HOME RANGE OF THE TEXAS RIVER COOTERS (*PSEUDEMYS TEXANA*) AT SPRING LAKE, HAYS COUNTY, TEXAS

THESIS

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ABSTRACT

HOME RANGE OF TEXAS RIVER COOTERS (*PSEUDEMYS TEXANA*) AT SPRING LAKE, HAYS COUNTY, TEXAS

by

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Nineteen Texas river cooters, *Pseudemys texana*, were studied at Spring Lake, Aquarena Center, Hays County, Texas, from May 2003 to February 2005. Radio telemetry was used to locate individual turtles to determine home range size and seasonal shifts within the lake. Yearly home ranges were significantly larger for females (3.77 ha) than in males (2.06 ha) and home ranges overlapped considerably between the sexes. Seasonal home ranges were calculated but not tested statistically due to small sample size. Mean distance traveled during each season was calculated for each sex. Females moved significantly longer distances between seasons than males, and there were seasonal shifts in the areas of the lake used by each sex. The mean distance from a fixed anchor point to seasonal locations was 289.42 m for spring females, and only 163.14 m for males in the spring. These seasonal shifts follow the nesting habits of this

species, as females move to areas of Spring Lake adjacent to nesting sites in the spring and summer.

INTRODUCTION

Most animals are not nomadic, but carry out their daily activities within a confined area (Powell, 2000) called the home range. These daily activities include foraging, resting, mating, and caring for young (Burt, 1943), and many of an animal's requirements, such as food, cover, space, and water, occur within this area. The home range, defined by parameters including size, location, content, and movement patterns, is a fundamental ecological aspect of species (Warrick et al., 1998). Knowledge of an animal's home range can give insight to multiple ecological and behavioral components of a species' natural history such as mating patterns and reproduction, social organizations and interactions, foraging patterns and food sources, limiting resources, population parameters and dynamics, and habitat selection (Warrick et al., 1998; Powell, 2000).

Movements of animals are not random within their home ranges but are motivated in terms of escaping or seeking a particular area or resources (Gibbons et al., 1983; Gibbons, 1990). Some species appear to have a cognitive map of their habitat, or at least a concept of where resources occur within the home range and how to travel to these resources. Understanding movement patterns of animals is crucial in determining and explaining distribution and abundance, gene flow, and behavior interactions among individuals (Johnson and Gaines, 1990). Understanding movements also is necessary to describe ecological and evolutionary mechanisms and patterns of dispersal, migrations, or movements within the habitat (Gibbons et al., 1990).

Turtle movements were classified spatially as intrapopulational (short-range) and extrapopulational (long-range) movements and have been identified temporally as occurring daily, seasonally, or sporadically (Gibbons et al., 1990). The most apparent reasons for intrapopulational movements in turtles are: feeding, basking, searching for favorable hiding or dormancy sites, and reproduction (mate seeking, courtship, and nesting) (Stickel, 1950; Bury, 1979; Obbard and Brooks, 1980; Congdon et al., 1983; Gibbons et al., 1990). Seasonal or extrapopulational movements of freshwater turtles consist of overland movement by hatchlings from nests to the aquatic habitat, searching for seasonal resources, movement to and from overwintering sites, searching for mates, and nesting by females (Sexton, 1959; Bury 1979, Obbard and Brooks, 1980; Congdon et al., 1983, Gibbons et al., 1990). Turtles also move to escape desiccating habitats (Gibbons et al., 1983; Buhlman, 1995). These movements are thought to confer probability of benefit to the individual, and are balanced by some form of negative feedback (Bury, 1979; Gibbons et al., 1990).

Since the early 1960's, radio telemetry has been used to collect home range and movement information on many different groups of animals. This technique allows animals to be tracked and located providing increased opportunities to gather data with great accuracy and less time on home range, movement, behavior, habitat use, productivity, and survival (Samuel and Fuller, 1996).

Radio telemetry was used to gather ecological data for: wood turtles (*Clemmys insculpta*) (Kaufman, 1995; Arvisais et al., 2002), spotted turtles (*Clemmys guttata*) (Graham, 1995; Haxton and Berrill, 2001; Milam and Melvin, 2001), bog turtles (*Clemmys muhlenbergii*) (Carter et al., 2000), yellow-blotched map turtles (*Graptemys flavimaculata*) (Jones, 1996), Blanding's turtles (*Emydoidea blandingi*) (Rowe and Moll, 1991), alligator snapping turtles (*Macroclemys temminckii*) (Harrel et al., 1996), common snapping turtles (*Chelydra serpentina*) (Obbard and Brooks, 1981), softshell turtles (*Trionyx spiniferus*) (Plummer et al., 1997; Galois et al., 2002), and chicken turtles (*Deirochelys reticularia*) (Buhlmann, 1995). The ecology of river cooters (*Pseudemys concinna*) was studied using radio telemetry (Buhlmann and Vaughan, 1991; Dreslik et al., 2003), as was the home range of the Florida red-bellied turtle (*Pseudemys nelsoni*) (Kramer, 1995). However, there are no current radio telemetry studies or home range estimates of the Texas river cooter, *Pseudemys texana*.

The Texas river cooter, *Pseudemys texana*, is one of the least known and ecologically neglected species of emydid turtles (Lindeman, 2001). It belongs to the family Emydidae, which is the largest extant family of turtles in the Northern Hemisphere consisting of the semiaquatic pond and marsh turtles (Pritchard, 1979; Ernst et al., 1994). This turtle is endemic to Texas and restricted to the Colorado, Brazos, and Guadalupe/San Antonio River drainages of central and south-central Texas, and it is abundant in its geographic distribution (Vermersch, 1992). The basking behavior of this species is highly developed, as it may bask on logs for hours. It selects slow moving water, such as ponds, lakes, rivers, or creeks, with an abundance of aquatic vegetation, but it also can occasionally be found in cattle tanks or large drainage ditches (Vermersch, 1992; Conant and Collins, 1998). Adult *P. texana* feed primarily on aquatic vegetation (Vermersch, 1992).

Prior to Ward (1984) and Seidel and Smith (1986) the taxonomic status of the Texas river cooter was ambiguous (Carr, 1952; Vermersch, 1992). For this reason, little of the life history of *P. texana* is known. Most data on *Pseudemys texana* were published under other names, *P. concinna* or *P. floridana* (Ernst et al., 1994). Because of its unstable taxonomic status, a thorough assessment of its ecology and behavior is needed for this species (Ernst et al., 1994).

The objectives were: 1) to estimate and compare by sex and season the home range size of *Pseudemys texana* and 2) to estimate and compare by sex and season the movements of *P. texana.*

MATERIALS AND METHODS

Study Site

This study was conducted at the 7.9 ha Spring Lake, Aquarena Center in San Marcos, Hays County, Texas. The San Marcos Springs is the second largest spring system in Texas emerging from the Edwards Aquifer along or near the San Marcos Fault (Guyton, 1979; Brune, 2002). In 1849, outflow from the springs was dammed forming Spring Lake (Brune, 2002; Lemke, 1989). At its deepest point, the lake measures a maximum of 12.2 meters in depth (Guyton, 1979). These springs have an average annual discharge of 169 cfs (Gandara et al., 2000). Flow rates vary due to the fluctuations in the underlying Edwards Aquifer, but the springs have not ceased flowing in historical times (Brune, 2002). A relatively constant water temperature at 21.7 $\pm$ 3 °C is sustained due to the springs that emerge along the length of the lake (Guyton, 1979; Groeger et al., 1997).

In 1946, Aquarena Springs was developed as a resort and theme park around the springs with glass bottom boats and an underwater submarine theater (Denena et al., 2003). In 1994, Texas State University-San Marcos (formerly Southwest Texas State University) acquired the property and dedicated it to education, research, and outreach (Denena et al., 2003; Towns et al., 2003).

The lake is naturally divided into two sections: the main lake and the slough (Fig. 1). The natural springs discharge into the northern portion of the main lake. The spring flow creates a lotic environment ending at a spillway that empties into the San Marcos River. Small amounts of floating vegetation are found on the surface of this lotic section. The eastern shoreline is curbed in concrete for 350 meters downstream and the western shore is a steep hillside formed by the Balcones Escarpment.

The slough is a lentic system. This backwater area of the lake is continuous with Sink Creek, an intermittent water course. There is an abundance of vegetation along the shoreline with fallen trees and floating vegetation. A golf course and softball/soccer practice fields border this section of the lake.

The shoreline throughout the lake is typically steep sloped with little shallow water for emergent vegetation. The emergent vegetation present is dominated by invasive elephant ear (*Colocasia esculenta*) with scattered stands of cattail (*Typha latifolia*) and giant cutgrass (*Zizaniopsis miliacea*). Woody shoreline vegetation consists of bald cypress (*Taxodium distichum*), American elm (*Ulmus americana*), hackberry (*Celtis spp.*), black willow (*Salix nigra*), box elder (*Acer negundo*), Japanese honeysuckle (*Loniceria japonica*), and poison ivy (*Toxicodendron radicans*). Dense mats of algae and macrophytes, including numerous invasives such as hydrilla (*Hydrilla verticillata*), water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), and Brazilian parrot's

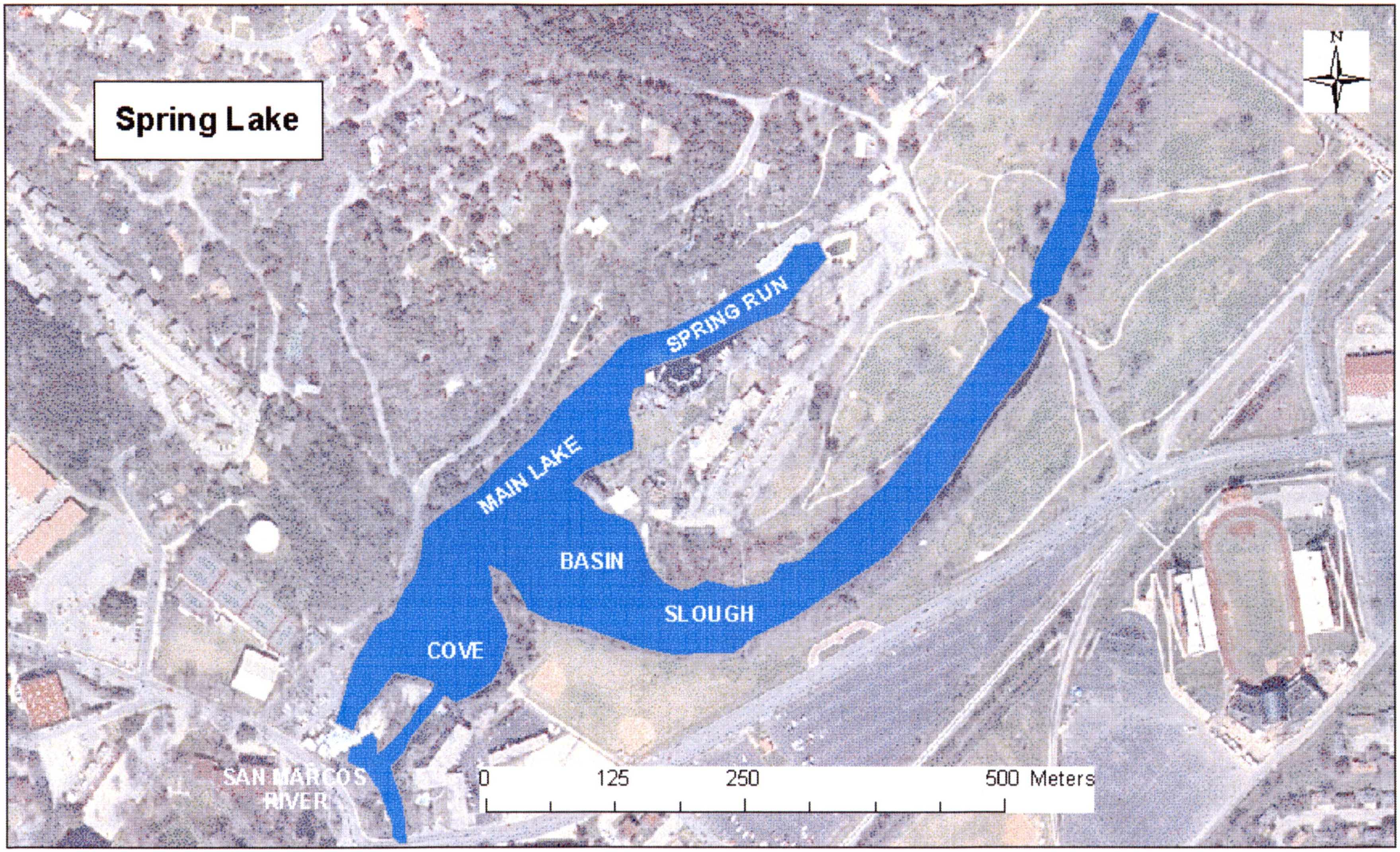


Figure 1. Spring Lake, Aquarena Center, San Marcos, Hays County, Texas.

feather (*Myriophyllum brasiliensis*) cover much of the surface of the slough and southern section of the main lake in the spring and summer. Native aquatic plants include delta arrowhead (*Sagittaria platyphylla*), Carolina fanwort (*Cabomba caroliniana*), floating fern (*Ceratopteris thalictroides*), and yellow pond lily (*Nuphar lutea*) (Denena et al., 2003).

Capture and Radio Telemetry Techniques

From May 2003 to June 2004, turtles were captured using basking traps, dipnets from a canoe, and by hand as females came on land to nest. Ten female and nine male adult *P. texana* with minimum weights of 900 grams were captured (IACUC #03CA888B30_03) and equipped with radio transmitters.

Standard measurements and data of each turtle were taken on initial capture, including sex, body weight, carapace length and width, and plastron length to the nearest millimeter (Ernst et al., 1994). For identification, newly captured turtles were coded with notches in the marginal scutes (Cagle, 1939; Plummer, 1979). A carapacial code was marked on the left and right marginal (LM and RM) scutes and a yearly plastral code was marked on the left or right gular or humeral scutes (lg, rg and lh, rh). A Passive Integrated Transponder (PIT) tag (AVID Identification Systems, Inc.; Norco, CA) was inserted under the skin on the turtle's right forelimb (Buhlmann and Tuberville, 1998) (Table 1). Marks and PIT numbers from previously captured turtles were recorded.

Standard radio telemetry techniques were used to track the turtles (Shubauer, 1981; Rowe and Moll, 1991; Carter et al., 1999; Milam and Melvin,

Date	Mark	PIT	Frequency	Sex	CL (mm)	CW (mm)	PL (mm)	WT (g)	Capture Method
19-Oct-2003	LM1,5-RM1,5lg2	031-578-099	151.020B	F	268	202	246	2500	Dipnet
12-May-2004	LM2,3-RM1rh	031-584-108	151.040B	M	232	171	191	1400	Basking trap
5-Apr-2004	LM3,8-RM5rg	051-099-016	151.060B	F	281	209	254	2550	By hand
27-May-2004	LM1 lg2	051-559-079	151.080B	M	198	143	174	860	Basking trap
27-May-2004	LM1,3-RM2lg	051-372-887	151.100B	M	206	154	177	950	Basking trap
23-Apr-2004	LM8 lh	051-124-050	151.120B	M	213	132	179	1050	Basking trap
2-May-2003	LM2,4-RM7lg	017-003-081	151.140A	F	290	213	256	2950	By hand
27-May-2004	LM2RM11rh	025-256-822	151.160B	M	210	156	175	1050	Dipnet
2-May-2003	LM1,6-RM1lh	051-070-583	151.180A	F	282	199	250	2600	By hand
2-May-2003	LM1,7-RM7rh	025-535-848	151.200A	F	277	197	243	2450	By hand
27-May-2003	LM8rg2	——	151.220A	M	206	157	173	1100	Basking trap
8-Apr-2004	LM7-RM6rg	015-517-547	151.240B	F	298	212	257	3150	By hand
29-May-2003	LM1,2-RM1mg	031-584-881	151.260A	M	243	178	217	1825	Basking trap
29-Apr-2004	LM1,2-RM11mg	031-581-797	151.280B	M	247	179	206	1550	Basking trap
27-May-2004	RM7 lh2	051-333-110	151.300B	M	198	150	171	835	Basking trap
1-Jun-2004	LM1,7-RM6rh	025-518-781	151.320B	F	233	176	200	1475	Basking trap
4-Apr-2004	LM1,2-RM6lg	015-026-544	151.340B	F	315	217	275	3950	Basking trap
6-May-2004	RM1 lh2	051-264-308	151.360B	M	255	186	217	2850	Basking trap
25-Oct-2003	LM1,6-RM6rg2	051-268-528	151.380B	F	287	225	258	3250	Dipnet
16-Nov-2003	LM1,8-RM4rg	025-087-292	151.400B	F	288	205	257	—	Basking trap

Table 1. Initial data taken on captured and telemetered turtles at Spring Lake. CL = carapace length, CW = carapace width, PL = plastron length, WT = weight.

2001) from May 2003 to February 2005. All turtles were equipped with Telemetry Solutions transmitters (model TS-25), with frequencies ranging from 151.020-151.400. Originally, 20 turtles were fitted with a 28 mm diameter transmitter with a 30 cm long free-trailing whip antenna weighing 14 grams (Fig. 2). Since *Pseudemys* are known to shed their scutes annually (Ernst et al., 1994), the outer keratin layer of the right, anterior pleural scute was removed and the transmitter was attached to the underlying keratin using PC-7 epoxy (Protective Coating Co.). The transmitters were attached in a way that did not hinder the normal behavior or movements following the manufacturer's instructions as well as Schubauer's protocol (1981).

Due to problems with waterproofing, only 4 original transmitters remained operational during the project. A new transmitter design was developed mid-study by Telemetry Solutions. These transmitters were a modified version of the TS-25 model. The transmitter was 30 mm in diameter, due to an increase in potting material, with a loop antenna completely incased in waterproof potting (Fig. 3). These transmitters weighed 18 grams, had a pulse rate of 55 ppm, and had a battery life of 18 months. Fifteen new turtles were equipped with the modified transmitters, which were applied in the same manner as the previous transmitters, and met the recommended loading of ≤ 5% of the animal's body weight (Kenward, 2001).

Locating and observing turtles were acheived from a canoe and from the shore. A custom receiver and antenna (Televilt TVP Positioning AB) were used to locate each animal (Legler, 1979; 1996; Plummer et al., 1997; Morrow et al.,

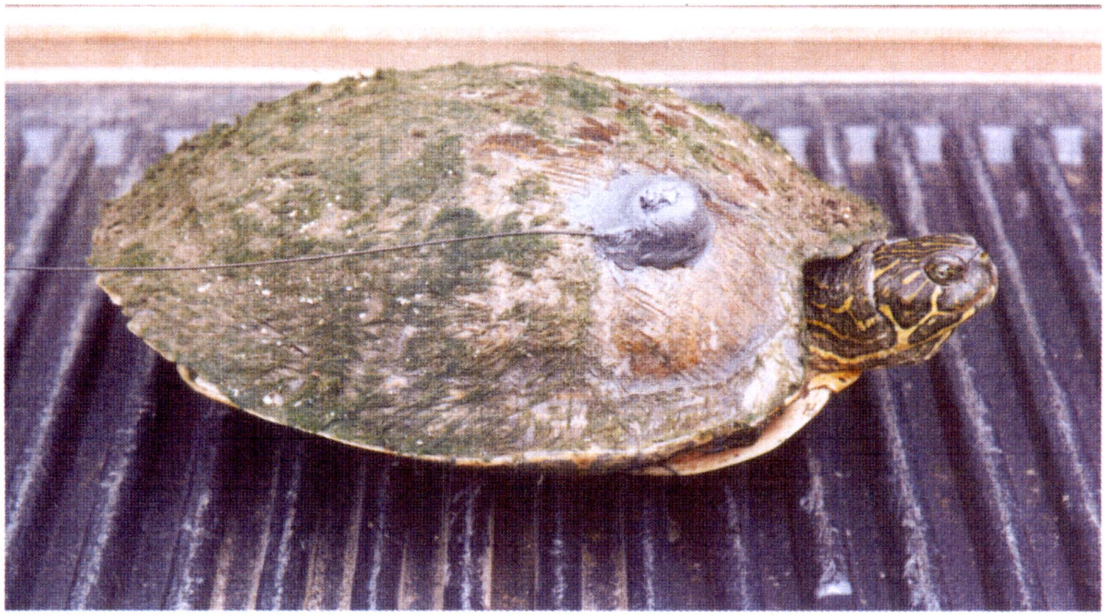


Figure 2. The original transmitter with a whip antenna.

Figure 3. The revised transmitter with a loop antenna.

2001). An attempt was made to track each turtle at least once a week. The order in which the turtles were located was randomized. Times for locating turtles were randomly assigned.

Time, date, and location were recorded at each observation and an attempt was made to make a visual sighting of each turtle. If the turtle was seen, its activity, such as basking, swimming (underwater or at the surface), and terrestrial movements (Haxton and Berrill, 2001; Galois et al., 2002), was recorded. Habitat description (water depth, vegetation) and microclimate parameters (air temperature, water temperature (ca.15 cm below the surface), wind, cloudiness, and presence of precipitation) also were recorded.

The location of each turtle was recorded with a Etrex Vista GPS (Garmin International, Inc.; Olathe, KS). These points were entered into the Geographic Information System (GIS) software Arc GIS 9.1. Locations were marked on a site map and used to calculate home ranges and movements.

Analysis Techniques

Both yearly and seasonal home ranges were calculated for all turtles. Home range size was estimated by the Minimum Convex Polygon (MCP) method (Samuel and Fuller, 1996; Carter et al., 1999; Galois et al., 2002) using the GIS extension Hawth's Tools 3. This yielded MCPs that included both the lake and the surrounding land areas. Because *P. texana* seldom travels on land except for nesting purposes (Vermersch, 1992), home ranges were clipped to include only the lake area (Fig. 4). In the case of disjunct home range segments

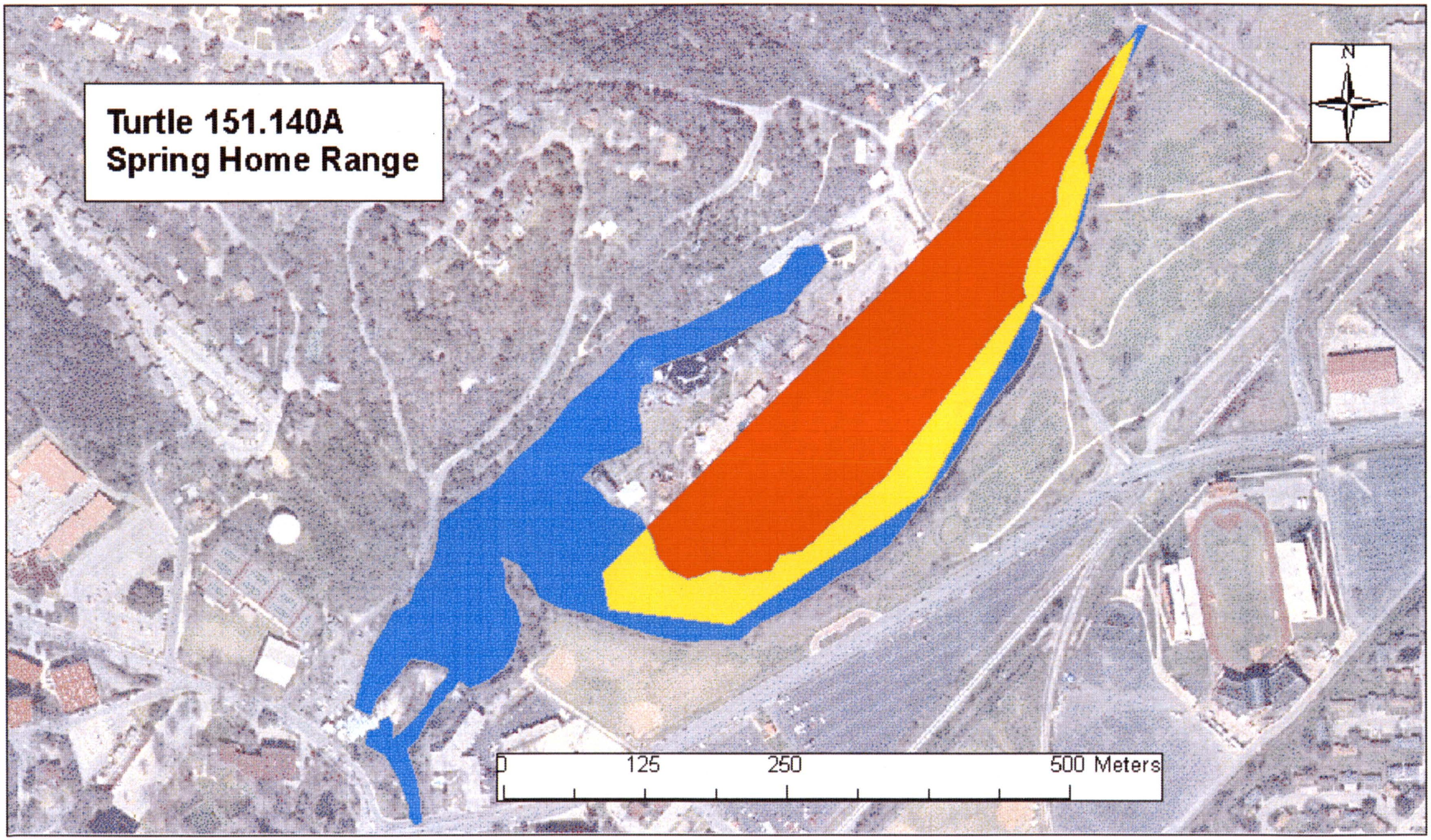


Figure 4. Spring Minimum Convex Polygon (MCP) of Turtle female151.140A modified to include only the aquatic habitat within Spring Lake. Red = the original MCP including the land area, Yellow = the new clipped MCP only including Spring Lake in its area.

produced by clipping, a minimum number of points were added to connect the disjunct sections around the lake (Fig. 5, 6). For those home ranges, a new home range estimate was calculated. A simple linear regression was run on the number of individual location points recorded for each turtle and the size of the home range to determine if the number of locations taken influenced the home range size. A two-sample t-test was run to test for differences between yearly home range size and sex. The seasonal home ranges were not statistically tested due to an insufficient number of locations recorded.

Seasonal shifts in home range locations were measured for each turtle for each season. A fixed map point was designated at the eastern bank of the main lake and used to calculate the distance to each point in each season (Fig. 7). The distances between the fixed point and each location were averaged for each season. A two factor repeated measures ANOVA, where turtles were nested in sex and crossed with season, was conducted to determine interactions between sex and seasonal mean distance traveled.

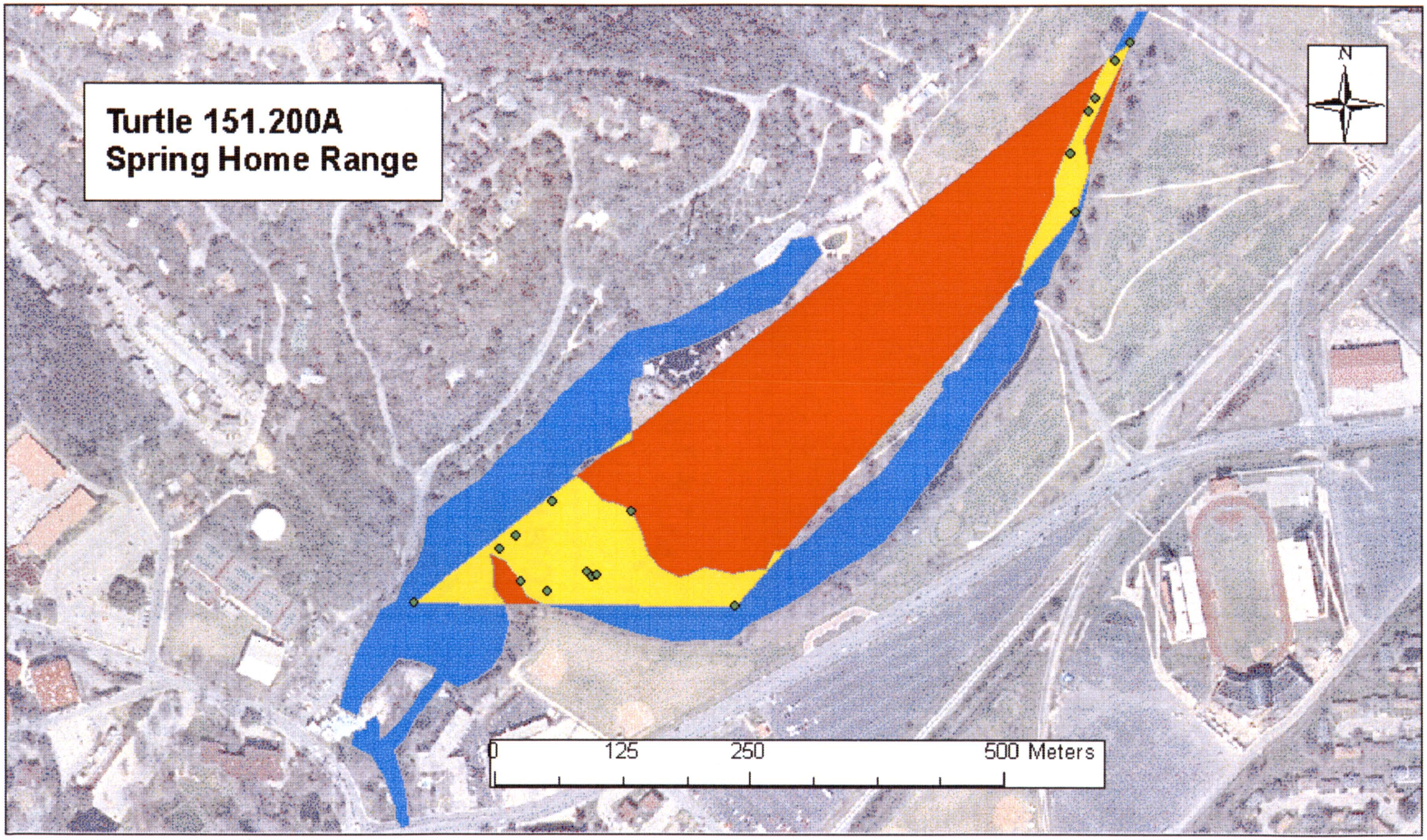


Figure 5. Modified spring Minimum Convex Polygon (MCP) of female Turtle 151.200A resulting in a disjunct home range. Red = the original MCP including land area, Yellow = a new disjunct MCP resulting from clipping the original MCP to only include Spring Lake in its area, Green points = original locations taken for this turtle.

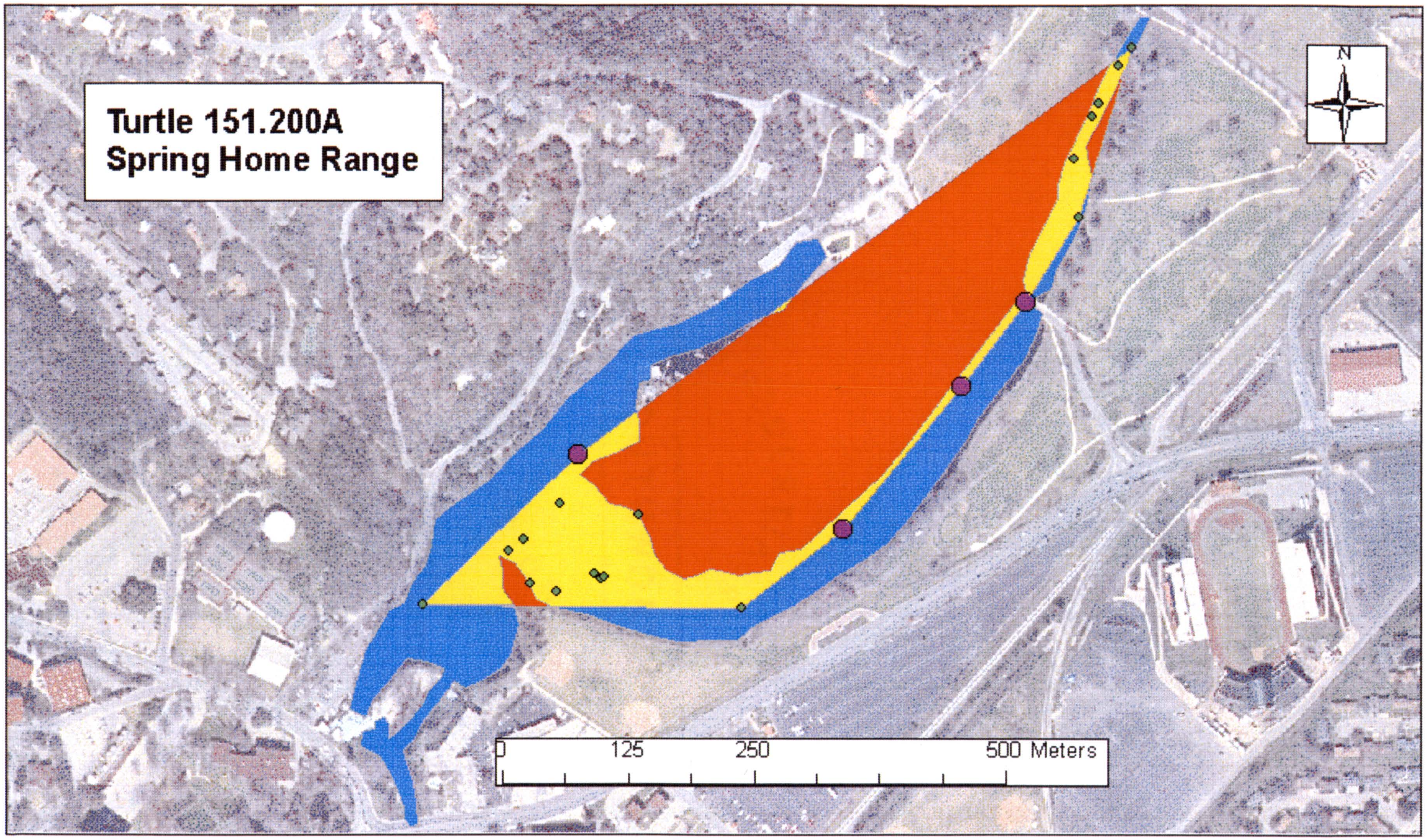


Figure 6. Points added to connect disjunct segments of the spring home range of female Turtle 151.200A. Red = the original Minimum Convex Polygon (MCP) including land area, Yellow = a new disjunct MCP resulting from clipping the original MCP to only include Spring Lake in its area, Green points = original location points, Purple points = added points to join the disjunct MCP.

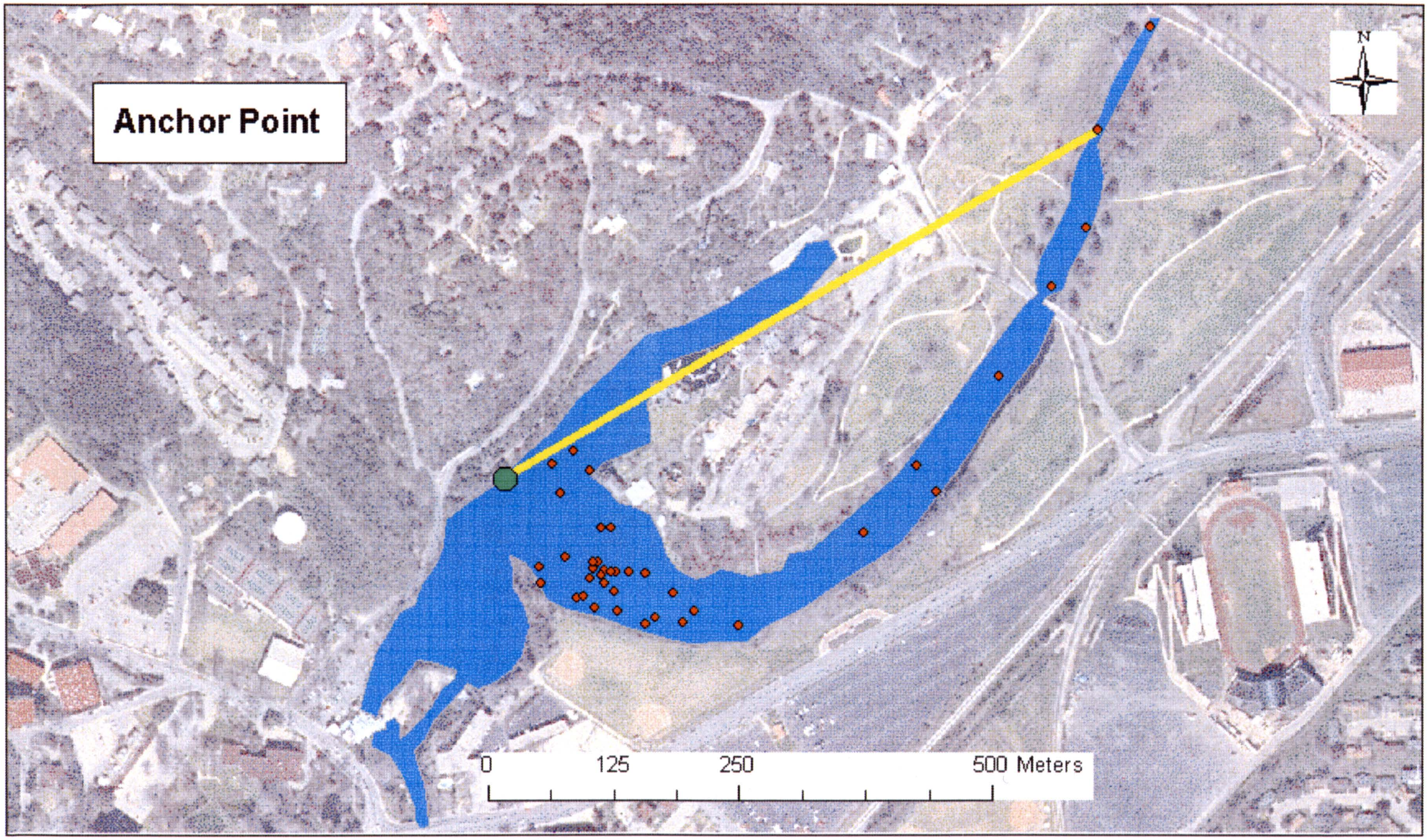


Figure 7. Distance measured from the fixed map point to a location in the spring to calculate a seasonal shift. Green point = fixed map point, Red points = original annual location points taken, Yellow line = distance measured that was used to calculate the mean seasonal shift distances.

RESULTS

Radio transmittered turtles (n = 19) were located a total of 22 to 40 times (mean = 28.8 locations) each during May 2003 to February 2005 (Table 2). A total of 547 unique locations was recorded (Figure 8). Annual home ranges were calculated for the 19 turtles. Home range size was not influenced by the number of locations recorded for either males or females (r^2 = 0.036 males and 0.085 females).

The mean annual home range for all telemetered turtles was 2.96 $\pm$ 0.27 ha (mean $\pm$ SE). The mean annual home range for female turtles was 3.77 $\pm$ 0.24 (min. 2.23 – max. 5.13 ha). Male turtles averaged 2.06 $\pm$ 0.30 ha (min. 1.05 – max. 3.6 ha) for the annual home range (Table 3). A two-sample t-test suggested that the females have a significantly larger yearly home range than males (P = 0.0002).

Seasonal home ranges were calculated for turtles that had a minimum of four locations for each season. Four seasonal home ranges (spring, summer, fall, winter) were calculated for 14 turtles (n = 9 females, n = 5 males) (Table 3). Mean home range sizes for females were larger than that for males during each season. Based on the results from the regression analysis ran on the yearly home range size and number of locations, there was an insufficient number of locations taken per season to test statistically.

Turtle	Sex	Date Transmittered	Date of Last Location	SPRING Mar. 20 - June 20	SUMMER June 21 - Sept. 21	FALL Sept. 22 - Dec. 20	WINTER Dec. 21 - Mar. 19	Total Number of Locations
151.020B	F	19-Oct-03	4-Feb-05	10	8 (2)	6 (3)	13	37 (5)
151.040B	M	12-May-04	21-Feb-05	5	8	5	7 (3)	25 (3)
151.060B	F	5-Apr-04	21-Feb-05	10	8	5	7	30
151.080B	M	27-May-04	21-Feb-05	2	8	5	7	22
151.100B	M	27-May-04	21-Feb-05	2	8	5	7	22
151.120B	M	23-Apr-04	21-Feb-05	6	8	4	7	25
151.140A	F	2-May-03	12-Jul-04	14	13	6	7	40
151.160B	M	27-May-04	21-Feb-05	2	8	5	7 (3)	22 (3)
151.180A	F	2-May-03	4-Jun-04	13	9	5	7	34
151.200A	F	2-May-03	17-Jun-04	17 (4)	8	6	7	38 (4)
151.220A	M	27-May-03	22-Jun-04	12	10	6	7 (2)	35 (2)
151.240B	F	8-Apr-04	21-Feb-05	10	8	5 (1)	6	30 (1)
151.280B	M	29-Apr-04	21-Feb-05	6	8 (1)	5	7	26 (1)
151.300B	M	27-May-04	21-Feb-05	2	8	5	7	22
151.320B	F	1-Jun-04	21-Feb-05	2	8 (5)	5	7	22 (5)
151.340B	F	4-Apr-04	21-Feb-05	10 (2)	8	5 (1)	5 (1)	28 (4)
151.360B	M	6-May-04	21-Feb-05	5	8	5 (3)	7 (1)	25 (4)
151.380B	F	25-Oct-03	9-Nov-04	11	8	7	7	33
151.400B	F	16-Nov-03	20-Oct-04	12	8	4 (1)	7	31 (1)

Table 2. Transmitter duration and number of seasonal and annual locations taken for all telemetered turtles at Spring Lake. Numbers in parenthesis represent the extra points added to join disjunct MCPs and calculate new home range areas.

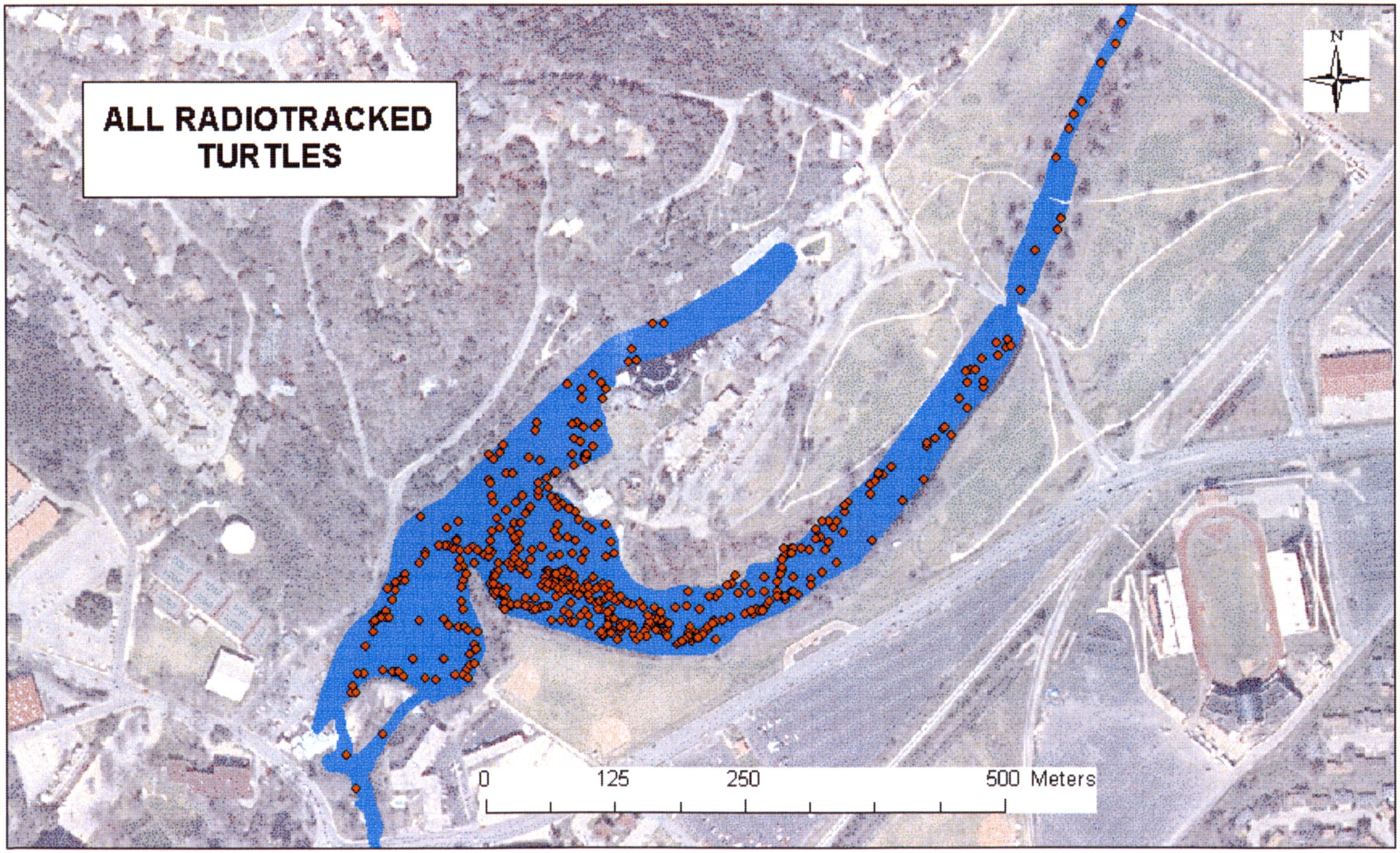


Figure 8. All unique locations taken for all 19 telemetered turtles at Spring Lake.

Turtle	Sex	Spring HR (hectares)	Summer HR (hectares)	Fall HR (hectares)	Winter HR (hectares)	Yearly HR (hectares)
151.020B	F	1.56	2.11	0.83	3.39	5.13
151.060B	F	0.54	1.13	0.18	0.19	2.23
151 140A	F	2.53	1.18	0.62	1.34	4.53
151.180A	F	1.28	2.09	0.31	0.61	3.48
151.200A	F	3.22	1.04	0.26	0.25	3.74
151.240B	F	1.36	1.67	2.18	0.76	3.85
151.320B	F	—	2.67	0.14	1.15	4.01
151.340B	F	1.27	1.14	1.21	1.47	3.93
151.380B	F	2.01	1.44	1.69	0.43	3.34
151.400B	F	1.22	1.85	0.93	0.72	3.44
MEAN		1.67	1.63	0.84	1.03	3.77
SE		0.27	0.17	0.22	0.29	0.24
151.040B	M	0.24	1.09	0.63	0.48	2.09
151.080B	M	—	0.72	0.72	0.36	1.22
151.100B	M	—	0.17	0.09	0.66	1.05
151.120B	M	0.15	1.35	0.19	0.65	2.05
151.160B	M	—	1.20	0.67	0.28	1.26
151.220A	M	0.78	1.97	0.62	0.22	2.15
151.280B	M	0.32	0.91	1.33	2.27	3.60
151.300B	M	—	0.21	1.43	2.28	3.37
151.360B	M	0.32	0.88	0.67	0.89	1.76
MEAN		0.36	0.94	0.71	0 89	2.06
SE		0.11	0.19	0.15	0.27	0.30
GROSS MEAN		1.20	1.31	0.77	0.97	2.96
SE		0.24	0.15	0.13	0.19	0.27

Table 3. Seasonal and annual home ranges (HR) areas and standard errors (SE) for all 19 telemetered turtles at Spring Lake. A dash indicates no home range was calculated.

Seasonal mean distances calculated between the fixed point and each location point for each season were tested for differences between males and females (Table 4). There is an interaction between season and sex ($P = 0.0001$). The seasonal mean distance to locations differed significantly between the seasons. During the spring, the mean distance to locations was large for the females (289.415 $\pm$ 28.081 m) as the locations shifted up into the slough, and it still remained large during the summer. The fall and winter mean distances to locations evened out and were close to the males' mean distances to locations. The mean distances to locations for males were constant across all the seasons and show no seasonal shift in the use of the lake.

Turtle	Sex	Spring (meters)	Summer (meters)	Fall (meters)	Winter (meters)
151.020B	F	250.75	148.15	183.26	157.86
151.060B	F	420.47	322.48	244.54	162.52
151.140A	F	397.27	124.23	142.95	130.13
151.180A	F	336.41	229.90	272.81	274.30
151.200A	F	333.35	116.98	178.76	147.01
151.240B	F	311.58	142.23	205.05	207.28
151.320B	F	151.88	280.05	111.06	154.77
151.340B	F	285.38	281.85	158.59	202.19
151.380B	F	169.25	116.50	110.28	143.83
151.400B	F	237.81	167.33	166.73	153.83
MEAN		289.42	192.97	177.40	173.37
SE		28.08	24.77	16.66	13.62
151.040B	M	84.21	93.71	140.04	97.16
151.080B	M	93.10	90.45	110.92	75.18
151.100B	M	197.70	169.02	206.93	252.53
151.120B	M	113.57	148.19	93.93	105.38
151.160B	M	240.47	269.57	274.19	252.91
151.220A	M	124.78	127.63	142.80	140.62
151.280B	M	153.60	127.49	101.79	146.82
151.300B	M	191.14	212.95	285.38	186.89
151.360B	M	269.68	275.97	278.50	298.49
MEAN		163.14	168.33	181.61	172.89
SE		21.88	23.33	26.79	26.43

Table 4. Mean distances and standard errors (SE) taken from the fixed map point for each season.

DISCUSSION

This study provides the first estimates for home range of *P. texana*, 3.78 ha for females and 2.06 ha for males. Kramer (1995) reported the home range estimate for Florida red-bellied turtles (*P. nelsoni*) in a Florida spring run and a shallow lake and compared those results to *P. floridana* found in the same spring run. He looked at the linear home range sizes in these turtles and found that *P. nelsoni* had a small home range, 120 m in length, with no differences detected between the sexes and *P. floridana* appeared to have a larger home range. Buhlmann and Vaughan (1991) estimated home ranges for two *P. concinna* (one female, one male) at 1.2 ha and 1.6 ha, but Dreslik et al. (2003) reported much larger home ranges in *P. concinna*. He estimated a mean home range size of 4.9 ha and 5.3 ha in males. This study's estimation of home range size of 3.78 ha for female and 2.06 ha for male *P. texana* falls between the estimates from these two studies for *P. concinna*.

No radio-telemetered *P. texana* used the entire lake in its annual home range. Spring Lake is 7.9 ha, and the largest annual home ranges were 5.13 ha (female) and 3.60 ha (male). These home range estimates are not confined by the area of the lake since none of the turtles used all of the available space in the lake. Female *P. texana* used 64.9% of the lake and males used 45.6% of the lake. Seasonal home ranges were smaller than the annual home ranges, and the turtles appeared to use specific parts of the lake during the year. These turtles appear to be selective in their home range locations.

There was considerable spatial overlap in home ranges between males and females. For turtles, home range size may be more strongly related to population density due to the high amount of competition and habitat quality rather than species-specific characteristics (Stickel, 1989; Gibbons, 1990). These home range sizes may be related to foraging strategies, the kind of food being utilized, and its distribution (McNab, 1963), as well as trophic status, productivity of habitat, season, and animal weight (Harestad and Bunnell, 1979). This study site appears to be a productive habitat for this species, and there are enough resources to limit the amount of competition occurring. Schubauer et al. (1990) suggested there could be a species-specific relationship of the home range of males and females. Females had significantly larger home ranges than males, and they appeared to use more of the lake than the males on average.

Little is known about the reproductive strategies of *P. texana* (Vermersch, 1992), but it is thought that they have similar breeding patterns to *P. nelsoni* (Ernst et al., 1994). Mating occurs from October to March, but possibly throughout the year in *P. nelsoni* (Ernst et al., 1994). Male turtles are expected to invest more energy during breeding season to find mates and, therefore, will move greater distances than females during the mating season to increase their reproductive success (Morreale et al., 1984; Brown and Brooks, 1993). Females should have a low level of activity until the nesting season (Gist and Jones, 1989). At that time their movements should equal or exceed those of the males due to searching for nest sites (Morreale et al., 1984). During this research, female home ranges for fall and winter were the smallest, and home range size increased for the spring and summer supporting Morreale's (1984) and Brown and Brook's (1993) hypothesis. However, male's home ranges were similar for all seasons except the spring, which was substantially smaller, and there was no observed seasonal shift in location.

The hypothesis that males will move greater distances during the breeding season to find mates only holds true if there are few females. At Spring Lake, there are a total of 1,323 marked *P. texana*. This amounts to 167.5 turtles per hectare with a 1.5 males: 1 female sex ratio. At this site, males do not have to travel far in the breeding season to find a female.

Most locations were concentrated in the basin and slough, and no telemetered turtle was ever recorded in the headwaters of the lake in Spring Run (Fig. 8). Lake and slough habitats differ markedly. The main lake is a different habitat compared to the slough. The main lake is lotic with less submerged vegetation, while the slough is lentic with higher amounts of submerged vegetation. Fields et al. 2003 reported the diet of *P. texana* consisted primarily of submerged vegetation, which could explain why more locations were found in the basin and slough because these areas have more food available.

Gibbons (1990) found that one reason for turtle movement is to locate basking sites. The slough has more basking sites, and turtles were seen basking more often in the slough than any other part of the lake. Shallower habitats are located in the slough where turtles may bask in shallow water and in dense muskgrass (*Chara* spp.) without structures such as fallen logs. These habitat differences might affect the home range sizes, and these turtles could be actively selecting certain areas in the lake to conduct their daily activities.

Reagan (1974) stated that since turtles are ectothermic animals their use of the environment may be constrained by physical factors. This did not pose a significant problem at this study site because the lake is spring fed and remains a stable temperature year round (Groeger et al., 1997). However, temperature fluctuations are greater in the slough because there is no spring flow in this area. Turtles were active year round, and found in both the main lake and the slough during the fall and winter, as well as in the spring and summer, indicating that the temperature changes are not a factor in any part of Spring Lake.

A large portion of female's annual home range was due to the size of the spring and summer home ranges (Table 4). This was due to a shift in location into the slough during the spring and summer nesting season. The majority of nesting for this species at Spring Lake occurs in April through June, (F. L. Rose per. comm.). The golf course surrounding the slough is a favorable nesting site for turtles. During the nesting season, females move upstream into the slough, prior to exiting the water. Females often are found resting on the banks of the slough before nesting actually occurs. Movement into the slough for staging and nesting purposes is responsible for the large seasonal shifts by females up the slough for the spring. Females were the only ones that moved into the upper reaches of the slough (Fig. 9), and this activity occurred primarily in the spring

(Fig. 10). These turtles still are found in the upper slough after laying in the spring before moving back down into the lower part of the slough and main lake. With locations still occurring in the upper slough in the summer, the summer home range size remains large.

While the majority of locations and movements were within Spring Lake during this study, one female was recorded below the dam in the San Marcos River in the fall. This female was recorded back in the lake in the winter (Fig. 11). Therefore, Spring Lake is not a closed system. Some turtles are immigrating and emigrating.

Home range estimates provide important ecological information needed for species conservation and aid in understanding their natural history. These data contribute to our understanding of mating patterns and reproduction, habitat selection and use, and differences in activity and movement patterns between sexes. This study has provided some much needed data on an ecologically neglected species, and will define some of *P. texana*'s natural history requirements. A more in depth study still is needed to ascertain movement patterns. Because this species also inhabits rivers, a similar study should be conducted in an open ended riverine habitat to elucidate similar movement patterns.

Turtle species are declining at an alarming rate worldwide (Ernst and Barbour, 1989). Many of these species have not been studied, and there is inadequate knowledge and understanding of their ecology. Sound life history

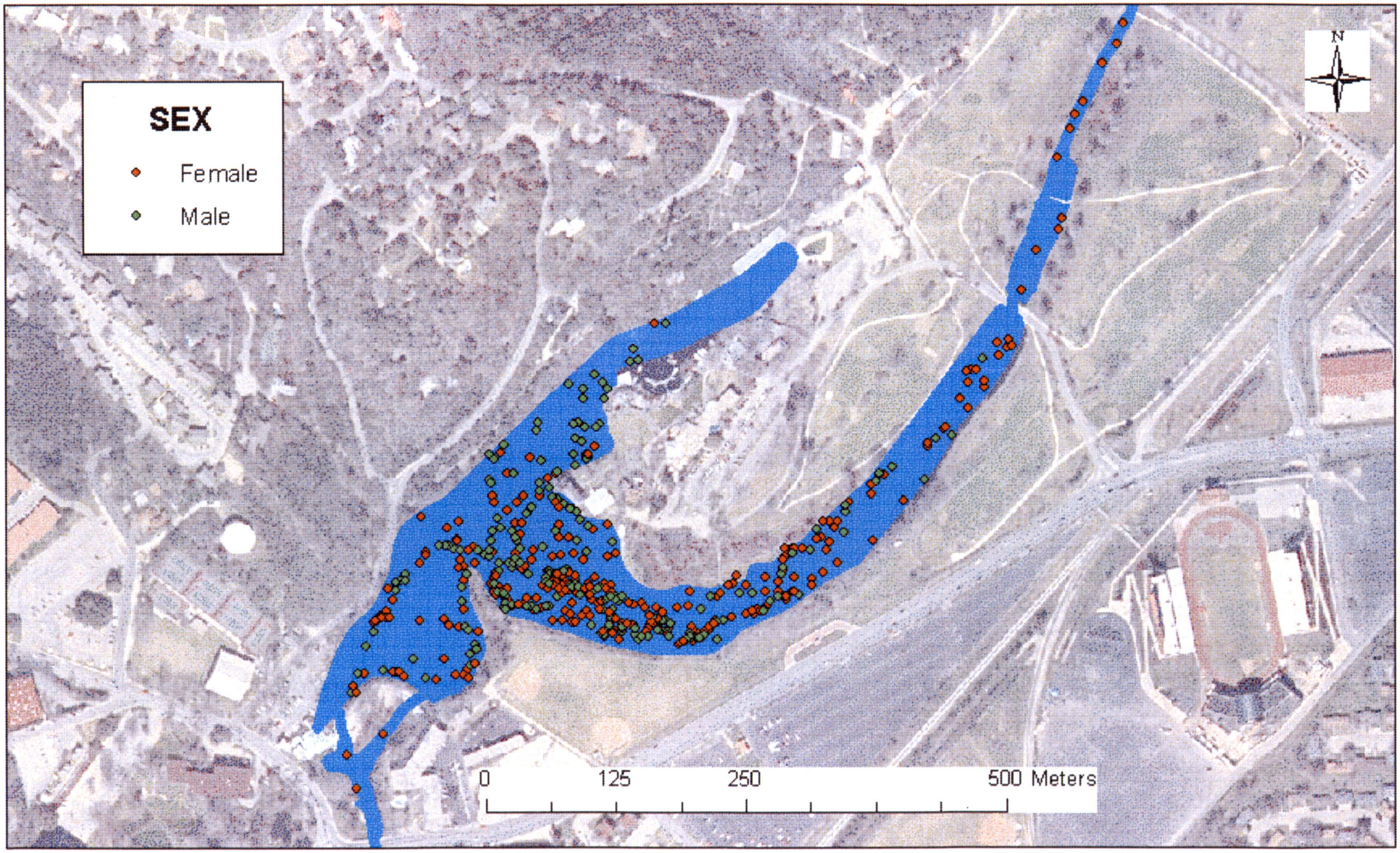


Figure 9. All unique locations taken from all 19 telemetered turtles at Spring Lake divided by sex.

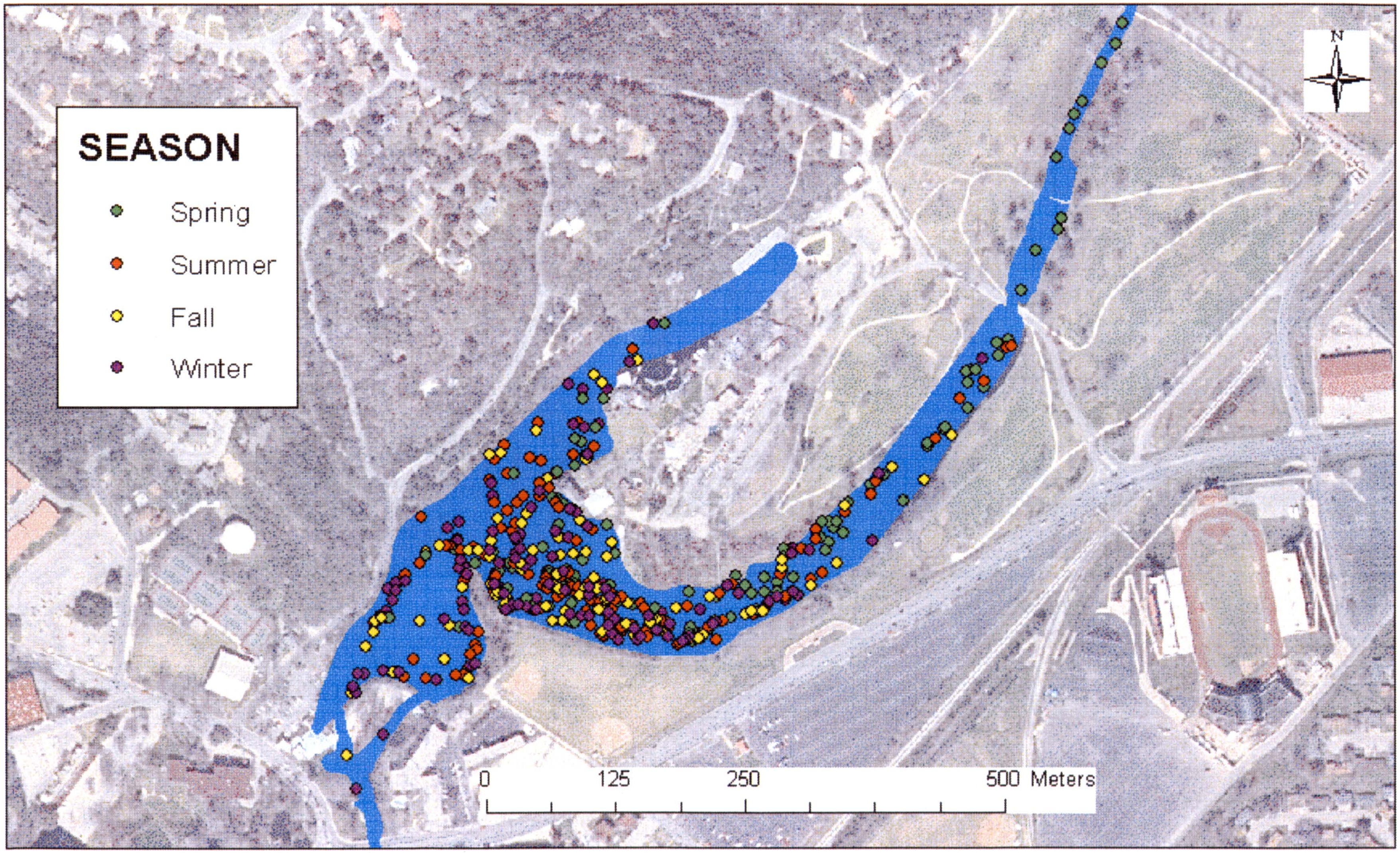


Figure 10. All unique location taken from all 19 telemetered turtles at Spring Lake divided by season.

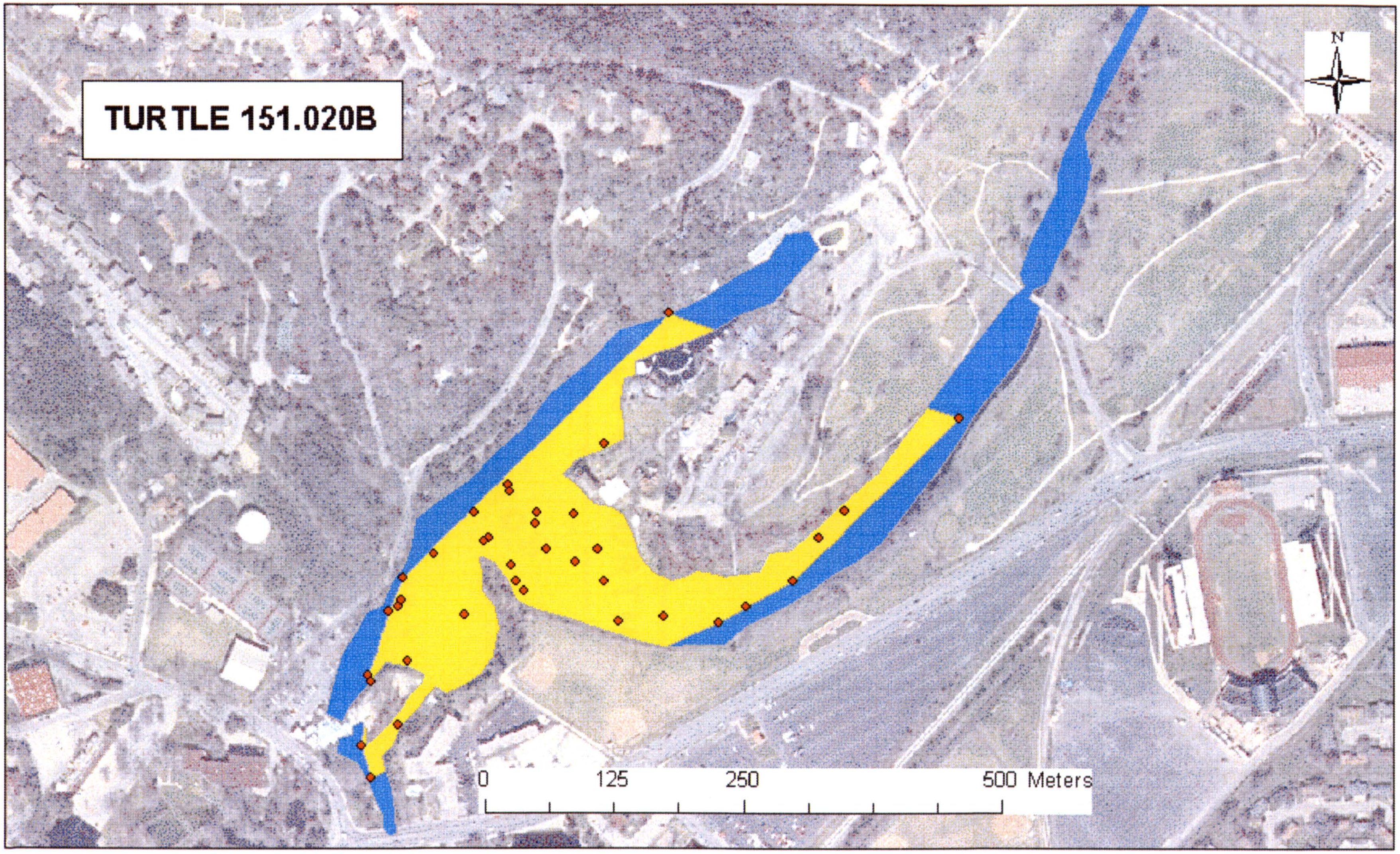


Figure 11. The annual home range area for female Turtle 151.020B.

information is critical to the conservation of these species (Ernst et al., 1994). The Big Bend slider (*Trachemys gaigeae*) and Rio Grande cooter (*Pseudemys gorzugi*), two poorly studied turtles, both are species of concern in Texas. Baseline ecological information is necessary on turtle species to use as comparison for ever changing populations. The data collected on *Pseudemys texana* in this study can be used as a life history model, and this information can be used to help understand other turtle species of similar size, habitat, and behavior, as well as aiding in the recovery and conservation of threatened and endangered species.

APPENDIX I

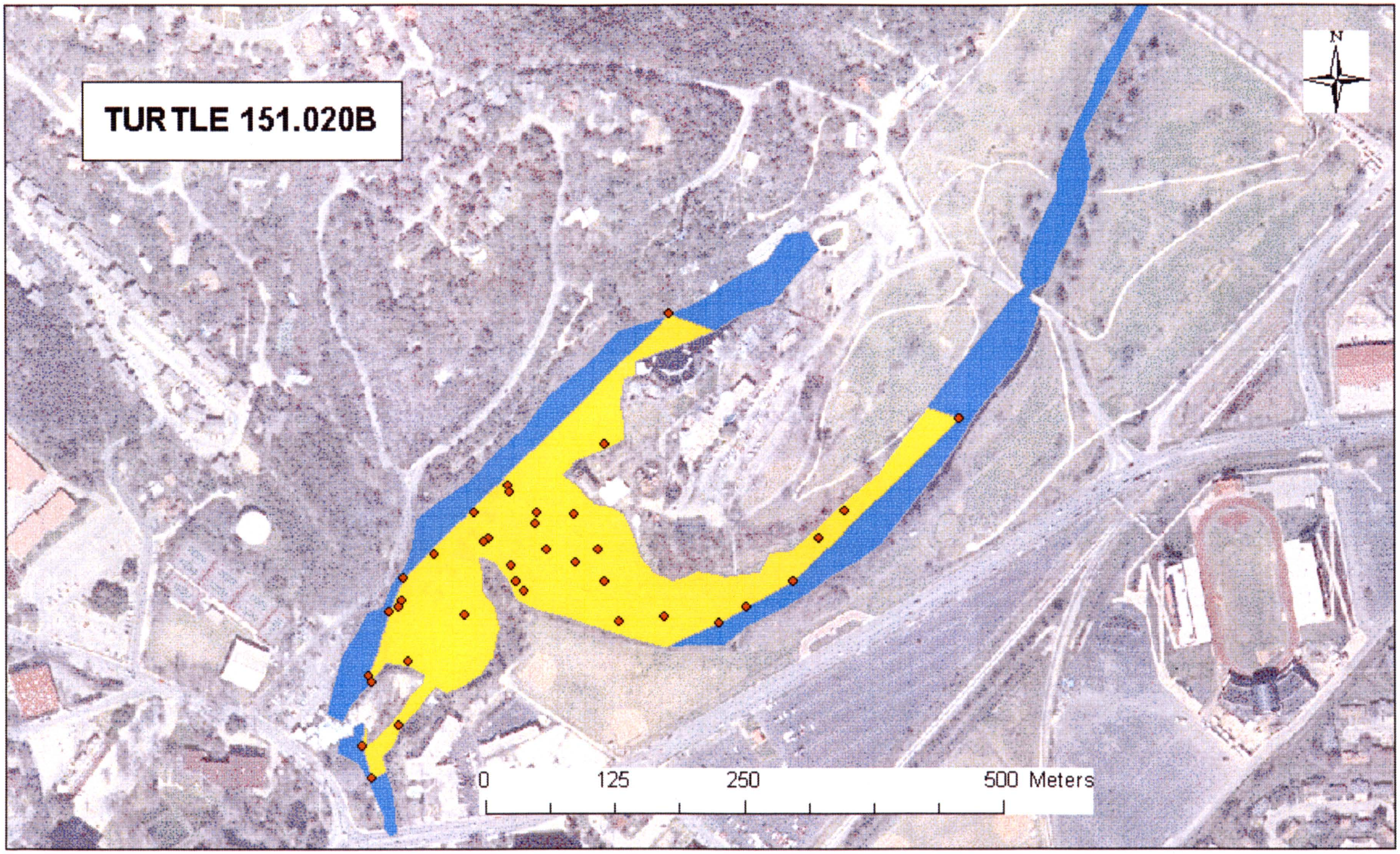


Figure 11. Annual home range for female Turtle 151.020B.

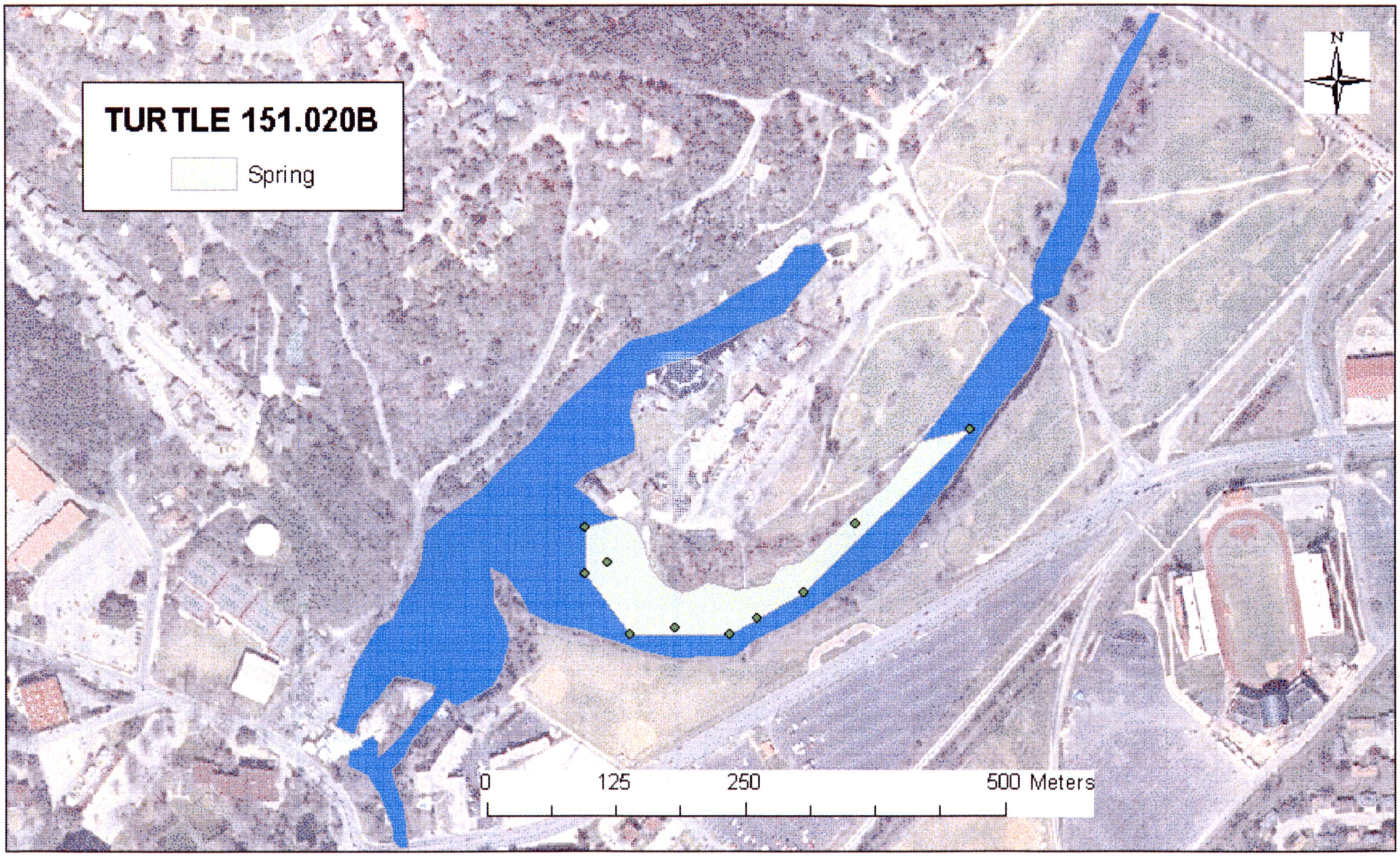


Figure 12. Spring home range for female Turtle 151.020B.

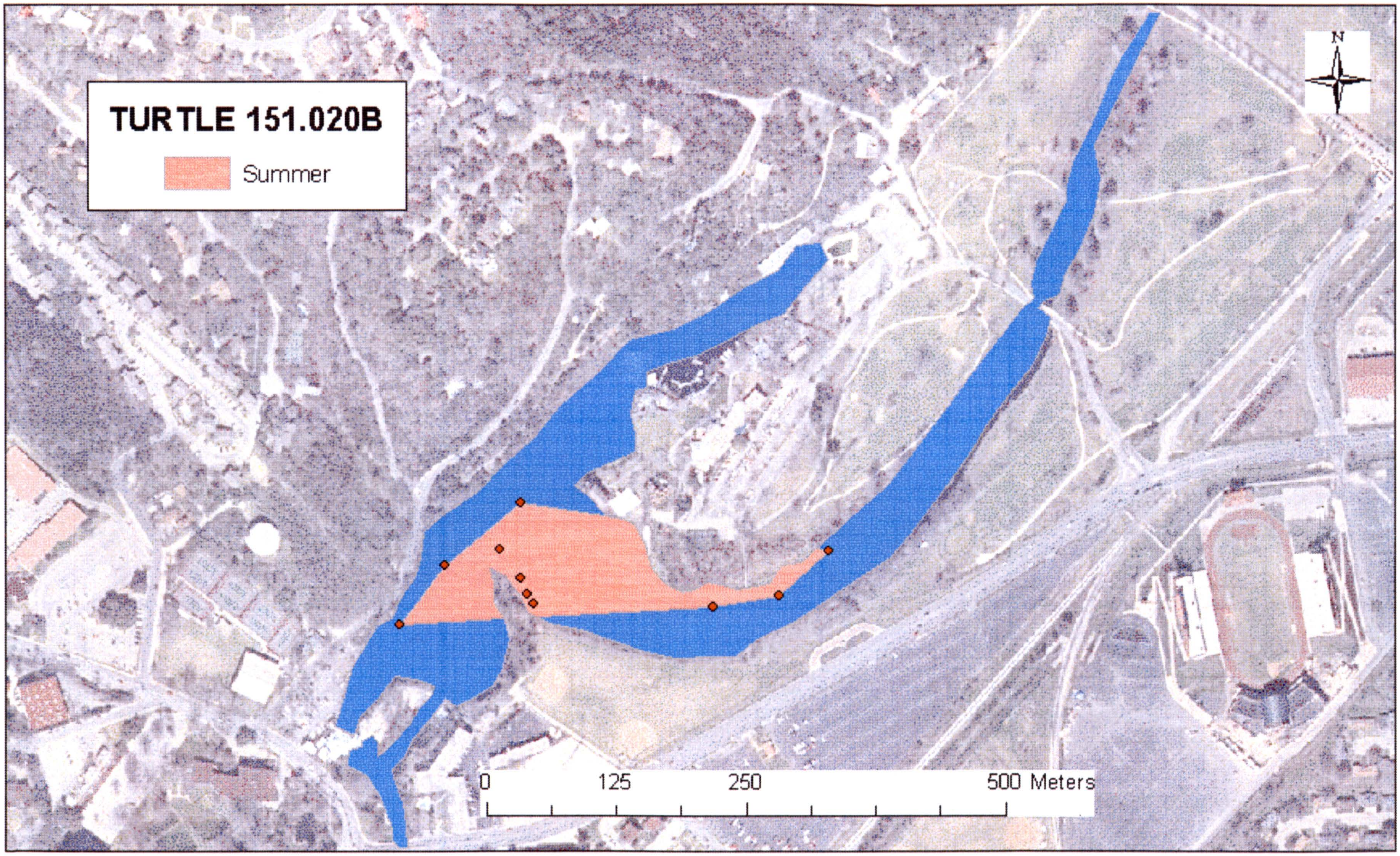


Figure 13. Summer home range for female Turtle 151.020B.

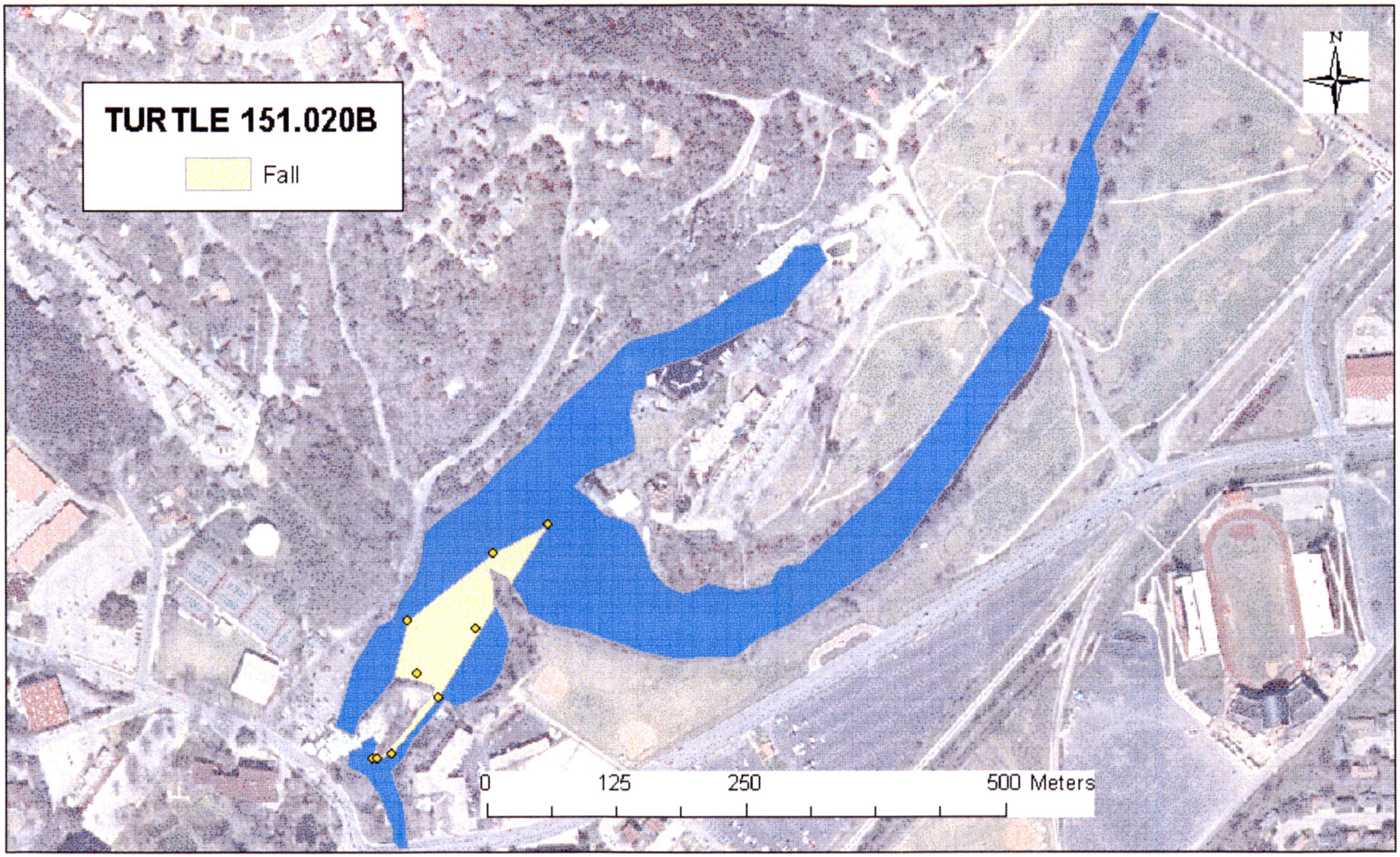


Figure 14. Fall home range for female Turtle 151.020B.

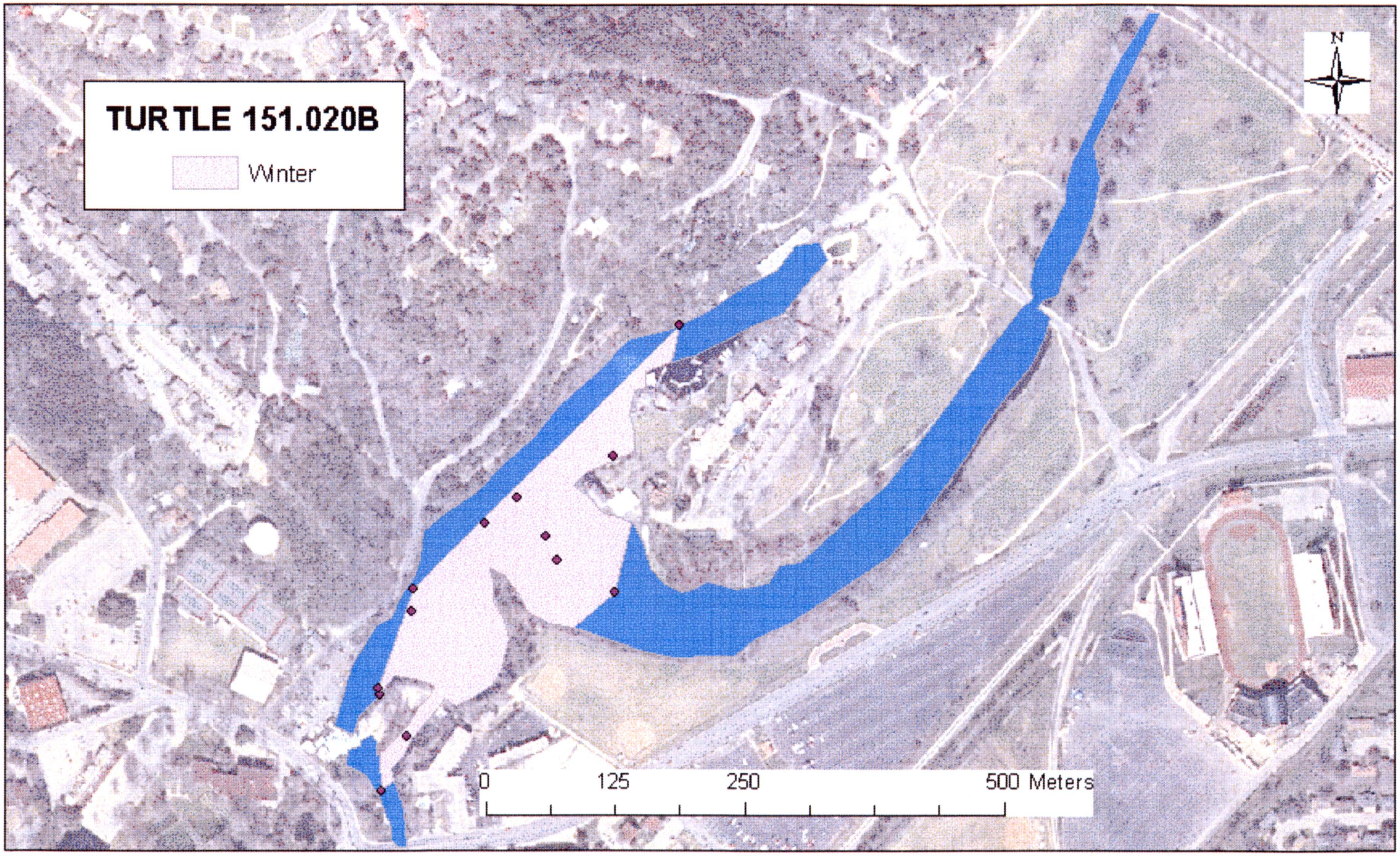


Figure 15. Winter home range for female Turtle 151.020B.

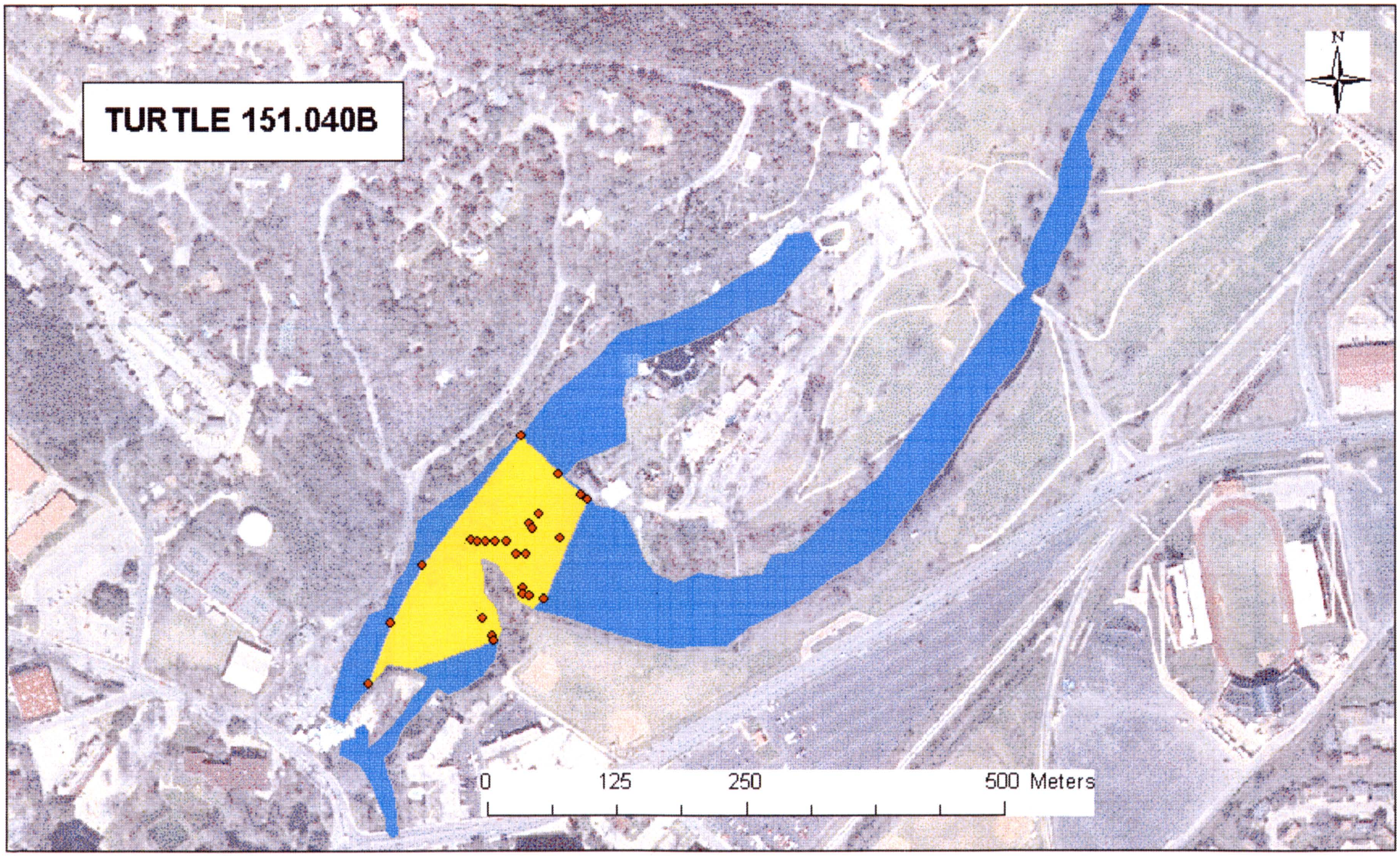


Figure 16. Annual home range for male Turtle 151.040B.

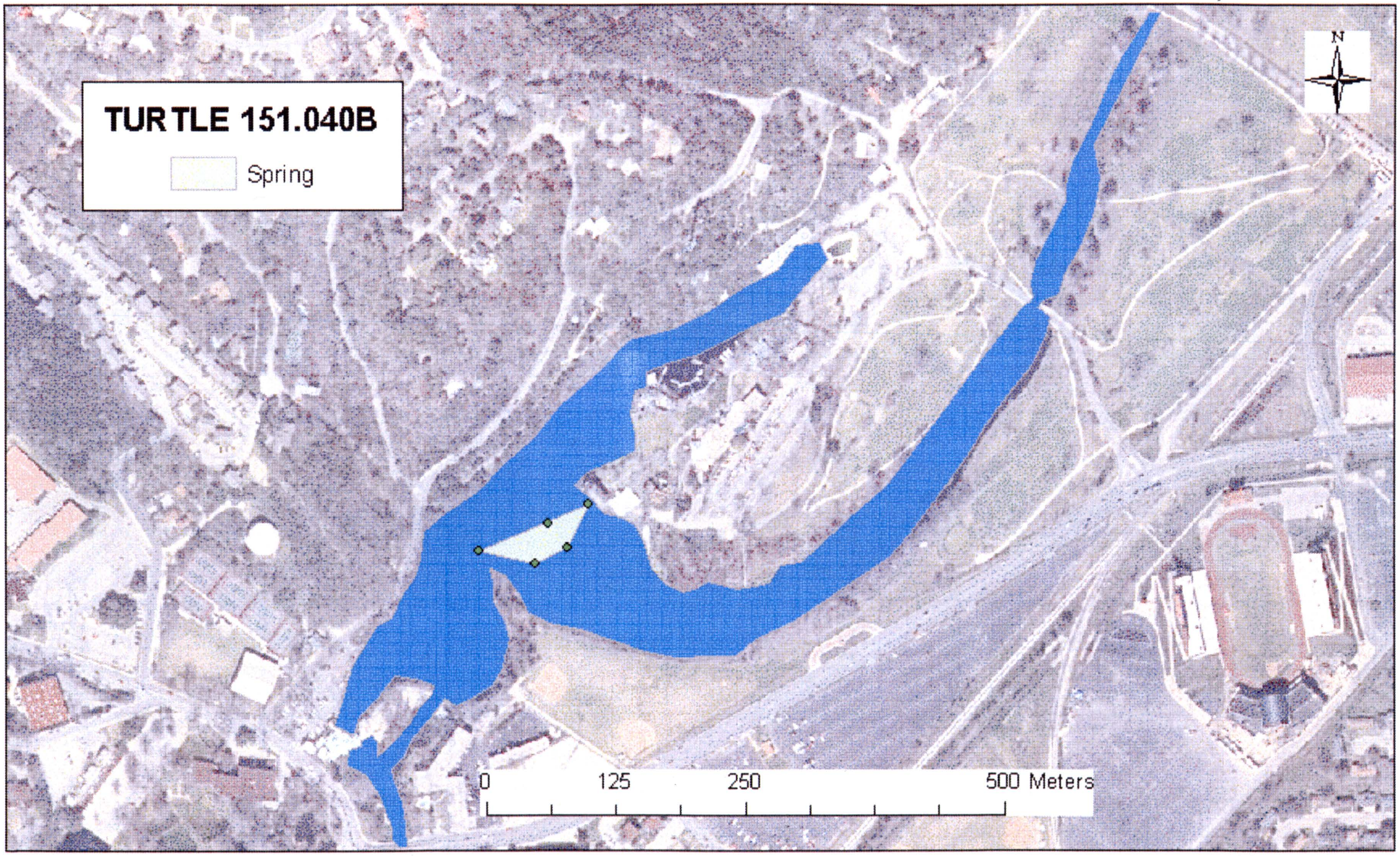


Figure 17. Spring home range for male turtle 151.040B.

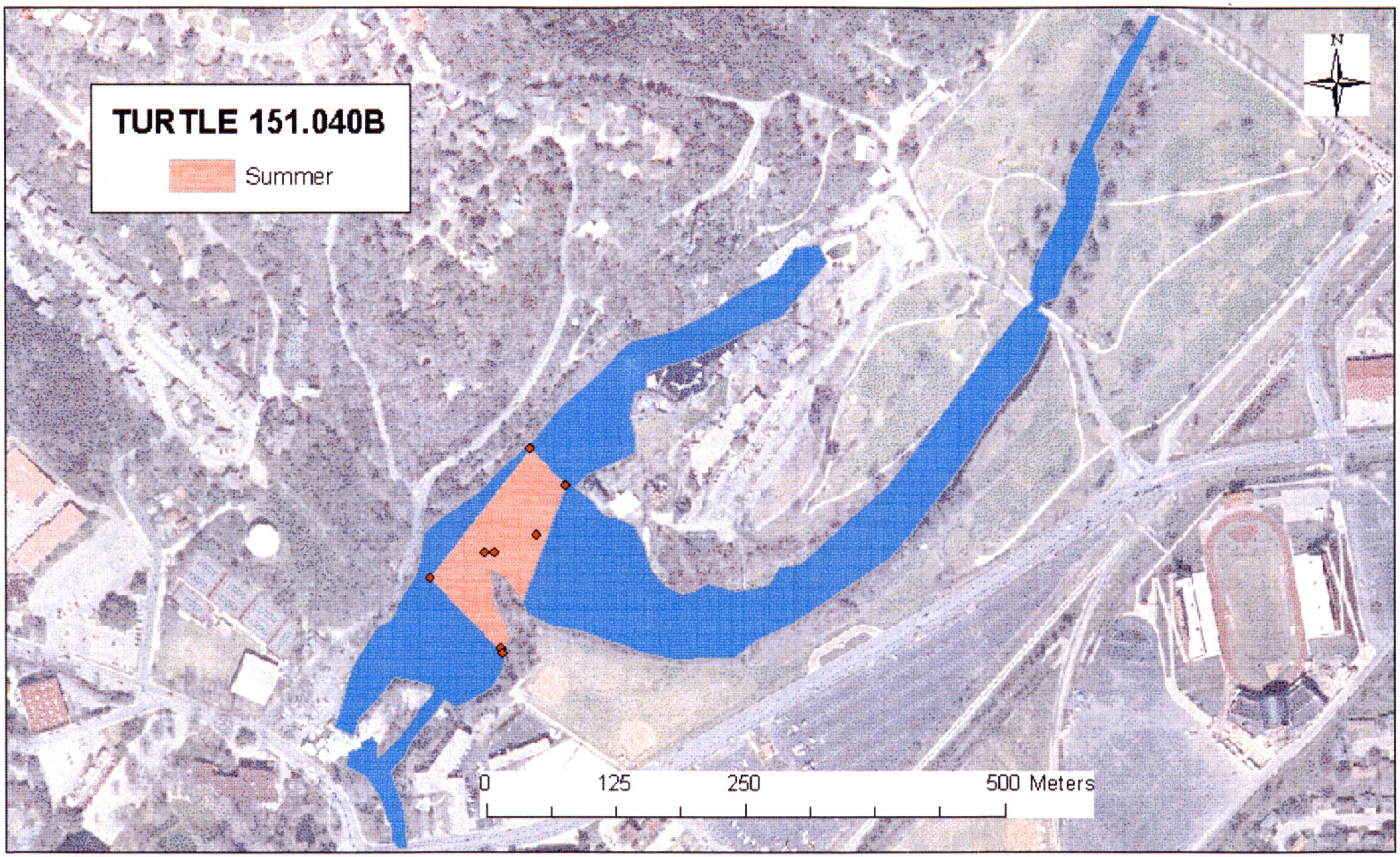


Figure 18. Summer home range for male Turtle 151.040B.

Figure 19. Fall home range for male Turtle 151.040B.

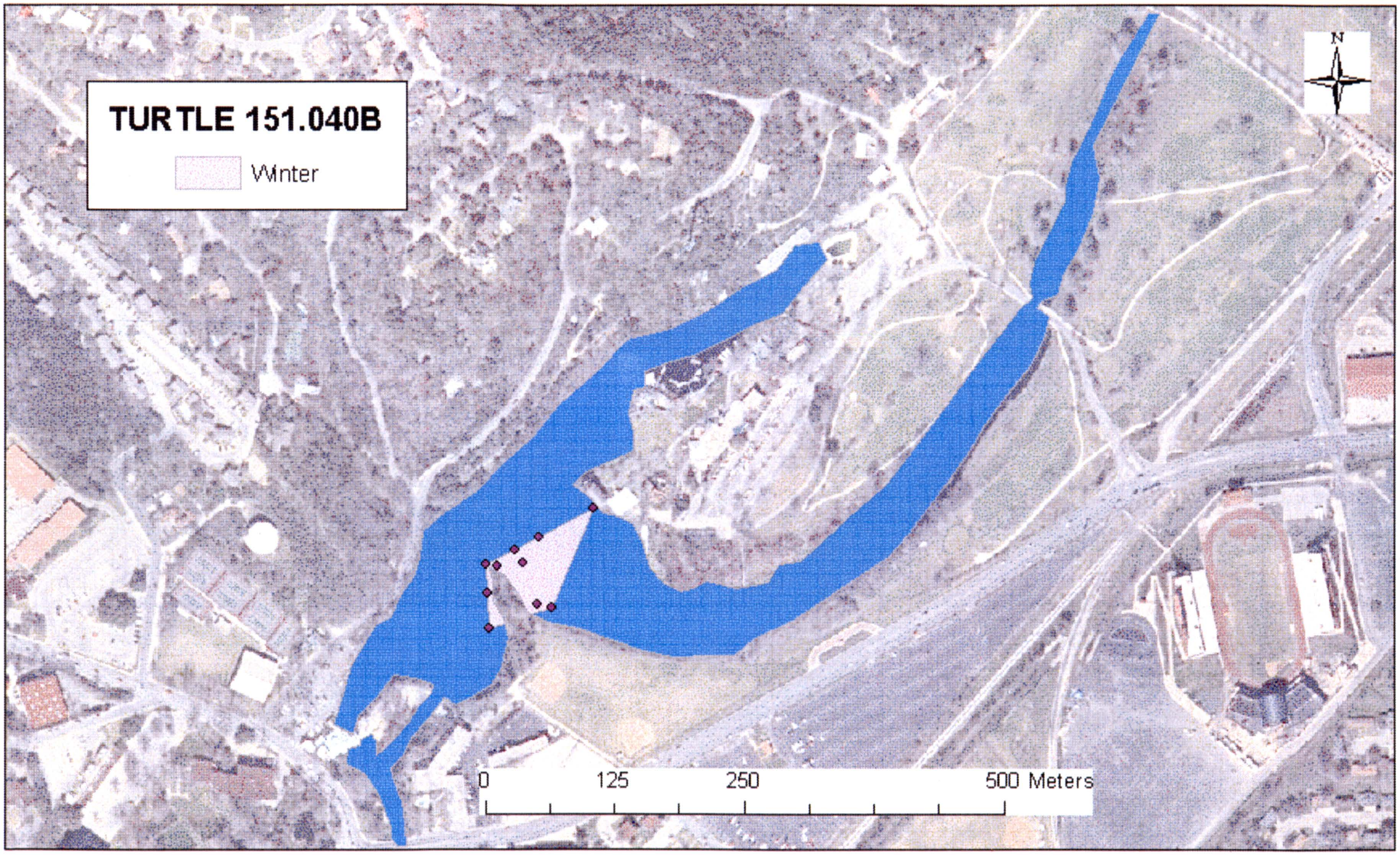


Figure 20. Winter home range for male Turtle 151.040B.

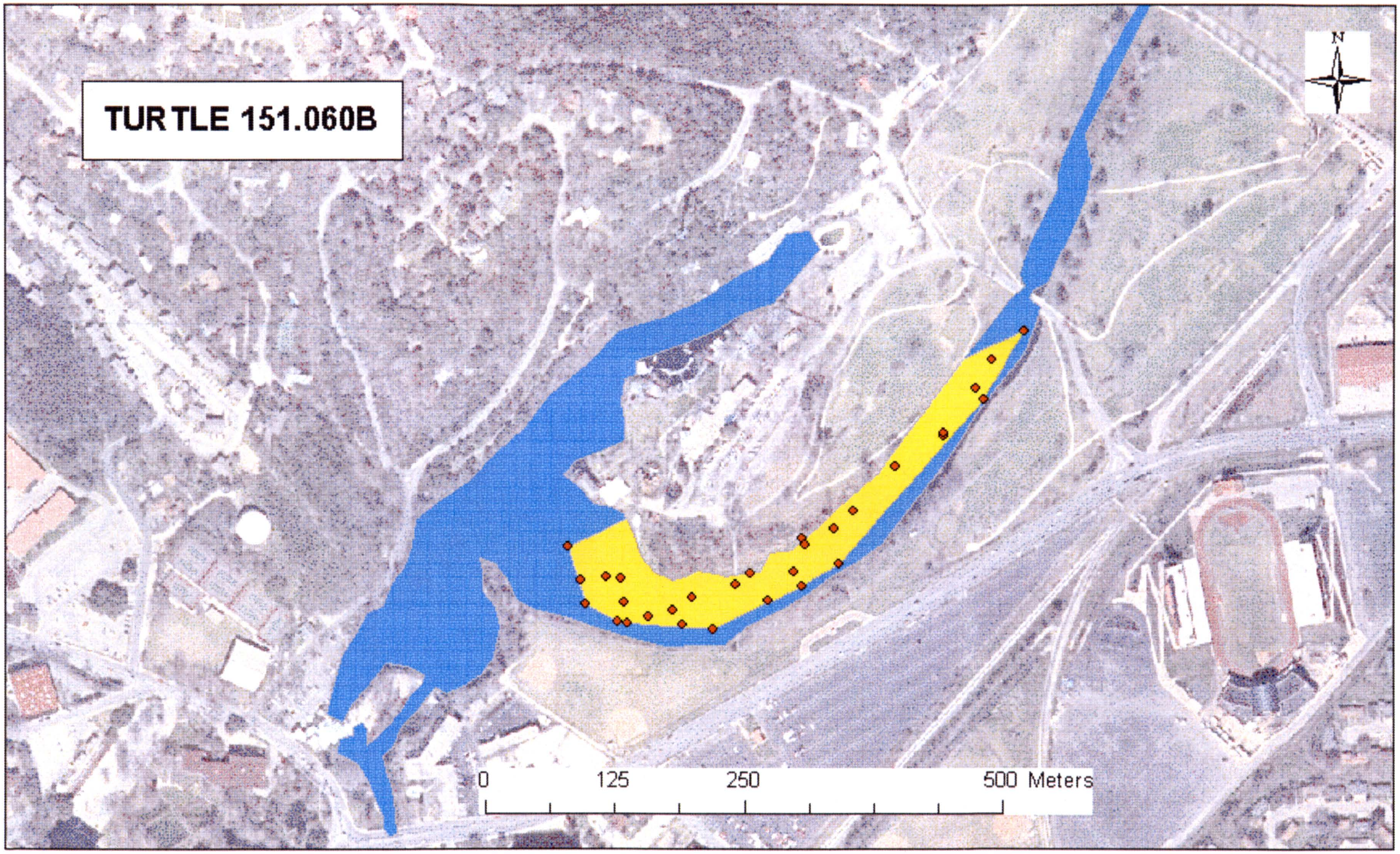


Figure 21. Annual home range for female Turtle 151.060B.

Figure 22. Spring home range for female Turtle 151.060B.

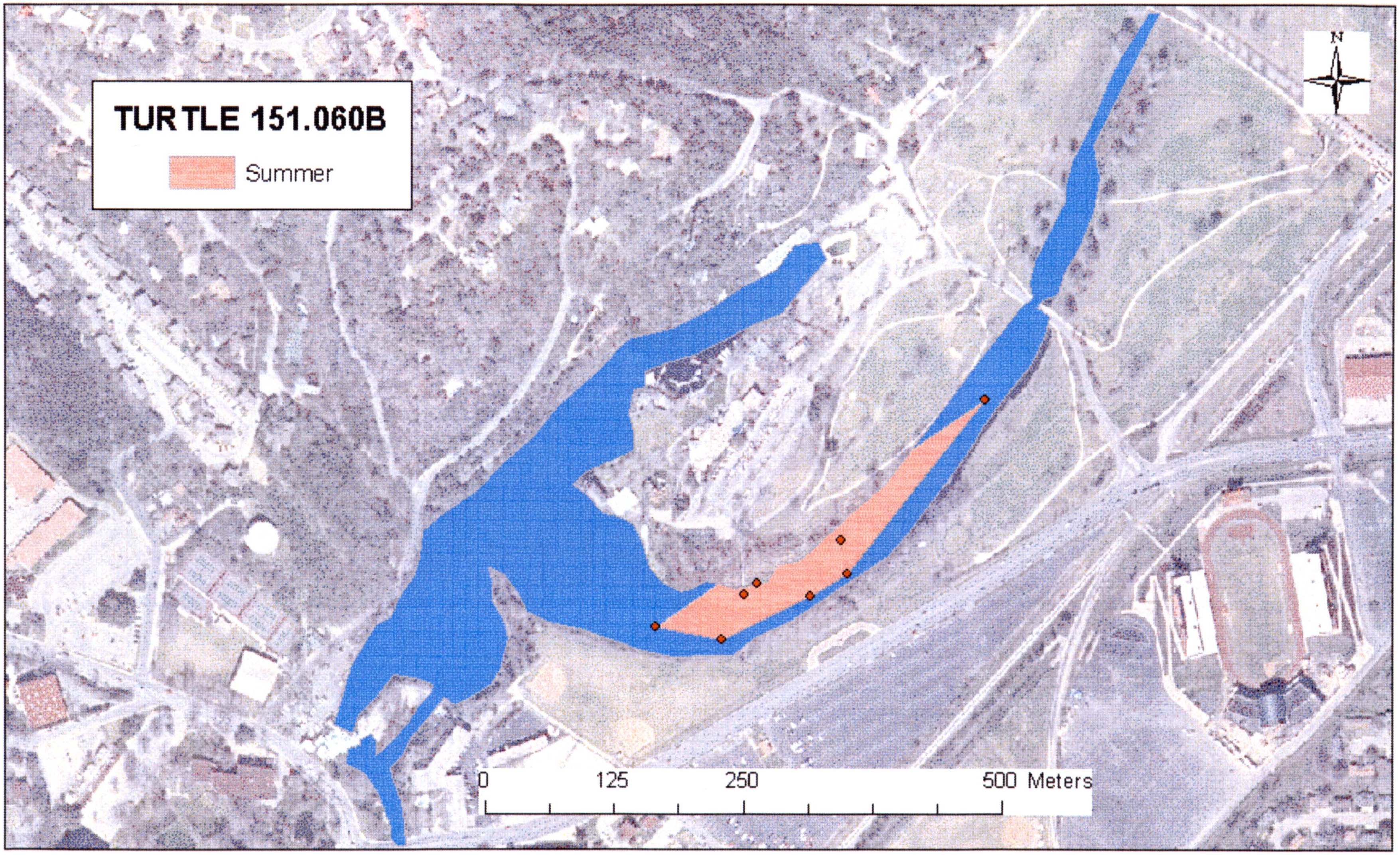


Figure 23. Summer home range for female Turtle 151.060B.

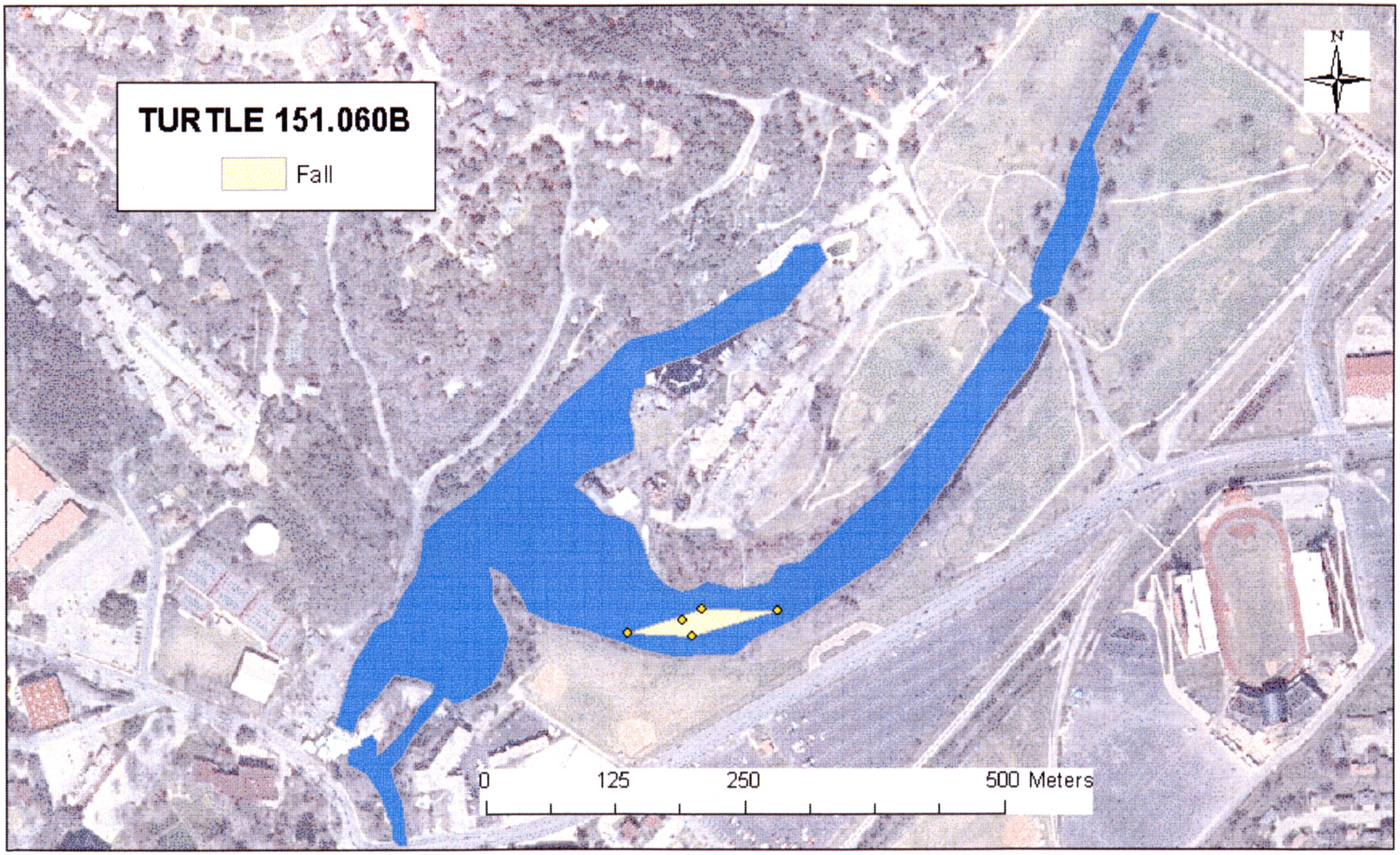


Figure 24. Fall home range for female Turtle 151.060B.

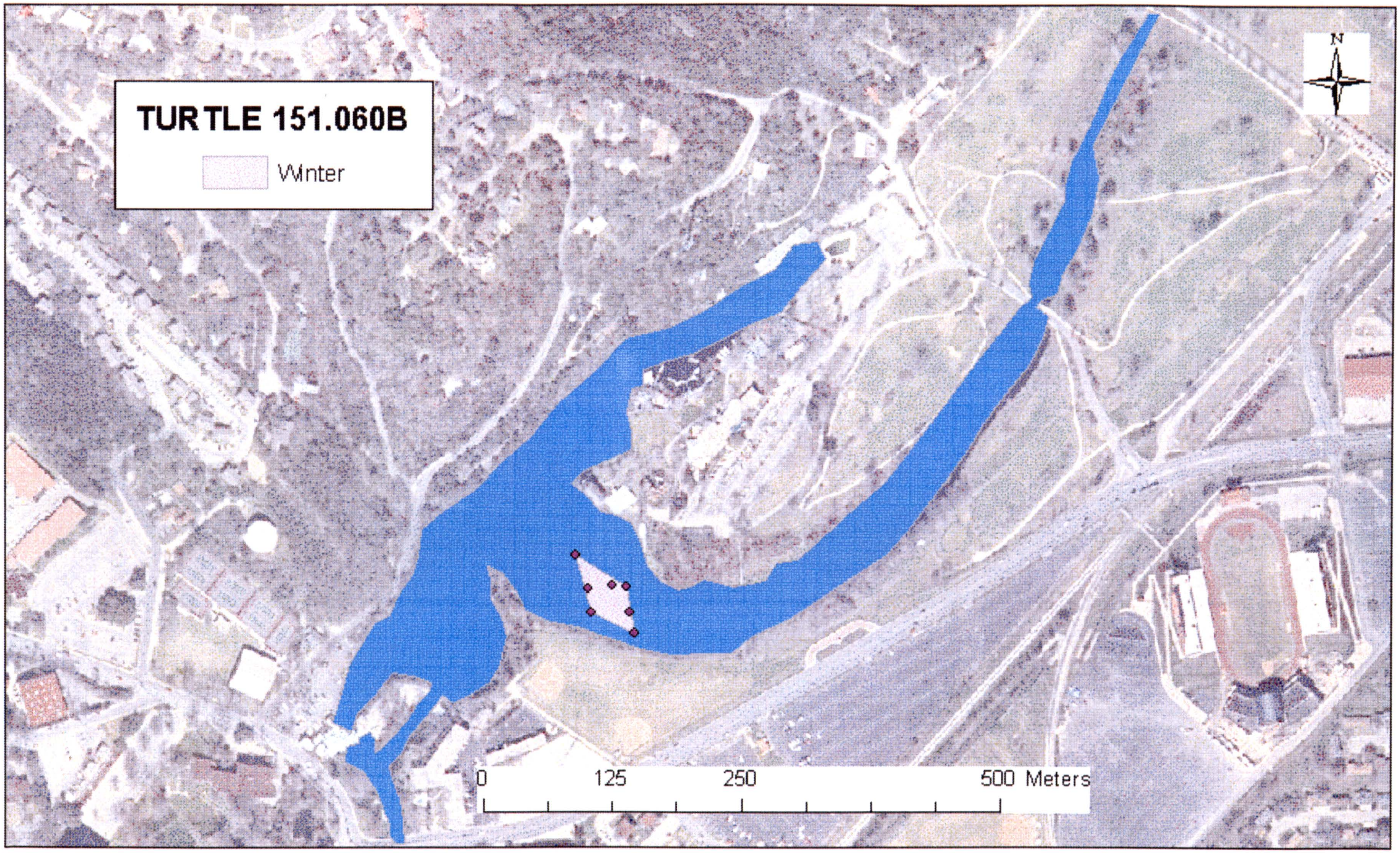


Figure 25. Winter home range for female Turtle 151.060B.

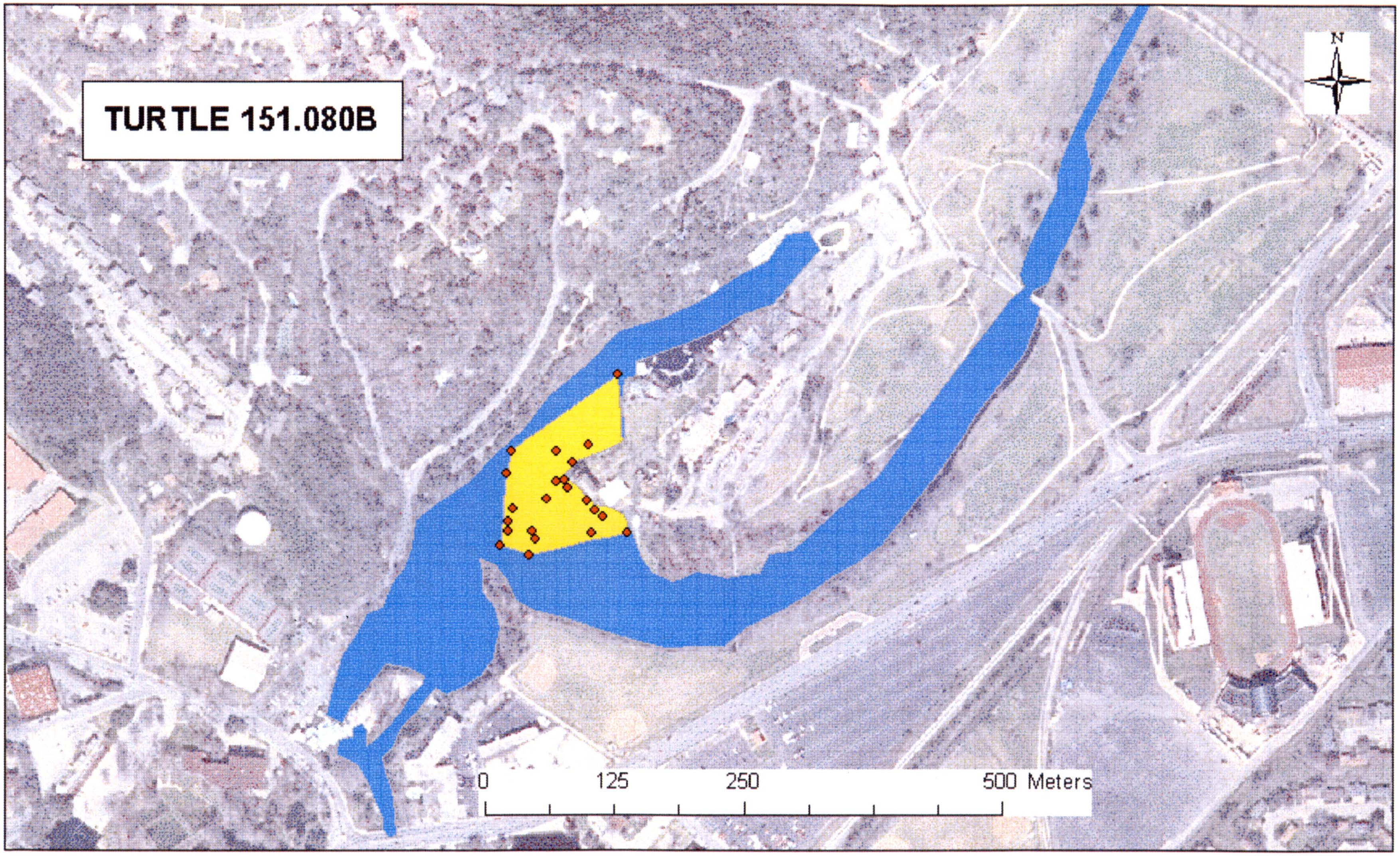


Figure 26. Annual home range for male Turtle 151.080B.

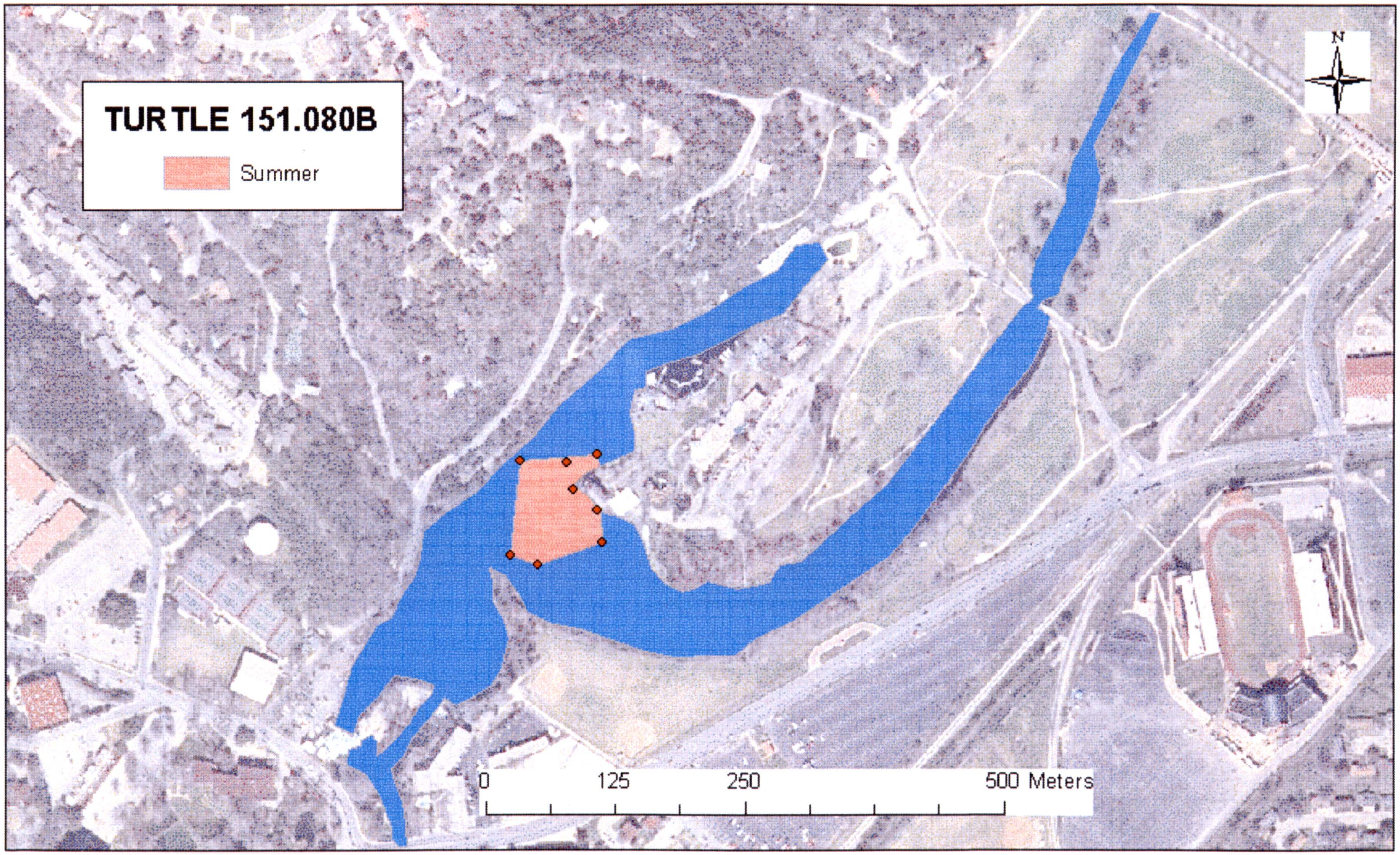


Figure 27. Summer home range for male Turtle 151.080B

Figure 28. Fall home range for male Turtle 151.080B.

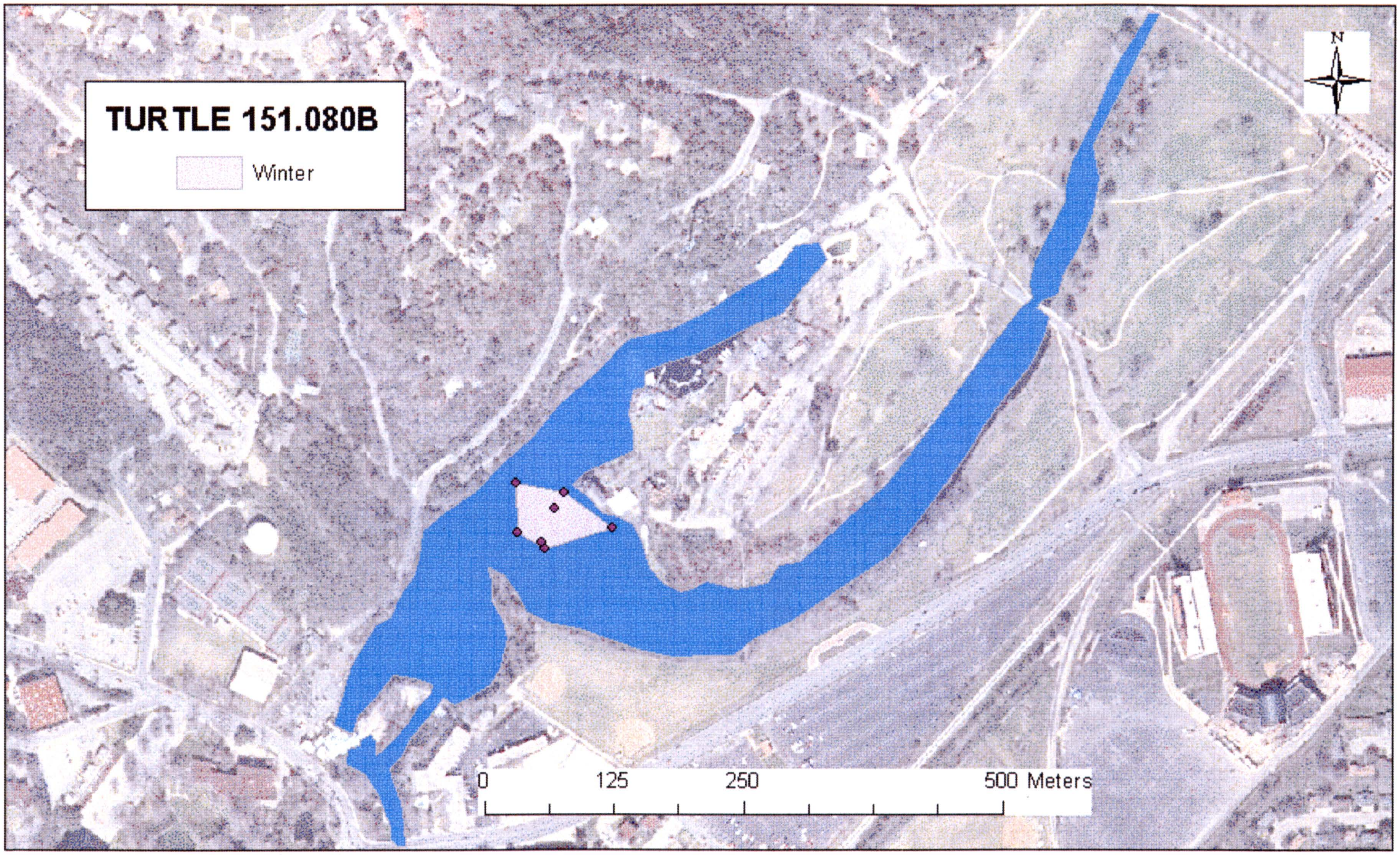


Figure 29. Winter home range for male Turtle 151.080B

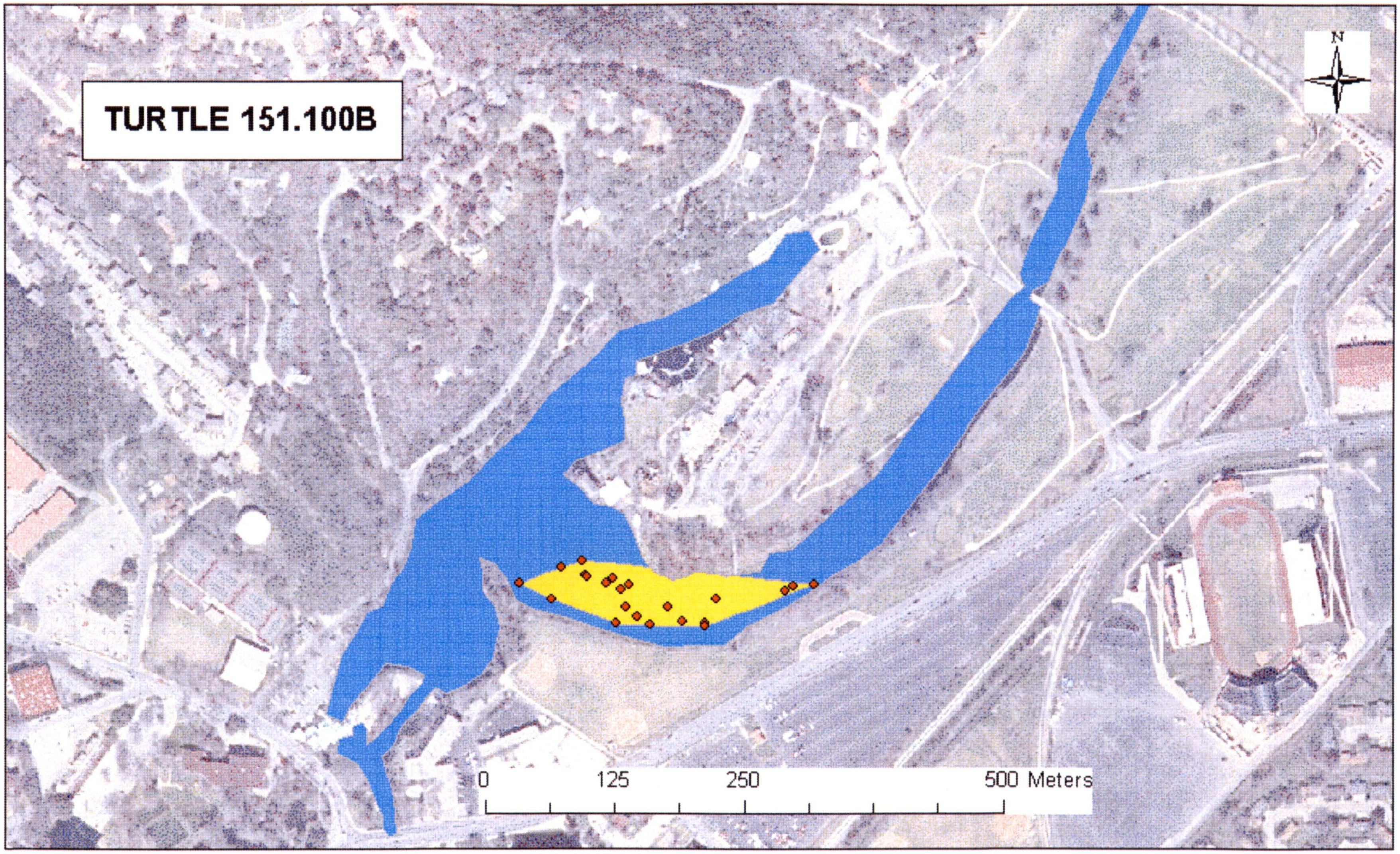


Figure 30. Annual home range for male Turtle 151.100B.

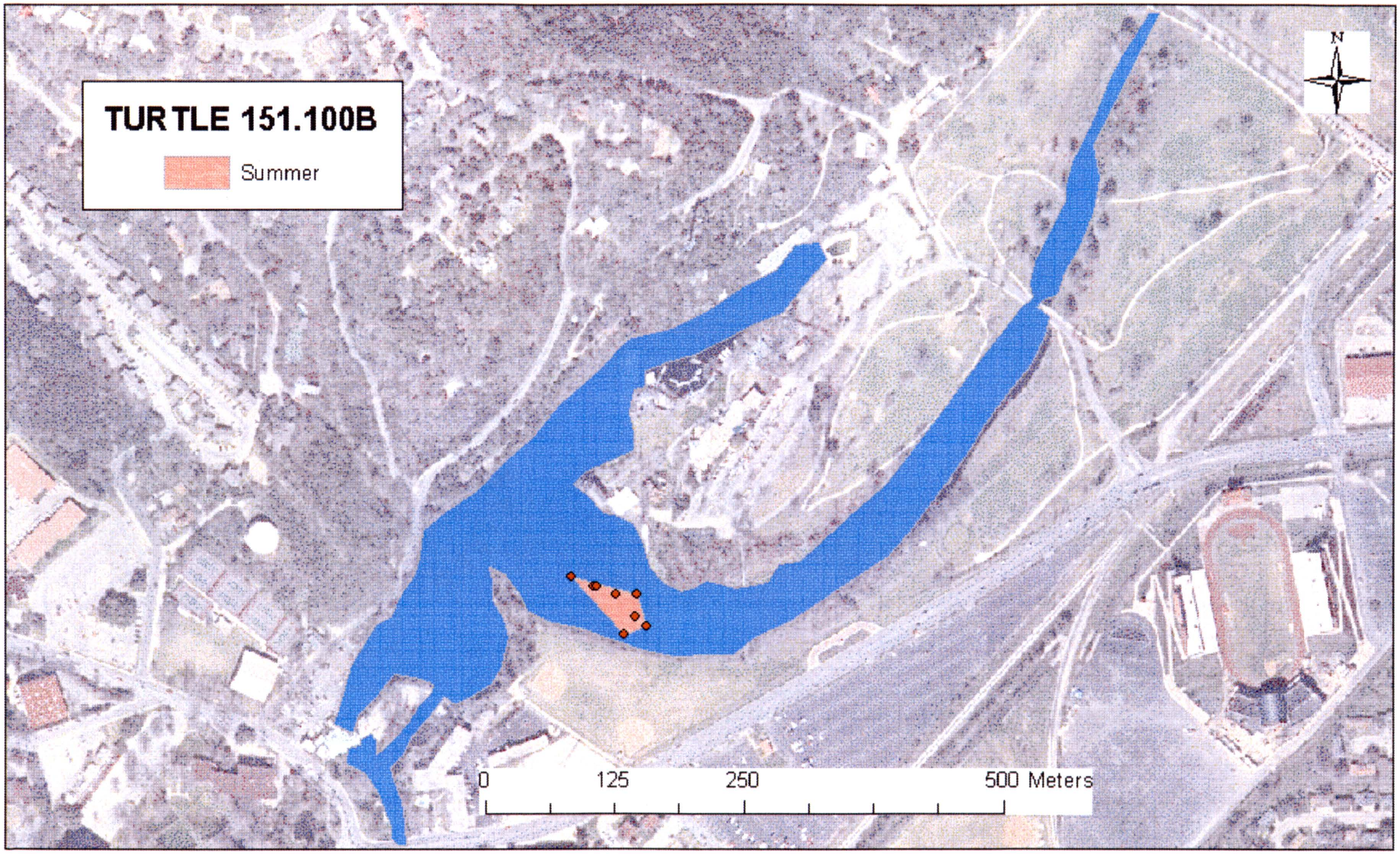


Figure 31. Summer home range for male Turtle 151.100B.

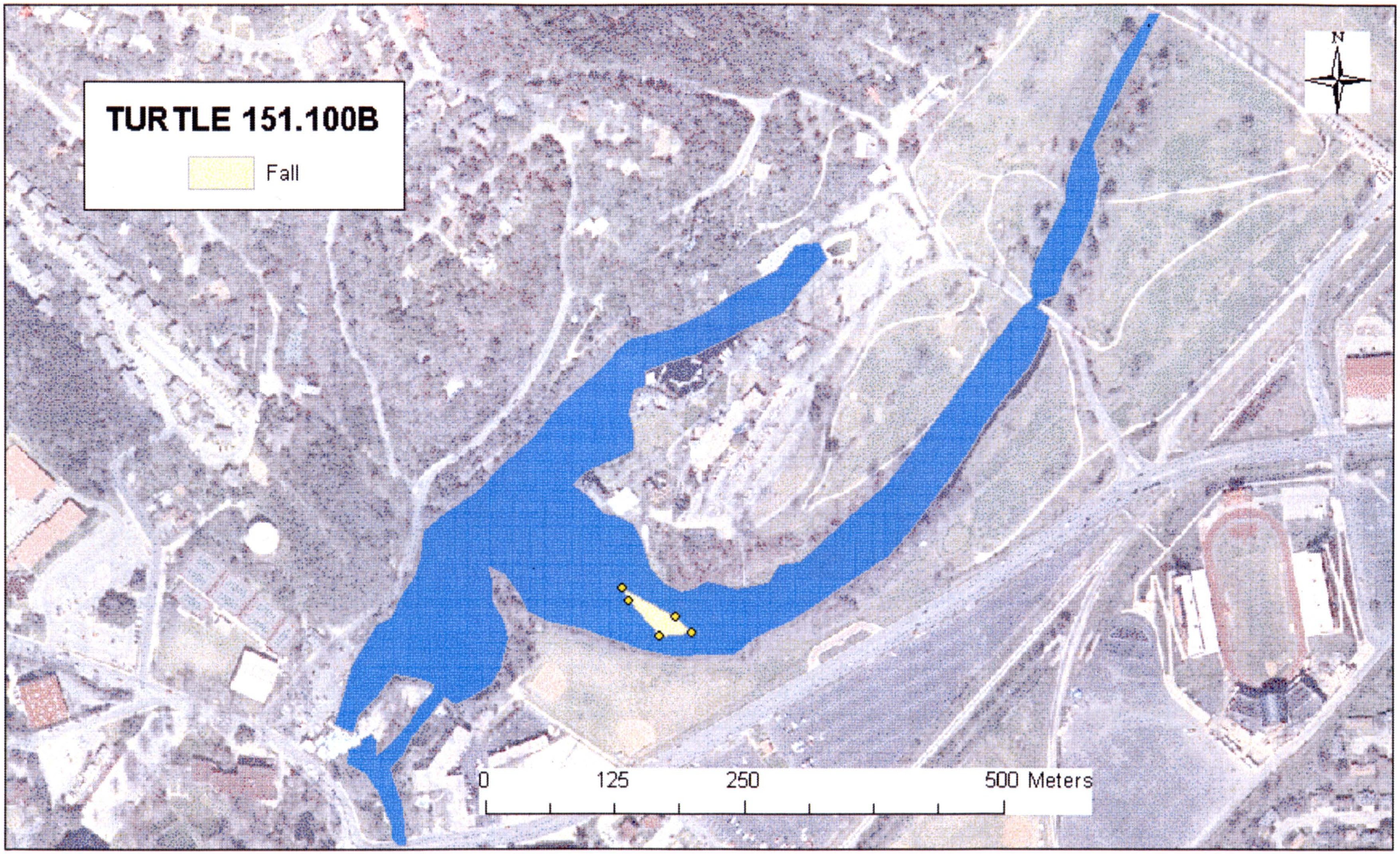


Figure 32. Fall home range for male Turtle 151.100B.

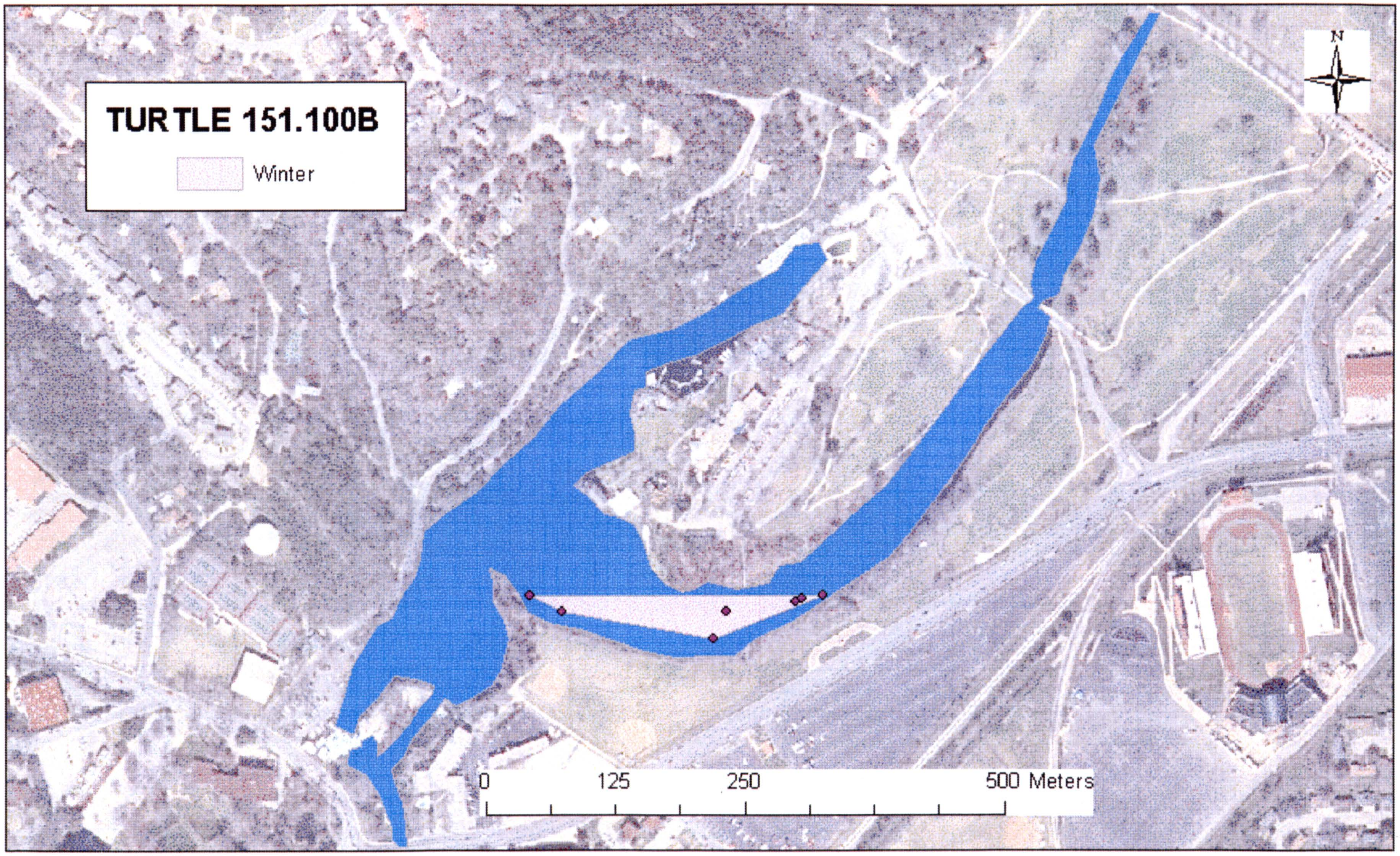


Figure 33. Winter home range for male Turtle 151.100B.

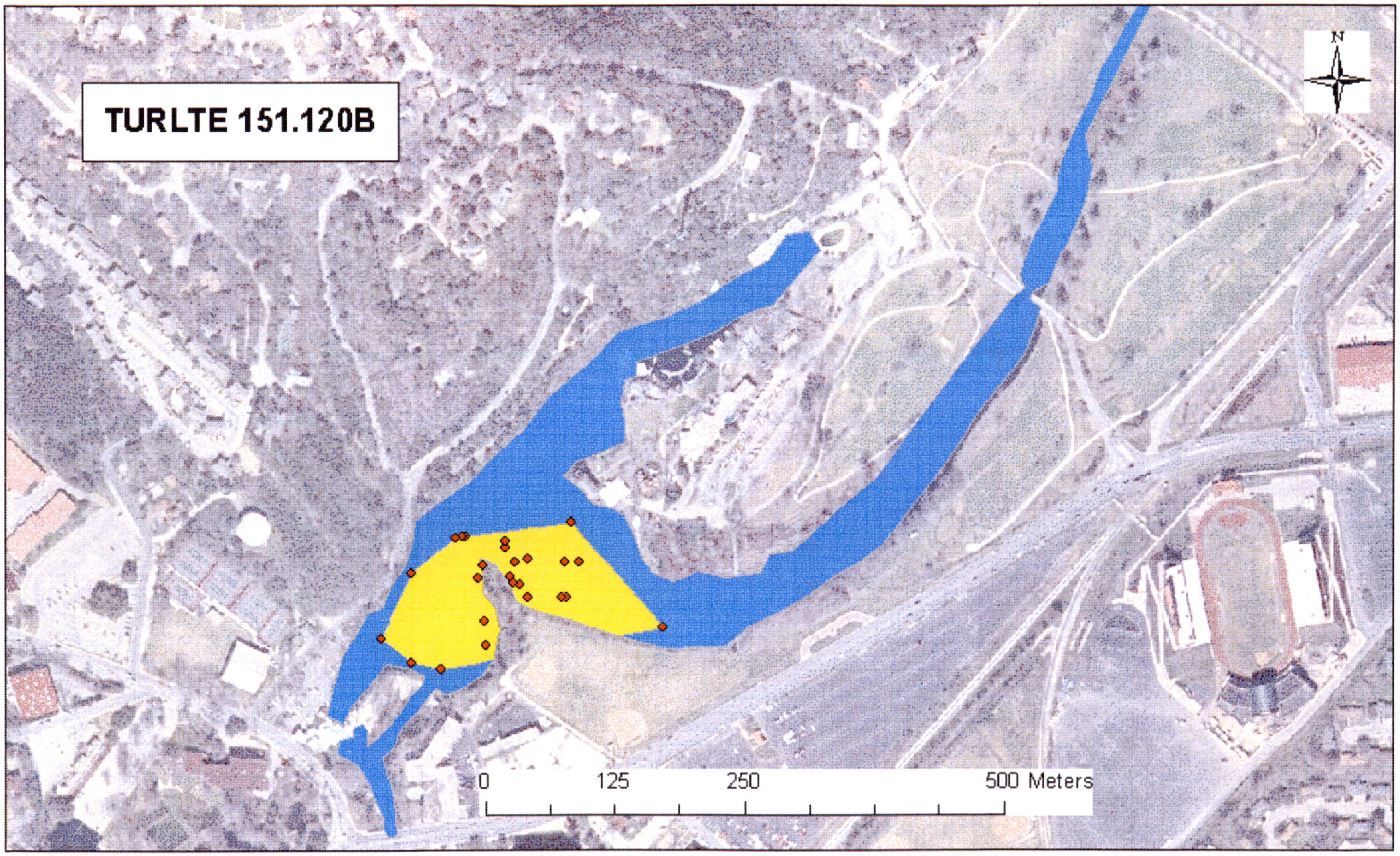


Figure 34. Annual home range for male Turtle 151.120B.

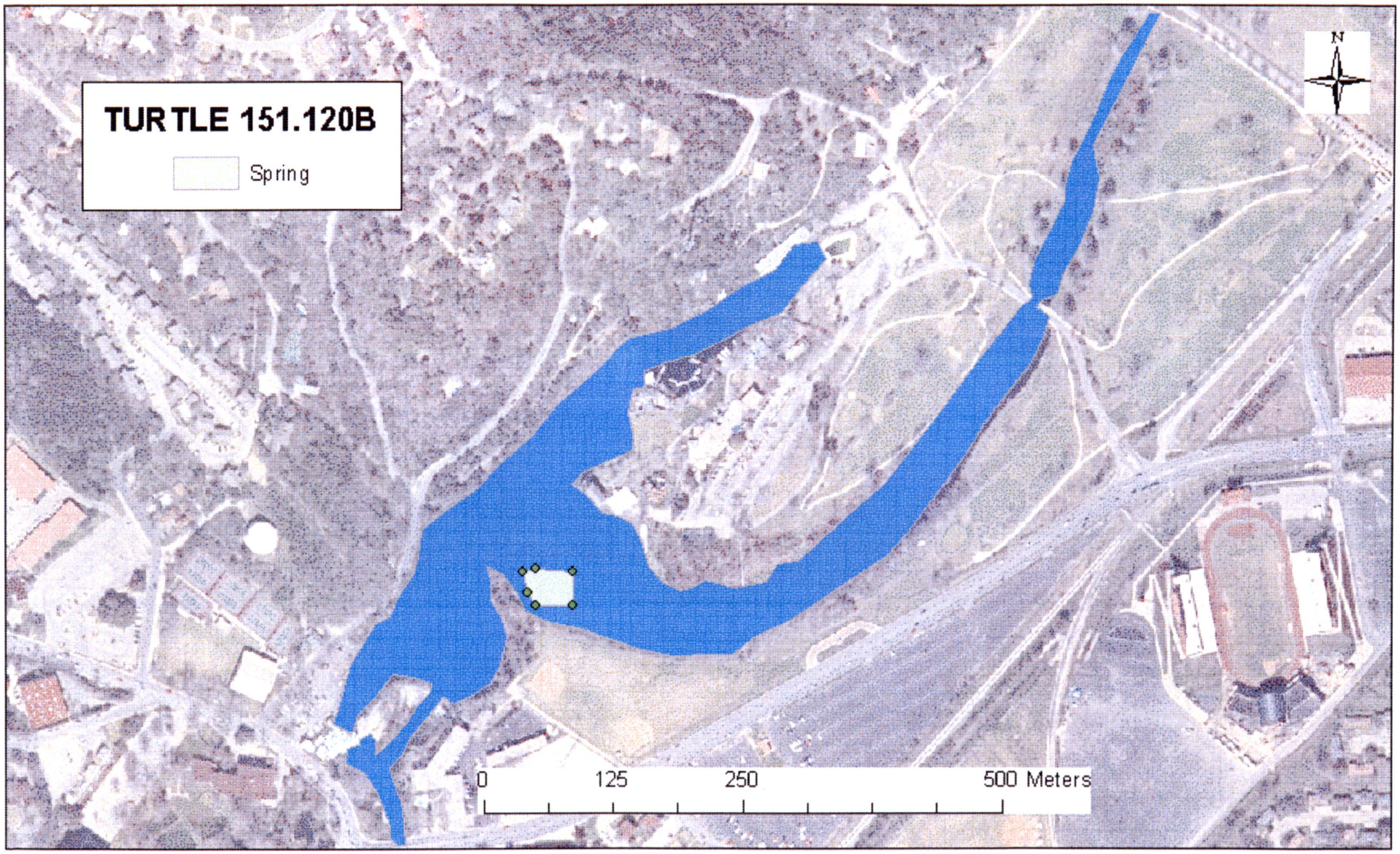


Figure 35. Spring home range for male Turtle 151.120B.

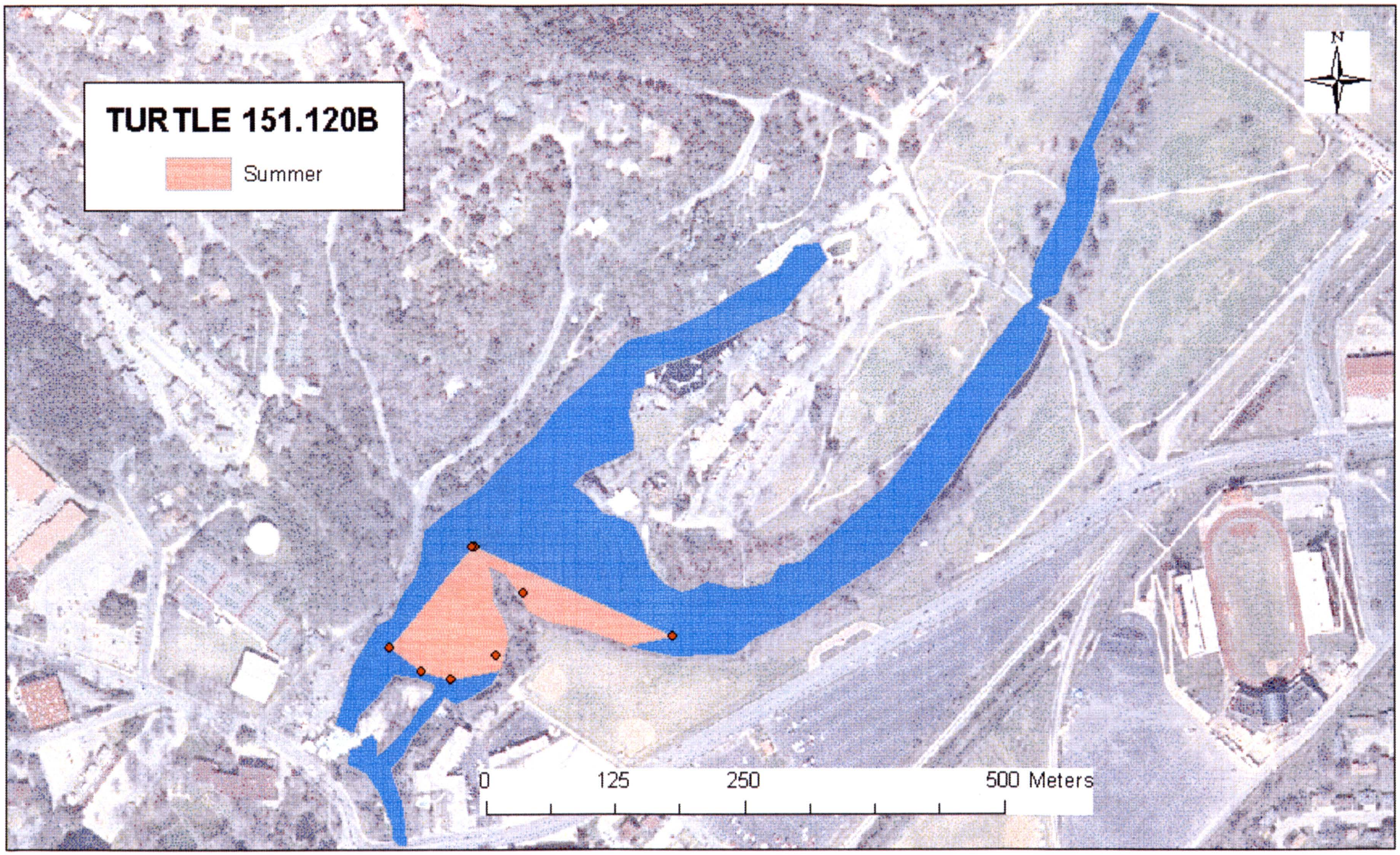


Figure 36. Summer home range for male Turtle 151.120B.

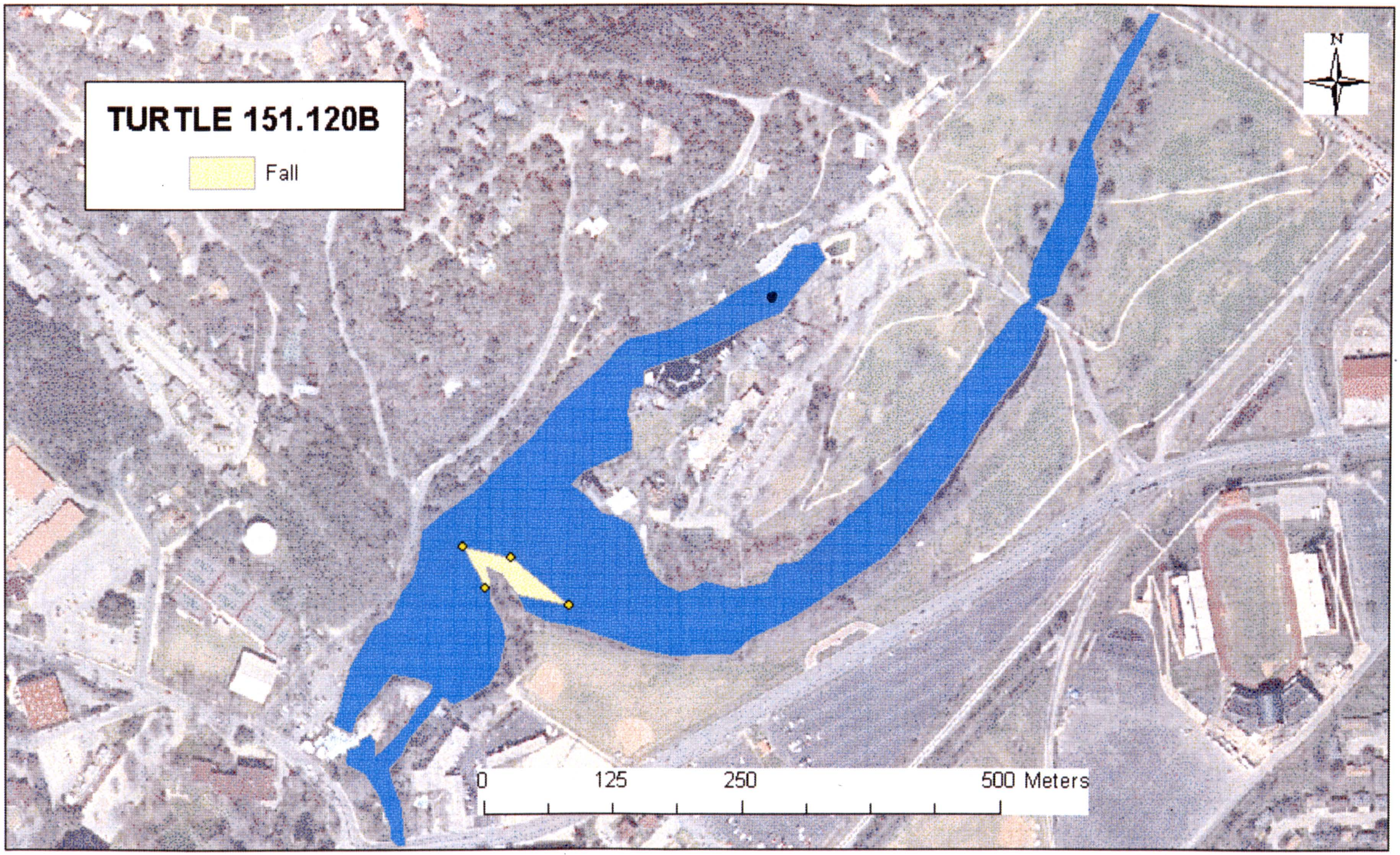


Figure 37. Fall home range for male Turtle 151.120B.

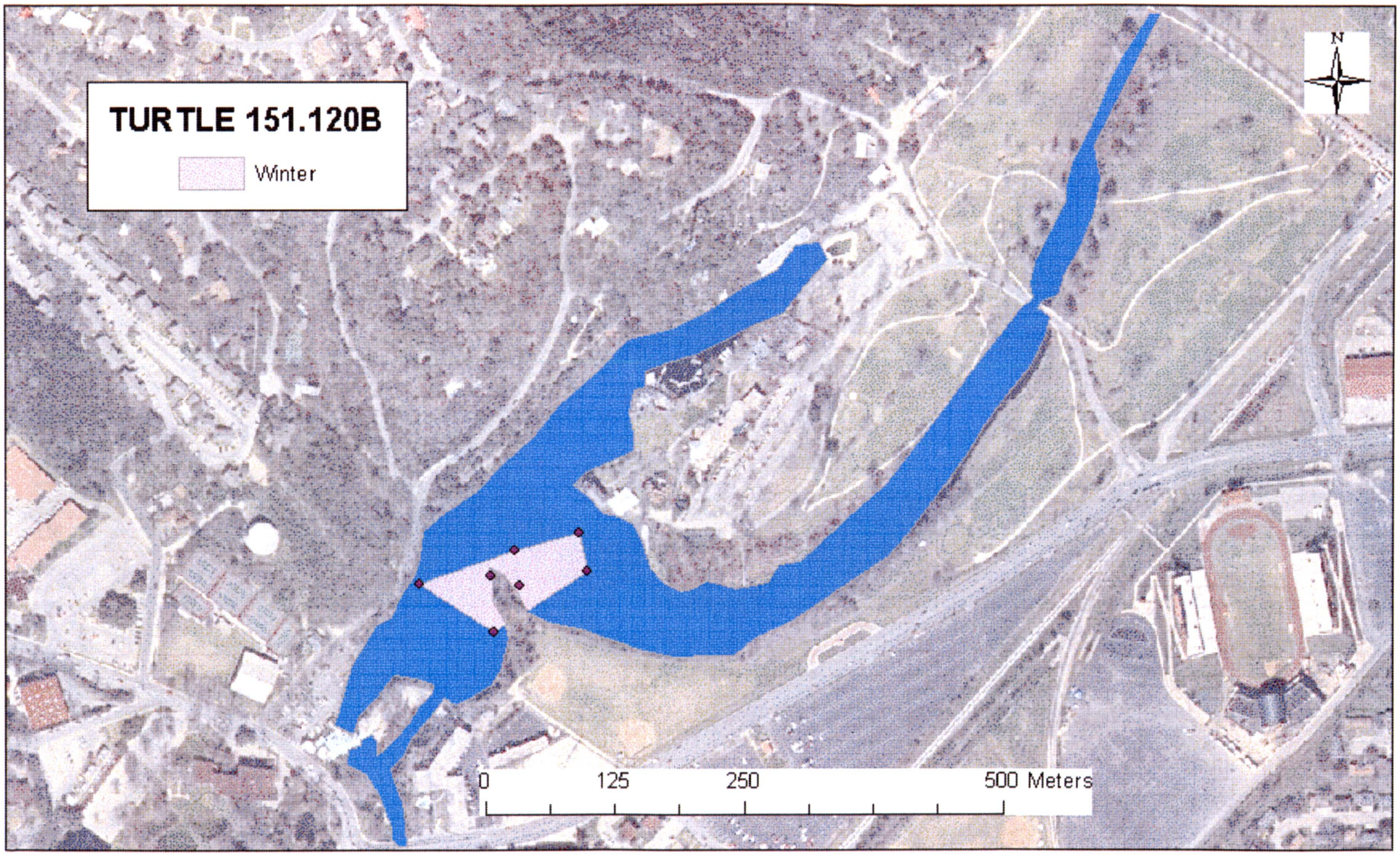


Figure 38. Winter home range for male Turtle 151.120B.

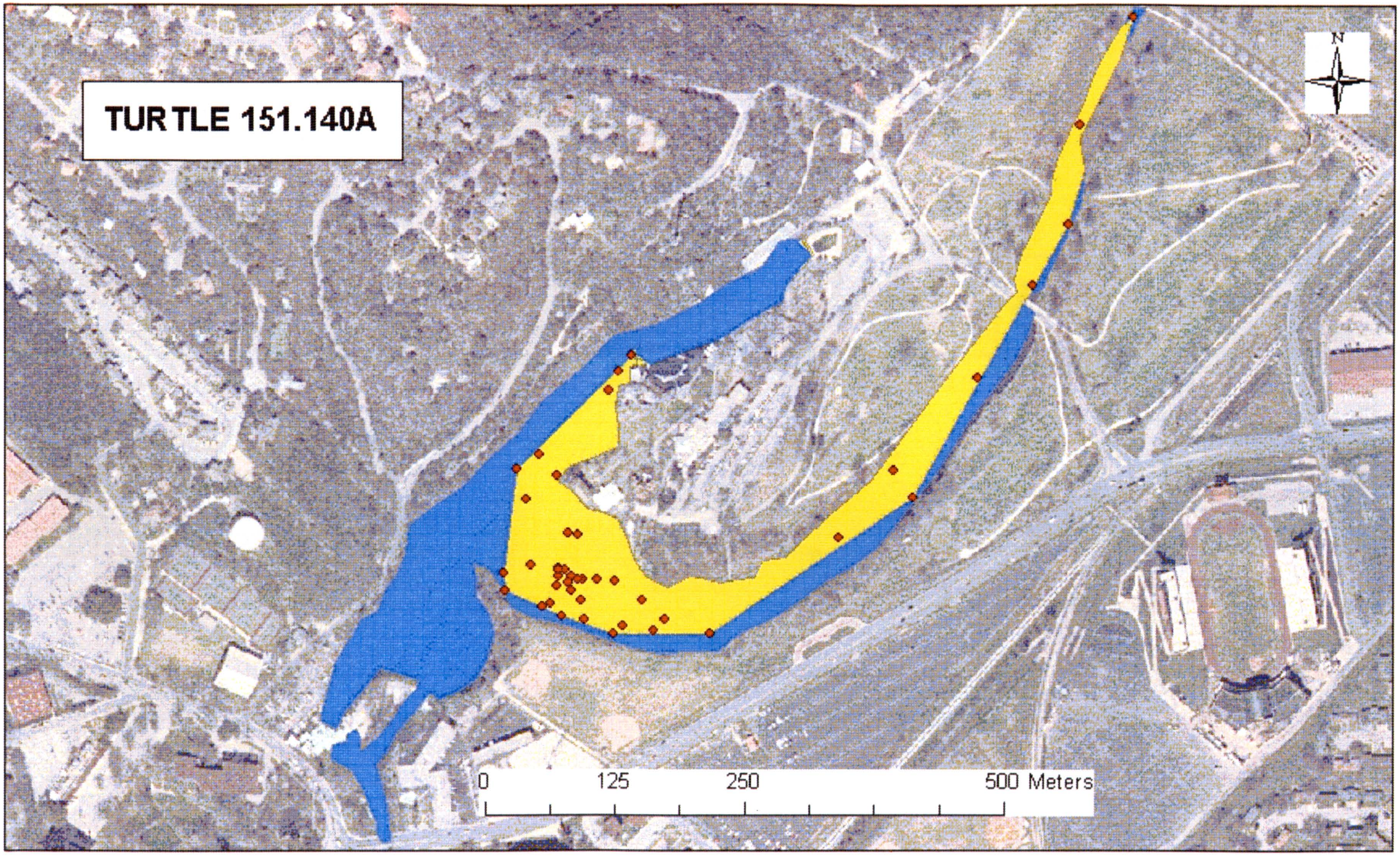


Figure 39. Annual home range for female Turtle 151.140A.

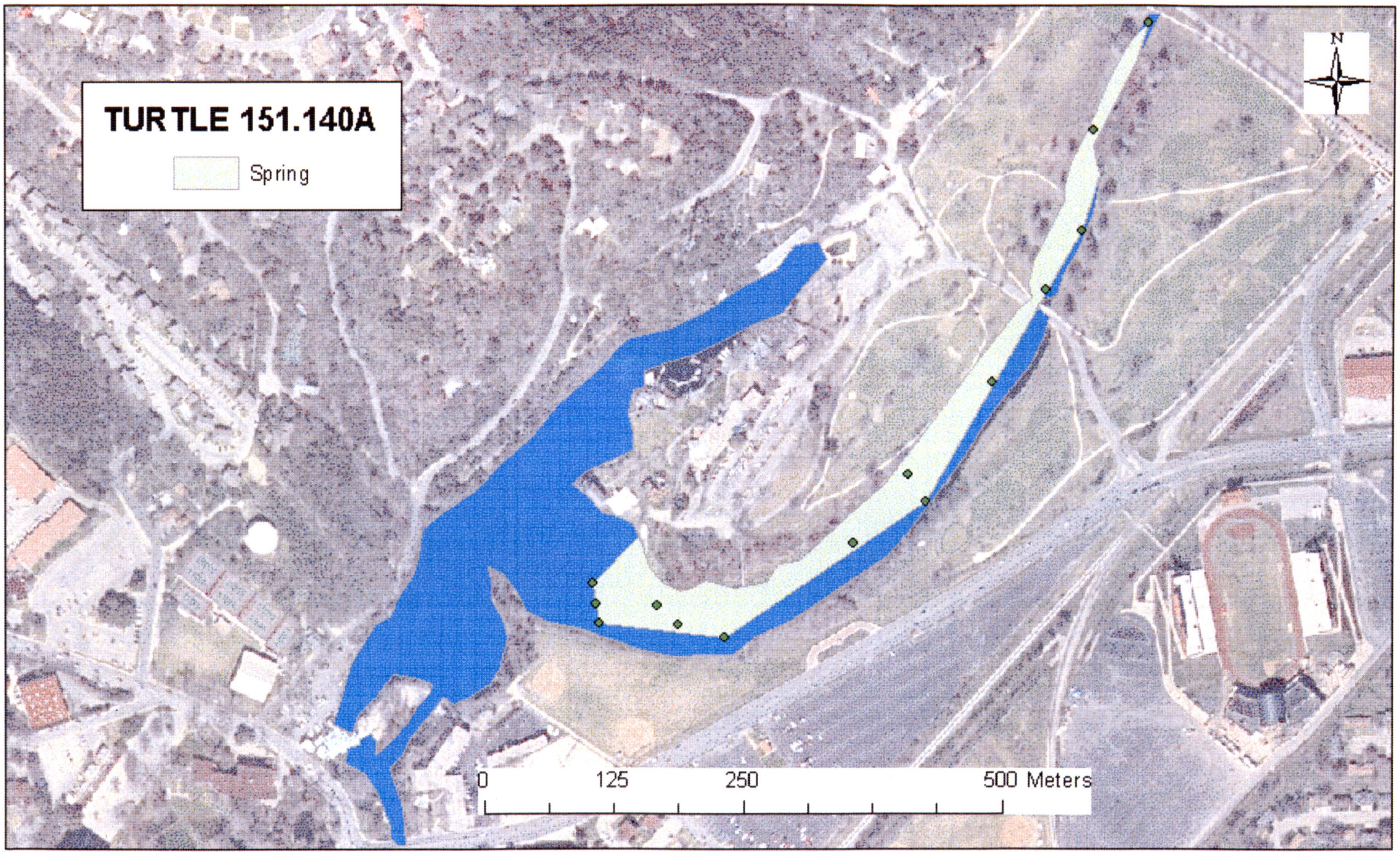


Figure 40. Spring home range for female Turtle 151.140A.

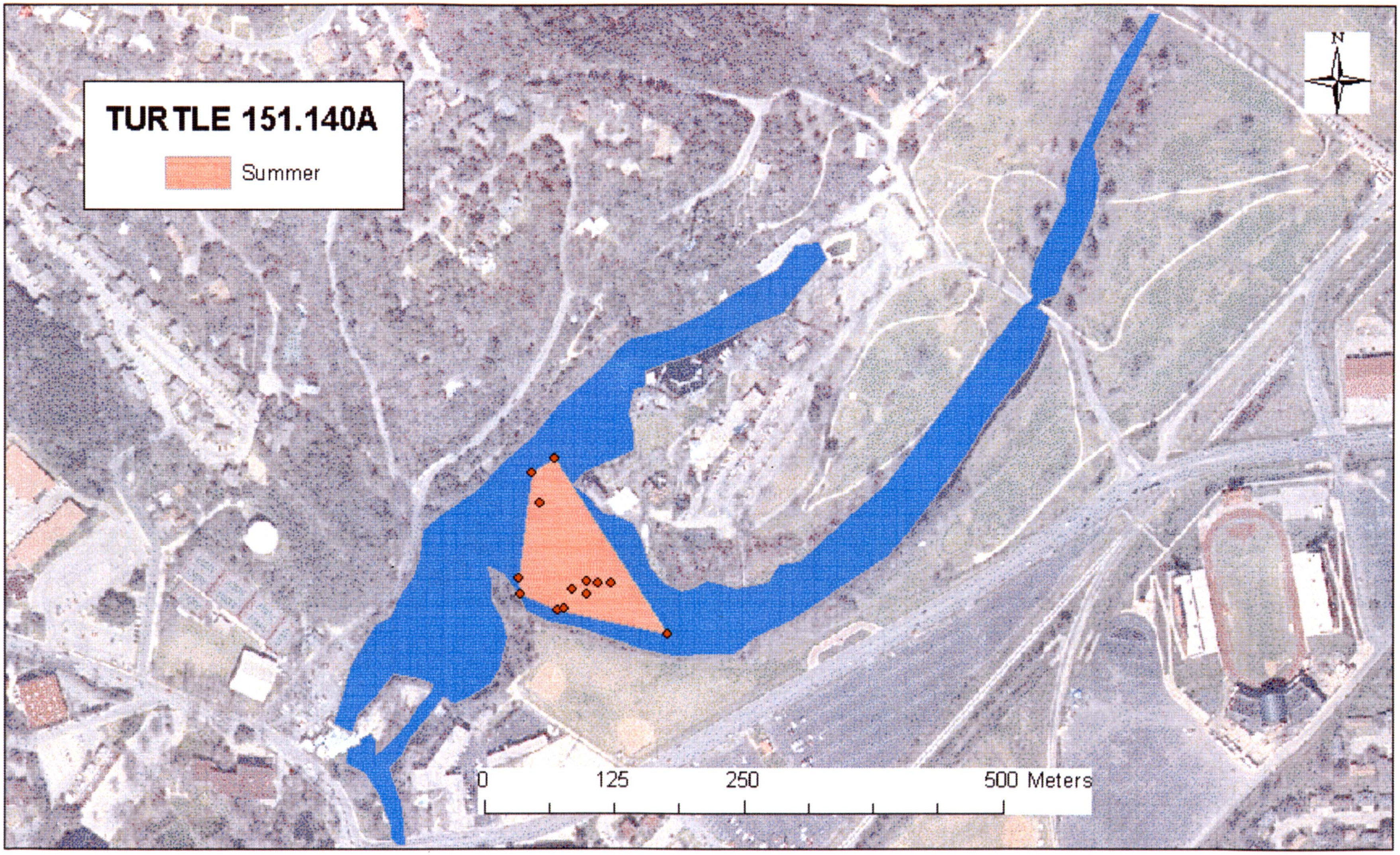


Figure 41. Summer home range for female Turtle 151.140A.

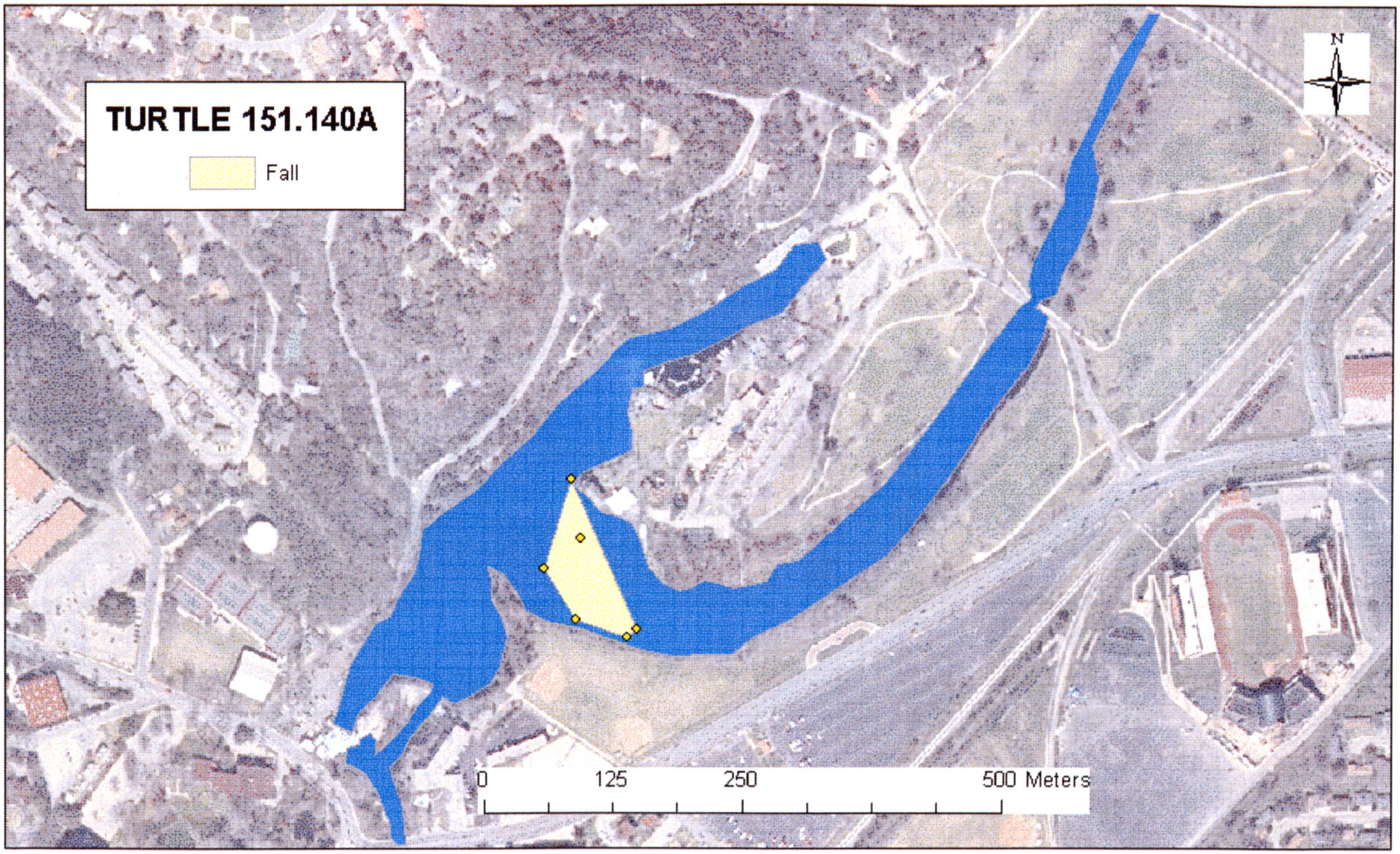


Figure 42. Fall home range for female Turtle 151.140A.

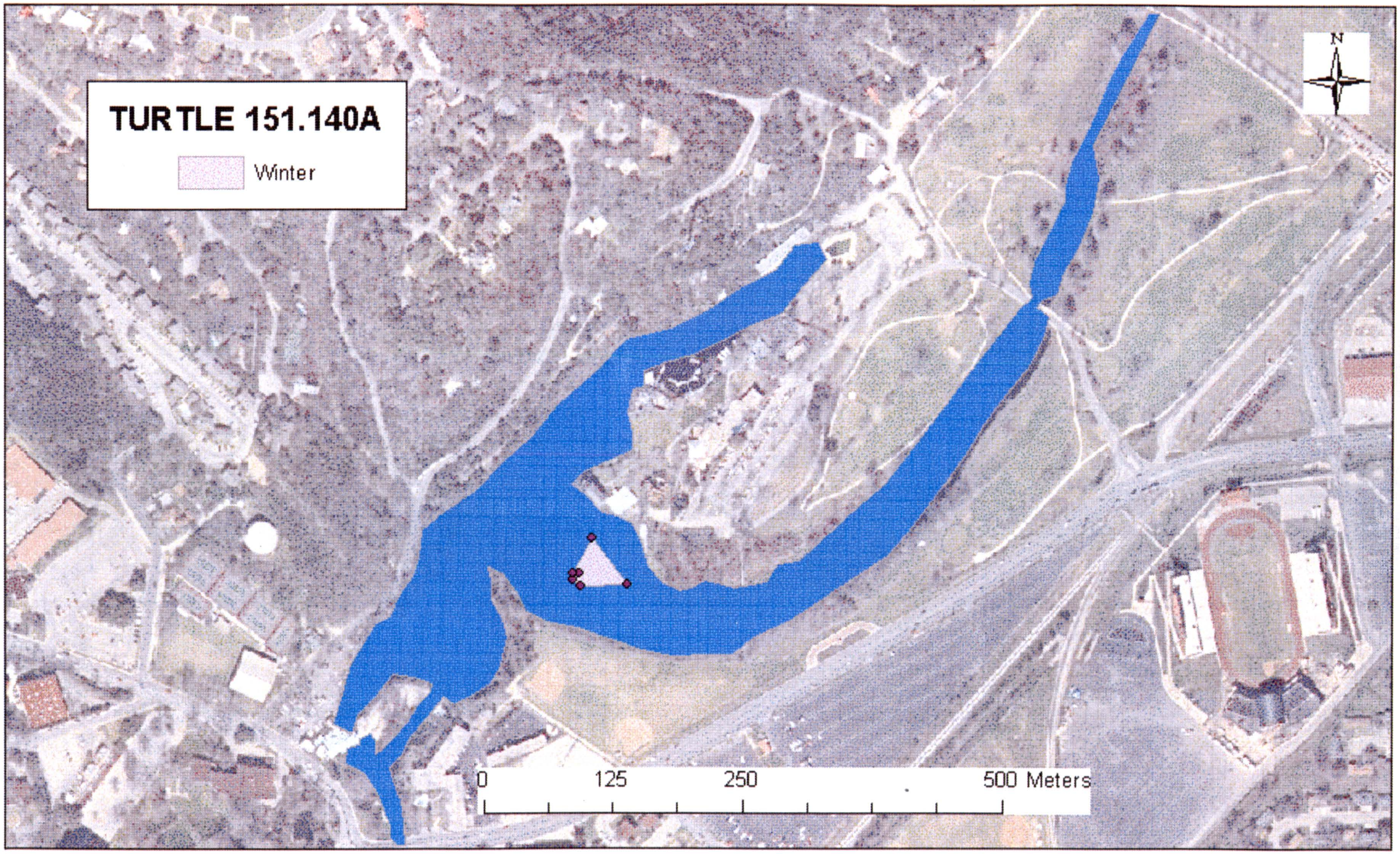


Figure 43. Winter home range for female Turtle 151.140A.

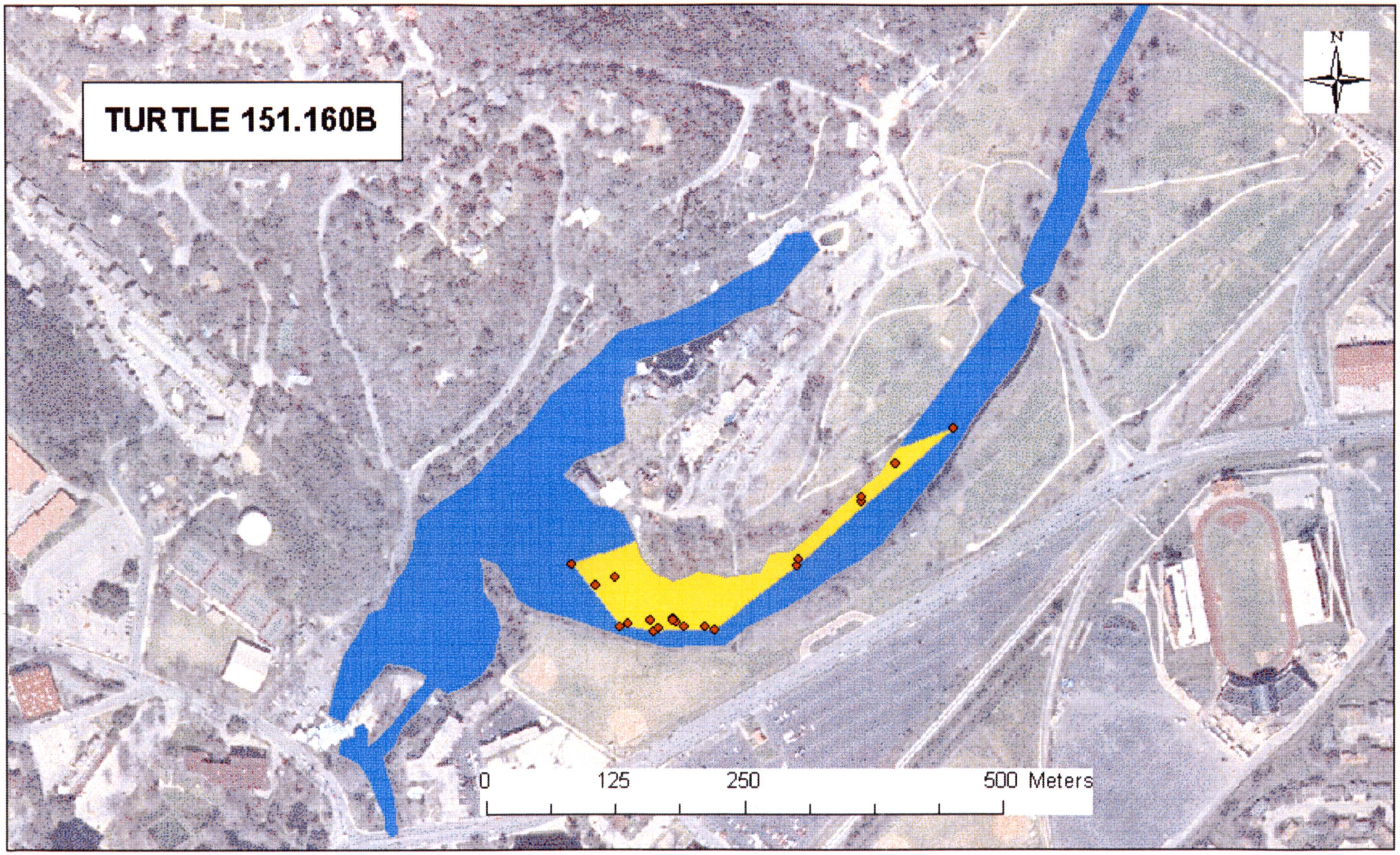


Figure 44. Annual home range for male Turtle 151.160B.

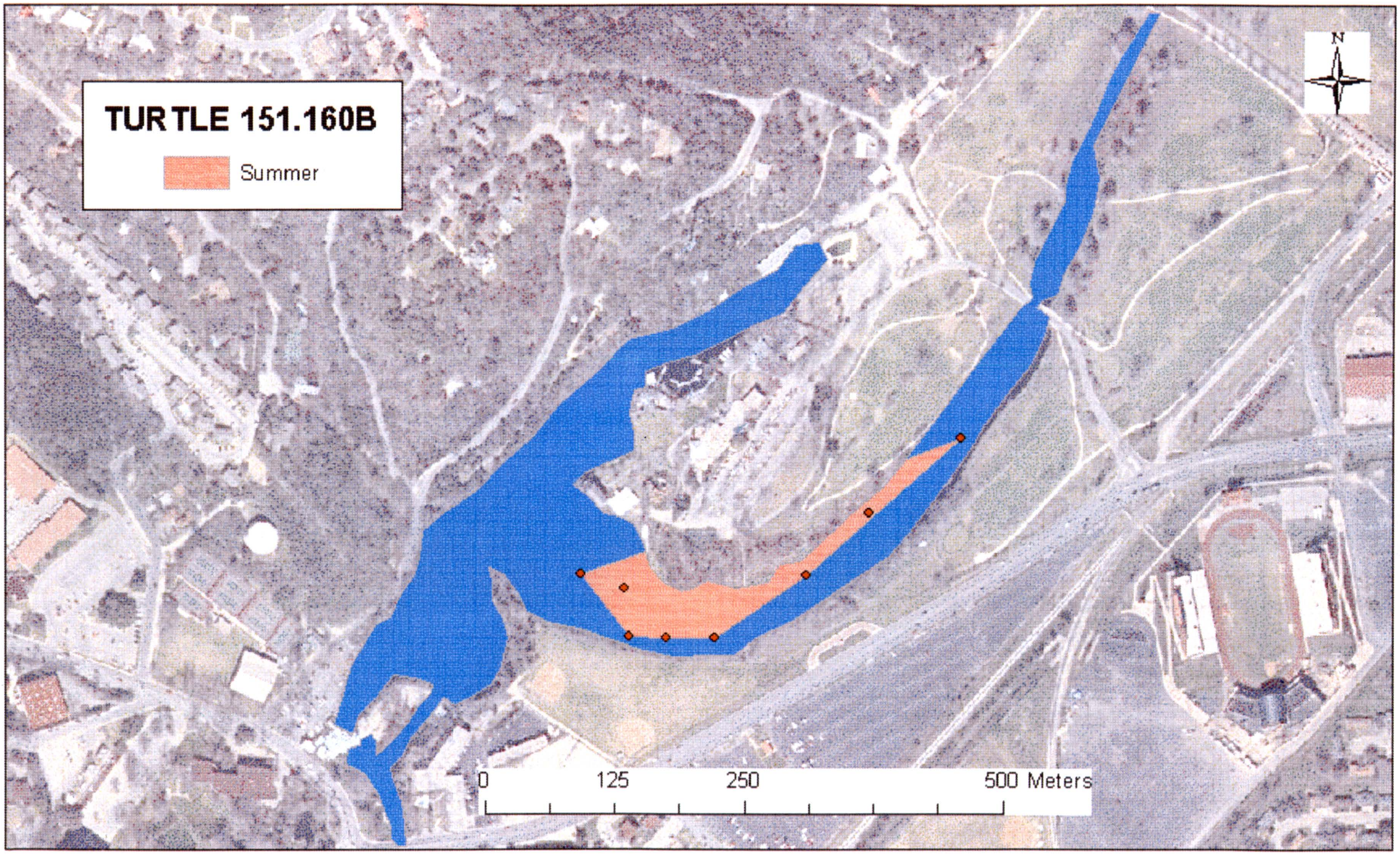


Figure 45. Summer home range for male Turtle 151.160B.

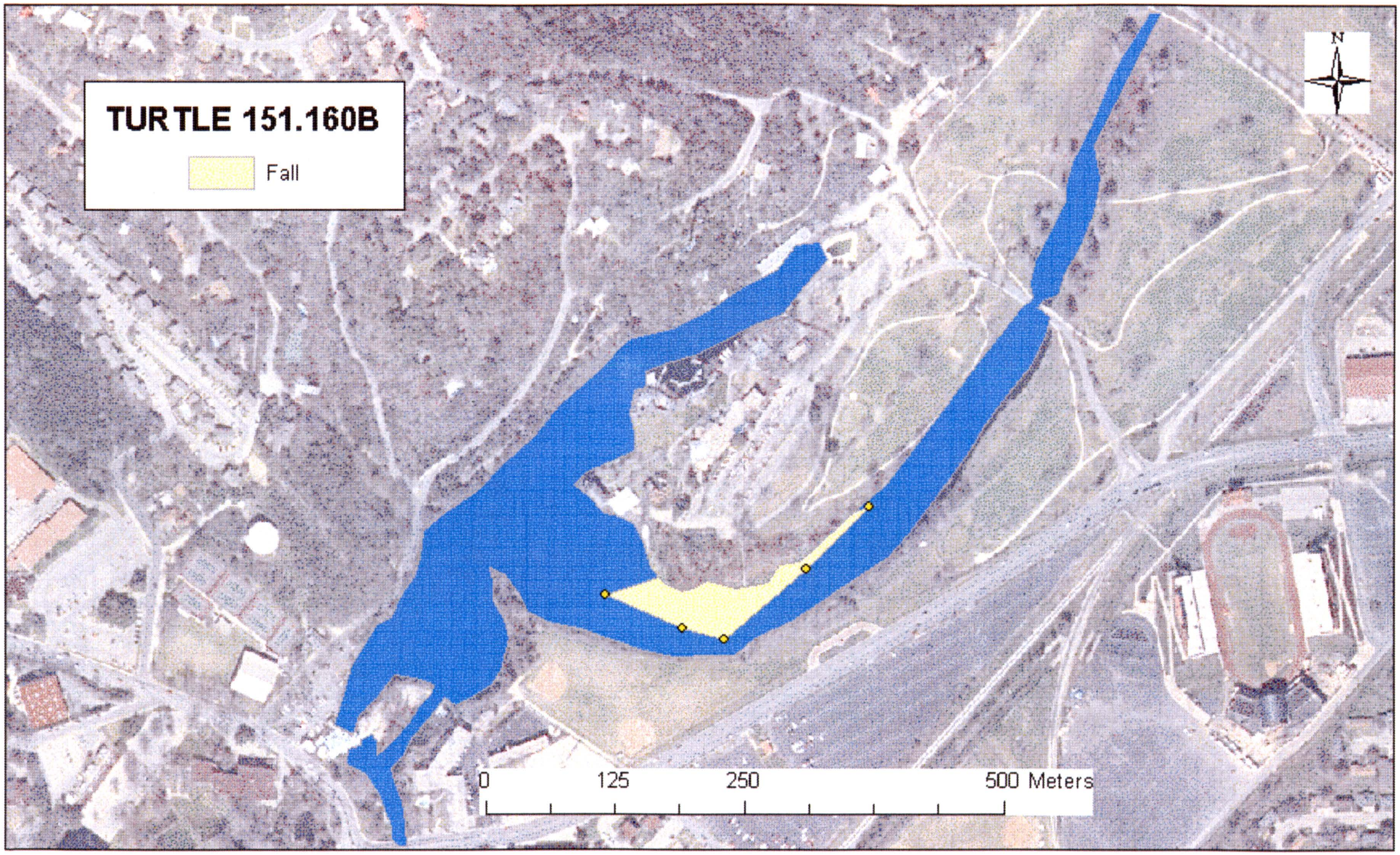


Figure 46. Fall home range for male Turtle 151.160B.

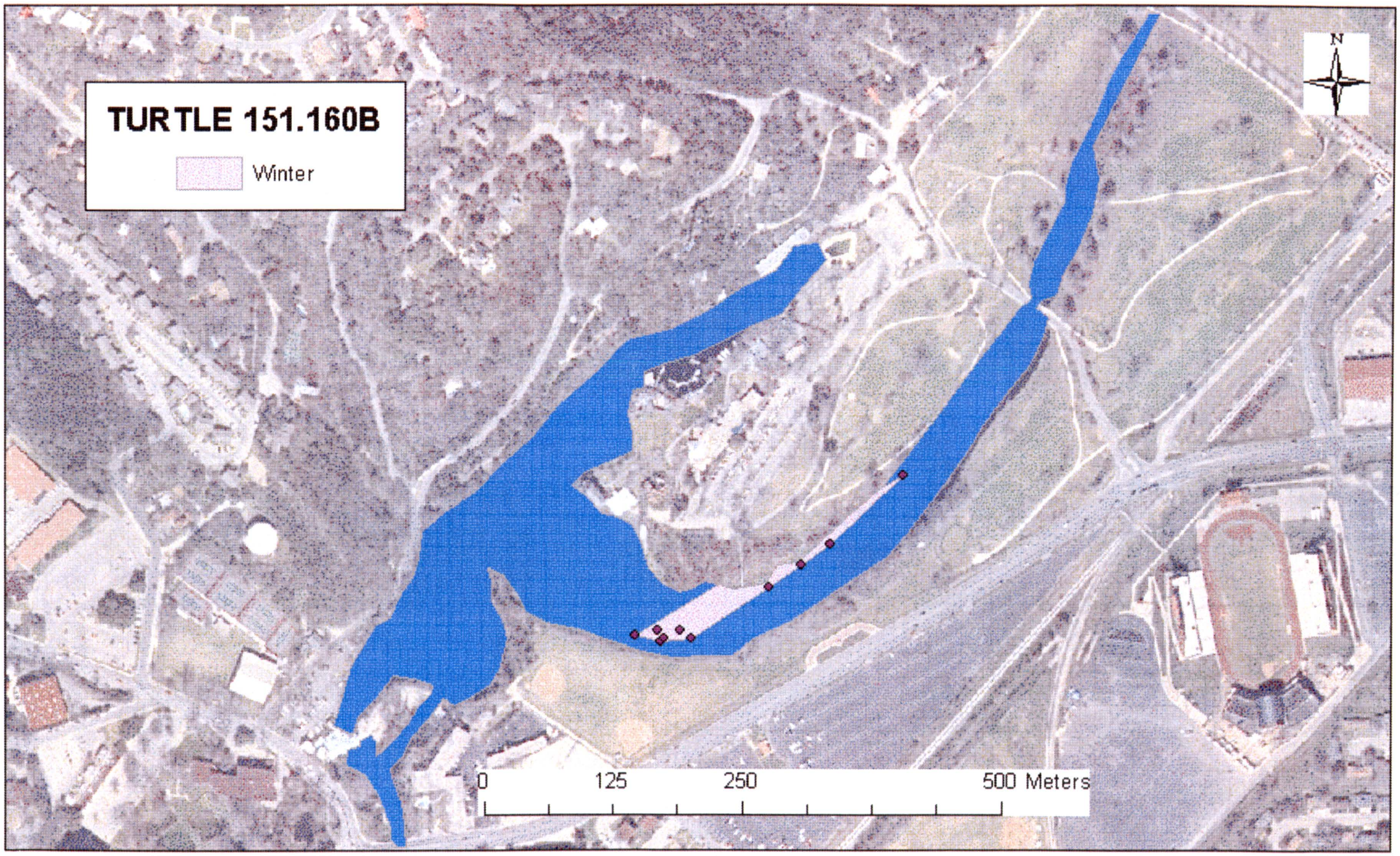


Figure 47. Winter home range for male Turtle 151.160B.

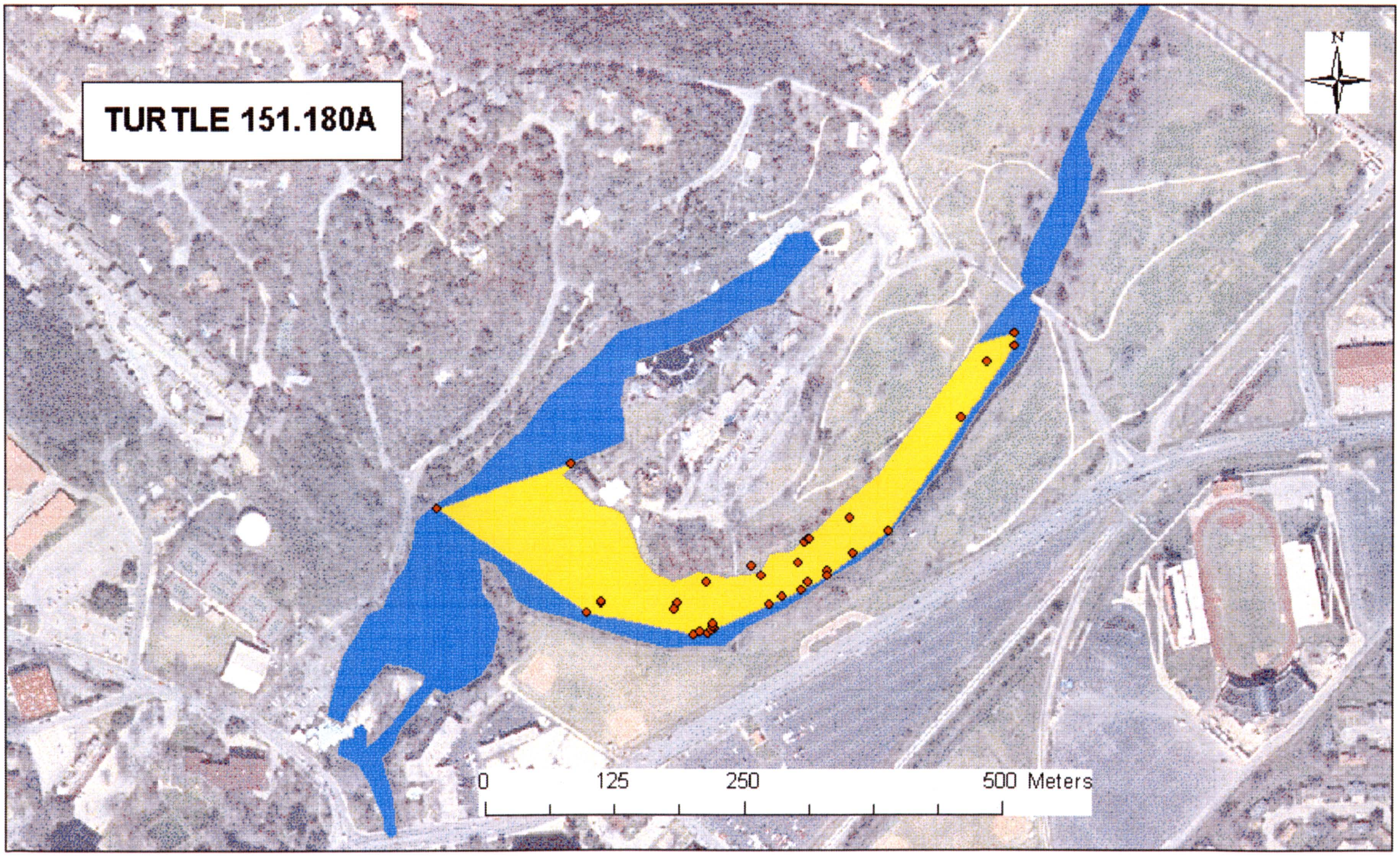


Figure 48. Annual home range for female Turtle 151.180A.

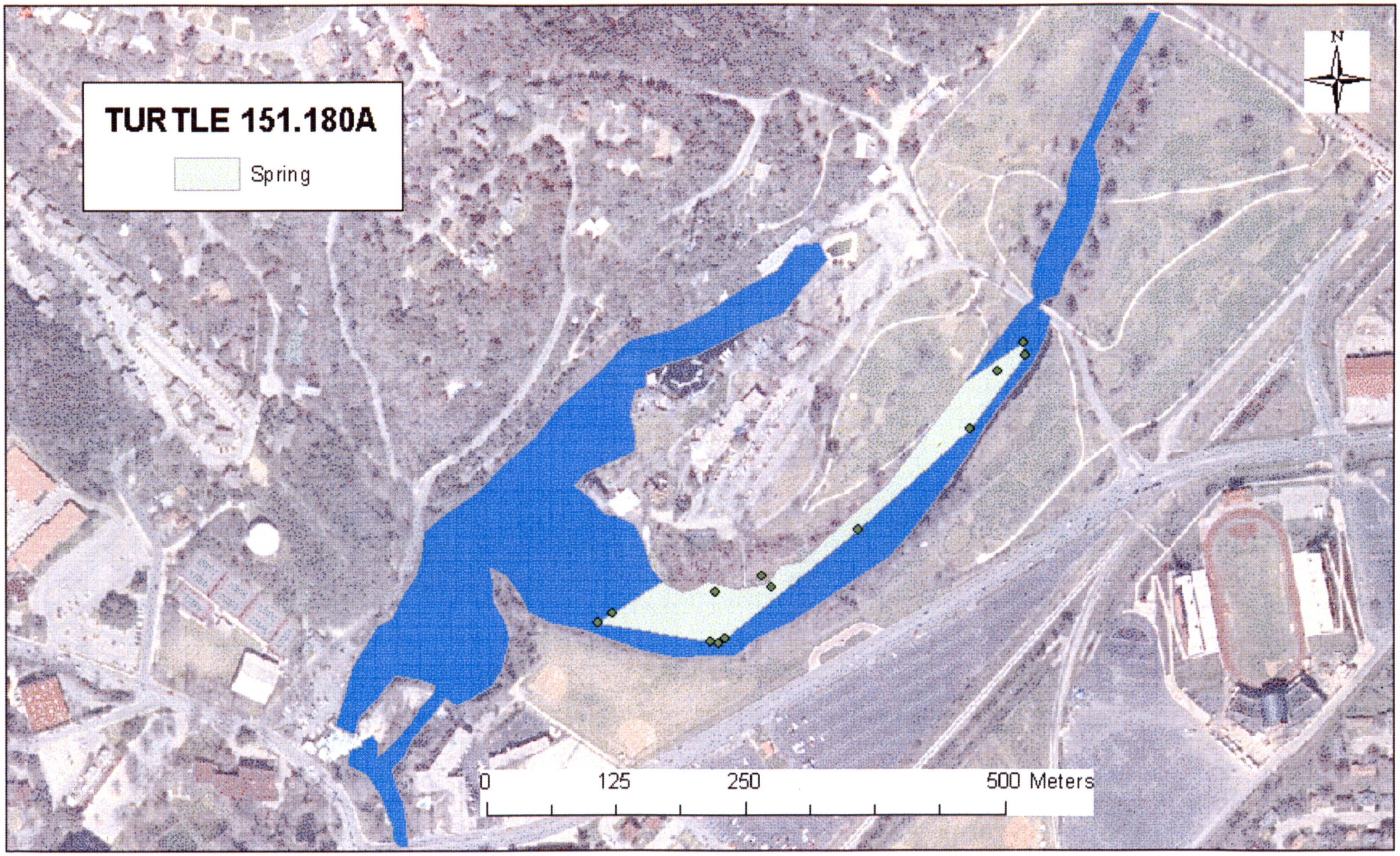


Figure 49. Spring home range for female Turtle 151.180A.

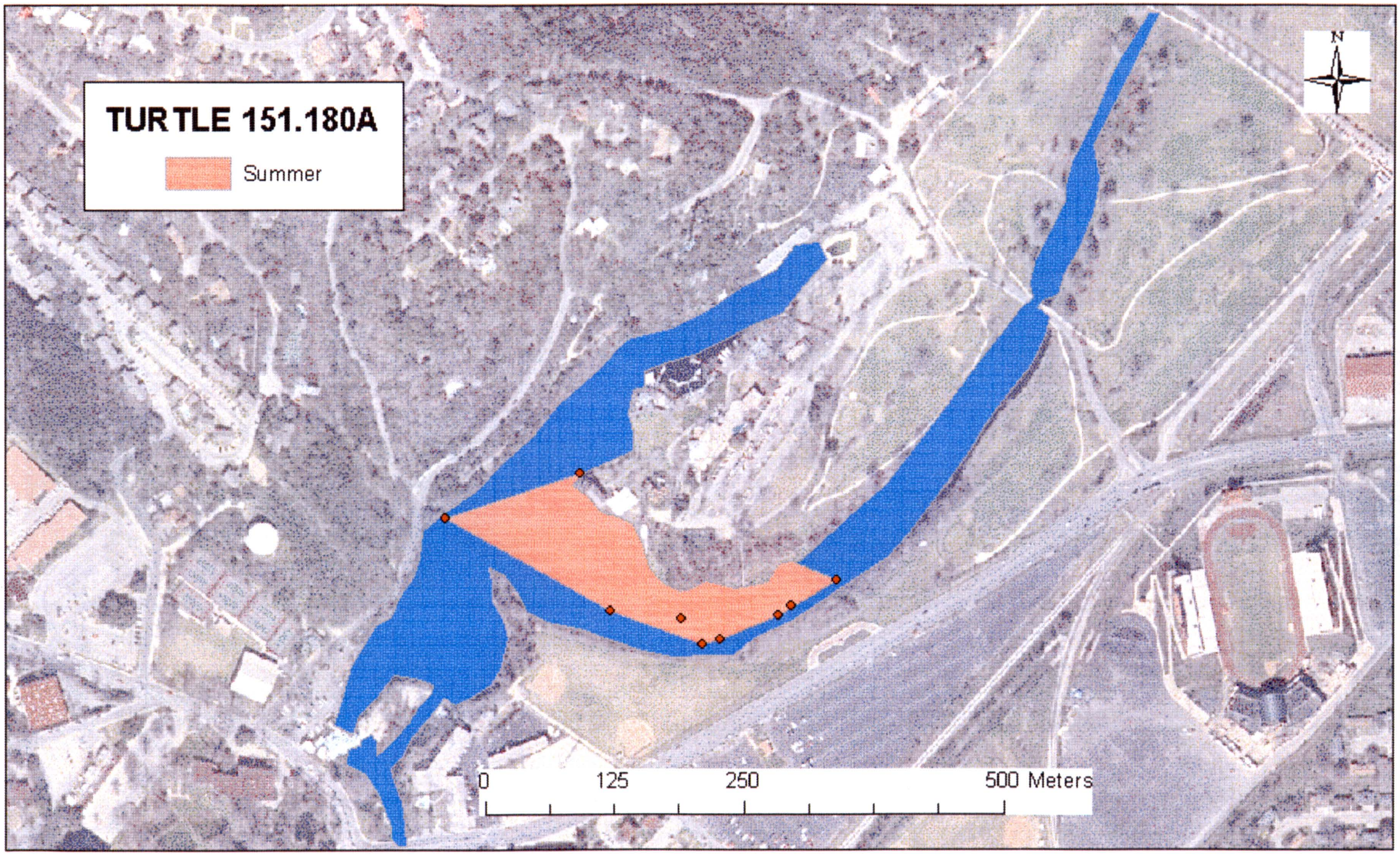


Figure 50. Summer home range for female Turtle 151.180A.

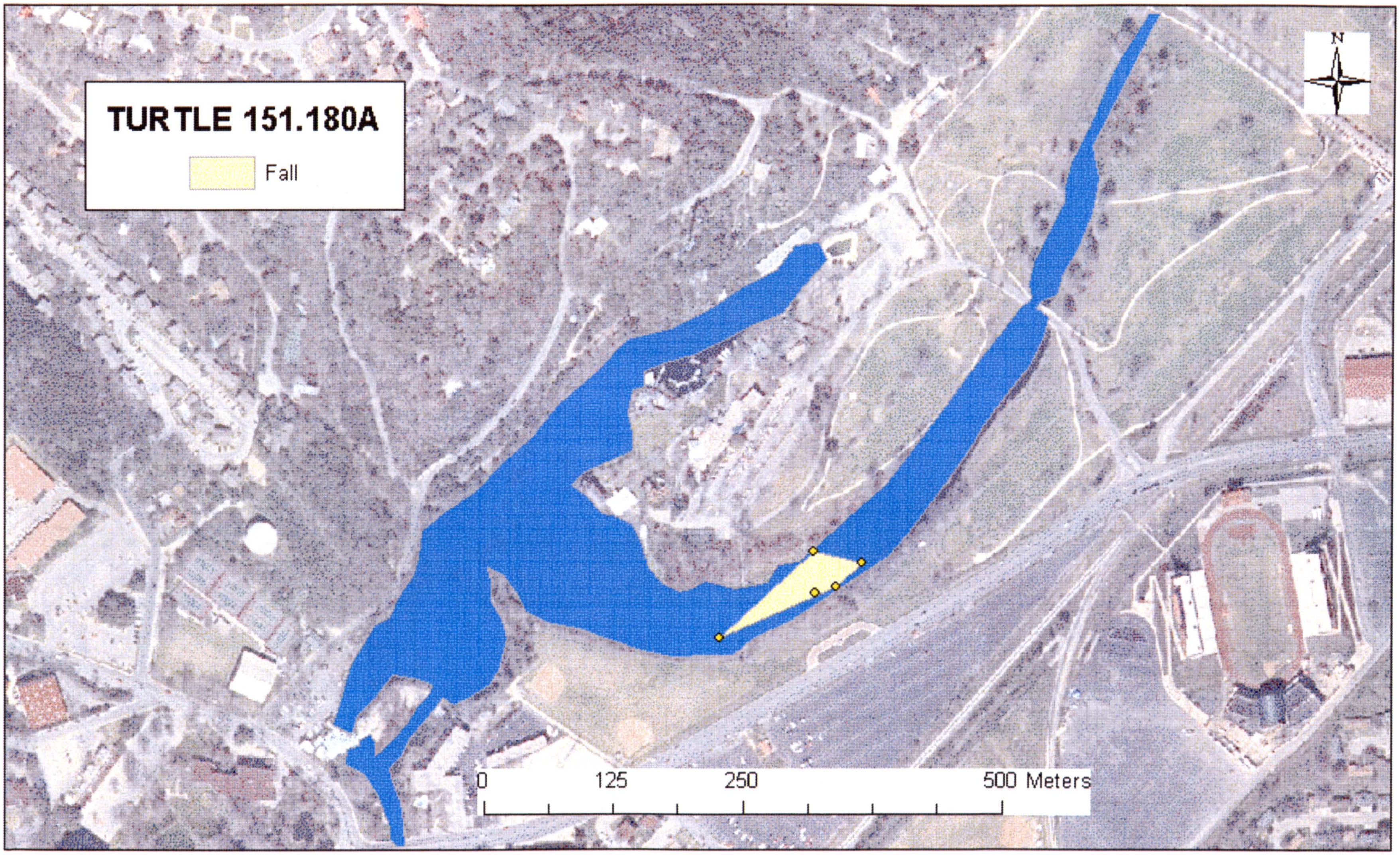


Figure 51. Fall home range for female Turtle 151.180A.

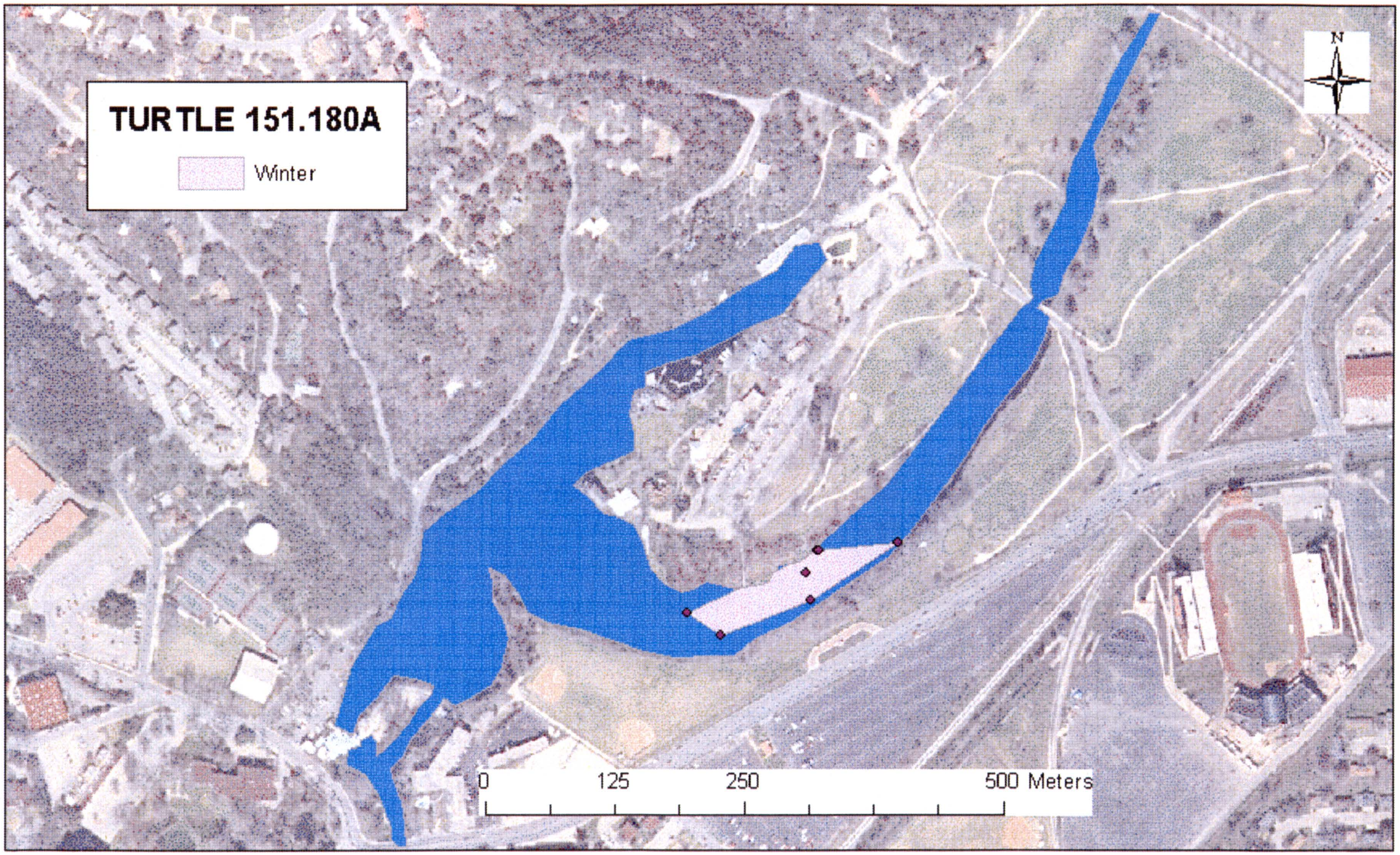


Figure 52. Winter home range for female Turtle 151.180A.

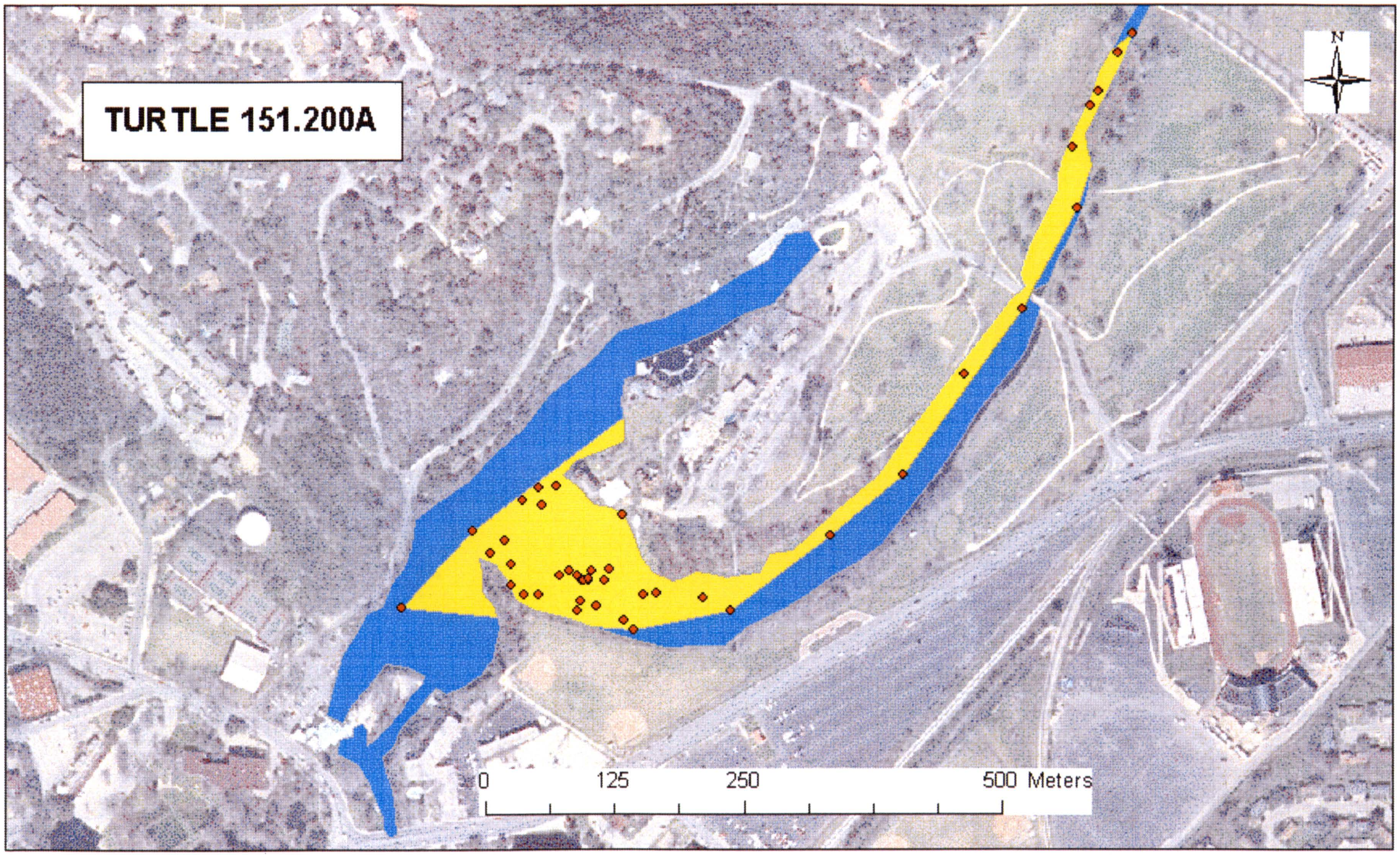


Figure 53. Annual home range for female Turtle 151.200A.

Figure 54. Spring home range for female Turtle 151.200A.

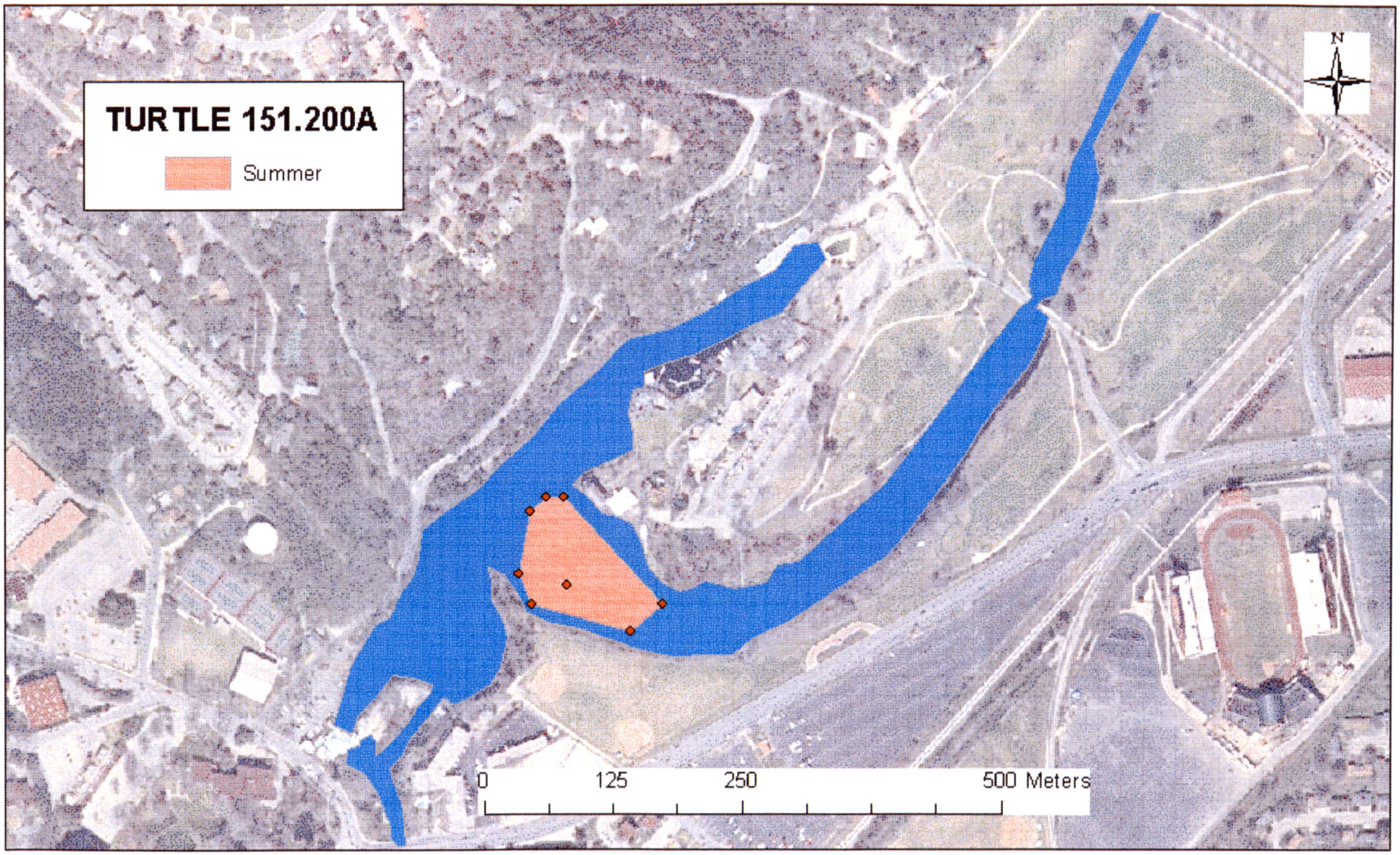


Figure 55. Summer home range for female Turtle 151.200A.

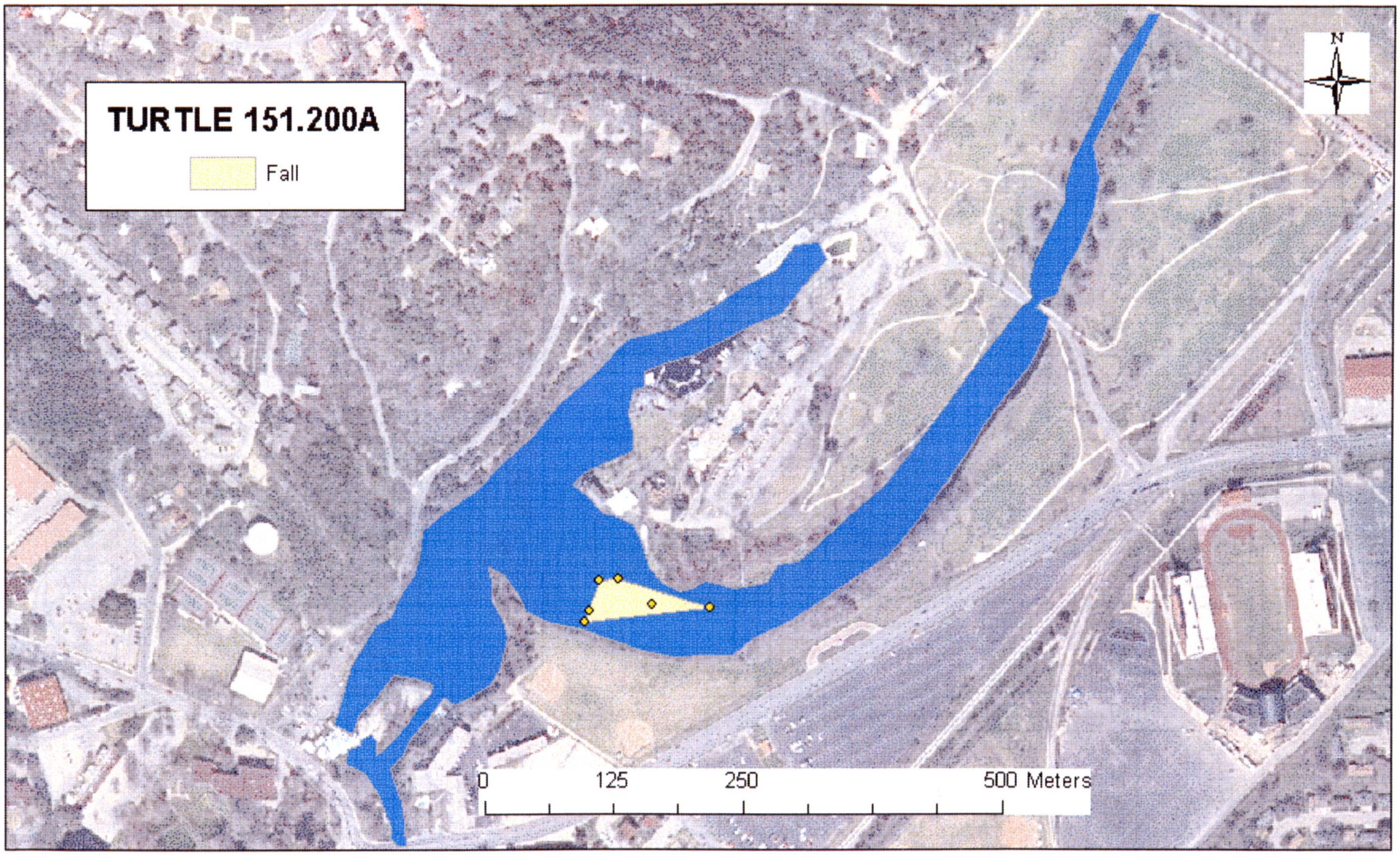


Figure 56. Fall home range for female Turtle 151.200A.

Figure 57. Winter home range for female Turtle 151.200A.

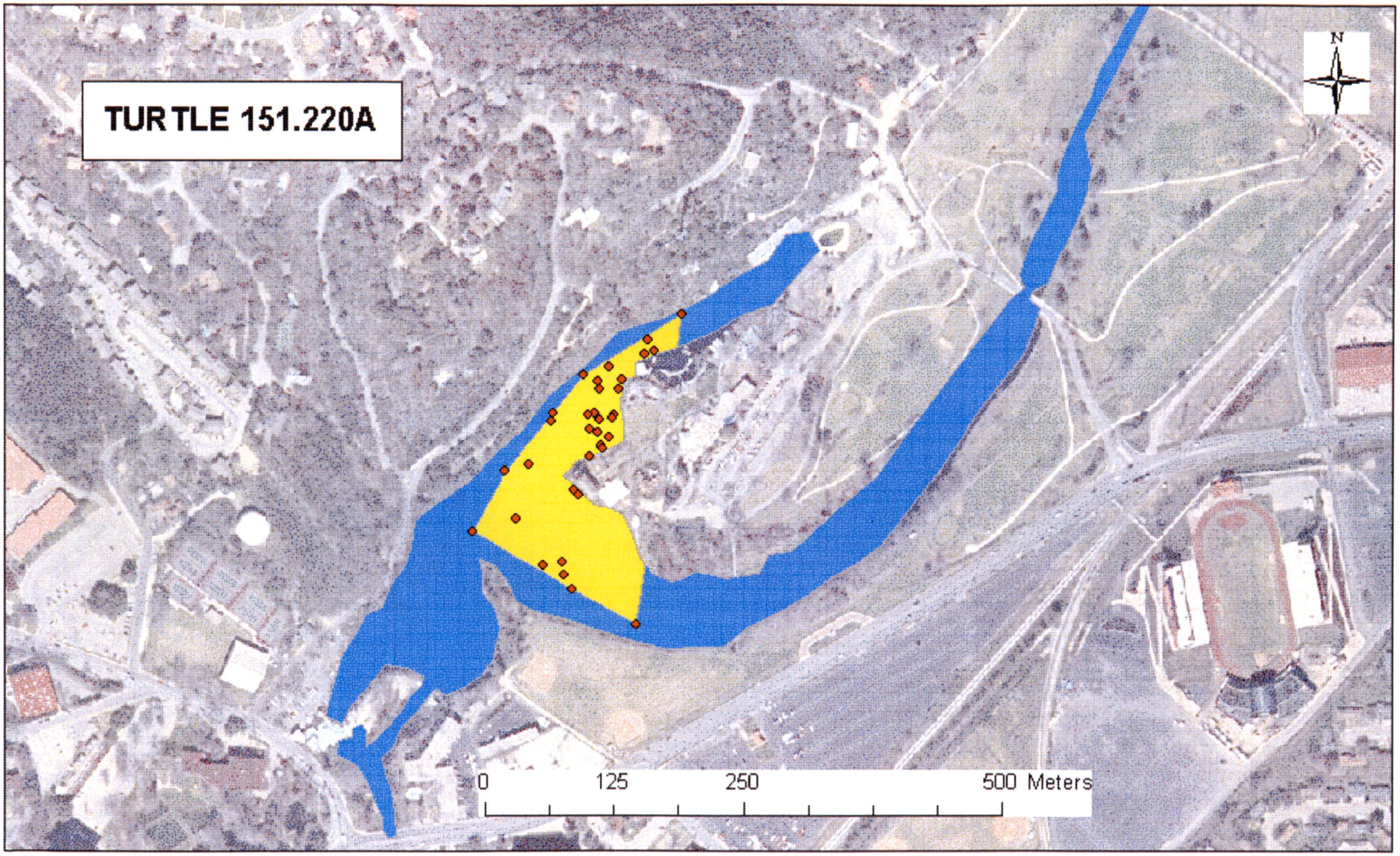


Figure 58. Annual home range for male Turtle 151.220A.

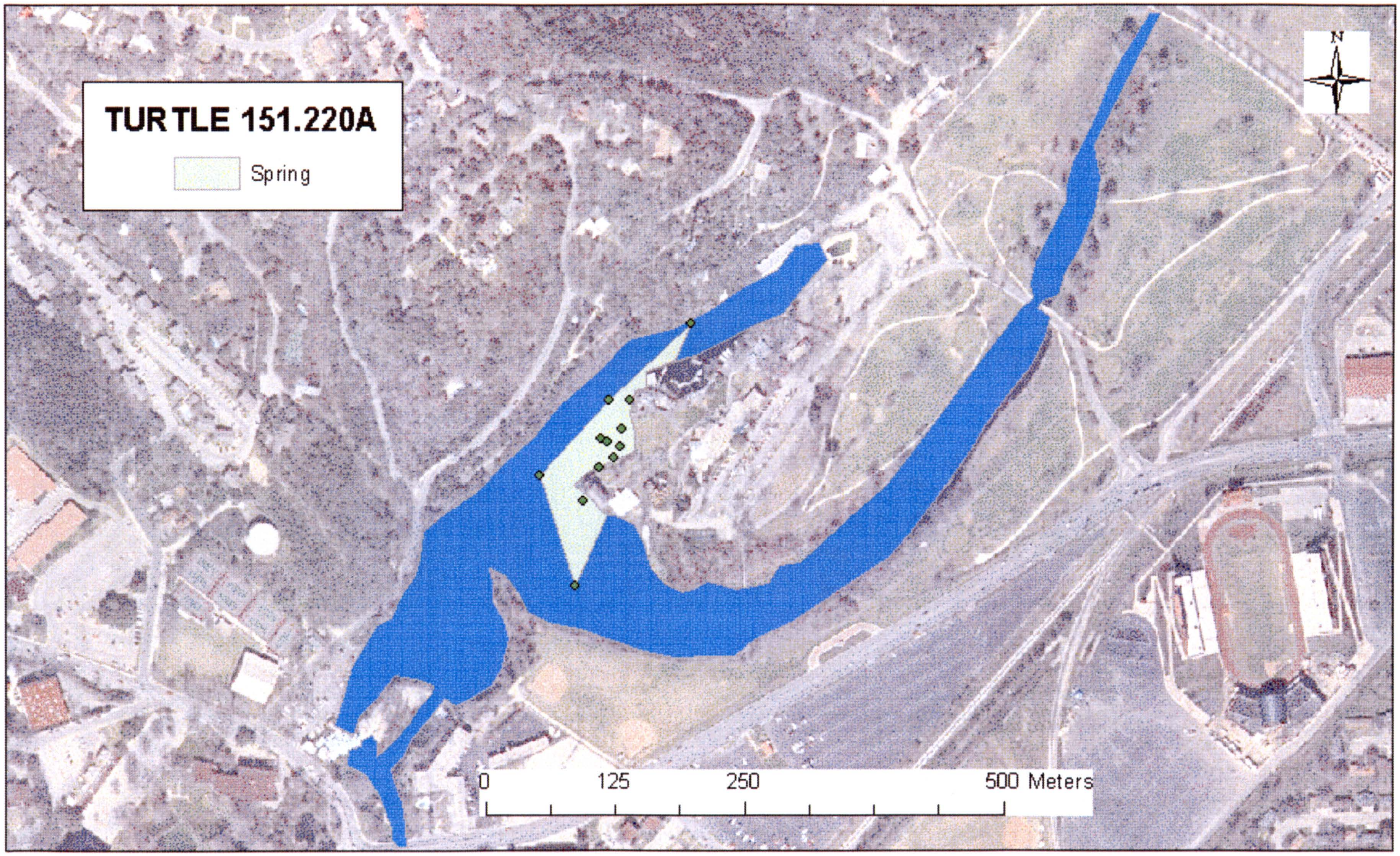
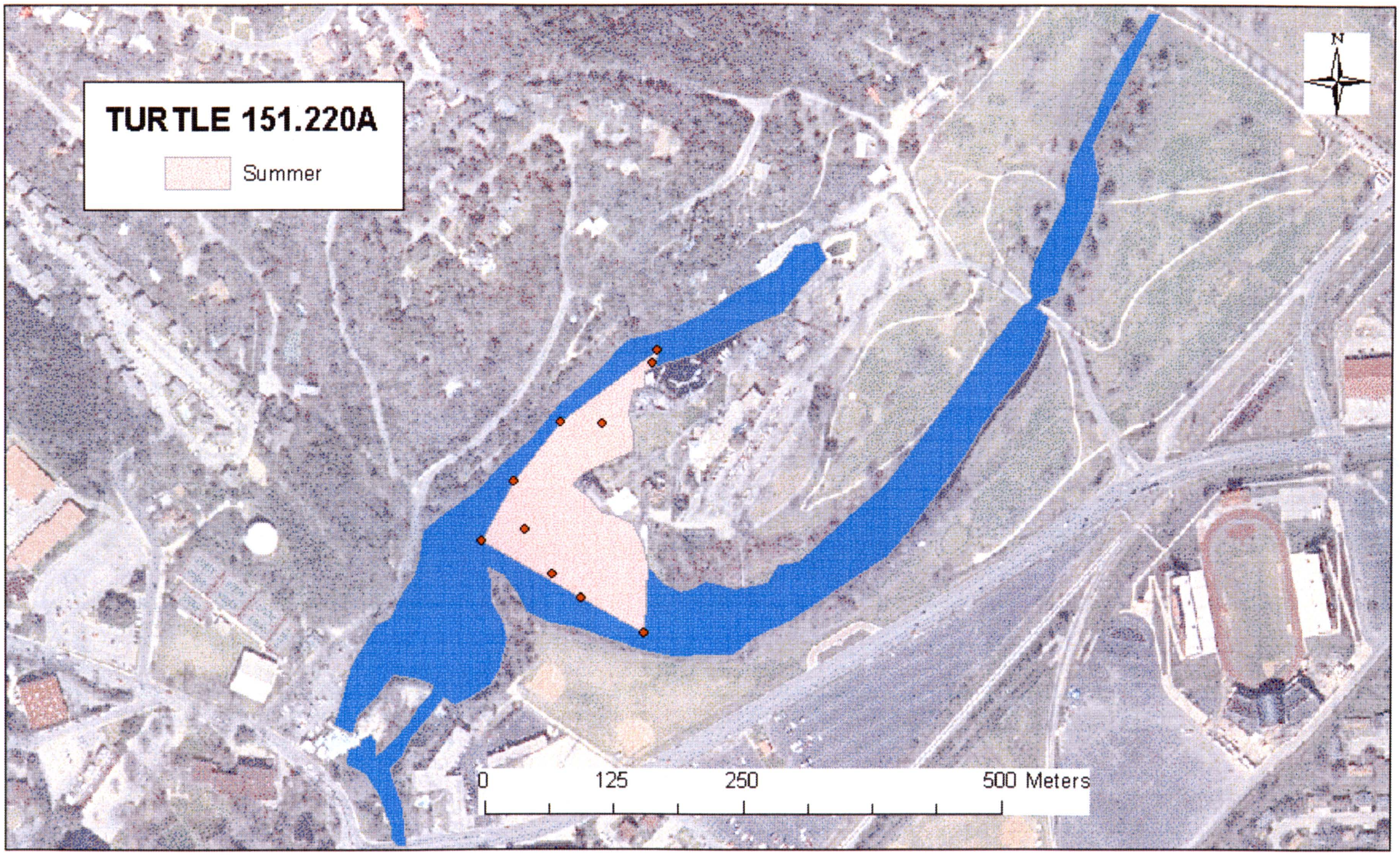


Figure 59. Spring home range for male Turtle 151.220A



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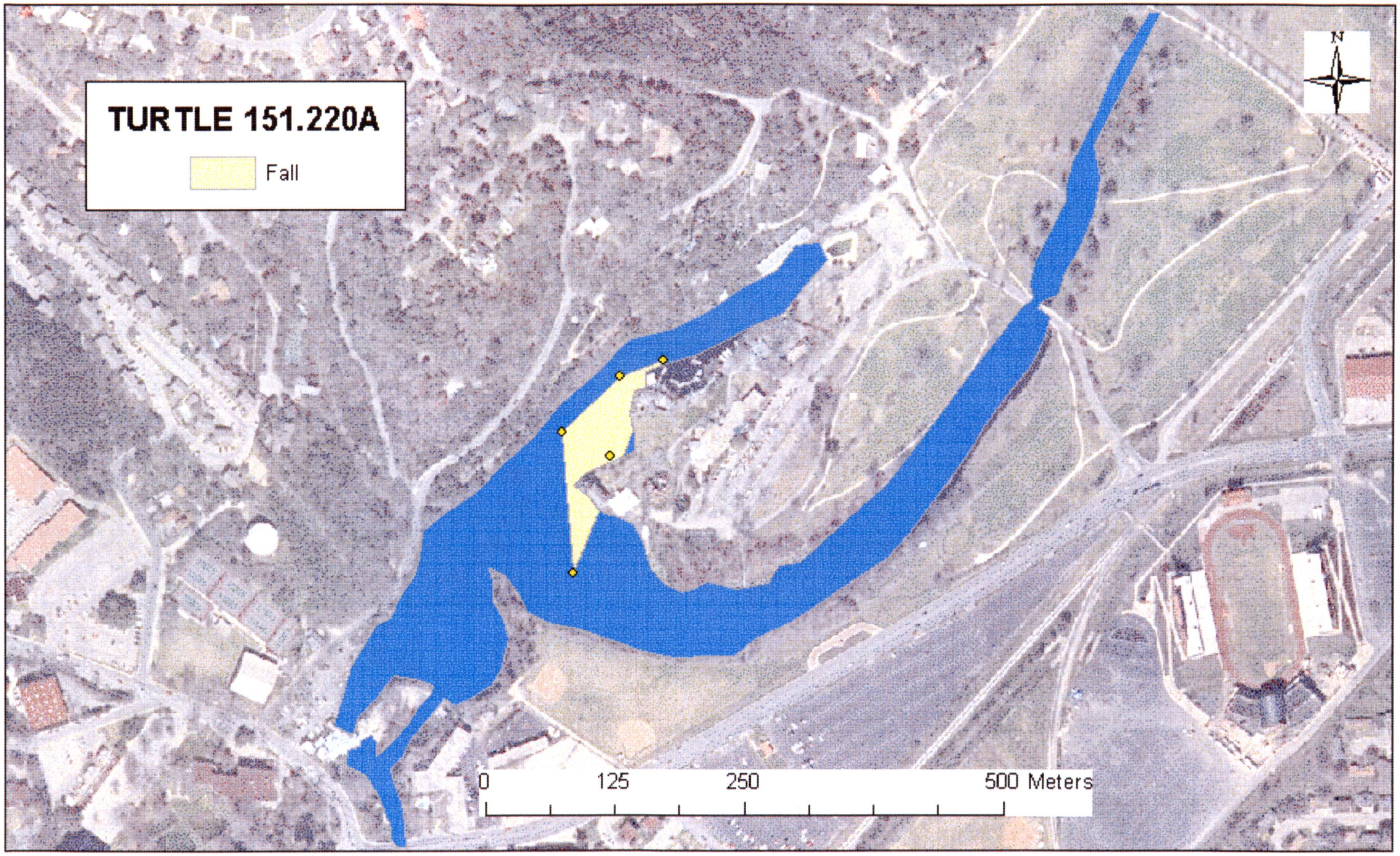


Figure 61. Fall home range for male Turtle 151.220A.

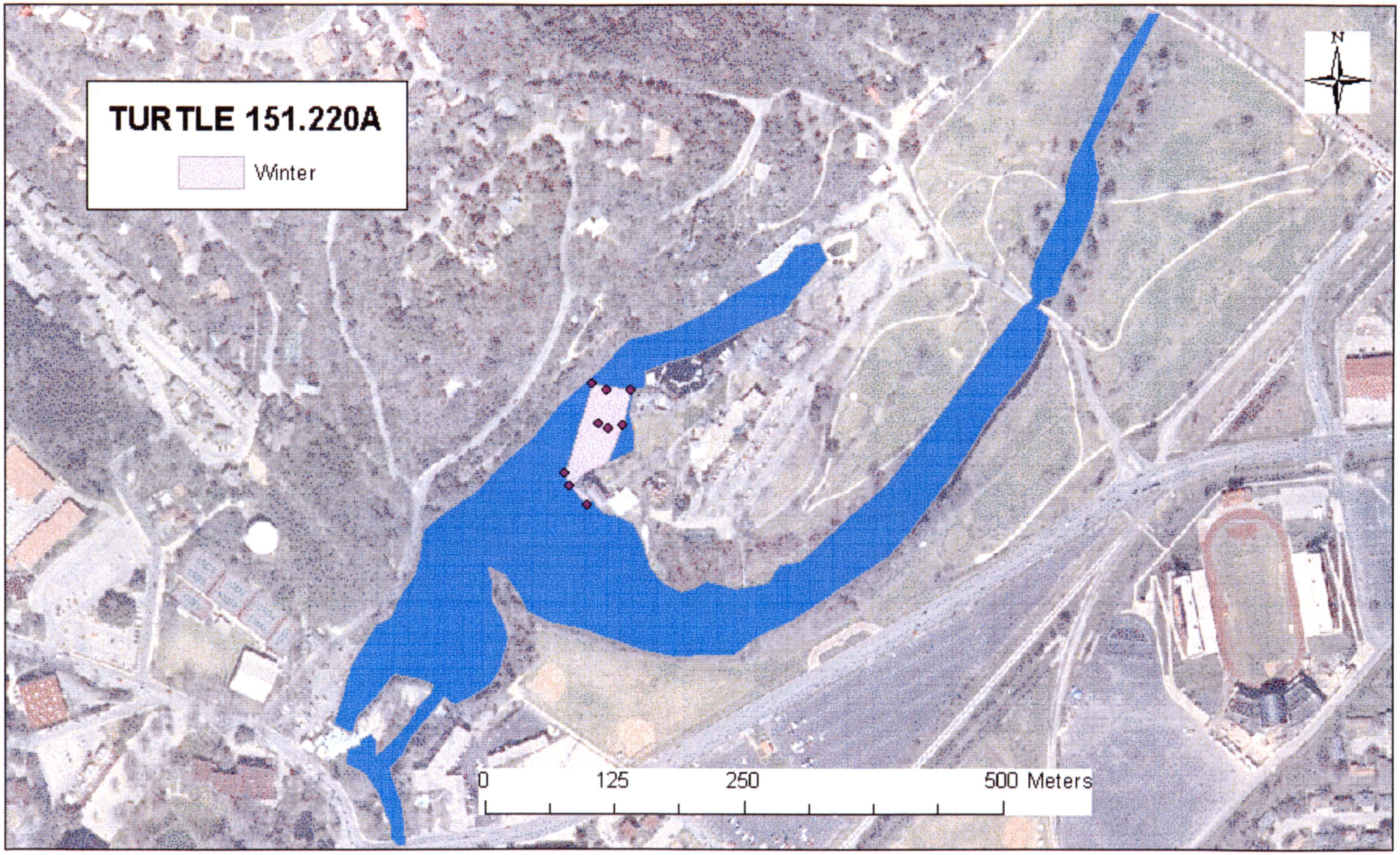


Figure 62. Winter home range for male Turtle 151.220A.

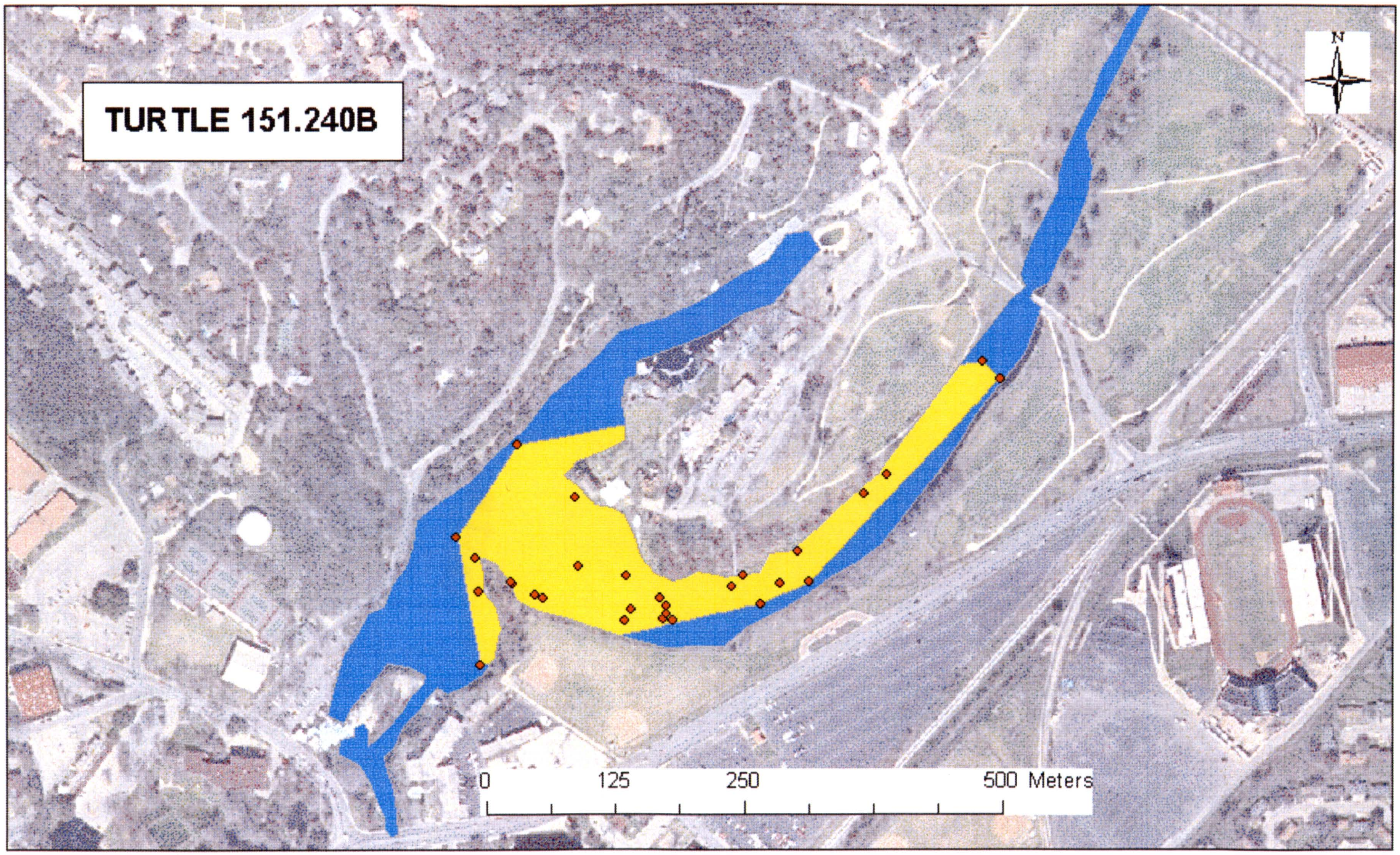
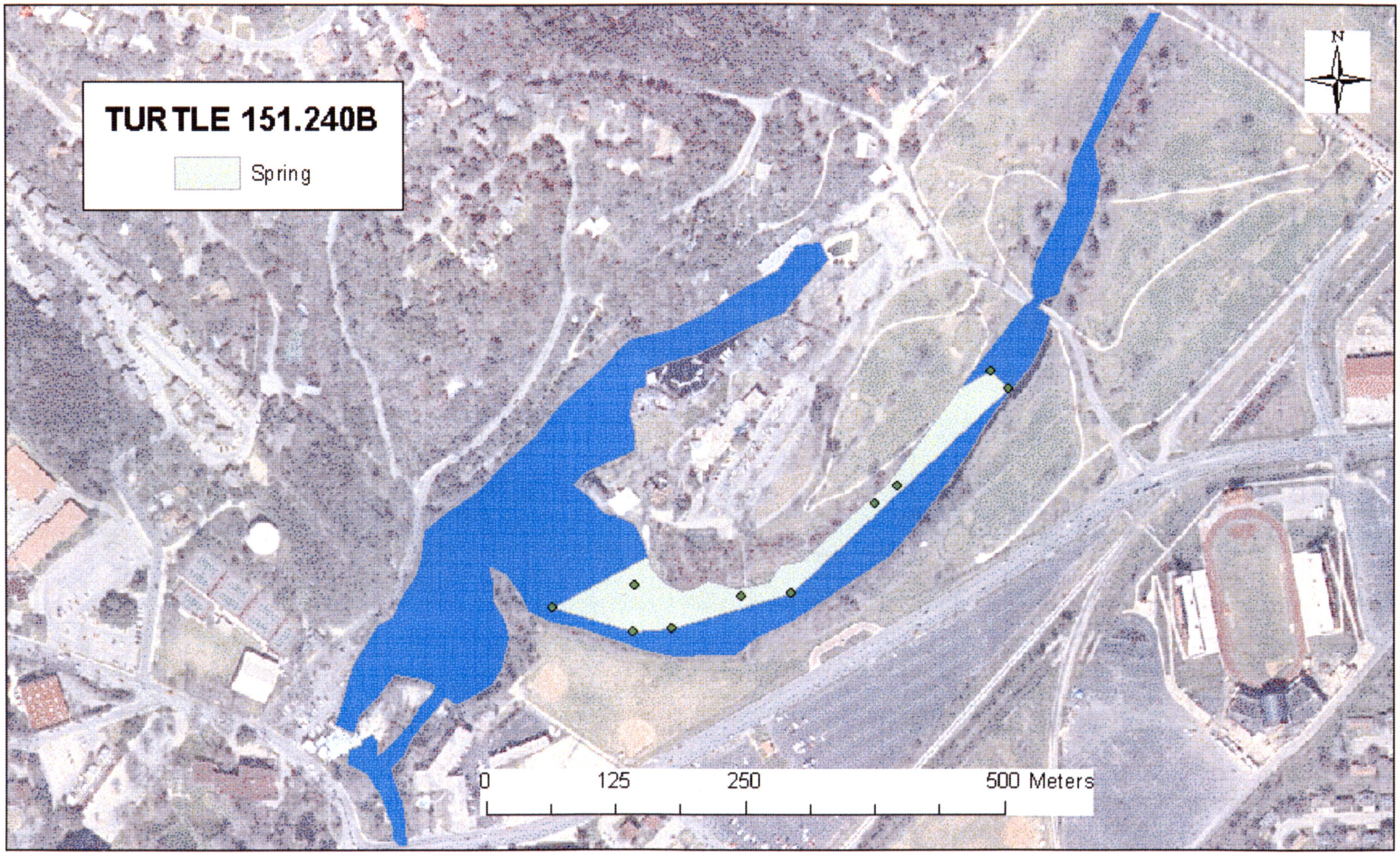


Figure 63. Annual home range for female Turtle 151.240B.



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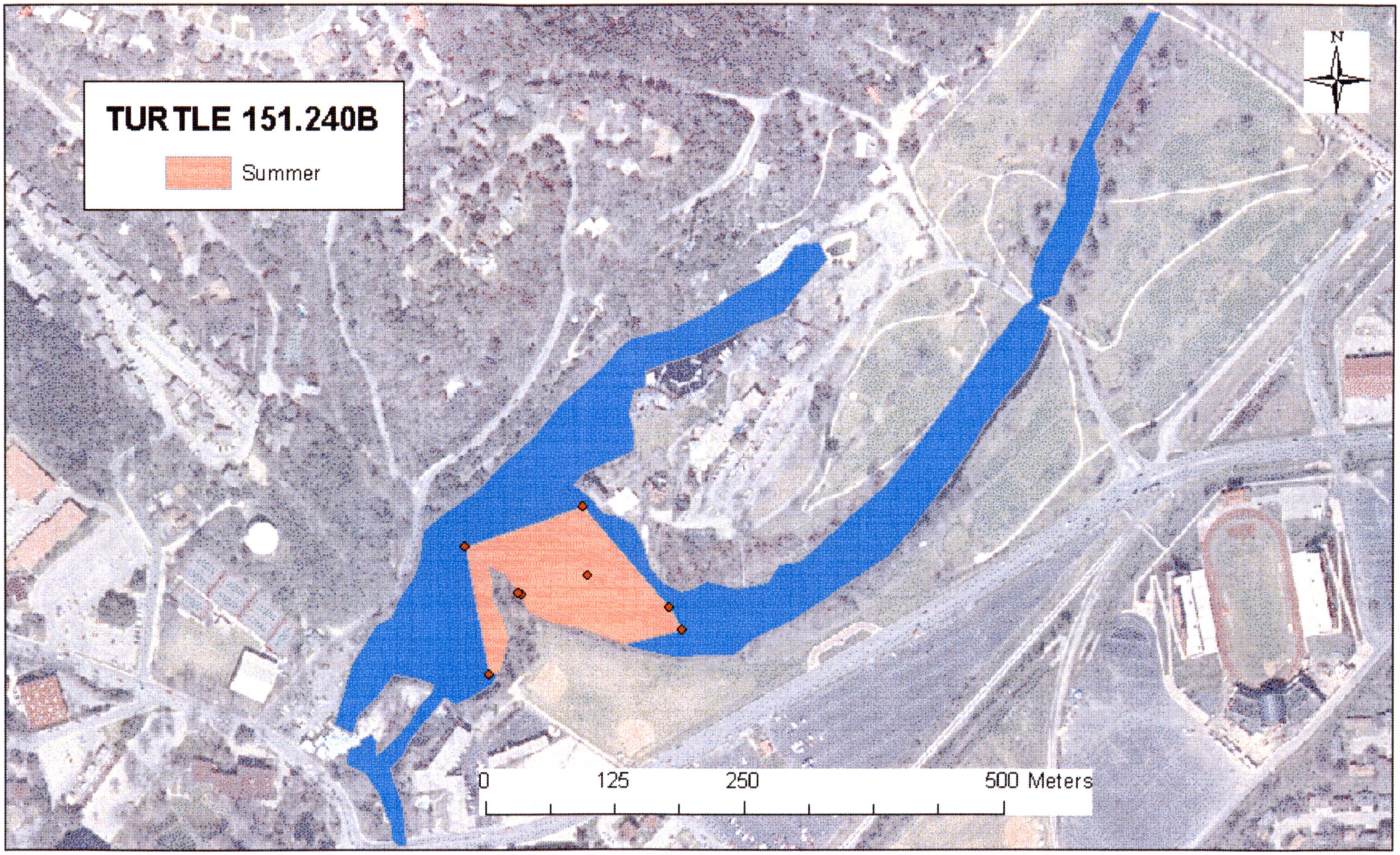


Figure 65. Summer home range for female Turtle 151.240B

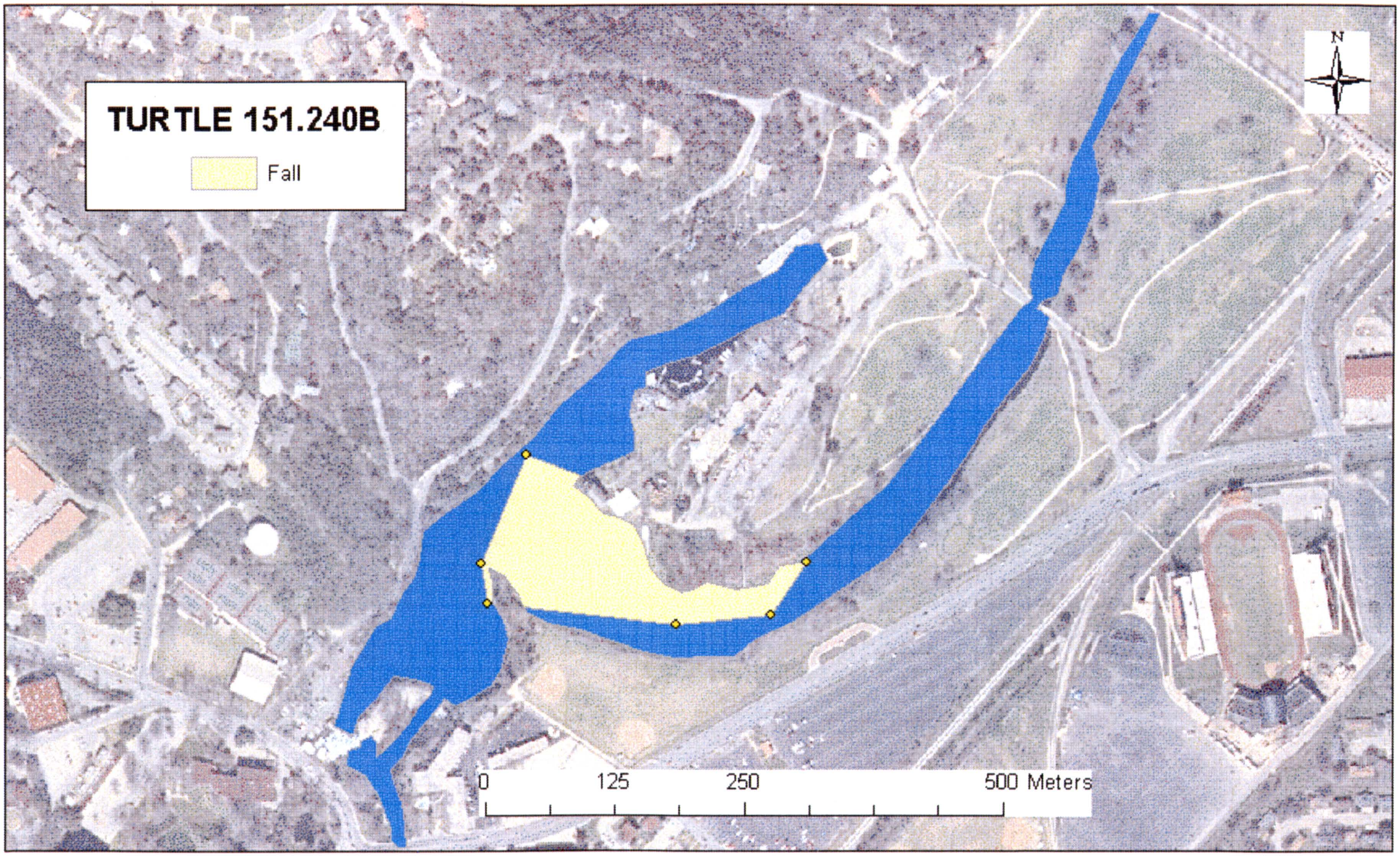


Figure 66. Fall home range for female Turtle 151.240.B.

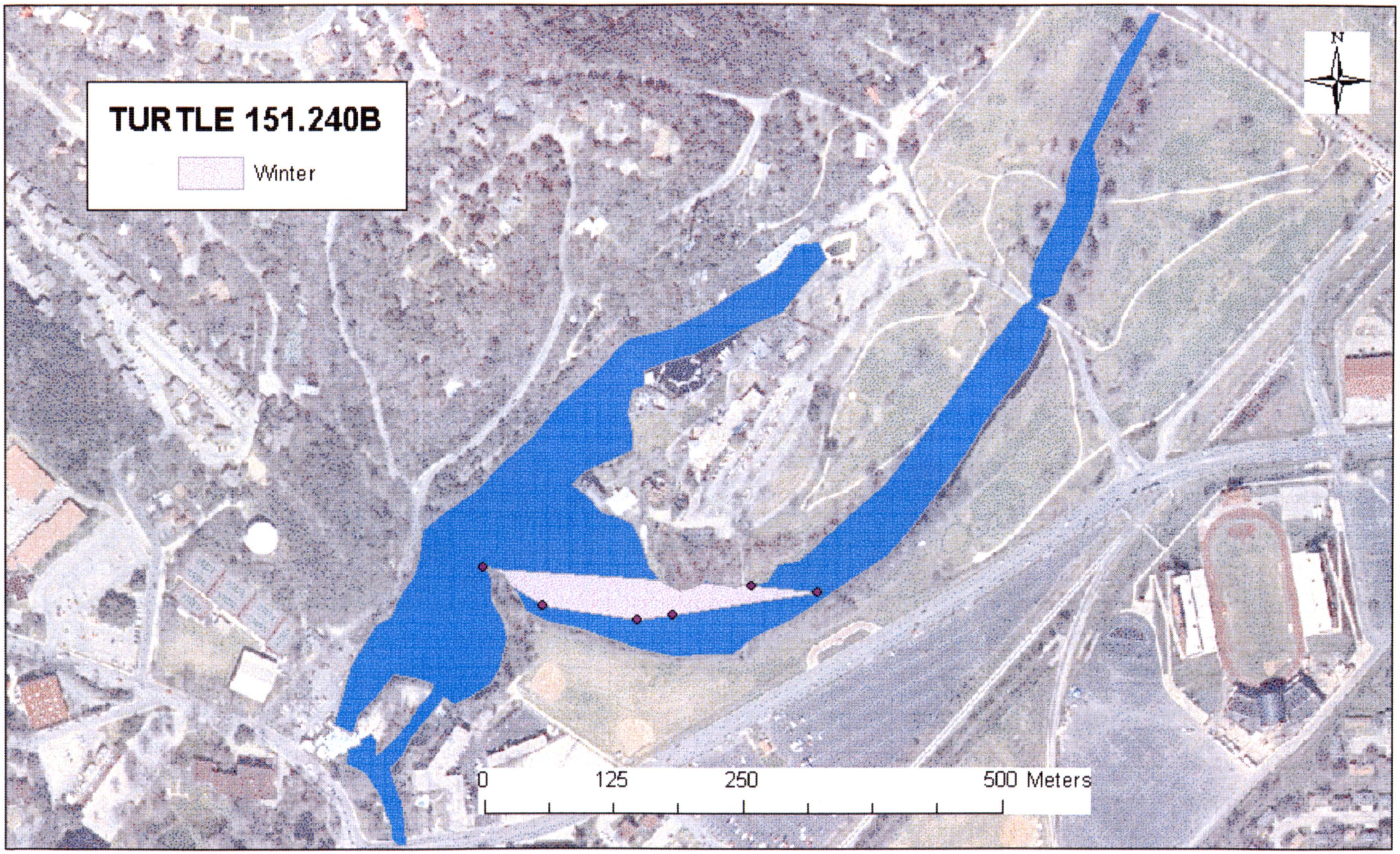


Figure 67. Winter home range for female Turtle 151.240B.

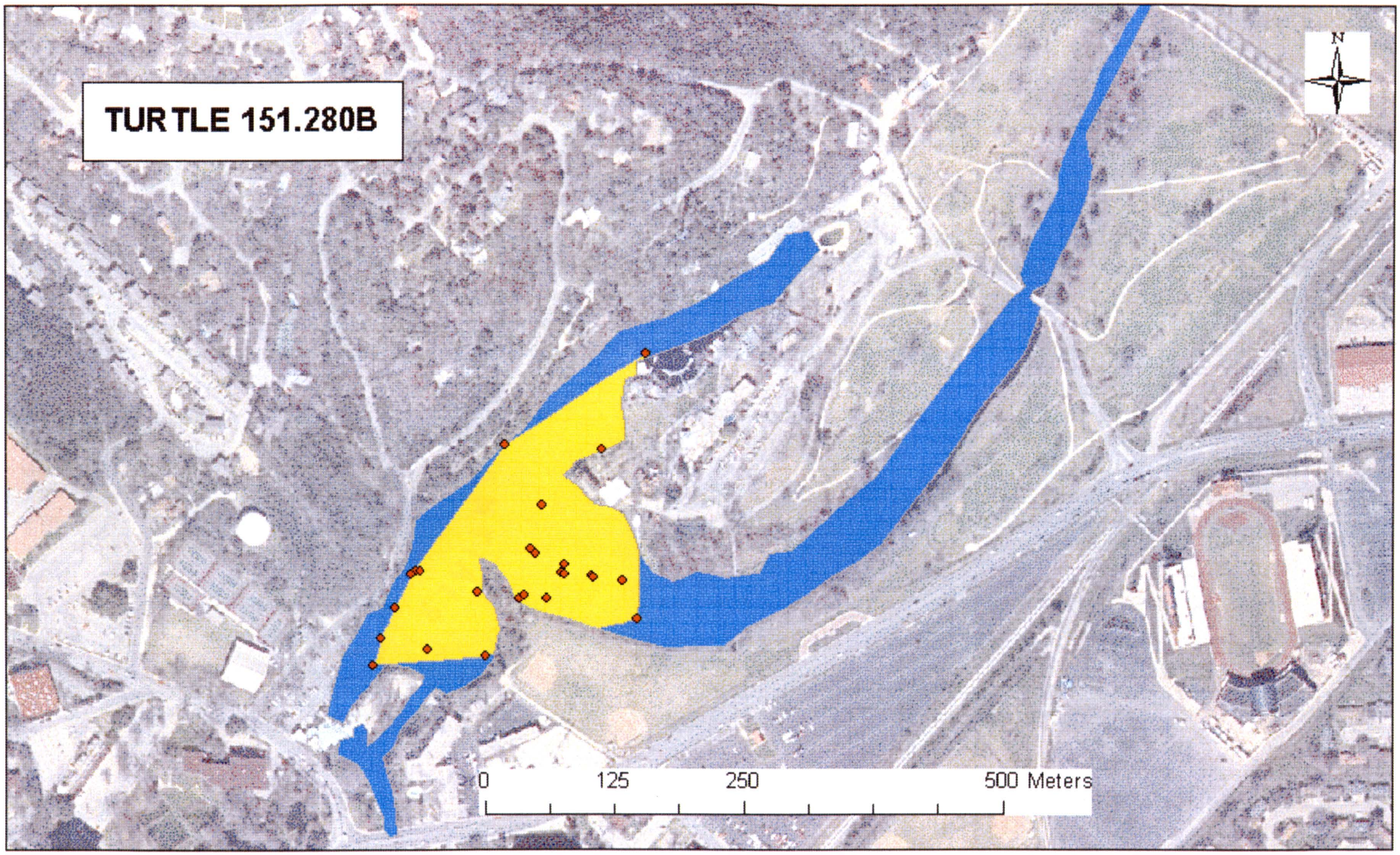


Figure 68. Annual home range for male Turtle 151.280B.

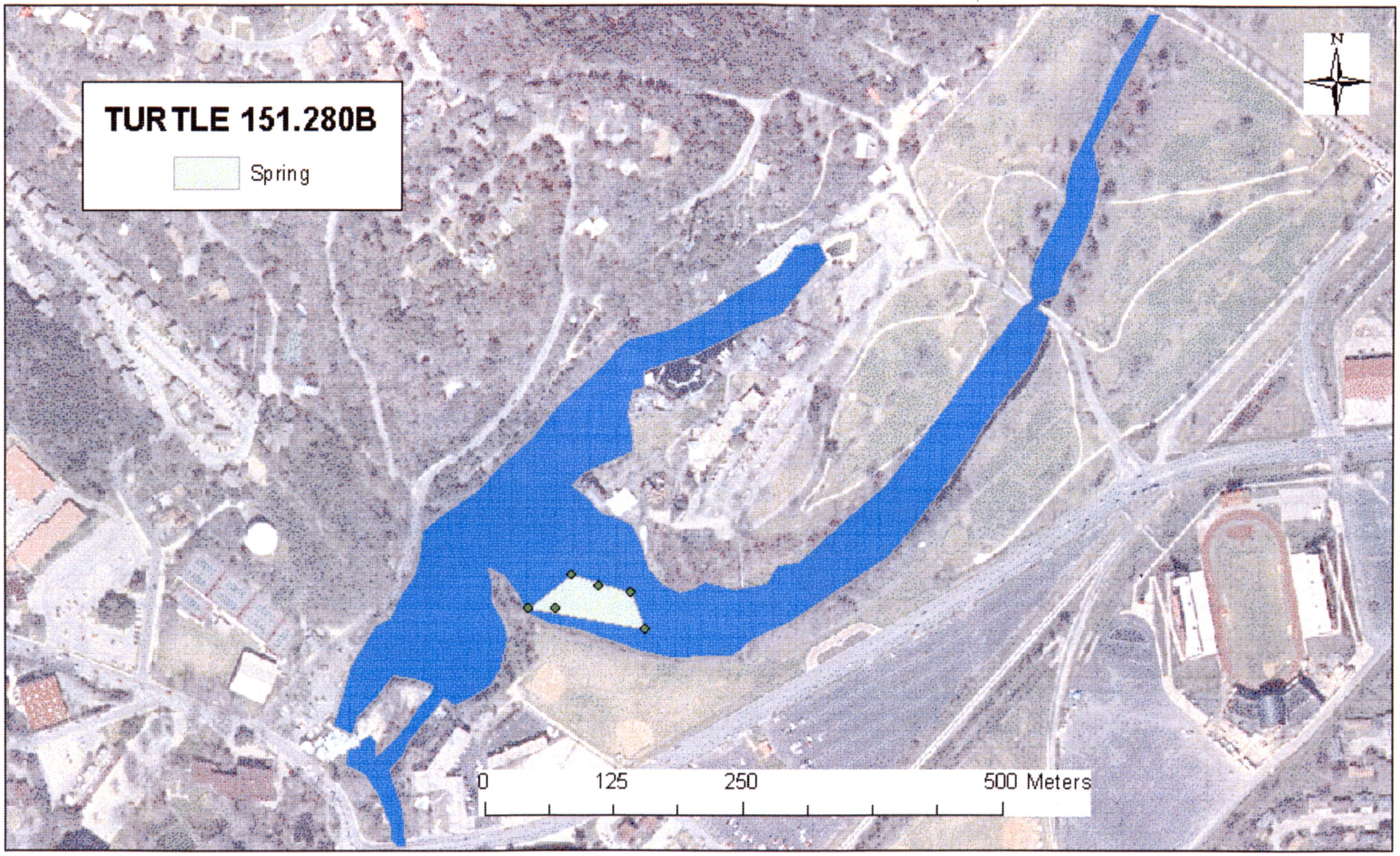


Figure 69. Spring home range for male Turtle 151.280B.

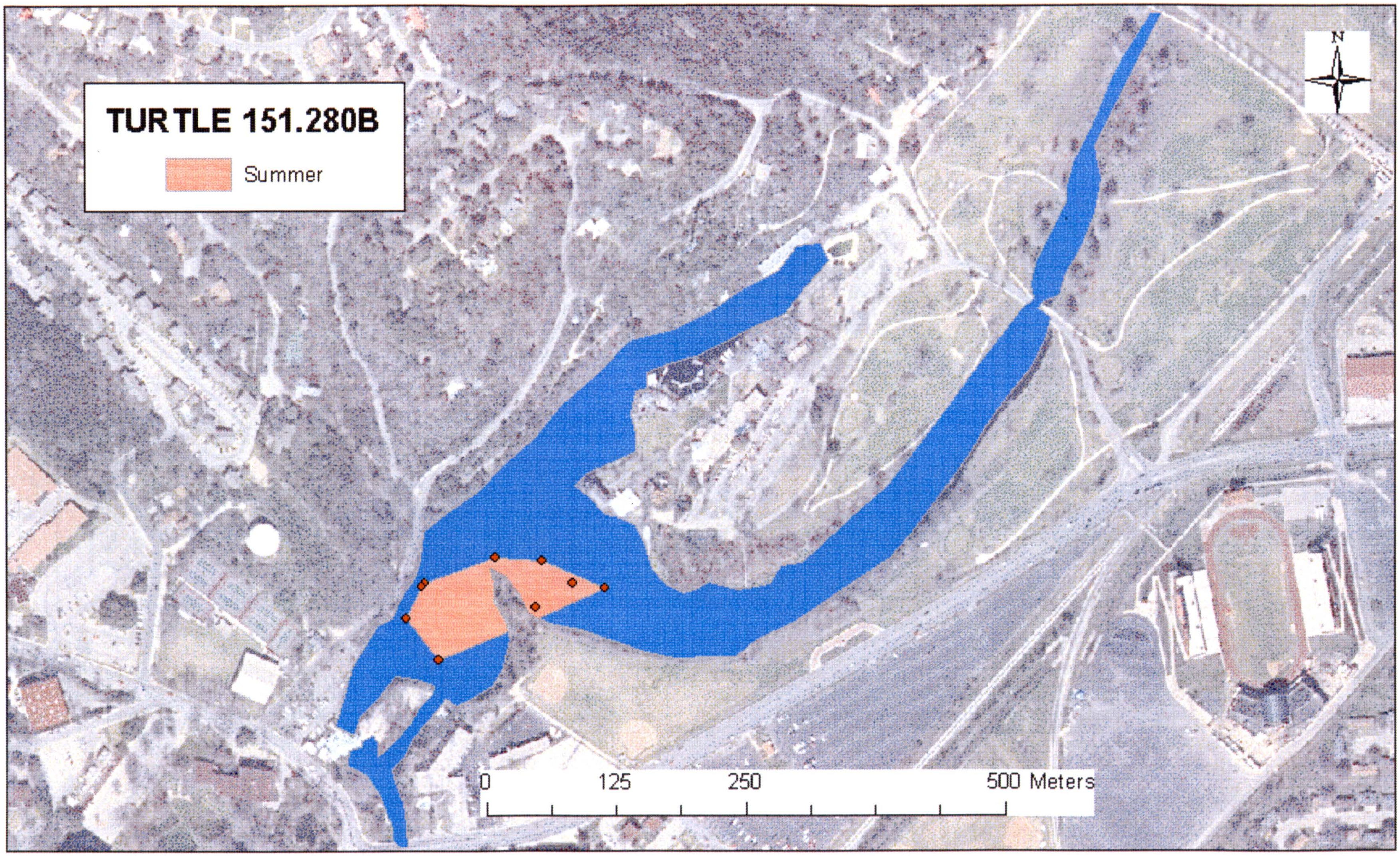


Figure 70. Summer home range for male Turtle 151.280B.

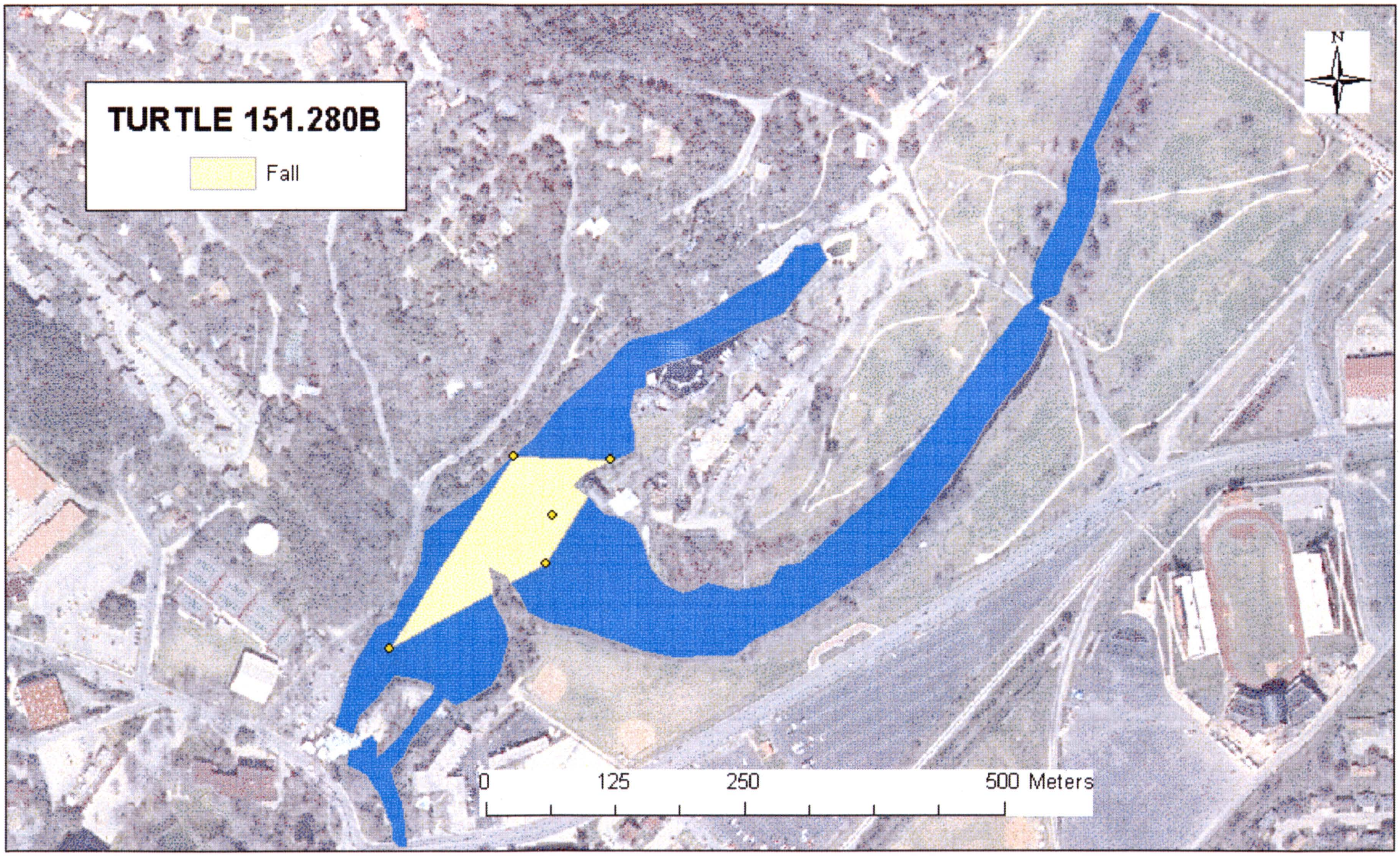
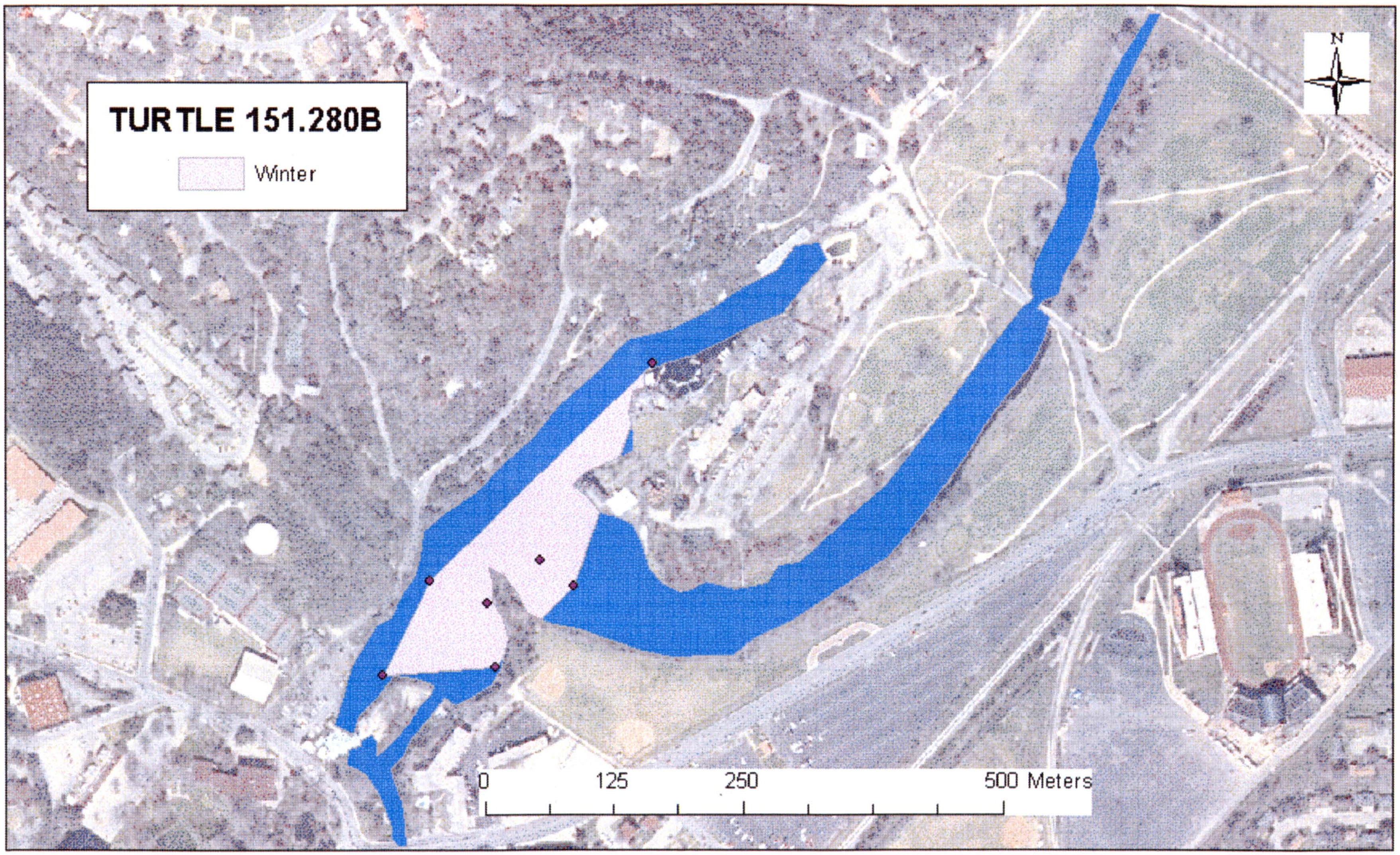


Figure 71. Fall home range for male Turtle 151.280B.



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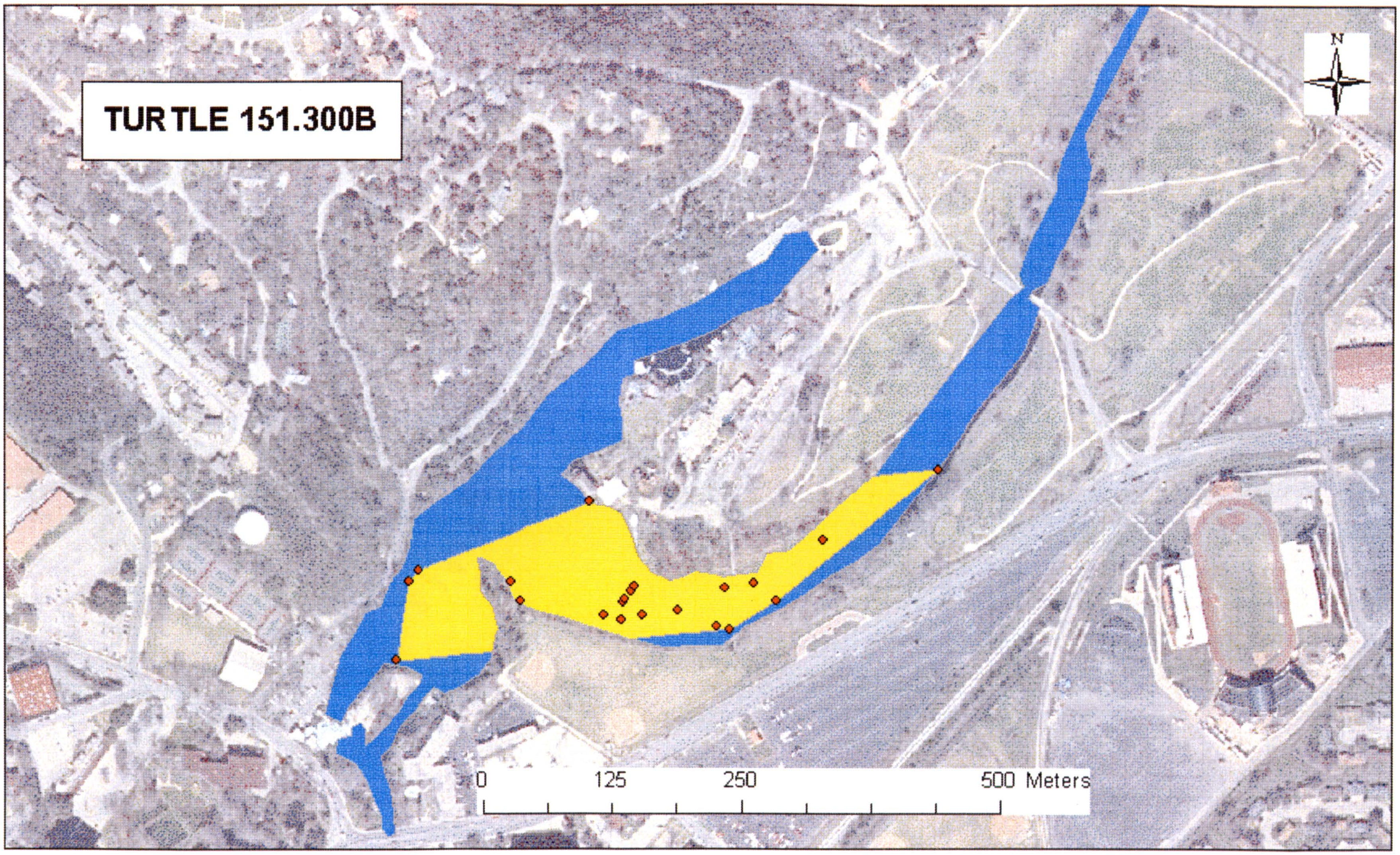
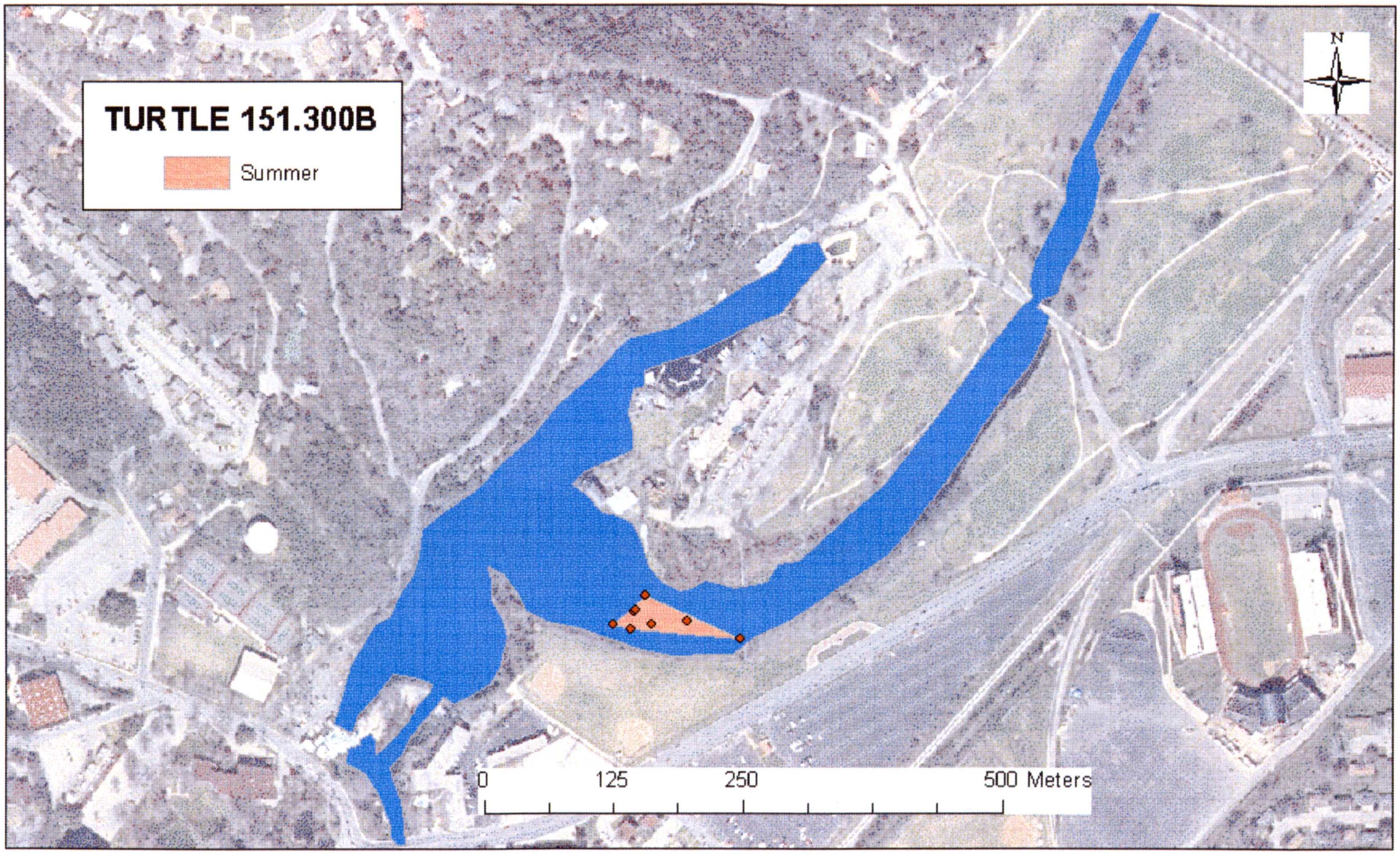


Figure 73. Annual home range for male Turtle 151.300B.



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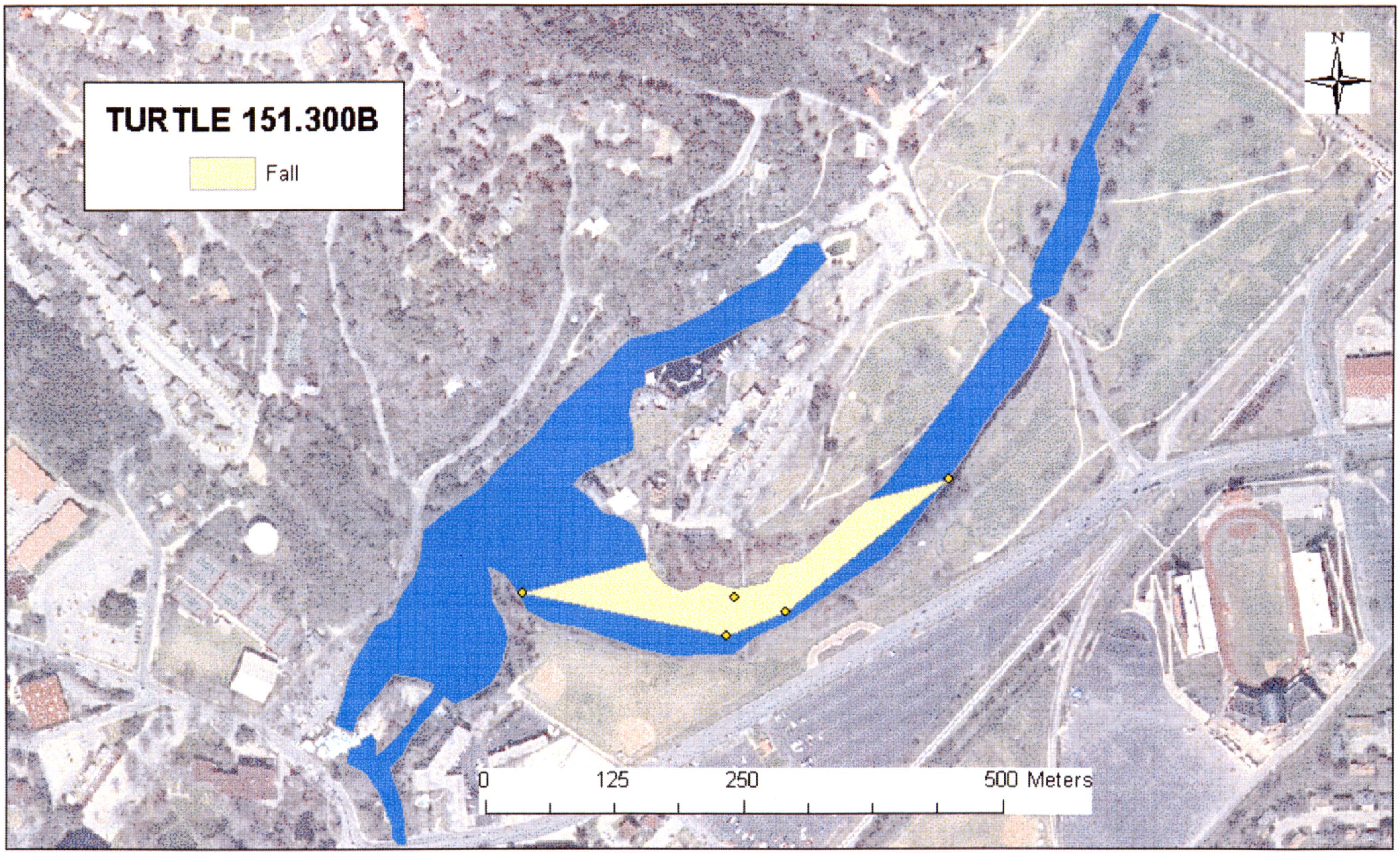
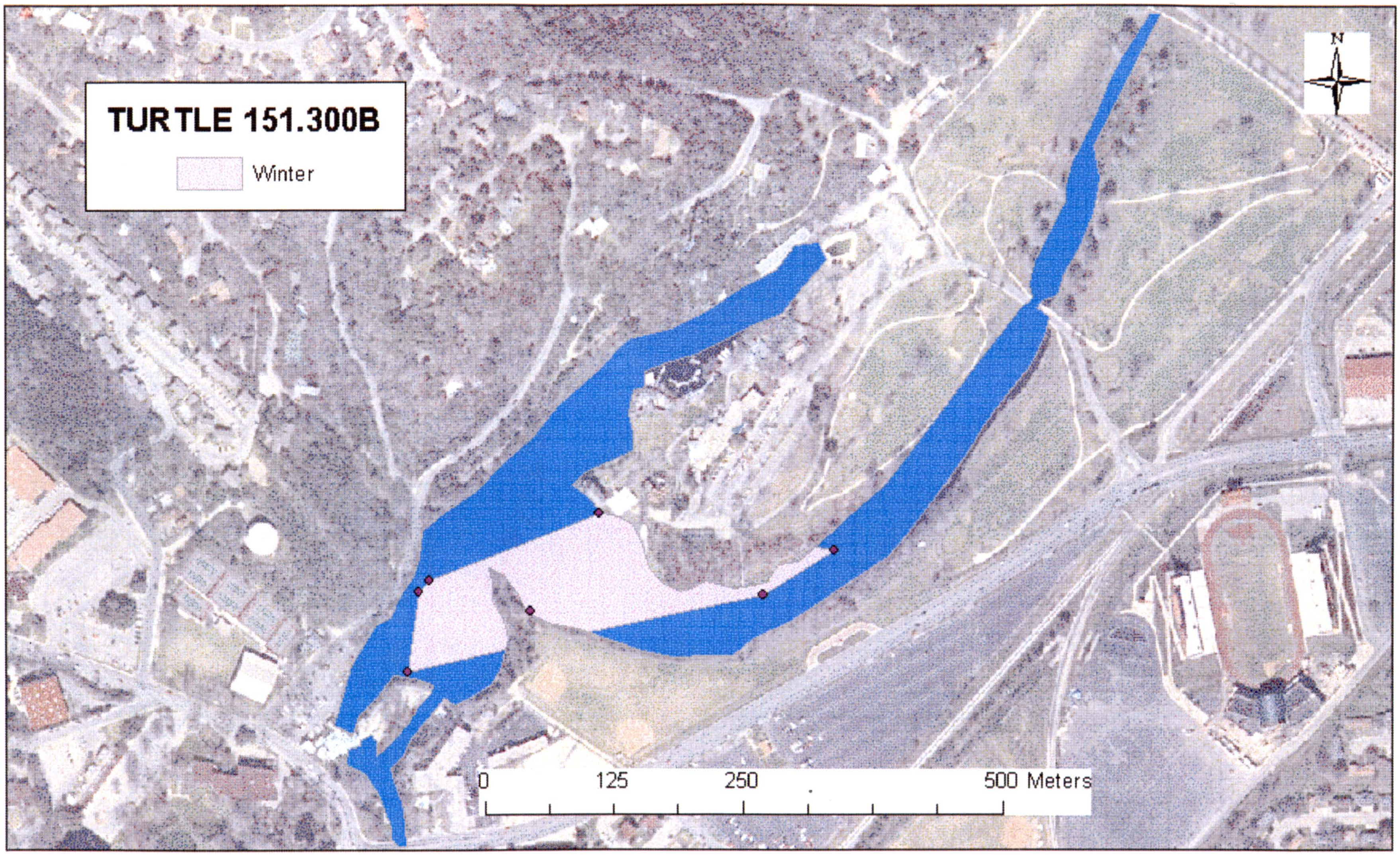


Figure 75. Fall home range for male Turtle 151.300B.



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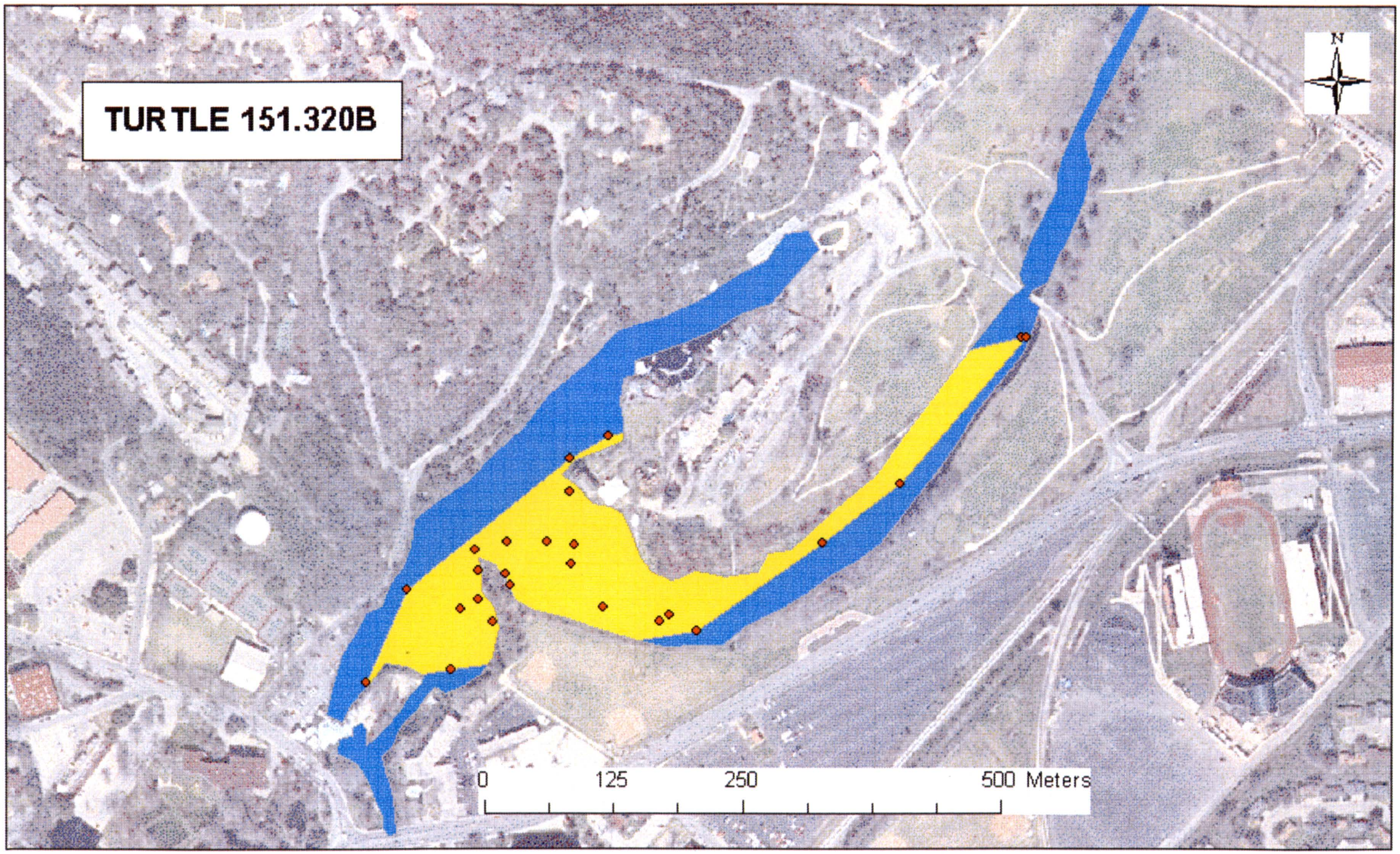


Figure 77. Annual home range for female Turtle 151.320B.

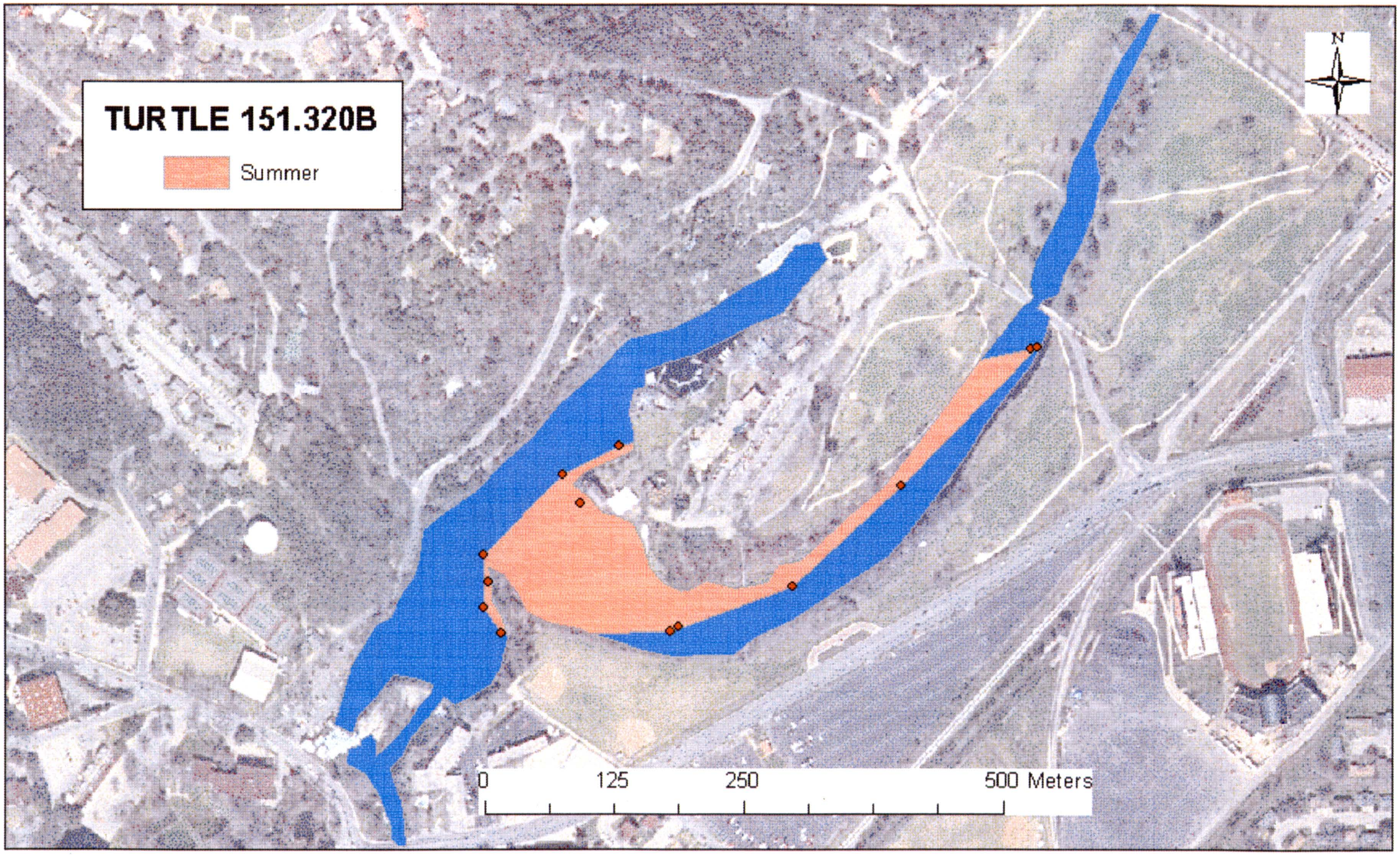
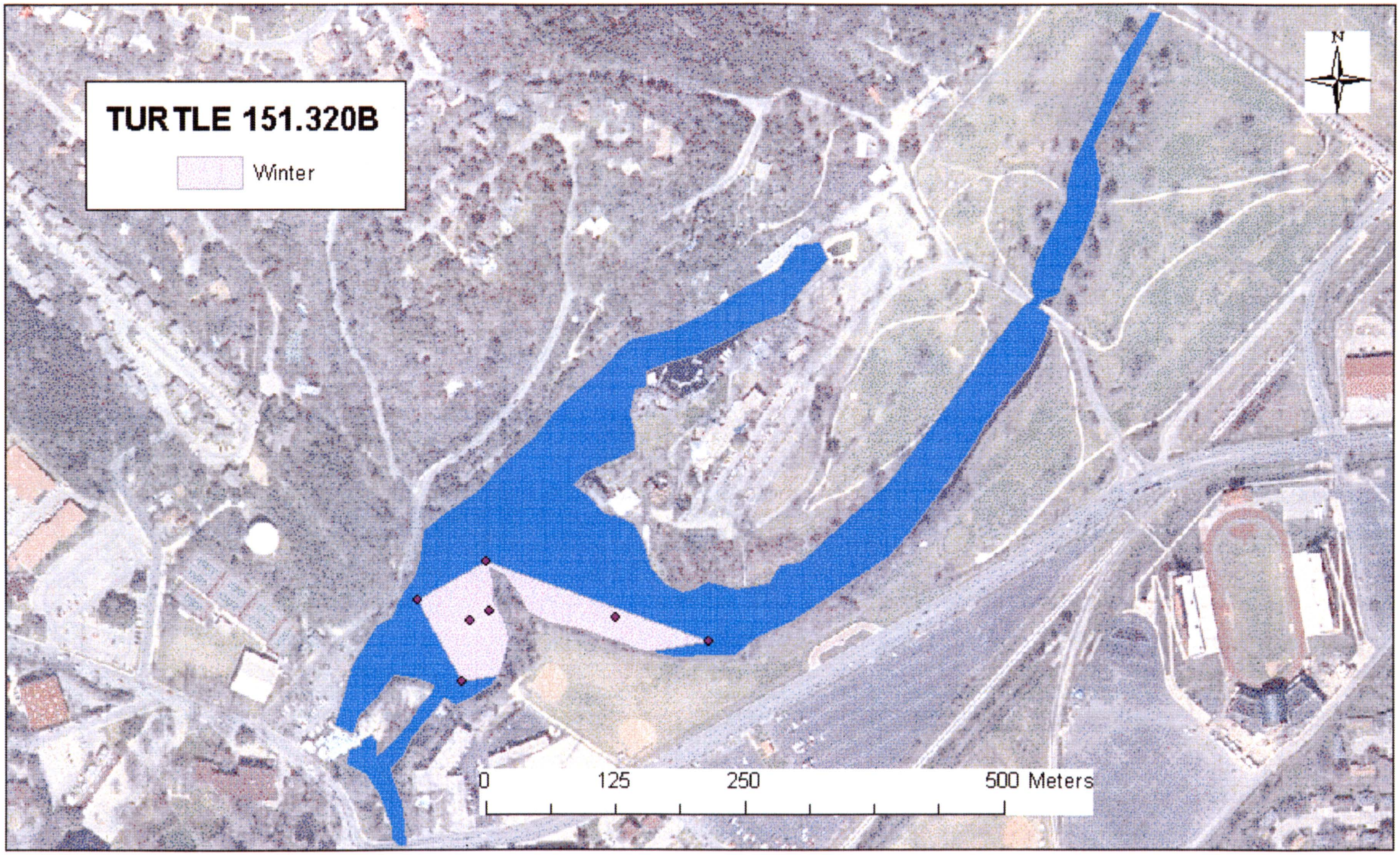


Figure 78. Summer home range for female Turtle 151.320B.

Figure 79. Fall home range for female Turtle 151.320B.



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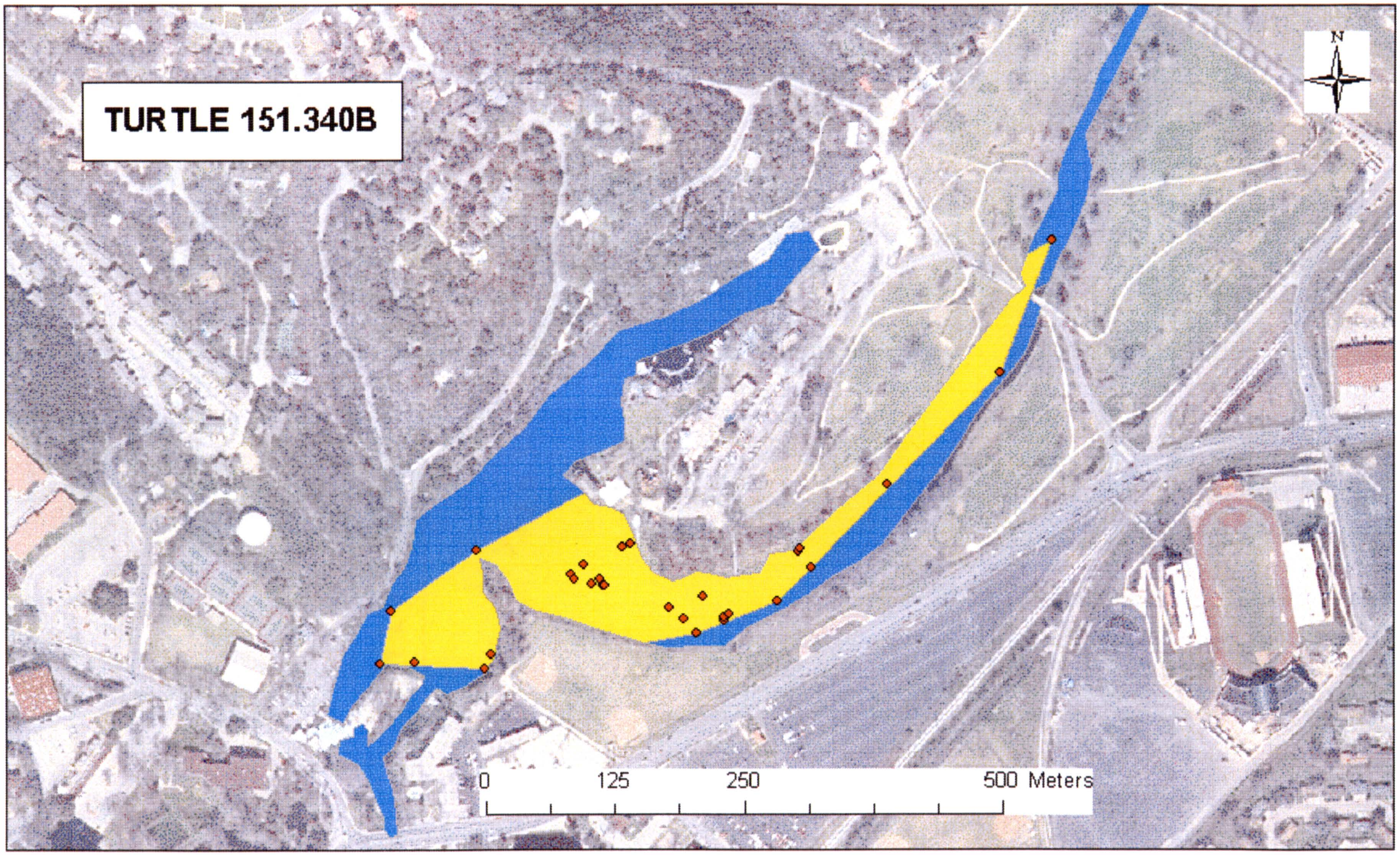

Figure 81. Annual home range for female Turtle 151.340B.

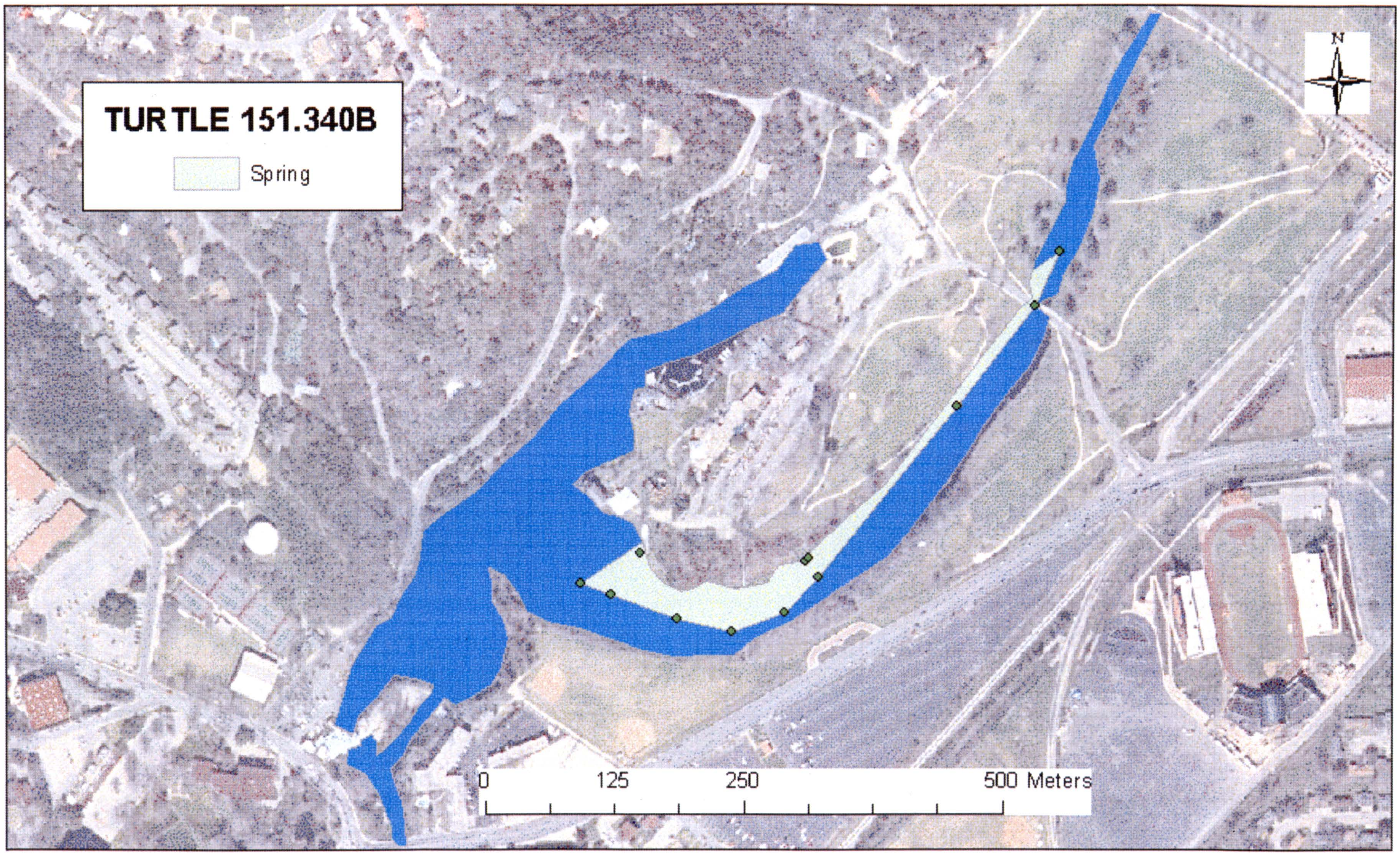

Figure 82. Spring home range for female Turtle 151.340B.

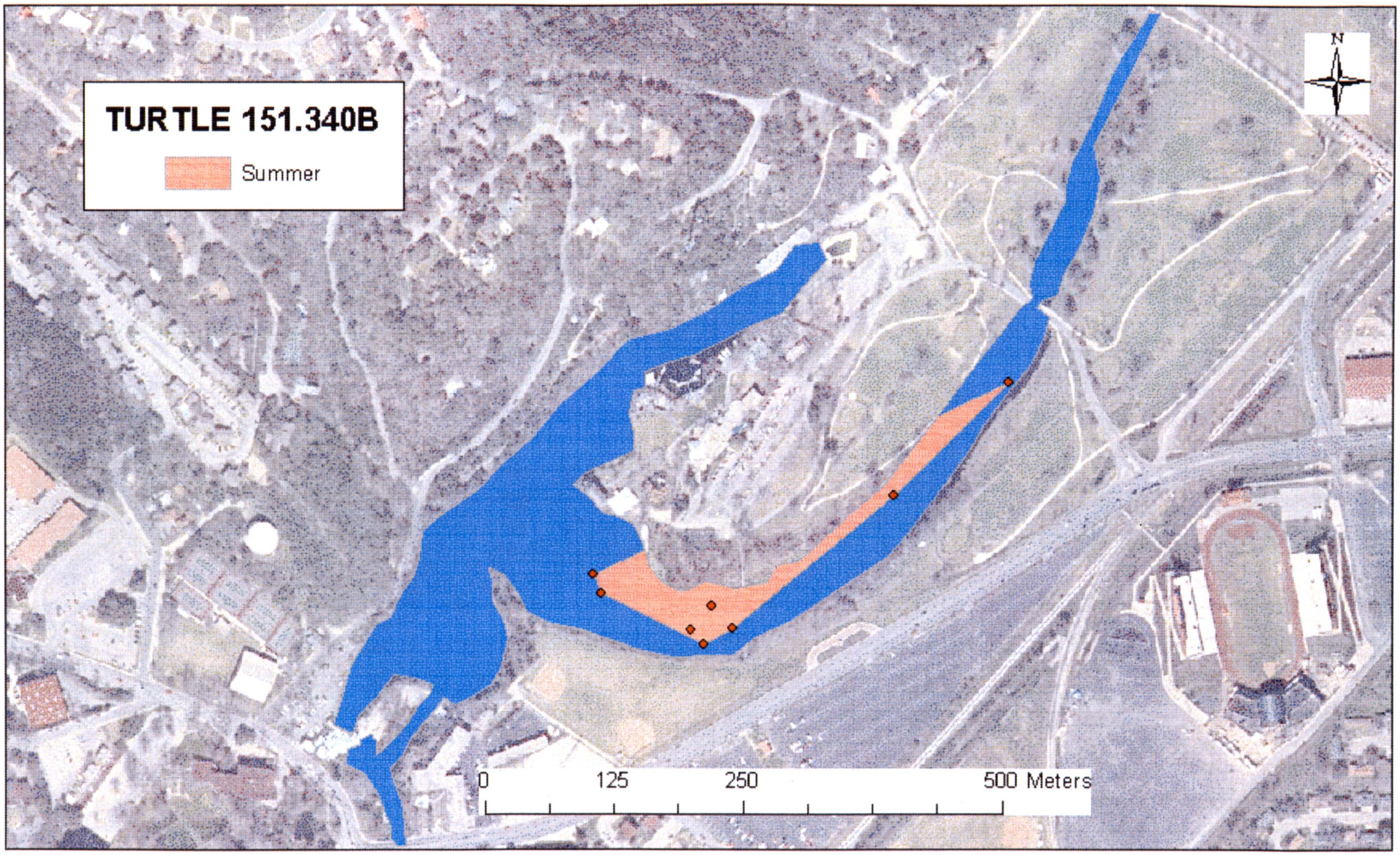

Figure 83. Summer home range for female Turtle 151.340B.

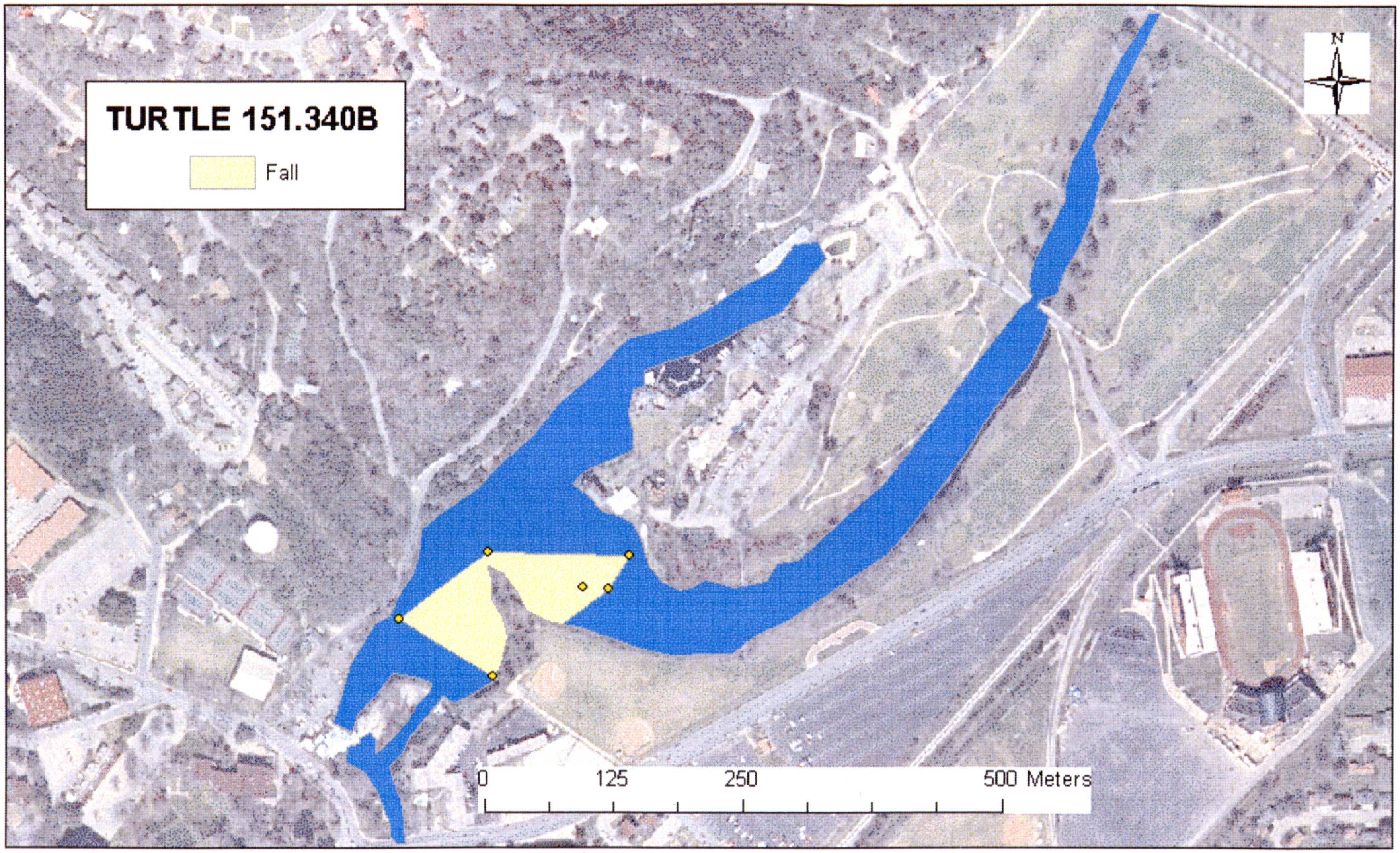

Figure 84. Fall home range for female Turtle 151.340B.

Figure 85. Winter home range for female Turtle 151.340B.

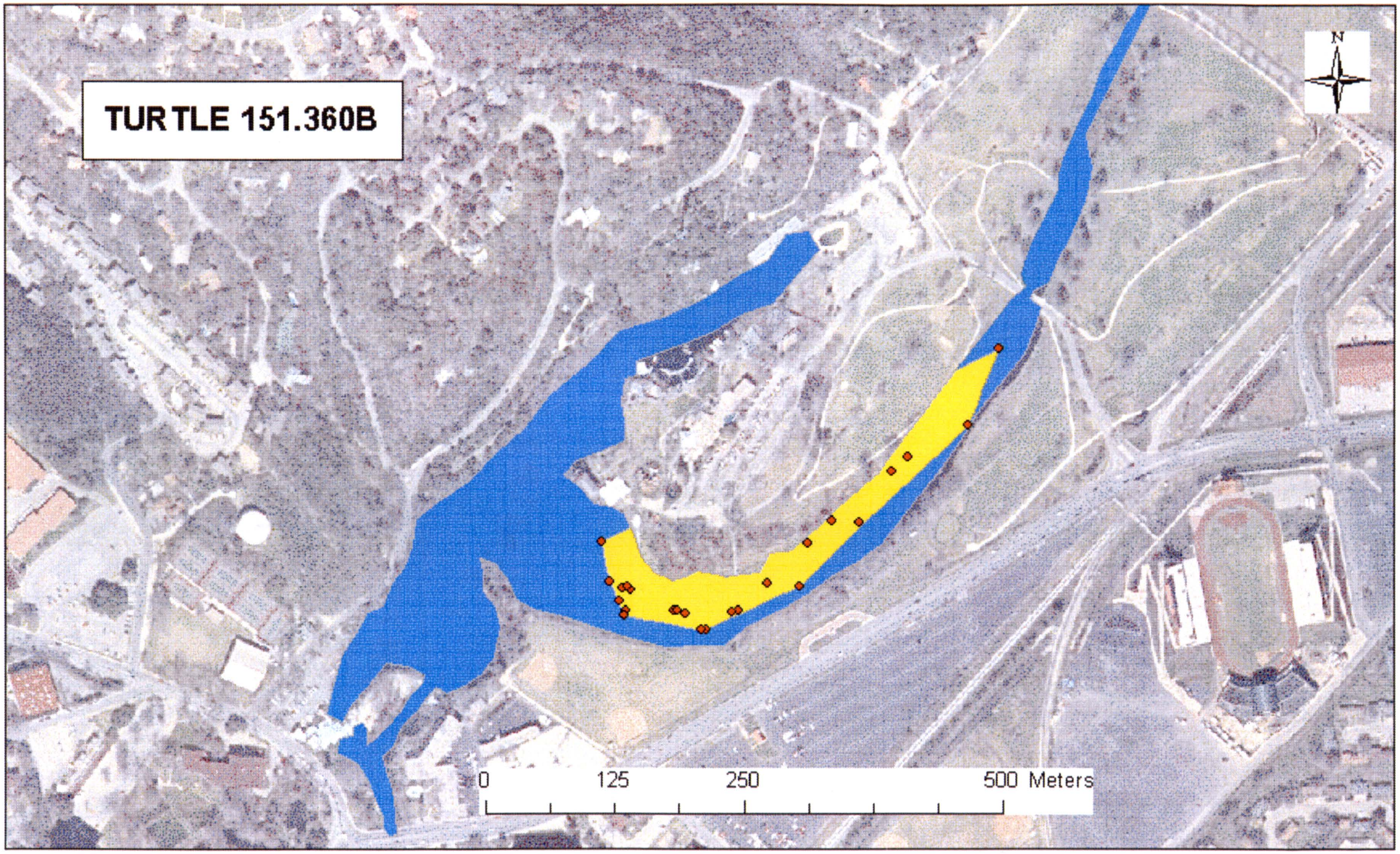

Figure 86. Annual home range for male Turtle 151.360B.

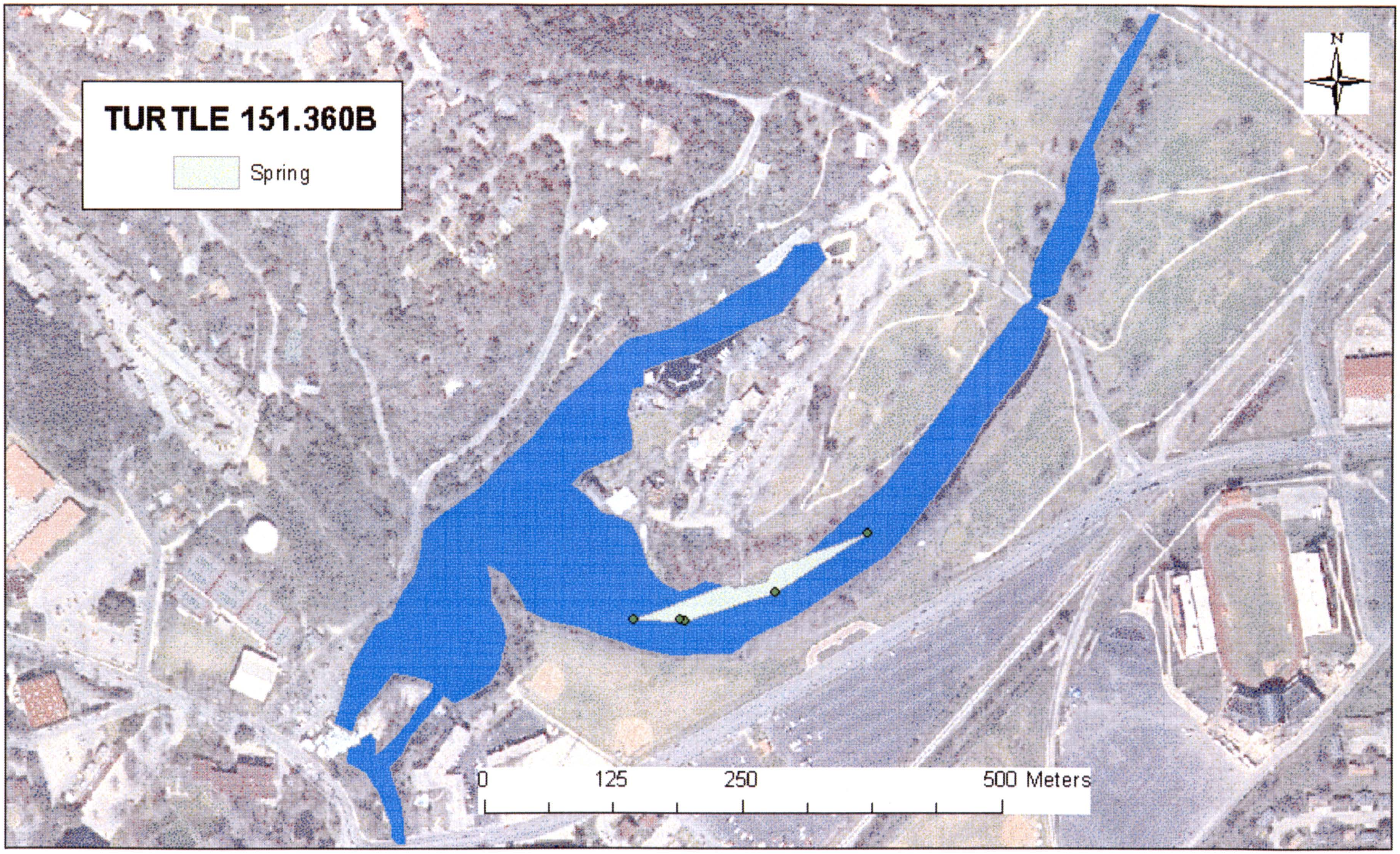

Figure 87. Spring home range for male Turtle 151.360B.

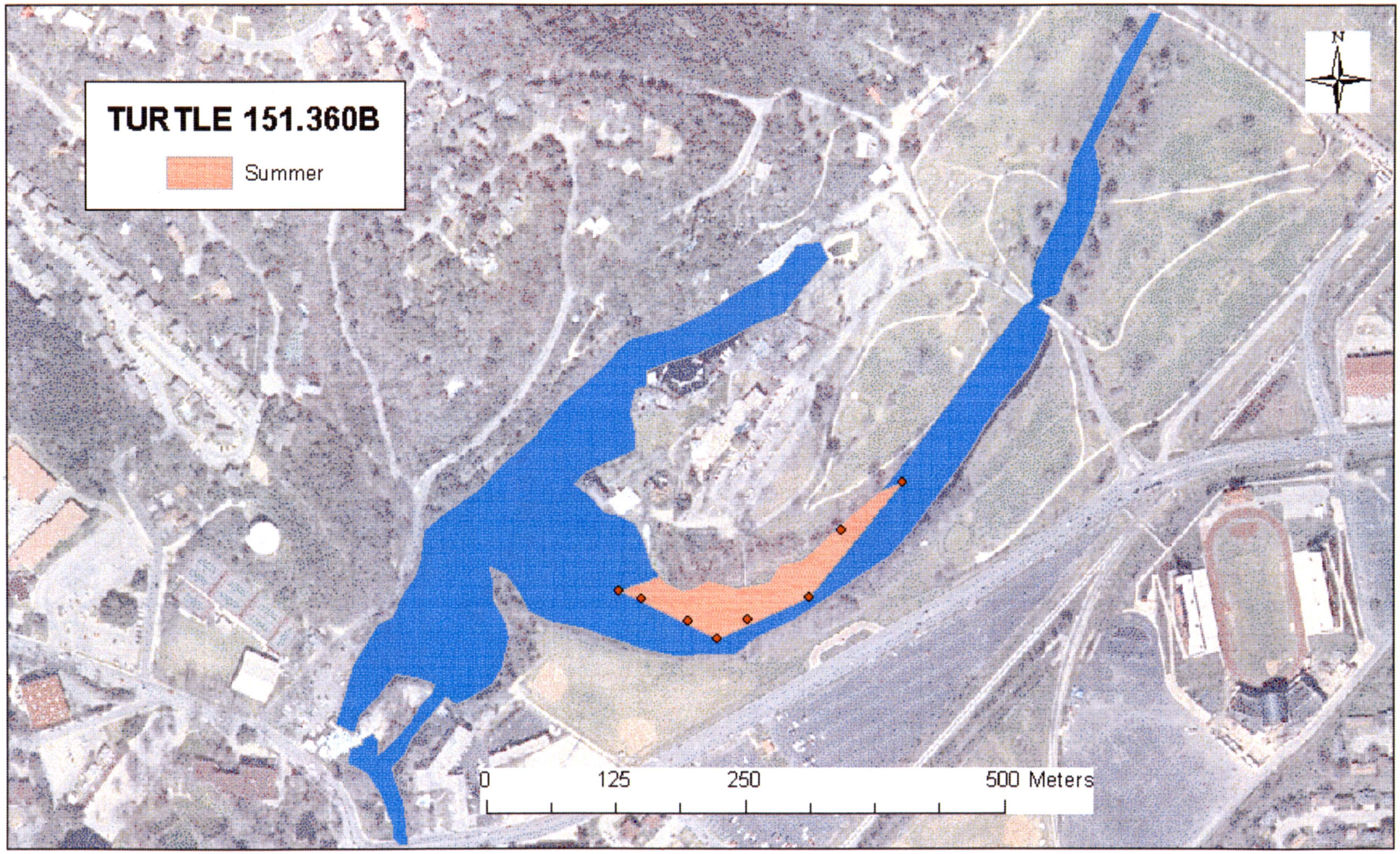

Figure 88. Summer home range for male Turtle 151.360B.

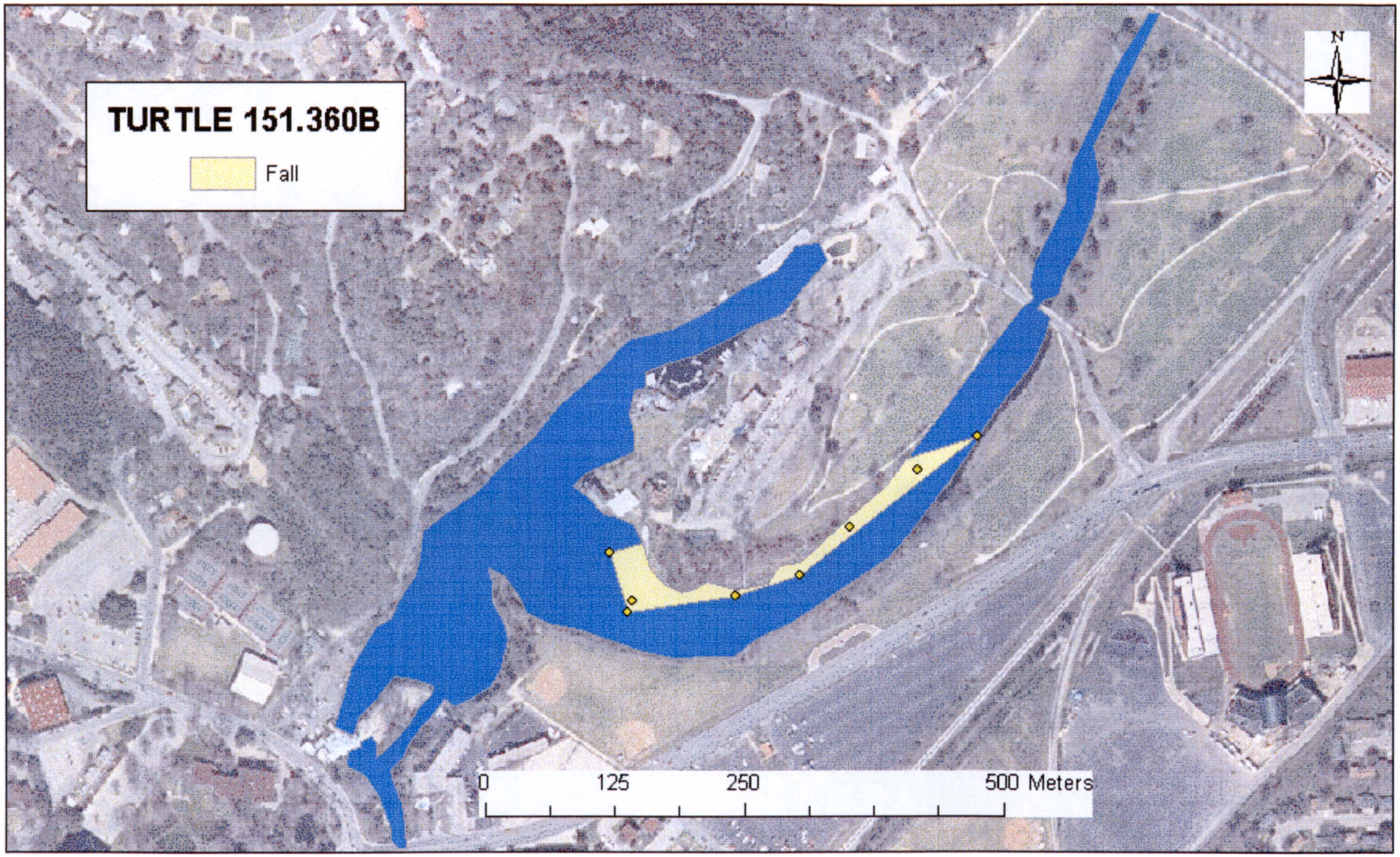

Figure 89. Fall home range for male Turtle 151.360B.

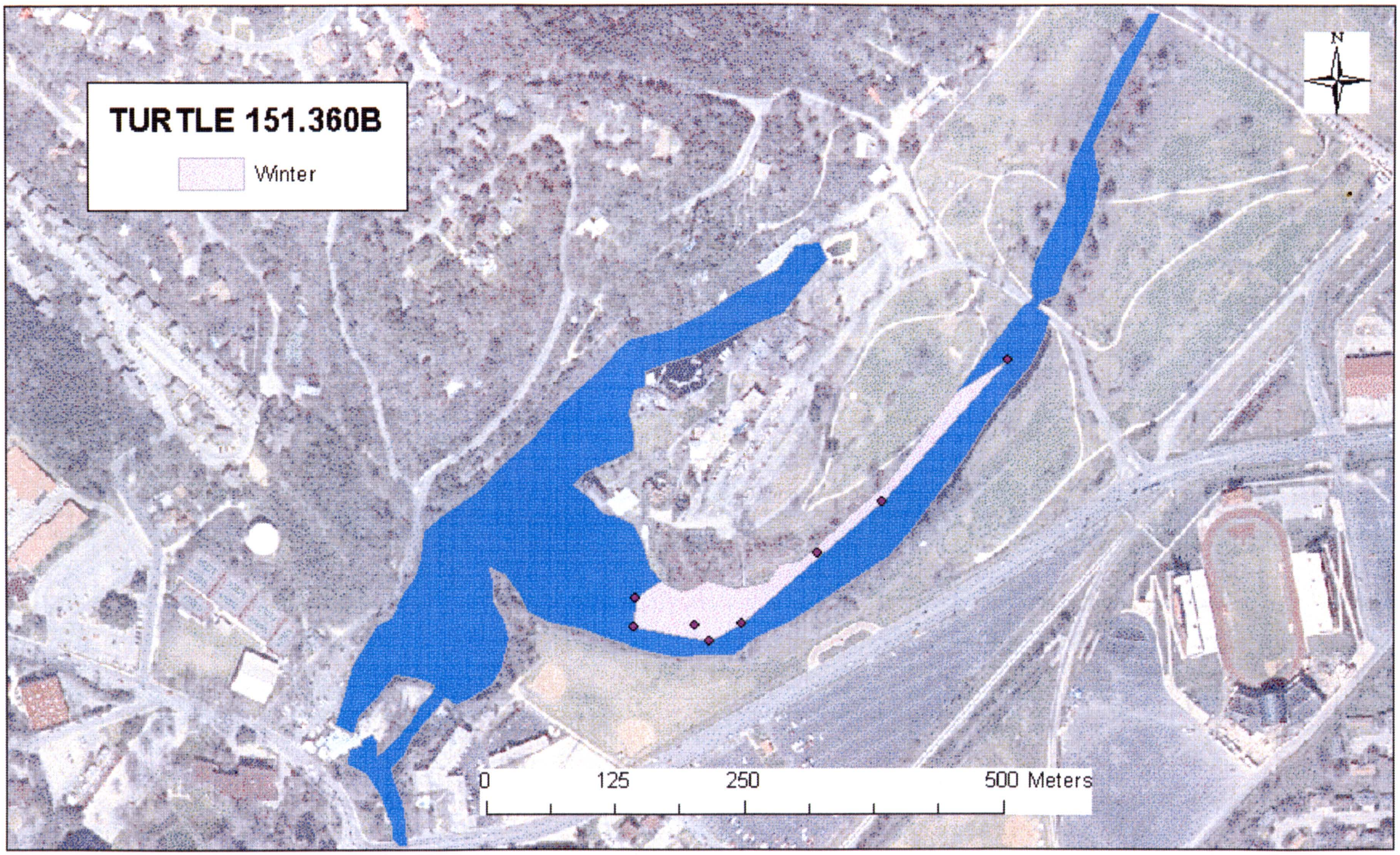

Figure 90. Winter home range for male Turtle 151.360B.

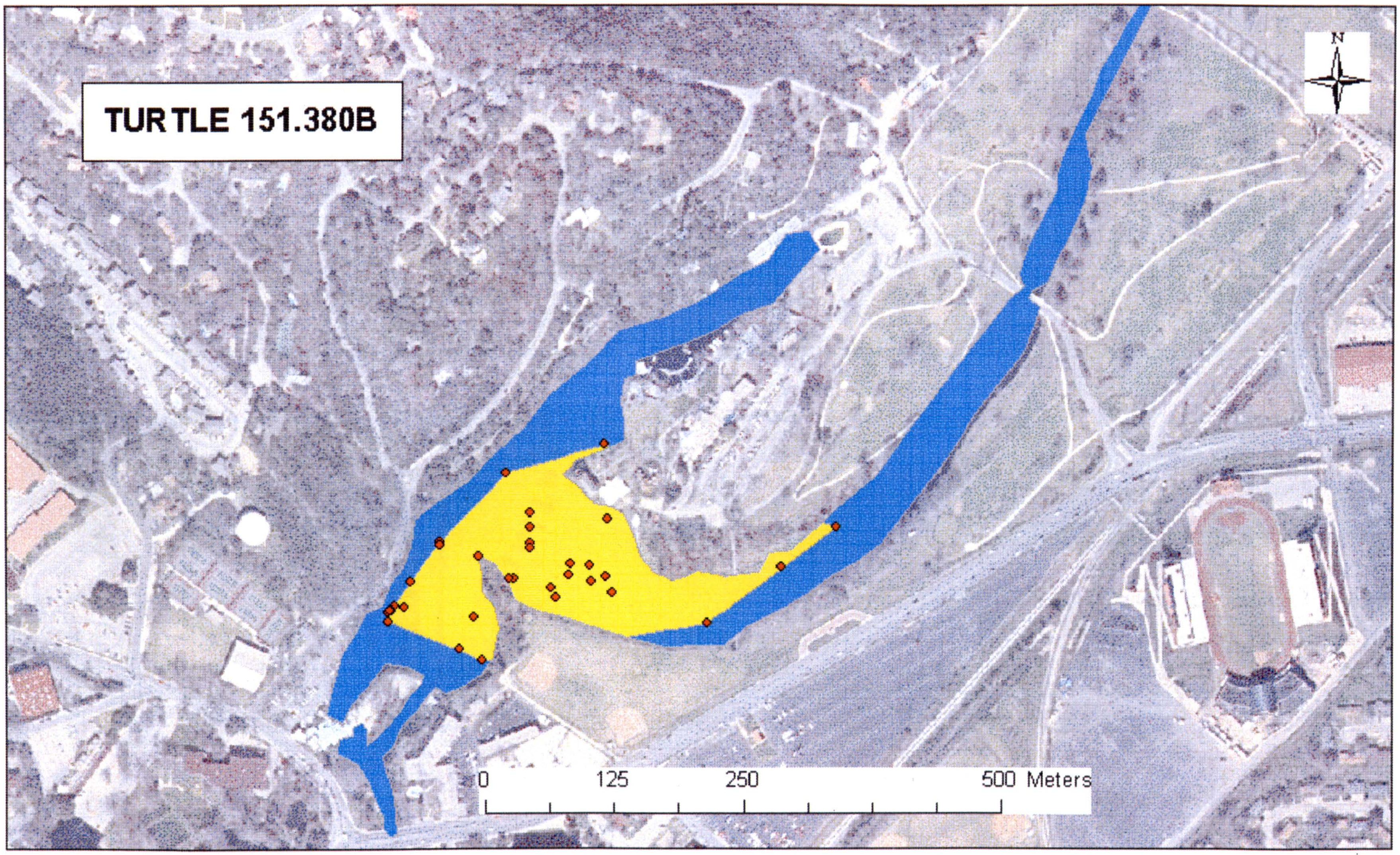

Figure 91. Annual home range for female Turtle 151.380B.

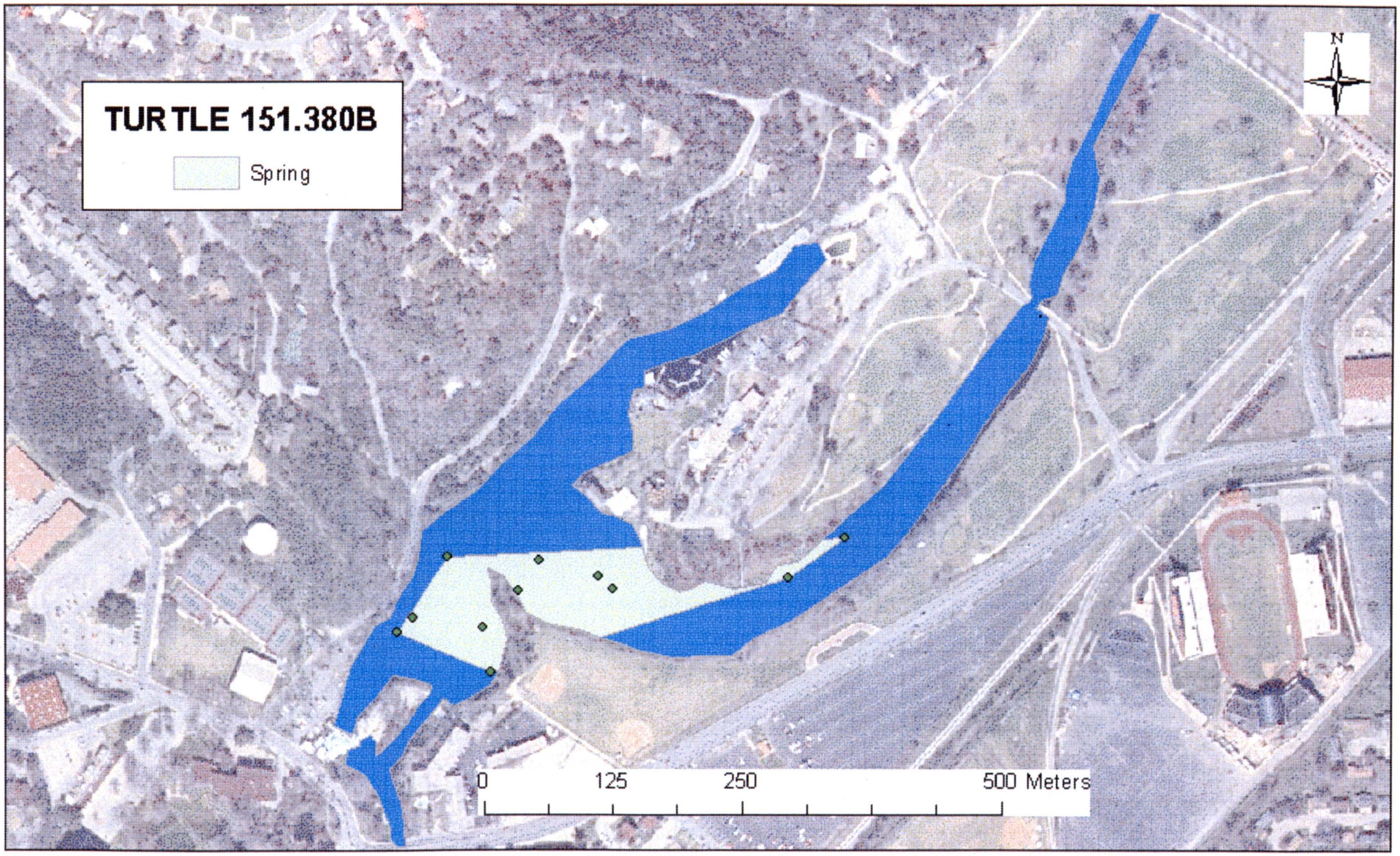

Figure 92. Spring home range for female Turtle 151.380B.

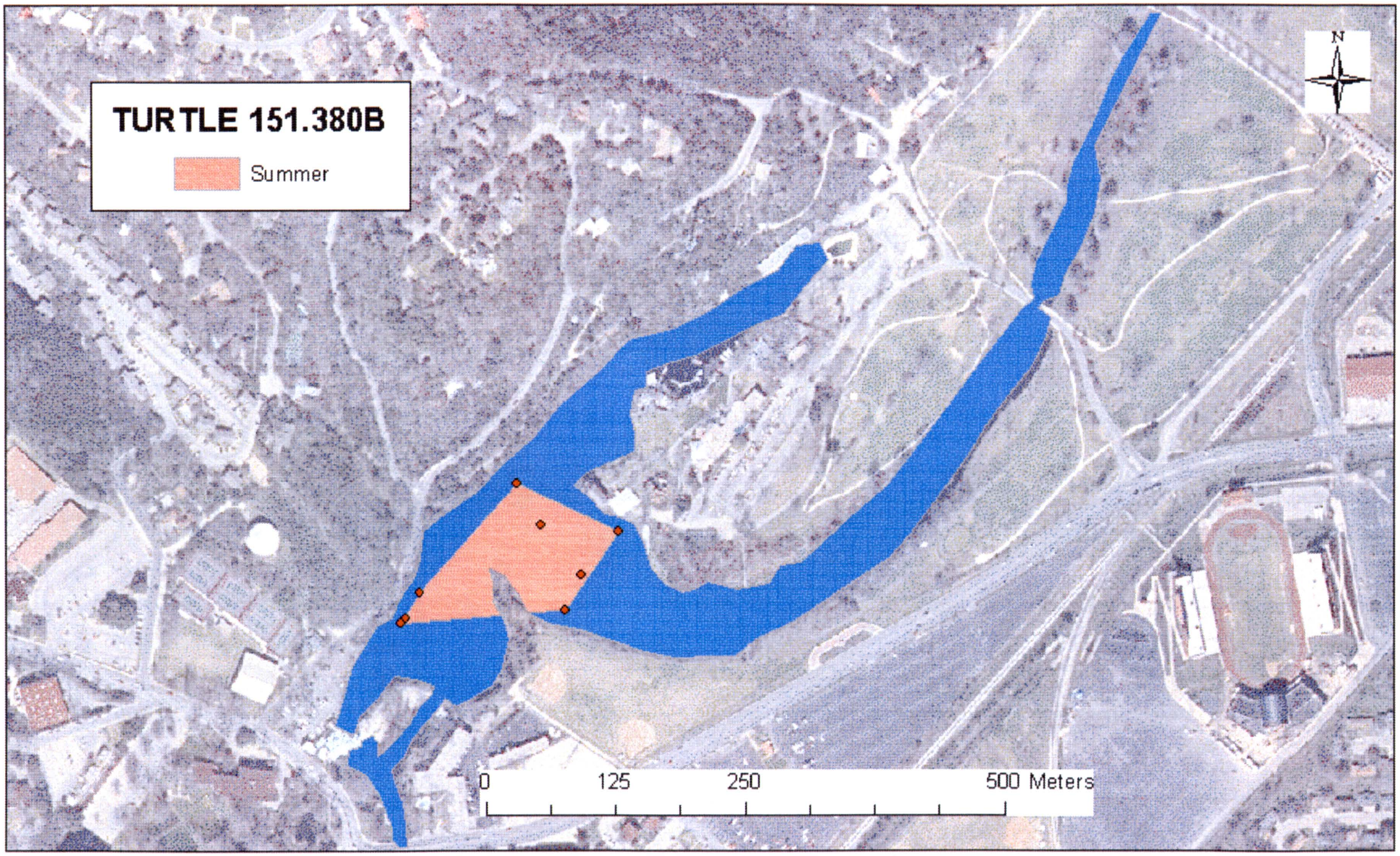

Figure 93. Summer home range for female Turtle 151.380B.

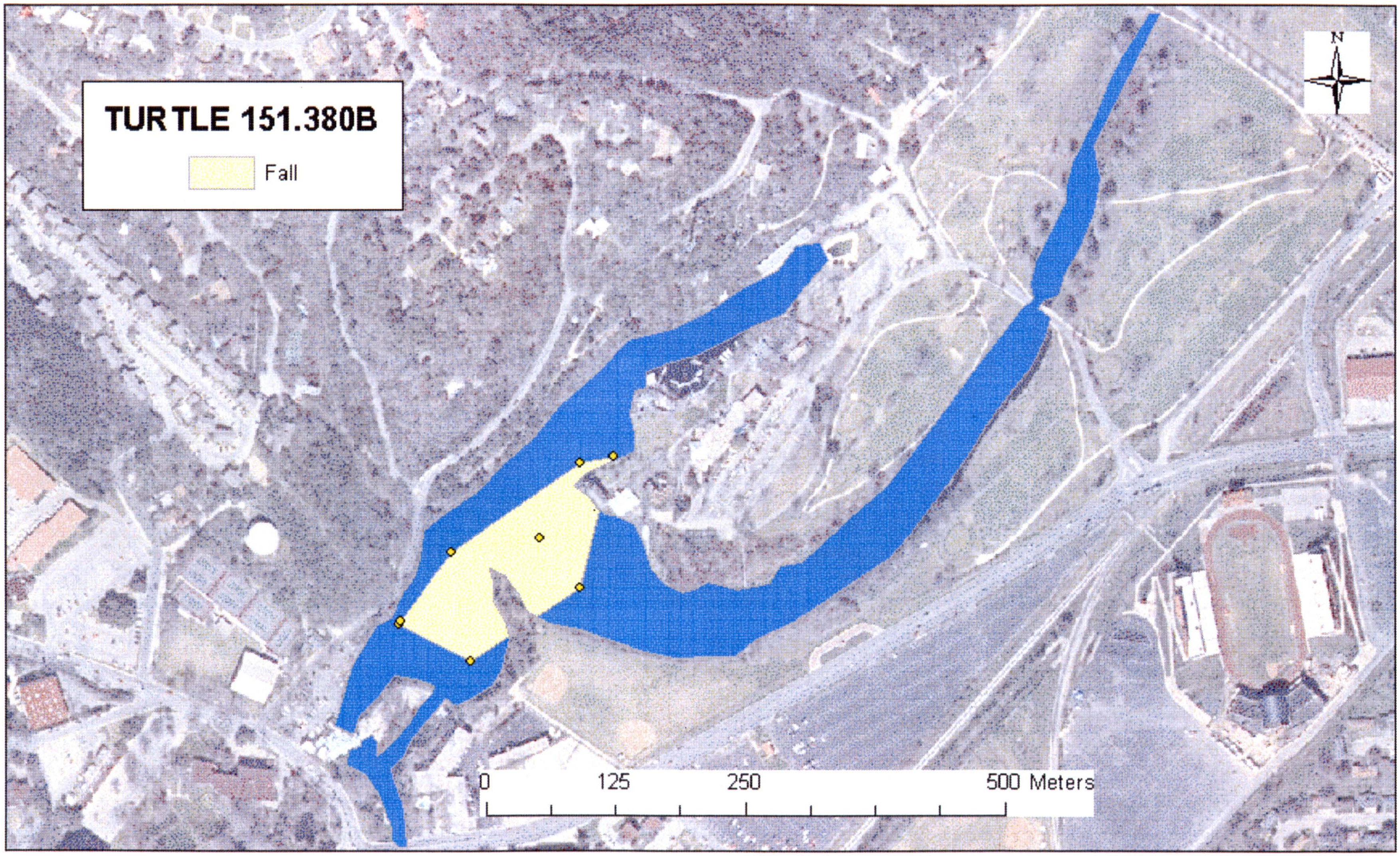

Figure 94. Fall home range for female Turtle 151.380B.

Figure 95. Winter home range for female Turtle 151.380B.

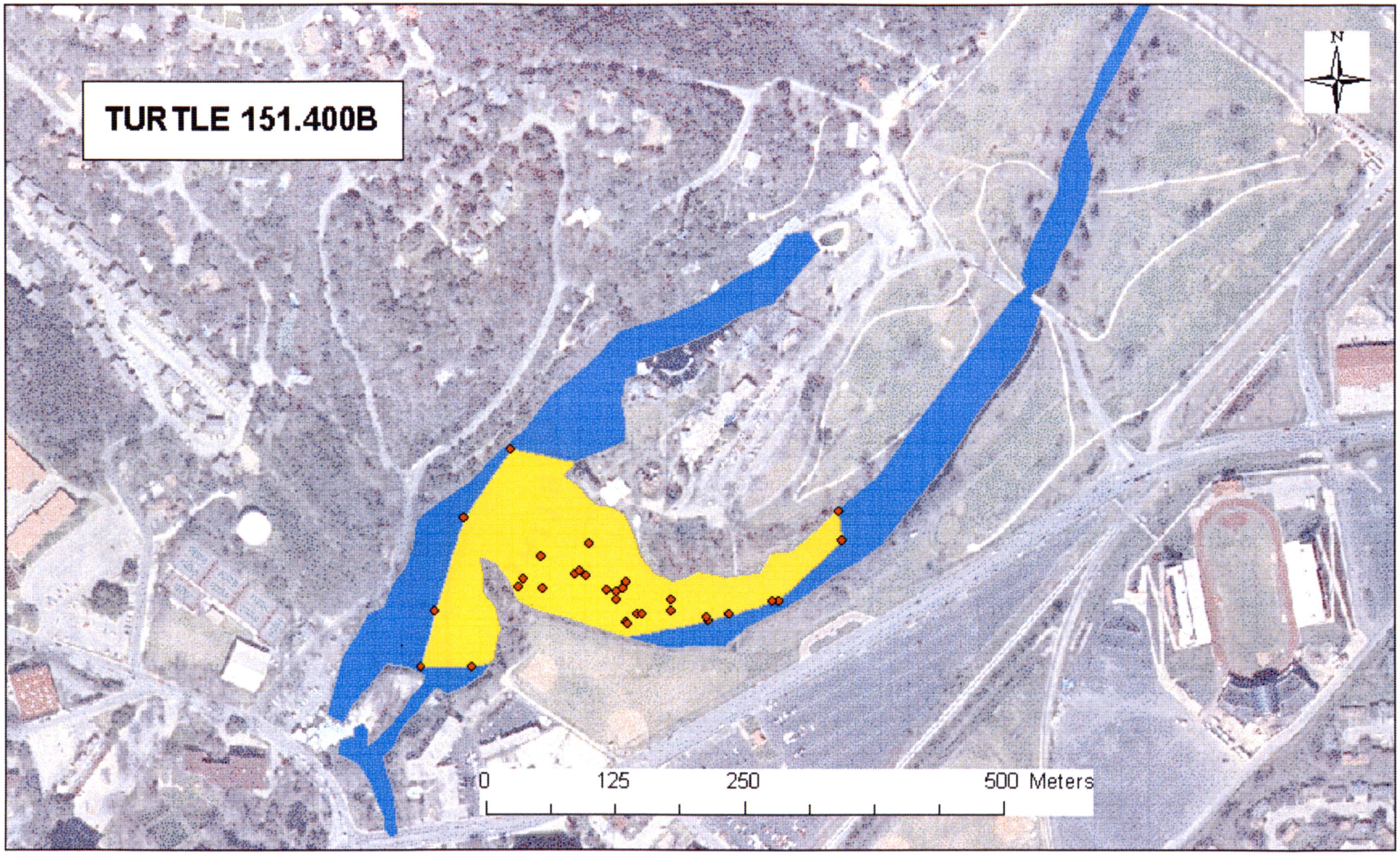

Figure 96. Annual home range for female Turtle 151.400B.

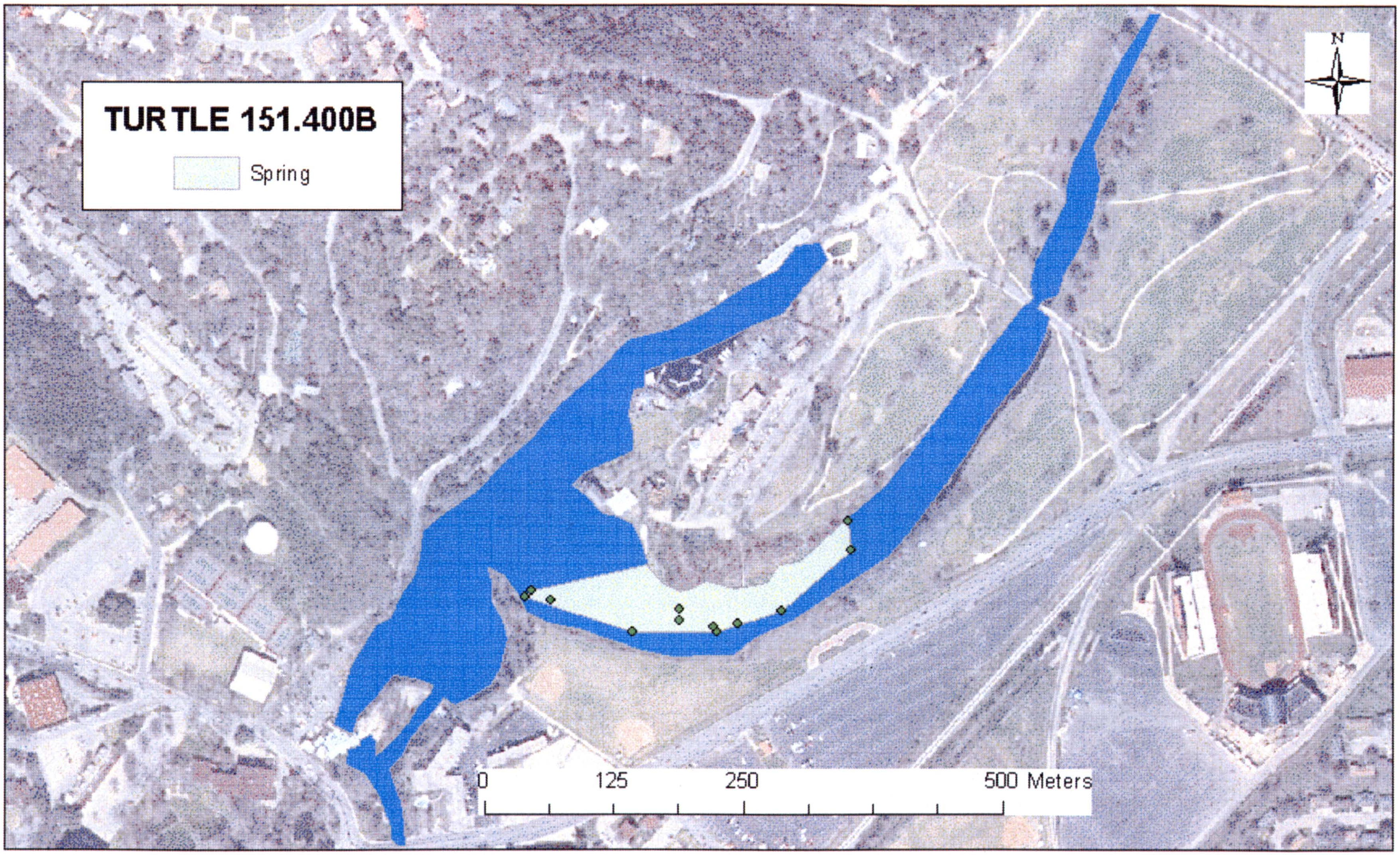

Figure 97. Spring home range for female Turtle 151.400B.

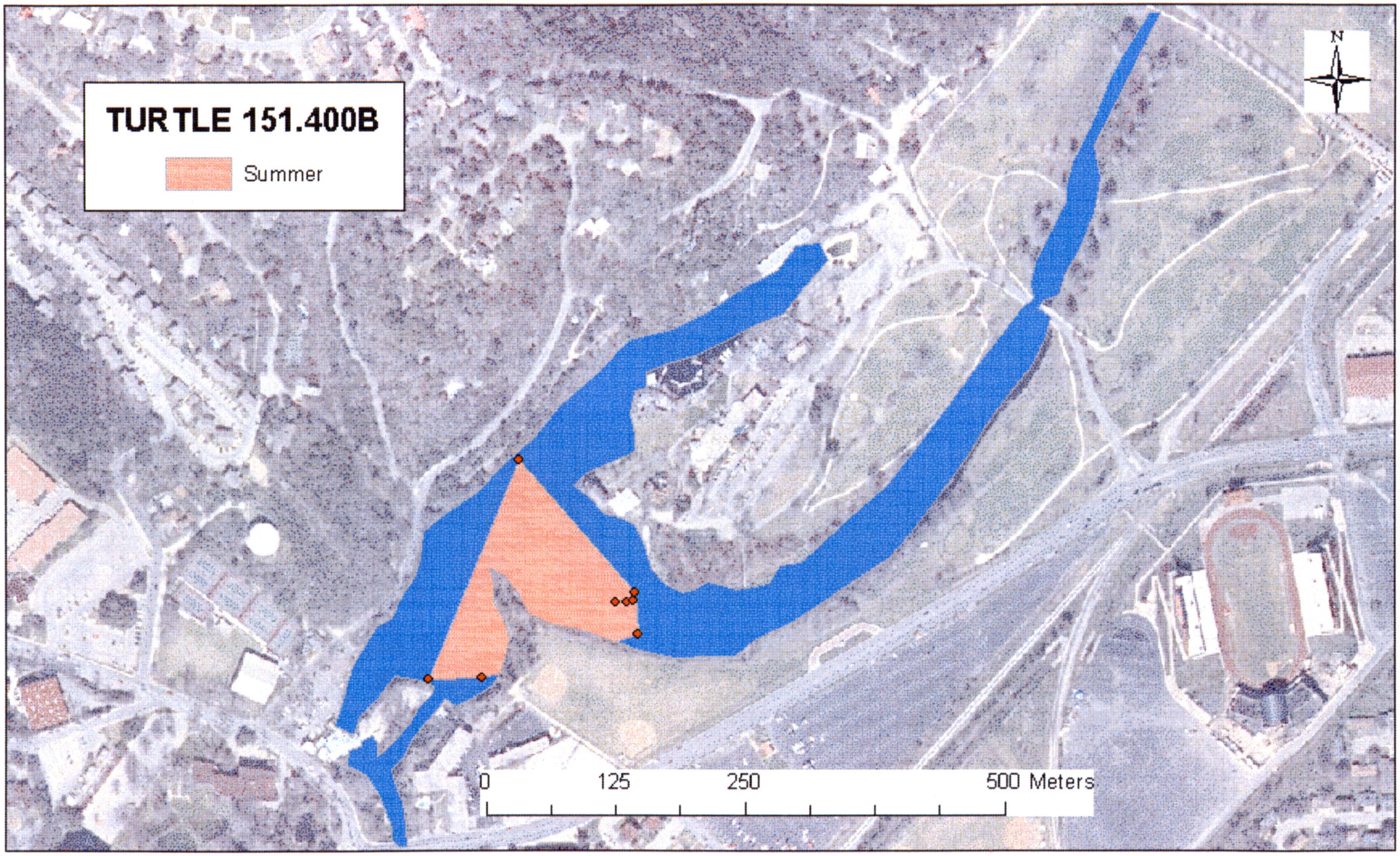

Figure 98. Summer home range for female Turtle 151.400B.

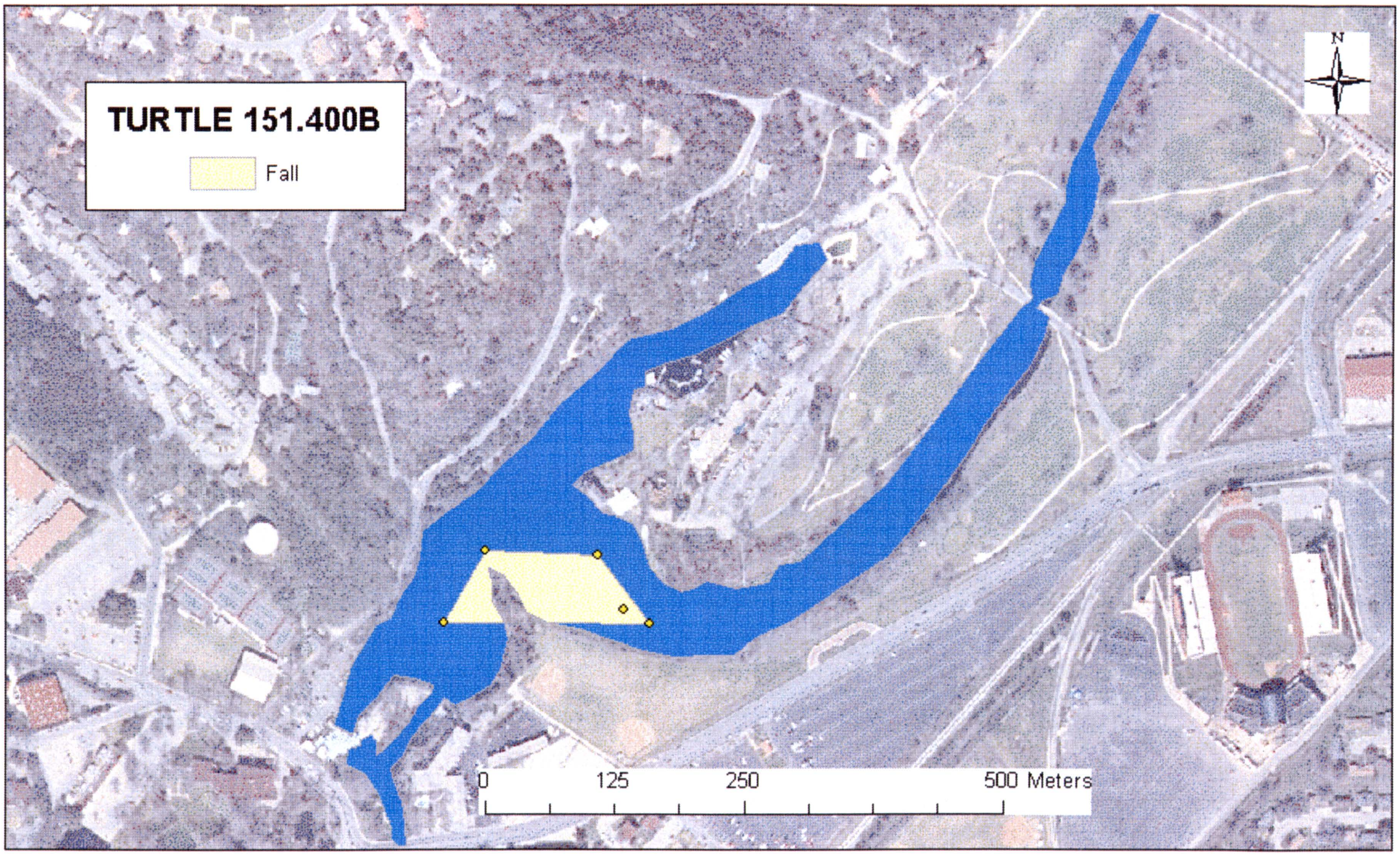

Figure 99. Fall home range for female Turtle 151.400B.

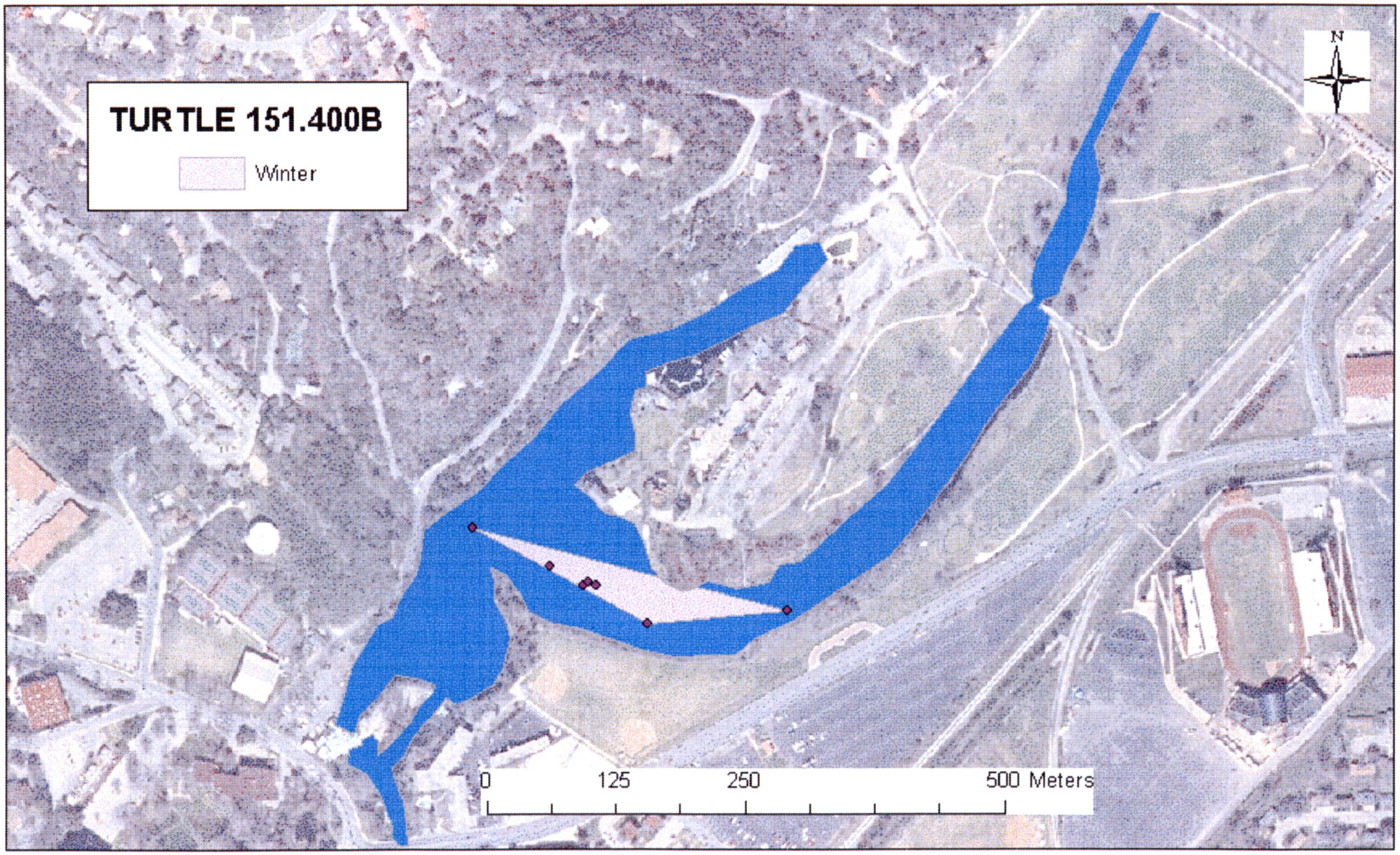

Figure 100. Winter home range for female Turtle 151.400B.

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