# THE ROLE OF RADAR-ACTIVATED WATERFOWL DETERRENTS ON TAILINGS PONDS

Tim J. Nohara, Ph.D.,P.Eng, Accipiter Radar Technologies Inc., Fenwick, ON CANADA
Robert C. Beason, Ph.D., Accipiter Radar Corporation, Orchard Park, NY USA
Sean P. Clifford, B. Eng., Accipiter Radar Technologies Inc., Fenwick, ON CANADA

## ABSTRACT

Like other groups of animals, birds habituate to repeated threats that do not harm them. Consequently, they gradually learn to ignore continuously activated scare devices such as spinning lights, scarecrows, and propane cannons. Two approaches can be used to reduce or eliminate the rate of habituation. The first is to lethally reinforce threats; a practice that is unacceptable for tailings ponds. The second is to reduce bird exposure to threats that are not reinforced. Continuous or random activation of deterrents exposes birds to deterrent stimuli almost continuously, causing the birds to habituate rapidly. Activating the deterrents only when the birds are present greatly reduces their exposure to the deterrents and simultaneously causes them to associate offensive stimuli with a specific, defended location.

We have developed and deployed an operational wide-area, radar-activated deterrent system (RADS) using these principles in the Alberta oil sands. The implemented control and activation strategy is based on networked digital avian radars and deterrent devices that respond only to the presence of birds in designated locations. This approach provides defence of not only tailings ponds and other sensitive areas but also produces inner and outer defence perimeters. For most oil sands tailings operations, the sand beach and the water surface of these industrial facilities serve as the outer and inner perimeters, respectively. Responding to birds as they approach a sensitive area means that they can be turned away using long-range deterrents before reaching the sensitive area, offering greater protection. Those birds which penetrate the outer line of defence and continue are met by the inner deterrents.

A comprehensive information system at the heart of the RADS retains forever the movements of birds and their responses to the deterrents in support of risk assessment and management, investigations, reporting and information sharing, system performance assessment including habituation, system improvements, and R&D.

## INTRODUCTION

### Background

The Clark hot-water extraction process produces tailings ponds that retain residual amounts of bitumen. This bitumen can be hazardous or lethal to birds that contact or ingest it from a tailings pond or its adjacent shores. A variety of potentially useful deterrent technologies, used alone or in combination, are available to keep birds off the tailings ponds.  These technologies differ in their efficacies.

One problem faced by tailings pond managers using deterrents to keep the birds away is preventing the birds from becoming used to the repeated application of deterrents. Because they constantly hear and see deterrents that activate on a regular or irregular schedule, birds learn that the threat is meaningless. They soon come to ignore the empty threats the deterrents represent; a behavior called habituation. On-demand activation of deterrents has been shown to prevent habituation and to prevent waterfowl from landing on small contaminated ponds (Stevens et al. 2000).

### The Challenge

The challenge is to maintain the efficacy of the deterrents, by keeping the birds from habituating to and ignoring the deterrents without harming the birds. Habituation can be slowed or perhaps prevented by not continuously exposing the birds to the deterrents. The more “false alarms” a bird experiences each day, the more rapidly it will habituate to the stimulus. Slowing or avoiding habituation requires a mechanism to activate selected bird deterrents only when the birds are in position to land on a contaminated tailings pond. Birds that are migrating overhead should not activate the deterrents for two reasons. First, they

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are transient and will not attempt to land on the tailings pond. Their migration altitude is hundreds of meters above the terrain and directing deterrents at them is useless. Second, activating deterrents frequently (in response to migration which usually continues for several hours through the night) and in irrelevant situations to birds near the tailings ponds will produce more rapid habituation.

For the purposes of this paper, we say that a flight path, trajectory, or track of a bird or flock of birds is *geo-feasible* with a tailings pond landing if the bird's 3D location (latitude, longitude, altitude), speed and heading make such a landing reasonably possible. Birds approaching a pond at altitudes and on headings capable of a pond landing must be turned away by selectively activating only those deterrents proximate to the birds in question. The radar-activated deterrent system (RADS) must be able to distinguish between birds on geo-feasible flight paths from those that are not; for example, between low-flying local birds heading towards a tailings pond and high-flying migrating birds passing through overhead.

All this must be accomplished on a large scale to include all of the tailings ponds at a mine which can be spread across a collective area larger than a thousand square kilometers; and it must operate automatically, be user-friendly and be controllable by a single human operator from a single location for economic feasibility.

In the remainder of this paper, we present a state-of-the-art approach undertaken by Accipiter Radar and installed at Syncrude Canada Ltd that addresses this challenge for maximum bird protection.

## OPERATIONAL CONCEPT

The operational concept of the RADS is illustrated in Figure 1. Waterfowl a geo-feasible flight path towards a tailings pond turn away in response to deterrents activated as they approach the sensitive area. In this case, deterrents consist of two varieties, high-power (pressure) acoustic devices (HPADs) and floating deterrent devices. HPADs are used as long-range deterrents in a first line of defence. They are spaced around the perimeter of a tailings pond as illustrated in Figure 1 and are directed outwards, away from the tailings pond. Each HPAD is typically responsible for responding to geo-feasible flight paths in a specific sector around the tailings pond. HPADs are effective at directing very loud acoustic sounds within a focused spatial sector (approximately 10 degrees in azimuth and 10 degrees in elevation) at distances of 0.5 km to 1.5 km from the device. An HPAD is illustrated in Figure 2.

If birds make it through the first line of defence and continue to approach a tailings pond, they are met by a second line of defence as they attempt to land on the tailings pound. These deterrents are necessarily mounted on floating platforms and arranged on a grid-like pattern (Figure 1). Groups of floating deterrents are logically programmed to activate together to protect a sub-region of a pond, and respond directly to birds on geo-feasible flight paths overhead or on near-approach to the tailings pond. As birds alter their course and enter other sub-regions, other deterrents in respective sub-regions will activate until birds fly clear of the pond. A typical floating deterrent platform is illustrated in Figure 2. Each floating platform houses multiple deterrent devices for maximum effectiveness.

Avian radars are used to provide 360$^{o}$ 3D surveillance of each tailings pond, the air space above, and the approach to each. Their coverage and monitoring are optimized to respond to birds on geo-feasible flight paths. A radar track is automatically formed for each bird (or flock) and the 3D coordinates of its trajectory (latitude, longitude, altitude versus time), in addition to speed, heading and size information is capture by the radar system. Because more than a single radar sensor is typically needed to monitor a mine, the surveillance coverage from multiple radar sensors is seamlessly integrated to provide the desired overall coverage. Figure 1 illustrates two radar trailers covering a large tailings pond, each with two, 360$^{o}$ 3D radar sensors providing complimentary coverage. 3D surveillance is essential to distinguish birds at different altitudes; i.e., to determine geo-feasibility to reduce habituation. 360$^{o}$ coverage is essential to detect geo-feasible flight paths from all directions approaching the tailings pond. Figure 2 provides a close-up of a typical, dual-radar surveillance trailer.

### Automatic System Control

A large tailings pond (say at least 10 square kilometers) may require a few radar sensors and tens of deterrent devices to provide good protection. To minimize habituation, numerous virtual alert zones are formed in association with the multiple lines of defence within the integrated coverage pattern of the radars. Each alert zone causes a subset of associated deterrents to automatically activate in response to a geo-feasible bird threat penetrating such zone.

Because of the vastness of the areas being protected, the deterrents can not be hardwired to the RADS controller economically, which is responsible for the deterrent activation logic. Rather, the deterrents are located wherever it is deemed necessary and convenient; then they are networked wirelessly. Each season, they may be deployed differently. Floating deterrents may move a little during a season with wind, and as ice forms before they are removed for the deep freeze. A GPS is installed on each deterrent to deal with movements and the deterrent's position is communicated regularly so that the RADS always knows its location.

As a result of the varied and changing landscape common to mining operations, line of sight communications can not be assured. As a result, the RADS controller uses robust mesh networks to communicate with its deterrents, send activation commands to the deterrents, and receive status information from the deterrents.

RADS subsystems are typically self-powered through generators and solar panels. The radar trailers and HPADs are typically powered with diesel generators, while the floating deterrents are typically powered with solar and batteries. Propane cannons on the floating modules require propane to operate. Fuel/battery levels need to be automatically monitored by the RADS as environmental conditions can cause significant variations in energy consumption. System health must be monitored and remotely diagnosed and corrected to minimize the need to send out personnel for maintenance.

A RADS bird activity information system is essential to recording all bird movements, zone alerts, deterrent activations, and bird responses. In addition, system health information must be monitored and maintained to assess system availability and support subsequent analyses.

### User Requirements

With hundreds of sensors and devices to monitor and control over a large mining operation, a common operating picture (COP) is essential for RADS usability. The RADS COP integrates all system components and information in real-time and presents a single, unified display and console so that a single user can quickly gain situational awareness and can apply command and control to system elements. The COP provides the user with an integrated view of all of the birds in the air-space, all of the alert zones and their status, and all of the deterrents and their status.

## TECHNICAL APPROACH

### Bird Behaviour and Control Logic

The birds to be targeted are limited to those that might potentially land on the tailing ponds or their shores. This constraint means that the radar surveillance sensors must provide monitoring of the complete surface of the pond as well as the shores and surrounding area to about 2 km from the shore. Large ponds require multiple radars to provide coverage with the resolution that is necessary to determine bird behavior and selectively control the deterrents.

Two criteria are used to indicate geo-feasible birds that might be landing on a tailings pond: (1) they are flying towards the pond and (2) they are at an altitude (typically < 200 m) suitable for landing.

The birds of interest range in size from gulls and small ducks, such as teal, to flocks of waterfowl. Songbirds do not land on the tailings ponds and rarely on the ground around the pond where they might encounter bitumen. Using the size classes of birds, as measured by the radar, we filter out radar returns from songbirds (Beason et al. 2012, Nohara 2010, Nohara et al. 2011). This prevents unnecessary activation of the deterrents and reduces the rate of habituation to the deterrents.

Birds flying away from the pond are ignored because they are engaging in a desirable behaviour and activating the deterrents might be perceived as "punishment". A second reason for not triggering on such birds is that it would increase exposure of all birds in the area to the deterrents and could increase the rate of habituation.

A multistage strategy of defence is employed. The surrounding approaches of each pond are divided up into multiple virtual zones as a first line of defence protected by HPADs. If these are penetrated, a second line of defence is met by the birds. In this case, the pond surface is divided up into a number of sub-regions or surface zones, each of which is protected by an array of floating deterrents that respond to birds in that zone.

Geo-feasible radar tracks from birds or flocks that come within about 1.5 km of the shoreline and are flying more-or-less towards a tailings pond cause an automatic zone alert. The long-range deterrents associated with that zone respond and broadcast a very loud programmed sound with user-defined timing. If the birds continue towards the pond, the sound is broadcast a second time (say about 60 seconds later) until the birds depart the zone.

If the birds continue and cross the shoreline of a pond entering a sub-region or zone on the pond, a group of short-range floating deterrents in that zone are automatically triggered. The short-range deterrents are triggered at intervals of say 60 seconds for as long as the birds are within the zone over the pond. As soon as the birds exit a given zone, those respective deterrents cease.

**Architecture**

The RADS network architecture is illustrated in Figure 3 and further described in Nohara 2010. The collection of Accipiter radar nodes used to provide surveillance coverage of the tailings ponds communicates over an intranet/Internet to the Bird Activity Information System which is the heart of the RADS and tracks all geo-feasible birds in the airspace. Land-based acoustic devices (i.e., HPADs) and Floating Deterrent Units are distributed around and on the tailings ponds and controlled over a mesh radio/communications network by a Deterrent Activation Processor. The mesh network supports non-line-of-sight communication among the deterrents. The Deterrent Activation Processor interacts directly with the Bird Activity Information System in real-time, and implements the zone alerts and deterrent activations.

**Radar Sensors**

X-band avian radar systems with dish antennas are selected for use because they have proven to provide the best performance in terms of high-resolution, 360$^{o}$, 3D capabilities (Beason et al. 2012, Nohara et al. 2011). Specialized radar capabilities such as multipath and sidelobe suppression to mitigate extraneous returns from large machinery, and adaptive clutter mapping to mitigate the changing clutter environment, are especially needed for mining environments. X-band is ideal for providing excellent, local weather data, which has proven to be essential during spring and fall migration periods to predict when birds may be forced down by unfavorable flying conditions.

**Deterrents**

Two categories of deterrents are presently used; one for long range and one for short range. The long-range deterrents consist of high-power acoustic devices (HPAD) to replace traditional shore-mounted propane cannons. Propane cannons have been used as bird deterrents because they produce a sound that (to humans) resembles the blast of a shotgun. Thus, the sound from the cannon is reinforced by hunters shooting at the birds elsewhere during migration.

The HPADs (HyperSpike HS-24 is used at Syncrude) are spaced along the perimeter of the ponds and directed away from the pond towards approaching birds. The projected sounds are typically transmitted for short periods (e.g., 10 seconds) and repeated at longer (e.g., 1-minute) intervals if geo-feasible birds are still present. To further reduce the rate of habituation, the projected sounds can be changed daily.

The short-range floating deterrent platforms provide multi-sensory stimulation produced by a combination of visual and auditory deterrents that are activated simultaneously. The visual stimuli include a super-normal sized falcon effigy with flapping wings when activated and a strobe light. The strobe light functions to draw the bird's attention to the effigy. Because birds do not estimate distance based on binocular vision but size-constancy (Martin 2009), the large falcon effigy appears to be much closer to the birds than it actually is. The auditory stimuli include the call of a predatory bird, to go with the falcon effigy, and on-board propane cannons.

The short-range deterrents are arranged together as a set and, for tailings ponds, mounted on a floating platform. Several platforms are distributed within a deterrent zone or sub-region and activated simultaneously when birds intrude into that zone. These deterrents are activated for a short interval (on the order of 10 seconds) when activated. The short-range deterrents have a longer time-out (on order of 1-minute) similar to the long-range deterrents. This interval gives the birds time to clear the area without repeated stimuli, which might increase the rate of habituation.

## OPERATIONAL EXAMPLES

In this section, we provide examples to illustrate the concepts and designs described earlier. We begin with a view of the Common Operating Picture (COP) at Syncrude, shown in Figure 4. The left-hand pane of the COP is used for controlling the various views availabe and the current view is shown in the image window on the right-hand pane. Figure 4 shows a zoomed-out view with few outlined tailings ponds visible, along with birds currently being tracked, alerted zones (one is lit up), and symbols representing each deployed deterrent.

The image window is developed in GoogleEarth™ so the user can zoom, pan and tilt to provide 3D, real-time views of the current activity. Geo-feasible bird tracks will cause appropriate zones to activate (shaded) so the user has instant awareness; the triggered deterrent devices (i.e., their symbols) also light up. Right-clicking on a deterrent symbol raises a dialog which reports status attributes (such as state, fuel levels, system health, location) and provides control functions (e.g., reset, test).

Each tailings pond is organized as a logical subsystem that can be separately controlled. Redundancies are built into the system to accommodate its size and complexity.

Broad-scale migration is visible in Figure 5 as birds fly over multiple tailings ponds. The radar tracks from all ponds are integrated into the single COP display, providing complete situational awareness to the operator in a single view.

In Figure 6, geo-feasible tracks from a flock of birds are seen turning away from a tailings pond in response to five floating deterrents modules (numbered 28-32) activating on an inner alert zone. The inner alert zone containing the five deterrents is automatically activated in response to the geo-feasible birds (Figure 6).

## FUTURE WORK

With the large-scale RADS only recently deployed, there is considerable opportunity for continued improvement of system effectiveness, based on performance metrics derived from the extensive observations collected by the bird activity information system.

An extremely important need is to determine the efficacies of various auditory stimuli. The HPAD devices are highly directional and efficient at transmitting sounds long distances. The most common sound used is the explosion to resemble a shotgun blast. Other sounds, such as avian alarm and distress calls, have been used with varying success. While it is unlikely that a single sound will be effective against all species of waterfowl, researchers can evaluate a variety of sounds and determine which are most effective against specific species or groups of birds. The radar-activated deterrent system is the ideal device to collect those data. It records when the deterrents are activated and the behavioral responses of the birds to the stimuli, as well as the time-lag from stimulus to response. Because the system is automated, it can collect data continuously without human oversight or bias.

Developing additional deterrents is also important. Although the deterrents should not be activated by migrating birds passing overhead, they need to be activated by migrating birds that approach a pond to land. Migrating waterfowl can stop their night's migration at any time during the night or the following morning. Although the auditory deterrents should be equally effective at night, the visual deterrents will not be. Red and green lasers have been reported to disperse some waterfowl from water surfaces (Blackwell et al. 2002, Werner and Clark 2006). In a recent study, Syncrude and Accipiter scientists verified this response to lasers (Beason and Polak, 2012). As a result, radar-activated laser deterrents may be added to the deterrent system in the future to provide additional nighttime protection.

Since the deterrents can be deployed and grouped arbitrarily, and since any number and design of virtual electronic zones can be created by the RADS to trigger deterrents in response to geo-feasible bird flight paths, additional research should lead to further optimization of the RADS protection strategies based on the collected observations.

Furthermore, the wide-area bird behavior observations collected by the RADS has the potential to supply researchers including biologists, ornithologists, conservationists, public health officials and others with valuable data sets and understanding.

The RADS architecture described herein fully supports real-time integration and sharing of data from adjacent mining operations providing early warnings to neighbours of migration events. In the fall, operators to the north will be able to provide early warning to operators to the south; in the spring, the situation reverses.

Finally, with the deployment of high-resolution X-band avian radars that can track weather well, a wide-area, high-fidelity, parallel weather channel can be developed and added to the RADS to provide real-time warning of significant weather events, and to provide local weather pattern forecasting. High-quality, real-time, local weather information will not only improve bird protection, but can protect operations and humans as well.

## CONCLUSIONS

The highest standard in bird protection has been presented for mining applications involving the need to keep waterfowl away from tailings ponds. A state-of-the-art approach undertaken by Accipiter Radar and rolled out at Syncrude Canada Ltd addresses this need by employing a large scale, integrated, radar-activated deterrent system that only responds to birds that are at risk in order to reduce habituation and maintain effectiveness. Notwithstanding the harsh (wind, blowing sand, $-40^{o}$ C temperatures) and ever changing environment presented by the Alberta oil sands, the deployed systems have proven capable in operating reliably and providing the necessary data, situational awareness and control to be operationally useful.

The concept of operation, technical approach, implemented systems, and examples we present are applicable to other situations such as off-shore platforms, wind-farms, and airports.

## ACKNOWLEDGMENTS

The authors wish to express their thanks and gratitude to Syncrude Canada Ltd for their sincere commitment to protecting birds from exposure to tailings ponds. The state-of-the-art, radar-activated deterrent system described here would not have resulted had it not been for Syncrude's determination and vision to challenge system developers to provide state-of-the-art bird protection today, while factoring in the flexibility for improvements tomorrow. The authors are also indebted to Alarm Control Systems, Salt Lake City, Utah, whose personnel are responsible for the state-of-the-art deterrents that are integrated into the RADS. Finally, our thanks goes out to the entire team at Accipiter Radar who continue to work tirelessly and innovatively with our partners in developing and improving RADSs for the protection of birds in energy-generation applications.

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Figure 1: Illustration of radar-activated deterrent system protecting tailings pond showing a trailer with two X-band radars, shore-mounted high-power acoustic devices, and floating deterrent modules..


Figure 2: Radar-activated deterrent system subsystems: dual-radar trailer, floating deterrent, and HPAD deterrent.

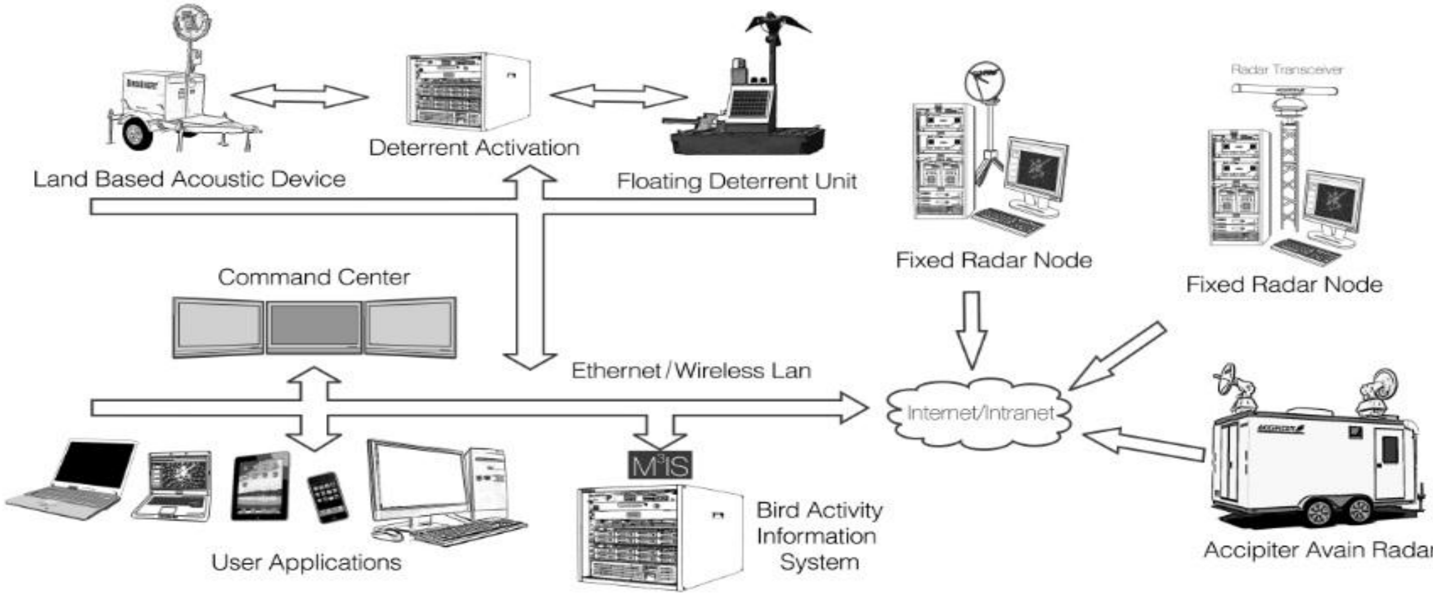


Figure 3: Radar-activated deterrent system network architecture


Figure 4: Common operating picture for real-time viewing and command and control of system. The symbols on the ponds represent floating deterrent modules.

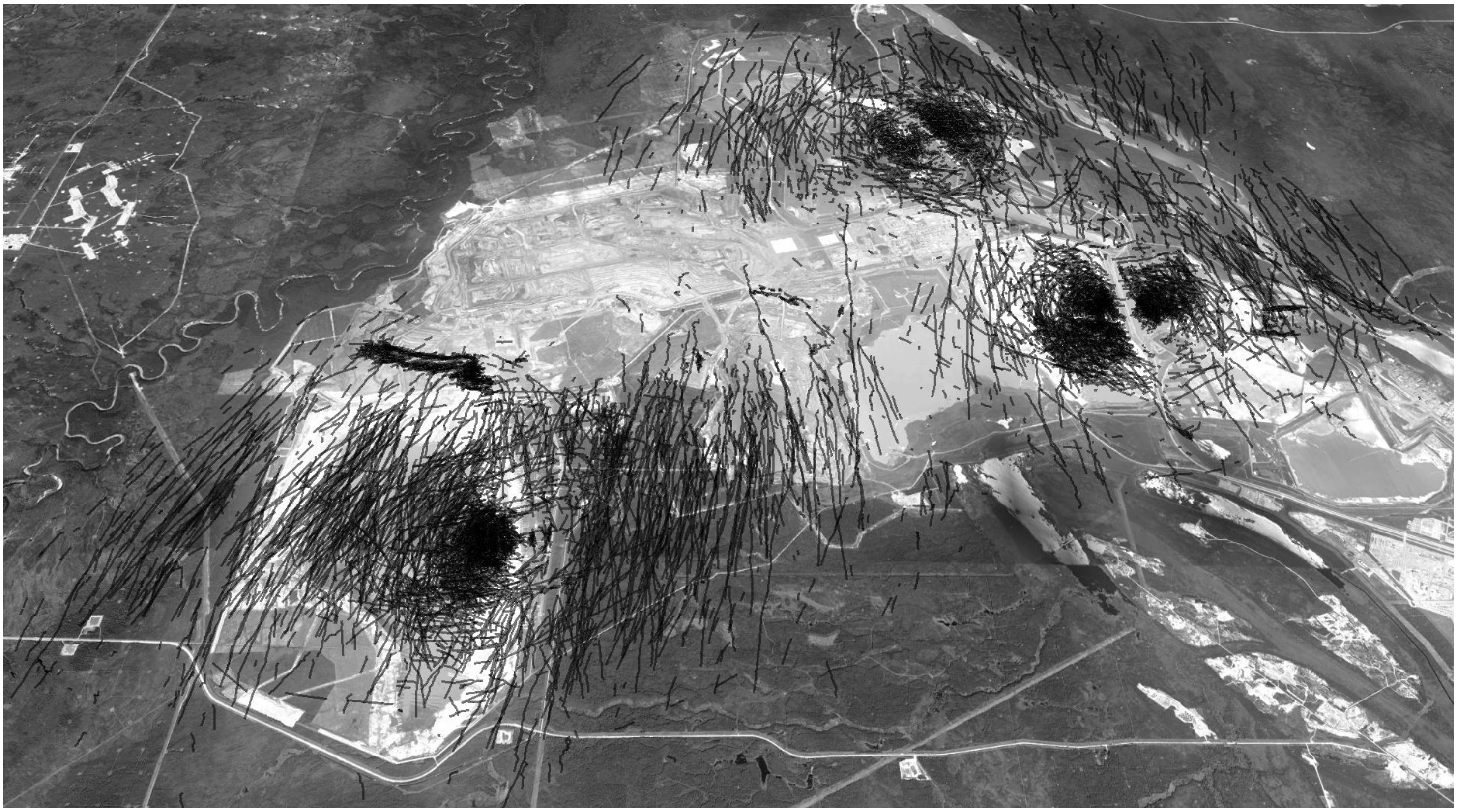

Figure 5: Broad-scale, night-time migration across multiple tailings ponds. The black lines represent the tracks of individual migratory birds.

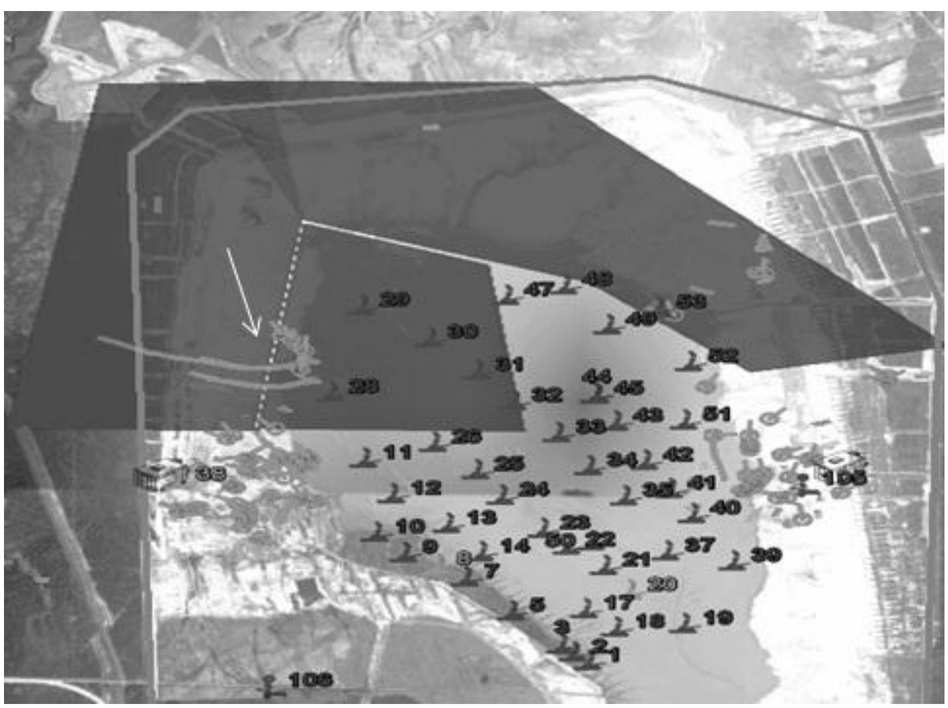

Figure 6: Birds (arrow) turning away in response to floating deterrent modules 28-32 after entering sub-region of tailings pond. The numbered symbols on the pond represent individual deterrent modules.