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Effects Of Land Use Changes On Trumpeter Swan (*Cygnus buccinator*) Use Of Lakes In The Grande Prairie Region Of Alberta

By

Tara Renee Banks ©

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Effects Of Land Use Changes On Trumpeter Swan (*Cygnus buccinator*) Use Of Lakes In The Grande Prairie Region Of Alberta submitted by Tara Renee Banks in partial fulfillment of the requirements for the degree of Master of Science in Wildlife Ecology and Management.

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ABSTRACT

The purpose of this study was to assess the effects of changes in land use surrounding lakes on trumpeter swan use of those lakes. Human related disturbance and environmental conditions were assessed. Comparisons were made using t-tests and logistic regression analysis to determine which disturbance types, at what distance from the lake had a significant impact on whether the lake was used by breeding or non-breeding trumpeter swans. Lake area and geographic location of the lakes (boreal versus agricultural zone) significant. Human disturbances that impact trumpeter swan use of lakes include agriculture, well sites, roads, seismic activities, and forestry. Disturbances within 1 km of the lake had a significant impact on trumpeter swan use of the lakes.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE
INTRODUCTION

1.0 BACKGROUND

Trumpeter swans (*Cygnus buccinator*) are the second rarest migratory bird in the interior of western Canada. However, trumpeter swans used to nest in Canada from as far west as British Columbia to as far east as Ontario and north to the southern portion of the North West Territory and Yukon Territory (Shandruk 1986). The trumpeter swans found nesting in Canada are referred to as the interior Canada sub-population and make up approximately half of the Rocky Mountain population and 4.5% of the world population. The trumpeter swans in this population utilize habitat in northwestern Alberta and northeastern British Columbia (Shandruk 1986).

There are increasing demands being placed on the habitat in northwestern Alberta due to an increasing human population. As the population in this area increases, so will the amount of development occurring around lakes used by trumpeter swans for various activities, including breeding and brood rearing. Habitat degradation is most prevalent in the Peace River parkland in northwestern Alberta (Shandruk 1986). Disturbance mostly occurs in the form of recreational use, oil and gas exploration, forestry, and agriculture (Shandruk 1986).

Information about trumpeter swan production on lakes in the Grande Prairie region is available due to the annual aerial surveys conducted by the Canadian Wildlife Service almost every fall since 1957. Within that data base there are trends to indicate some lakes have increased swan use and others have decreased use over time. With the increasing demands placed on trumpeter swan habitat and the trumpeter swans history of being a very sensitive bird, it is vital to determine what is causing trumpeter swans to stop utilizing, or change their use of certain areas of their habitat. Since specific information on swan response to disturbance is lacking, a more broadly based approach was chosen for this study.

The general objective for this research was to assess the effects of changes in land use around lakes on trumpeter swan use of those lakes. More specifically, this study attempted to determine what type of land use activity creates the changes in the lakes that cause trumpeter swans to abandon or change their use of them.

The null hypothesis for this research was that land use and development surrounding lakes in the Grande Prairie region of Alberta have no impact on trumpeter swan use of those lakes. The alternative hypothesis is that the development and associated human activity occurring around lakes in the Grande Prairie region of Alberta has an influence on trumpeter swan choice of habitat.

2.0 TRUMPETER SWAN HISTORY

Trumpeter swans were once prevalent throughout the north, west, and central parts of North America (Mackay 1978). However, by the 1930s, population surveys showed estimates of between 37 and 97 remaining trumpeter swans. Almost all of those birds existed in Yellowstone National Park and Red Rock Lakes Wildlife Refuge (Johnsgard 1978). Several human activities contributed to the decline of these birds, including hunting for skins and quills (Mackay 1978). In London, between 1823 and 1880, 108,000 swan skins were sold (Brechtel 1982). Other activities that led to the decline of trumpeter swans included native hunting for food, the selling of eggs to collectors, destruction of habitat, and expanding disturbance of habitat (Mackay 1978, Banko 1960, Neiman and Isbister 1974, Johnsgard 1978). For example, in Alberta, Saskatchewan, and Manitoba, an estimated 40% of total wetlands have been lost to agricultural drainage (Di Silvestro 1989). Such drastic losses of habitat often have severe consequences for species with very specific habitat requirements such as trumpeter swans.

Since the 1930s, trumpeter swans have made remarkable progress in increased production and improved population status. In 1995 there were 448 trumpeter swans in the Grande Prairie region of Alberta alone, and as of April 1996, trumpeter swans were removed from the endangered species list in Canada (Beyersbergen 1996). Several factors led to the establishment of new breeding populations and therefore maintenance of the species. One such factor was the establishment of the Red Rock Lakes Migratory Waterfowl Refuge in Montana. As well, Grand Teton National Park established protection for trumpeter swans from disturbance due to ranching and other activities (Johnsgard 1978, Hansen 1973). Coupled with the establishment of protected areas, was the establishment of protective legislation. For example, in 1894 the Lacey Act was introduced to provide protection for the wildlife of Yellowstone National Park. In 1918, the Migratory Bird Treaty Act was introduced which closed the hunting season on both species of native swans (Banko 1960, Brechtel 1982). The Migratory Birds Convention Act provided further protection for trumpeter swans by authorizing the acquisition of land for wildlife refuges and is the reason for the establishment of the Red Rock Lakes Wildlife Refuge in Montana (Banko 1960). In Canada, the Migratory Birds Convention Act made it illegal to "hunt, molest, kill, or have possession of any native swan" (Brechtel 1982). From 1941 to 1946, the hunting season on snow geese was closed in Idaho, Montana, and Wyoming to protect swans from accidental shootings (Brechtel 1982). Although the earlier legislation was not introduced in time to prevent trumpeter swans from becoming endangered, the earlier acts provided stepping stones for later. more effective legislation (Banko 1960).

The trumpeter swan population is currently healthy, and trumpeter swans are no longer on the endangered species list in Canada. However, the level of human development and industrial activity occurring in and around their habitat, affecting habitat suitability, is increasing over time. For example, as the human population expands in the Grande Prairie region, so will the demand for recreation on lakes. The increase and intensification of agricultural activity, resource development and exploration, urban expansion, and rural subdivision development all potentially degrade trumpeter swan habitat and therefore influence potential, future trumpeter swan population levels (Shandruk 1986).

This intensity of development occurring in Alberta may affect the breeding populations of trumpeter swans because trumpeter swans are aware of "any change in appearance of the landscape within their nesting territory" (Banko 1960). Trumpeter swans are also noted for being extremely slow to colonize new nesting areas (Hansen 1973). This could become very important as the amount of habitat free from disturbance decreases and the population has increasing demands for new nesting areas. Another important consideration is that more than 50% of the breeding lakes in the Grande Prairie region of Alberta are surrounded by private lands which have few land use regulations associated with them. If land use trends are not monitored and managed, the population of trumpeter swans in Canada could become extirpated (Shandruk 1986).

3.0 TRUMPETER SWAN ECOLOGY

The trumpeter swan population in the Grande Prairie region of Alberta leaves its summer area near the end of October. From Grande Prairie, they travel south to

Idaho where they spend the winter on the Snake River (Mackay 1978). The young swans from the previous breeding season remain with the parents throughout the winter and return to the Grande Prairie region with them in late April (Mackay 1978).

Nesting sites must meet specific criteria for trumpeter swans to breed. For example, breeding and brood rearing territories must be at least two hectares in size to insure an adequate food supply for the young and parents (Johnsgard 1978). Hansen et al. (1971) observed that suitable water bodies for nesting were between two and 14 ha and that on average, there were between 28 and 61 ha of marsh per nesting pair. Large water bodies are suitable for nesting because they support extensive stands of emergent vegetation needed by trumpeters (Hansen et al. 1971). Along with being large, the nest area must be free from intraspecific competition and protected from human disturbance (Hansen 1973, Brechtel 1982). Hansen et al. (1971) found that territorial isolation was more important than food supply or the size of the territory. Trumpeter swans are so territorial that they will not let mammals near nesting sites and have been observed, on two separate occasions, aggressively chasing a beaver and a cow moose from the water near their nests (Hansen et al. 1971).

The water in the lake must be stable in depth, and preference is given to lakes with little or no wave action (Banko 1960). Stable water levels are beneficial to trumpeter swans because they regulate the establishment and maintenance of emergent plant communities. Similarly, wave action and currents retard the growth of emergent vegetation, depended upon by trumpeter swans (Hansen et al. 1971). Ideal water levels are between 30 and 90 cm to allow for subsurface foraging (Johnsgard 1978). According to Hansen et al. (1971), 90% of 35 nests studied were found in water 30 to 90 cm deep.

Muskrat houses made of cattails (*Typha* sp.) are almost always used for nest sites (Mackay 1978). Nests are normally located so that all or most of the nest is surrounded by water, or the nest is on an island (Banko 1960, M[c]Kelvey, Dennington, and Mossop 1983). Thus nests are usually located near the outer edge of emergent vegetation and average 1.22 m across and 0.61 m high (Brechtel 1982). Nests can often be reused from year to year (Hansen et al. 1971). Trumpeter swans do not select for species of emergent vegetation (Holton 1982) although it is important as a source of cover, and submerged and floating plants provide food (Johnsgard 1978). The emergent vegetation is normally used as a loafing site and the water around the nest serves as protection from terrestrial predators (Holton 1982). Another important factor determining the availability of nesting sites for trumpeter swans is protection from wind (Holton 1982, Banko 1960). These specific requirements for nesting sites are part of what make trumpeter swans vulnerable to development activity around their nesting areas.

Young swans begin developing pair bonds at the age of 20 months and begin nesting activity at the age of 33 months. Trumpeter swans will not actually breed and raise a clutch until they are between the ages of four and six years. Swans are believed to mate for life (Banko 1960), but a mate will be replaced if a member of the pair dies (Hansen et al. 1971). Nesting activity normally begins soon after the birds arrive in the Grande Prairie region. When nest building is complete, the pen lays an egg every other day for approximately 18 days. Only the female of the pair incubates the eggs and incubation starts the day after the last egg is laid. Incubation lasts for 32 or 33 days (Mackay 1978). Incubation normally ends between June 15 and 21 but can go into July (Banko 1960). Once the eggs start hatching, the entire brood will hatch within 12 to 18 hours. The young are ready to go into the water after one more day on the nest (Mackay 1978). The average clutch size in Grande Prairie is between 5.5 and 5.8 eggs and hatching success is between 77 and 86% (Brechtel 1982).

Normally, only two or three cygnets will survive to fly south with the adults in October (Mackay 1978). Cygnets that survive hatching are vulnerable during the first two weeks of life. They may be trampled by the parents, get leeches in their air passages, or get tangled in vegetation and drown (Mackay 1978).

In the early stages of life for trumpeter swan cygnets, an important food source is aquatic invertebrates. For the first three weeks of life, cygnet droppings consist of 95% animal matter (Banko 1960, Brechtel 1982, Hansen et al. 1971). The first food eaten by cygnets is brought to the surface of the water by the parents and consists of aquatic beetles, insects and crustaceans and parts of sedges (Banko 1960). This stage, when the cygnets consume aquatic invertebrates can affect growth and survival (Banko 1960 and Hansen et al. 1971). During the first two weeks that cygnets are in the water, they feed mostly in shallow water (15 to 30 cm) unless they are feeding with the adults who bring material to the surface for them (Banko 1960). The portion of animal matter in the cygnet diet begins to decrease when the cygnets begin to feed with the adults on vegetative material in deeper water (Banko 1960).

Adult trumpeter swans consume up to 9 kg of vegetation per day (Brechtel 1982). The species of vegetation most preferred by adult swans after the eggs have hatched is horsetail (*Equisetum* sp.). More time was spent feeding on horsetail than all other foods combined (Grant, Henson, and Cooper 1994). Specifically, 82.6% of the female foraging activity budget is spent feeding on horsetail. During incubation, emergent vegetation was chosen, due to the lower amount of energy needed to get this food source. In contrast, during the pre-laying period, 88.6% of the female foraging budget is spent foraging on submergent vegetation (Grant, Henson, and Cooper 1994). Some of the favorite plant species taken by trumpeter swans include: arrowhead (*Sagittaria latifolia* Willd.), pondweed (*Potamogeton filiformis* Pers.), sedge (*Carex rostrata* Stokes), water-milfoil (*Myriophyllum* sp. L.), waterweed (*Elodea canadensis* Michx.), ivy duckweed (*Lemna trisulca* L.), bulrush (*Scirpus* sp. L.), and water-lily (*Nymphaea* sp. L.). Trumpeter swan feeding patterns vary with food availability and nutrition (Grant, Henson, and Cooper 1994).

4.0 TRUMPETER SWANS AND HUMAN DISTURBANCE

That trumpeter swans were once an endangered species, leads to a great deal of concern about maintaining current populations and ensuring habitat is available for population expansion. There has always been development activity in trumpeter swan nesting areas and this activity is only going to increase and intensify as time passes. It is important to know how trumpeter swans have responded to development and human activity historically so this information can be used to make decisions about land use and how to prevent problems that occurred in the past, leading to trumpeter swans becoming endangered. For example, Hansen et al. (1971) found that trumpeter swans responded to disturbance caused by helicopter flight and seismic activity by abandoning their old territories and establishing new ones. This type of activity is difficult for trumpeter swans due to their high degree of territoriality. If swans are forced to establish new territories mid way through the breeding season, and most areas already have an established pair, both pairs (the one invaded and the one forced off their original territory) may not breed successfully (Brechtel 1982).

Researchers (Johnsgard 1978, Brechtel 1982, and Shea 1979) agree that trumpeter swan populations are vulnerable to disturbance because they are sensitive to the presence of humans and are quick to react to any type of disturbance. The disturbance can be human activity close to or even human activity creating noise around trumpeter swan habitat. For example, human disturbance has been known to cause problems such as abandonment of nests (temporarily and permanently), and desertion of breeding or staging areas (Henson and Grant 1991). In particular, inexperienced trumpeter swans were intolerant of human disturbance (Henson and Grant 1991). Inexperienced refers to young trumpeter swan pairs (four or five years old) that have not raised many (if any) broods. Specifically, out of six interactions between incubating swans and pedestrians, three resulted in disturbance recesses lasting 22, 41, and 90 minutes (Henson and Grant 1991). Henson and Grant (1991) define a disturbance recess as an occasion when the swan fled the nest with failure to cover the eggs. It has been noted that trumpeter swans, when threatened by humans, may abandon their young without protective action (Banko 1960).

Holton (1982) found that some lakes providing suitable nesting habitat will be avoided due to persistent human disturbance. Human disturbance of breeding swans can cause increased loss of eggs to predators and inhibit successful nesting (McCormick and Shandruk 1986). On the Kenai peninsula in Alaska, trumpeter swans relocated nesting sites to less disturbed areas when human activity moved into historical breeding areas (Bangs et al. 1982). Hansen et al. (1971) found that trumpeter swans were extremely wary of human presence and immediately fled their nests at the approach of humans. In Minnesota, there is an example of high losses of trumpeter swans resulting from a large, recreation oriented human population (Hansen 1973).

Any disturbance that causes an interruption in incubation for trumpeter swans is of particular concern due to the short summers in northern Alberta and the limited opportunity to raise cygnets in time to fly south in the fall (Holton 1982). The possible repercussions of interrupted incubation include egg mortality due to exposure when the pen leaves the nest, increased predation of the unattended nest, and decreased feeding rates due to the intrusion by humans (Henson and Grant 1991). For example, the average feeding time during a disturbance recess was 32.7 minutes compared to a normal recess when the average feeding time was 44 minutes (Henson and Grant 1991). A normal recess is when the female leaves the nest while not in distress and covers the nest with vegetation before leaving (Henson and Grant 1991). Since there is only one breeding pair of trumpeters per lake and each pair only raises one brood per year (Banko 1960), the number of lakes affected by human disturbance may be the number of reproductive attempts that fail each year. This could have very serious implications for trumpeter swan production and population levels and thus it is important to determine what causes trumpeter swans to respond to disturbance.

4.1 Effects of Vehicular and Pedestrian Traffic Disturbance on Trumpeter Swans

There are few examples of quantitative measurement of disturbance on trumpeter swans and therefore little knowledge of the subject. However, a study by Henson and Grant (1991) attempted to quantify some of the behavioral responses of breeding trumpeter swans to specific types of disturbance. One of the types of disturbance was traffic.

Henson and Grant (1991) found that swans were most disturbed by vehicular traffic on nesting sites closest to roads and where there was no vegetative barrier between the nesting site and the source of traffic disturbance. However, swan response to normal vehicular traffic such as vans and pick-up trucks was limited unless the vehicle stopped or honked its horn (Henson and Grant 1991). In general, swan behavior was not seriously affected by vehicle traffic on the highway.

In contrast, pedestrian traffic had definite impacts on nesting swans. For example, on three occasions during brood rearing when trumpeter swans experienced pedestrian disturbance, the brood swam to the other side of the wetland and concealed themselves in vegetation (Henson and Grant 1991). Pedestrians and observers caused the greatest response by incubating and brood rearing swans. Barriers to sight between the nest site and the disturbance source, in the form of vegetation or hills, decreased the probability of disturbance reaction by the swans (Henson and Grant 1991). These results have implications for this research since these types of disturbances are unavoidable in areas as heavily developed as the Grande Prairie region of Alberta.

4.2 Effects of Agricultural Disturbance on Trumpeter Swans

The effects of agricultural disturbance around trumpeter swan lakes is variable. Holton (1982) found differences in characteristics between those lakes used by swans and those not used that may be due to agricultural development. For example, the mean width of emergent vegetation in occupied lakes was significantly greater compared to historically unoccupied lakes. Width of emergent vegetation surrounding occupied lakes ranged from 69 to 159 m compared to historically unoccupied lakes it ranged from zero to 123 m (Holton 1982). Water level has an impact on swan selection of lakes because water level determines the abundance of emergent vegetation, invertebrates, and submerged macrophytes (Holton 1982). Holton (1982) also found that trumpeter swans used low use agriculture lakes significantly less frequently than non-agricultural lakes. Lakes were defined as agriculture and non-agriculture lakes based on the percentage of natural vegetation within 500 m of the lake (Holton 1982). However, trumpeter swans breeding on low-use agricultural lakes were no less successful at hatching and rearing cygnets as trumpeter swans on no use agricultural lakes (Holton 1982). Holton (1982) defined the level of agricultural use depending on the proximity to agricultural activities. These results led Holton (1982) to conclude that trumpeter swan establishment on a lake may be partially dependent on the level of agricultural activity close to the lake or the ability of the swans to avoid the disturbance.

Trumpeter swans occupying white zone lakes may become habituated to agricultural and other human activities occurring around these lakes (Holton 1982). For instance, in one situation, two observers were standing in a plowed field approximately 100 m from the shore of a lake where there were seven swans. Gun shots were being fired from nearby. However, as the observers approached the lake shore, the swans made no move to fly off the lake. The swans also showed no signs of alarm in their postures or behavior. In another situation, two observers were standing on a road that bordered the shore of the lake. After a few minutes of observation, two trumpeter swans flew up out of the vegetation on the other side of the lake and flew closer to the two observers. The pair of swans then landed on the lake approximately 50 m from the observers. Again, the presence of the observers and related noise and disturbance seemed to have no effect on the swans behavior and activities. According to Banko (1960), the deciding factor in whether or not trumpeter swans can tolerate the presence of humans is not simply human presence, but the degree and regularity of disturbance.

There are several questions that remain to be addressed. For example, how much activity can swans tolerate, are the effects of different activities additive, and does the ability to habituate apply to all types of disturbance? These are some of the questions that this study will attempt to answer.

5.0 EFFECTS OF DISTURBANCE ON OTHER SPECIES

Information on the effects of different types of disturbance and development on trumpeter swans and nesting success is limited. The information is particularly scarce concerning any type of development other than agriculture. Therefore, it may be helpful, when trying to determine the impact of development on trumpeter swans, to consider the impact of development (agricultural and otherwise) on other species using the same habitat.

Human disturbance in general has negative impacts on nesting waterfowl species. The types of human activity that can disturb waterfowl include transportation, hunting, hiking, and other recreational activities. Human disturbance has a negative effect on nesting success in herring gulls (*Larus argentatus*) (Burger 1981). The result of human activity around black crowned night herons (*Nycticorax nycticorax*) nests was, "nest abandonment, predation of eggs, and mortality of young" (Burger 1981). Ground nesting, brown pelican (*Pelecanus occidentalis*) colonies suffered from the presence of humans due to losses of eggs and young due to predation and hyper and hypothermia as a result of nest abandonments (Anderson and Keith 1980). Persistent disturbances of colonies of nesting marine birds could affect productivity of the entire population (Anderson and Keith 1980).

Disturbance by humans also causes increased predation by crows (*Corvus brachyrhynchos*) and gulls (*Larus* spp.) in double crested cormorants (*Phalacrocorax auritus*). Out of 14 nests with 44 eggs, all were destroyed by gulls following a visit by human researchers (Ellison and Cleary 1978). Another study found that arctic-nesting geese (*Chen* sp.) were vulnerable to disturbance in the spring and the effects were manifested in the birds activity budgets, distribution, and ability to store fat reserves for migration and breeding (Belanger and Bedard 1989). Human disturbance could also disrupt pair bonds and cause mortality (Belanger and Bedard 1989). Staging birds have been impacted by human activity. For example, staging greater snow geese (*Chen caerulescens*) that were disturbed by humans had changes in their feeding activities as well as their use of staging sites (Belanger and Bedard 1989).

Wetland habitats that are depended on by waterfowl species are extremely specific in their characteristics and therefore what necessities they provide to the species living there. This specificity makes riparian habitats quite fragile in response to changes such as vegetation removal. For example, the alteration of riparian habitats (i.e. vegetation removal) affects water quality, and other community associations with the wetland habitat (Croonquist and Brooks 1993) including avian communities. According to Croonquist and Brooks (1993), the alteration of riparian habitat from farming, grazing, and logging causes decreased avian densities. In one instance, where disturbance had removed natural vegetation along riparian areas, "the total number of birds was reduced by 93% ha^{-1} yr^{-1}". However, in agricultural areas where the riparian areas were well vegetated, "there were 32% more birds ha^{-1} yr^{-1}" (Croonquist and Brooks 1993).

Another study by Remner, Reynolds, and Batt (1995) supports the claim that agricultural activity such as cultivation and cattle grazing negatively affects waterfowl. Waterfowl nest success and nest densities were higher in fields with undisturbed vegetation compared to fields that were hayed or grazed. The mean nest density per 40 ha was 27.37 on hayed fields compared to 59.32 on undisturbed fields (Remner, Reynolds, and Batt 1995). Ducks have greater reproductive success on land not grazed by livestock or harvested for hay (Di Silvestro 1989). For example, 25% of waterfowl nesting on untilled lands were successful compared to 17% on tilled lands (Di Silvestro 1989). The types of changes created in riparian habitats by these activities that affect ducks and other waterfowl likely have similar impacts on trumpeter swans since they depend on the same habitats for food and nesting sites.

Some specific changes to riparian habitats cause ducks and other waterfowl to be less successful when disturbed by agriculture and other development activity. For example, runoff water into wetlands from developed areas often contains pollutants that are harmful to many species of plants and animals that depend on the water. According to Liverman and Hemker (1995), range management, agriculture, and forestry practices are suspected contributors to poor water quality. Even naturally occurring minerals and elements from the soil can become toxic when they are concentrated into wetlands due to runoff from cleared land. For example, at the Kesterson National Wildlife Refuge, selenium built up to toxic levels in the runoff and began to poison ducks in the area. The effect on the birds included death as well as birth defects among young birds born in the area (Di Silvestro 1989).

Eutrophication of wetlands is another possible consequence of agriculture practiced in and around wetland areas. Dissolved salts and residues from agricultural chemicals may be moving into many wetlands, along with highly organic feedlot runoff (Kantrud 1986). Although it is not specifically known what is causing trumpeter swans to stop using some white zone lakes in the Grande Prairie region, these are examples of potential impacts.

Cattle farming is another impact of agriculture on wetland areas that affects breeding waterfowl. Most cattle farmers use a natural water source and let cattle graze freely in and around wetland areas. This can have both positive and negative impacts on breeding waterfowl in these areas. For example, livestock grazing around a wetland can create problems such as increased bacteria levels and sediment load in the water, increased water temperature, and reduced water depth (Blackburn and Wood 1992). If the wetland area is overgrazed there will be decreased primary production and increased water turbidity (Kantrud 1986). Unfortunately, wetland areas are often overgrazed regardless of stocking density due to the tendency of cattle to congregate around the water source. This impact of cattle grazing would likely affect trumpeter swans due to their preference for quiet, still water for nesting areas.

There are several positive impacts of livestock grazing in areas where waterfowl nest. For example, livestock grazing and trampling of vegetation opens up areas along the shoreline of wetlands. This increases visibility for the pen and therefore decreases nest predation by crows (Kantrud 1986). There may also be increases in planktonic algae which is the primary food of aquatic invertebrates (Kantrud 1986). As previously mentioned, trumpeter swan cygnets depend on aquatic invertebrates as a critical food source early in their development.

There are examples in the literature of other species of birds who have habituated to human disturbance in their breeding areas. For example, bridled terns (*Sterna anaethetus*) have habituated to the presence of human intruders and have therefore decreased their escape responses to human disturbance (Dunlop 1996).

Different types of development that may occur around trumpeter swan habitat areas include transportation of heavy equipment onto the site, and road building or road use. The impacts on trumpeter swans and their habitat occur from the clearing of vegetation to build the road, runoff into the water from the road, increased access to trumpeter swan habitat due to the existence of a road, and noise and visual disturbance from traffic using the road. The presence of a road and related traffic noise affects trumpeter swans, but it is important to determine if the existence of a road has any effect on trumpeter swan habitat choices of breeding territories specifically. In a study by Reijnen, Foppen, and Veenbaas (1997), there were depressed densities of breeding birds, including waterfowl, adjacent to roads. The reductions in total density of bird species was 39% in open grassland and 35% in woodland areas (Reijnen, Foppen, and Veenbaas 1997). If other types of waterfowl are impacted by the presence of a road, it is reasonable to assume that similar impacts may occur in trumpeter swan populations in habitat areas that have many roads and associated traffic problems.

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CHAPTER TWO

EFFECTS OF HUMAN ACTIVITY ON TRUMPETER SWAN UTILIZATION OF LAKES

1.0 INTRODUCTION

In the 1930s, trumpeter swans numbered between 37 and 97 birds and could be found almost exclusively in Yellowstone National Park and Red Rock Lakes Wildlife Refuge (Johnsgard 1978). The decline of trumpeter swans was associated with several human activities such as hunting, egg collecting, habitat destruction, and disturbance of habitat (Mackay 1978, Banko 1960, and Johnsgard 1978). The trumpeter swan made a remarkable comeback in population size and productivity due to protective legislation (Banko 1960) and protected area development (Johnsgard 1978).

Trumpeter swans have very specific requirements for nesting territories and only one pair of trumpeter swans will occupy each available lake for nesting. Each pair will raise only one brood per year (Banko 1960). This makes the trumpeter swan population dependent on the amount of suitable territory available. If otherwise suitable lakes are being made unavailable for nesting due to human disturbance, this could have serious repercussions for the continued growth of the population. The information from previous studies is variable. The one detail that seems to be fairly well agreed upon is that trumpeter swans are a sensitive species (Johnsgard 1978, Banko 1960, Henson and Grant 1991, and Shea 1979). Therefore, it is important to study whether there are changes due to human development that make lakes unusable by nesting swans.

2.0 OBJECTIVES AND HYPOTHESES

The general objective of this research was to assess the effects of changes in land use surrounding lakes on trumpeter swan use of those lakes.

2.1 Specific Objectives

1. To summarize and identify trends in historical data of trumpeter swan use and productivity on lakes in the Grande Prairie region of Alberta.
2. To determine whether the location of the lake in the white or the green zone has an influence on whether swans are present and / or breeding on the lakes. (White zone refers to the area of Alberta that is highly developed, highly populated and mostly privately owned land, whereas the green zone refers to the area of the province that is mostly crown land, not highly developed in agriculture and not highly populated (George 1998)).
3. To determine what types of land use create the changes in lakes that cause trumpeter swans to alter their use of them (e.g. breeding or non-breeding activity).
4. To determine whether swan use of lakes is affected by different types of land use surrounding the lakes and different distances from the lake shore.
5. To provide recommendations to land managers and users to minimize the effects of their activities on trumpeter swans lakes and therefore trumpeter swan production.

2.2 Null Hypothesis

The amount and type of land use and development activity surrounding lakes in the Grande Prairie region of Alberta does not impact trumpeter swan production or use of lakes.

2.3 Alternative Hypothesis

The development and associated human activity occurring around lakes in the Grande Prairie region of Alberta have a negative impact on trumpeter swan production and an influence over their choice of nesting habitat.

3.0 MATERIALS AND METHODS

3.1 Site Description

The location for this study includes lakes in and around the Grande Prairie region of Alberta (Figure 2.1). This area of the province is within the Boreal Ecoprovince which is characterized by low annual precipitation and short summers with long days (Strong and Leggat 1992). More specifically, the area where the study lakes are found includes the Lower Boreal Cordilleran, the Low Boreal Mixedwood, and the Mid Boreal Mixedwood. There are very subtle differences between these areas which include temperature, precipitation, and the species of vegetation present. For example, the Lower Boreal Cordilleran region receives approximately 464 mm of precipitation annually and has annual temperatures averaging 12.8 °C. In contrast, the Mid Boreal Mixedwood receives approximately 397 mm of precipitation annually and has annual temperatures averaging 13.5 °C. Some of the species of vegetation common to all three regions include: aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.), western wheat grass (*Agropyron smithii* Rydb.), fireweed (*Epilobium angustifolium* L.), and prickly rose (*Rosa woodsii* Lindl.). The most common soils in these areas are Luvisolic (Strong and Leggat 1992).

The area encompassing the study lakes includes both the green and white zones. Approximately half the lakes are surrounded by boreal forest and are therefore within the green zone. The other half of the lakes are in the white zone and are surrounded by either agricultural production or city and residential developments. Throughout both the white and green zones, there is oil and gas activity including well sites, roads, pipelines, and seismic lines. In the green zone there is forest harvesting activity since some of the land north of the city of Grande Prairie is part of Weyerhaeuser Canada's Forest Management Agreement Area (FMA). Within Weyerhaeuser Canada's FMA, there are two companies operating. Weyerhaeuser Canada Ltd. has the rights to the coniferous component of the FMA whereas Ainsworth Lumber Co. Ltd., (who are quota operators) has access to the deciduous component of the FMA.

3.2 Study Lake Selection

The specific locale for this research includes 49 lakes surrounding Grande Prairie. The 49 lakes were chosen from a list of 181 lakes for which there are trumpeter swan population and production data from aerial surveys conducted by the Canadian Wildlife Service (CWS) and Alberta Fish and Wildlife Services. One selection criterion was whether the lake was surrounded by agricultural development or by boreal forest as determined from locating each lake on a map. For lakes surrounded by boreal forest, preference was given to those on the Weyerhaeuser FMA since forest harvesting was one of the land use activities being examined for effects on swan use. Lakes were not chosen based on swan use or productivity. If the lake was on the list of lakes surveyed by CWS it was assumed swan activity occurred on them at some time. The type of swan use (breeding versus non-breeding) was not a deciding factor.

The lake selection process was random with hierarchical steps to provide consistency in comparison among lakes. The first level of the hierarchy was to ensure all the lakes had swan use data available for them. The raw data from CWS and the Fish and Wildlife Service has been summarized into Table A.1 in the Appendix. The second step was to ensure all the study lakes had aerial photographs available for the same years. The last step was to ensure there was a relatively even split between lakes within the agricultural and boreal forest areas. Of the 49 study lakes, 25 are located in the white zone, and 24 are located in the green zone. The sample size of lakes represents 27% of the population. Zone and type of utilization by swans has been summarized into Table 2.1.

3.3 Aerial Photo Analysis

Photos for the years 1961 (1:31 680) and 1995 (1:40 000) were procured from Air Photo Services in Edmonton, Alberta. These years were chosen because they roughly corresponded to the beginning and end of the population data available for trumpeter swans and 1961 and 1995 photos were available for all 49 lakes.

The next step was to delineate distances from the lake shore of 100, 200, 500, and 1000 m on each photo. These distances were chosen to include the area close to the lake where any disturbance would most likely affect swans as well as distances far enough away that the swans may detect noise or residual disturbance. The required distance between the lake shore and surrounding development (for a buffer zone) is 500 m (James 1997). Twice that distance was believed adequate to detect any effect of disturbance on swans occupying the lake. Calculations, according to the scale of the photo, (see Table A.2 in the Appendix for an example calculation) were done to determine the length on the air photo represented by each of the distance categories. Delineations were then drawn onto the photos using a Stabilo pen (specially designed for writing on photos) and a ruler (Figure 2.2). The distance was measured from the obvious water line on the photos. The shore line was used because the water and shore area are trumpeter swan prime habitat.

Changes in land use, at each distance from the lake, between 1961 and 1995 were assessed using a ten times magnification hand lens. The types of changes identified included: roads, removal of vegetation, occurrence of well sites, occurrence of seismic lines, city and residential developments, and the presence of cutblocks. The type of vegetation surrounding a lake, such as crop agriculture versus forest, could be distinguished, but the species of crop could not be ascertained.

The changes visible on the air photos were divided into categories of land use including: agriculture, forestry, well sites, seismic, roads, city development, and other development. Agriculture included any land on the photos that was obviously dedicated to farming (including farm yards). Pipelines were included with well sites because although a pipeline is a linear disturbance, it is a much wider and extensive disturbance than a seismic line and the frequency of disturbance is not the same as for a road. Seismic was given a separate category because seismic lines are narrow and the disturbance of construction occurs only once. However, later human activity may occur due to increased access, in the form of recreational use with all terrain vehicles and hunting. Roads were given a separate category because although they are a linear disturbance like seismic and pipelines, the level and frequency of disturbance is much greater. City development included all areas such as towns, cities, or acreage developments. Other development included areas such as provincial parks that did not fit into any other category. Objects on photos that could not be identified but were obvious changes on the landscape were included in this category. Less than 10% of disturbances fit into this category. The methods for detecting the different kinds of disturbances on aerial photos is summarized into Table 2.2.

Two trips to Grande Prairie were taken during this study for the purposes of ground truthing disturbances seen on the air photos. Lakes that could be easily accessed were visited. The types of disturbances that were checked against air photos were: agriculture, residential development, well sites, provincial parks, and roads. Disturbances identified on the air photos were the same as those seen when ground truthing.

For each photo, the area of land in hectares or meters squared dedicated to each land use category was calculated for each distance from the lake category (see Table A.3 in Appendix for example calculations). Areas were calculated using a dot grid (Avery 1968). The area per dot on the dot grid was calculated using a region of known area (such as a section of land) on the photo and counting the number of dots contained in that area. Dividing the number of acres in a section by the number of dots per section, yields the number of acres per dot. This number was converted to hectares by dividing the number of acres by 2.47 acres ha^{-1} (see Table A.3 in the Appendix for an example calculation). Once the area represented by each dot was known, the dot grid was laid over each photo and the number of dots per land use type, per distance category counted. When placing the dot grid on the photo, marks or boundaries on the photo were used as points of alignment to avoid positioning bias (Avery 1968). The number of dots per land use type was multiplied by the area per dot to get the area dedicated to each land use type per distance category. Each of these numbers was recorded in tables for each lake (Appendix Table A.4). The area of the lake in 1961 and 1995 was also calculated using the dot grid.

Seismic lines and roads were calculated using a 1:300 scale for 1961 photos and a 1:400 scale for 1995 photos. The scale was used like a ruler to measure the distance on the photo of the seismic line or road and then a conversion was done to convert the measurement to meters (Appendix Table A.3). For total area, the distance measurement for seismic lines was multiplied by six meters (width) and the distance measurement for roads was multiplied by twenty meters (width). These numbers were recorded into tables for each lake (Appendix Table A.4).

3.4 Assessment of Swan Population Data

Trumpeter swan population data (from aerial surveys conducted in spring and fall by CWS) for 1957 to 1995 were obtained from CWS and the Alberta Fish and Wildlife office in Grande Prairie. The data included the names of 181 lakes (or areas of a creek or river) as well as the legal land description for each lake. For each year between 1957 and 1995 that a survey had been conducted, there were data on the number of swans present as well as the number of young (cygnets) present if the swans were a breeding pair. Not all areas were surveyed every year.

For consistency of comparisons, only the fall survey numbers were used. Fall survey numbers show production success through the presence or absence of cygnets. The swan population data were organized for each study lake so patterns in swan use and production could be easily detected. The lakes were initially categorized as having increasing, decreasing, incidental, or continuous swan use. These categories were very difficult to fit to all of the swan data and therefore, were only used for preliminary analysis. A lake with increased swan use had no swan use for many years (approximately twenty), and then had consistent swan use on it for many years. A lake with decreased swan use had swans on it for many years and then a very sudden decrease in swan use and no use. Continuous use lakes showed evidence of swan use on the lake for the duration of the study years. Incidental use refers to lakes that had swans present a few times over the time of the surveys.

The lakes were further divided into breeding and non-breeding lakes. This division is particularly important since the trumpeter swan population in Grande Prairie is growing and only one pair of trumpeters occupies any lake. Lakes suitable for breeding are an important resource to the growing population of trumpeters in the area. Lakes were further separated into the white and green zones of the province.

3.5 Statistical Analyses

Data were initially arranged into four separate tables, each one representing one of the distance categories from the air photos (100, 200, 500, or 1000 m from the shore). For example, the table representing the 100 m distance category contained all of the areas (ha or m^2) of each of the types of development, within 100 m of the shore of each lake. Also in these tables, were the areas (ha) of each lake in 1995, and the values representing the categories of white zone lakes versus green zone lakes. Status of swan use was categorized as breeding lakes (1) and non-breeding lakes (2). These two groups of lakes were compared in the statistical analysis (i.e. tests were performed to determine if there were statistically significant differences between lakes used by breeding swans and those used by non-breeding swans). If a lake was used by both breeding and non-breeding swans over the 38 year period, then the most recent use was used to classify the lake as breeding or non-breeding. These data sets were referred to as 100 95, 200 95, 500 95, and 1000 95.

The first step in the statistical analysis of the data was to perform a one way ANOVA on the data for each of 1961 and 1995 for descriptive statistics such as means and standard errors (Norusis 1993). The computer program used to perform the statistical analysis was SPSS version 8.0 (Norusis 1993).

The second step in the statistical analysis was to perform t-tests (Mansfield 1986) to compare the means of the area (ha or m^2) of development of each type, at each distance category between breeding and non-breeding lakes. This analysis was performed using Microsoft Excel.

The final step in the statistical analysis was to perform stepwise logistic regression on the data for the area of each type of development, at each distance from the lake, in 1995. Stepwise logistic regression is used when there is a set of predictor variables (X) from which a subset is desired to explain variation in a response variable (Y) (Steidl 1998). The logistic regression was performed in a stepwise manner and separately on each data set (100 95, 200 95, 500 95, and 1000 95). Logistic regression was performed on each data set for the distance categories using the status variable (breeding versus non-breeding lake) as the dependent variable (Norusis 1993). This analysis was performed using SPSS version 8.0. This analysis was chosen because it is appropriate for situations where the response variable is dichotomous and can be classified as 0 or 1 (i.e. breeding versus non-breeding lakes) (Steidl 1998).

4.0 RESULTS

4.1 Trumpeter Swan Population and Use Data

The swan use and production data from the 49 study lakes is summarized in Table 2.3. There is a trend towards increased numbers of breeding pairs of swans over the 38-year period. The number of pairs of trumpeter swans on the 49 study lakes specifically show a period of increased growth (greater than 20 pairs) from 1957 to 1973. After 1973, the population seems to stabilize and shows only slight variations. Since there is normally only one pair of trumpeter swans breeding on each lake, it was expected that the number of lakes would equal the number of pairs seen. However, this was not always the case. For example, in several years between 1960 and 1995 there was more than one pair of swans found per lake. This trend does not coincide with the increased growth between 1957 and 1973 because out of the eight years with more trumpeter swan pairs than lakes, five occur between the years 1973 and 1986.

There was also an increase in the number of cygnets on the study lakes starting in 1957 and continuing to 1973. After 1973, there was a slight increase in the number of lakes with cygnets found on them. Although it might be expected that the number of lakes with pairs would equal the number of lakes with cygnets, that was not the case. In every year between 1957 and 1995, the number of lakes with cygnets was less than the number of lakes with swan pairs on them.

There were a large number of individual (non-paired) birds found on a small number of lakes. For example, 78 birds were found on only three lakes in 1972. The number of individual (non-breeding) trumpeter swans has the widest range in the number of birds found on the forty-nine study lakes. For example in 1973, 100 individual trumpeter swans were found on seven lakes. This is in contrast to 1993 when there were no individuals found on any of the surveyed lakes. Lastly, many of the changes occurring in this data summary occurred around the year 1973. The changes occurring around 1973 are all positive (i.e. in the direction of increased production). The number of lakes with individual (non-breeding) swans is in most cases lower than both the number of lakes with pairs and cygnets. However, in most years, the number of individual swans was greater than both the numbers of pairs and cygnets.

There was a notable decrease in the number of trumpeter swans in the Grande Prairie region during the following years: 1984, 1986, 1987, and 1989 due to die offs on the tri-state wintering area (Shandruk 1986, Shandruk 1991, and Alvo 1996). There was also significant flooding in nesting areas in 1990 contributing to decreased survey numbers (Shandruk 1991). The deficiency of data for the years 1987 through 1989 can be explained by a lack of fall surveys for those years. No survey data were represented for those years to ensure consistency of numbers since all other numbers are fall survey values.

4.2 Area of Disturbance Data

The data from the aerial photos of each lake in 1961 and 1995 has been summarized into Table 2.4. Mean areas (ha or m^2), ranges, and percentage of lakes with disturbance have been included. Again, the data follow some interesting trends and patterns over the 34 year period.

Table 2.4 illustrates a general trend toward increased development from 1961 to 1995. The amount of development surrounding the lakes also generally increases as the distance from the lake increases from 0 to 1000 m. The agriculture and road disturbances show a decrease in area from 1961 to 1995. Agriculture showed a decrease (in area) in all distance categories, and roads show a decrease in mean area at 0 to 100 m. The most dramatic change in development is shown by the road disturbance type at 500 to 1000 m, where the mean area of roads increased from 59.5 m^2 to 90.5 m^2 from 1961 to 1995. Although the mean area of agriculture within a certain distance of the lake may be decreasing, the proportion of lakes with agricultural disturbance around them increased from 1961 to 1995 at every distance except 0 to 100 m.

The areas of disturbance for each disturbance type all increased between 1961 and 1995 and also increased between distance categories. For example, road disturbances at 500 to 1000 m in 1995, range from 2 to 280.8 m^2. This means that every lake (out of 49) had some road disturbance around it between 500 and 1000 m from the lake shore. The disturbance type and distance category with the widest range in area is the agriculture disturbance type at 500 to 1000 m where the area increased from 0 to 772.6 ha in 1961 and from 0 to 596.9 ha in 1995.

Percent of lakes with agricultural disturbance decreased only at 0 to 100 m. The seismic disturbance category showed a decrease in the percent of lakes with the disturbance around them at 200 to 500 m and 500 to 1000 m. Every other distance and disturbance type show an increase or no change in the percent of lakes with each disturbance type from 1961 to 1995 as well as from 0 to 1000 m from the lake shore. The disturbance and distance categories showing the most drastic change in percent of lakes between 1961 and 1995 is the well site disturbance category at 500 to 1000 m where the percent of lakes with well sites around them increased from 4% in 1961 to 59% in 1995.

The number of lakes showing an increase or decrease in development area between 1961 and 1995 has been summarized into Table 2.5. The amount of land area disturbed by roads and agriculture between 1961 and 1995 decreased in the most lakes at all distances. At every distance, every category of human disturbance (except forestry) has lakes with increased disturbed area between 1961 and 1995. Agriculture, roads, seismic, and well sites are the categories of development with the greatest number of lakes showing increases in disturbed area from 1961 to 1995. All disturbance categories have more lakes showing increases in development than decreases in development except agriculture. For example, at 0 to 100 m, there were 11 of 49 lakes showing an increase in agriculture between 1961 and 1995 compared to 15 out of 49 lakes showing a decrease in agriculture. There are no lakes out of the 49 study lakes that show a decrease in forestry from 1961 to 1995 and only one lake that shows a decrease in city development at 500 to 1000 m. The development type with the greatest number of lakes with an increase in area is roads at 500 to 1000 m where there were 39 (out of 49) lakes showing an increase in road area. In contrast, the development type with the greatest number of lakes showing a decrease in area is agriculture with 20 (of 49) lakes showing a decrease at both 100 to 200 m and 500 to 1000 m.

4.3 Results of Statistical Analyses

The mean area of each disturbance type for each distance category was calculated for lakes with breeding swans compared to lakes with individual, non-breeding swans and summarized into Table 2.6. In almost every case, the mean area of disturbance around non-breeding lakes was higher than surrounding lakes supporting breeding swans. This was especially true at the 0 to 100 m and 100 to 200 m distance categories. The mean area of lakes where swans were found was significantly different between breeding and non-breeding lakes with non-breeding lakes being greater in size. At the 100 to 200 m distance, the amount of agriculture surrounding the lakes is also significantly different between breeding and non-breeding lakes. Again, the amount of agriculture surrounding non-breeding lakes is greater than surrounding breeding lakes.

There were a few cases at the 200 to 500 m and 500 to 1000 m distance categories where the amount of disturbance around the breeding lakes is much greater than that around non-breeding lakes. For example, at the 200 to 500 m distance, the mean area of 20.9 ha dedicated to well sites around breeding lakes is much greater than the 2.3 ha around non-breeding lakes. This difference is significant. However, that is not the only significant difference between breeding and non-breeding lakes at the 200 to 500 m distance. The differences between agriculture, forestry and roads are also significant at this distance. The mean area around non-breeding lakes is greater in all three cases.

At 500 to 1000 m, usually the amount of disturbance surrounding non-breeding lakes was significantly greater than that surrounding breeding lakes. For example, there are significant differences between agriculture, forestry, roads, and seismic disturbances at this distance. The number of significant differences at the further distances is greater than at the closer distance categories.

The results of the logistic regression analysis are summarized into Table 2.7. The R^2 value shows that the model accounts for 18.7% of the variability in the data. Two R^2 values were produced by SPSS. One value was the Cox and Snell version and the other was the Naglekerke. The Nagelkerke value was chosen because for the type of data used in this research, the maximum value that could be achieved with the Cox and Snell R^2 calculation would be 0.75 (Nagelkerke 1991). The percent overall classification was similar for all distance categories. The group membership was predicted correctly around 70% of the time. However, for breeding lake prediction, the result was much better. Most of the time, the breeding lakes were predicted correctly. Non-breeding lakes were predicted incorrectly most of the time. For example, at the 500 - 1000 m distance, non-breeding lakes were predicted correctly only 7% of the time.

Only variables that had a significant impact on whether lakes were used by breeding or non-breeding swans were included in the table. Variables that were significant at any step in the stepwise logistic regression were included in the model. The values in the table are the B values (slopes). At 0 to 100 m, the only variables that impacted swan use of lakes were whether the lake was in the white or green zone, and if there were well sites present. When the lake is in the white zone, it is less likely to be a breeding lake. Since the slope associated with well sites is positive, as the amount of land around the lake (up to 100 m from shore) in well sites increases, the lake is less likely to be used by breeding swans.

At 100 to 200 m, the two variables that had a significant impact on swan use of lakes were whether the lake was in the white or green zone and if forestry was practiced. The positive B value means that as the amount of forestry disturbance between 100 and 200 m of the lake shore increases, the lake is less likely to be used by breeding swans. At 200 to 500 m, the two variables that had an impact on swan use of lakes were forestry and agriculture. Agriculture, like forestry had a positive slope (B value), meaning that as the amount of agriculture increases, the lake is less likely to be used by breeding swans. Lastly, at 500 to 1000 m, the two variables that had a significant impact on swan use of lakes were white versus green zone lakes and forestry uses. Again, the lakes in the white zone around Grande Prairie are less likely to be used by breeding swans. As the amount of forestry around the lake at 500 to 1000 m increases, this also decreases the probability of use by breeding swans.

5.0 DISCUSSION

5.1 Strengths and Limitations of the Research

As with many research experiments. this research had some limitations. For example, the method of collecting the swan use and production data used by the Canadian Wildlife Service may not have been completely accurate. The data for swan use and production on lakes in and around the Grande Prairie region of Alberta were gathered by aerial surveys conducted twice a year. Surveys were normally conducted once in the spring and once in the fall for each of approximately 181 locations. However, not every lake was surveyed every year. This makes comparisons among lakes difficult and somewhat less meaningful than they would have been if data were available for every lake and every year between 1957 and 1995.

When doing aerial surveys, it is possible to miscalculate swan use. For example, if at the time the survey flight went over a lake, the swans were in the dense, shoreline vegetation and couldn't be seen, they would not be included in the survey. As a result, the lake would be recorded as having no swans present when there may have actually been birds on the lake. Similarly, even if there are swans detected on a lake, the actual number and whether or not there were cygnets produced may have been underestimated. This results in gaps in the data where there are no swans recorded and it is not known if this is a true decrease in swan use or a miscalculation due to the timing of the survey. This makes it difficult to divide the lakes into legitimate categories of swan use based on production or presence / absence data for analysis. This is the main reason that the study lakes were divided according to whether they were used by breeding or non-breeding swans. This division was thought to be much less arbitrary and theoretical.

One of the strengths of this study is that the sample size is large (49 of 181 possible lakes). Forty-nine study lakes makes the sample size approximately 27% of the population which is adequately large considering that a normal sample size is 10% of the population. A large sample size is important to ensure that the study lakes (sample) are representative of the population on average. Another positive aspect of this research is that the aerial survey data dates to 1957 making the total number of years surveyed 38. Therefore, even if there are gaps in the production data, since there are 38 years of survey data, there is still enough information from the surveys to make the data analysis meaningful.

The level of detail and the accuracy with which information can be gathered from aerial photos is limited. For example, some of the disturbance types were more difficult to detect on the photos than others. Specifically, seismic lines were easily detected on photos with boreal vegetation. However, in agricultural areas, seismic lines were difficult to detect due to lack of and linear organization of the vegetation that was present. As well, there were a few instances where there was some type of disturbance on the photo that could not be identified. Due to the location of some of the lakes (i.e. remote areas of Alberta) ground truthing was not always possible. There are also some types of disturbance that are impossible to quantify by use of aerial photography. For example, the recreational use of lakes by boaters and other people can not be detected on air photos. This may have led to some underestimation of the amount of disturbance.

The orientation of the lake on the photos between 1961 and 1995 was different in most cases. In a few cases, not all of the area of land on the photo up to 1000 m from the lake shore could be seen on the photos for both 1961 and 1995. Since the purpose of the photos was not to photograph lakes, the orientation of the lakes in the photos was incidental. Therefore, in a few cases, the amount of disturbance around the lake at the 1000 m distance may have been underestimated in 1961 and / or 1995. This may also affect the analysis of the disturbance data.

When analyzing the disturbance data from the aerial photos, it was not known exactly in what year the disturbance occurred. The change in land use could have occurred any time between 1961 and 1995. Therefore, it was impossible to relate directly the changes in land use to changes in trumpeter swan use of lakes.

Although there are some drawbacks associated with this type of research, there are also some very strong points to consider. Wildlife researchers have very little control over most aspects of the area of interest, including both the environment and the study subject. There are random events and environmental conditions that make wildlife research imperfect. Therefore, long term trends and patterns become very important. This research included many years of data over a large area of landscape to determine general patterns and relationships. Information regarding patterns and relationships between trumpeter swans and land use was lacking and this study was able to provide some insights into these relationships as well as provide a starting point for further research.

5.2 How Do the Results of This Research Relate to What Was Expected?

5.2.1 Trumpeter swan response to disturbance

Most of the historical literature about trumpeter swans mentions the sensitivity of these birds and how vulnerable they are to human disturbance. For example, trumpeter swans have responded to human disturbance by temporary and permanent nest abandonments, and movement from nesting or staging areas (Banko 1960 and Hansen et al. 1971). Bangs et al. (1982) noted the loss of some nesting sites corresponded with increased human disturbance. Hansen et al. (1971) found that trumpeter swans were wary of humans and fled their nests at the first sign of an approaching human. The expectations of this research were based on information from studies such as the ones listed above. It was therefore thought that lakes with a large increase in development around them would result in a decrease in swan use or a change in type of swan use over time. There was also an assumption that any type of human disturbance would have an impact on swan use. For example, disturbances such as agricultural development, roads, or a well site around a lake were all thought to have some impact on swan use. Since trumpeter swans were supposed to be highly sensitive to disturbance, it was assumed that the closer to the lake the disturbance was, the greater the impact on swan use would be.

5.2.2 Development expectations around the lakes in the Grande Prairie region of Alberta

The amount of development around the study lakes was expected to dramatically increase in every type of disturbance, around every lake, at every distance category. It was assumed that due to the long period of time between photos (34 years), development would have increased in every area around Grande Prairie and would therefore include every lake in the area. This could be due to the oil and gas industry in Alberta as well as a function of the increase in population over 34 years.

5.2.3 How do the results from this research relate to results from other literature?

The results that are as expected are summarized in Table 2.7. The variables included in the equation for the regression model fit with what was expected because it was thought that all types and amounts of development would impact swan use.

5.2.3.1 White versus green zone

That the location of the lake, white versus green zone of the province, had an impact on swan use is interesting since development types in both areas also had an impact on swan use. For example, agriculture (which occurs in the white zone) had an impact on swan use as did forestry (which occurs in the green zone). This suggests that the location of the lake has an impact on swan use, independently of development occurring in the area. Perhaps there are factors that influence the suitability of habitat for breeding trumpeter swans that depend only on the type of ecosystem that surrounds the lake. However, if this were the case, it seems logical there would be no overlap in lake use by breeding and non-breeding swans in the two areas. However there is overlap between the white zone and green zone and breeding versus non-breeding lakes.

Perhaps there is a preference for the boreal zone by breeding swans due to the degree of development and the timing of the disturbance. Trumpeter swans may not establish on a lake with suitable habitat if they are frequently disturbed (Holton 1982). For example, when there is development in the form of forest harvesting, there is a dramatic change in the landscape due to large amounts of vegetation being removed. However, the actual disturbance of human activity in the area and large amounts of noise due to heavy equipment working, etc., often occurs in the winter when there are no swans on the lakes. As well, the disturbance is a singular event since forest harvesting does not occur in the same area at the same time. In contrast, trumpeter swans on lakes in the agricultural area (which is in the white zone) surrounding Grande Prairie experience fairly constant disturbance during the time that they occupy lakes in the area. Depending on the type of crop surrounding the lake, some of the activities involved are: cultivation, seeding, fertilizing, herbicide application, harvesting, and baling. These activities occur at various intervals throughout the breeding and rearing season and may create sufficient disturbance to cause swans to stop using a lake for breeding. In cattle farming, the disturbance (if the cattle are grazed close to or on the lake shore). is constant. Brechtel (1982) found that the biggest problem affecting trumpeter swans in Grande Prairie is disturbance during the breeding season.

The amount and degree of disturbance associated with agriculture is much less localized than with forest harvesting. With agricultural development comes many other developments. For example, in agricultural areas there is generally a large number of roads as well as residential developments. In areas where forest harvesting is occurring, there are roads built which are used temporarily. and no residential or constant human presence occurs in the area. It is possible that the activities of non-breeding swans are such that they are not bothered by these types of disturbances enough to cause them to stop using a particular lake. Non-breeding swans have less stringent habitat requirements than breeding swans (Brechtel 1982). In contrast, the relatively constant harassment of swans attempting to nest on a lake may be sufficient to cause them to abandon a nest site.

There are several other types of disturbance that occur in the green zone along with forest harvesting, including seismic lines, well sites, and roads. The timing of these disturbances does not necessarily correspond to when trumpeter swans are not breeding or utilizing the lakes in the area. The overlap between green zone and white zone lakes and breeding and non-breeding swans could occur because there is a preference for breeding on green zone lakes and because swans occupying green zone lakes are more isolated from humans and human related disturbance. Since swans on green zone lakes are more isolated from disturbance, they may be less habituated and more sensitive to disturbance (Brechtel 1982). Therefore, they respond readily to any type of disturbance by altering their use of lakes.

5.2.3.2 The impact of well sites

According to the logistic regression analysis, well sites have a significant impact on whether a lake is used by breeding or non-breeding swans, but only at the 0 to 100 m distance. This means that the activity has to occur very close to the lake to influence swan use. This is not consistent with what was expected since it was thought that swans would be impacted by activity such as well sites further away from the lake than 100 m due to their highly sensitive nature. Perhaps since a well site is a relatively localized disturbance, without constant human presence and activity, swans only react to the disturbance if it is very close to the lake. It is also possible that trumpeter swans have sufficiently habituated to the presence of humans and therefore human activity that they are unaffected by this type of activity as long as it is farther away from the lake than 100 m.

There is an example of construction activity 500 m from the lake shore not having an impact on trumpeter swan use of Anderson lake in 1985. Dome Petroleum Limited constructed a gas plant to the east of Anderson lake which was used by trumpeters at the time for nesting and brood rearing. The construction of the plant occurred between April and September. A buffer zone of 500 m between the lake and the construction site resulted in no response by the swans on the lake and nest success was as good or better in 1985 than in other years (Ward 1986). Based on the results of this research, 100 m would be a sufficient buffer to the noise and disturbance of construction to allow trumpeter swan activities to carry on undisturbed. However, a 500 m buffer (as was provided by Dome Petroleum Limited) would obviously provide even better protection from the disturbance and would ensure that trumpeter swan breeding activity could carry on without interruption. The results of both the above studies are not as expected if historical literature was followed as a guide to trumpeter swan behavior. As was previously mentioned, most historical literature stresses the reactive nature of trumpeter swans and their tendency to abandon any habitat that is effected by human intrusion.

5.2.3.3 Impact of forestry activity

Forestry had an impact on swan use of lakes at every distance except 0 to 100 m from the shore of the lake. There is no forest harvesting activity within 100 m of the lake shore because forest companies are not allowed to harvest that close to water bodies. A minimum permanent reserve of 200 m is required in forested areas around all water bodies known to have trumpeter swan activity on them (Moyles and Johnson 1991). There is very little forest activity surrounding the 49 study lakes in the Grande Prairie region of Alberta. It is surprising that the small area dedicated to forestry on the very few (three out of 49) lakes in the area would have a significant impact on trumpeter swan activity on the lakes. However, as was previously mentioned, forest harvesting is a dramatic change in the landscape due to the large areas of complete vegetation removal and trumpeter swans are aware of any change in the appearance of the landscape within their nesting territory (Banko 1960). Although the human disturbance does not actually occur when the swans are occupying the lake causing a behavioral response by trumpeter swans, perhaps the level of change on the landscape is too drastic for breeding swans to tolerate. It is possible that since trumpeter swans are highly territorial and faithful to their territories, as well as being sensitive to changes in the landscape, that they cannot tolerate any disturbance as extreme as forest harvesting within their territories. Croonquist and Brooks (1993) found that riparian areas that experienced removal of natural vegetation by logging (and agriculture), caused decreased avian densities in the total number of birds decreasing by 93% ha^{-1} $year^{-1}$.

There are other potential reasons why forestry has such an impact on swan use. It is possible that the huge areas of vegetation removal have effects on water quality. There could be runoff from the logging roads and cutblocks that impact water quality and leave the wetlands unusable by breeding swans. According to Liverman and Hemker (1995), forestry practices are a suspected contributor to poor water quality. There are very specific food requirements for cygnets compared to mature swans. Specifically, for the first two weeks cygnets feed primarily on animal matter such as aquatic beetles and crustaceans brought to the surface of the water by their parents feeding on aquatic vegetation (Banko 1960). Runoff from cutblocks and logging roads could alter the chemical composition of the water so that the invertebrates and aquatic plants that are depended on by trumpeter swans are no longer produced in adequate numbers, if at all.

The increased human access to remote lakes in the Grande Prairie region, as a result of the building of logging roads, may reduce breeding swans use. Human access has been considered a major concern where trumpeter swans and development are concerned. Brechtel (1982) found that the expansion of human access to trumpeter swan breeding areas was problematic and caused decreased use of lakes or decreased nesting success. Increased human access can cause more serious problems for trumpeter swans in normally isolated areas in particular since swans in these areas are less habituated to human presence and activity (Brechtel 1982). The green zone, around Grande Prairie where forest harvesting occurs, is typically quite isolated and therefore, the swans in this area may be hyper-sensitive to human activity. This may explain why such a small amount of forest harvesting activity seems to have had an effect on trumpeter swan use of lakes in the area.

Due to the small sample size of lakes with forestry within the predetermined distance limits from the lake shore, it is prudent to look at the data for other lakes with forestry around them and the effects of the disturbance on trumpeter swan use of those lakes for comparison purposes. This will help determine whether the results seen from the statistical analysis on the smaller sample are valid. There are at least five other lakes within the 49 study lakes that had forestry activity around them sometime between 1961 and 1995. None of the five lakes have noticeable changes in use by trumpeter swans, and four of the five lakes were used consistently by breeding swans. For example, Bethel Lake had forestry operations around it (more than 1000 m from the lake) in 1993. Bethel Lake had no trumpeter swans on it until 1986. In 1990. breeding trumpeter swans were found on Bethel Lake and were found there consistently until 1995 when the last surveys were conducted. Another example, is Cutbank 2 Lake. Logging occurred around this lake in 1995 (more than 1000 m from the lake shore). On Cutbank 2 Lake, trumpeter swans were found breeding between 1979 and 1985 as well as between 1994 and 1995. There were no surveys between 1985 and 1994. The only difference between these lakes and those included in the statistical analysis is the distance from the lake that the activity occurred. Based on this information, it seems that forestry has an impact within

1000 m of the lake although the extent of this impact is not known due to the small sample size of lakes with forestry within 1000 m that could be included in the statistical analysis. Further away from the lake than 1000 m, it seems unlikely that forestry has an impact on trumpeter swan use of a lake.

5.2.3.4 Impacts of agriculture

The fact that agriculture was only significant 200 to 500 m from the lake shore (according to logistic regression) is puzzling and unexpected. It seems logical that the closer to the lake the disturbance occurred, the more impact it would have on trumpeter swan use of the lake. In particular, it was thought that agriculture would have a great impact on swan use of lakes due to the rather constant and extensive disturbance that occurs. It is particularly curious that whether or not a lake occurs in the white or green zone has a significant impact on swan use but the area around the lake dedicated to agriculture has no impact except between 200 and 500 m from the shore.

This result is different from that found with the t-test analysis. There is a significant difference between the mean area of land dedicated to agriculture at every distance from the lake except 0 to 100 m (Table 2.6). The measurements on the photos were taken from the waterline and therefore, most of the area 100 m from the water could be occupied by land too wet to cultivate and is dominated by corresponding wetland vegetation such as *Typha* sp.

The results of the t-test disagrees with the results of the regression analysis. The result of the t-test is however consistent with what was expected. It follows with historical knowledge about trumpeter swans that increased agricultural disturbance would cause breeding swans to stop utilizing those lakes. For example, Holton (1982) found that the establishment of a pair of trumpeter swans on a lake depends on the amount of agricultural activity around the lake and the ability of the swans to avoid it. Since there has always been concern about trumpeter swan populations and their status, breeding swans have typically been the focus of most research. Therefore, it is not well known how non-breeding swans respond to disturbance and how much harassment they can tolerate. What is known is that breeding swans are highly intolerant of harassment and trumpeter swans are most susceptible to disturbance during territory establishment and nest building (Brechtel 1982). This implies that non-breeding trumpeter swans would be less susceptible to harassment since they would not be carrying out these delicate activities.

5.2.3.5 Trumpeter swan habituation to human disturbance

It is possible that trumpeter swans were not affected by agriculture at certain distances from the lake because they have habituated to human disturbance. As early as 1948, there were trumpeter swans nesting and raising cygnets on lakes near active farms in northwestern Alberta (Banko 1960). Banko (1960) suggested that trumpeter swans repeatedly exposed to human disturbance habituated to the presence of humans. There are also examples of other species habituating to human disturbance in their breeding areas. For example, Dunlop (1996) found that bridled terns habituated to continuous human presence and that the escape response was dampened. As well, Mannan et al. (1996) found that some animals could habituate to humans on roads if the animals were not hunted. Therefore, it is possible that trumpeter swans would habituate to human presence due to the long period of time that trumpeter swans have been exposed to human disturbance, and the hunting of trumpeter swans has not been permitted.

Some observations made in the field during this study also support the possibility that trumpeters have habituated to human disturbance. For example, in one instance, two observers were standing on a road that bordered the shore of a lake. At first it appeared that there were no trumpeter swans on the lake. However, after a few moments of observation, a pair of trumpeters flew up out of the vegetation on the other side of the lake. The pair flew in the direction of the observers and proceeded to land on the lake approximately 50 m from the observers. The swans were relatively unconcerned about the presence of the road or the people on the road suggesting that trumpeter swans are not as sensitive as was previously reported and believed.

In another situation, the same two observers were standing on another road close to a lake where there were seven non-breeding trumpeter swans. Between the road and the lake was approximately 50 m of cultivated land. Again, the swans on the lake did not appear to change any behavior or show any outward reaction to the approaching observers. As well, there were gunshots being fired that could easily be detected at the lake. The shots were being fired somewhere to the west of the lake. The swans appeared not to notice the disturbance. This also suggests that swans are somewhat used to the presence of humans in their habitat and some of the disturbance that occurs as a result. In the first case, the swans seen were a pair and in the second situation the swans were a group of non-breeders. This suggests that both breeding and non-breeding swans are capable of habituating to human disturbance. However, the pair observed did not have any cygnets with them. Since the observation occurred in the fall, if cygnets had been present, they would have been able to fly and therefore would have been detected with the pair. This suggests habituation to human disturbance because other studies have found that pedestrians have elicited serious responses by trumpeters. Henson and Grant (1991) discovered that pedestrian traffic affected trumpeter swan behavior, "more dramatically than aircraft and vehicular disturbance". The most common response for trumpeter swans faced with pedestrian threats was to swim away from the disturbance and conceal themselves in the emergent vegetation (Henson and Grant 1991).

It does seem possible that trumpeter swans are capable of habituating to some types of human disturbance. However, the fact that certain types of disturbance had effects on swan use of lakes at particular distances from the shore suggests that they can only tolerate a certain degree of disturbance and may not be able to habituate to all types of disturbance. Therefore, we cannot assume that eventually trumpeter swans will habituate to all types and amounts of disturbance, and therefore humans should be able to cause any amount of habitat disturbance and destruction necessary for development.

5.2.3.6 Results of t-test analyses

The t-tests showed a trend towards increased development and disturbance surrounding non-breeding lakes. It makes sense that non-breeding swans would be less sensitive to disturbance since they are not carrying out activities as important as incubation and brood rearing. Also, non-breeding swans have much less time and energy invested in their habitat and have no offspring to protect.

The t-test showed that there is a significant difference between the area of breeding lakes compared to non-breeding lakes. Non-breeding lakes were significantly larger than breeding lakes. This is not what was expected according to Holton (1982) who found that the total surface area of occupied lakes was greater than unoccupied lakes. Breeding swans need large territories to insure there is enough food for the cygnets and pair to feed on (Johnsgard 1978). Therefore, it was thought that breeding lakes would be larger than non-breeding lakes. However, McKelvey, Dennington, and Mossop (1983) encountered swans in large flocks on large lakes which means that they were not using the large lakes as breeding territories. Hansen et al. (1971) found that large lakes supported very few nesting sites and were mostly used for feeding, loafing, and molting by non-breeding swans. According to Banko (1960), it is important that breeding lakes not have too much wave action. Based on this, it is reasonable that non-breeding swans would be utilizing habitat available on larger lakes. Larger lakes have a greater surface area and are subject to more wind and therefore wave action which is not desirable to breeding swans.

There are two results from the t-tests that do not seem logical. First, the t-test showed a significant difference between the area of well sites between 200 and 500 m from the lake shore. However, it is the breeding lakes that have more area of land dedicated to well sites. Similarly, at 500 to 1000 m, seismic lines were significantly greater around breeding lakes compared to non-breeding lakes. These results are not consistent with the other results and the historical trumpeter swan information. For example, Hansen et al. (1971) found that helicopter and seismic disturbance associated with oil exploration caused trumpeter swans to abandon territories and find new ones.

Seismic disturbance was not significant at any other distance category in the t-tests or at any distance with regression analysis. It is possible that seismic disturbance is not detected by swans between 500 and 1000 m from the lake and therefore, even though there is a significantly greater amount of seismic around breeding lakes, it has no impact on whether the lake is used by breeding or non-breeding swans. A similar circumstance could exist for well sites. The only distance well sites were significant with regression analysis was 0 to 100 m. It is possible that beyond the 100 m distance, swans are not affected by the disturbance due to well sites. Truett, Short, and Williamson (1996) found that habitat loss or change does not cause proportionate losses in wildlife populations because some parts of the habitat may be more crucial than others. This could explain why non-breeding trumpeter swans seem able to tolerate more disturbance than would be expected for breeding swans.

The disturbance resulting from seismic lines does not only include the removal of vegetation or even the explosions that occur at the time of construction. Once seismic lines are put in and the actual disturbance associated with that is past, the presence of humans often continues due to recreational use of the areas by recreational users on all terrain vehicles and hunters. Although these disturbances were impossible to detect on aerial photos, they would have been detected by swans in the areas used by humans. Therefore, it is considered that this source of disturbance was included in the analysis indirectly since swans reacting to any disturbance associated with seismic would have been evident in the results of the analysis. However, since seismic was not detected as a disturbance having an effect on choice of breeding habitat, it is considered that the human use of seismic lines also had no noticeable effect on trumpeter swan choice of breeding habitat. In the green zone, where seismic is readily identifiable on air photos, seismic was not found to have an effect on swan choice of breeding habitat. The green zone is also where recreational use may occur because in the white zone, where seismic is not detectable on aerial photos, recreational use is not a factor. Recreational users would be unable to use seismic lines in the white zone due to the land being privately owned and the presence of crops that could be damaged with recreational use. Since seismic was not found to have an effect on trumpeter swan use of breeding habitat in the green zone where seismic is detectable and more disturbance occurs in the form of recreational use, it is thought that the inability to identify seismic on white zone lakes is irrelevant.

Through t-tests, it was found that roads were significantly greater surrounding non-breeding lakes between 200 and 500 m and 500 and 1000 m from the lake. This is consistent with expectations of breeding versus non-breeding lakes. Since breeding swans are sensitive to disturbance during territory establishment, early nesting, and other stages (Brechtel 1982), it makes sense that the lakes used by non-breeding swans had more disturbance surrounding them. The regularity of disturbance with roads is frequent due to high traffic volume associated with a well populated area such as Grande Prairie. The degree of disturbance due to noise, runoff, and loss of habitat is also large. Henson and Grant (1991) found that breeding swans responded to large passing vehicles (such as gravel trucks) by ceasing their present activities and assuming a head up posture for between five and sixty seconds. Reijnen, Foppen. and Veenbaas (1997) discovered that dense traffic caused an important loss of species in habitats near roadways. The loss of species and degradation of habitat was thought to be a result of noise primarily in wooded areas since visual stimulation is not as prominent in wooded areas. In open areas however, visual disturbance is thought to be more of a factor due to the inability to exclude visual disturbance in an open habitat area (Reijnen, Foppen, and Veenbaas 1997). Therefore it is logical that breeding swans would show preference for lakes with fewer roads and therefore less disturbance.

It is possible that some of the results seen in this research are a function not only of the type of disturbance being discussed, but of many types of disturbance in the same area having an additive effect on habitat degradation (cumulative effects). Given the nature of this research, it is not possible to know if the effects seen are due to a combination of disturbance types, but additive effects are a possible explanation for some of the more drastic impacts resulting from relatively little development.

6.0 PRACTICAL IMPLICATIONS

The population of trumpeter swans in the Grande Prairie region of Alberta is increasing from 267 in 1991 to 448 total swans in 1995 (Beyersbergen 1996). This means that there are going to be increasing demands on habitat in the area and a requirement for new territories for young pairs to colonize. This is particularly important for the trumpeter swan population since on each lake, there can only be one breeding pair due to the trumpeter swans fiercely protective and territorial nature. This makes the requirements for population expansion quite substantial. Therefore, it is important to know what determines which lakes are used for breeding and which are used by non-breeding juveniles. The type and degree of disturbance that will cause breeding swans to stop using a lake but will still render it usable by non-breeding swans is important information for land managers to know about a species that has just recently been taken off the endangered species list in Canada.

This research is also important because many of the lakes that trumpeter swans nest on are located on private land which means that they are not subject to the same regulations as lakes on crown land. Therefore, it is important to know what kind of disturbances can be tolerated by trumpeter swans to ensure that on crown land there are no unnecessary risks being taken that endanger trumpeter swan habitat. Responsible land owners that are aware of wildlife and habitat issues may wish to know what kind of practices they can incorporate into their farming and land management that may help to minimize their impact on trumpeter swans and swan habitat. However, since the activity around lakes on private land cannot be controlled, if there were areas of crown land with lakes that were protected from harmful developments, this would help to insure that there is habitat available for the expanding trumpeter swan population. This research has taken a step towards determining what types of human disturbance create problems for trumpeters attempting to nest in the Grande Prairie area of Alberta.

This research has examined the large scale effects of changes in land use and the consequences on lake use by trumpeters. The proposed land use conditions set out by the Fish and Wildlife Service are consistent with the results of this research. For example, according to the land use regulations proposed by the Fish and Wildlife Service, there is to be no activity within 500 m of the high water mark and no work around lakes within 800 m of the high water mark between

April 1 and September 30 (James 1997). These stipulations are consistent with the findings of this study to ensure that activity around lakes does not occur too close to the lake or during the crucial period of nest building and brood rearing and thus impair trumpeter swan production.

The main aspect of land use regulations that determines if they are effective or not however, is enforcement. In the past, lakes that were designated as first priority for swan habitat later had a large amount of development occur around them that caused swans to alter their use. Therefore, some checking system or permit system is needed so that whenever any type of development is occurring around a lake that is or could be used by swans, people in control of land management know about and are making sure that regulations are not overlooked.

Land use guidelines for private landowners who have trumpeter swan habitat on their land are needed. Perhaps a land purchase program could be adopted by conservation agencies in the area to make sure that there is habitat available on private land without harmful development occurring around it. A large number of the lakes used by trumpeters occur in the white zone and are on private land. This may serve to perpetuate the problems being seen now with development causing changes in swan use if guidelines are not imposed on private land owners. This is a very difficult step due to the freedom people have to do whatever they want on their own property. It is important to take appropriate steps to educate the public about wildlife and the effects their actions have on habitat and consequently individual species. There are shifting attitudes and perspectives regarding wildlife and human and wildlife interactions and relationships, but until such time as people are willing to put wildlife and habitat values above the monetary gains from impacting habitat, there will have to be programs that offer compensation to the landowner for protection of habitat on private land. Some partnership needs to be built so that wildlife biologists in the area can work with landowners to protect swan habitat.

An example of a conservation program that allows for wildlife habitat values to be maintained on private land is the Conservation Reserve Program (CRP) that has been functioning in the United States for several years. The CRP is a voluntary program where farmers place bids on the amount of compensation they would be willing to accept to give up agricultural production on a piece of land for an amount of time to maintain wildlife habitat (Young and Osborn 1990). The farmer is in control of the situation ultimately since it is his land, but by being in control he ensures that the deal made is acceptable for both parties involved. A program of this nature may be useful in situations where there is limited habitat available or where the wetlands in the area are vital to the trumpeter swan population stability or production.

7.0 WHAT QUESTIONS STILL NEED ANSWERING?

This research answered very broad questions about how trumpeter swan use of lakes is affected by land use and changes therein. Many years of data and a large area of trumpeter swan habitat were studied on a large scale to identify trends and patterns. What is needed now is a study that looks at finer details and specific aspects about why and how trumpeter swans respond to land use changes and disturbance by humans. For example, a study that examined how the chemical composition of the water in a lake or wetland change when a road or cutblock is put in near by is needed. Another important question to address is how the emergent and submergent vegetation in and around wetlands change when there is development activity in the surrounding area. Lastly, invertebrate population responses to development and different types of human activity could be studied. For instance, the impact of agricultural runoff on the species of plants and invertebrates in wetlands used by trumpeter swans would be useful information for habitat managers.

Another possible approach to studying trumpeter swans and their habitat would be to study the specific requirements for each group of swans (i.e. non-breeders and breeding swans) as well as each type of activity (i.e. loafing, nesting, staging etc.). It is known generally what trumpeter swans require for each of these activities but not specifically enough so that one could pick out lakes in an area and predict what their usefulness would be to trumpeters in the area. This information along with the information from this study would help habitat managers to set up conservation areas that represented habitat that is useful for each activity that trumpeter swans need it for.

One other study that would provide useful information to land managers is on the effects of predation on trumpeter swan nesting success; or, a study that focuses on trumpeter swan nest success and all of the factors that have an influence on it. The data used in this study showed some drastic changes in the number of cygnets on the 49 study lakes. Perhaps there are reasons for changes in nest success beyond environmental fluctuations that would be helpful to know about. Predation is one of the many possible influences. It is also possible that the impact of predation and other factors on trumpeter swan nesting success is tied to other sources of disturbance. There are many other species of birds who experience increased nest predation when disturbed by other sources such as humans.

8.0 CONCLUSIONS

The increases and decreases in numbers of adults and cygnets were normal trends that could be explained by changes in habitat and environmental conditions. The overriding trend was a general increase in total trumpeter swan numbers from 1957 to 1995.

Whether a lake is located in the agricultural (white) zone around Grande Prairie, or the boreal forest (green) zone, influences whether the lake is used by breeding or non-breeding trumpeter swans. Lakes in the boreal forest zone are used significantly more often by breeding swans and lakes in the agricultural zone are used significantly more often by non-breeding swans. The amount of disturbance in the agricultural zone is sufficient to deter breeding swans from using lakes in the area to nest.

Between 0 and 100 m of the lake shore well sites are the only type of human disturbance that has an influence on whether the lake is used by breeding or non-breeding swans. At 100 to 200 m from the lake shore, the types of land use that impact the use of the lake by trumpeter swans are agriculture and forestry. There is significantly more agriculture between 100 and 200 m of lakes with non-breeding swans than breeding swans. As the amount of forestry from between 100 and 200 m of a lake increases, the probability that the lake will be used by non-breeding swans also increases.

At 200 to 500 m from the lake shore, the types of human disturbance that have an influence on trumpeter swan use of a lake are roads, forestry, well sites, and agriculture. There is significantly more area in agriculture, forestry, roads, and well sites surrounding non-breeding lakes than breeding lakes. As the amount of land used for forestry and agriculture increases, so does the probability of the lake being used by non-breeding swans.

At 500 to 1000 m from the lake shore, the types of human activity that impact trumpeter swan use of lakes include forestry, agriculture, roads, and seismic. As the amount of forestry around a lake increases, so does the probability of use by non-breeding swans. There is significantly more seismic, roads, agriculture, and forestry around non-breeding lakes than breeding lakes.

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Table 2.1 Lakes and Their Use by Trumpeter Swans

Lake Name	Legal Location	Use Zone	Swan Use
Wembly	15 71 8 6	White	Breeding
Saskatoon	12 72 8 6	White	Non-Breeding
Hermit	2 72 7 6	White	Breeding
Gummer	34 73 7 6	White	Non-Breeding
Jones	9 74 7 6	White	Breeding
Wolfe	20 74 8 6	White	Breeding
Mulligan	35 73 8 6	White	Breeding
Little	36 71 8 6	White	Breeding
Hughes	31 71 6 6	White	Non-Breeding
Clairmont	19 72 5 6	White	Non-Breeding
Mc Naught	15 71 10 6	White	Breeding
West Buffalo	4 74 7 6	White	Non-Breeding
Dimsdale	10 71 7 6	White	Non-Breeding
Wood	17 71 5 6	White	Non-Breeding
Deep	24 72 8 6	White	Non-Breeding
Horse	24 73 12 6	White	Breeding
Valhalla	3 74 10 6	White	Breeding
Lowe	16 71 11 6	White	Non-Breeding
Flyingshot	9 71 6 6	White	Breeding
Cutbank 1	26 72 8 6	White	Non-Breeding
Henderson	24 73 8 6	White	Breeding
Ferguson	26 72 6 6	White	Breeding
Twin North	34 69 11 6	White	Non-Breeding
Twin South	27 69 11 6	White	Breeding
Crystal	31 71 5 6	White	Non-Breeding
Yoke	7 72 11 6	Green	Breeding
Burgess	3 72 11 6	Green	Breeding
Fowell	32 71 11 6	Green	Breeding
Lowen	33 71 11 6	Green	Breeding
Hackmatack	29 71 11 6	Green	Non-Breeding
Funnell	33 71 11 6	Green	Breeding
Kamisak	22 71 12 6	Green	Breeding
Preston	34 73 13 6	Green	Breeding
Keeping	33 74 13 6	Green	Breeding
Albright	8 75 12 6	Green	Breeding
Ksituan	36 78 10 6	Green	Non-Breeding
Updike	29 74 12 6	Green	Breeding
Martin	25 74 11 6	Green	Breeding
East Boone	17 76 9 6	Green	Breeding
SW Boone	35 75 11 6	Green	Breeding
W Boone	11 76 11 6	Green	Breeding
N Boone	9 77 9 6	Green	Breeding
Bethel	28 76 13 6	Green	Breeding
C Chain 3	15 74 13 6	Green	Breeding
N Martin	25 74 11 6	Green	Breeding
Ponita	19 75 12 6	Green	Breeding

Table 2.1 Lakes and Their Use by Trumpeter Swans (cont'd)

Lake Name	Legal Location	Use Zone	Swan Use
Dickson	24 75 13 6	Green	Breeding
Boone	14 76 10 6	Green	Breeding
Cutbank 2	35 77 12 6	Green	Breeding

White Zone = Agricultural Area
Green Zone = Boreal Area

Table 2.2 Identifying Characteristics of Disturbances on Aerial Photos

Disturbance	Characteristics Observed on Aerial Photos
Agriculture	Low growing, well organized vegetation
Forestry	Checkerboard logging pattern visible due to dark patches alternating with light patches
	Large polygons with linear boundaries and a lack of vegetation
Well Sites	Square white areas
Seismic	Narrow, straight lines (light in color) with no particular point of origin or destination
Roads	White lines, straight or curving. with an obvious point of origin or destination
City Development	Large groups of buildings in a small area and mazes of roadways

Table 2.3 Summary of Historical Trumpeter Swan Use on 49 Study Lakes

Year	Pairs	Lakes	Cygnets	Lakes	Non-Breeders	Lakes
1957	6	6	15	5	35	4
1958	8	8	6	2	6	3
1959	8	8	28	7	43	2
1960	11	10	34	7	23	1
1961	10	10	26	8	54	3
1962	11	11	23	5	39	4
1963	10	10	16	6	63	7
1964	12	12	17	7	59	3
1965	16	15	7	3	11	2
1966	12	12	13	4	37	4
1967	13	13	24	7	10	2
1968	13	13	16	6	9	3
1969	12	12	9	4	12	2
1970	12	12	22	8	24	2
1971	15	15	31	9	26	2
1972	13	13	28	10	78	3
1973	24	20	53	17	100	7
1974	16	16	41	12	50	10
1975	21	21	23	8	13	5
1976	18	18	21	7	22	5
1977	22	21	62	17	5	3
1978	26	25	47	15	13	3
1979	24	23	41	11	37	6
1980	18	18	33	13	11	5
1981	25	25	74	17	37	5
1982	15	15	41	11	74	6
1983	23	23	36	12	41	4
1984	24	24	58	18	9	1
1985	26	24	59	16	12	3
1986	20	20	52	13	25	5
1987	-	-	-	-	-	-
1988	-	-	-	-	-	-
1989	-	-	-	-	-	-
1990	16	16	24	7	72	4
1991	9	9	22	7	35	5
1992	19	19	68	14	17	3
1993	14	14	33	9	0	0
1994	23	23	52	15	27	4
1995	19	18	42	13	79	5

Table 2.4 Summary of Disturbance Area Within Each Distance Category During 1961 and 1995

Distance	Agriculture hectares		City Development hectares		Forestry hectares		Other Development hectares	
	1961	1995	1961	1995	1961	1995	1961	1995
0 - 100 m								
Mean Area	12.6	10.5	0	0.3	0	0	0.2	0.6
Range	0 - 86.5	0 - 96.6	0	0 - 8.1	0	0	0 - 10.9	0 - 18.4
% of Lakes	49	45	0	6	0	0	4	6
100 - 200 m								
Mean Area	25.9	22.4	0.2	1.2	0	0.2	0.3	0.9
Range	0-115.6	0-116.2	0 - 5.5	0 - 16.1	0	0 - 5.8	0 - 12.7	0 - 19.6
% of Lakes	61	61	4	10	0	4	4	8
200 - 500 m								
Mean Area	99.5	98.3	1.1	3.3	0	1.5	1	3.2
Range	0-409.5	0-442.8	0 - 30.9	0 - 35.7	0	0 - 43.7	0 - 34.6	0 - 54.1
% of Lakes	69	71	4	12	0	6	6	14
500 - 1000 m								
Mean Area	224.7	213.5	2.3	5.2	0	2.8	0.4	0.9
Range	0-772.6	0-596.9	0 - 57.9	0 - 81.7	0	0 - 75.9	0 - 9.1	0 - 25.3
% of Lakes	73	80	6	12	0	6	6	6

Table 2.4 Summary of Disturbance Area Within Each Distance Category During 1961 and 1995 (cont'd)

Distance	Roads meters squared		Seismic meters squared		Well Sites hectares	
	1961	1995	1961	1995	1961	1995
0 - 100 m						
Mean Area	5.9	5.4	0.7	1.8	0	0.1
Range	0 - 59.2	0 - 42	0 - 7.6	0 - 11	0	0 - 2.3
% of Lakes	41	41	31	51	0	10
100 - 200 m						
Mean Area	8.8	9.7	1.4	4.1	0	0.3
Range	0 - 54	0 - 44	0 - 9.7	0 - 24	0 - 1.8	0 - 3.5
% of Lakes	59	65	43	53	2	18
200 - 500 m						
Mean Area	29.1	39.5	6	15.3	0.1	2.2
Range	0 - 120.4	0 - 175.4	0 - 22.8	0 - 66.2	0 - 3.6	0 - 20.7
% of Lakes	76	90	61	57	2	53
500 - 1000 m						
Mean Area	59.5	90.5	10.8	28.6	0.2	4.2
Range	0 - 214	2 - 280.8	0 - 53.6	0 - 103.8	0 - 7.3	0 - 23.1
% of Lakes	80	100	61	55	4	59

Table 2.5 Number of Lakes (Out of 49) With A Change in Surrounding Disturbance Area From 1961 to 1995

Distance	Agriculture		City Development		Forestry		Other Development		Roads		Seismic		Well Sites	
	Inc.	Decr.	Inc.	Decr.	Inc.	Decr.	Inc.	Decr.	Inc.	Decr.	Inc.	Decr.	Inc.	Decr.
0 - 100 m	11	15	3	0	0	0	2	1	13	5	17	5	5	0
100 - 200 m	12	20	4	0	2	0	4	1	19	11	22	4	8	1
200 - 500 m	16	21	6	0	3	0	6	2	29	14	24	6	26	1
500 - 1000 m	19	20	5	1	3	0	3	1	39	8	24	6	29	0

Inc. = Increase
Decr. = Decrease

Table 2.6 Mean Area of Each Type of Disturbance per Distance Category for Breeding Versus Non-Breeding Lakes

Distance	Breeding Lakes (35)	Non-Breeding Lakes (14)	T Statistic	Significance
0 - 100 m				
Agriculture	7.8	17.2	-1.88	
Well Sites	0.1	0.3	-0.41	
Forestry	0	0	0	
Roads	4.6	7.4	-0.8	
Seismic	2.3	0.5	1.11	
City Dev.	0.3	0.4	-0.13	
Other Dev.	0.3	1.3	-0.84	
Lake Area	91.8	153	3.91	*
100 - 200 m				
Agriculture	17.7	34.1	-2.27	*
Well Sites	0.2	0.6	-0.39	
Forestry	0	0.7	-0.81	
Roads	7.9	14.3	-1.35	
Seismic	4.1	4	0.03	
City Dev.	1.4	0.8	0.4	
Other Dev.	0.7	1.4	-0.49	
200 - 500 m				
Agriculture	71.3	165.8	-6.14	*
Well Sites	20.9	2.3	3.86	*
Forestry	0.2	4.6	-2.01	*
Roads	33.9	53.5	-2.1	*
Seismic	17.4	10	1.42	
City Dev.	3	4	-0.39	
Other Dev.	3.1	3.7	-0.25	
500 - 1000 m				
Agriculture	168.2	326.9	-7.13	*
Well Sites	4.9	2.4	0.94	
Forestry	1.1	7.2	-2.15	*
Roads	81.3	113.3	-2.3	*
Seismic	33.8	15.3	2.64	*
City Dev.	4.6	6.9	-0.69	
Other Dev.	0.6	1.8	-0.81	

Critical t Value = T 0.05(2), 47 = 2.012

Table 2.7 **Summary of Logistic Regression Analysis Results**

Statistical Variable	0 - 100 m	100 - 200 m	200 - 500 m	500 - 1000 m
R2	0.187	0.187	0.187	0.187
% Overall Classification	77.08	75	77.08	70.83
% Correct Prediction of Breeding Lakes	100	100	94.12	97.06
% Correct Prediction of Non-Breeding Lakes	21.43	14.29	35.71	7.14
Constant For Model Equation	1.9576	2.7104	-2.2764	2.4887
Significant Equation Variables				
Agriculture vs. Boreal Lake	-2.2663	-2.8775		-2.6558
Well Sites	1.7256			
Forestry		2.881	0.2118	0.0811
Agriculture			0.0097	

Figure 2.1 Map of Alberta
Adapted from the Atlas of Breeding Birds of Alberta (Semenchuk 1992).

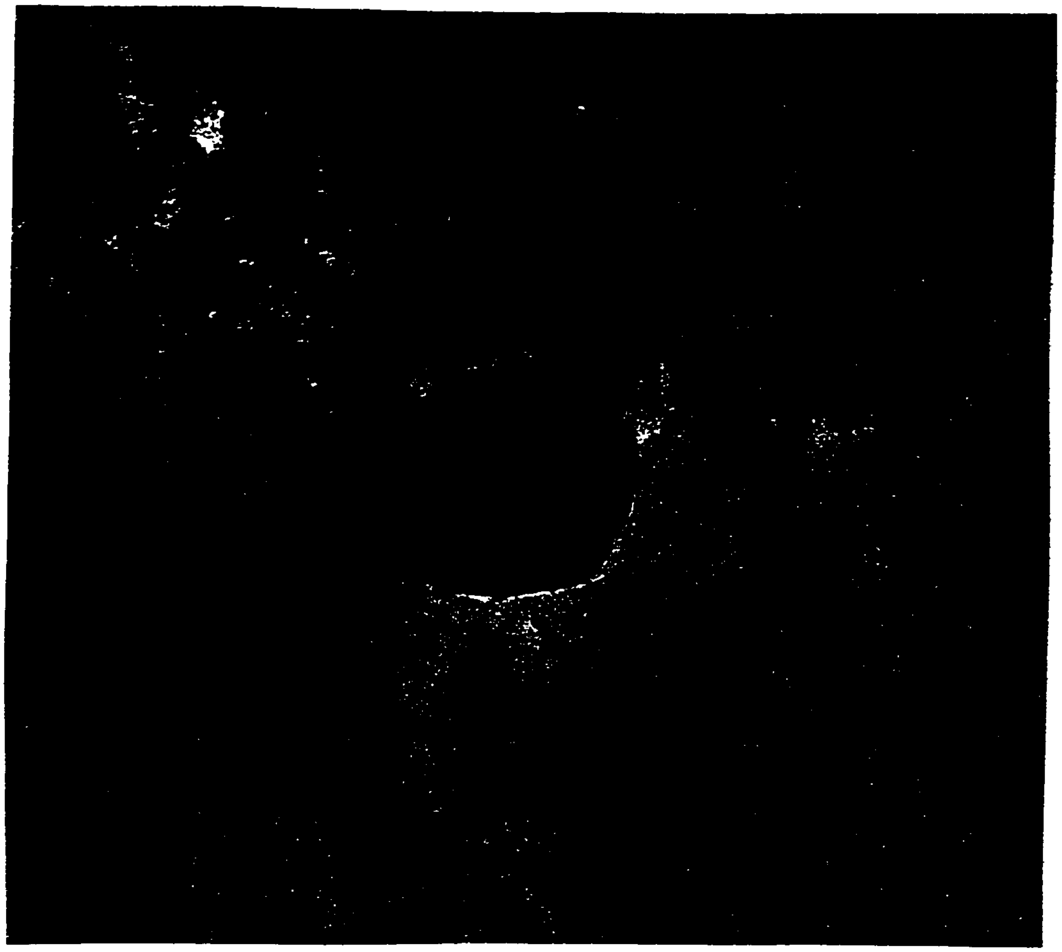

Figure 2.2 Aerial Photograph Example Showing Distance Measurements From the Shore Line of the Lake

APPENDIX

Table A.1 Summary of Swan Use and Production Data for 49 Study Lakes

Year	Valhalla	Saskatoon	Wembly	Lowe	Crystal	Flyingshot	Ferguson
1957	-	28	-	2	0	-	5
1958	-	0	-	-	-	0	2
1959	-	16,2,2,19	-	2+2	0	0	0
1960	-	23.2+5	-	0	0	0	2
1961	-	47	-	2+2	4	0	0
1962	-	32	-	2+5	2	0	3
1963	-	17	-	2+4	0	1	0
1964	-	54	-	2+3	2+1	0	2+2
1965	-	0	0	2	0	2	2+2
1966	-	0	2	2	0	2+4	2+3
1967	2+4	2,2,2	0	2	0	2+3	0
1968	0	2,4	0	2	2+3	2+2	2
1969	0	11	2+1	2	2+3	2+3	0
1970	0	15	0	2	2+1	0	0
1971	0	15,10	2+2	0	0	0	2+1
1972	0	2,16	0+2	2	0	0	0
1973	2+3	2	0	0	0	2+4	8+6
1974	2	5	0	2	0	0	2+4
1975	2	0	2+3	2	0	2	2+1
1976	2	-	-	2	0	2.3	2
1977	2+2	0	0	0	0	2+4	2+4
1978	1	0	0	0	0	2+4	2
1979	2	2	0	0	0	2+6	0
1980	2+2	0	0	0	0	2+5	0
1981	2+3	1	0	0	0	2+5	0
1982	0	0	0	0	0	2+4	0
1983	2	0	0	4,4,3,4,5,6	0	2+4	0
1984	2+2	0	0	0	0	2+5	0
1985	2	0	0	0	0	2+2	0
1986	0	2	0	3	0	2	0
1987	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-
1990	0	0	0	2+0	0	2+1	2+0
1991	0	0	0	0	0	2+3	0
1992	2+5	0	-	0	-	2+5	0
1993	0	0	-	0	-	2+4	0
1994	2+5	8	-	10	-	2+6	0
1995	1	25	0	43	-	2+5	0

Table A.1 Summary of Swan Use and Production Data for 49 Study Lakes (cont'd)

Year	Gummer	Wood	Deep	West Buffalo	Dimsdale	Clairmont	Mc Naught	Jones
1957	-	-	1	-	-	2	-	0
1958	0	-	0	-	-	1,2,2+2	-	2
1959	0	0	0	-	-	2,2	2+4	2+6
1960	0	0	0	-	-	2+1,2+5	2+4	2+6
1961	0	0	0	-	-	2,3	2+4	2+4
1962	2	0	0	-	-	0	0	2+5
1963	0	2+3	0	-	-	1+1	0	2
1964	2	0	0	-	-	1,2	0	2
1965	0	2, 2	0	-	-	2,8	2	3
1966	0	0	0	-	-	2,2,2	2	0
1967	0	2	0	-	-	2,2,2+3	0	2
1968	2	2	-	-	2	2+1	2+3	0
1969	0	2	0	-	0	1	0	2
1970	0	2+1	0	0	0	2	0	5,4
1971	0	1+4	0	0	2	2+5	2+5	2
1972	0	2	0	0	2	2	2+3	0
1973	11	2	0	0	2	2+5	2+5	12+15
1974	2	2+2	10	0	2,2,1	1+5	0	2,4
1975	0	0	0	0	2	2	2+3	3
1976	-	2+3	2	-	-	-	2	-
1977	0	2+2	0	0	0	1	2+3	0
1978	0	2+2	0	0	0	0	2+3	0
1979	0	2	0	0	2	2,2+4,3	2	2
1980	0	2+3	0	0	2,3	0	0	0
1981	2	2+3	0	0	13	0	2	2
1982	0	2+2	11	0	0	0	1	2+4
1983	4,3	2+1	0	0	2	2	2+1	2+2
1984	2	2+3	0	0	0	0	2	2+5
1985	-	2+3	2	0	2	0	2+4	-
1986	2,4	0	0	0	0	0	0	0
1987	-	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-	-
1990	53	0	17	0	0	2+0	0	0
1991	16	3	0	0	0	0	0	0
1992	0	-	0	0	3	1	2+6	13
1993	0	-	0	0	-	0	2+0	0
1994	0	-	0	0	-	0	-	2+0
1995	0	0	0	0	0	4	0	0

Table A.1 Summary of Swan Use and Production Data for 49 Study Lakes (cont'd)

Year	W. Boone	N. Boone	Preston	Albright	Yoke	Burgess	Lowen	Fowell	Keeping
1957	-	-	1+4	0	0	-	-	-	-
1958	-	-	2	2	0	-	-	-	-
1959	-	-	-	2+1	0	-	-	-	-
1960	-	-	2	0	0	-	-	-	-
1961	-	-	2+2	2	0	-	-	-	-
1962	-	-	2	2	0	-	-	-	-
1963	-	-	2+3	2+1	2	-	-	-	-
1964	-	-	0	2+3	2	-	-	-	-
1965	-	-	0	2	0	-	-	-	-
1966	-	-	3	2+3	0	-	-	-	-
1967	-	-	2	2+5	2	-	-	-	-
1968	-	-	0	2	1	-	-	-	-
1969	-	-	2	2	2	-	-	-	-
1970	0	-	2+5	2+1	2	-	-	-	-
1971	2+4	-	0	2	2	-	-	-	-
1972	2+4	-	0	2	2+2	-	-	-	-
1973	2+5	0	2+1	1+1	0	-	-	-	-
1974	2+5	2+6	0	2+4	2+3	0	0	0	-
1975	2	2+5	2+4	2+1	3	0	1	0	-
1976	-	2+5	2+2	-	2	-	-	-	-
1977	2+4	0	1	2+5	0	0	0	2+1	0
1978	4+4	2+4	2	0	2	0	0	0	2
1979	2+5	2+3	2	2+5	2+2	0	0	0	2. 2
1980	2, 2	2+4	2	2	2+1	0	0	0	0
1981	2	2+1	0	2	2+2	0	0	2+4	0
1982	1	2+4	0	2	2+1	0	0	0	1
1983	2+1	2	2+3	2+3	2	0	0	0	0
1984	2+2	2	2+3	8, 1	2+3	0	0	0	0
1985	2+1	2+3	2+2	2	2, 2+3	2	-	0	2
1986	2	2. 4	2	2+5	2+3	0	2+4	2+4	0
1987	-	-	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-	-	-
1990	-	-	2+0	2+3, 1	0	0	0	2+0	0
1991	-	-	4	2+1	2+2	2+5	0	0	2+0
1992	-	-	2+0	2+7	2+5	2+4	0	2+0	2+5
1993	-	-	0	2+3	2+4	2+0	2+3	0	2+5
1994	0	2+3	2+0	2+4	2+1	2+0	2+0	0	2+7
1995	2+1	6	2+0	2+4	2+6	2+3	0	0	2+4

Table A.1 Summary of Swan Use and Production Data for 49 Study Lakes (cont'd)

Year	Cutbank 1	Twin S	Henderson	Twin N	Wolfe	Mulligan	Little	Hughes	Hermit
1957	0	-	-	-	2+4	-	2+2	0	2+1
1958	0	-	-	-	2	-	2	-	2
1959	0	-	-	-	2+2	0	0	0	2+7
1960	0	-	-	-	2	0	2+4	0	2+6
1961	0	-	-	-	2+4	-	2+4	2+4	0
1962	0	-	-	2	2	-	2+7	2+3	2+3
1963	36	-	0	6	2	-	2+4	0	2
1964	0	-	-	2+2	0	-	2+3	0	2
1965	0	-	0	2	2+3	0	2	0	2
1966	0	-	0	2	0	1,2,22	2	0	2
1967	0	-	0	0	0	0	-	0	2+1
1968	0	-	0	0	2	0	-	0	2
1969	0	-	0	0	2	-	-	0	0
1970	0	0	0	0	2	0	2+3	0	2+2
1971	0	0	0	0	0	0	2	2+4	2+4
1972	0	0	0	0	2,32,2,2	0	2+4	22	2+2
1973	0	0	0	0	16+6	22+14	2+2	2+5,1	2+3
1974	0	0	0	0	2,8	0	2+2	2	2+5
1975	0	0	0	0	0	0	2+3	2	1
1976	-	-	2	-	2,2	-	2,5	-	-
1977	0	3	2+6	0	2+3	0	0	2	4+6
1978	0	2	2+6	0	2+3	0	2+2	3	2+4
1979	0	0	2	0	1	0	0	2	0
1980	0	0	2	0	0	2	2+3	0	2+1
1981	0	0	2+4	0	17	0	2+6	1	2+4
1982	0	0	2+4	0	48	0	2	0	0
1983	2	3	2+4	0	2	0	2+6	0	2
1984	0	2	2+2	0	2	0	2+5	0	0
1985	0	2+5	2+6	0	3	4,3	2+4	-	-
1986	0	0	2	0	2+2	0	2+7	0	2
1987	-	-	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-	-	-
1990	0	2+N	-	0	2+3	2+0	2+3	0	0
1991	0	0	-	0	1	2+3	2+6	0	0
1992	0	2+0	-	0	2+5	2+0	2+7	0	0
1993	0	-	-	-	2+4	2+2	2+0	0	2+3
1994	0	0	2+0	0	2+6	2+2	0	3	2+0
1995	0	2+1	0	0	2+0	0	0	0	0

Table A.1 Summary of Swan Use and Production Data for 49 Study Lakes (cont'd)

Year	Horse	Bethel	C Chain 3	Cutbank 2	Boone	Ponita	N Martin	Dickson	SW Boone
1957	0	-	-	-	-	-	-	-	-
1958	1	-	-	-	-	-	0	-	-
1959	0	-	-	-	-	-	0	-	-
1960	0	-	-	-	-	-	0	-	-
1961	0	-	-	-	-	-	0	-	-
1962	2	-	-	-	-	-	0	-	-
1963	0	-	-	-	-	-	1	-	-
1964	0	-	-	-	-	-	2	-	-
1965	2	-	-	-	-	-	2	-	-
1966	3	-	-	-	-	-	2	-	-
1967	2	-	-	-	-	-	0	-	-
1968	0	-	-	-	2+3	-	0	-	-
1969	0	-	-	-	-	-	-	-	-
1970	0	-	-	-	2+5	0	-	0	-
1971	0	-	-	-	2	0	-	-	-
1972	-	-	0	-	2+4	0	-	-	-
1973	2	-	0	-	2+5	0	2+1	2+1	0
1974	1	0	0	-	2+1	0	2	2,1,5	2
1975	0	0	0	-	2	2	2	5	2
1976	2	-	-	-	1	2	2	5	2+2
1977	2	0	0	0	2	0	2+2	2+5	2+5
1978	2	0	2+1	2	2,3,4	2	2+1	2+2	2+5
1979	2	0	2+1	2+6	2	2	1+5	2+3	2
1980	2+4	0	1	2+2	2	0	2+2	2+2	2+2
1981	2+6	0	0	2+5	2+5	2+2	2+3	2	2+3
1982	2+5	0	2+6	2+5	2,10	2	0	2	2+2
1983	2	0	0	2	0	0	0	5	2+3
1984	2+2	0	0	2+3	2+1	2+2	0	2	2+2
1985	2+7, 2	0	0	2+3	2+4	2	0	2+2	0
1986	2+3	0	2+2	2	2+4	5,1,3	0	2+5	0
1987	-	-	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-	-	-
1990	0	2+6	2+1	-	-	-	1	-	-
1991	0	2+2	0	-	-	-	0	-	-
1992	2+5	2+2	2+6	-	-	-	Dry	-	-
1993	2+0	0	0	-	-	-	Dry	-	-
1994	2+1	2+2	0	2+1	2+0	0	-	2+0	2+1
1995	2+0	2+1	0	2+6	0	2+1	-	2+0	2+4

Table A.1 Summary of Swan Use and Production Data for 49 Study Lakes (cont'd)

Year	Kamisak	Funnell	Hackmatack	Ksituan	Updike	Martin	E. Boone
1957	-	-	-	-	2+4	-	-
1958	-	-	-	-	2+4	0	-
1959	-	-	-	-	2+6	0	-
1960	-	-	-	-	2+3	0	-
1961	-	-	-	-	2+2	0	-
1962	0	-	-	-	2	0	-
1963	0	-	-	-	2	1	-
1964	0	-	-	-	2+3	2	-
1965	0	-	-	-	2+2	2	-
1966	0	-	-	-	2+3	2	-
1967	2+5	-	-	-	2+3	0	-
1968	0	-	-	-	2+4	0	-
1969	0	-	-	-	2+2	-	-
1970	0	-	-	-	0	-	2+4
1971	0	-	-	-	2	-	2+2
1972	2+1	-	-	-	2+3	-	0+3
1973	0	2	-	-	2, 2+2	2+1	2+3
1974	0	0	0	-	2+2	2	2+2
1975	0	0	0	-	2	2	2+3
1976	2+3	-	-	-	2+1	2	2+5
1977	2+4	2	2+1	0	0	0	2+5
1978	2+4	0	0	0	2+2	2	2
1979	0	0	24, 3	0	0	1	2+1
1980	0	0	0	0	4	2+2	2
1981	2	0	0	5	2	2+3	2+5
1982	0	0	0	0	0	0	2+4
1983	0	0	0	0	2+4	0	2+4
1984	2+4	2+4	0	0	2+8	0	2+2
1985	2	0	0	-	2+4	2	2+6
1986	2+6, 1	0	0	0	2+6	0	2+1
1987	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-
1990	2+0	0	0	2+0	2+7	1	-
1991	2+0	0	0	0	1	0	-
1992	2+0	2+4	0	0	2+2	Dry	-
1993	2+0	0	0	0	2+5	-	-
1994	2+1	0	-	6	2+6	-	2+6
1995	0	0	0	2+0	2+1	-	2, 2+5

Table A.2 Conversion Calculations for Measuring 100 m, 200 m, 500 m, and 1000 m from the Lake Shore

For 1995 (1 : 40 000) Photos:
1 cm on the photo = 40 000 cm on the ground
40 000 cm = 400 m
Therefore, 1 cm on the photo is equal to 400 m on the ground.

1 cm / 400 m = X cm / 100 m
X cm = 100 m / 400 m
X = 0.5 cm

1 cm / 400 m = X cm / 200 m
X cm = 100 m / 400 m
X = 0.25 cm

1 cm / 400 m = X cm / 500 m
X cm = 500 m / 400 m
X = 1.25 cm

1 cm / 400 m = X cm / 1000 m
X cm = 1000 m / 400 m
X = 2.5 cm

For 1961 (1 : 31 680) Photos:
1 cm on the photo = 31 680 cm on the ground
31 680 cm = 316.8 m
Therefore, 1 cm on the photo equals 316.8 m on the ground.

1 cm / 316.8 m = X cm / 100 m
X cm = 100 m / 316.8 m
X = 0.32 cm

1 cm / 316.8 m = X cm / 200 m
X cm = 200 m / 316.8 m
X = 0.63 cm

1 cm / 316.8 m = X cm / 500 m
X cm = 500 m / 316.8 m
X = 1.6 cm

1 cm / 316.8 m = X cm / 1000 m
X cm = 1000 m / 316.8 m
X = 3.2 cm

Table A.3 Calculations for Using the Dot Grid on 1961 and 1995 Air Photos

For 1995 (1 : 40 000) Photos:
1 section = 640 acres
640 acres = 223 dots

640 acres / 223 dots = X acres / 1 dot
X = 2.84 acres / dot
2.84 acres / 2.5 ha = 1.15 ha / dot

For 1961 (1 : 31 680) Photos:
1 section = 640 acres
640 acres = 284 dots

640 acres / 284 dots = X acres / 1 dot
X = 2.25 acres / dot
2.25 acres / 2.5 ha = 0.91 ha / dot

Example Calculations Using the Scale and Dot Grid:
Boone Lake: Seismic Within 100 m of the Lake Shore

Scale Measurement = 12.6
12.6 * 100 = 1260 m
1260 m * 6 m = 7560 m^2

Bethel Lake: Agriculture Within 200 m of the Lake Shore

7 dots counted
7 dots * 0.91 ha / dot
6.37 ha of agriculture between 100 m and 200 m of the lake shore

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes

***Note:** measurements in the lake row and under the other developments category are lake areas.

Valhalla Lake

Distance	Agriculture (ha)		Well Sites (ha)		Forestry (ha)		Roads (m2)		Seismic (m2)		City Dev. (ha)		Other Dev. (ha)	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	145.6	105.8
0 - 100 m	59.15	27.6	0	0	0	0	42	42	0	0	0	0	0	0
100 - 200 m	52.78	101.2	0	0	0	0	8	11	0	0	0	0	0	0
200 - 500 m	209.3	179.4	0	0	0	0	32	23	0	0	0	0	0	0
500 - 1000 m	428.61	503.7	0	1.15	0	0	36	52	3.6	0	0	0	0	0

Saskatoon Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	769.86	713
0 - 100 m	66.43	66.43	0	0	0	0	2	5	0	0	0	0	0	18.4
100 - 200 m	85.54	63.25	0	0	0	0	18	10	0	0	0	0	0	19.55
200 - 500 m	271.18	346.15	0	5.75	0	0	120.4	175.4	0	0	0	0	0	46
500 - 1000 m	675.22	500.25	0	0	0	0	100.4	111	0	0	0	0	0	0

Wembly Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	25.48	16.1
0 - 100 m	0	8.05	0	0	0	0	0	5	0	0	0	0	0	0
100 - 200 m	22.75	17.25	0	0	0	0	14	6	0	0	5.46	10.35	0	0
200 - 500 m	158.34	121.9	0	0	0	0	50	60	0	0	30.94	34.5	0	0
500 - 1000 m	429.52	282.9	0.91	1.15	0	0	76	76	1.8	0	0	12.65	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Lowe Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	52.78	39.1
0 - 100 m	22.75	28.75	0	0	0	0	0	0	0	0	0	0	0	0
100 - 200 m	49.14	48.3	0	2.3	0	0	28	28	0	0	0	0	0	0
200 - 500 m	200.2	227.7	0	1.15	0	0	18	36	0	0	0	0	0	0
500 - 1000 m	411.7	481.85	0	1.15	0	0	44	80	0	0	0	0	0	0

Crystal Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	30.03	33.35
0 - 100 m	1.82	1.15	0	0	0	0	0	0	0	0	0	2.3	0	0
100 - 200 m	19.11	11.5	0	0	0	0	0	0	0	0	0	11.5	0	0
200 - 500 m	91	75.9	0	0	0	0	18	40	7.8	0	0	35.65	0	0
500 - 1000 m	282.1	92	0	0	0	0	64	90	0.6	0	30.94	81.65	0	0

Flyingshot Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	128.31	121.9
0 - 100 m	0	2.3	0	0	0	0	2.8	8	0	0	0	8.05	0	0
100 - 200 m	16.38	20.7	0	0	0	0	24.8	44	0	0	1.82	16.1	0	0
200 - 500 m	193.83	181.7	0	0	0	0	74	97	0	0	0	0	0	0
500 - 1000 m	438.62	384.1	0	0	0	0	112.8	133	0	0	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Ferguson Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	11.6	0	-	-	-	-	296.66	202.4
0 - 100 m	86.45	96.6	0	0	0	0	4	26	0	0	0	0	0	0
100 - 200 m	109.2	116.15	0	0	0	0	10.8	41.5	0	0	0	0	0	0
200 - 500 m	223.86	341.55	0	0	0	0	61.6	78	0	0	0	6.9	0	0
500 - 1000 m	345.8	466.9	0	0	0	0	54.4	126.4	0	0	51.87	40.25	0	0

Cutbank 1 Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	217.49	158.7
0 - 100 m	40.95	52.9	0	1.15	0	0	20	32	0	0	0	0	0	0
100 - 200 m	91	87.4	0	2.3	0	0	12	34	0	0	0	0	0	0
200 - 500 m	394.03	442.75	0	9.2	0	0	108	132	0	0	0	0	0	0
500 - 1000 m	550.55	585.35	0	11.5	0	0	214	230	0	0	0	0	0	0

Twin S. Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0 - 100 m	1.82	2.3	0	0	0	0	0	0	0.36	0	0	0	0	0
100 - 200 m	10.92	6.9	0	0	0	0	0	0	1.2	0	0	0	0	0
200 - 500 m	41.86	23	0	0	0	0	12	9	18.6	21.9	0	0	0	0
500 - 1000 m	152.88	146.05	0	0	0	0	30	34	4.2	12.6	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Wolfe Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	142.87	87.4
0 - 100 m	33.67	23	0	0	0	0	0	0	0	0	0	0	0	0
100 - 200 m	89.16	59.6	0	0	0	0	19	19	0	0	0	0	0	0
200 - 500 m	247.52	172.5	0	0	0	0	65	65	0	0	0	0	0	0
500 - 1000 m	563.25	443.9	0	0	0	0	80	86	0	0	0	0	0	0

Mulligan Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	48.23	51.75
0 - 100 m	9.1	4.6	0	0	0	0	0	0	1.6	11	0	0	0	0
100 - 200 m	34.58	23	0	0	0	0	6	16	0.6	0	0	0	0	0
200 - 500 m	136.5	85.1	0	0	0	0	39	22	1.8	0	0	0	0	0
500 - 1000 m	468.65	420.9	7.28*	21.85*	0	0	68	89	0	0	0	0	0	0

Little Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	163.8	90.85
0 - 100 m	4.55	0	0	0	0	0	0	0	0	0	0	0	10.92	8.05
100 - 200 m	62.75	26.45	0	0	0	0	6	0	0	0	0	0	12.74	19.55
200 - 500 m	182	157.55	0	0	0	0	32	50	0	0	0	0	34.56	54.05
500 - 1000 m	318.5	299	0	2.3	0	0	96	104	0	0	0	0	4.55	12.65

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Hughes Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	80.08	43.7
0 - 100 m	10.92	0	0	0	0	0	0	0	0	0	0	0	0	0
100 - 200 m	53.69	23	0	0	0	0	4.8	14	0	0	0	0	0	0
200 - 500 m	249.34	164.45	0	0	0	0	34	33	0	0	0	0	0	0
500 - 1000 m	517.79	371.45	0	0	0	0	116.4	55.8	0	0	0	0	0	0

Hermit Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	258.44	201.25
0 - 100 m	43.68	19.55	0	0	0	0	14	16	0	0	0	0	0	0
100 - 200 m	84.63	57.5	0	0	0	0	14	8	0	0	0	0	0	0
200 - 500 m	252.98	221.95	0	0	0	0	25	23	4.8	1.2	0	0	0	0
500 - 1000 m	495.95	427.8	0	0	0	0	58	27	0	0	0	0	0	0

Gummer Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	81.9	54.05
0 - 100 m	40.95	16.1	0	0	0	0	6	14	0	0	0	0	0	0
100 - 200 m	69.16	47.15	0	0	0	0	12	26	0	0	0	0	0	0
200 - 500 m	216.58	164.45	0	0	0	0	52	36	6	1.8	0	0	0	0
500 - 1000 m	514.15	399.05	0	0	0	0	100	86	10	3	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Wood Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	61.88	52.9
0 - 100 m	5.46	0	0	0	0	0	12.6	2	0	0	0	5.75	0	0
100 - 200 m	10.01	11.5	0	0	0	0	6.6	2	0	0	0	11.5	0	0
200 - 500 m	91	90.85	0	1.15	0	0	18	14	0	0	0	33.35	0	0
500 - 1000 m	293.02	273.7	0	0	0	0	114.4	136	0	0	0	50.6	0	0

Deep Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	81.9	54.05
0 - 100 m	32.76	29.9	0	0	0	0	0	0	0	0	0	0	0	0
100 - 200 m	57.33	66.7	0	0	0	0	0	0	0	0	0	0	0	0
200 - 500 m	214.76	226.55	0	4.6	0	0	24	32	0	0	0	0	0	0
500 - 1000 m	483.21	491.05	0	5.75	0	0	82	136	0	0	0	0	0	0

W. Buffalo Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	22.75	9.2
0 - 100 m	6.37	0	0	0	0	0	0	0	0	0	0	0	0	0
100 - 200 m	28.21	18.4	0	0	0	0	21.2	23	0	0	0	0	0	0
200 - 500 m	150.15	117.3	0	1.15	0	0	29.2	38.5	0	0	0	0	0	0
500 - 1000 m	335.79	249.55	0	0	0	0	49.6	75.5	0	0	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Dimsdale Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	99.19	62.1
0 - 100 m	20.93	9.2	0	1.15	0	0	0	0	0	0	0	0	0	0
100 - 200 m	45.5	31.05	0	1.15	0	0	15.2	11	0	0	0	0	0	0
200 - 500 m	197.47	142.6	0	0	0	0	69.2	78.7	0	0	0	0	7.28	5.75
500 - 1000 m	333.06	343.85	0	0	0	0	139.2	202.7	0	0	0	0	3.64	25.3

Clairmont Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	797.16	586.5
0 - 100 m	66.43	37.95	0	0	0	0	32.8	38	0	0	0	0	0	0
100 - 200 m	115.57	77.05	0	1.15	0	0	6.8	16	0	0	0	0	0	0
200 - 500 m	409.5	342.7	0	2.3	0	0	90	97	0	0	21.84	23	0	0
500 - 1000 m	772.59	596.85	0	0	0	0	194.8	280.8	0	0	30.03	46	0	0

Mc Naught Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	33.67	23
0 - 100 m	2.73	0	0	0	0	0	2.8	0	0	0	0	0	0	0
100 - 200 m	20.02	17.25	0	0	0	0	4	0	0	0	0	0	0	0
200 - 500 m	126.9	104.65	0	0	0	0	32	31	0	0	0	0	0	0
500 - 1000 m	375.83	286.35	0	1.15	0	0	60.4	85.2	0	0	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Jones Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	181.09	125.35
0 - 100 m	37.31	25.3	0	0	0	0	12.4	12.4	0	7.65	0	0	0	0
100 - 200 m	47.32	42.55	0	0	0	0	4	4	0	0	0	0	0	0
200 - 500 m	211.12	188.6	0	0	0	0	13.6	12	0	0	0	0	0	0
500 - 1000 m	479.57	385.25	0	0	0	0	102.8	118	0	0	0	0	0	0

Horse Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	392.21	325.45
0 - 100 m	19.11	24.15	0	0	0	0	4	6	2.4	4.8	0	0	0	0
100 - 200 m	24.57	34.5	0	0	0	0	28	29	3.6	3	0	11.5	0	0
200 - 500 m	89.18	278.3	0	3.45	0	0	57	89	22.8	6	0	27.6	0	0
500 - 1000 m	303.03	469.2	0	1.15	0	0	131	149	7.2	16.2	0	25.3	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Henderson Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	25.48	19.55
0 - 100 m	1.82	2.3	0	0	0	0	22	22	0	0	0	0	0	0
100 - 200 m	39.13	19.55	0	0	0	0	2.8	10	0	0	0	0	0	0
200 - 500 m	100.1	113.85	0	1.15	0	0	15.6	30	0	0	0	0	0	0
500 - 1000 m	384.93	445.05	0	0	0	0	78	98	0	0	0	0	0	0

Twin N. Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	45.5	34.5
0 - 100 m	0	0	0	0	0	0	0	0	1.2	3	0	0	0	0
100 - 200 m	0	0	0	0	0	0	0	0	1.2	24	0	0	0	0
200 - 500 m	5.64	39.1	0	0	0	0	2.4	3	9	11.7	0	0	0	0
500 - 1000 m	212.03	232.2	0	0	0	0	24	39	3	16.2	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Bethel Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	74.62	52.9
0 - 100 m	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0
100 - 200 m	6.37	6.9	0	0	0	0	0	0	4.08	8.88	0	0	0	0
200 - 500 m	29.12	33.35	0	0	0	0	0	0	8.76	14.64	0	0	0	0
500 - 1000 m	101.01	174.8	0	0	0	0	13.6	13.6	12.96	26.34	0	0	0	0

C Chain 3 Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	21.84	14.95
0 - 100 m	0	0	0	0	0	0	0	0	0	1.65	0	0	0	0
100 - 200 m	0	0	0	0	0	0	0	0	2.28	3.9	0	0	0	0
200 - 500 m	0	0	0	0	0	0	0	0	6.24	16.5	0	0	0	0
500 - 1000 m	11.83	10.35	0	3.45	0	0	0	23.2	23.88	45	0	0	0	0

Cutbank 2 Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	104.65	29.9
0 - 100 m	0	0	0	0	0	0	0	0	4.2	0.6	0	0	0	0
100 - 200 m	0	0	0	0	0	0	0	0	3.48	1.8	0	0	0	0
200 - 500 m	0	0	3.64	0	0	0	0.6	0	11.28	6.6	0	0	0	0
500 - 1000 m	0	0	0	2.3	0	0	15.2	2	53.64	64.65	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Boone Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	220.22	165.6
0 - 100 m	0	0	0	0	0	0	0	0	7.56	7.56	0	0	0	0
100 - 200 m	0	0	0	0	0	0	0	0	7.2	7.92	0	0	0	0
200 - 500 m	0	0	0	20.7	0	0	0	105	11.4	30.6	0	0	0	3.45
500 - 1000 m	0	0	0	19.55	0	0	0	137	37.56	50.46	0	0	0	0

Ponita Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	95.55	70.15
0 - 100 m	0	0	0	0	0	0	0	0	3.24	3.45	0	0	0	0
100 - 200 m	0	0	0	0	0	0	0	0	9.72	9.78	0	0	0	3.45
200 - 500 m	0	0	0	0	0	0	0	0	3.12	38.7	0	0	0	21.85
500 - 1000 m	0	0	0	9.2	0	0	0	55	8.28	63	0	0	0	0

N. Martin Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	47.32	39.1
0 - 100 m	0	0	0	0	0	0	0.8	2	0.72	0.72	0	0	0.91	1.15
100 - 200 m	0	0	0	0	0	0	2.4	5	5.16	5.16	0	0	0	0
200 - 500 m	0	0	0	3.45	0	0	8.8	54	16.32	16.32	0	0	0	8.05
500 - 1000 m	0	0	0	2.3	0	0	10.4	98	17.76	16.2	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Dickson Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	49.14	36.8
0 - 100 m	0	0	0	0	0	0	8.4	8.4	0	0.6	0	0	0	0
100 - 200 m	0	0	0	0	0	0	8	8	0	0.6	0	0	0	1.15
200 - 500 m	0	0	0	1.15	0	0	16	20	5.04	21.6	0	0	0	19.55
500 - 1000 m	0	0	0	0	0	0	17.2	58	9.36	41.7	0	0	0	6.9

S.W. Boone Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	35.49	27.6
0 - 100 m	0	0	0	0	0	0	0	0	1.2	1.2	0	0	0	0
100 - 200 m	0	0	0	0	0	0	0	0	1.8	6	0	0	0	0
200 - 500 m	0	0	0	1.15	0	0	4	0	12	22.2	0	0	0	0
500 - 1000 m	0	0	0	10.35	0	0	42	20	23.4	32.4	0	0	0	0

W. Boone Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	335.79	248.4
0 - 100 m	0	0	0	2.3	0	0	8	12	0	0	0	0	0	0
100 - 200 m	0	0	1.82	1.15	0	5.75	54	28	0	3.6	0	0	0	0
200 - 500 m	0	0	0	3.45	0	20.7	86	38	0	27	0	0	0	0
500 - 1000 m	0	0	0	8.05	0	25.3	94	82	3	49.2	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

N. Boone Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	245.7	146.05
0 - 100 m	0	0	0	0	0	0	0	1	0.3	0.3	0	0	0	0
100 - 200 m	0	0	0	0	0	0	0	2	6	7.8	0	0	0	0
200 - 500 m	0	0	0	6.9	0	0	0	28	8.64	45.6	0	0	0	0
500 - 1000 m	0	0	0	21.85	0	0	0	112	40.2	103.8	0	0	0	0

Preston Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	318.5	240.35
0 - 100 m	0	11.5	0	0	0	0	4	0	0	0	0	0	0	0
100 - 200 m	7.28	18.4	0	0	0	0	14	14	3.78	8.4	0	0	0	0
200 - 500 m	36.4	57.5	0	11.5	0	0	16	28	8.4	22.2	0	0	0	0
500 - 1000 m	33.67	85.1	0	23.1	0	0	100	144	9.6	46.2	0	0	0	0

Albright Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	368.55	312.8
0 - 100 m	0	0	0	0	0	0	59.2	1.2	0.6	0.6	0	0	0	0
100 - 200 m	0	0	0	0	0	0	50.8	2	0.6	12.3	0	0	0.91	0
200 - 500 m	11.83	0	0	1.82	0	0	56	24	18.84	66.21	0	0	6.37	0
500 - 1000 m	13.65	5.75	0	2.3	0	0	72	78	29.76	100.2	0	0	9.1	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Yoke Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	73.71	55.2
0 - 100 m	1.82	8.05	0	0	0	0	0	0	0	3	0	0	0	0
100 - 200 m	3.64	18.4	0	1.15	0	0	0	12	2.28	14.1	0	0	0	0
200 - 500 m	16.38	26.45	0	3.45	0	0	32.4	60	16.2	29.4	0	0	0	0
500 - 1000 m	54.6	134.55	0	10.35	0	0	22.8	159	13.32	80.1	0	0	0	0

Burgess Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	18.2	17.25
0 - 100 m	0	0	0	0	0	0	0	0	0	2.4	0	0	0	0
100 - 200 m	0.91	0	0	0	0	0	2	0	0	4.8	0	0	0	0
200 - 500 m	21.84	9.2	0	4.6	0	0	40	6	5.4	22.2	0	0	0	0
500 - 1000 m	33.67	120.75	0	1.15	0	0	68	18	7.8	43.8	0	0	0	0

Lowen Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	8.19	8.05
0 - 100 m	0	0	0	0	0	0	0	0	0	3	0	0	0	0
100 - 200 m	0	0	0	0	0	0	0	0	0	1.65	0	0	0	0
200 - 500 m	0	0	0	1.15	0	0	0	18	9.6	13.05	0	0	0	0
500 - 1000 m	11.83	2.3	0	3.45	0	0	0	93	28.2	22.35	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Fowel Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	25.48	20.7
0 - 100 m	0	0	0	1.15	0	0	0	1	1.2	8.55	0	0	0	0
100 - 200 m	1.82	0	0	3.45	0	0	0	3	1.2	7.2	0	0	0	0
200 - 500 m	11.83	0	0	1.15	0	0	0	28	14.64	22.2	0	0	0	0
500 - 1000 m	0	6.9	0	3.45	0	0	0	87	25.08	45.6	0	0	0	0

Keeping Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	20.02	17.25
0 - 100 m	1.82	17.25	0	0	0	0	10	10	0	1.8	0	0	0	0
100 - 200 m	10.92	16.1	0	0	0	0	20	20	1.2	1.8	0	0	0	0
200 - 500 m	38.22	54.05	0	0	0	0	18	18	3.6	7.8	0	0	0	0
500 - 1000 m	62.79	108.1	0	5.75	0	0	72	114	17.4	40.2	0	0	0	0

Kamisak Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	209.3	200.1
0 - 100 m	0	0	0	0	0	0	20	0	0	8.4	0	0	0	0
100 - 200 m	0	6.9	0	0	0	0	14	0	0	6.6	0	0	0	0
200 - 500 m	0	11.5	0	0	0	6.9	38	36	2.4	63	0	0	0	0
500 - 1000 m	0	10.35	0	0	0	36.8	28	106	16.2	88.2	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Funnell Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	23.66	16.1
0 - 100 m	0	0	0	0	0	0	0	0	0	4.2	0	0	0	0
100 - 200 m	0	0	0	0	0	0	0	20	1.2	5.4	0	0	0	0
200 - 500 m	10.92	20.7	0	4.6	0	0	0	48	9	12	0	0	0	0
500 - 1000 m	57.33	78.2	0	3.45	0	0	12	82	7.8	25.8	0	0	0	0

Hackmatack Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	18.2	16.1
0 - 100 m	0	0	0	0	0	0	0	0	4.8	1.8	0	0	0	0
100 - 200 m	0	3.45	0	0	0	0	0	2	4.68	11.85	0	0	0	0
200 - 500 m	0	16.1	0	0	0	0	0	12	6.12	36	0	0	0	0
500 - 1000 m	0	50.6	0	0	0	0	0	7	25.92	42.3	0	0	0	0

Ksituan Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	90.09	70.15
0 - 100 m	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0
100 - 200 m	0	0	0	0	0	3.45	0	5.5	0	16.5	0	0	0	0
200 - 500 m	0	0	0	3.45	0	43.7	0	23	10.8	63.3	0	0	0	0
500 - 1000 m	0	0	0	6.9	0	75.9	0	65	31.68	103.5	0	0	0	0

Table A.4 Area of Disturbance for Each Distance Category and Each of 49 Study Lakes (cont'd)

Updike Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	403.13	264.5
0 - 100 m	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0
100 - 200 m	0	0	0	1.15	0	0	0	0	0	16.5	0	0	0	0
200 - 500 m	33.67	24.15	0	2.3	0	0	18.8	31.5	10.8	63.3	0	0	0	0
500 - 1000 m	56.42	31.05	0	6.9	0	0	123.6	84	31.68	103.5	0	0	0	0

Martin Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	23.66	9.2
0 - 100 m	0	0	0	1.15	0	0	0	0	0	6.6	0	0	0	0
100 - 200 m	0	0	0	2.3	0	0	0	1.5	1.68	5.1	0	0	0	0
200 - 500 m	0	11.5	0	2.3	0	0	0	24	14.04	33.72	0	0	0	0
500 - 1000 m	4.55	64.4	0	2.3	0	0	0	27	10.2	58.29	0	0	0	0

E. Boone Lake

Distance	Agriculture		Well Sites		Forestry		Roads		Seismic		City Dev.		Other Dev.	
	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995	1961	1995
Lake	-	-	-	-	-	-	-	-	-	-	-	-	111.93	73.6
0 - 100 m	0	0	0	0	0	0	0	0	2.4	1.8	0	0	0	0
100 - 200 m	0	0	0	0	0	0	0	0	4.2	4.2	0	0	0	0
200 - 500 m	0	0	0	2.3	0	0	0	28	8.4	12.6	0	0	0	0
500 - 1000 m	0	0	0	12.65	0	0	0	68	15	57.6	0	0	0	0