeed. In this way, the various phases of flight in the vicinity of the airport were assigned a worst-case severity rating. Category A was assigned for take-offs, climbs, missed approaches and go-arounds between the ground and 1500 feet above ground. Category B was assigned to all other operations during the descent-to-approach, the approach, the initial climb and the en route climb.

Avifauna Characteristics: Category A or B damage as described above would only result from bird strikes involving certain species under worst case circumstances. Therefore, the identification of bird species by category of risk becomes an important step in assessing the risks to aircraft operating near the airport.

The consequence of a bird strike varies with the (i) weight and density of the bird, (ii) the impact speed, and (iii) the number of birds that are struck during a bird-strike event. Therefore, the physical characteristics of bird species and their nesting, feeding, flocking and flying characteristics were examined to develop a bird hazard ranking system to categorize the potential risk related to each species. When examining 'size', the average weight of the species was employed because damage is determined by the density and mass of the bird.

The flocking behaviour of the species is important because it affects the probability that more than one bird is likely to be involved in the event. A flock of birds can lead to numerous birds being ingested into one or more engines, thereby greatly increasing the risk of an accident. An often-cited example is that of a Lockheed Electra that ingested a flock of starlings into three of four engines just after take-off from Boston's Logan Airport. It is noteworthy that starlings are a species with little individual biomass, and that the Electra was a turboprop aircraft, and thus less susceptible to engine damage than most modern turbofan aircraft. The aircraft lost power, stalled and crashed into Boston Harbour with a loss of life of 62 persons.

The flight behaviour of species is important when assessing risk. For instance, birds that at other times stay close to the ground may fly during annual migrations at higher altitudes[1]. The study focused on the local, daily movements associated with feeding and nesting around an airport site. Some species fly very close to the ground where they pose little risk. Others, such as gulls, hawks and vulture regularly fly between ground level and 1000 to 1500 feet above ground, where they

[1] Migratory behaviour is for the most part not influenced by local land-use, and was not included in this study.

pose significant risk to departing and arriving aircraft. A six-tiered ranking system was devised to categorize species by their potential risk to aircraft, accounting for the body density and mass, flocking characteristics and feeding and nesting behaviours[2] (table 1).

Only species from Levels One to Four were employed in the framework, because species from Levels Five and Six could rarely if ever be expected to result in a Category A or B bird strike event[3].

Table 1 – Bird Hazard Ranking System

Level of Risk	Characteristics	Illustrative Species
Level One	Very large (>1.8 kg), flocking	Geese, cranes, cormorants
Level Two	Very large (>1.8 kg), solitary or large (1-1.8kg), flocking	Vultures, Mallards, Great Black-backed Gulls
Level Three	Large (1-1.8 kg), solitary or Medium (300-1000 g), flocking	Red-tailed Hawk, American Crow
Level Four	Medium (300-1000g), solitary or small (50 – 300 g), flocking	European Starling
Level Five	Small (50-300 g), solitary or Very small (<50 g), flocking	Eastern Meadowlark, swallows
Level Six	Very small (<50 g), solitary	Warblers, vireos, sparrows

Land-use: Two facts underpin the consideration of risk associated with various types of land-use near an airport site. These are: all lands attract birds of some kind; and birds are not a threat to aircraft when they are on or close to the ground adjacent to the airport. The characteristics that need to be evaluated include: the species that are attracted; the numbers that are attracted; their behaviours when on or over the land; the frequency by which they use the land; the land's location relative to the airport; and the scope of the land-use.

[2] This categorization, developed initially for a previous Transport Canada project, is remarkably similar to a classification scheme developed independently in the United States that categorized bird strike data by strike damage and species type. See references 2 and 3.

[3] Species from levels five and six are most commonly involved in bird strike events. They seldom result in more than very minor damage. Many of the strikes go undetected by the flight crew and airline maintenance staff, and are detected because dead birds are found on or near the runway by bird control and runway patrol staff.

- Species. Land-use that attracts species from Level One to Level Four, and particularly Levels One and Two signify greater risk.

- Numbers. Land-use that attracts large numbers of hazardous species signifies greater risk.

- Behaviour. Land-use that influences birds to soar over the site, or to transit to or from the site at higher altitudes signifies greater risk.

- Frequency of use. Land-use that attracts frequent visits by hazardous species signify greater risk. For example, a small landfill may be visited by several hundred gulls every day of the year, whereas a recently ploughed farm field may attract several hundred gulls, but only for a day or two in spring and fall.

- Location. The location of the land-use relative to the airport and the species it attracts may signify different degrees of risk. For instance, a land-use that attracts low-flying and feeding birds might pose little risk to aircraft if it is located 2-3 kilometers from the runway. The same land-use immediately adjacent to the runway would signify greater risk.

- Scope of land-use. It is much easier to zone against a hazardous, site-specific land-use such as a waste transfer station or a hog farm than it is to zone against widespread agricultural practices such as ploughing and cultivating.

Taking these factors into consideration, a simple, four-level ranking of land-use was developed. High-risk land-uses regularly attract large numbers of hazardous bird species. These birds often fly long distances to reach the high risk land-use, and these flights may take the birds through aircraft approach or departure paths. High-risk land-uses included putrescible waste landfills, food waste hog farms, wildlife refuges, waterfowl feeding stations, and racetracks.

Moderate-risk land-uses regularly attract smaller, but still substantial numbers of hazardous bird species. They included open or partially enclosed waste transfer stations, cattle paddocks, sewage lagoons, municipal parks and picnic areas, and golf courses.

Low-risk land-uses attract small numbers of hazardous species irregularly. These included dry waste landfills, marshes, swamps and mudflats, commercial shopping malls and plazas, fast food restaurants, outdoor restaurants, schoolyards, and community and recreational centers.

The fourth category of land-uses was termed the "potentially risky land-uses" to describe land-uses that if operated according to standard procedures should not attract hazardous bird species. They included enclosed waste transfer stations, wet/dry recycling facilities, poultry factory farms, ploughing and cultivating, and storm-water management ponds.

Summary

The framework enables planners to chart the areas of highest bird-related risk relative to the departure and arrival ends of the various runways at an airport, and by associating high-risk bird species to land-use, identify different categories of more or less favourable land-use. The results are illustrated when examining the future Pickering Airport site.

The Framework Applied to the Pickering Airport Site

General

The approximate location of the runways at Pickering is depicted in Figure 1. The high risk areas where aircraft could be exposed to a Category A and B occurrence were charted using formulae employed to design standard instrument approach procedures (i.e. Cat I ILS approaches).

Knowledge of bird species, numbers and behaviours in the vicinity of Pickering was derived from numerous avifauna studies conducted in the previous three decades. Canada Geese were by far the most significant Level One species. Of the Level Two species, three species were very large, solitary birds (Great Blue Heron, Turkey Vulture and Bald Eagle, and four species were large flocking birds (Mallard, Black Duck, Great Black-backed Gull and Herring Gull). Eleven other species were identified as Level Three and Level Four species.

Sites that are used by feeding birds may attract some individuals from remote locations. Many birds that feed at landfills spend the night at communal roosts. These birds, including gulls, crows and starlings, make daily flights to and from the landfill, some of which are many kilometers from the night roost. Transiting birds may fly through the approach and departure paths of aircraft using the Pickering airport. Gulls regularly fly up to 30 kilometres between a landfill and their night roost in the Toronto region, illustrating that neither the landfill site nor the night roost need to be near the airport to create bird hazards to the aircraft that operate from it. This is particularly important at Pickering in light of the proximity of Lake Ontario. A landfill to the north of the airport could create a serious hazard by drawing gulls from the night roost on Lake Ontario over the airport twice a day. On the other hand, a landfill the same distance, but to the south of the airport, may pose little threat to aircraft operating to and from the future airport site.

Recommended Airport Zoning

Three categories of land-use were created: the Primary Bird Hazard Zone, the Secondary Bird Hazard Zone, and a Special Bird Hazard Zone (figure 1).

Primary Bird Hazard Zone: This zone depicted the area within which a Category A accident could occur[4]. The zone is bounded vertically at 1500 feet above ground, and laterally and horizontally by projecting a 3-degree glide slope from all runways. This resulted in three-dimensional cone extending up and out 8.8 kilometers from the end of each runway[5].

Consideration was given to including locations where a Category B accident could occur. This zone would include areas where aircraft operate at altitudes over 1500 feet above ground. Experience in southern Ontario is that most non-migrating birds fly at altitudes of less than 1500 feet above ground level. In fact, most birds affected by local land-use fly at altitudes lower than 1000 feet above ground level. For this reason, Category B accidents were

[4] A Category A accident caused by migrating birds could occur anywhere and cannot be prevented by airport zoning.
[5] A departing aircraft in all cases reaches 1500 feet agl long before 8.8 kilometres, so the governing condition became the instrument approach.

not considered in determining the location and extent of zoning around the future Pickering airport.

Secondary Bird Hazard Zone: The Primary Bird Hazard Zone included a "buffer" to account for occasions when pilots do not conduct the instrument approach precisely, and when winds cause departing aircraft to track off the extended centerline of the runway. Similarly, an additional buffer zone of four kilometers was added to account for predictable variations in bird behaviour.

For instance, birds that are attracted to a particular site may also visit other, nearby areas. Also, it cannot be anticipated that birds always fly along the same route, or even that our knowledge of bird behaviours is sufficiently sophisticated to accurately predict local movements.

Special Bird Hazard Zone: The third hazard zone was designed to address the highest-risk land-uses relating to the Pickering Lands. There was concern that a major attraction such as a landfill may create a significant safety hazard if it is located north of the airport. It would predictably lead to daily flights of thousands of gulls over the airport or through aircraft flight

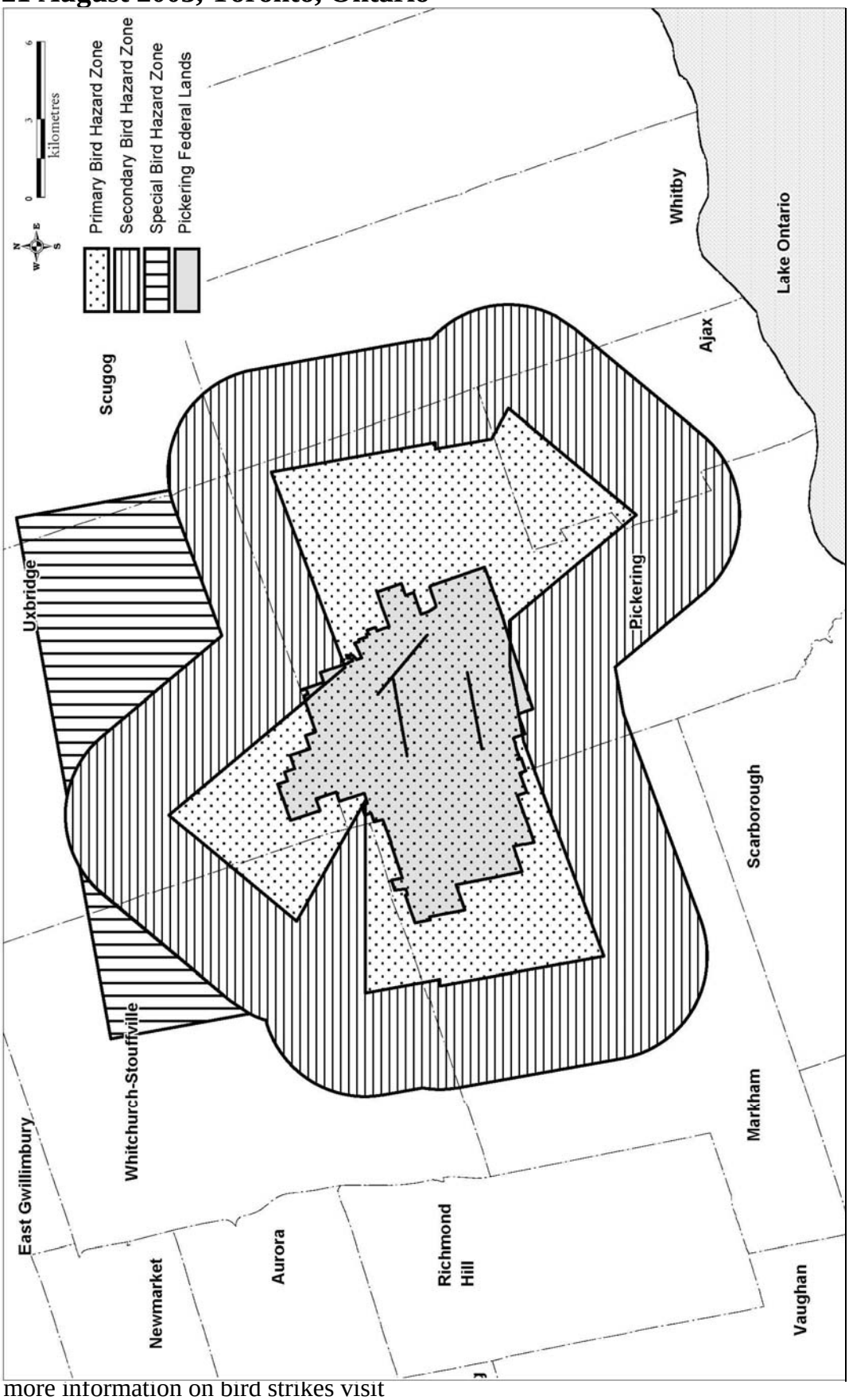

FIGURE 1. Proposed Bird Hazard Zoning for the Pickering Airport Site.

paths as the birds transit daily to and from their night roosts located on Lake Ontario to the south.

For this reason, it was recommended that a rectangular zone be added extending north from the northern boundary of the zoning for the northernmost east-west runway (figure 1).

Information from the bird hazard zones was integrated with information regarding land-use to create a checklist to assist stakeholders in identifying land-use that is appropriate for aviation operations.

Table 2 – Land-Use Within the Bird Hazard Zones

Land-Use	Permitted in Primary Zone	Permitted in Secondary Zone	Permitted in Special Zone
High Risk			
- Putrescible waste landfill	No	No	No
- Food waste hog farm	No	No	No
- Wildlife refuge	No	No	No
- Waterfowl feeding station	No	No	No
- Racetrack	No	No	No
-			
Moderate Risk			
- Open or partially enclosed waste transfer station	No	No	Yes
- Cattle paddock	No	No	Yes
- Sewage lagoon	No	No	Yes
- Municipal park, recreational	No	No	Yes
- Golf course	No	No	Yes
Low Risk			
- Dry Waste Landfill	No	Yes	Yes
- Marsh, swamp, mudflat	No	Yes	Yes
- Shopping mall, plaza	No	Yes	Yes
- Fast food restaurant	No	Yes	Yes
- Out door restaurant	No	Yes	Yes
- School yard	No	Yes	Yes
- Community/Rec. Centre	No	Yes	Yes
Potentially Risky			
- Poultry factory farm	Various	Various	Various
- Enclosed transfer station	Various	Various	Various
- Wet/dry recycling facility	Various	Various	Various
- Storm water mgmt pond	Various	Various	Various
- Plowing/cultivating	Various	Various	Various

Conclusion

The framework described in this paper offers a number of benefits over more traditional, prescriptive methods for managing land-use near airports. In many cases, past practices have led to the unrealistic prohibition of land-use near airports, often with uncertain and non-measurable safety dividends. The municipalities and landowners surrounding the Pickering Airport would have viewed the imposition of a massive prohibition of land-use as onerous, particularly as the airport is not to be built for some time.

The approach to zoning described in this paper offers flexibility based on sound scientific data and applied risk management principles. The actions that result from use of the framework will enable the current stakeholders (i.e., Transport Canada, nine municipal governments, and numerous land owners) and the future stakeholders (i.e., the airport authority and the airlines) to demonstrate due diligence when managing bird-related risks. Application of the framework will result in communication about, and the management and measurement of, safety-risks in an area that has sometimes in the past led to misunderstanding, suspicion, and ultimately compromises that may have jeopardized the achievement of the desired safety goals.

The framework has subsequently been modified and applied with success at a medium-sized airport in Thunder Bay, Ontario, on the north shore of Lake Superior. The framework is in the process of being adapted for national application, and tested in what is likely the most demanding environment in Canada. Vancouver International Airport is situated on Sea Island, a flat delta formation of alluvial sediments in an estuary that provides a rich environment for many wildlife species. During peak migration periods, as many as 1.4 million birds use the Fraser River delta, more than 250,000 water birds winter in the estuary; and it is the location of one of the largest gatherings of winter raptors and Great Blue Herons in Canada. A number of federal, provincial and municipal government agencies, not to mention numerous local and national advocacy groups, have mandates that are concerned with land-use in the bio-diverse environment surrounding the large, international airport. Various Safety Reviews conducted by Transport Canada have identified the need to manage the co-existence of what is essentially incompatible land-uses. The framework will be employed to analyze the aviation safety-risks resulting from land-use in the vicinity of Vancouver International Airport.

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