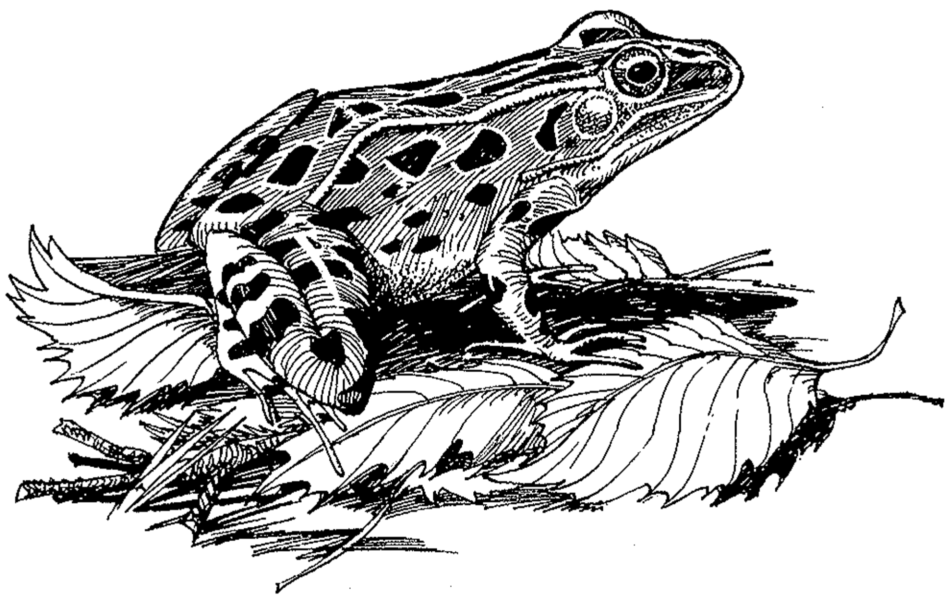
Fisheries & Wildlife Management Division

RESOURCE STATUS AND ASSESSMENT BRANCH

Investigation of Northern Leopard Frog (*Rana pipiens*) Overwintering Ecological Requirements

Kris Kendell



April 2000

Alberta Conservation Association

Alberta ENVIRONMENTAL PROTECTION

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ENVIRONMENT

North American Waterfowl Management Plan
Plan nord-américain de gestion de la sauvagine
Plan de Manejo de Aves Acuáticas de Norteamérica

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ALBERTA SPORT, RECREATION PARKS & WILDLIFE FOUNDATION
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INTRODUCTION

In the province of Alberta, the Northern Leopard Frog (*Rana pipiens*) is designated as a Threatened Species (Wildlife Act, Alberta Environmental Protection, 1996). As a result, the Northern Leopard Frog merits special management consideration regarding existing populations as well as the habitats in which they occur. Once a common and widespread species throughout much of Canada, leopard frog populations vanished or declined from much of their historic western range.

In the spring of 1998 a management project was proposed to repatriate the Northern Leopard Frog (*Rana pipiens*) into currently vacant areas of its historic range. The primary objective of the project was to establish breeding populations of Northern Leopard Frogs in formally occupied habitats in the headwaters of the upper Red Deer and North Saskatchewan River drainage basins.

Data collected in this study will help to improve the understanding of the key habitat elements that are necessary to the survival and growth of leopard frog populations. In particular, essential winter habitat and water quality parameters. Over time, this information can be integrated with known breeding and summering habitat requirements to establish an 'ideal' habitat suitability prescription for the Northern Leopard Frog in Alberta. This information will help ensure that potential negative impacts related to changes in water management are avoided, and to allow current and future NAWMP projects to be designed and managed to include optimum benefits for this threatened species.

STUDY AREA

Nine study areas were selected in southern Alberta to collect a variety of ecological data on aquatic conditions necessary for leopard frog hibernation (Figure 1). All study areas were within the historic range of the leopard frog and contained one or more wetland sites. Study areas reflected three types of population status; extirpated, occupied, or absent – but could potentially support leopard frog populations. When possible sites affiliated with NAWMP managed wetlands were selected (Table 1). Two ecologically significant sites, (spring fed wetland complexes) were also represented. The following study areas fell within a 40 km radius of

Brooks, Alberta: Circle E Ranch, Bow City Ponds, Medicine Wheel, Scandia, Kinninvie, Kitsim, and Lake Newell. The Prince's Spring and Jenner Springs study areas were approximately 70 km and 110 km northeast of Brooks, respectively (see Appendix A for detailed location information on each individual study area).

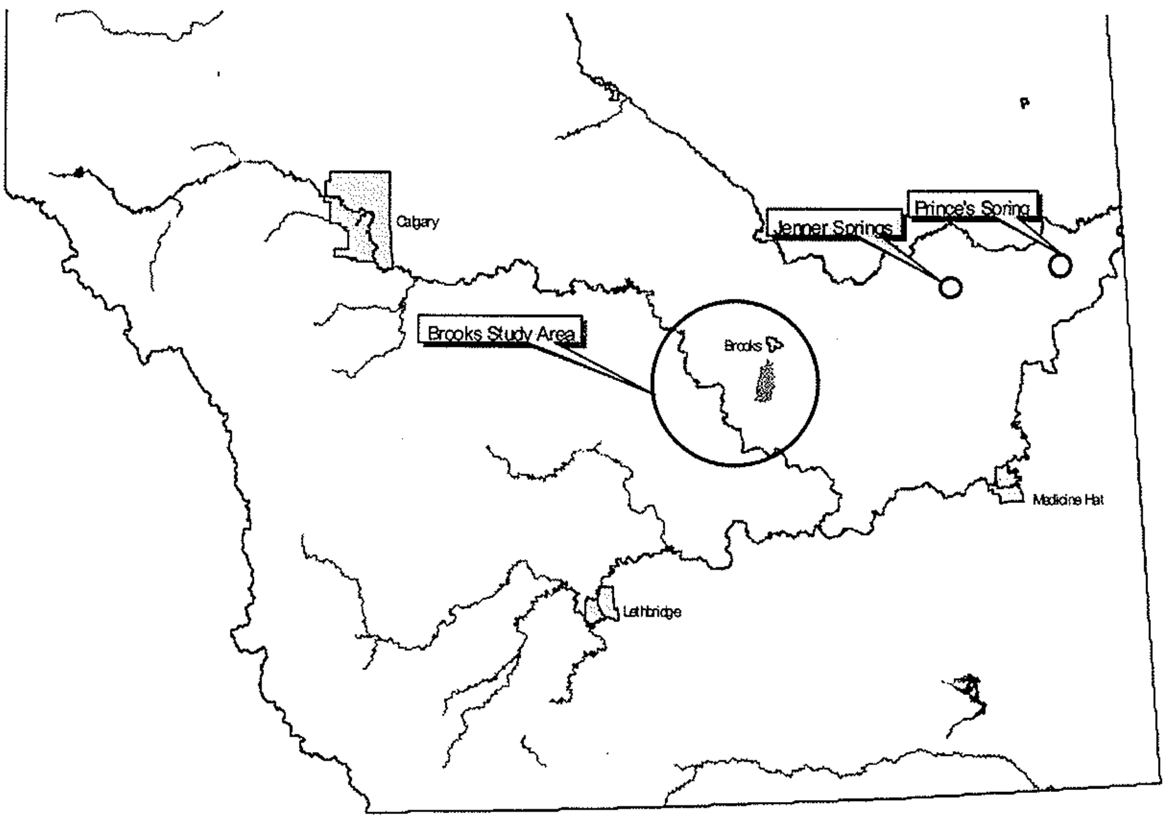

Figure 1 Map of southern Alberta (south of 52° Latitude) showing the three primary study areas from which water quality data was measured and recorded in February and March 2000.

METHODS

Study sites were chosen based on personal communications with area Alberta Environment biologists, local Ducks Unlimited biologists, and investigation of current and historic leopard frog occurrences within the study area using the Biodiversity / Species Observation Database. According to information acquired for each site, it was expected that the waterbodies surveyed were permanent. In all study sites, specific data gathering locations were determined upon initial survey. Suspected locations with the deepest water depth at each site were chosen as the preferred sites to sample. Deep-water was determined by vegetation type or lack of vegetation, distance from shore, physical inspection by drilling ice-auger holes, and proximity to the upstream side of dams and water control structures. Water bodies believed to be temporary or shallow enough to freeze to the bottom were not considered for sampling. Due to access problems associated with deep snow or sensitive terrain, some waterbodies capable of supporting over-wintering leopard frogs, were not surveyed. Study areas and sites sampled by Fisher 1999 were revisited in order to gain long-term comparable data (Table 1 and Appendix B).

Table 1 Study areas selected in southern Alberta; see Appendix A for area maps and Appendix D for site specific maps.

Study Area	Population Status**	DU/NAWMP Managed	ATS Location (W4M)	
			Tp	Rg
Jenner Springs†*	Occupied	No	21	7
Prince's Spring†*	Occupied	Yes	21	3
Circle 'E' Ranch*	Occupied	Yes	15,16,17	16,17,18
Bow City Ponds*	Occupied	No	17	17
Medicine Wheel	Absent	Yes	17,18	17,18
Scandia	Observed	Yes	15,16	16
Kinninvie	Absent?	Yes	15,16	11,12
Kitsim	Absent?	Yes	17	16
Lake Newell	Extirpated	No	16	15

(†) Ecologically unique sites (springs).
(*) Sites previously surveyed by Fisher (1999).
(**) Status determined by personal communication with D. Watson, T. Sadler, K. Kaczanowski, E. Hoffman, R. Russel, S. Brechtel and records held in the Biodiversity / Species Observation Database (BSOD).

Dissolved oxygen (D.O.), water temperature, pH, ice thickness, water depth, snow cover, substrate description, water flow were measured and recorded at each study area. The presence or absence of aquatic invertebrates and fish (both alive and dead) was noted whenever they were readily observed in the ice-auger hole or frozen in the ice. Detailed assessment on numbers and species of aquatic invertebrates and fish was not conducted during the course of this study. The familiar odour of decomposition, often associated with anoxic under ice conditions, was also noted when evident.

All data was collected during two trips in order to identify late winter and early spring water quality. Mid February and the end of March were chosen as the premium periods to sample water quality as it related to over-wintering leopard frog requirements. These periods best represented critical under ice conditions, when ice thickness may be at its greatest (late winter) and water quality may be at the minimum (early spring). Two survey trips were necessary in order to ensure sufficient data was collected at each site representing the "poorest" under-ice water quality conditions. This allowed the researcher to accurately assess the given waterbody as a possible hibernation site for leopard frogs. This assessment was based on critical D.O. and temperature levels cited in literature searched. Because of time constraints during each visit, a second visit to each study area allowed the researcher resample previous sites as well as to apply knowledge and insight gained from the first visit to select new sample locations at each site. Data from the first trip was collected between 15 February and 18 February 2000 and data from the second trip was collected between 22 March and 24 March 2000. The number of sample locations in each study area was determined during the initial survey and varied depending on complexity and size of the site, access to individual wetland sites, ecological characteristics of each wetland and ice conditions.

A total of 51 water quality parameter tests were conducted on the 2 field trips to southern Alberta, representing 42 separate locations, on 20 different waterbodies in 9 study areas (Appendix B and Appendix D). Of the 18 study areas surveyed during the 2 trips, 3 sites could not be surveyed. Prince's Spring and Jenner Springs were not surveyed on the February trip and Lake Newell was not surveyed on the March trip. The omission of these sites was primarily the result of access problems caused by deep snow and later mud, in concert with time restrictions. Sites identified as having poor water quality, relating to over-wintering leopard frog requirements, were omitted in favour of new sites on the second survey trip. Jenner Springs, Prince's Spring, Circle 'E' Ranch and Bow City Ponds, sampled by Fisher (1999) during winter field studies, were revisited to achieve data over consecutive years (Appendix B).

A handheld dissolved oxygen and temperature system (YSI model 55) was used to measure and record dissolved oxygen and water temperature. The system displayed temperature in °C and dissolved oxygen in either mg/l (ppm) or % air saturation. The system is reliable to a temperature accuracy of +/- 0.2 °C with a resolution of 0.1 °C. Dissolved oxygen % saturation accuracy and resolution (in %) is identical to that of temperature, however dissolved oxygen mg/l accuracy and resolution is +/- 0.3 mg/l and 0.01 mg/l respectfully. Whenever possible, the sensory probe was positioned just above the substrate and the probe membrane and thermometer were kept free of debris and sediment. In water bodies exceeding the probes cord length in depth, the probe was suspended as deep as possible. Litmus paper (pHydrion Brilliant 0-13 Cat. #213) was used to test pH and air temperature was measured using a simple scientific dry bulb thermometer. Ice and water depths were measured with a tape measure and long ruler.

RESULTS

Pertinent quantitative and qualitative information gathered at each of the 9 individual study areas is highlighted below. Detailed line drawings for each of the 9 study areas, and associated water quality sample locations, can be found in Appendix D. Water quality data, including ice thickness and under ice water depth, collected in each study area and at all the sample locations during the 2 survey trips is referenced in Appendix B. A summary of significant maximum and minimum data recorded during the survey periods is listed in Appendix C.

1. Jenner Springs

Jenner Springs was surveyed on 22 March 2000. Water quality parameters were measured at two relatively deep burrow pits located to the north and northeast of the first catch basin of the spring. The burrow pits were named south and north based on their relative position with the first catch basin. A number of apparent seeps or springs were also investigated in the meadow north of the first catch basin and south of the north burrow pit (map 1, Appendix D). The majority of these appeared to be shallow (less than 30 cm) in water depth and were for the most part still covered with ice. Some seep activity also appeared at the north end of the south burrow pit; apparently originating form the hillside and draining into the south burrow pit. A relatively large ice field also existed to the east of the west burrow pit. No localized area was identified as the springhead, however flowing water was tracked to a cattail area just south of the north burrow pit. Moderate to slightly detectable water flow was observed over much of the suspected spring area. The two large catch basins to the south and southeast were nearly ice-free and were not sampled due to extensive thawing that may prevent accurate under-ice water quality measurements. D.O. levels recorded in the two burrow pits were found to be less than 0.5 ppm during the two visits in 2000. In 1999, Fisher recorded a D.O. level less 1 ppm in the south burrow pit and just above 1.1 ppm in the wetland area near the two burrow pits (Appendix B).

2. Prince's Spring

Prince's Spring was surveyed on 22 March 2000 and water quality parameters were measured at 7 different locations (map 2, Appendix D). The first measurement was taken from a seep in the immediate vicinity of the origin of the spring. With a D.O. level of 0.18 ppm at this location, it was found to be the lowest value obtained in the entire study site. Conversely the spring-head had the warmest water temperature of the entire study site of 6.5°C. It was impossible to determine the source of every discharge spring outlet, as some may have been present under the thick grass and sedge vegetation in the area or underwater in the cattail marsh. The ground in the area of the first measurement quaked and trembled when walked on, and had numerous localized areas from which water seeped. Many of the smaller spring sources (seeps) were similar in appearance to a small crater and varied in diameter and shape from nearly round to irregular. The smallest seeps were between 30-40 cm in diameter and about 15 cm in water depth. These seeps frequently contained mineral like deposits. Larger areas of spring water seepage also occurred in the area, undoubtedly spanning several meters in diameter with ill-defined perimeters, sources and water depth. Additional water quality measurements were also obtained from a nearby dugout that appeared to be runoff filled, at culvert locations, in cattail marsh and the first catch basin – the second catch basin (sedge meadow) was dry. Although a variety of aquatic invertebrates were observed including water boatmen, scuds and damselfly larva, no hibernating leopard frogs were observed. Seeping water with a moderate flow was present throughout much of the area with flow increasing substantially at the locations of the culverts. At these locations D.O. levels were the highest reaching values of about 10 ppm at culvert 1 and 13 ppm at culvert 2. While D.O. levels were similar, water temperature measured at the same two culvert locations had a greater variation. Water temperatures at the two culverts were 4.6°C and 1.2°C for culvert 1 and culvert 2, respectively. Water flow was exclusively the result of spring activity.

3. Circle E Ranch

Circle E Ranch was surveyed on 15 February and 23 March. 2000. A total of 6 locations were surveyed in this study area along Drainage K and Lonesome Lake (map 3, Appendix D). On the February trip, Drainage K was frozen solid at the south end of Lonesome Lake at its origin. Approximately 10 km from Lonesome Lake, downstream along Drainage K, water with a depth of 9 cm was present beneath 68 cm of ice. No flow was evident along this section of Drainage K. A short distance downstream (approximately 0.5 km) along Drainage K water depth and ice thickness remained the same, however the water in the ice auger hole pulsed, indicating some water movement. An active spring located less then 100 m to the north of the canal/creek had several discharge areas and moderate flow. The spring drained toward the creek creating a large ice field as the spring water travelled further from its source. Several small channels of the spring water join up with Drainage K along this section of the creek. This was undoubtedly the source of the pulsating water observed in the augured hole in Drainage K. Despite shallow under-ice water depth, D.O. levels along Drainage K were found to be surprisingly high at over 8 ppm with associated water temperatures of 0.1°C. The spring itself was investigated and a stretch of snow and ice covered flowing water, approximately 5 cm deep, had a D.O. level of nearly 6 ppm and water temperature of 1.7°C. Air temperature at the time was minus 10 °C. Upon the second visit in March, Drainage K was beginning to thaw and some open areas existed on sharp corners and on the west side of the first culvert encountered on the north-south main grid road (heading south) (map 3, Appendix D). D.O. levels were found to be above 9 ppm with associated water temperatures between 0.1°C and 0.2°C or slightly above freezing. Lonesome Lake was sampled in 3 locations, 2 of which occurred on the main reservoir and one of which occurred on the south reservoir. Two samples were taken from the south reservoir (one in February and one in March) and two samples were taken from the main reservoir on the March trip. D.O. levels were found to be quite low (0.3 ppm) on the south reservoir during the February trip and a dead stickleback was observed in the ice auger hole accompanied by the odour of decomposition. However, with the addition of flowing water under the ice in the south reservoir, the D.O. level increased on second visit in March to nearly 8 ppm. At this time Drainage K had began to flaw and flow again. Several pike and dozens of sticklebacks were observed on the bottom of drainage K where it exits the south reservoir. Also observed were several dead sub-adult leopard frogs. The frogs were all spread-eagle and were in various states of decomposition. The dead fish and frogs may have been winter killed due to anoxic under-ice water conditions on the upstream side (south reservoir) and washed through the water control structure to the location were they were observed. Alternatively, they may have been trapped in the encroaching ice of Drainage K, as it froze solid. The main reservoir was only sampled on the March trip and yielded high D.O. levels of 7.8 ppm to 10.9 ppm with water temperatures of 6.3 C to 7.4 °C.

4. Bow City Ponds

Bow City was surveyed on 18 February and 23 March 2000. Three ponds were sampled in total (map 4, Appendix D) with D.O. levels ranging from 3.9 to 8.0 ppm. Water depth in two of the three ponds at the site of sampling exceeded 200 cm in depth. Water temperatures varied between 1.8 to 3.5°C over the two trips.

5. Medicine Wheel

Medicine Wheel was surveyed on 16 February and again on 23 March 2000. In total, 8 wetlands were surveyed comprising 10 samples (map 5, Appendix D). Large permanent wetlands with water control structures were targeted in this study area. The most northerly pond sampled (Site 3) was found to have the highest water temperature (4.5 °C) recorded in all study areas during the February visit. An unusual ice formation, similar to a frozen seep was observed directly to the east of the water control structure at the outlet of this wetland. Since the culvert attached to the water control structure was frozen solid, exhibiting no water flow; it was believed that the unusual ice formation was a result of underground water seepage. Associated D.O. levels at Site 3 were 0.7 ppm. With D.O. levels of nearly 14 ppm, Site 16 on 23 March was the only wetland found to have D.O. levels above 4 ppm of the 8 sites sampled.

6. Scandia

Scandia was surveyed on 17 February and 24 March 2000. Four water quality samples were taken from Basin 3 over the 2 trips, each at a new location (map 6, Appendix D). On the March visit 2 samples were taken from the wetland, one at the east end and one toward the center of the water body. It was found that a percentage of Basin 3 may freeze to the bottom as the second sample site yielded ice 41 cm thick and frozen to the bottom.

7. Kinninvie

Kinninvie was surveyed on 18 February and 24 March 2000. Water quality was tested in 4 different location on the south basin (Kinninvie South) (map 7, Appendix D). Kinninvie Flat located north of the south basin (Kinninvie South), was not surveyed for water quality. This was due to time constraints and initial investigations indicating that Kinninvie Flat was extensively a cattail marsh that appeared to be too shallow to not freeze solid. Sites sampled at Kinninvie South yielded relatively shallow under-ice water conditions (10 to 40 cm) and low D.O. levels (1 to 3 ppm) on the first visit in February. The second visit in March yield higher D.O. levels of about 9 ppm and reduced ice thickness.

8. Kitsim

Kitsim was surveyed on 17 February and 24 March 2000. All water quality sites occurred on the Kitsim Reservoir (map 8, Appendix D). Three sites were chosen, two toward the north end of the reservoir and one toward the west side of the reservoir. The north end of the reservoir had a cattail-dominated shoreline and a shallow under-ice water depth at the two sites samples (53 and 35 cm) compared to over 100 cm of under-ice water depth at the site sampled on the west side. A canal outlet was also present at the north end of the reservoir near the location of site 2. The west side of the reservoir was also void of emergent vegetation and simply gave way to rangeland. D.O. levels on Kitsim Reservoir ranged between 0.4 to 13 ppm and water temperatures varied between 0.6 to 5.5°C. Ice thickness remained fairly constant between the 2 visits at 44 to 55 cm.

9. Lake Newell

Lake Newell was surveyed on 17 February 2000. Water quality was surveyed on the extreme south end of the Lake Newell on the Skandia Draw and the draw immediately to the south and east of the Skandia Draw (map 9, Appendix D). High D.O. levels were found to be associated with deeper water at these locations. For example, D.O. levels on the north and south draw were 6 ppm and 8 ppm respectively with under-ice water depths of 107 cm and 199 cm, respectively. Water temperatures were also found to be significantly higher (1.5 to 2.8 °C) than in the sites surveyed with shallow water of 17 and 52 cm (0.2 to 0.7 °C).

DISCUSSION

The Northern Leopard Frog (*Rana pipiens*) is a member of the family Ranidae or 'true frogs'. Many ranid anurans hibernate in aquatic habitats (Wright and Wright 1949, Porter 1972) to escape freezing temperatures. In Alberta, the Northern Leopard Frog and Colombia Spotted Frog (*Rana luteiventris*) are the only frog species that hibernate underwater beneath ice. There are few documented records in Alberta of leopard frogs hibernating in water that is not ice covered. In December 1997 several live leopard frogs were observed hibernating in an open section of Lone Pine Creek that was influenced by spring water (McAdam 1998). Some frog species that hibernate on land, such as the Boreal Chorus Frog (*Pseudacris maculata*) and Wood Frog (*Rana sylvatica*), are capable of producing a glucose "antifreeze" in their blood in response to cold temperatures. This "antifreeze" inhibits tissue damage caused by freezing, making the Boreal Chorus Frog and Wood Frog (unlike the leopard frog) freeze tolerant. To ensure winter survival, hibernating leopard frogs require specific aquatic over-wintering conditions. Most basic of these required aquatic conditions include, suitable dissolved oxygen levels, low water temperatures and substrates that remain free of ice. These parameters are further discussed below. Permanent springs, creeks, ponds, lakes and other water bodies that possess these critical water quality parameters may offer suitable hibernacula locations for leopard frogs. Over-wintering sites may not be used for breeding, or may be a considerable distance from breeding and summering habitats.

It is of no surprise that fish (requiring similar aquatic conditions) may over-winter in these water bodies along side leopard frogs. Live and winter killed sticklebacks were observed at Medicine Wheel, Circle E Ranch, and Scandia, and winter killed pike were observed in Drainage K were it begins at the south end of Lonesome Lake, at Circle E Ranch. Large predatory fish (pike and trout) are also present in at least three additional study areas; Bow City Ponds, Lake Newell and Kitsim. Over-wintering leopard frogs are believed to exist in at least two of these study areas; Circle E Ranch and Bow City Ponds. Emery et al. (1972) reported *Rana pipiens* successfully overwintering in a fish-bearing pond in Ontario that was stocked with two introduced trout species and contained several species of minnow. Leopard frogs were also observed in a southern Ontario stream inhabited with several species of fish including trout, sucker, dace and sculpin. It is unclear how the presence of large predatory fish, such as pike, affects over-wintering leopard frog populations within the study areas.

As previously mentioned D.O. concentrations are critical to the survivorship of overwintering leopard frogs. However, little is known about the winter physiology and critical requirements of Northern Leopard Frogs in Alberta. Once in a wintering aquatic environment, leopard frogs absorb oxygen cutaneously (respire across the skin) to meet oxygen requirements (Hutchinson and Whitford 1966, Hutchison and Dady 1964, Johansen 1962). Therefore, when exposed to anoxic conditions at over-wintering sites, *Rana pipiens* may experience high mortality (Litch

1991). A D.O. level in an ice-covered pond in Ontario known to contain hibernating leopard frogs was found to be 7 ppm just above the sediments. Cunjak (1985) recorded dissolved oxygen levels of 10 ppm in the Credit River in southern Ontario another known leopard frog overwintering site. During a radiotelemetry study of over-wintering habitat selection and conditions of translocated leopard frogs, Kendell (2000) noted dissolved oxygen levels of at least 10 ppm at a known leopard frog wintering site in Beaver Creek near Caroline, Alberta. It is reasonable to conclude that dissolved oxygen levels greater than 7 ppm are not a limiting factor for over-wintering leopard frogs. Four of the 7 study areas surveyed on the late winter trip (February) had sites with dissolved oxygen levels greater than 7 ppm. D.O. levels recorded in the study areas during both trips as they relate to suitable over-wintering conditions for leopard frogs are summarized in Table 2 All study areas surveyed in March, with the exception of Jenner Springs and Lake Newell, had some areas capable of sustaining over-wintering leopard frogs. Jenner Springs and Lake Newell were not surveyed on the second visit due to time constraints. However, Jenner Spring has been known to support leopard frogs with records as recent as 1999 (Table 2).

Table 2 Summary of dissolved oxygen levels above 7 ppm at each study area surveyed in February and March 2000. The presence of suitable over-wintering requirements is based on under ice water D.O. levels above 7ppm.

Study Area	**Dissolved Oxygen (ppm)**		**Suitable Dissolved Oxygen Concentrations Present**	
	February	**March**	**February**	**March**
Jenner Springs	not surveyed	below 7	not surveyed	no*
Prince's Spring	not surveyed	7.8 to 13.1	not surveyed	yes
Circle E Ranch	8.3 to 8.7	7.8 to 12.2	yes	yes
Bow City Ponds	8.0	8.0	yes	yes
Medicine Wheel	below 7	13.8	no	yes
Scandia	below 7	8.6 to 10.8	no†	yes
Kinninvie	below 7	9.4 to 9.6	no	yes
Kitsim	8.0	13.1	yes	yes
Lake Newell	8.3	not surveyed	yes	not surveyed

(*) Leopard frogs observed at this site in 1999.
(†) Leopard frogs observed at this site in 1991.

Several environmental and physical conditions determine the amount of D.O. that water is capable of holding at saturation. These include temperature, salinity and elevation. According to Avault (1996) certain sources of water, such as springs and well water, are chronically low in D.O. Dissolved oxygen concentrations recorded in a seep at Prince's Spring was 0.18 ppm, however quickly increased with water depth in the area and water flow (through the summation of multiple seeps over a broad area). Therefore, it is unlikely that over-wintering leopard frogs would select the immediate origin of the spring due to the presence of low D.O. levels.

Limiting dissolved oxygen levels relating to hibernating leopard frogs is poorly understood. Herman and Meyer (1990) report that fish experience mortality when dissolved oxygen concentration drops below 2 ppm (usually 0-1 ppm). However, it should be noted that a number of factors may influence fish mortality as it relates to oxygen depletion and submerged leopard frogs may behave considerably different when exposed to similar dissolve oxygen levels. Hibernating leopard frogs may be able to survive at reduced oxygen levels that are below preferred concentrations for unspecified periods of time. When placed in sealed battery jars containing water with no oxygen and at 5°C, Hutchison and Dady (1964) found that *Rana pipiens* survived a mean time of 62.1 hours. Christiansen and Penny (1973) found that *Rana pipiens* could survive anoxic conditions in excess of 120 hours and as long as 168 hours when placed in deoxygenated water of 4 °C. These findings suggest leopard frogs may have the ability to survive short lengths of time or even extended periods of less than ideal dissolved oxygen provided water temperature remains cold. These conditions can naturally result from thick ice, reduced water flow, low water levels or decaying vegetation at hibernation sites and may appear in some years at several over-wintering leopard frog sites within the study areas investigated.

As discussed earlier, water temperature is critical in determining over-wintering success of leopard frogs. Water temperatures have a two-fold affect on hibernating leopard frogs. Firstly, water at a higher temperature holds less oxygen than water at a colder temperature; thus warmer water holds less oxygen available for submerged frogs. Brenner (1969) observed a 40% decrease in oxygen consumption when *Rana pipiens* was exposed to 4°C water compared to water at 22-28 °C. Secondly, water temperatures directly affect the metabolic rate (Cook, 1949) and utilization of body fat (Brenner, 1969) of leopard frogs. The storage of body fat is important in the maintenance of energy reserves during hibernation when the frogs have stopped feeding. Starvation may occur if water temperatures are not sufficiently low enough to suppress the utilization of accumulated energy reserves. On the February trip, water temperatures varied between 0.1 °C and 4.5 °C and on the March trip water temperatures varied between 0.1 °C and 7.1 °C (Appendix B). Brenner (1969) conducted experiments on overwintering leopard frogs in 4 °C water from December through January. Under laboratory conditions similar to hibernating habitat in the field, Licht (1991) observed *Rana pipiens* completely submerged in 1.5 °C water with no apparent desire to surface. Cunjak (1985) reported leopard frogs hibernating in the Credit River where winter water temperatures rarely exceed 3.0°C and during the course of the study ranged between 0.5 °C and 2.1 °C. Emery et al. (1972) recorded water temperatures of 2.5°C at the bottom of a pond known to contain hibernating leopard frogs. Kendell (2000) reported a leopard frog remaining submerged for 23 days in one location in a section of Beaver Creek, near Caroline, Alberta. Water temperatures at that location ranged between 3.9 °C to 6.3 °C. The same frog was later located in the Raven River were water temperatures were recorded between 1.3 °C to 2.5 °C. Finally, Oliver (1955) observed *Rana pipiens* to remain submerged when water temperature dropped below 4.4°C. Supported by observations of successfully overwintering frogs at specific hibernation sites, it is reasonable to assume that leopard frogs can successfully remain submerged and can utilize waterbodies in which temperatures range from 0.5°C to up to 6.3 °C. However, water temperatures approaching 6 °C may be too high to initiate deep hibernation. On the March trip water temperatures exceeded 6.3 °C at just 2 sites, Pond (14) at Medicine Wheel and Reservoir (10) at Circle E Ranch (Appendix B). These findings indicate that all sites visited in February possess potentially suitable water temperatures supportive of over-wintering ecology of leopard frogs.

It is well known that leopard frogs hibernate on the bottom of water bodies on a variety of substrate types. McAdam (1998) observed over a dozen leopard frogs lying on the bottom of spring fed creek in Cypress Hills Inter-provincial Park. The substrate was described as muddy with abundant cobblestones. Emery et al. (1972) observed several leopard frogs resting in small pits in the mud on the bottom of a pond. Substrates of mud, silt, sand, gravel, cobble, vegetation and various organic debris were commonly encountered in the wetlands surveyed in the study areas. Oxygen depletion associated with substrates in water bodies containing a high percentage of organic debris and soft mud or silt covered bottoms may result in characteristic anoxic conditions in the water layer near the substrate and below a few centimetres of mud-depth

(Emery et al. 1972). Under these conditions oxygen available to hibernating leopard frogs may be insufficient and lead to winter mortality. It is not known how the various substrates may have affected over-wintering frogs in the study areas surveyed. Conversely, as ice forms oxygen is often squeezed form the ice producing a relatively oxygen rich zone on the underside of the ice. In this case, particularly in years of low water depths and thick ice conditions hibernating frogs may have access to enough D.O. to survive.

Ice and snow cover can prevent photosynthesis and increase the decay of vegetation leading to aerobic decomposition resulting in oxygen depletion. Ice thickness in the study areas were recorded on both trips (February and March) on all sites where water quality was measured. Ice thickness at individual sites where measurements were recorded ranged between 31 to 68 cm in February and 0 to 55 cm in March (Appendix C). Emery et al. (1972) recorded ice thickness on a pond known to contain hibernating leopard frogs of 66 cm to 76 cm with no negative effects on the frogs. Ice thickness is not limiting factor at leopard frog hibernacula provided that under-ice water oxygen concentrations are sufficient and the substrate remains ice-free. Water depths of 0.09 m to over 3 m were recorded during the two trips to southern Alberta (Appendix B). Cunjak (1985) found hibernating leopard frogs in the Credit River where water depths were generally greater than 0.85 m and Emery et al. (1972) observed frogs up to 3.1 m below the ice on the bottom of a pond. At some sites surveyed, water depth had little influence on observed D.O. levels. For example, dissolved oxygen concentrations recorded along Drainage K in February, with only 9 cm of under-ice water were, found to be above 8 ppm. Dissolved oxygen concentrations recorded (also in February) in 3 waterbodies exceeding 2 m in depth were found to be, in some cases, well below 8 ppm.

RECOMMEDATIONS

1. All wetland sites investigated in the winter 2000 should be revisited in the corresponding spring and summer to conduct leopard frog surveys. This would confirm population status as of 2000, breeding evidence and subsequent breeding success at these sites.

2. Ideally, study areas should be surveyed at least twice, once in early spring (for calling males and egg masses) and once in mid summer (for young of the year and breeding success). Two additional surveys, one before calling activity is recorded and one in late fall just prior to the onset of hibernation may provide valuable information and insight into possible overwintering locations. The optimal survey period may be early fall (late August to late September) when leopard frogs begin to congregate at overwinter hibernation sites.

3. Leopard frog surveys should also be conducted in additional wetland sites within each study area (and neighbouring areas) to provide a better understanding of distribution and frog moments within the region.

4. A standardized leopard frog survey protocol should be developed and distributed to biologists at the various Ducks Unlimited and Natural Resources Services area offices in the region and other areas of the province. This protocol would offer specific information on leopard frog phenology and natural history requirements that would increase the productivity of leopard frog surveys. In addition, the protocol would also offer various techniques and methodologies that would increase the efficiency and success of frog surveys.

5. Based on background research and relevance to over-wintering leopard frogs, additional water parameters should be considered when conducting water quality tests at current and new sites in the future. Potential water quality tests may include; nitrates, nitrites, phosphorus, ammonia, alkalinity, standard metals, zinc, pesticides, herbicides.

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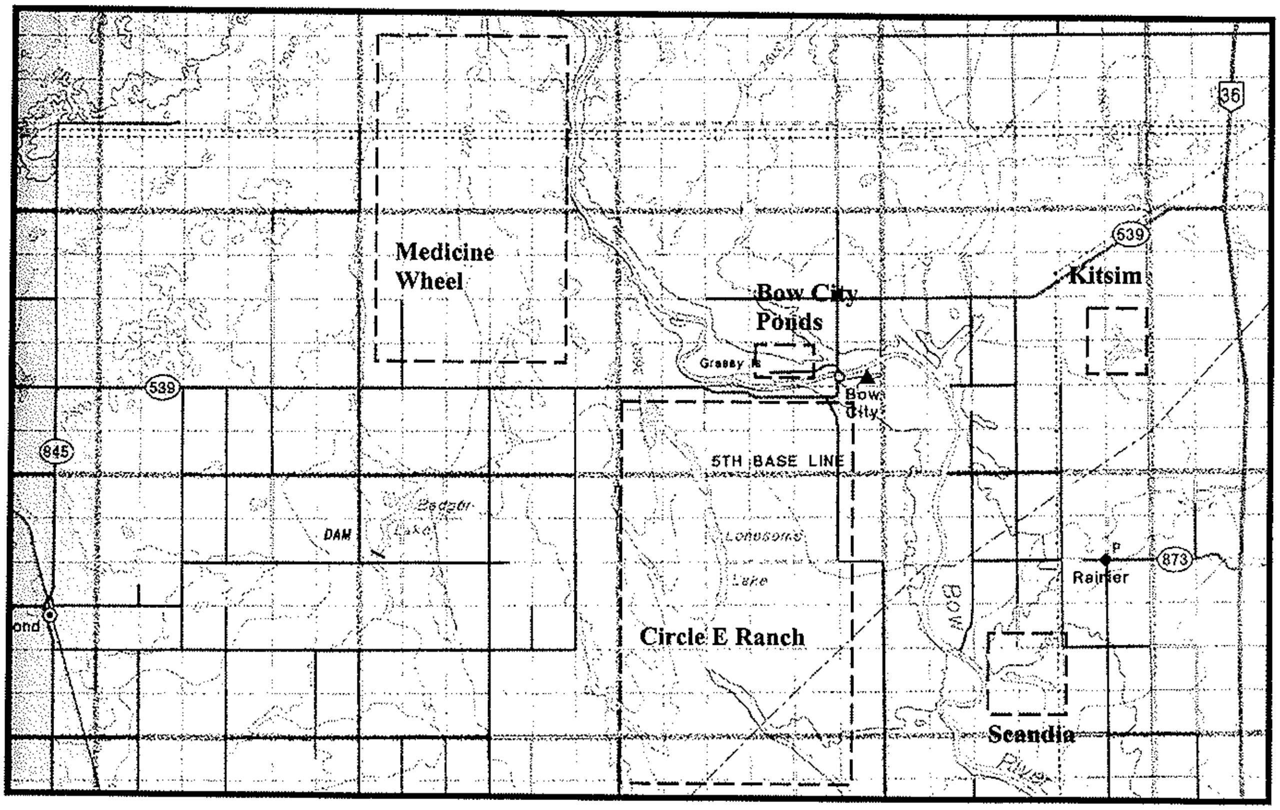
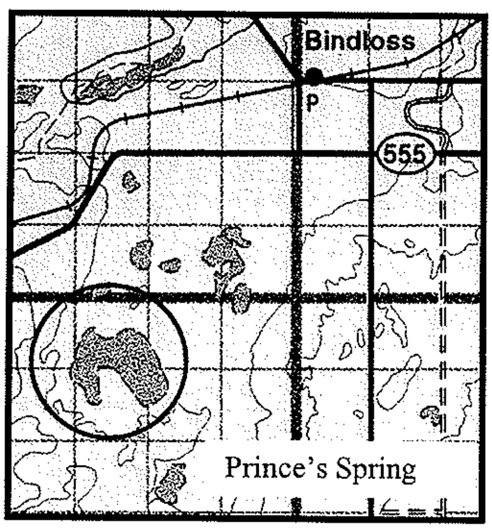
APPENDIX A Topographical maps of study areas in relation to towns and major roads near Brooks, Alberta.

(West Map – Southwest of Brooks, Alberta)

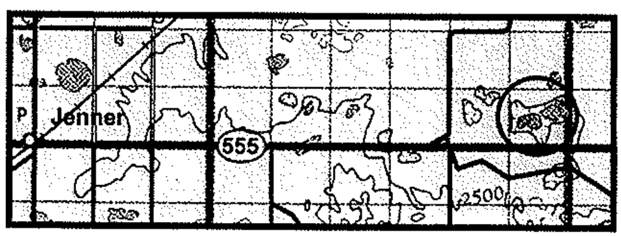


Approximate boundaries of study areas.

Northeast Maps (Prince's Spring and Jenner Springs sites identified by O)

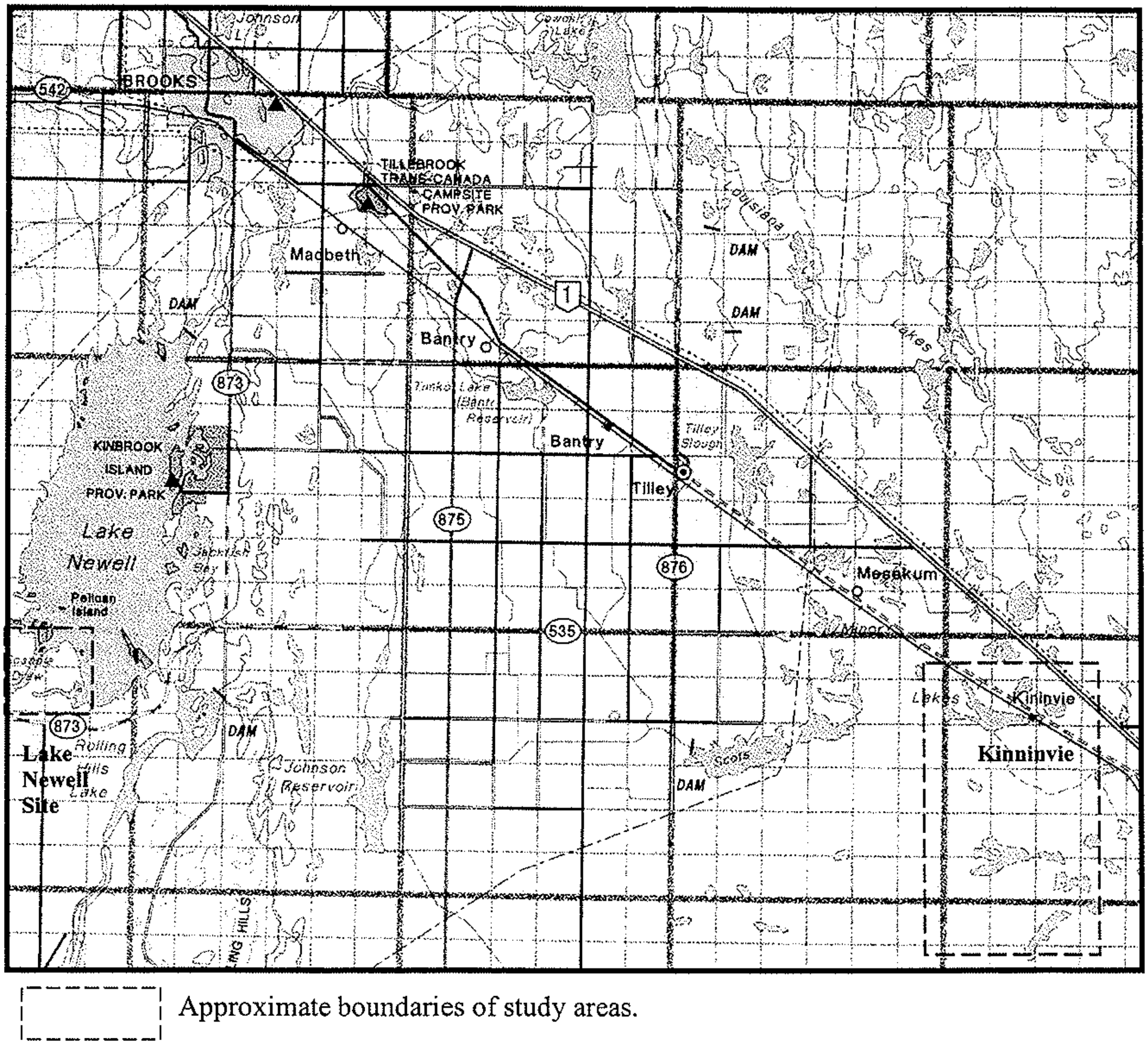


Prince's Spring



Jenner Springs

APPENDIX A *continue* (East Map – south and east of Brooks, Alberta)



Approximate boundaries of study areas.

APPENDIX B Water quality parameters recorded in nine study areas near Brooks, Alberta.

Study Area	Site	Date (D/M/Y)	D.O. (mg/l)	Water Temp. (°C)	pH	Ice Thickness (cm)	Water Depth Under Ice (cm)
Jenner Springs	Burrow Pit (south)*	09/12/98	0.95	0.5	7.4	25	-
	Wetland*	17/02/99	1.1	2.2	7	45	-
	Burrow Pit (north)	22/03/00	0.43	5.4	6	31	60+
	Burrow Pit (south)	22/03/00	0.48	4.4	6	55	68+
Prince's Spring	North of culvert2* (1)	09/12/99	7.75	0.5	8	25	-
	Spring Head (2)	22/03/00	0.18	6.5	7	0	15
	Dugout (3)	22/03/00	8.25	1.4	6	20	75+
	Culvert 1 (4)	22/03/00	10.15	4.6	6	0	12
	Channel / Marsh (5)	22/03/00	11.1	6.0	6	0	18
	Cattail Marsh (6)	22/03/00	11.42	6.0	6	0	40
	Culvert 2 (7)	22/03/00	13.09	1.2	6	0	31
	Catch Basin 1 (8)	22/03/00	2.2	1.3	6	43	30+
Circle E Ranch	Drainage K (1)*	09/12/98	11.75	2.5	7.4	2	-
	Drainage K (1)*	17/02/99	13.6	0.4	7.0	40	-
	Spring / seep	15/02/00	5.76	1.7	-	0	5
	Drainage K (1)	15/02/00	8.69	0.1	6	68	9
	Drainage K (2)	15/02/00	8.28	0.1	6	68	9
	Drainage K (3)	15/02/00	1.3	0.1	6	31	22
	Reservoir (11)	15/02/00	0.33	2.8	6	39	104
	Reservoir (10)	23/03/00	9.48	7.4	5	20	160
	Reservoir (11)	23/03/00	7.75	6.3	6	20	80
	Reservoir (10)	23/03/00	10.87	7.1	5	20	40
	Drainage K (3)	23/03/00	9.21	5.1	-	0	50
	Drainage K (1)	23/03/00	9.64	0.1	6	0-30	51
	Drainage K (2)	23/03/00	12.19	0.2	6	30-51	-
Bow City Ponds	1*	09/12/98	8.75	1.0	8	30	-
	1	18/02/00	6.91	2.7	6	41	250+
	2	18/02/00	3.91	3.6	-	39	200+
	3	18/02/00	5.47	1.8	-	40	40
	1	23/03/00	8.02	3.1	-	-	-
	2	23/03/00	6.17	3.5	-	-	-
Medicine Wheel	3	16/02/00	0.71	4.5	5	37	75
	31	16/02/00	2.02	0.4	6	41	40
	16	16/02/00	0.24	1.2	6	44	20
	16	16/02/00	0.37	1.3	6	44	40
	15	16/02/00	3.48	3.3	6	41	329
	3	23/04/00	0.84	3.9	5.5	30	100
	15	23/04/00	3.78	6.4	5	24	40
	9	23/04/00	1.18	4.9	6	20	50
	16	23/04/00	13.78	6.3	5.5	32	70
	18	23/04/00	1.4	5.7	5	27	30
	20	23/04/00	0.65	4.0	5.5	27	50
Skandia	2	17/02/00	0.37	2.2	6	40	42
	1	17/02/00	-	-	-	41	0
	3	23/03/00	10.84	6.7	5	10	50
	4	23/03/00	8.59	6.2	5	18	20

(*) Sites previously visited by Fisher in 1998/1999 – see Fisher 1999.

APPENDIX B *continue*

Study Area	Site	Date (D/M/Y)	D.O. (mg/l)	Water Temp. (°C)	pH	Ice Thickness (cm)	Water Depth Under Ice (cm)
Kinninvie	South Basin (1)	18/02/00	3.00	1.5	6	49	10
	South Basin (2)	18/02/00	1.01	2.1	6	49	15
	South Basin (3)	24/03/00	9.40	5.5	6	30	30
	South Basin (4)	24/03/00	9.56	6.6	6	30	40
Kitsim	Reservoir (1)	17/02/00	0.41	2.7	6	52	53
	Reservoir (2)	17/02/00	8.03	0.6	6	50	35
	Reservoir (3)	24/03/00	13.05	5.5	5	44	100+
Lake Newell	1 South Draw	17/02/00	1.23	0.7	6	41	17
	2 South Draw	17/02/00	2.86	0.2	6	45	52
	3 Skandia Draw	17/02/00	8.26	1.5	6	52	199
	4 Skandia Draw	17/02/00	6.20	2.8	6	53	107

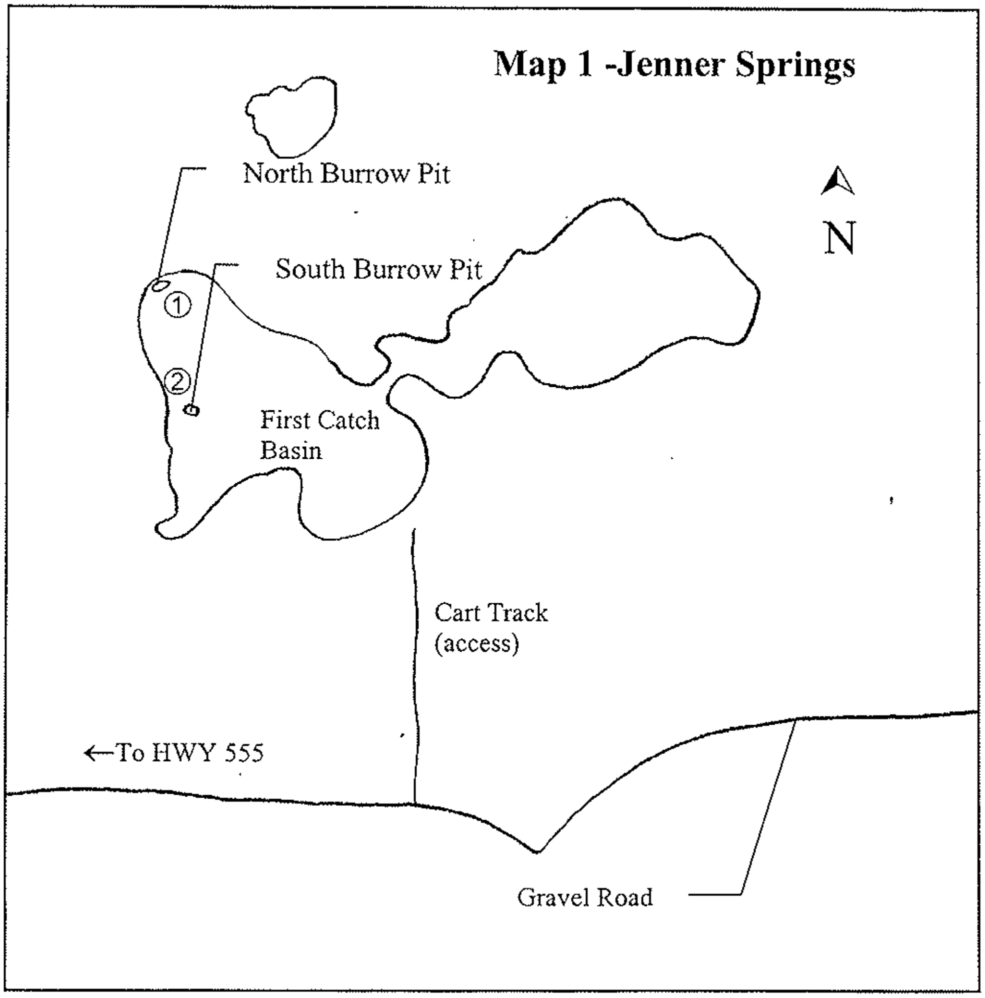
See Appendix D for specific site locations.

APPENDIX C Summary of significant data (max / min) recorded at the two study areas during February 2000 and March 2000.

February Trip				March Trip			
Parameter	Measurement		Site / Study Area	Parameter	Measurement		Site / Study Area
Dissolved Oxygen (mg/l)	Max	8.69	Drainage K (1) Circle E Ranch	D.O. (mg/l)	Max	13.78	Pond (16) Kitsim
	Min	0.24	Pond (16) Medicine Wheel		Min	0.43	Burrow Pit (north) Jenner Springs
Water Temp. (°C)	Max	4.5	Pond (3) Medicine Wheel	Water Temp. (°C)	Max	7.1	Reservoir (10) Circle E Ranch
	Min	0.1	Drainage K Circle E Ranch		Min	0.1	Drainage K (1) Circle E Ranch
pH	Max	6	*	pH	Max	7	Springhead Prince's Spring
	Min	5	*		Min	4.5	*
Snow Cover (cm)	Max	10	*	Snow Cover (cm)	Max	10	Drainage K Circle E Ranch
	Min	3	*		Min	0	*
Ice Thickness (cm)	Max	68	Drainage K (1,2) Circle E Ranch	Ice Thickness (cm)	Max	55	Burrow Pit (south) Jenner Spring
	Min	31	Drainage K (3) Circle E Ranch		Min	0	Drainage K Circle E Ranch
Water Depth (cm)	Max	200+	Bow City Pond (1) and Lake Newell	Water Depth (cm)	Max	160+	Reservoir (10) Circle E Ranch
	Min	0	Basin 3 (site 2) Scandia		Min	12	Culvert 1 Prince's Springs

(*) See Appendix B

APPENDIX D Sketches of NAWMP managed wetland complexes and other wetland sites sampled for water quality. Specific sample location at each site are indicated by either circled or bracketed number on map.



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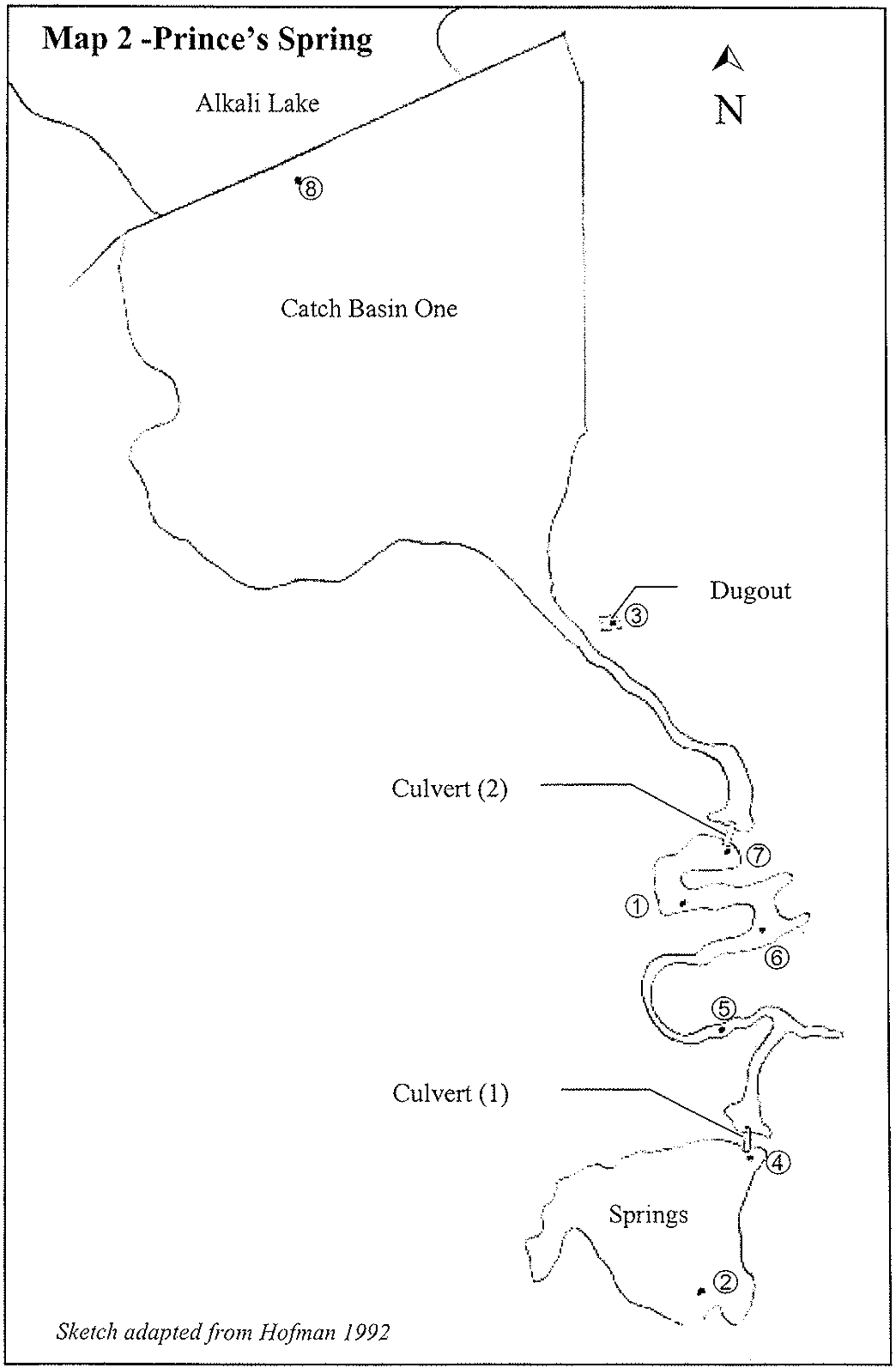

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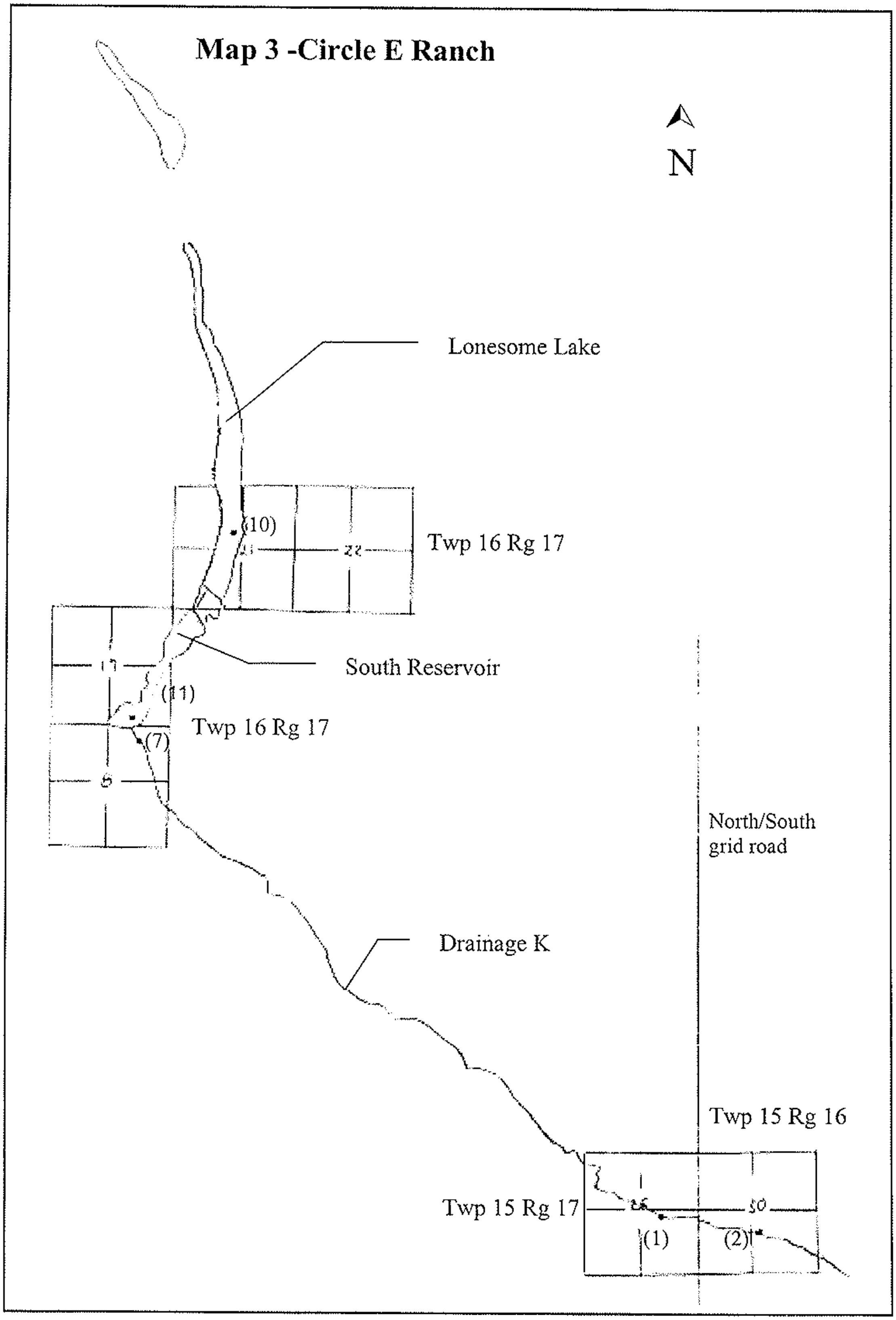

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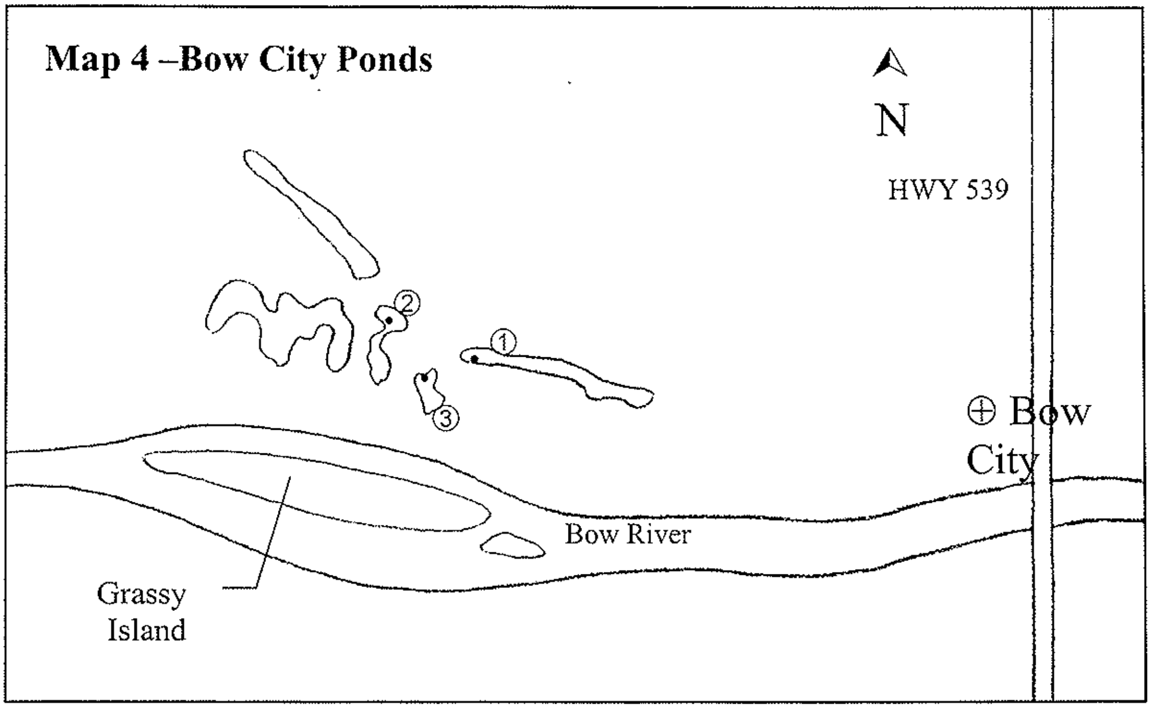

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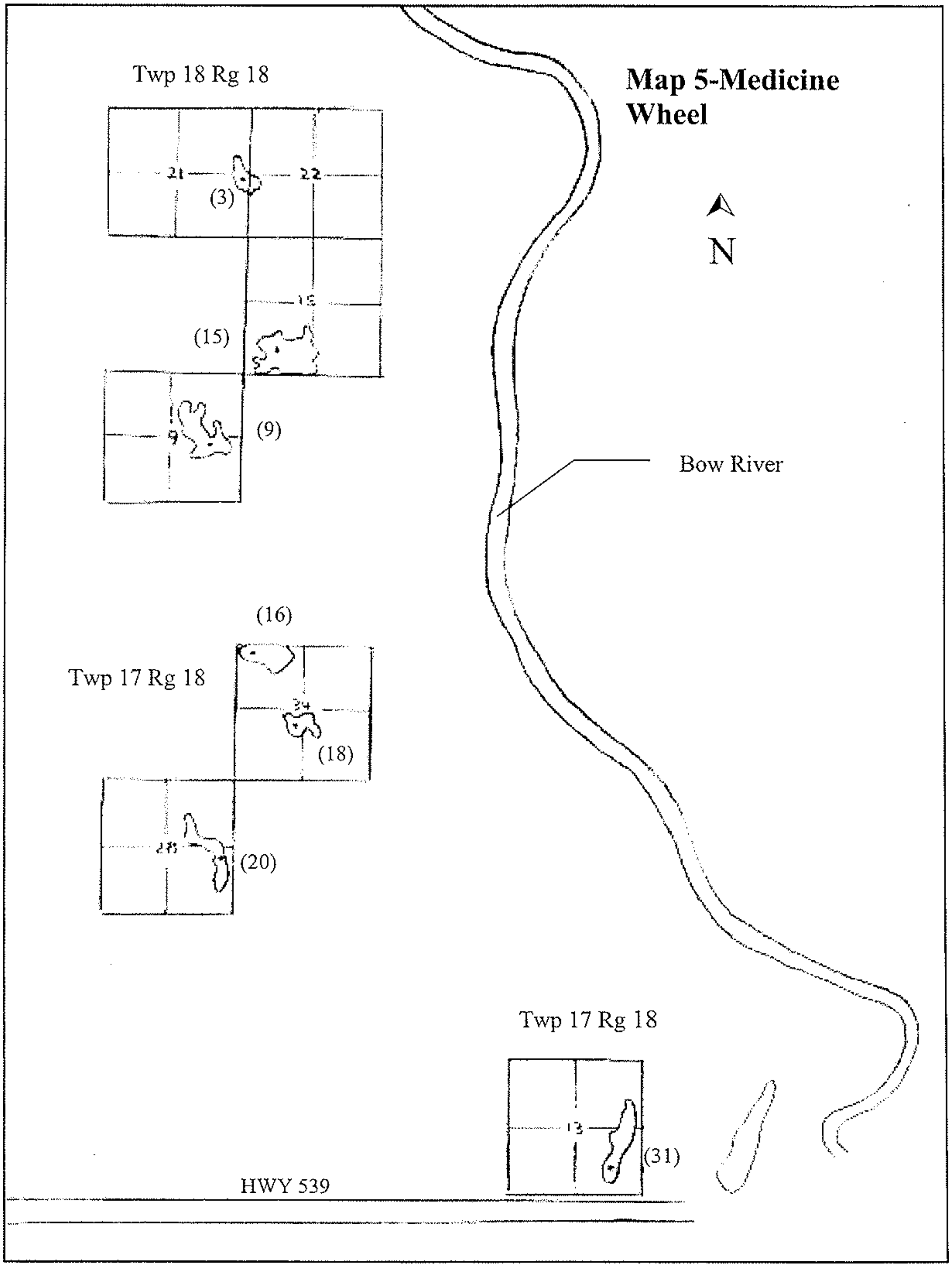

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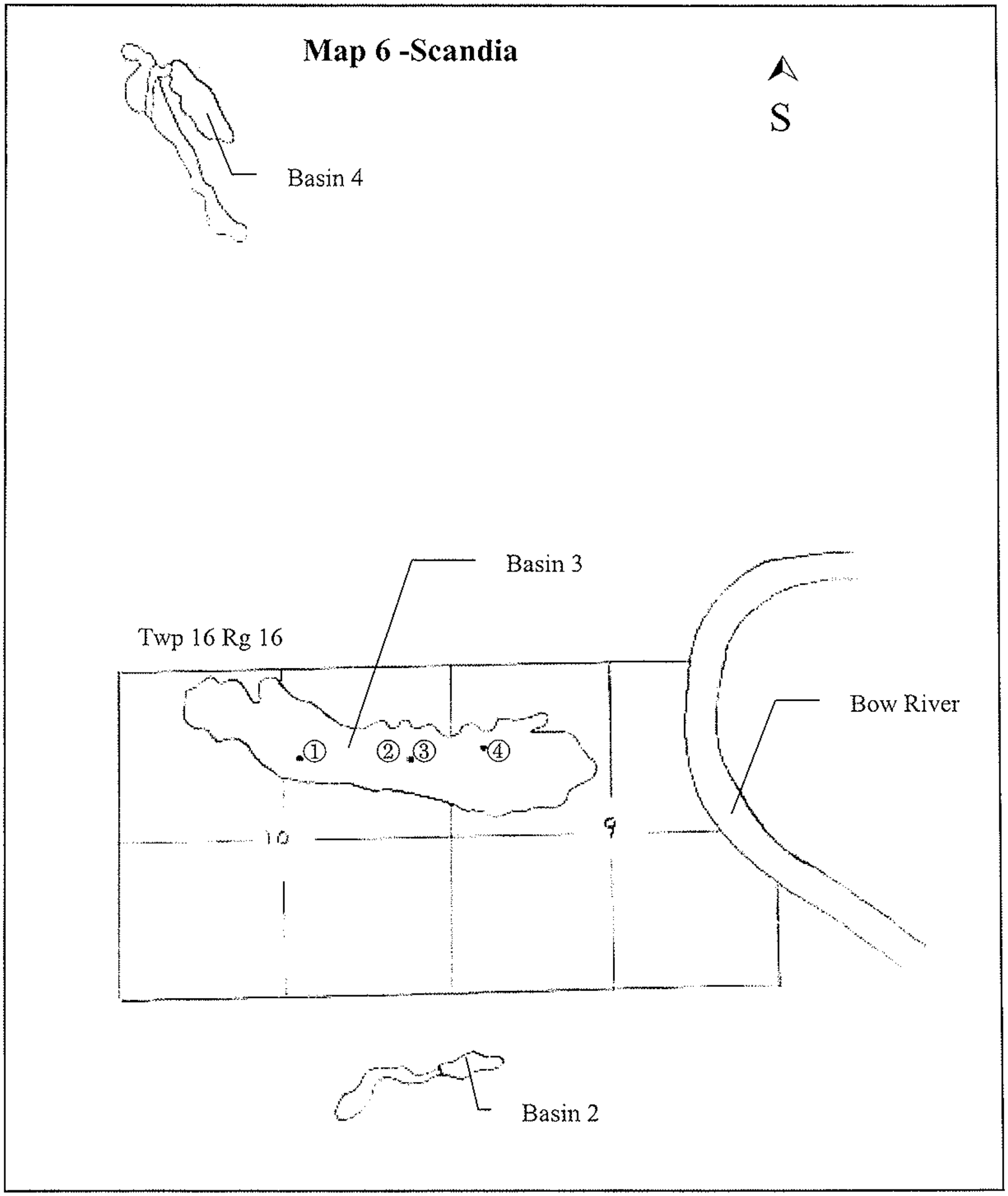

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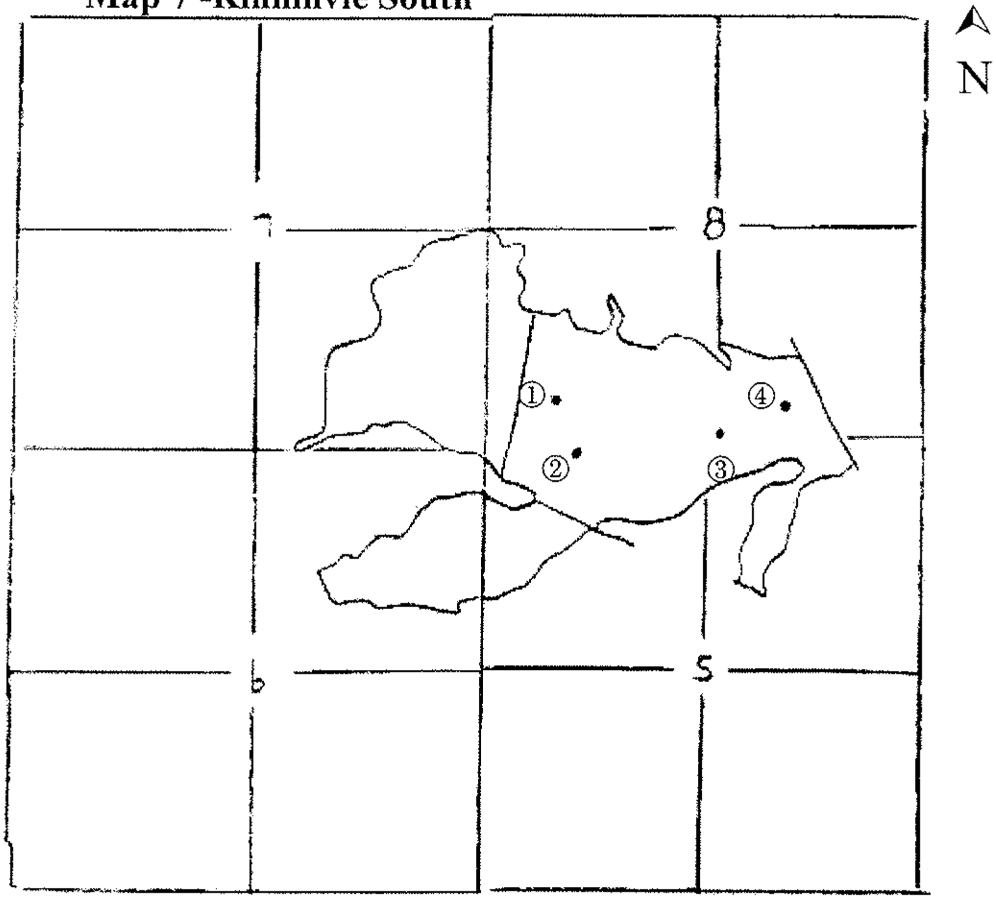
Map 7 -Kinninvie South



Twp 16 Rg 11

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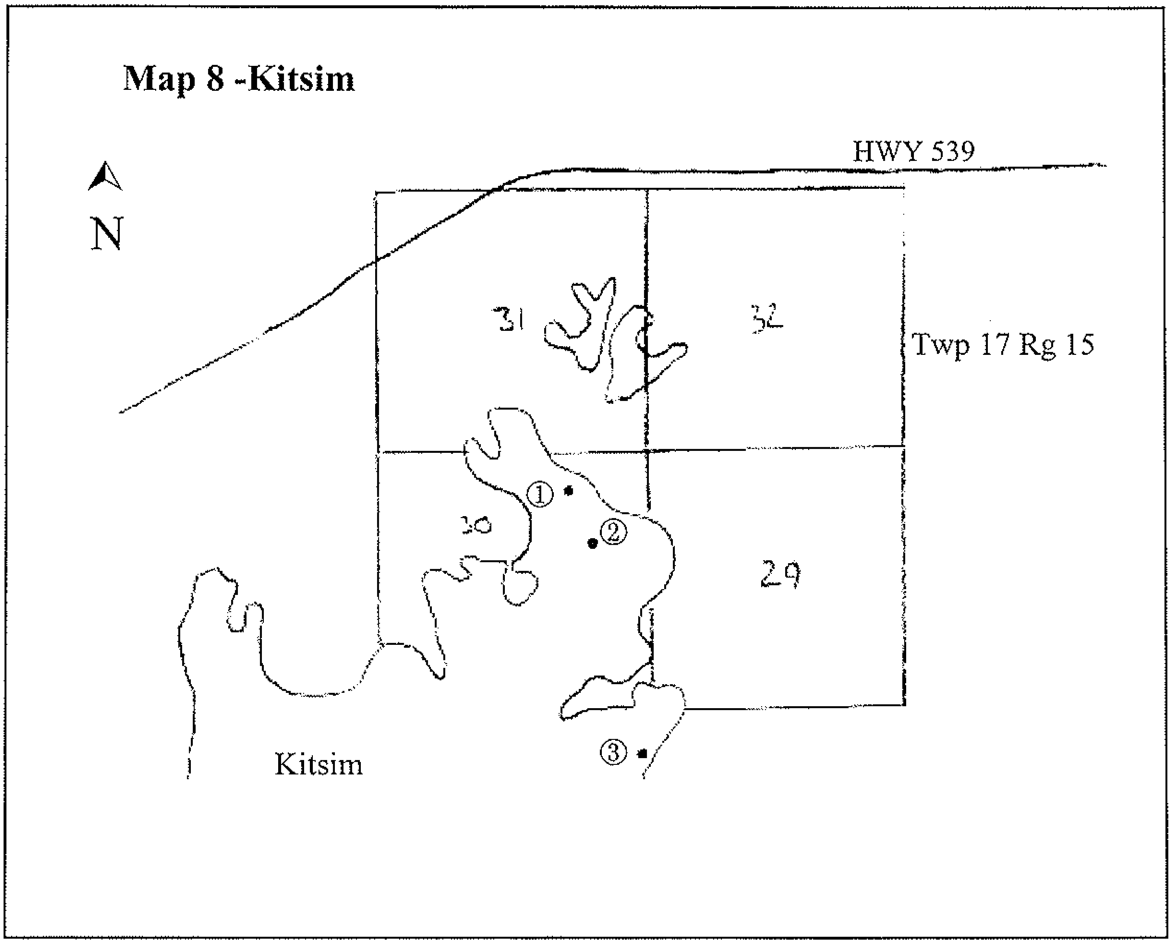

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