INVESTIGATING HABITAT LOSS AS A CAUSAL FACTOR IN WESTERN TOAD (BUFO BOREAS) DECLINE IN THE LOWLAND PUGET SOUND ECOREGION USING FIELD SURVEYS AND GIS ANALYSIS

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by

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ABSTRACT

Investigating Habitat Loss as a Causal Factor in Western Toad (*Bufo boreas*) Decline in the Lowland Puget Sound Ecoregion Using Field Surveys and GIS Analysis

Sanders B Freed

The western toad (*Bufo boreas*) was once a common inhabitant of the western U.S. Multiple causal factors (i.e. habitat loss/degradation, chemical contamination, UV-B radiation and global warming, invasive species, and pathogens) have lead to population decline throughout the known historical range of the species, resulting in federally "threatened" status in several western states, and the listing as a "species of concern" in Washington State. In the lowland Puget Sound ecoregion, population decline is suspected, although the severity and causes of decline have not been investigated. Using field surveys of known historical populations, and GIS analysis of land cover within population home ranges, regional decline was assessed and habitat loss was investigated as a causal factor. Twenty-five sites were monitored for presence/absence of *Bufo boreas*. Results of the field surveys revealed population decline ranging from 35-56%, depending on metapopulation sink site inclusion. Land conversion within the *Bufo boreas* home range, as determined by the literature, was evaluated and categorized as agricultural, residential, and industrial. GIS analysis results revealed a general trend towards *Bufo boreas* presence at sites of limited development. Industrial and residential development at sites of *Bufo boreas* presence never exceeded 4% of the home range, suggesting a threshold of development compatible with *Bufo boreas* presence. Metapopulation structure was another population dynamic revealed by the results of this investigation. Source population dispersal to sink sites was evident in the GIS analysis. In conclusion, *Bufo boreas* has experienced significant decline of known historical populations, which is likely the result of habitat loss/degradation. Thus, *Bufo boreas* requires conservation action if the remaining populations in the lowland Puget Sound ecoregion are to persist.

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I. Introduction

Worldwide amphibian decline has become the subject of increasing attention, controversy and research (Lips 1999; Houlahan et al. 2000; Wake 1991; Pechmann and Wilbur 1994). Multiple hypotheses have been proposed as causal factors in the declines, including habitat loss/degradation (Davidson et al. 2001), UV-B radiation (Blaustein et al. 1994a), non-native predators (Knapp and Mathews 2000), climate change (Lips 1999), pathogens (Berger et al. 1998; Kiesecker et al. 2001b), and chemical contamination (Ankley et al. 1998). Each factor has been linked to individual cases, however, there is no evidence of a single cause for all of the declines (Blaustein and Wake 1990). In fact, there is increasing evidence that in many cases several factors may be acting synergistically to cause the declines (Carey 1993). Because of their complex life cycle, which encompasses both terrestrial and aquatic stages, and highly permeable skin, amphibians are considered "bio-indicators" of environmental integrity (Stebbins and *Cohen 1995). As bio-indicators, amphibian declines,* especially those directly traceable to anthropogenic causes, could indicate the overall deterioration of ecosystems and the likelihood of future extinctions of non-amphibian species (Parsons 1989).

The western toad (*Bufo boreas*) was once considered a ubiquitous species in western North America (Stebbins 1985). Prior to declines, it was not uncommon to see thousands of toadlets migrating from breeding sites or to witness spectacular breeding aggregations involving hundreds of adult toads. Within the past fifty years, the western toad has suffered drastic population declines throughout its range (Drost and Fellers 1996; Stebbins and Cohen 1995; Blaustein et al. 1994b; Carey 1993), which has lead to its threatened status in several regions (Federal Register 1991), and to its listing as a "species of concern" in Washington State (WDFW 2003). The family Bufonidae, to which the western toad belongs, is the most imperiled family of anurans in the New World tropics, with a total of 18% of known species to be in decline (Semlitsch 2003). Difficulty in establishing decline plagues amphibian conservation efforts, and is often due to lacking and incomplete historical information on abundance and distribution, which would allow meaningful comparisons with the present (Fisher and Shaffer 1996). This is the current situation regarding the western toad in Washington State; although decline is suspected it is difficult to verify. The Washington Department of Fish and Wildlife (WDFW) has a database of historical sightings that can be used to evaluate decline by conducting a presence/absence inventory. If decline is confirmed, as defined by a reduction in breeding aggregations/ populations, then habitat loss/degradation can be investigated as a causal factor in the decline of the western toad (*Bufo boreas*) using GIS analysis of land use.

Investigating habitat loss/degradation is a logical first step in assigning cause in the decline of any organism. Direct human impacts, such as habitat alteration, are the most easily identified and quantified. In the case of the western toad, habitat loss must be considered before directing research towards the many other causal factors attributed to declines. If habitat loss/degradation is responsible for the suspected decline of the western toad in Washington, a negative relationship should exist between the amount of land altered within the western toad home range and the likelihood of persisting, viable breeding populations.

The first step in evaluating habitat loss as a causal factor in western toad decline was to determine the severity of decline, which was accomplished by using the WDFW historical sightings database to assess historical distribution. This was followed by field surveys to assess current distribution. The second step was to determine habitat loss at each site using GIS analysis of land cover to elucidate the relationship between habitat loss and population persistence. The results of this investigation provide a useful foundation that can be used to gain insight into and evaluate the decline of the western toad in western Washington, develop conservation strategies to ensure population persistence, and direct further research.

II. Methodology

This paper is essentially an evaluation of western toad (*Bufo boreas*) decline in the lowland Puget Sound ecoregion and an investigation of one causal factor: habitat loss. Using the Washington Department of Fish and Wildlife historical sightings database, water bodies used as breeding sites where populations of western toads have been reported as far back as 1985, were inventoried to assess presence or absence of populations. Presence was assessed by visual sightings of breeding aggregations, egg strings, or tadpoles. Once presence or absence was confirmed, GIS analysis of sites was used to determine if breeding populations are more likely to occur with decreasing percentage of home range development.

The WDFW historical sightings database contained 177 entries, 25 of which met the criteria of possible breeding sites since 1985. This investigation arbitrarily chose the year 1985 because the focus was aimed at determining recent decline. Given the number and distribution of all 177 sightings contained in the database, historical decline has been much more severe than the recent decline considered in this study. Sites included in this study had historical records mentioning large numbers of toads, indicating a breeding aggregation; multiple sightings at a single location, signifying a population in close proximity; or eggs or tadpoles, indicating a breeding site.

Field surveying of sites began in late March, coinciding with breeding aggregations. Surveying began at lower elevations and progressed to higher elevations in an attempt to witness breeding aggregations: the most conspicuous way to assess presence. Surveying was accomplished by several means, including wading, kayaking, and canoeing water bodies where breeding occurs. Wading was generally the most reliable means, enabling a thorough assessment of the entire water body. Presence was assessed by visual confirmation of individuals, egg strings, or audible vocalization. Breeding aggregations were generally consumed by the task at hand and fairly conspicuous.

Upon completion of field surveys, results were entered into a GIS program and overlayed on a land cover raster data set that was written by the Washington Department of Natural Resources under the Natural Heritage Program in 1999. Land cover was assessed in each 30 square meter block of the data set and categorized. As determined by the literature, each field-surveyed site was then buffered by 2.3 km, representing the home range of the western toad. Land use categorized as industrial, residential, and agricultural was assessed within each buffer. At each site, percentages of the various land use types, as well as the total development within each buffer was determined, graphed, and analyzed.

Materials utilized included: the Washington Department of Fish and Wildlife historical sightings database; peer-reviewed literature; books addressing amphibian biology, natural history and conservation; GIS software (ArcMap); and land cover raster data written for the Natural Heritage Program by the Washington Department of Natural Resources.

III. Western Toad Natural History

Understanding an organism's natural history is an essential prerequisite to any management or conservation attempt. Western toads (*Bufo boreas*) exhibit a typical biphasic life cycle that involves both aquatic and terrestrial life stages. Adult toads, which require 4-6 years to reach sexual maturity (Carey 1978), synchronously aggregate at small breeding sites in early spring, generally from April to May (depending on elevation and regional considerations). These aggregations often contain several hundred individuals (Marco et al. 1998), although Nussbaum et al. (1983) recorded over 5000 individuals in a single population. Sex ratios in western toad populations are usually disproportionately skewed towards males. Campbell (1970) had a sex ratio of 73% male to 27% female in all populations studied. Western toads may move long distances to breeding sites and utilize the same reliable sites year after year (Nussbaum et al.

1983). Breeding site fidelity is attributed to the well-developed olfactory capacity used in homing behavior (Tracy and Dole 1969).

Muths (2003) studied home range and movement in undisturbed habitat in boreal toads (*Bufo boreas boreas*) and found the maximum distance traveled in her study was 2.3 km, although males in her study traveled significantly lesser distances. On average, females traveled 2.4X the distance of males and had 4X larger home ranges. These results were supported by the results of Bartelt (2000), suggesting these distances are representative of the species. Larger home ranges in female toads probably leads to greater mortality, especially in the lowland Puget Sound ecoregion, due to the increased probability of moving into altered or developed habitat and the concurrent increase in predation risk. Clearly, this could also have repercussions for population level fecundity.

Upon arrival at breeding sites, western toads are explosive breeders and males exhibit scramble competition for mates (Olson et al. 1986). Communal breeding, communal oviposition, and explosive breeding are believed to reduce predation risks of adult anurans (Kagarise Sherman 1980). This belief is supported by the results of Olson (1989), where predation on toads by ravens (*Corvus corax*) did not increase proportionately with size of breeding aggregation. The mating period is short (4-6 nights) and males do not produce advertisement calls (Marco et al. 1998). Instead, males rest quietly in the water and swim vigorously towards movement. Upon reaching another toad or similar artificial mate, males exhibit a strong clasping response. Male toads give a bird-like twittering call (release call) in response to amplexus by other males (Nussbaum et al. 1983), although

Campbell (1970) suggests this vocalization may also serve to attract other conspecifics to a specific area of the breeding site. Amplexus with females is tenacious and prolonged. Females lay eggs in long intertwined strings at a depth of 5-10 cm (O'Hara 1981), and generally are fairly conspicuous and easily detected (Blaustein et al. 1994). An average spawn produces 12,000 eggs (Blaustein et al. 1994b; Samollow 1980). After egg laying, females quickly leave the breeding site (Marco et al. 1998).

Egg development takes 3 to 13 days (Corn 1998; Leonard et al. 1993), depending on temperature. Upon hatching, western toad tadpoles commonly form large schools, which scavenge and feed upon algae and organic detritus, growing to approximately 1 inch in length. Western toad tadpoles contain bufotoxins in their skin, making them unpalatable to many predators (Brodie 1987). Predators that swallow tadpoles whole, or insects that pierce and suck body fluids, are less deterred by the chemical defenses than those predators that bite, masticate, or taste the tadpoles (Peterson and Blaustein 1992). Salamanders, frogs, birds, garter snakes, and aquatic invertebrates are common predators of larval (tadpole) western toads (Arnold and Wassersug 1978), although roughskin newts (*Taricha granulosa*) and rainbow trout (*Oncorhynchus mykiss*), two co-occurring predators, find western toad tadpoles unpalatable (Peterson and Blaustein 1991).

Many studies have investigated the response of tadpoles to predation and chemical alarm cues (Chivers et al. 1999; Kiesecker et al. 1996; Hews 1988). Hews (1998) found that tadpoles increased their activity and avoided areas where conspecifics were being eaten. This alarm response reduced the capture efficiency of predators. Kiesecker et al. (1996) found that western toad tadpoles can recognize predators using chemical cues, resulting in decreased movement, avoidance of predator compartment, and an increase in shelter use. This ability to chemically detect predators and alter behavior in response increases larval survivorship and provides tadpoles with critical information at night, in turbid water, and in highly structured environments. Congruently, Chivers et al. (1999) demonstrated that tadpoles raised in the presence of chemical cues of predators and injured conspecifics metamorphosed in significantly shorter time than tadpoles raised in benign environments. This shift in life history may reduce exposure to aquatic predators, although it may have consequences for fitness if metamorphs emerge at a reduced size.

Multiple studies have shown that adult body size is positively correlated with female fecundity, male mating success, physical performance, and resistance to starvation (Davies and Halliday 1977; Lillywhite et al. 1973). Indeed, Goater (1994) found evidence that larval toads, when reared at low densities, were significantly larger at metamorphosis and emerged earlier. This may positively affect reproductive success by directly affecting adult life history traits or by indirectly affecting fitness related characteristics. Examples of the benefits of large size at metamorphosis include both increased adult size and early time to first reproduction (Pechmann 1994; Semlitsch et al. 1988; Smith 1987). Therefore, high larval mortality may not necessarily result in population level reductions in fitness and persistence.

Tadpoles develop in 30-45 days depending on temperature, density, food supply and regional differences. The juvenile (toadlet) stage in western toad development is subject to tremendous mortality rates (Stebbins 1962). This is expected because it is the toadlets' first experience with terrestrial habitats. Clarke (1977) averaged all information available on toad metamorph and juvenile survival, arriving at a 20% annual survival rate. Nussbaum (1983) concluded that mortality to reproductive age must be well over 99%. Although western toads do contain bufotoxins, they still suffer high mortality from frog and garter snake predation after metamorphosis (Pearl and Hayes 2002). Belden et al. (2000) found that juvenile western toads avoided chemical cues of snakes fed juvenile conspecifics, but did not avoid snakes fed larval conspecifics. This behavior may have advantages, as it reduces the amount of time responding to alarm, and increases the time allowed for foraging. After dispersal from the breeding site, little information is available on western toads until they return to breeding sites after reaching sexual maturity (Muths 2003).

The importance of thermoregulation in western toad behavior seems to be critical in all aspects of its terrestrial ecology. Smits (1984) studied microhabitat use in toads over the course of a year, finding predictable seasonal and daily activity related to a relatively narrow range of acceptable temperatures. The study also noted the importance of burrows in thermal buffering and anuran ecology. Hailman (1984) found that western toads exhibit a nocturnal bimodal activity pattern that coincides with ambient illumination. This study and others (Campbell 1970) suggest this activity pattern derived from illumination is important in foraging success. Muths and Corn (1997) have documented basking behavior by adult and juvenile western toads in the late summer after the breeding season. The authors speculate the behavior may serve multiple beneficial purposes, including increased rates of spermatogenesis, enhanced functioning of the immune system, and increased rates of digestion and growth. Lillywhite et al. (1973) studied behavioral thermoregulation in juvenile western toads and concluded that the western toad has evolved a thermoregulatory mechanism, which maximizes growth and economic utilization of energy. Energy ingestion, linear growth, weight increase, and gross conversion efficiencies were all maximal at 27°C-the identical temperature that toads preferred in a thermal gradient.

After reaching maturity, western toads will return to their natal ponds during the breeding season. No information is available on the percentage of a population that disperses to new breeding sites, or the process that catalyzes colonization. Adult western toads probably experience very little predation and have high natural survival rates after the larval and juvenile stages (Campbell 1970). Western toads have long adult life expectancies, estimated to survive from 6 years (Stebbins 1985) to 16 years (Blaustein et al. 1998).

IV. Western Toad Status

The western toad (*Bufo boreas*) was once widely distributed in the Pacific Northwest, and occurred throughout the western U.S. In 1985, Stebbins (1985) proclaimed the species to be ubiquitous. Since this time, western toad populations have precipitously declined throughout their former range (Stebbins and Cohen 1995). Although some decline has been accepted as a consequence of development and human habitat alteration, disappearances of populations from relatively pristine areas, such as national parks and forests, has raised alarm. In the case of the western toad, alarm has been compounded by the fact that decline has occurred over a broad geographic range thereby suggesting that global atmospheric factors are responsible (Lips 1999; Pounds et al. 1999; Blaustein and Wake 1990).

Stebbins and Cohen (1995) provide a comprehensive compilation of regional western toad decline. In California, Papenfuss (1980), Drost and Fellers (1993), and Martin (1992) all documented decline. Papenfuss surveyed transects in the Sierra Nevada foothills, finding toads on only five of twenty-seven transects where the presence of the western toad was classified as highly probable. Drost and Fellers resurveyed a transect performed by Grinnell and Storer (1924), finding toads at only one of six historical sites, and in extremely low numbers. In Colorado, Carey (1993) and Corn et al. (1989) have also documented western toad decline. Carey eventually abandoned field studies begun in 1971 because of severe population declines, and by 1979 eleven populations had vanished. Corn et al. (1989) surveyed fifty-nine historical localities and found only ten remaining populations (17%). Acid precipitation and low pH levels have been attributed to these declines, although scientific research has not proven causality in the declines (Vertucci and Corn 1993).

Almost every western state throughout the range of the western toad has documented a case of decline. In New Mexico, Stuart and Painter (1994) documented a loss of several populations from the San Juan Mountains. In the Cascade Mountains of Oregon, Blaustein et al. (1994a) documented high levels of egg mortality, finding 50%, 60% and 95% mortality at three different study sites. Yet from 1980 to 1989 egg mortality had never exceeded 5%. UV-B radiation has been attributed to these declines, although other factors such as pathogens have been implicated as well (Kiesecker and Blaustein 1997). In Utah, western toads were common up to around the 1960's. Today only a single breeding population is known to remain. Similar declines have occurred in Wyoming. Peterson et al. (1992) found toads at only three of eight sights in Yellowstone and Grand Teton National Parks, and at the two sites where toads were found there were less than ten total individuals. Historically, Carpenter (1953) reported western toads as the most widespread amphibian in the Jackson Hole region. Clark et al. (1993) reported similar declines finding toads at only nine of ninety-eight (9%) sites surveyed.

In Washington, the situation is presumably similar to other regions, except historical information on distribution and abundance is lacking. Lardie (1963) and Slipp (1940) reported *Bufo boreas* to be abundant and common in Pierce County and around the Tacoma area. More currently, Leonard et al. (1993) reported the species as uncommon in Western Washington and the North Cascades for unknown reasons, although development and loss of wetlands have been implicated. Since the 1700's, about half of the wetlands in the nation have been lost or severely altered by human activities (Council on Environmental Quality 1989). In Washington, it is estimated that the greatest losses of freshwater wetlands and marshes have resulted from development and most of the wetlands lost were between 0.2 and 2.0 hectares (Canning and Stevens 1989). Adams and Bury (1998) found six toads at one locality in a survey of the Fort Lewis military reservation, a relatively undisturbed habitat, where vehicle maneuvers are prohibited within 50 meters of wetlands. Richter and Azous (1995) found western toads at approximately 20% of wetlands surveyed in King County, although no information on population size was gathered. Other amphibian surveys (McAllister et al. 1993; McAllister and Leonard 1990, 1991, 1993) suggest decline throughout the lowlands of western Washington. Contrary to Nussbaum's (1983) assertion that the western toad adapts well to agricultural and residential suburban areas, this species appears to be in danger of extirpation from the lowland Puget Sound ecoregion.

V. Causal Factors in Western Toad Decline

Multiple factors have been implicated in western toad decline, although no single factor has been proven responsible in all declines (Blaustein and Wake 1990). To better elucidate causal factors in western toad decline in the lowland Puget Sound ecoregion, each must be investigated, with specific attention given to the unique regional characteristics.

A. Habitat Loss/Degradation

Habitat loss and degradation has been the most common culprit in western toad decline (Blaustein et al. 1994), although it cannot explain population disappearances in pristine areas, such as national parks. Habitat alteration and development in the lowland Puget Sound ecoregion has been extensive. There are currently over 4 million people in the Puget Sound ecoregion, with the majority of growth concentrated along the I-5 corridor (Puget Sound Health 2002). Between 1990 and 1999 the lowland Puget Sound ecoregion experienced a 19.9% population growth rate (Puget Sound Regional Council 2002). Concurrent with population growth, land conversion is extreme. The greatest wetland losses in Washington State have been freshwater palustrine marshes and forested wetlands from 0.2-2.0 hectares in size (Canning and Stevens 1989), which is a size class that is readily used by breeding amphibians, including western toads. Increasing evidence suggests that smaller (<4.0 hectares) temporary wetlands often have higher amphibian species diversity and produce more metamorphosing juveniles than ephemeral wetlands or permanent ponds (Pechmann et al. 1989; Semlitsch et al. 1996).

Concordant with aquatic habitat, terrestrial habitats must also be conserved to maintain amphibian populations. Given the known home range of the boreal toad, a close relative of the western toad, the approximate size of the terrestrial habitat utilized is a circle with a 2.3 km radius surrounding the wetland or water body (Muths 2003). To adequately protect populations of this species a significant amount of terrestrial habitat must be maintained; a fact which emphasizes the importance of landscape level wetland spatial arrangement and matrix land for source/sink dispersal. Too often, conservation efforts for amphibians focus on conservation of aquatic habitats/breeding sites and only protect the terrestrial habitat around wetlands as "buffer zones" or "buffer strips", thereby denoting a protective function for aquatic habitats (Semlitsch 2003). In addition, another problem with contemporary conservation efforts is the fact that the terms used to define adjacent terrestrial habitat, along with the regulations to protect it, are very unclear (Semlitsch and Jensen 2001). Moreover, research has confirmed that the surrounding terrestrial habitat is equally important to many species for performing essential life history functions. Therefore, it must be stressed that the core habitat of the western toad has both an aquatic and terrestrial component, and the conservation of both is required in order to maintain population persistence.

B. Chemical Contamination

Chemical contamination from acid precipitation and the concurrent low pH levels have also been investigated as a causal factor in western toad decline (Vertucci and Corn 1996). Several factors must be considered when making judgments about the degree or effects of chemical contamination on amphibian populations. First, only extreme contamination, resulting in mass mortality, is visible. Secondly, chemical contamination can act on both the aquatic and terrestrial life stages of amphibians, often having different effects on both. Third, chemical contamination can have both direct and indirect effects on amphibian populations.

Chemical contamination of aquatic environments can result in changes in amphibian distribution, reproduction, egg and larval growth, and mortality (Freda et al. 1991; Freda and Dunson 1985). Aquatic life stage sub-lethal contamination can result in delayed or early hatching, reduced larval body size, disturbed swimming behavior, and slower growth rates resulting from diminished prey capture ability (Horne and Dunson 1994; Preest 1993; Bradford et al. 1992; Andren et al. 1988). Chemical contamination has also been implicated in acting synergistically with other factors, such as UV-B radiation, to result in decreased embryo survival (Long et al. 1995). In addition, although no effect may be observed on amphibian life history variables, chemical contamination may alter food resources or community composition, which can result in decreased recruitment into adult populations. Overall, this can be problematic for the western toad because only 3-5% of all offspring produced annually reach metamorphosis, and recruitment into terrestrial stages from year to year is episodic (Semelitsch et al. 1996). Thus, anthropogenic stress from chemical contamination may further reduce recruitment and/or increase the time interval between bouts of successful recruitment, thereby affecting the long-term fitness and demographics of amphibian populations.

Multiple studies have concluded that low pH due to acid deposition is an unlikely cause of amphibian decline (Vertucci and Corn 1996; Dunson et al. 1992). Lethal pHs of the boreal toad (*Bufo boreas boreas*) range from 3.1 to 4.0 (Porter and Hakanson 1976), and it is likely that the lethal pH of the boreal toad is representative of the western toad (*Bufo boreas*). Declines of the boreal toad in the Colorado Rockies could not be explained by low pH or acidic deposition (Corn et al. 1989). Carey (1993) speculated that decline in the Colorado Rockies may have been indirectly caused by chemical contamination, arguing that pH levels do not need to be lethal to result in population decline and extinction-they only need to cause stress or increase the susceptibility to infection. Although largely terrestrial, boreal toads must rehydrate daily require contact with water during hibernation, which would likely result in stress if chemical contamination is present (Campbell 1970). Supporting Carey's (1993) assertions for a synergism between causal factors resulting in stress, which eventually leads to decline, Long et al. (1995) found low pH and UV-B radiation acting in concert to reduce embryonic survival. Clearly, the direct, indirect, and synergistic effects of chemical contamination must be considered whenever addressing amphibian decline.

In the case of the western toad in the lowland Puget Sound ecoregion, little research has been directed toward water quality with regard to amphibian decline. In a study of King County amphibian richness and wetland characteristics, Richter and Azous (1995) concluded that water quality was not an acute problem that could account for decreased amphibian richness. They reported all water quality characteristics at concentrations below documented levels for deformities and mortality (Power et al. 1989). However, they did note the lack of information on sub-lethal impacts and synergistic effects that could contribute to decreased amphibian richness. Although chemical contamination should be investigated as a causal factor in western toad decline, little direct evidence supports this factor, especially when considering the amount of precipitation the region receives and the broad geographic range of decline.

C. Climate Change and UV-B Radiation

Climate change and other atmospheric factors such as increased UV-B radiation, have also been implicated and investigated in amphibian declines (Pounds 2001; Blaustein et al. 2001; Blaustein et al. 1994a). It is unclear how global climate change will affect amphibian populations, although it is logically assumed that effects will be site specific, as well as species specific. Several attempts have been made to ascertain global warming impacts on amphibian populations by examining breeding phenology. Several studies have shown amphibian populations are breeding earlier (Gibbs and Breisch 2001; Beebee 1995); whereas others have suggested that early breeding may be related to mean daily temperatures over the 40 days previous to breeding activity (Reading 1998). Although difficult to prove conclusively, global warming will impact amphibian populations if weather patterns, temperature, and precipitation are altered. Aside from altering the ambient environmental conditions of home ranges, including temperature, humidity, moisture, rainfall, and changes in hydroperiods of aquatic sites-indirect effects such as increased stress could also result in increased susceptibility to parasites and disease (Donnely and Crump 1998).

Climate change has been investigated as a causal factor in western toad decline (Blaustein et al. 2001; Pounds 2001). Blaustein et al. (2001) did not find significant changes in breeding phenology in four populations of the western toad in the Oregon Cascade Range with increasing temperatures, although one population did exhibit a nonsignificant trend towards earlier breeding. Pounds (2001) suggested another model for the role of climate change in western toad decline. Beginning with the El Nino/ Southern Oscillation in the tropical Pacific, warming trends since the 1970's have reduced winter precipitation in the Cascades, which has resulted in reduced winter snow pack and concurrently reduced spring water levels in lakes and ponds. Thus, western toads have been depositing their eggs at reduced water depths. This leads to increased exposure to UV-B radiation, which can result in the increased vulnerability of western toad eggs to infection from *Saprolegnia ferax* (Blaustein et al. 1994b). Indeed, in water less than 20cm deep, *Saprolegnia ferax* invades and kills about 80% of embryos; in sharp contrast when compared to 12% in water deeper than 50cm (Kiesecker et al. 2001a). Clearly, climate change must be addressed when considering amphibian decline, and unfortunately, remedial actions are limited in the short term.

UV-B radiation has also been investigated as a causal factor in amphibian decline. Blaustein et al. (1994a) experimentally showed that western toad embryo hatching success was significantly greater when eggs were shielded from UV-B radiation. They also found that western toad photolyase levels, an enzyme that repairs UV-B damage, was one-sixth the level present in Pacific treefrog (*Hyla regilla*), a species that seems unaffected by UV-B radiation. This study generated considerable controversy, and stimulated numerous studies and articles in refute. Corn (1998) found no relationship between embryo mortality and UV-B radiation in the southern Rocky Mountain amphibian populations. To date, Licht (1995; 1996) and Licht and Grant (1997) have been the most vocal opponent of the UV-B radiation hypothesis. Abiotic factors such as water depth, water color, and dissolved organic matter, along with biotic factors, such as jelly capsules around eggs, melanin pigmentation of eggs, and the color of larvae and metamorphosed forms, are all proposed as factors that negate the potential negative impacts of UV-B radiation on amphibians. Palen et al. (2002) assessed 136 aquatic breeding sites across the Pacific Northwest, finding that 85% of sites were naturally protected from UV-B radiation by dissolved organic matter, thus only a small fraction of the clearest waters experience UV-B levels exceeding levels associated with elevated egg mortality.

Although these criticisms of the UV-B hypothesis are applicable, multiple studies have shown that UV-B radiation can act in tandem with other factors to produce mortality. UV-B has been shown to act synergistically with pathogens, low pH, and climate change to increase embryo mortality. Kiesecker and Blaustein (1995) showed UV-B radiation and a pathogen (*Saprolegnia ferax*) act synergistically to kill amphibian embryos, with the combined effects of both factors being greater than either factor acting alone. Long et al. (1995) found a similar synergistic relationship between UV-B radiation and low pH. Although neither factor acting alone had a detectable effect on embryo survival, in concert they led to a significant decrease in embryo survival. Additionally, Kiesecker et al. (2001a) found a synergistic reaction between climate induced water level reductions, UV-B radiation, and increased vulnerability to pathogen infection of embryos.

Although UV-B radiation may not be the ultimate cause of mortality for amphibian embryos, it has been suggested that UV-B radiation and other factors, such as habitat degradation and chemical contamination may stress organisms and increase their vulnerability to infection (Schaefer et al. 1981). Furthermore, life history attributes of the western toad may contribute to increased probability of infection by pathogens when stressed. Species that lay eggs in communal egg masses, such as the western toad, have been shown to experience higher egg mortality rates from *Saprolegnia ferax* infection (Kiesecker and Blaustein 1997). The authors suggest that UV-B radiation and other stress causing environmental conditions, such as low pH and low temperature, may weaken amphibian immune systems, and therefore increase their vulnerability to infection. Thus, UV-B radiation must be carefully examined as a contributor to amphibian declines because of its ability to act directly and indirectly through multiple pathways. In the case of the western toad in the lowland Puget Sound ecoregion, UV-B radiation is probably not a direct cause of embryo mortality because the harmful effects of UV-B radiation are diminished at lower elevations; however, indirect effects, such as increased stress, are possible.

D. Invasive/ Introduced Species

Invasive species have also been implicated in amphibian decline (Fisher and Schaffer 1996). Fish stocking and the introduction of bullfrogs (*Rana catesbeiana*) have had the most deleterious effect on native amphibians in the Pacific Northwest. Additionally, in the lowland Puget Sound ecoregion, habitat modification often benefits introduced bullfrogs and introduced fish by converting large ephemeral wetlands to permanent small ponds with less shallow water and emergent vegetation (Richter and Azous 1995). Fisher and Shaffer (1996), in their survey of California's Great Central Valley, found that native amphibians and introduced fish and bullfrogs tended not to co-occur; introduced exotics tended to occupy the low elevation sites and native species tended to persist at the higher elevations. Although plausible, western toads are less susceptible to adverse effects from introduced fish for two reasons: 1) western toads often breed in ephemeral water bodies that do not harbor fish; and 2) western toad larvae contain bufotoxins, so fish tend to avoid eating them (Peterson and Blaustein 1991).

Although western toad larvae may not be susceptible to predation by introduced fish, fish stocking may indirectly introduce pathogens such as *Saprolegnia ferax* (Kiesecker et al. 2001b). It has been estimated that 45% of the mountain lakes in the western U.S have been stocked with fish (Bahls 1992). Continued stocking of introduced species in mountain lakes for sport fishing will continue to adversely affect native amphibians. Even after fish stocking has been discontinued, introduced pathogens may become established and further stocking may introduce new strains of pathogens as they emerge. Furthermore, Blaustein et al. (1994b) hypothesize that infected amphibians may transmit the pathogen to other populations as they migrate or disperse. Therefore, invasive/introduced species have undoubtedly had adverse impacts, both directly by predation and indirectly by pathogen introduction, on populations of the western toad in the lowland Puget Sound ecoregion.

E. Pathogens

As mentioned previously, pathogens may also play a role in the decline of the western toad. To date, two pathogens have been identified that have been experimentally shown to increase embryo mortality or produce malformations. Blaustein et al. (1994) identified a species of water mold (*Saprolegnia ferax*) that had infected western toad egg masses and resulted in 95% mortality. *S. ferax* is an important worldwide pathogen of fish, and may have been introduced to amphibian populations by fish stocking. Blaustein et al. (1994) speculate that several years of extreme egg mortality may be attributable to this fungus. Follow-up research has shown that fish infected with *S. ferax* are capable of transmitting the pathogen to both amphibians and sediment, thereby establishing pathogen populations (Kiesecker et al. 2001b).

The trematode parasite (*Ribeiroia ondatrae*) has also been shown to induce severe limb malformations and reduce survivorship in western toads (Johnson et al. 2001). This parasite exhibits a complex life cycle involving a primary host and two intermediate hosts. Generally, the primary host will be avian, followed by a secondary snail host, and then lastly a secondary amphibian host. Upon reaching the amphibian host, the parasite forms cysts on the tadpoles' skin, which penetrate the tissue. These cysts disrupt natural limb bud formation, and result in malformed adult amphibians. *Ribeiroia* will parasitise any stage in amphibian development, although only attack at larval stages before limb budding will induce substantial abnormalities (Sessions et al. 2001).

Speculation abounds as to why amphibian populations are seemingly more vulnerable to infection and parasitism in the more recent past. Green et al. (2001) examined museum preserved specimens of Yosemite toads (*Bufo canorus*) from a die-off in the 1970's in an effort to elucidate a causal factor. Inability to find a primary etiological agent, but finding a variety of infectious diseases, Green et al.'s (2001) work suggests that the toads' immune systems were suppressed. Immune system suppression has been attributed to physical and environmental stressors, including handling, toe clipping, predation, unusual temperatures or weather patterns, UV-B radiation, and habitat alteration/ degradation (Kiesecker et al. 2001a; Carey 1993). Ultimately, western toad decline seems to be the result of a multifaceted attack on every life stage and at every type of environment that the toad encounters, with each attack compounding the probability of mortality.

VI. RESULTS

Field surveys confirmed nine sites of presence, fourteen sites of absence, and two sites that were indeterminate (Table 1). Figure 7 represents all sites visited and included in this investigation. Figures 8-22 show each site, including the buffer, land use and pie graph of land use within each buffer. Of all 25 sites, 12 sites were located on Fort Lewis Military Reservation, due primarily to the considerable resources allocated to monitoring on base. Site #6, Nisqually Lake, was not monitored because it is located in the Artillery Impact Area of Fort Lewis, and therefore resulted in a designation of "unable to determine presence or absence". Additionally, site #22, Bear and Porter Creek in Snohomish County, although surveyed twice, presence or absence of western toads was difficult to establish due to the number of possible breeding locations within the beaver dam complexes of the two creeks and the dense vegetation restricting movement and sight; consequently this resulted in a categorization of "unable to determine". The remainder of sites were thoroughly surveyed with a high degree of confidence in the designation of presence or absence.

Land use within a 2.3 km buffer of each site was determined using GIS analysis of land cover (Table 2). Considering all sites, the maximum percent developed was 18.9% (site # 13, Fagan and McEnniery Lake), while the least developed site was 0% (site # 6, Nisqually Lake). A comparison of land use at all sites, categorized as agricultural, residential and industrial, is shown in Figure 1. A comparison of total development at all sites is shown in Figure 2. Land use at sites of presence is shown in Figure 3. Land use at sites of absence is shown in Figure 4. Figure 5 represents a modified data set, showing percentage of each land use at included sites. Figure 6 represents a modified data set, combining industrial and residential development at included sites.

VII. DISCUSSION

The results of this investigation confirm western toad decline in the lowland Puget Sound ecoregion and inconclusively implicate habitat loss as a causal factor. Of the twenty-five sites of historically confirmed sightings since 1985, current presence was confirmed or was unable to determine at eleven sites (44%), while the remainder of sites did not support western toad populations (56%). Current decline revealed in this study should be considered concurrently with far more severe historical decline not covered in this paper. In addition, although decline was confirmed by field surveys, several caveats must be addressed in unison with the results.

A. Field Surveys

First, surveying of sites only assessed presence, absence, or inability to confirm. Therefore, presence could merely be the sighting of a single toad. This was the case at two sites of presence (Agnew Lake, site #18; Cat Lake, site #1). Therefore, these sites may not constitute source breeding populations, only dispersal sink sites from more robust breeding populations elsewhere on Fort Lewis. Even though a single toad doesn't constitute a breeding population, the life history of the western toad implies that these solitary toads were present to engage in breeding, because toads only aggregate at water bodies during the breeding season. Moreover, surveying only provided a glimpse of the breeding period, and once presence was confirmed monitoring progressed to other sites. Other toads may have arrived before or after monitoring, which would have allowed for reproduction.

Confirmation of absence is also plagued with difficulty, particularly when considering the fact that absence cannot be proven. Surveying generally consisted of a single, thorough assessment in a brief period of time. However, the possibility of missing a breeding aggregation was minimized by surveying sites according to elevation corresponding with the onset of breeding at the lowest elevation sites. Additionally, it is possible that some sites experience episodic breeding every few years, which is made possible by the longevity of the species, yet this would also suggest an unstable population that is highly vulnerable to stochastic events.

The results of field surveying in conjunction with the historical sightings database suggest the western toads on Fort Lewis exhibit a metapopulation structure, with source populations providing dispersal to sink sites. At Fort Lewis, Fiander Lake (site #17), Jolly Lake (site #12), and Cat Lake (site #1) appeared to be the sites of source populations, where breeding aggregations were found or heard. The remaining seven sites on Fort Lewis are all located within the home range buffer of source populations, suggesting that they act as episodic breeding sites in years following successful recruitment and dispersal from source populations (Figure 8). During the surveying season, No Name Lake (site #11), Rainier Training Area (site #10), and Bog Pond (site #15), historical breeding locations, received inadequate winter and spring precipitation. Consequently, this resulted in all of the aforementioned sites failing to fill with water, thereby negating any chance of successful reproduction. Given the metapopulation structure, maintaining the integrity of stable, reliable source sites (Fiander, Jolly, and Cat Lake) and the surrounding terrestrial home ranges should be a priority in the conservation of the western toad on Fort Lewis.

Two additional sites, Ranger Lake (site #14) and Fagan & McEnniery Lake (site #13), are also possible dispersal sites from Fort Lewis (Figure 13&14). Both sites currently do not support western toad populations, yet presence has been confirmed by historical sightings. Although both sites are outside of the known home range buffer, they are located in close enough proximity to Fort Lewis that it is feasible for dispersal to have established these sites as historical breeding populations. Dispersal to these sites is possible because the terrestrial environment between Fort Lewis' source populations and each site is relatively undisturbed; although land conversion is accelerating, reducing the likelihood of future dispersal and the rescue effect-where dispersing individuals supplement an existing population with genetic diversity and increased reproductive potential-an important process for population persistence and fitness (Blaustein et al. 1994c).

Another monitored site that also followed a similar source/sink dispersal pattern was Wye Lake (site #8) which appears to be a source population (Figure 12), with dispersal to Koenaman Lake (site #5). Koenaman Lake is approximately 2.3 km from Wye Lake, and therefore coincides with the literature supported home range area (Muths 2003; Bartlett 2000). Field surveying and home range examination also supports the metapopulation dynamic of the western toad populations. This fact justifies the modification of sites considered in land use analysis in an attempt to elucidate the responsibility of habitat loss in western toad decline.

An additional site surveyed and included in land use analysis of this study was of questionable validity. Tarboo Creek (site #2) was identified as a site of potential breeding because of a tadpole sighting (Figure 9). Yet, it must be noted, that the tadpole life stage is the most difficult life stage at which to identify western toads because of the similarities that western toad tadpoles have with numerous other species. Also, this site was the only creek visited during surveying. Western toads generally prefer small, reliable, standing water bodies for breeding. For these reasons, it is probable that misidentification of tadpoles occurred; consequently, Tarboo Creek was removed from GIS analysis of land cover in the modified data sets (Figures 5 & 6).

An additional site that requires further consideration is site #20, Carson Lake (Figure 19). Land use analysis suggests this site is suitable to support a population of western toads, although surveying resulted in a designation of absence. Upon further examination of the surrounding terrestrial habitat, it is probable that this sighting was a dispersing juvenile from an unidentified breeding site in close proximity. Several potential breeding sites are within 3km of Carson Lake, and further monitoring should reveal an undiscovered source population. Although included in analysis as a site of absence, the identification of a breeding population in close proximity, signifying a metapopulation sink site, would justify the removal of Carson Lake from analysis.

B. GIS Analysis

Analysis of land use in this study did not include habitat alteration caused by logging. Logging is a common habitat alteration that has occurred at all of the sites visited. The inherent difficulty with assessing the impact of logging on western toad population derives from the variability in both temporal and spatial parameters, imprecise or lacking information on the location and date of logging operations, and time lags in the publication of land conversion. Logging invariably impacts western toad populations due to changes in microclimate, moisture, vegetation, insect community composition, soil composition and structure, predation pressure, and temperature. To adequately assess the impact of logging on the western toad, research would need to identify and monitor an undisturbed population, subject it to a logging operation, and then follow this population with intensive monitoring and, ideally, telemetry data. This type of experiment exceeded the scope of this project, although it would be greatly beneficial to future management efforts. Obviously, logging operations do impact and affect the western toad populations considered in this study, although, because of the difficulties inherent in assessing logging impacts, they were not evaluated in this analysis, but should be considered qualitatively with the results.

The land use at sites of presence and absence is shown in Table 2 and Figures 1, 3 and 4. Total development at each site is shown in Figure 2. Although there are some anomalous results, the general trend expresses a negative relationship between development and western toad presence. The average development at sites of presence was 3.17%, while average development at sites of absence was 5.06%. By modifying the data, excluding sites of metapopulation dispersal (site #5, Koenaman Lake; site #10, Rainier training area; site #11, No Name Lake; site #15, Bog Pond; site #19, Pothole Ponds; site #21, States Marsh;

site #24, Toad Ponds), and site #2, Tarboo Creek (because of possible misidentification), a more obvious trend emerges (Figure 5). Except for two sites of absence (site #20, Carson Lake; site #14, Ranger Lake) and a single site of presence (site #18, Agnew Lake), a clear trend becomes apparent; less development equates to an increased likelihood of western toad populations. Although included in the modified data set, it may also be appropriate to include Agnew Lake (site #18) as a sink site from other source populations on Fort Lewis. Thus, when Agnew Lake is excluded, the results of this study are further clarified. A further modification involves reducing land use considered in analysis to include only residential and industrial development (Figure 6). Excluding agricultural development may be appropriate depending on the intensity with which the land is worked and the type of agricultural good produced. Western toads may be able to forage and move through a variety of agricultural landscapes, including orchards and non-industrial, low intensity crops. Sites of absence in this scenario average 4.42% habitat loss within the 2.3 km buffer, while sites of presence average 1.18%. Figure 6 suggests that western toads have a threshold of acceptable habitat loss to industrial and residential development within their terrestrial home range. This threshold is around 4%.

The significance of buffer size used in analysis should also be given consideration. Although the literature suggests a home range buffer of 2.3 km, representing the maximum distance a toad will move away from breeding sites during the season, several variables must concurrently be addressed. Female western toads are known to move greater distances, averaging 2.4X the distance of males (Muths 2003). Significantly smaller buffers would be adequate to protect male populations, although female western toads generally compose a small fraction of the population, around 25% (Campbell 1970). Therefore, the female populations and home ranges should be the focus of conservation efforts. Additionally, 2.3 km represents the farthest movement away from breeding sites, not the average. Using a smaller buffer in analysis may have been more useful, possibly using the average distance traveled, instead of the maximum. Upon examination of the site maps, a smaller buffer would have likely provided a more obvious trend, suggesting a stronger association between habitat loss and absence. Qualitatively, the majority of sites of absence had intensive development in close proximity to breeding sites, while sites of presence generally had less development in close proximity. Concurrently, sites of presence generally had an undeveloped avenue to terrestrial habitats immediately adjacent to breeding sites. Information on dispersal trajectory from breeding sites should be a priority in western toad conservation, because relatively little is known about their movements or activities away from breeding sites, or the rates of exchange between populations (Alford and Richards 1999).

The importance of the terrestrial habitat should be a priority in conservation efforts, especially in the case of the western toad, a largely terrestrial amphibian. To ensure population persistence and fitness, a significant amount of terrestrial habitat surrounding the breeding site should be maintained intact. Semlitsch (2003) provides a useful model that could be integrated into western toad conservation efforts. The model provides: 1) a protected aquatic habitat surrounding the breeding site; 2) a core habitat core habitat encompassing the aquatic buffer surrounding the breeding site; and 3) a secondary terrestrial habitat buffer surrounding the core habitat that is subject to limited nonpermanent extractive uses. This model would provide adequate protection to species such as the western toad that utilize a significant amount of terrestrial habitat during the majority of their life cycle. If possible, habitat corridors between source and sink sites should also be maintained, thereby ensuring the fitness, stability, and persistence of populations. Multiple examples are provided by the results of this investigation, including Fort Lewis and Wye Lake/Koenaman Lake.

The importance of the terrestrial habitat to western toads cannot be understated. Multiple studies have pointed to the importance of focusing conservation efforts on post-metamorphic vital rates, thus requiring the protection of adequate terrestrial habitat (Biek et al. 2002; Vonesh and De La Cruz 2002). Vonesh and De La Cruz (2002) found that even extreme egg mortality, which was attributed to increased UV-B radiation, was insufficient to result in the declines observed in western toad populations. This suggests that western toad abundance is more sensitive to changes in survival of later stages than the egg stage. In addition, Biek et al. (2002) found post-metamorphic vital rates are far more important to amphibian population persistence and fitness, thus making the prevention of perturbations in the later life stage vital rates a priority in the management and conservation of the western toad. To successfully accomplish this task, terrestrial habitat requirements must be determined and concordant habitat surrounding breeding sites must be maintained.

Several sites of western toad presence investigated in this study are nearing the threshold of development compatible with this species. Site # 25, Echo Lake (Figure 22), had a seemingly robust population of western toads, although the amount of development adjacent to the site was confounding (Figure 22). Interstate 90 runs within 200 yards of the lake, effectively reducing the terrestrial home range by half. All dispersal and home range movements must be directed away from the interstate. Homes also dot the lakeshore. If development continues around this lake it is likely that the western toad population will not persist. The only hope for this population is that the terrestrial habitat to the south east of the lake remains intact.

Another site in a similar situation is site #8, Wye Lake. Wye Lake is experiencing significant residential development (Figure 12). Houses surround the lakeshore of this breeding site. The only avenue for dispersal into the surrounding undeveloped terrestrial habitat is plotted out for sale and development. Given continued development around the lake, essentially insulating it from breeding toads, this population will likely be lost. Site #7, Anderson Lake had the most development of any site of western toad presence (Figure 14), excluding site #18, Agnew Lake, which is a probable dispersal site on Fort Lewis (Figure 8). This site most likely maintains a population of breeding western toads because it is buffered by Anderson Lake State Park. All development has occurred outside of the park boundaries, possibly making it a useful research site to determine minimum home range requirements. Given the date of the land use data set used in this study-1999-coupled with the accelerating rate of development in the Puget Sound, it is essential that western toad breeding sites are monitored and evaluated for possible protection before populations are lost. This is especially relevant when considering the fact that western toads do not effectively exploit new breeding sites or artificial ponds (Monello and Wright 1999).

Aside from development, a new threat has emerged that may accelerate western toad decline in the lowland Puget Sound ecoregion. The effects of climate change on breeding phenology became readily apparent during the monitoring conducted for this study. As previously mentioned, several historical breeding sites on Fort Lewis failed to fill with water. Additionally, breeding began several weeks earlier than in the past. Concurrent with straightforward consequences of climate change, including ponds failing to fill and breeding timing being altered, Kiesecker et al. (2004) have suggested another associated pathway for decline. Following decreased rainfall, which results in lower water levels in breeding ponds, increased levels of UV-B radiation penetrates western toad eggs, increasing the likelihood of *Saprolegnia ferax* infection, which results in greater than 50% egg mortality. Although the lowland Puget Sound ecoregion receives less UV-B radiation than higher elevations, the stage is set for disaster. To ensure population persistence of the western toad in the lowland Puget Sound ecoregion, actions must be taken immediately to conserve an invaluable component of our natural heritage.

VIII. CONCLUSION

Several conclusions emerge from the results of this investigation. First, the western toad is in decline throughout the region, nearing 60% since 1985, in addition to severe historical decline. Secondly, increasing evidence implicates habitat loss as the causal factor behind declines. Figure 2 exemplifies this trend most effectively. Modifications to the data set (Figures 5 and 6) further link habitat loss as a causal factor in western toad decline. Because the western toad is a "species of concern" in Washington State, it is imperative that actions be taken immediately to halt decline and ensure current population persistence, expansion, and, possibly, reintroduction. Steps include the protection of current breeding population terrestrial core habitats; continuing research and monitoring of existing populations in order to improve knowledge of terrestrial habitat movements and requirements; and the development of a conservation/reintroduction plan to be implemented to ensure population persistence, stability, and fitness. Given the small number of current breeding sites in the lowland Puget Sound ecoregion, protection of current populations could be ensured at a minimal cost. By restricting further development around current breeding sites, as well as the management and protection of terrestrial habitats in order to reduce impacts, population persistence will be probable if climate change, UV-B radiation, chemical contamination, invasive species, and pathogens do not contribute to further declines.

The western toad is a unique and exquisite species that plays an integral role in western Washington ecosystems, and remains a valuable element of the area's natural heritage. Prudence demands action and commitment to the preservation of a complete flora and fauna assemblage in the lowland Puget Sound ecoregion. The time to act is now, before further decline occurs, while populations are still viable, unless we are willing to relinquish the western toad to follow in the footsteps of the now extinct Costa Rican Golden Toad (*Bufo periglenes*), and the Australian gastric brooding frogs (*Rheobatrachis silus* and *R. vitellinus*). In the words of David Quammen in The Song of the Dodo (1996), "Meanwhile, though, there's still time. If time is hope, there's still hope."

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Table 1

Field Survey Results

Site Number	Elevation (Feet)	Date Visited	County	Site Name	Presence/ Absence
1	---	3/31/04 4/2/04	Thurston	Cat Lake	Presence
Comments: Single juvenile toad; heard breeding aggregation.					
2	16	3/28/04	Jefferson	Lower Tarboo Creek	Absence
Comments: Only creek visited; possible mis-identification of tadpoles.					
3	100	4/2/04 4/3/04	Thurston	Lake St. Clair	Absence
Comments: Canoed N. end of St. Clair and visited small lake across road.					
4	200	3/28/04	Jefferson	Crocker Lake	Presence
Comments: Caught 2 adults on N. end of lake and 1 adult and 3 toadlets on S. end.					
5	209	3/30/04	Kitsap	Koenaman Lake	Absence
Comments: No toads or eggs; possible dispersal site from Wye Lake.					
6	230	--------	Pierce	Nisqually Lake	Unable to Determine
Comments: Unable to visit because of location in Artillery Impact Area of Ft. Lewis.					
7	262	3/28/04	Jefferson	Anderson Lake	Presence
Comments: Over 50 toadlets observed and photographed.					
8	293	3/30/04 4/5/04	Kitsap	Wye Lake	Presence
Comments: 20 toad breeding aggregation; vocalizing.					
9	318	3/29/04	Mason	Oak Patch Lake	Presence
Comments: Numerous adults and juveniles; several in amplexus; egg strings present.					
10	383	3/31/03	Thurston	Rainier Training Area	Absence
Comments: Possible sink site from source populations on Ft. Lewis.					
11	391	3/31/04	Thurston	No Name Lake	Absence
Comments: No water this year; possible sink site from source populations on Ft. Lewis.					
12	394	3/31/04 4/1/04	Thurston	Jolly Lake	Presence
Comments: Saw five single males; 2 amplexed pairs; egg strings; dead juvenile.					

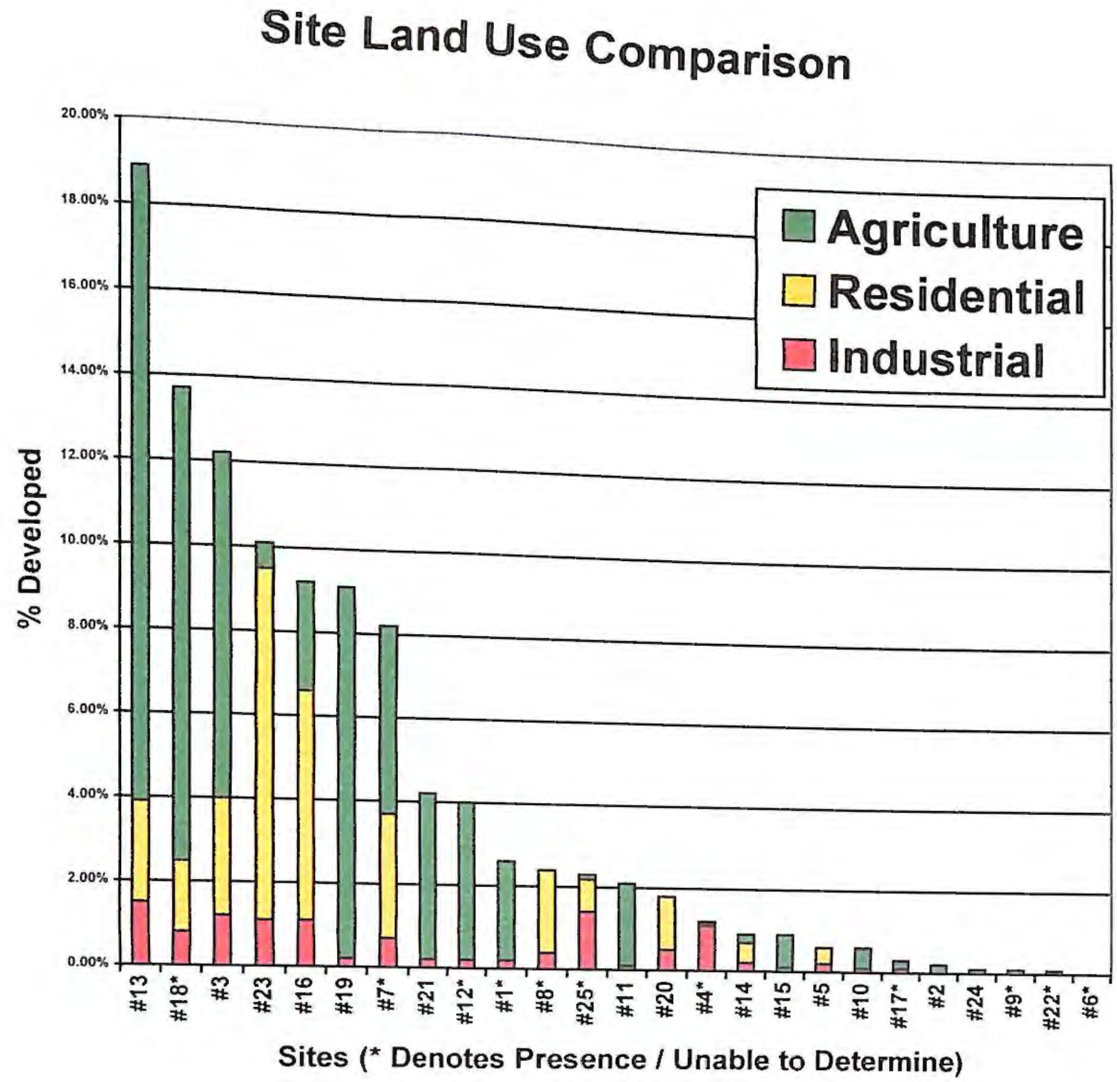
Site Number	Elevation (Feet)	Date Visited	County	Site Name	Presence/ Absence
13	399	4/3/04	Thurston	Fagan and McEnniery Lake	Absence
Comments: No toads or eggs; highly developed with residences and roads.					
14	406	3/31/04 4/2/04	Thurston	Ranger Lake	Absence
Comments: Waded lake; similar habitat to other source populations of Ft. Lewis.					
15	421	3/31/04	Thurston	Bog Ponds	Absence
Comments: Possible sink site from source populations on Ft. Lewis.					
16	441	4/6/04	King	Beaver Lake	Absence
Comments: Highly developed; spoke with resident who last saw toads 15 years ago.					
17	445	3/31/04	Thurston	Fiander Lake	Presence
Comments: Over 50 toads; vocalizing; amplexus; egg strings.					
18	446	3/31/04 4/1/04	Thurston	Agnew Lake	Presence
Comments: Saw single juvenile; good habitat; possible sink site from source site.					
19	448	3/31/04	Thurston	Pothole Ponds	Absence
Comments: Possible sink site from source populations on Ft. Lewis.					
20	461	3/29/04	Mason	Carson Lake	Absence
Comments: No toads, eggs or metamorphs; high degree of logging around site.					
21	477	3/31/04	Thurston	States Marsh	Absence
Comments: Possible sink site from source populations on Ft. Lewis.					
22	508	4/4/04 4/6/04	Snohomish	Bear and Porter Creeks	Unable to Determine
Comments: Beaver dam complex; vegetation too dense and too many ponds to determine.					
23	531	4/4/04	Whatcom	Our Lake	Absence
Comments: Highly developed and polluted; trailer park surrounds lake; dead rat.					
24	558	3/31/04	Thurston	Toad Ponds	Absence
Comments: Possible sink site from source populations on Ft. Lewis.					
25	908	4/6/04	King	Echo Lake	Presence
Comments: 3 amplexed pairs; 10 males; floating far out in lake compared to other sites.					

Table 2

Land Use Analysis Percentages

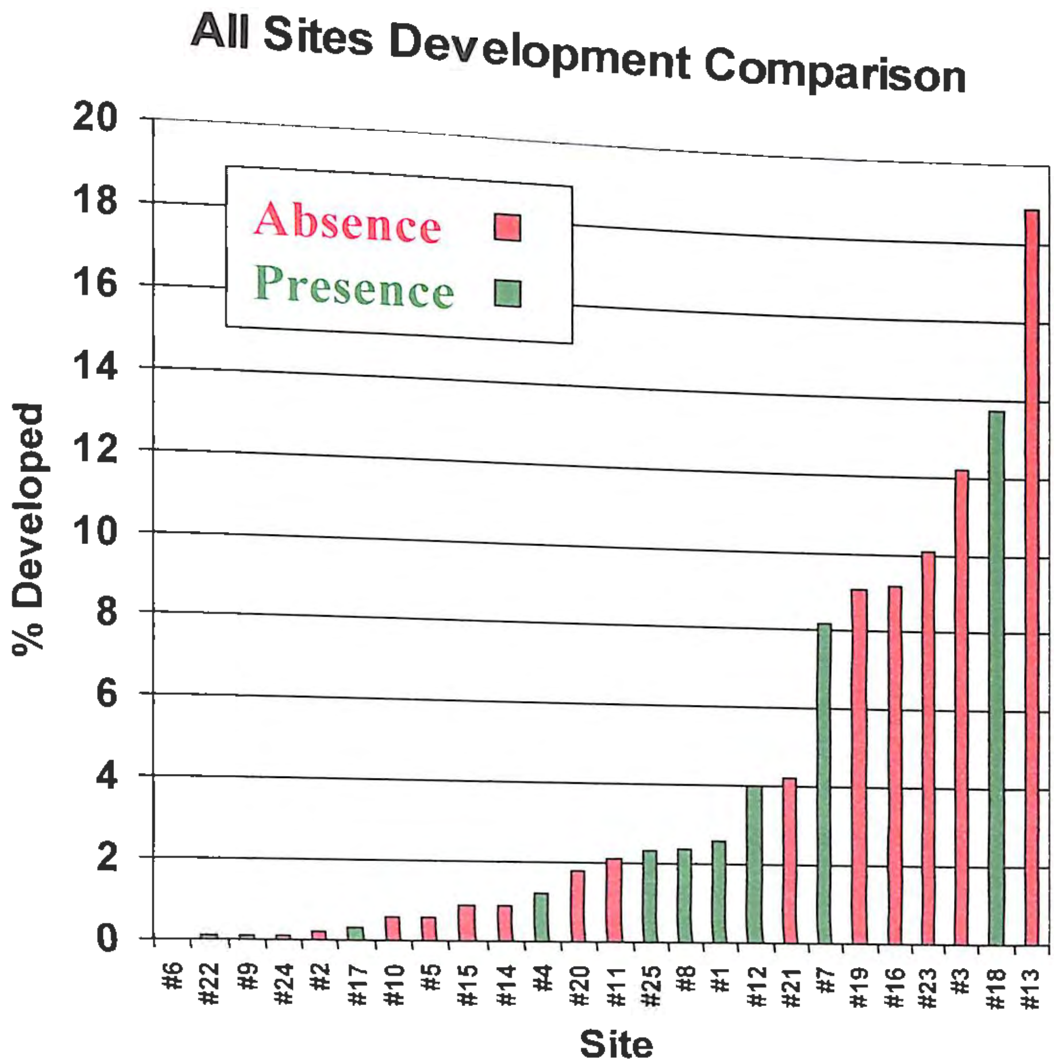
Site # (Location)	% Industrial	% Residential	% Agriculture	% Developed
1-Cat Lake	0.2%	0%	2.4%	2.6%
2-Tarboo Creek	0%	0%	0.2%	0.2%
3-Lake St. Clair	1.2%	2.8%	8.2%	12.2%
4-Crocker Lake	1.1%	0.05%	0.05%	1.2%
5-Koenaman Lake	0.2%	0.4%	0%	0.6%
6-Nisqually Lake	0%	0%	0%	0%
7-Anderson Lake	0.7%	3.0%	4.5%	8.2%
8-Wye Lake	0.4%	2.0%	0%	2.4%
9-Oak Patch Lake	0.1%	0%	0%	0.1%
10-Rainier Training Area	0.1%	0%	0.5%	0.6%
11-No Name Lake	0.1%	0%	2.0%	2.1%
12-Jolly Lake	0.2%	0%	3.8%	4.0%
13-Fagan and McEnniery Lake	1.5%	2.4%	15.0%	18.9%
14-Ranger Lake	0.2%	0.5%	0.2%	0.9%
15-Bog Pond	0.1%	0%	0.8%	0.9%
16-Beaver Lake	1.1%	5.5%	2.6%	9.2%
17-Fiander Lake	0.1%	0%	0.2%	0.3%
18-Agnew Lake	0.8%	1.7%	11.2%	13.7%
19-Pothole Ponds	0.2%	0%	8.9%	9.1%
20-Carson Lake	0.5%	1.3%	0%	1.8%
21-States Marsh	0.2%	0%	4.0%	4.2%
22-Bear and Porter Creek	0.02%	0%	0.06%	0.08%
23-Our Lake	1.1%	8.4%	0.6%	10.1%
24-Toad Ponds	0.1%	0%	0%	0.1%
25-Echo Lake	1.4%	0.8%	0.1%	2.3%

Figure 1



Site Land Use Comparison
Agriculture
Residential
Industrial
% Developed
20.00%
18.00%
16.00%
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
#13
#18*
#3
#23
#16
#19
#7*
#21
#12*
#1*
#8*
#25*
#11
#20
#4*
#14
#15
#5
#10
#17*
#2
#24
#9*
#22*
#6*
Sites (* Denotes Presence / Unable to Determine)

Figure 2



All Sites Development Comparison
Absence
Presence
% Developed
0
2
4
6
8
10
12
14
16
18
20
#6
#22
#9
#24
#2
#17
#10
#5
#15
#14
#4
#20
#11
#25
#8
#1
#12
#21
#7
#19
#16
#23
#3
#18
#13
Site

Figure 3

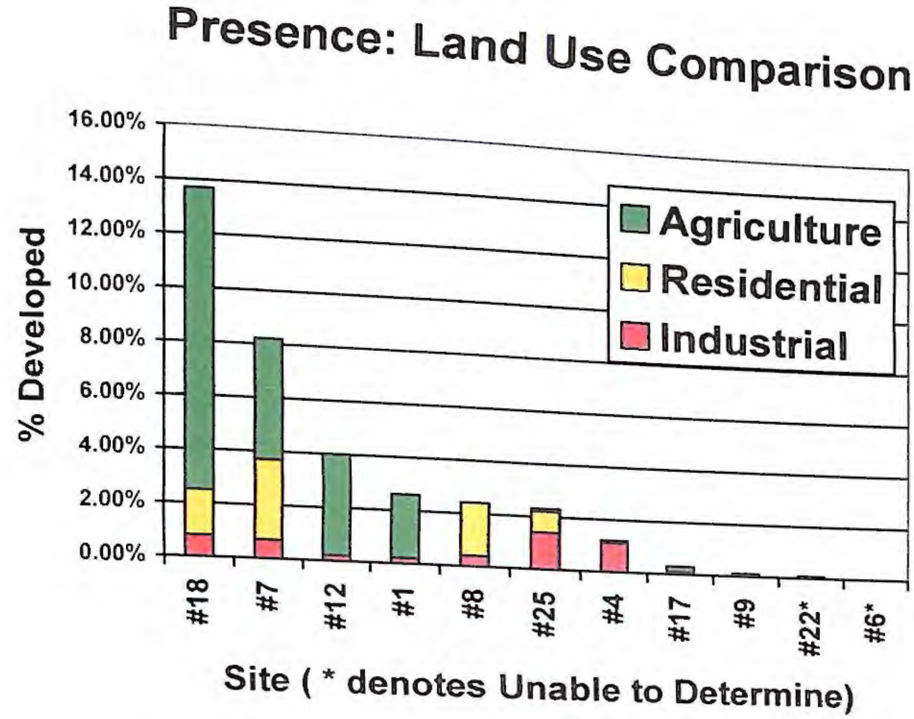


Figure 4

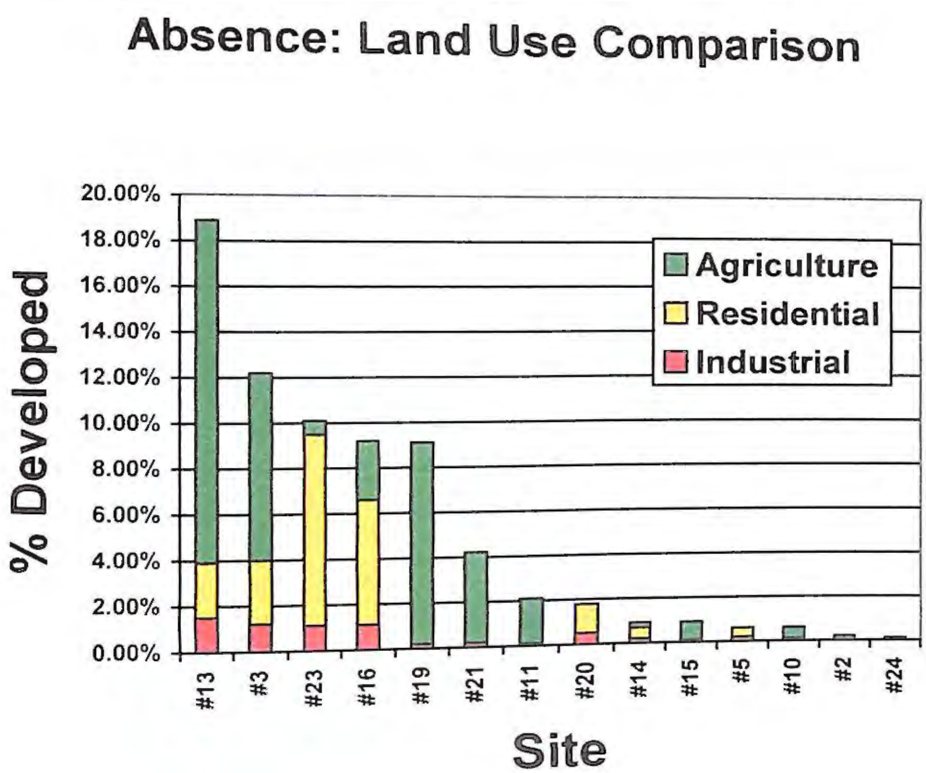


Figure 5

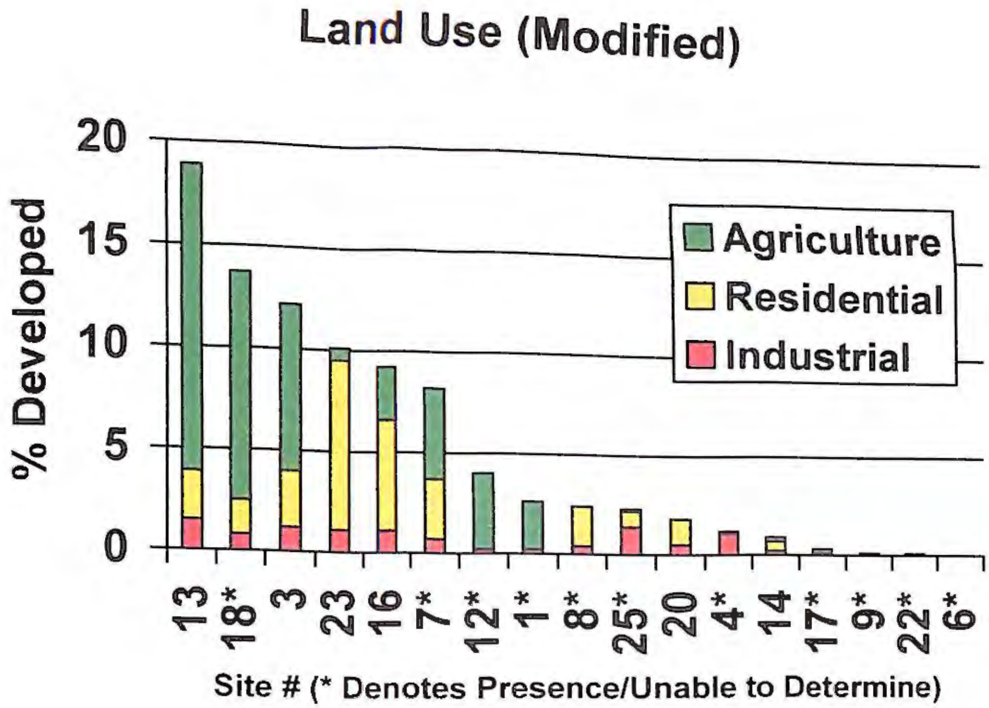


Figure 6

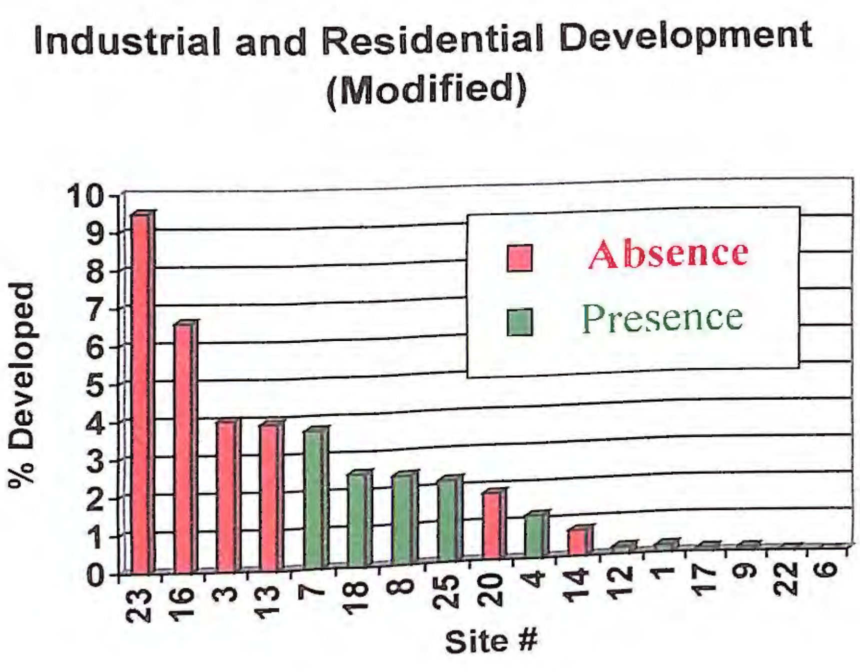


Figure 7 Survey Sites

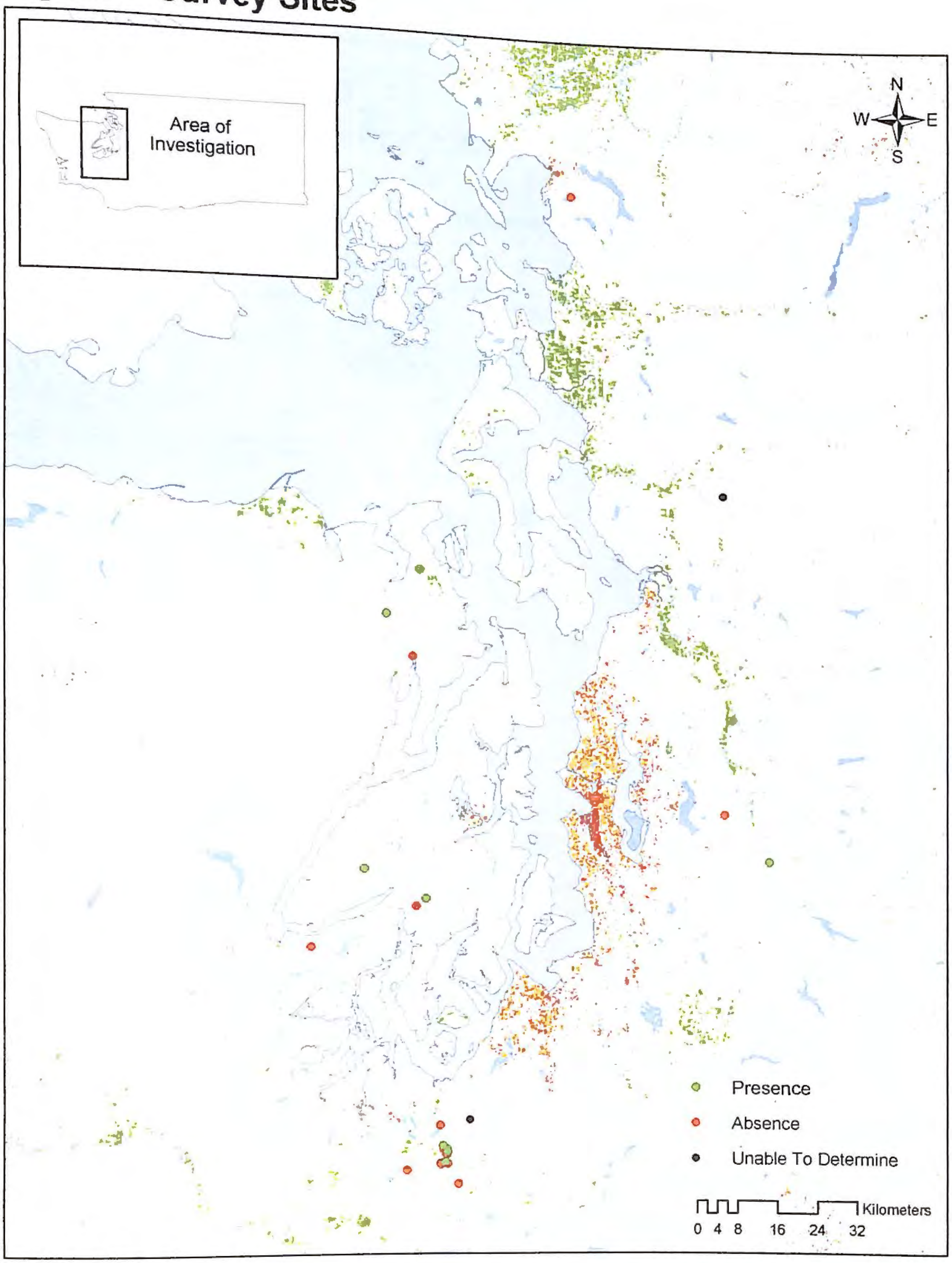


Figure 8

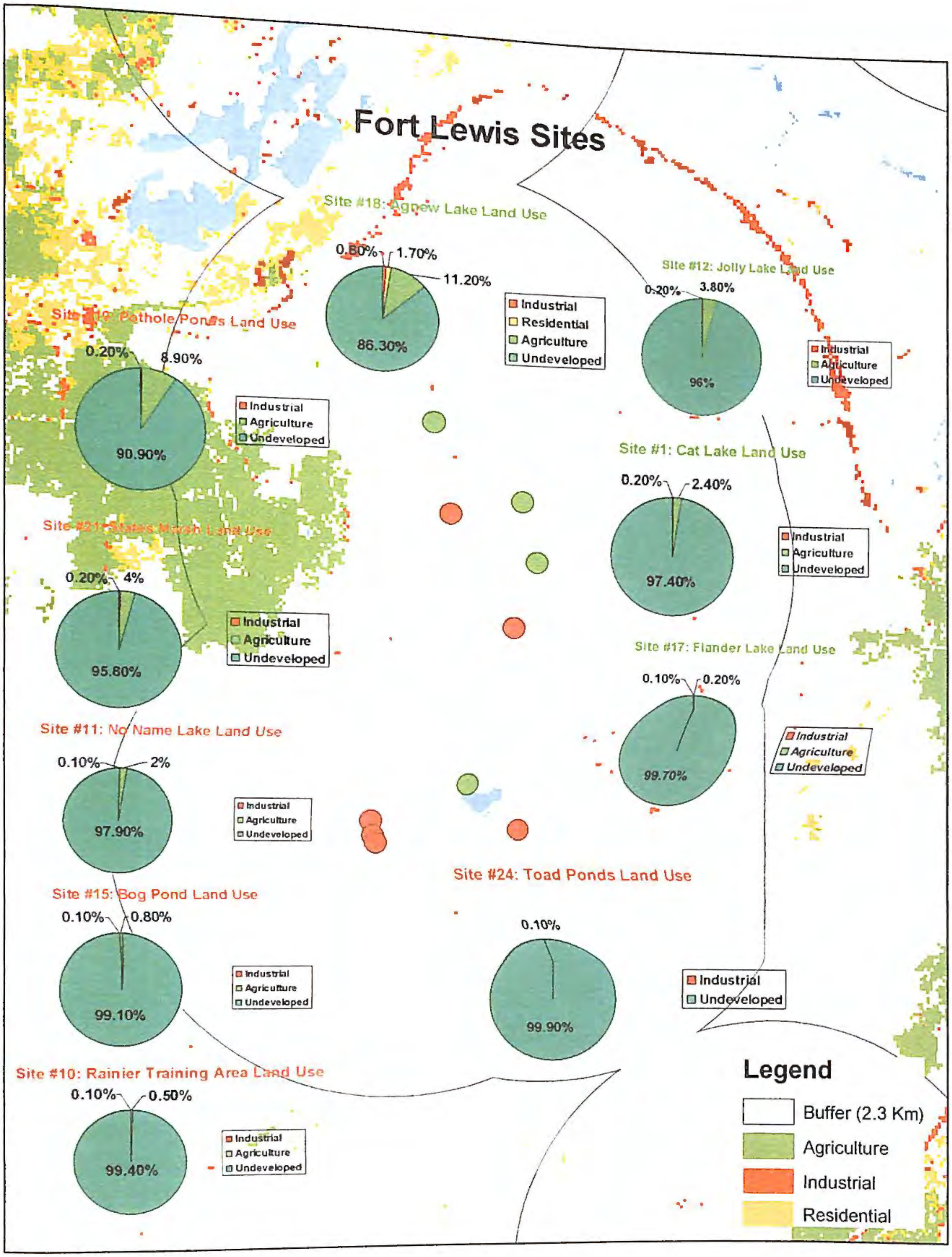
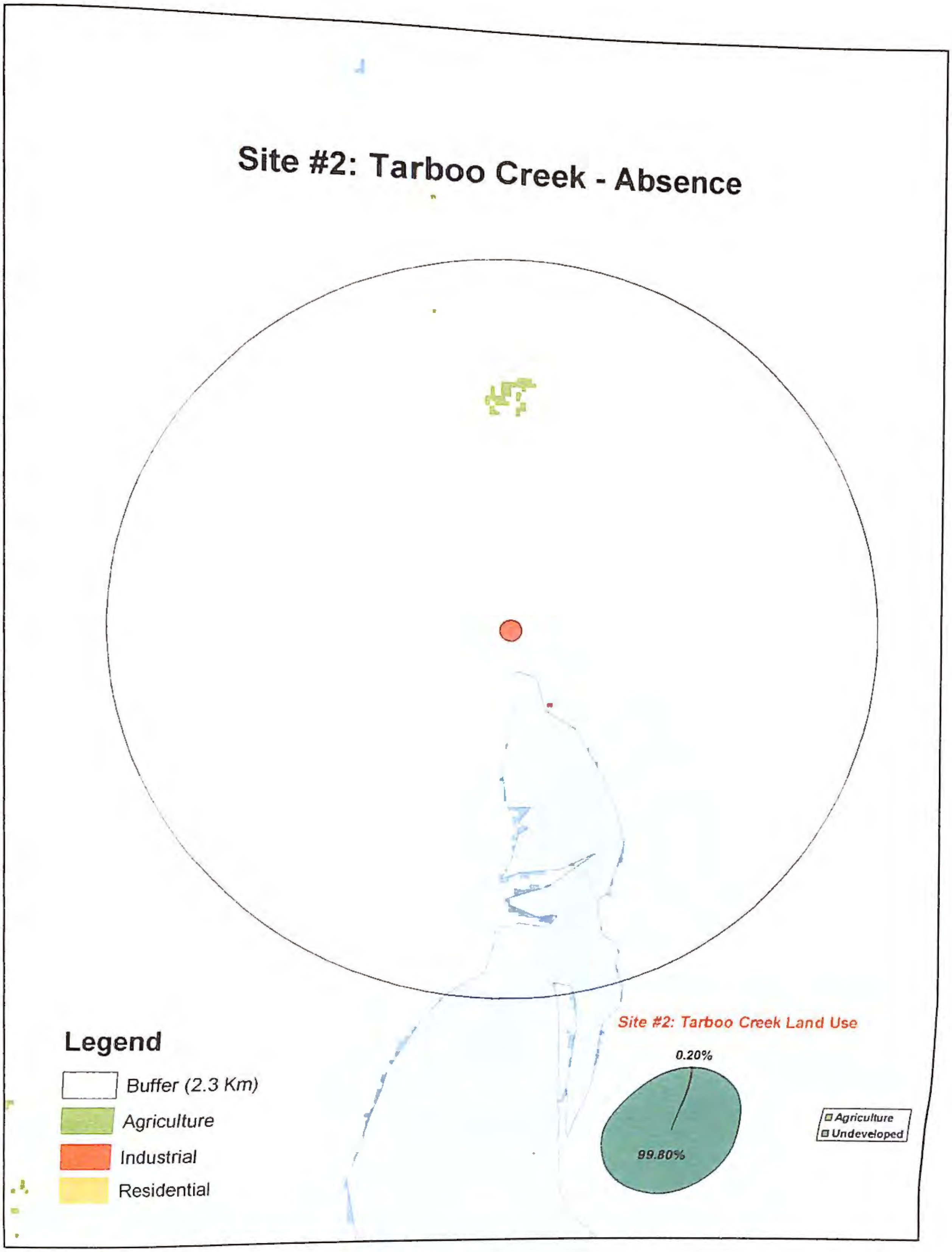
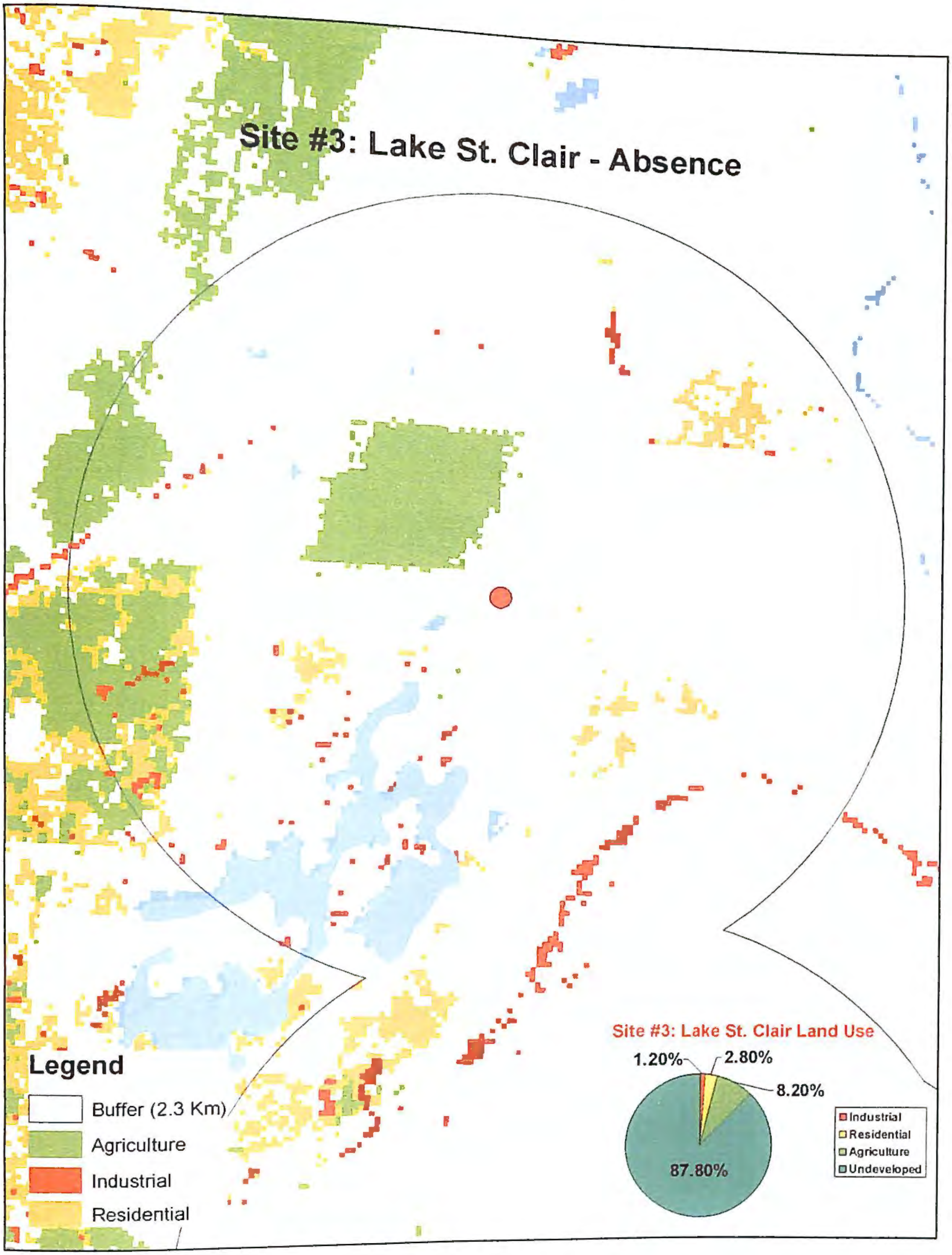

Fort Lewis Sites
Site #18: Agnew Lake Land Use
0.80%
1.70%
11.20%
86.30%
Industrial
Residential
Agriculture
Undeveloped
Site #12: Jolly Lake Land Use
0.20%
3.80%
96%
Industrial
Agriculture
Undeveloped
Potholes Ponds Land Use
0.20%
8.90%
90.90%
Industrial
Agriculture
Undeveloped
Site #1: Cat Lake Land Use
0.20%
2.40%
97.40%
Industrial
Agriculture
Undeveloped
0.20%
4%
95.80%
Industrial
Agriculture
Undeveloped
Site #17: Flander Lake Land Use
0.10%
0.20%
99.70%
Industrial
Agriculture
Undeveloped
Site #11: No Name Lake Land Use
0.10%
2%
97.90%
Industrial
Agriculture
Undeveloped
Site #24: Toad Ponds Land Use
Site #15: Bog Pond Land Use
0.10%
0.80%
99.10%
Industrial
Agriculture
Undeveloped
0.10%
99.90%
Industrial
Undeveloped
Site #10: Rainier Training Area Land Use
0.10%
0.50%
99.40%
Industrial
Agriculture
Undeveloped
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential

Figure 9



Site #2: Tarboo Creek - Absence
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential
Site #2: Tarboo Creek Land Use
0.20%
99.80%
Agriculture
Undeveloped

Figure 10



Site #3: Lake St. Clair - Absence
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential
Site #3: Lake St. Clair Land Use
1.20%
2.80%
8.20%
87.80%
Industrial
Residential
Agriculture
Undeveloped

Figure 11

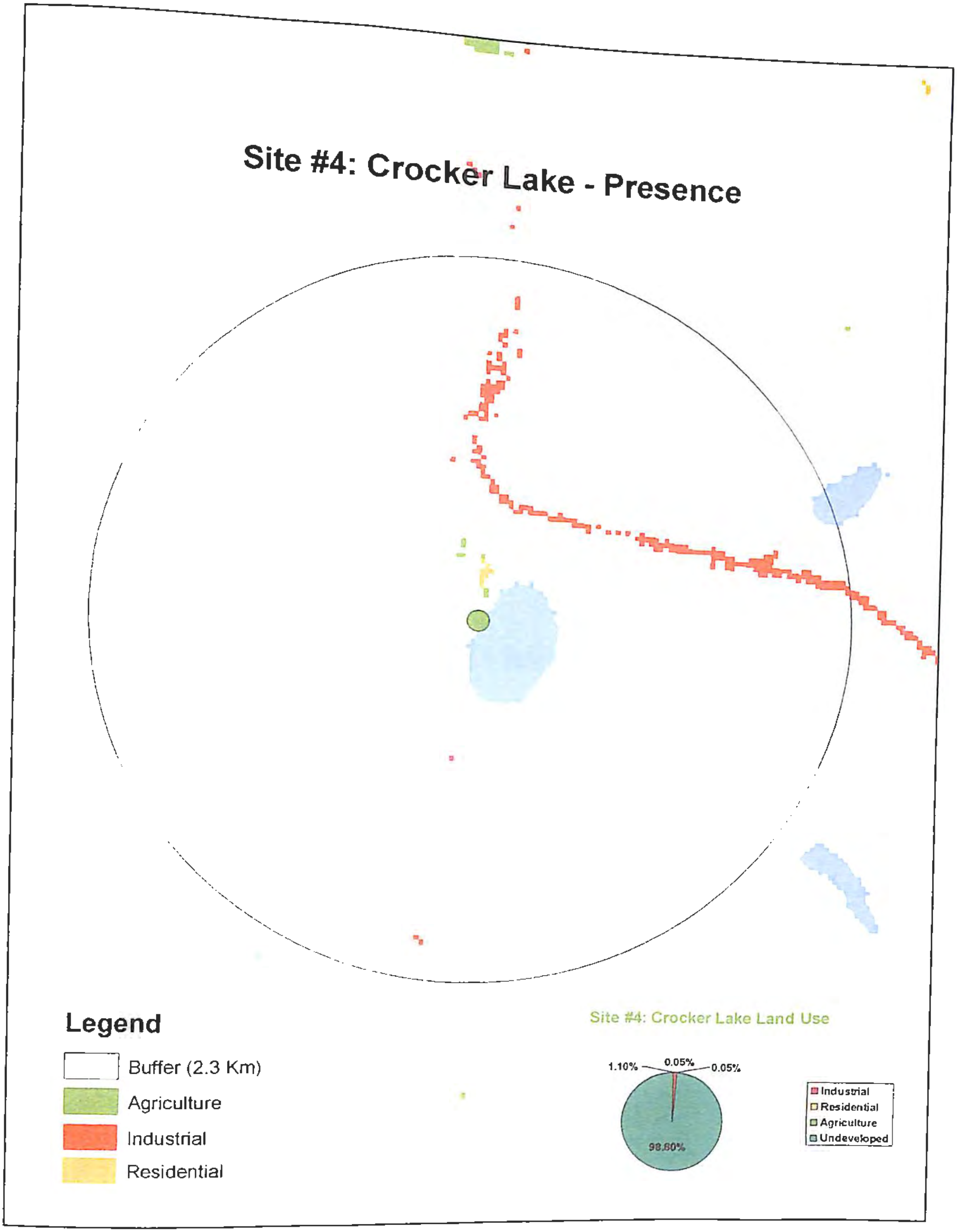

Site #4: Crocker Lake - Presence
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential
Site #4: Crocker Lake Land Use
1.10%
0.05%
0.05%
98.80%
Industrial
Residential
Agriculture
Undeveloped

Figure 12

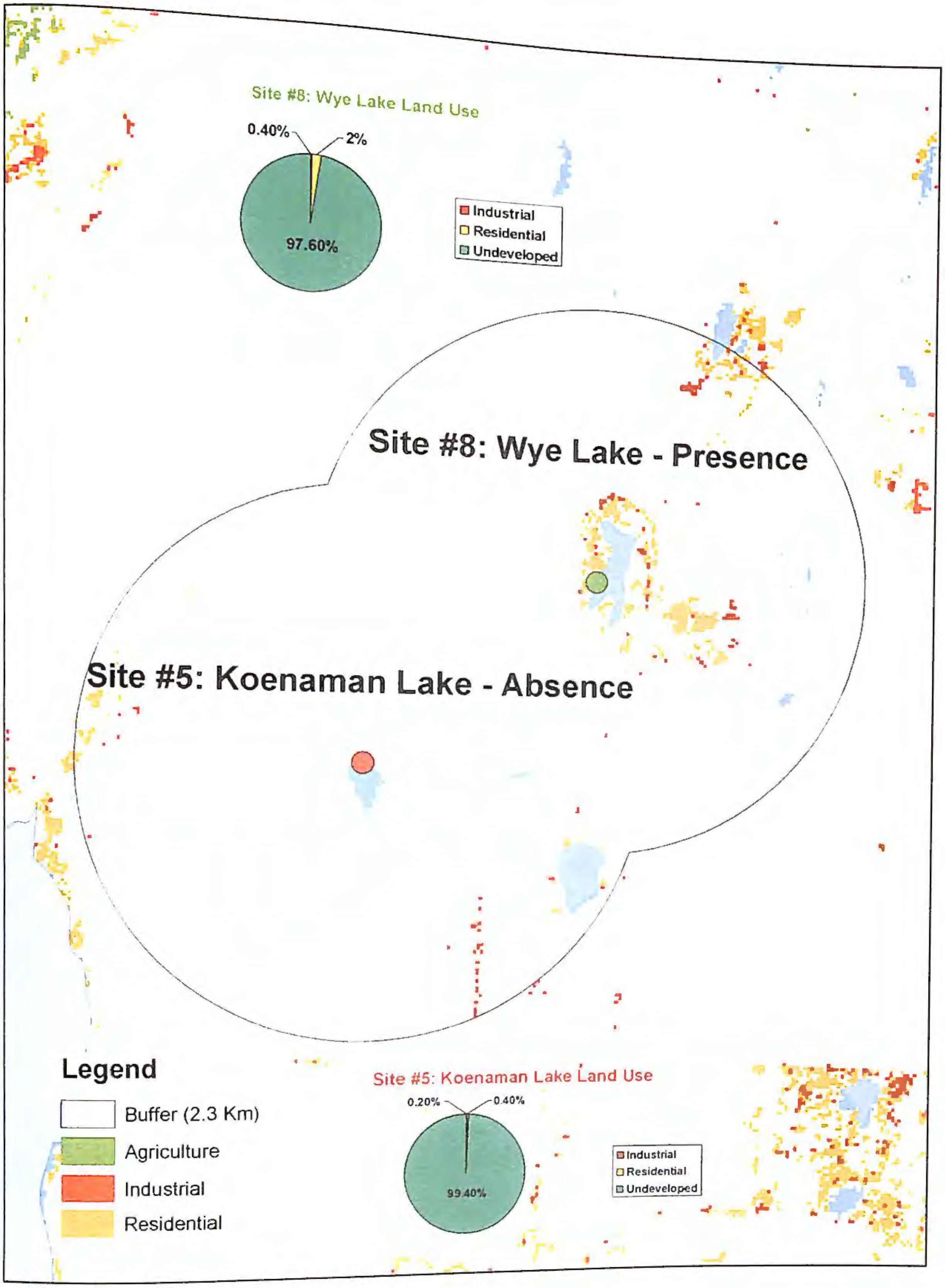

Site #8: Wye Lake Land Use
0.40%
2%
97.60%
Industrial
Residential
Undeveloped
Site #8: Wye Lake - Presence
Site #5: Koenaman Lake - Absence
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential
Site #5: Koenaman Lake Land Use
0.20%
0.40%
99.40%
Industrial
Residential
Undeveloped

Figure 13

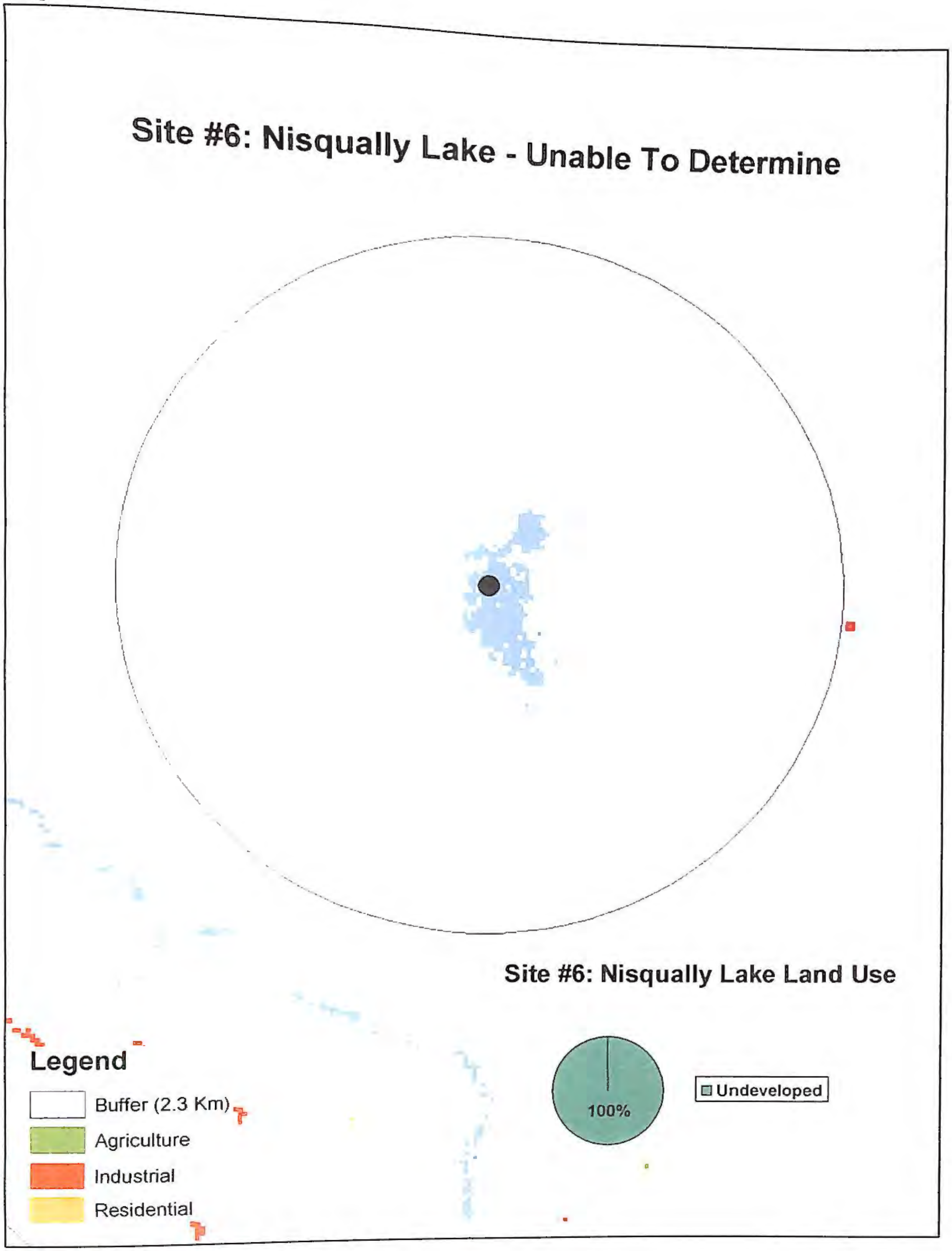
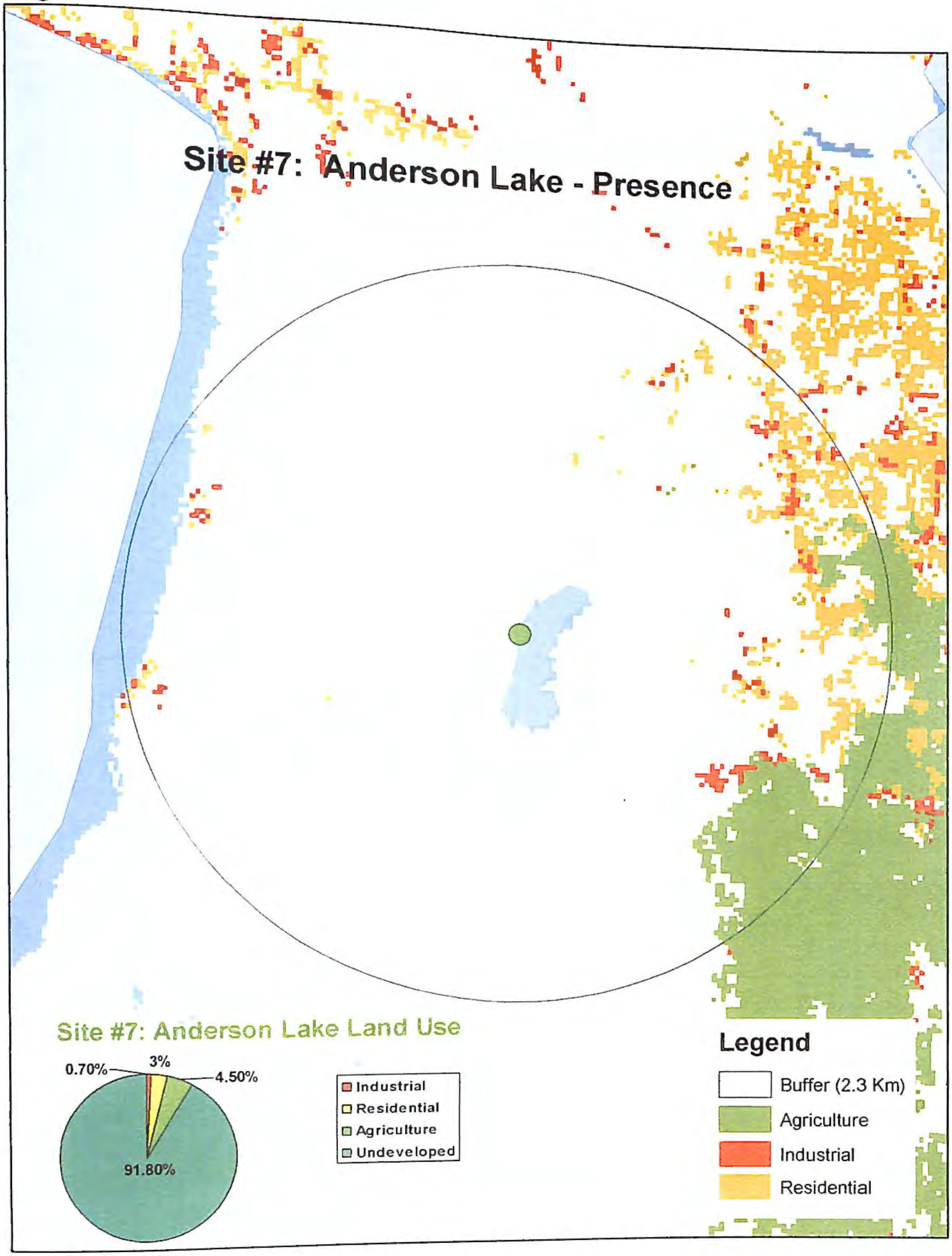
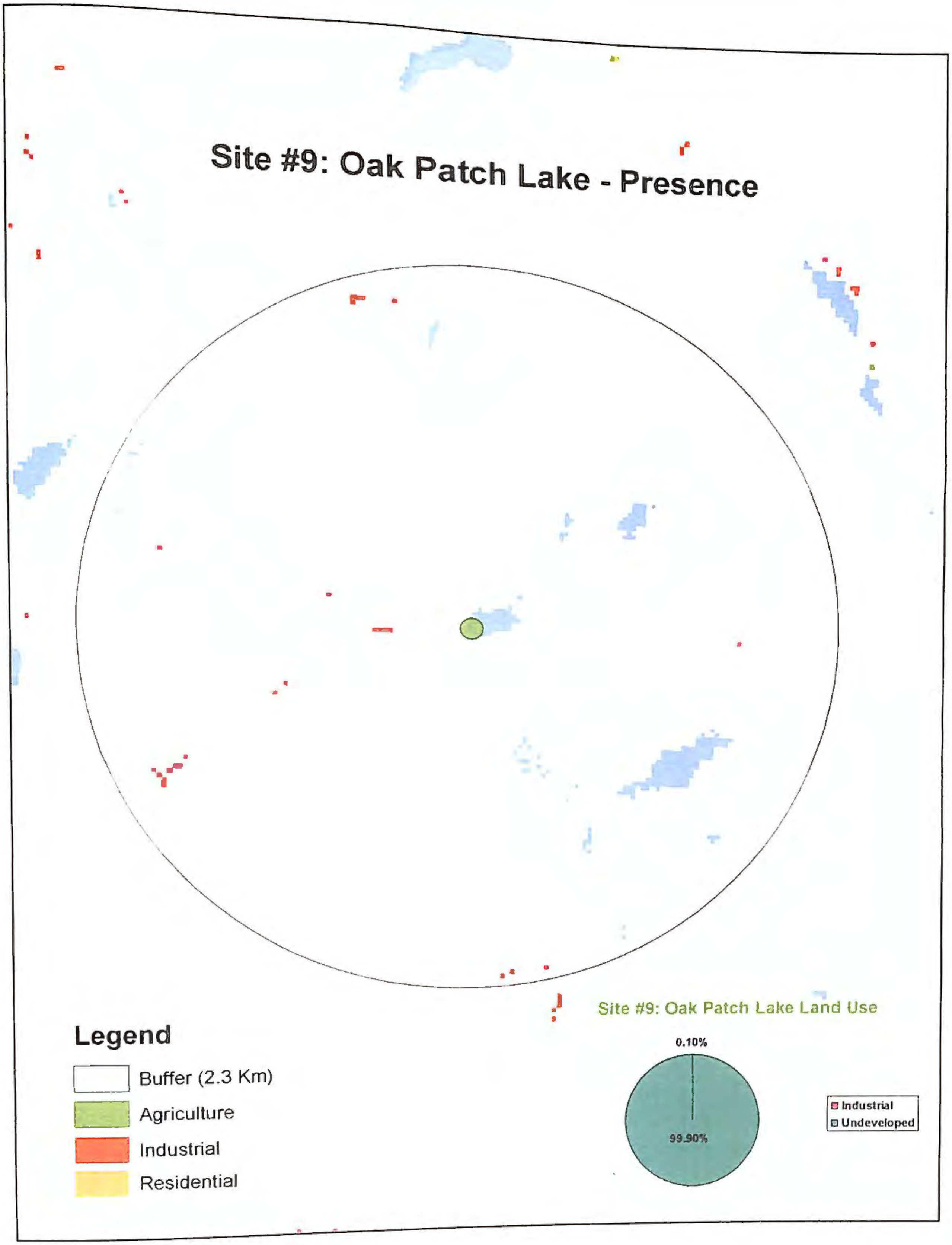

Site #6: Nisqually Lake - Unable To Determine
Site #6: Nisqually Lake Land Use
100%
Undeveloped
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential

Figure 14



Site #7: Anderson Lake - Presence
Site #7: Anderson Lake Land Use
0.70%
3%
4.50%
91.80%
Industrial
Residential
Agriculture
Undeveloped
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential

Figure 15



Site #9: Oak Patch Lake - Presence
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential
Site #9: Oak Patch Lake Land Use
0.10%
99.90%
Industrial
Undeveloped

Figure 16

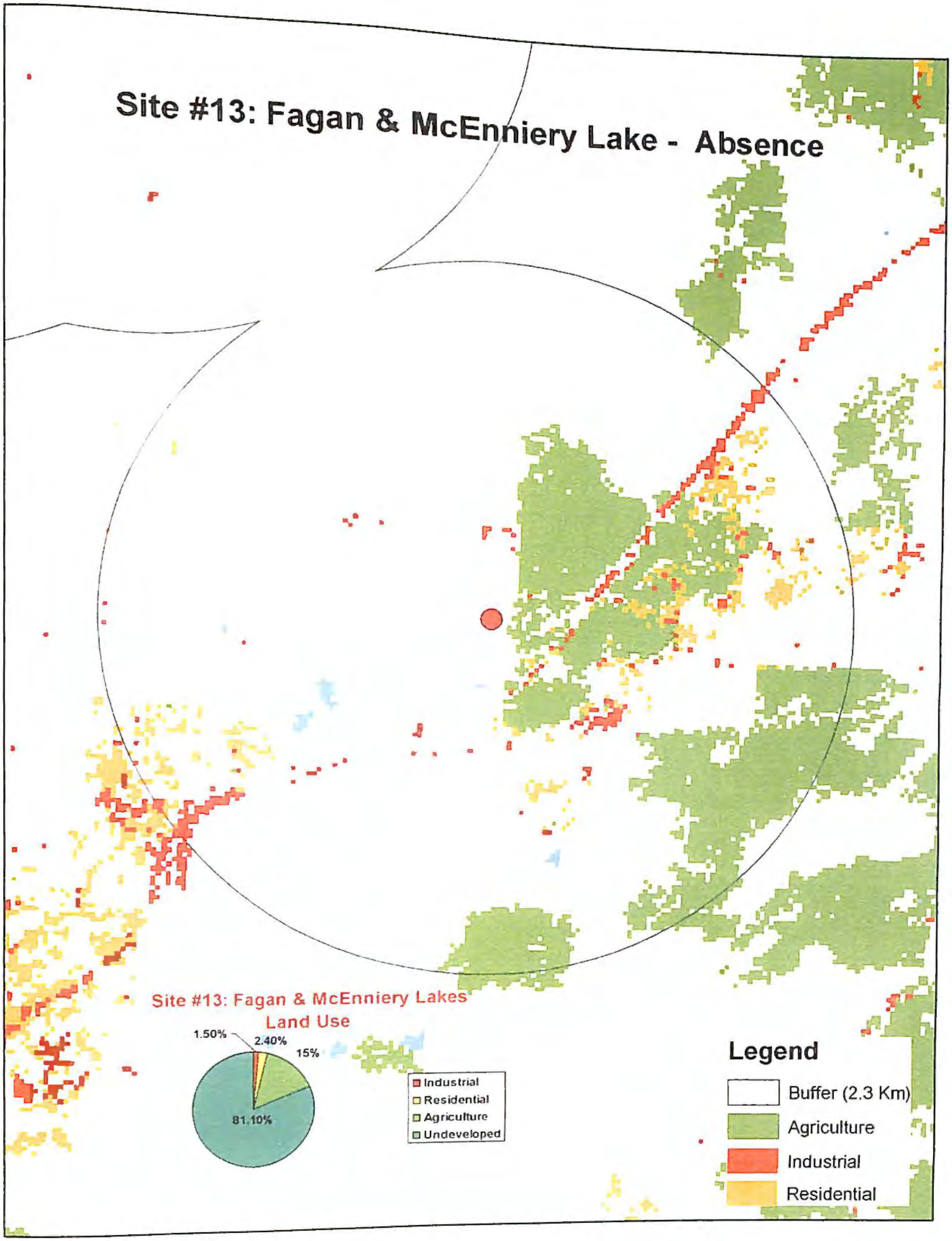
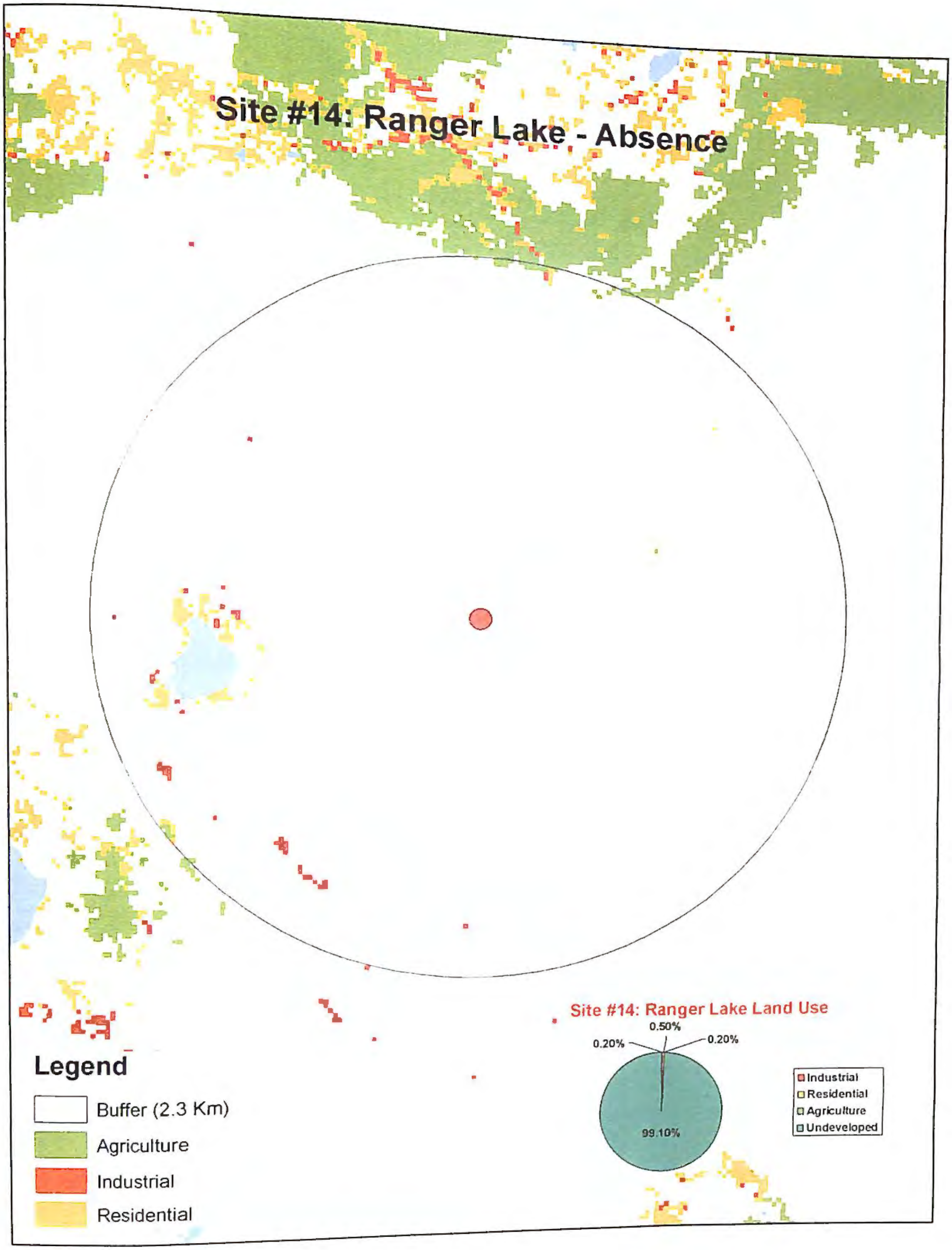
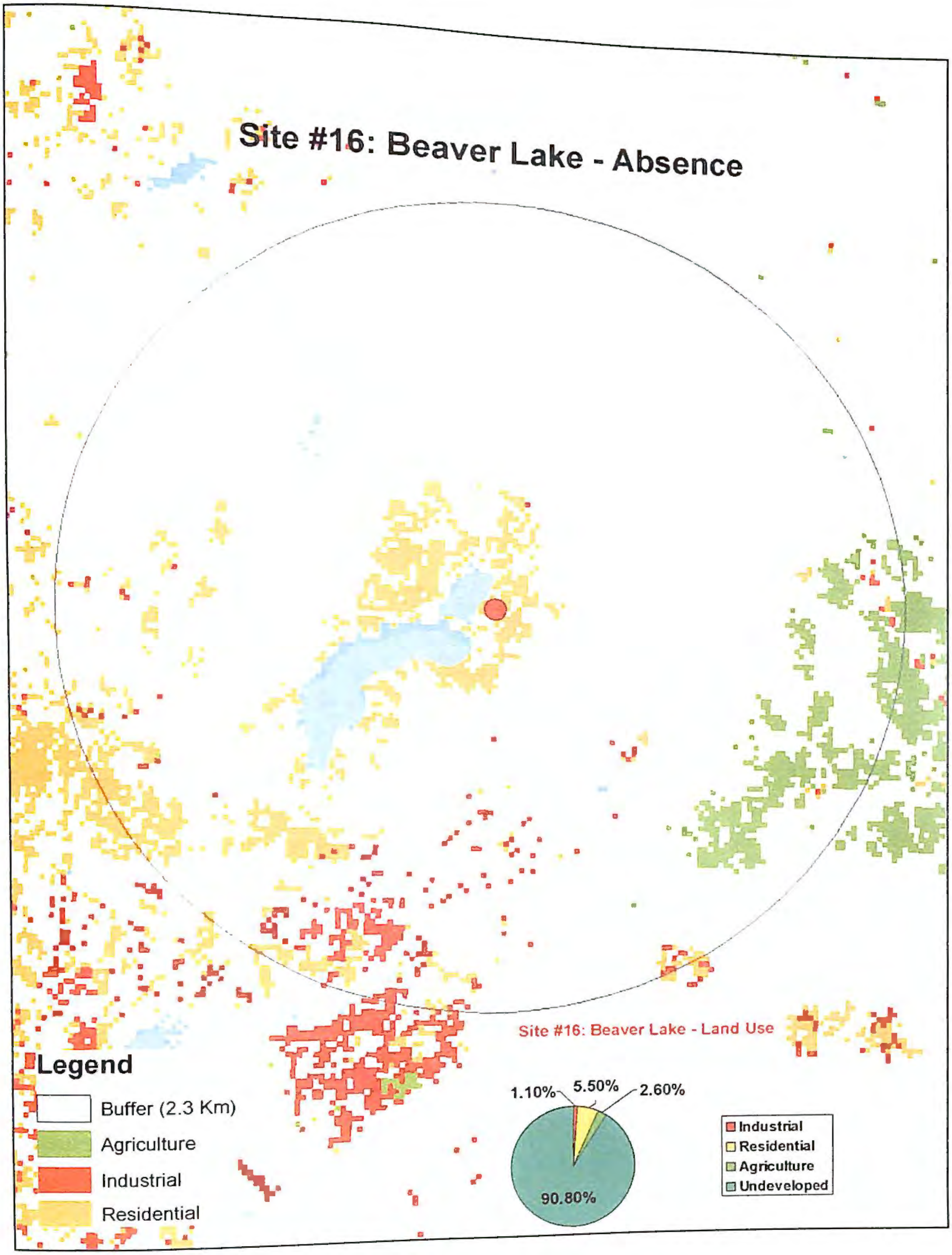

Site #13: Fagan & McEnniery Lake - Absence
Site #13: Fagan & McEnniery Lakes
Land Use
1.50%
2.40%
15%
81.10%
Industrial
Residential
Agriculture
Undeveloped
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential

Figure 17



Site #14: Ranger Lake - Absence
Site #14: Ranger Lake Land Use
0.50%
0.20%
0.20%
99.10%
Industrial
Residential
Agriculture
Undeveloped
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential

Figure 18



Site #16: Beaver Lake - Absence
Site #16: Beaver Lake - Land Use
1.10%
5.50%
2.60%
90.80%
Industrial
Residential
Agriculture
Undeveloped
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential

Figure 19

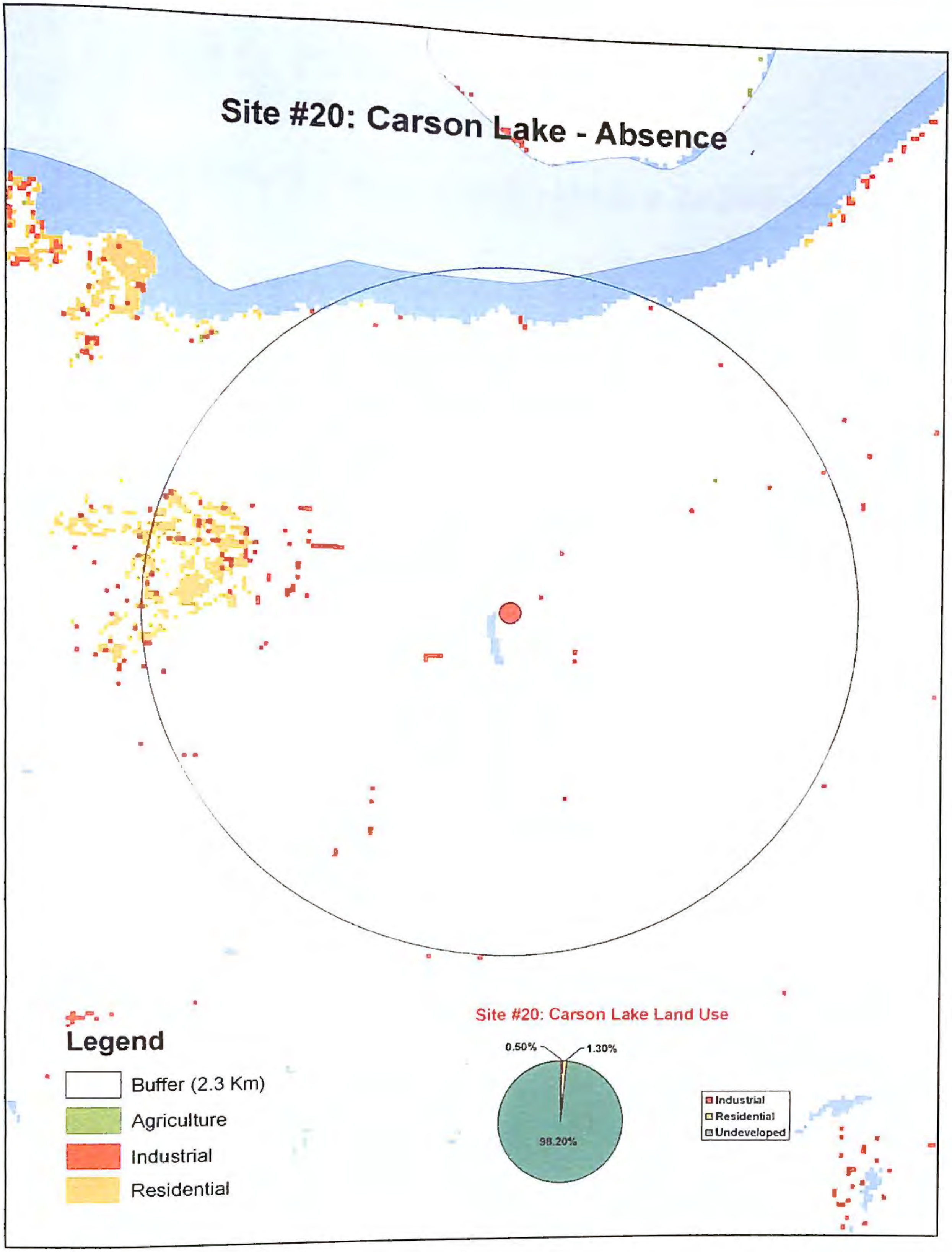

Site #20: Carson Lake - Absence
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential
Site #20: Carson Lake Land Use
0.50%
1.30%
98.20%
Industrial
Residential
Undeveloped

Figure 20

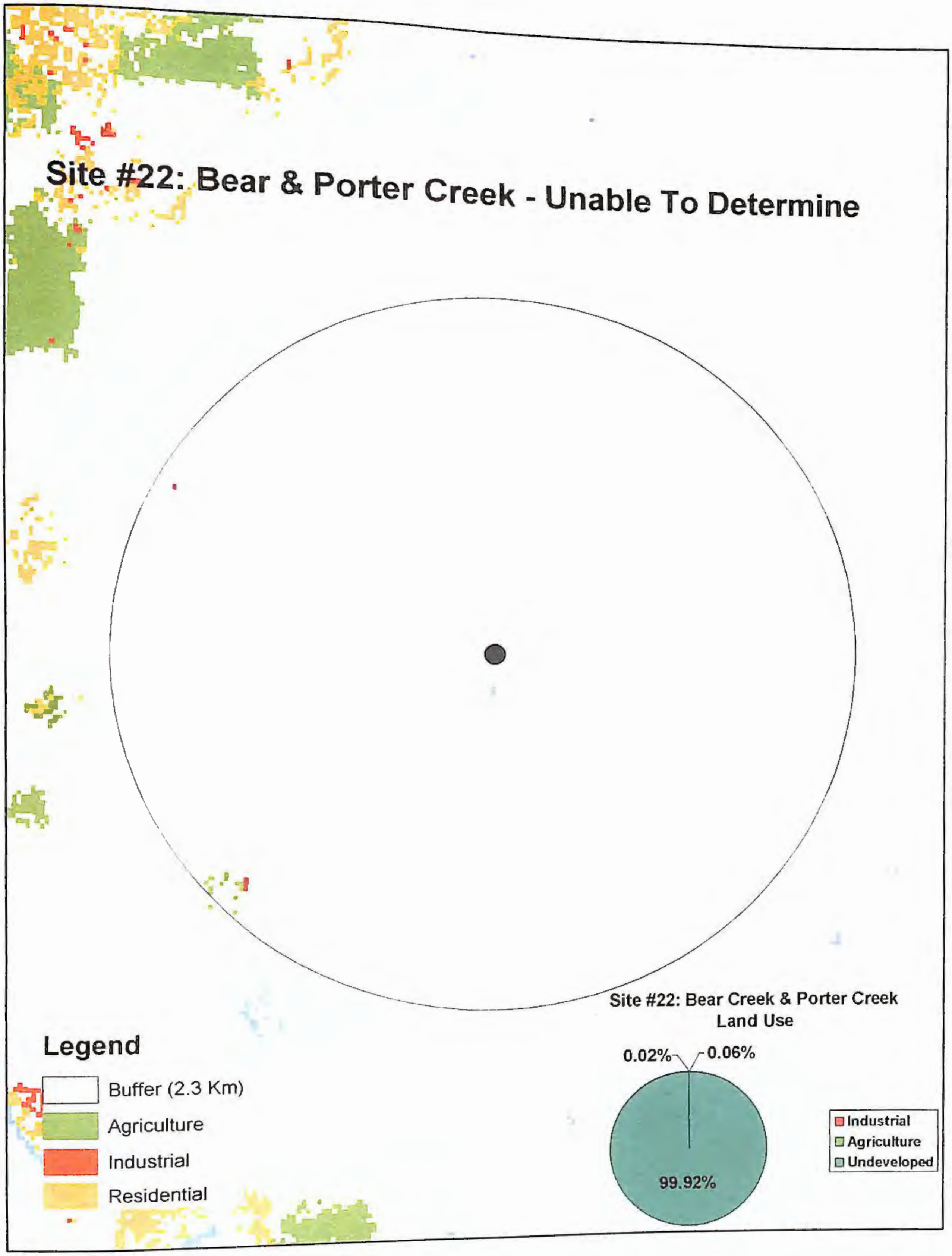

Site #22: Bear & Porter Creek - Unable To Determine
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential
Site #22: Bear Creek & Porter Creek
Land Use
0.02%
0.06%
99.92%
Industrial
Agriculture
Undeveloped

Figure 21

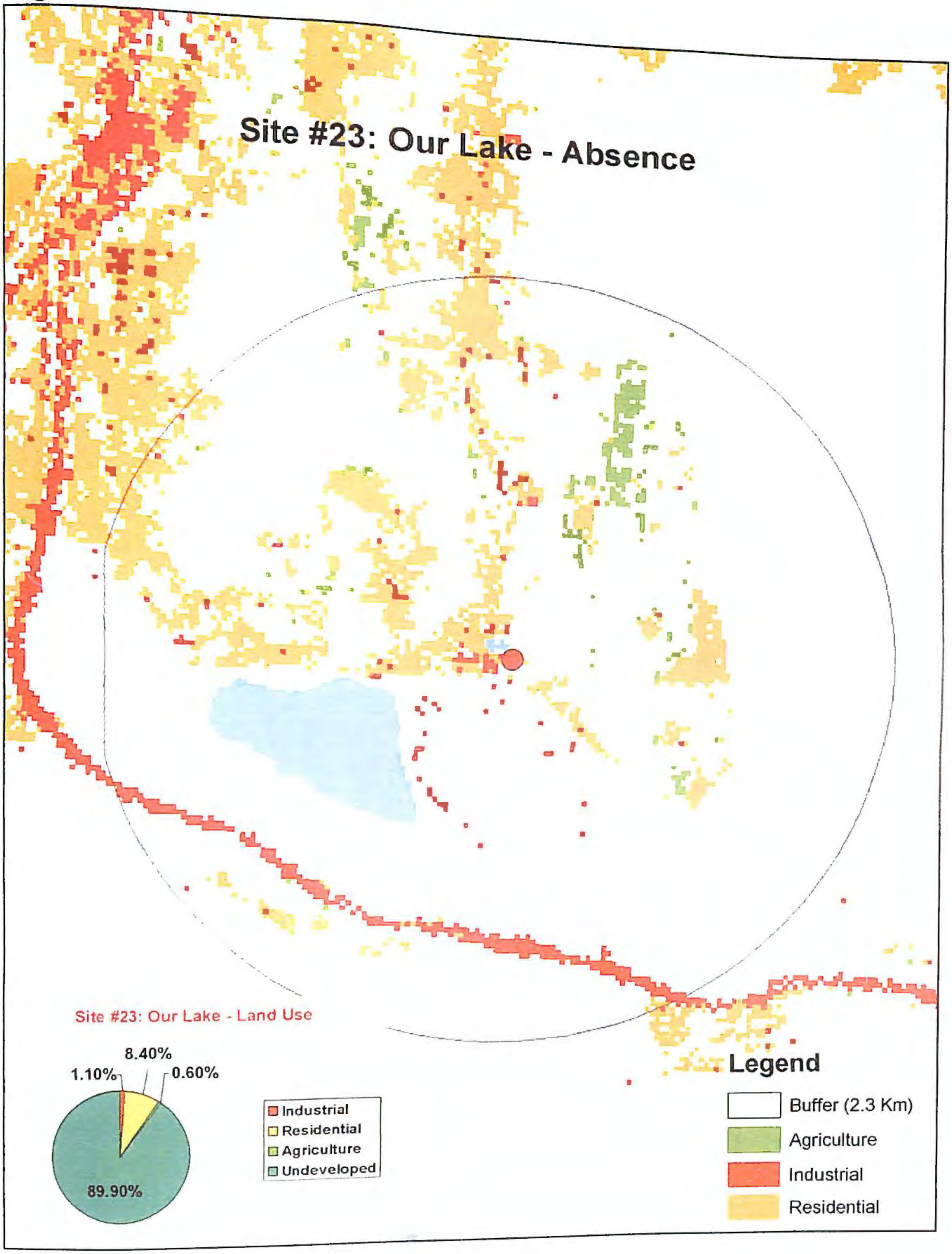
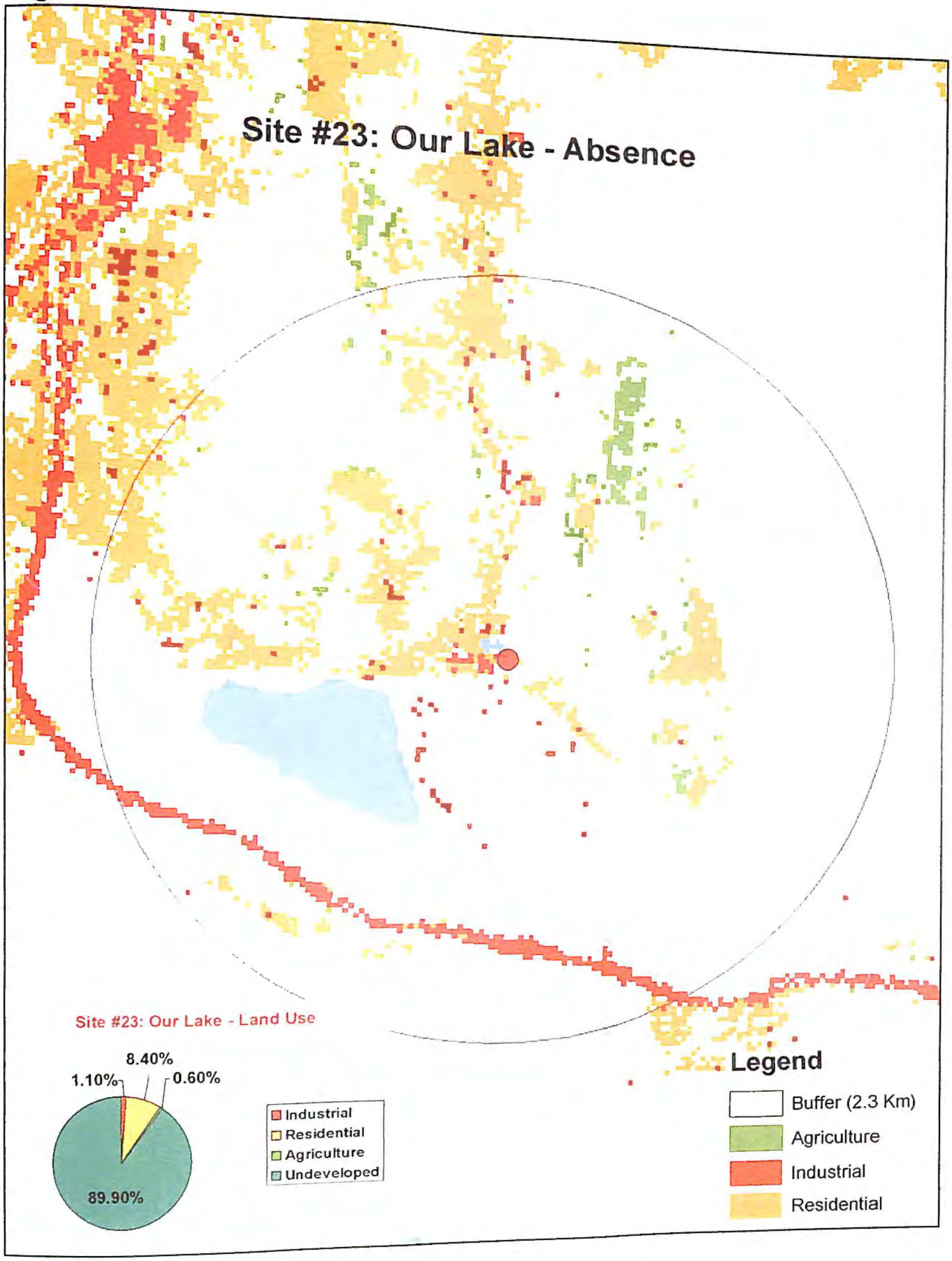
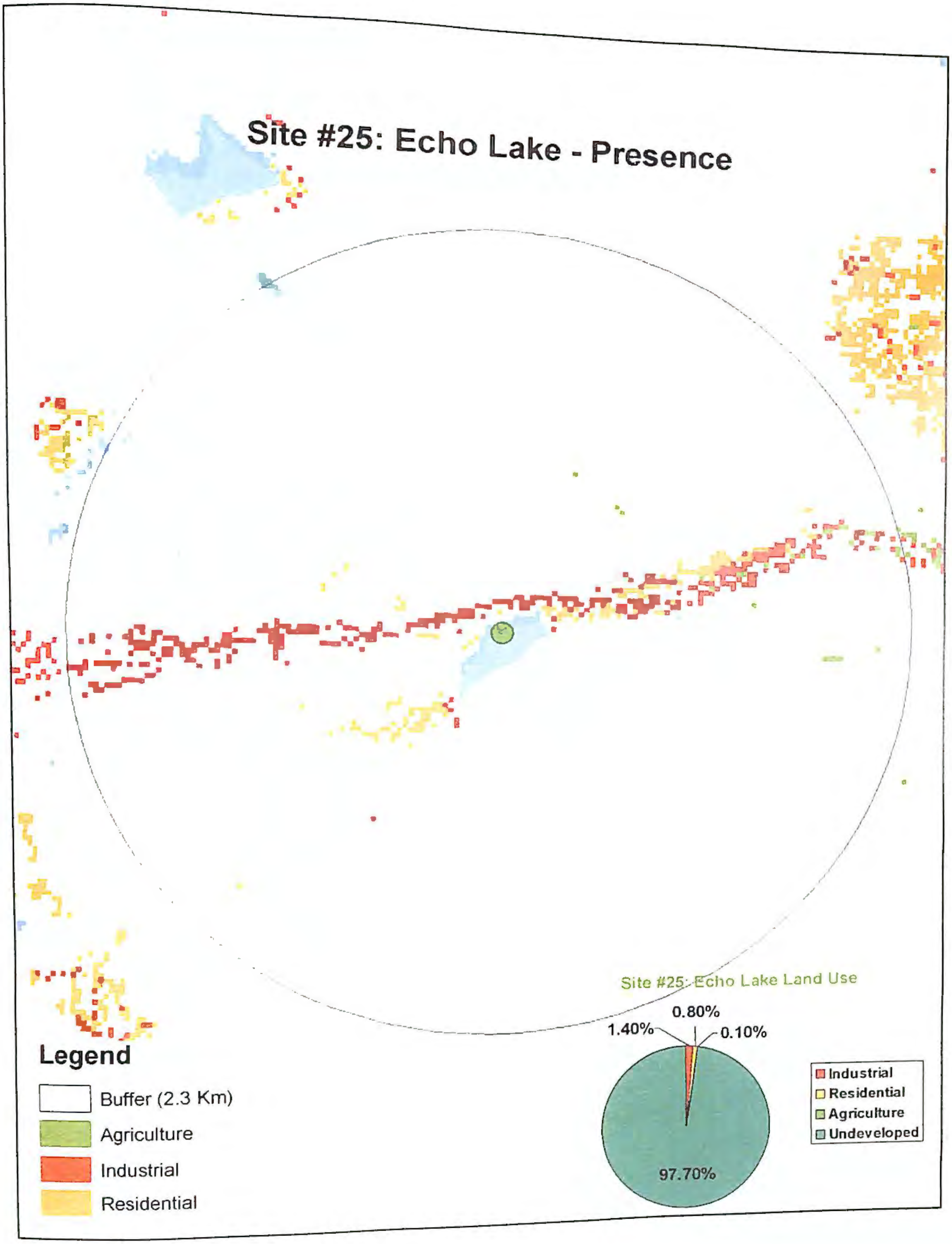

Site #23: Our Lake - Absence
Site #23: Our Lake - Land Use
8.40%
1.10%
0.60%
89.90%
Industrial
Residential
Agriculture
Undeveloped
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential

Figure 21



Site #23: Our Lake - Absence
Site #23: Our Lake - Land Use
8.40%
1.10%
0.60%
89.90%
Industrial
Residential
Agriculture
Undeveloped
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential

Figure 22



Site #25: Echo Lake - Presence
Legend
Buffer (2.3 Km)
Agriculture
Industrial
Residential
Site #25: Echo Lake Land Use
0.80%
1.40%
0.10%
97.70%
Industrial
Residential
Agriculture
Undeveloped