QUANTIFICATION OF 1986 WINTER POLLUTANT DEPOSITION IN THE ALBERTA OIL SANDS AREA

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EXECUTIVE SUMMARY

The chemical characteristics of snow in the Oil Sands area of northeastern Alberta have been monitored periodically since 1976. The accumulation of pollutants in the snowpack can be an effective indicator of total winter deposition as the snowpack preserves a continuous record of materials accumulated from the atmosphere.

The current study encompasses two main objectives. The first comprises the collection of snow samples from 51 sites in the Oil Sands area, their subsequent chemical analyses, a description of the resultant deposition patterns, and spatial variations of pollutant loadings, and a meteorological history of the snowpack. The second objective is to provide site documentation and evaluations of the locations where snow has been collected during the present study.

The snow survey was conducted between 4 and 8 February 1986, inclusive. In addition to snow sampling, site documentation was compiled and photographs of the sites' four cardinal directions and oblique aerials were taken.

The overall pattern among the various chemical constituents illustrates a strong tendency for the highest ion concentrations to be near the two major oil sands plants and north-south, along the Athabasca River Valley. Fallout from the two plants and the occurrence of a low-level inversion in the river valley, which inhibits ventilation, generally account for the these areal patterns. The lowest concentrations are usually situated at sites removed from the river and the oil sands plants. There are few exceptions to these patterns, except for odd stations that appear to have anomalously high or low values for the particular constituents. Without duplicates or replicates nothing can be conclusively determined about these anomalies.

There is a wide range in the quality of the snow sampling sites in terms of meeting the long-range goals of the network. As such, there should be more emphasis on quality control and hypotheses testing in terms of Alberta Environment's objectives for future snow surveys.

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ABSTRACT

The study encompasses two main objectives: (1) the collection of snow samples from 51 sites in the oil sands area for chemical analyses and interpretation of the results; and (2) to provide site documentation and evaluations of the snow sampling sites.

Snow samples and site documentation were collected between 1986 February 04 to 08, inclusive. The overall pattern among the various chemical constituents illustrates a strong tendency for the highest ion concentrations to be near the two major oil sands plants and north-south along the Athabasca River valley. Low-level inversions, which reduce the ventilation of the valley, appear to augment this feature.

There is a wide range in the quality of the snow sampling sites in terms of meeting the long-range goals of the network. As such, there should be more emphasis on quality control and hypotheses testing in all future snow surveys. Sites that appear to influence the integrity of the chemical characteristics of the sampled snow should be eliminated. The areal dimensions of the study are adequate to provide background data but, we recommend that the number of sampling sites be reduced so that multiple samples can be collected at each for necessary quality control and hypothesis testing purposes.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

The chemical characteristics of snow in the Oil Sands area of northeastern Alberta have been monitored periodically since 1976 (Fanaki 1978, Barrie and Kovalick 1980, Murray 1981, Gourlay and Blower 1983, 1984) (Figure 1). The purposes of these studies were to document the deposition patterns and spatial variability of snowpack pollutant loadings as a result of industrial emissions in the region. These studies consisted of sampling the accumulated snowpack and the chemical analyses of the snow melt to determine ionic and particulate constituents.

The current study encompasses two main objectives. The first comprises the collection of snow samples from 51 sites in the oil sands area (Figure 2), their subsequent chemical analyses, a description of the resultant deposition patterns, and spatial variations of pollutant loadings, and a meteorological history of the snowpack. The second objective is to provide site documentation and evaluations of the locations where snow has been collected during the present study.

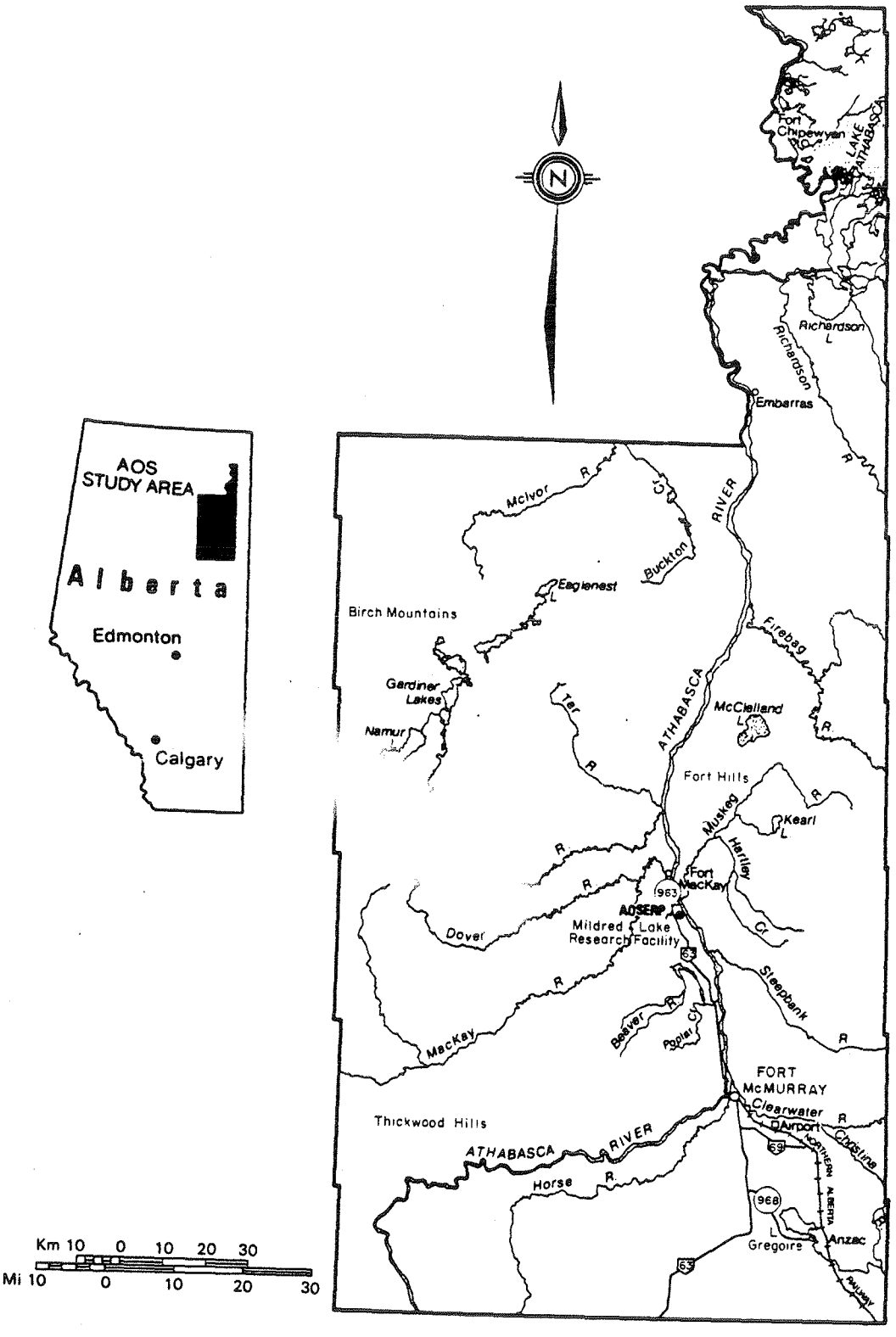

Figure 1: The Alberta Oil Sands area in northeastern Alberta.

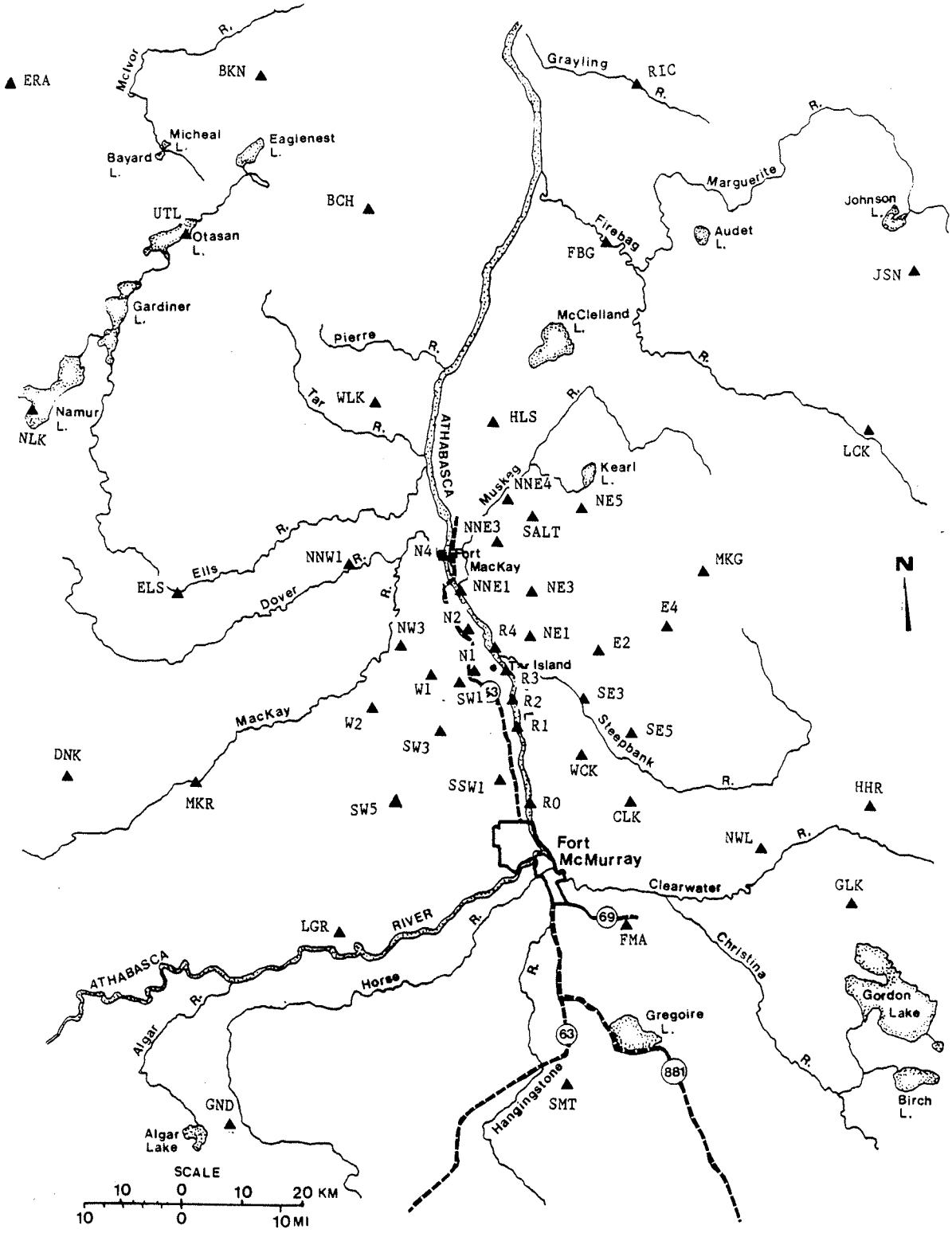

Figure 2: Snow sampling sites in the Alberta Oil Sands area.

2. SNOW SAMPLE COLLECTION: 1986

The snow sampling procedures outlined in Gourlay and Blower (1983) were observed during this study. The first snow survey was conducted between 4 and 8 February 1986, inclusive. In addition to snow sampling, site documentation was compiled and photographs of the sites' four cardinal directions and oblique aerials were taken. Snow was collected at 51 sites, five of these had duplicates (one large sample split into two bags) and another five had replicates (five separate samples at each site). Duplicate samples were taken to monitor quality control of the laboratory analytical procedures. Ideally, these samples should have similar ion concentrations as they are essentially the same sample divided into two parts. Replicates were taken to assess the within-site variability of the snow samples. Any given site should have low within-site variability compared to the regional inter-site variability.

Snow samples were not collected during the second survey because of unseasonably mild conditions. The high temperatures resulted in snow melt throughout the oil sands area. However, additional photographs were taken on the second survey.

2.1 SNOW SAMPLE COLLECTION AND MEASUREMENT PROCEDURES

The following materials and equipment were required at each site to collect and bag the samples:

- 2 - 18x32" 2.5 mil polyethylene sample bags;
- 2 - twist ties;
- 1 - label tag (heavy stock with string);
- 1 - meter stick;
- 1 - snow sampler and paddle; and
- 1 - sample collection form/clipboard/pencil (see Appendix I for a sample collection form).

The snow sampler is an acrylic, half-cylinder tube (Figure 3). Its flat side slides up and down to facilitate removal of sections of the snow core. It is 1-meter long and has an internal cross-section of 87.2 cm^2. A similar sampler was used in previous snow studies in the area (Barrie and Whelpdale 1978, Barrie and Kovalick 1980, Murray et al. 1981, Gourlay and Blower 1983, 1985).

Figure 3: Collecting snow samples. The acrylic, half-cylinder snow sampler is in the center of the image. The meter stick is used to gauge the depth of snow but, the person sampling has to correct for parallax errors by getting low.

Two people collected the snow samples and did the snowpack measurements. One person was responsible for recording the data and organizing the sample bags. The second person took the snow core, did the snow profile measurements and, with the assistance of the first person, bagged the sample. At each sample site a standardized procedure was used to collect the snow and conduct the physical measurements. The procedure, outlined below, was adapted from Gourlay and Blower (1983).

The helicopter landed down-wind of the sample site and the collection personal walked at least 100 m up-wind to the site. This minimized contamination and physical disturbance to the sample site by the helicopter. The sampler and paddle, which were stored in the rear cargo hold of the helicopter, were removed from their 6-mil polyethylene storage bag cover and repeatedly passed through the snowpack to clean and acclimatize them. While the sampler was being prepared the recorder noted the current weather conditions.

The sampler was held in a vertical position and slowly pushed to the base of the snowpack. The meter stick was inserted into the snow next to the face of the sampler and the total snow pack depth was recorded. In order to avoid parallax error in this and the other snow horizon measurements it was necessary to either lie or kneel close to the sampler so that observations could be taken along the snow surface (Figure 3). The paddle was then used to clear the snow away from the face of the sampler. The elevation from the snowpack base and thickness of any evident snow horizons, such as pukak[1], ice layers, equi-temperature metamorphic layers, and fresh snow were noted.

At this point the paddle was inserted into the bottom of the sampler, which was then carefully lifted from the snow pack and

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[1] Pukak (temperature gradient metamorphic layer) is a snow horizon of low density which forms at the bottom of the snow pack. It is created when there is a thermal gradient between the ground and the air above the snow pack. Relatively warm vapour from the ground and lower-most areas rises toward the colder surface and, in so doing, metamorphoses the crystals in the lower snow pack. This process produces large pyramidal crystals with air spaces between them.

placed in a horizontal position. The core was checked for vegetation and other contaminants. If these were evident the face of the sampler was opened to the position of the contaminants and, using the paddle, the core was cut at this point. That portion of the core from the contaminant to its base was discarded from the sample. The remaining length of core was measured and recorded.

The second person then opened up a collection bag, being careful to touch only its outside faces, and the snow was poured into the bag. This entire procedure was repeated until a total core-length of at least 75 cm of snow had been collected. The total length of the retained sample was recorded. The bag containing the snow was then secured with a twist tie, labelled and put into a second bag, which was also secured with a twist tie. This second bag was used to protect the sample bag from punctures which could result in both contamination and sample loss.

The snow sampler and paddle were put back into their plastic storage bag. After returning to the helicopter both the sample(s) and sampler were put into the unheated rear storage compartment.

Collection methods were modified at replicate and duplicate sample sites. At sites where replicates were taken the above procedure was repeated five times so that five separate samples, each with a minimum length of 75 cm, had been collected. For duplicate sites a total length of at least 150 cm of snow was put into a single bag. The bag was shaken to mix the sample and approximately half of this was poured into a second bag. The two bags were tagged and given different numbers before each was placed into a separate covering bag.

2.2 STORAGE AND TRANSPORT OF THE SAMPLES

Upon arrival at the Mildred Lake Research Station the samples were immediately removed from the helicopter and taken into an unheated lab where they were put into large deep-freezes. This was done to prevent any chemical changes that might occur upon melting of the sample. As suggested in Gourlay and Blower (1983),

the possibility of any changes occurring upon melting should be investigated as this adds another, perhaps unnecessary, quality control step to worry about in the overall sampling procedure.

At the end of the sampling session all the samples were put into large cardboard boxes which were then sealed with binding tape and labeled. Arrangements were previously made for a transport company to pick-up the samples and transport them in a freezer unit to Chemex Laboratories Ltd. in Calgary.

3. METEOROLOGICAL HISTORY OF THE SNOWPACK

The winter of 1985-86 was mild compared to the long term normal. December and January had mean daily temperatures of -12.8 and -11.8^{0}C. Normals for these months are -17.0 and -21.8^{0}C, respectively. February's mean of -14.6^{0}C was only slightly higher than the long term normal of -15.4^{0}C (Environment Canada 1982).

Above-freezing daily maximum temperatures were observed over five periods for a total of 18 days between 1 December 1985 and the first snow survey in early February. Three of the periods also had rainfall events. From 7 to 15 January the daily maximum temperatures ranged from 0.0 to 7.0^{0}C (Table 1). The warmest day, 11 January, also had 1.8 mm of rain and winds that averaged 26.3 km/h. The result was that the snow pack decreased from 20 to 30 cm that day. By the end of this mild spell the snow pack had decreased to 16 cm.

There were no above-freezing temperatures at Fort McMurray between mid-January and early-February and all precipitation occurred as snow. This resulted in an increased snow depth and eventual stabilization of the snow pack at 29 cm. On 3 and 4 February daily maximum temperatures rose to 3.0 and 1.3^{0}C, respectively, and there was no rainfall associated with this event. However, the snow pack depth decreased from 29 to 24 cm.

The winter periods that had rainfall and high temperatures may have resulted in significant leaching of contaminants into the basal portion of the snow pack and possibly into the ground. Shewchuk et al. (1981) state that ions in a snow pack which has experienced melt-freeze cycles may become concentrated in horizons where re-crystallization occurs. This is due to ions preferentially accumulating at the new ice-crystal surface. These horizons tend to form low in the snow profile and the crystals rapidly melt out of the snow pack, carrying ions with them (Shewchuk et al. 1981). Given the occurrence of rain-melt-freeze layers, melt-water transformed pukak layers, and unseasonably warm conditions, it is reasonable to assume that the snow packs experienced ion transport to their bases and perhaps, even loss of ions. Additionally, ions which accumulated in

Table 1: Climatological summary: Fort McMurray Airport, January and February 1986. Source: AES Monthly Climatological Summaries, Fort McMurray Airport.

Day/ Month	Temperature Max. (^{0}C)	Min. (^{0}C)	Precipitation Rain (mm)	Snow (cm)	Total (mm)	Snow on Ground (cm)	Wind Speed (km/h)
01/01	-18.0	-27.0	0.0	13.0	10.0	19	15.2
02/01	-16.4	-22.3	0.0	6.3	6.8	30	8.2
03/01	-14.3	-26.2	0.0	0.2	TR	31	3.2
04/01	-7.7	-18.7	0.0	0.6	0.4	31	7.4
05/01	-17.9	-23.5	0.0	0.6	0.4	32	12.8
06/01	-14.3	-23.4	0.0	TR	TR	31	13.5
07/01	2.8	-17.9	0.0	0.0	0.0	30	8.0
08/01	0.5	-7.5	0.0	3.0	2.6	30	6.2
09/01	0.0	-7.2	0.0	0.0	0.0	32	7.2
10/01	1.6	-4.2	TR	0.0	TR	32	4.5
11/01	7.0	-11.5	1.8	0.4	2.2	30	26.3
12/01	0.8	-14.1	0.0	0.0	0.0	20	8.7
13/01	1.0	-6.5	0.0	0.0	0.0	20	9.9
14/01	6.9	-8.7	0.0	0.0	0.0	19	12.0
15/01	0.3	-5.5	0.0	0.0	0.0	16	5.0
16/01	-4.4	-10.3	0.0	TR	TR	16	5.6
17/01	-3.8	-8.1	0.0	0.4	0.2	16	3.9
18/01	-3.3	-6.5	0.0	1.4	1.4	16	11.5
19/01	-5.6	-10.5	0.0	3.6	3.6	17	9.8
20/01	-9.4	-25.2	0.0	1.0	0.8	22	15.3
21/01	-18.0	-23.2	0.0	2.6	2.4	23	9.0
22/01	-17.6	-28.0	0.0	TR	TR	25	11.1
23/01	-14.2	-18.5	0.0	0.4	0.2	25	15.9
24/01	-8.6	-15.0	0.0	TR	TR	25	10.0
25/01	-14.2	-24.2	0.0	TR	TR	25	9.0
26/01	-6.5	-17.4	TR	0.4	0.4	25	14.7
27/01	-5.7	-14.6	0.0	1.8	0.8	25	8.3
28/01	-14.2	-20.5	0.0	3.6	2.0	26	9.0
29/01	-19.7	-22.7	0.0	0.2	TR	29	2.6
30/01	-12.0	-20.7	0.0	0.2	0.2	29	8.8
31/01	-5.9	-13.1	0.0	TR	TR	29	7.9
01/02	-5.8	-10.9	0.0	TR	TR	29	5.9
02/02	-4.0	-9.1	0.0	TR	TR	29	7.8
03/02	3.0	-6.1	0.0	0.0	0.0	29	11.5
04/02	1.3	-12.0	0.0	0.0	0.0	24	5.2
05/02	-6.9	-13.0	0.0	0.2	TR	24	11.0
06/02	-8.9	-15.4	0.0	TR	TR	24	3.1
07/02	-14.0	-25.6	0.0	TR	TR	24	11.9
08/02	-17.2	-29.5	0.0	0.0	0.0	24	6.2

melt-freeze layers at the base of the snowpack were likely missed in the sampling procedure as the lower layers were usually contaminated with vegetation if the site was not ice-covered and, therefore, were discarded. Also, the sampler had difficulty penetrating the thick, extremely hard, icy layers and it may have stopped short before reaching these lower horizons.

3.1 SNOW DEPTH

The average snow depth for all the snow chemistry monitoring sites during the February survey was 30.0 cm with a standard deviation of 11.0 cm (Table 2). This represents a between-site variability of about 37% around the mean. Intra-site variability, calculated from the 5 replicate sites, was about 4.5%.

From the areal distribution in snow depths illustrated in Figure 4 there appears to be no north-south gradient in snow depth. Snow packs 40 cm or deeper were found to occur in northwest, northeast and east-central sites while snow packs less than 20 cm deep were found in both extreme north-central and south-central sites. This is unlike the trend described by Murray et al. (1981) who reported that in both January and February of 1981 that the northern sites had shallower snow depths than the southern sites. Murray et al. (1981) also gave no indication that snow depths were shallow along the Athabasca River; this trend was quite evident in the 1986 survey (Figure 4). The shallow depths along the river may be due to high wind speeds along the channel which would both remove the snow and cause compaction by wind sublimation. These sites all had the relatively thick, hard layers, characteristically formed in sites that experience high wind speeds.

Relatively high accumulations of snow were found surrounding and immediately to the northeast of the oil sands plants. Murray et al. (1981) reported a similar trend and reasonably suggested that this was due to the precipitation of ice particles from the plants' smoke plumes.

Table 2: Snow depths and densities in the Alberta Oil Sands area, 4-6 February 1986.

Site	Mean Depth (cm)	Standard Deviation (cm)	Density (gm/cm^3)	Number of Cores	Replicate or Duplicate
NNE1	29.0	0.0	0.26	4	-
NNE3	24.9	0.2	0.19	4	-
NNE4	31.0	1.3	0.19	3	-
NE1	49.8	1.6	0.20	6	D
NE3	30.2	0.8	0.20	15	R
NE5	23.9	0.5	0.20	20	R
E2	35.4	0.2	0.27	4	-
E4	44.8	1.5	0.22	3	-
MKG	44.2	0.8	0.26	3	-
SE3	29.7	0.3	0.21	3	-
SE5	22.1	2.8	0.23	4	-
SSW1	13.7	0.6	0.20	8	-
SW1	17.2	0.3	0.22	7	-
SW3	28.1	1.0	0.21	4	-
SW5	14.1	0.7	0.19	8	-
W1	18.8	0.8	0.18	5	-
W3	38.7	2.5	0.25	3	-
NW3	22.2	0.5	0.20	10	D
NNW1	21.5	0.0	0.18	5	-
N1	51.7	2.5	0.20	3	-
N2	28.0	1.2	0.21	4	-
N4	27.8	2.0	0.22	8	D
R0	18.2	1.0	0.21	6	-
R1	19.5	0.3	0.18	5	-
R2	19.3	2.2	0.20	5	-
R3	19.2	2.9	0.23	6	-
R4	18.2	0.6	0.19	4	-
ELS	27.8	0.6	0.21	4	-
BCH	27.0	0.8	0.27	5	-
FBG	23.1	0.5	0.31	4	-
GLK	15.1	1.4	0.24	7	-
HHR	41.5	5.0	0.26	16	R
SMT	34.0	2.6	0.27	18	R
NWL	24.2	0.8	0.23	5	-
CLK	30.7	0.6	0.23	3	-
WCK	50.3	3.7	0.23	3	-
FMA	31.1	0.9	0.22	8	D
GND	42.3	1.4	0.24	15	R
LGR	16.8	1.0	0.19	6	-

Continued

Table 2 (Concluded): Snow depths and densities in the Alberta Oil Sands area, 4-6 February 1986.

Site	Mean Depth (cm)	Standard Deviation (cm)	Density (gm/cm^3)	Number of Cores	Replicate or Duplicate
MKR	22.0	5.5	0.20	4	-
DNK	31.4	0.7	0.19	4	-
SND	43.5	2.9	0.21	6	D
NLK	40.0	2.2	0.25	3	-
ERA	26.8	1.5	0.25	4	-
BKN	43.2	0.8	0.22	3	-
UTL	40.5	0.0	0.26	3	-
WLK	20.8	0.3	0.16	5	-
LCK	40.3	0.3	0.23	3	-
JSN	58.0	0.7	0.25	2	-
RIC	18.8	0.4	0.28	7	-
HLS	38.0	1.0	0.21	3	-

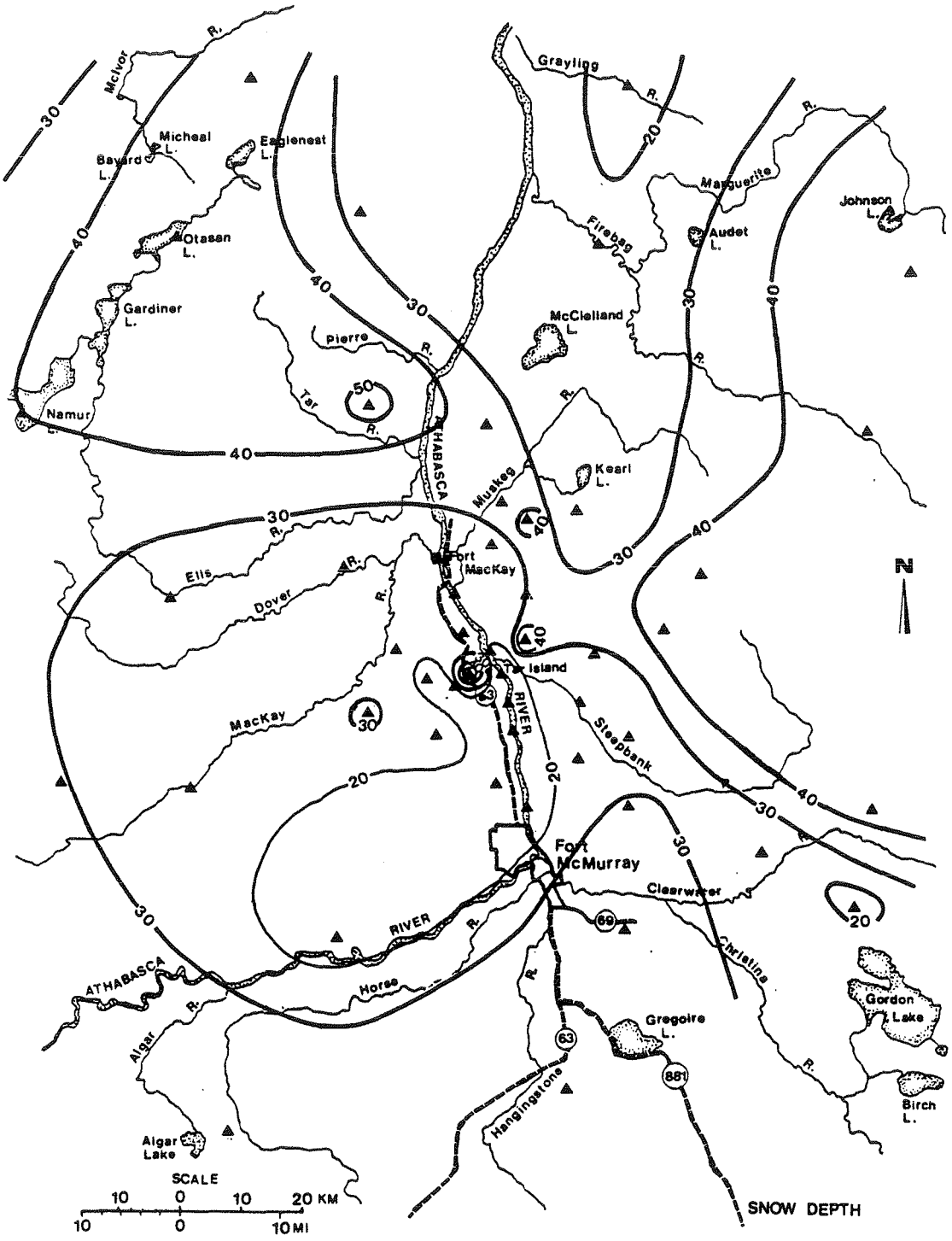

Figure 4: Snow depths between 4 and 8 February 1986 (cm).

3.2 SNOW PACK DENSITY AND STRUCTURE

Snow pack densities were estimated by dividing the volumes of melt-water by the volumes of snow sampled. The mean density of all the sites was 0.22 gm/cm^3 with a standard deviation of 0.03 gm/cm^3. The sites ranged from a low of 0.16 gm/cm^3 at WLK to highs of 0.28 and 0.31 gm/cm^3 at RIC and FBG, respectively (Table 2).

Sites in the northern part of the study area had higher than average densities (0.25 to 0.31 gm/cm^3). No northern sites, with the exceptions of UTL and BKN, had the rain-melt-freeze layer[2] which was commonly found in the southern high-density sites. With the above noted exceptions, the northern sites had relatively thick wind slabs[3] (7-8 cm) and it is this feature which probably resulted in the high densities (Table 2).

Three high-density (0.26-0.27 gm/cm^3) sites to the north and northeast of Mildred Lake (E2, E4, and MKG) had wind slabs but no evidence of rain-melt-freeze layers. NLK, on the south end of the Birch Mountains, had a greater than average density (0.25 gm/cm^3) but this was less than that of the more northerly sites. NLK's snow pack had a poorly developed wind slab with a rain-melt-freeze layer. Sites of higher than average density in the southern part of the study region had well developed and relatively thick rain-melt-freeze layers (2-5 mm). Except for the river channel sites (R0, R1, R2, R3, and R4), wind slabs were absent in the southern part of the study area, including in the relatively high elevation sites of GND and SMT

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[2] A rain-melt-freeze layer is a hard, icy horizon of high density. It is created when melt water percolates through the snow pack. The layer forms either from the freezing of the melt water or from the partial melting and subsequent re-crystallization of snow crystals. This layer may range from almost clear and smooth to cloudy and massively crystalline, depending upon the degree of incorporation of relatively unaltered crystals. It is often extremely strong due to the continuity between the grains.

[3] A wind slab is usually a near surface snow horizon of high density and hardness. It is formed when wind fragments and sublimates newly fallen snow crystals. The crystals break down into extremely small particles; this is considered to be a form of destructive metamorphism. The small particles pack tightly together to form a solid, massive horizon of considerable strength.

(Table 3). The buried icy horizons were probably the result of the rainfall events of late-December and mid-February. The icy layers would have formed either as a result of both rain and melt-water percolating through the snow pack and then freezing at depth, or they may be due to the snow melting on the snow pack surface during the day, refreezing before it percolates, and then being buried by a later snow fall. It appears that the high densities in the northern part of the region are due to the formation of wind slabs, in contrast to the southern sites where high densities are associated with rain-melt-freeze layers.

Pukak horizons were recorded at 44 of the 51 sites (Table 3). The mean pukak depth at these sites was 15.2 cm with a standard deviation of 7.0 cm about the mean. The mean snow depth at these sites was 30.7 cm. Thus, the pukak depth was, on average, about 50% of the snow pack depth. At some sites in the south (e.g. GND) the melt-water had percolated into the pukak layer where it froze to form hard masses of large crystals (Table 3).

Even though the pukak typically formed about 50% of the snow pack depth the densities were not as low as might be expected. Most of the pukak layers, especially in the southern sites, had evidence of melt or rain-water percolation; the crystals were fused and icy lenses could be seen. Thus the snow packs had higher densities than would be expected at such sites if the pukak had been unaltered. Examples of three representative snow profiles are presented in Figure 5.

Table 3: Snowpack conditions in the Alberta Oil Sands area, 4-6 February 1986.

Site	Fresh Snow (cm)	Wind Slab Thickness(cm) at height(cm) from base	Melt-Freeze-Thickness(mm) at height(cm) from base	Pukak Thickness(cm) and condition m-f = melt freeze
NNE1	2.5	1.0 at 26.5	1 at 16.0	15.0 (all m-f)
NNE3	0.0	none	2 at 19.5	13.0 (m-f 10 cm to base)
NNE4	0.0	none	2 at 23 and 18	13.0
NE1	2.0	none	none	30.0
NE3	2.0	none	none	16.0
NE5	1.5	none	2 at 19.0	16.0
E2	0.0	8.0 at 26.0	none	17.0
E4	0.0	7.0 at 32.0	none	29.0
MKG	0.0	9.0 at 33.0	none	20.0
SE3	0.0	none	1 at 29.5	16.0
SE5	0.0	none	11 cm to base	11.0 (all m-f)
SSW1	4.0	none	1 at 9.0	not recorded
SW1	2.0	none	3 at 15.0	11.5 (m-f 6.5 cm to base)
SW3	0.0	none	1 at 14.0	5.0 (some percolation)
SW5	0.0	none	1 at 9.0	9.0
W1	-	-	-	no information on structure
W3	-	-	-	no information on structure
NW3	0.0	none	2 at 13.5	11.0
NNW1	0.0	none	6 cm to base	10.5 (m-f 6.0 cm to base)
N1	0.0	none	1 at 39.0	35.0 (all m-f)
N2	0.0	none	1 at 16.5	15.0 (all m-f)
N4	0.0	none	4 at 13.0	12.0
RO	0.0	6.0 at 11.0	none	11.0
R1	0.0	4.8 at 14.7	2 at 14.5	12.5
R2	0.0	4.8 at 14.5	2 cm to base	14.5 (m-f 2.0 cm to base)
R3	0.0	15.5 at 8.5	2 cm to base	8.5 (m-f 2.0 cm to base)
R4	0.0	6.2 at 12.0	5 cm to base	12.0 (m-f 5.0 cm to base)
ELS	0.0	none	3 at 18.0	16.0
BM	0.0	8.5 at 18.0	none	14.0
FBG	0.0	none	none	13.0
GLK	0.0	none	15 at 8.0	not recorded
HHR	0.0	none	1 at 34.0	not recorded
SMT	0.0	none	30 at 26.0	16.0
NWL	0.0	none	1 at 15.0	not reorded
CLK	0.0	none	1 at 15.5	4.5
WCK	0.0	none	1 at 41.5	30.0
FMA	0.0	none	5 at 14.0	12.0
GND	1.0	none	2 at 28.5	19.5 (some percolation)
LGR	1.5	none	1 at 8.5	5.5

Continued

Table 3 (Concluded): Snowpack conditions in the Alberta Oil Sands area, 4-6 February 1986.

Site	Fresh Snow (cm)	Wind Slab Thickness(cm) at height(cm) from base	Melt-Freeze-Thickness(mm) at height(cm) from base	Pukak Thickness(cm) and condition m-f = melt freeze
MKR	2.0	none	none	14.5
DNK	2.0	none	1 at 24.0	22.5
SND	2.0	none	none	23.0
NLK	3.0	poorly formed	5 at 22.0	16.0
EDRA	0.5	7.0 at 18.0	none	14.5
BKN	3.5	none	25 at 46.0	15.0
UTL	0.0	none	5 at 31.0	18.5
WLC	0.0	none	none	15.0
LCK	0.0	none	2 at 32.0	18.0
JSN	2.0	7.0 at 49.0	none	24.0
RIC	0.0	19.0 at 0.0	none	0.0
HLS	0.0	none	2 at 30.0	17.0

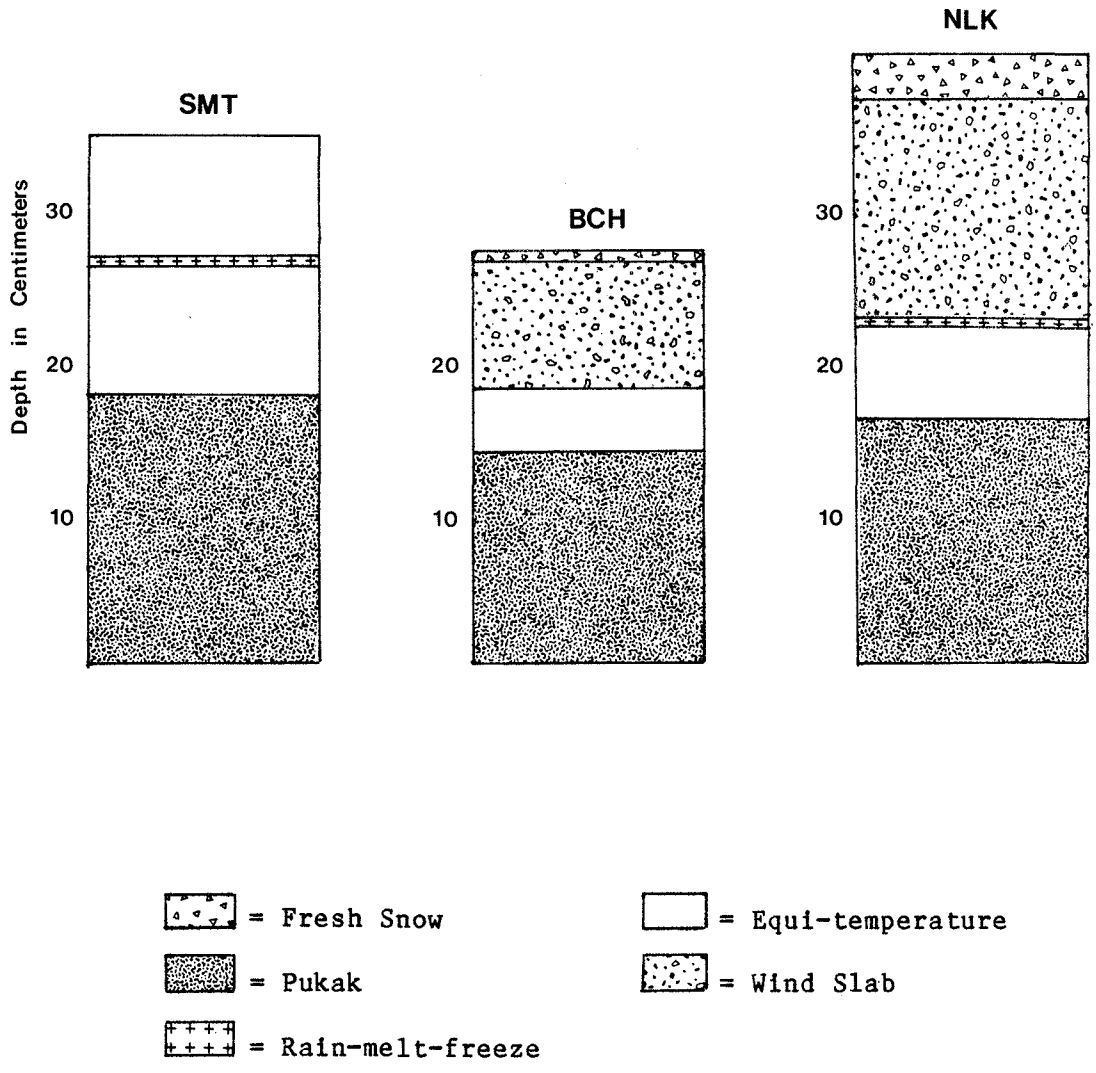

Figure 5: Structures of representative snow packs in the study area on 3 and 4 February 1986.

4. RESULTS OF SNOW CHEMISTRY ANALYSES

The accumulation of pollutants in the snowpack can be an effective indicator of total winter deposition as the snowpack preserves a continuous record of materials accumulated from the atmosphere, provided there are no melt periods (Shewchuk et al. 1981).

The snow samples from the 1986 survey were analyzed at Chemex Laboratories Ltd., a commercial lab in Calgary, Alberta. Seventy-six snow samples from the 51 sites were analyzed. Samples were tested for: chloride; nitrite; nitrate; phosphate; sulphate; potassium; sodium; ammonium; calcium; magnesium; alkalinity; acidity; pH; formate; acetate; propionate; strong acidity; total acidity; and conductance. The analytical techniques used by Chemex in analyzing snow are listed in Table 4.

Quality control of the laboratory analyses was monitored by utilizing known-concentration standards, multi-analyses of individual samples, inter-lab exchanges with Alberta Environmental Center, Vegreville, Alberta, and by analyzing duplicate field samples. The results from these comparisons and from those of the replicates were very good. (These measurements are available from Research Management Division, Alberta Environment).

Ion balances, determined by summing the positive and negative ion equivalents, were used to check the accuracy of the analyses and to identify the dominant ions at each site. Generally, there was good agreement in the sums of the positive and negative ions.

The areal distributions of the concentrations of the various constituents are plotted in Figures 6 to 20, with the exceptions of the organic acids, which consistently had concentrations of less than 0.10 ppm. In addition, the percentages of the RMD and CHX ion balances are plotted (Figures 21 and 22).

The overall pattern among the various chemical constituents illustrates a strong tendency for the highest ion concentrations to be near the two major oil sands plants and north-south, along the Athabasca River Valley. The lowest concentrations are usually

Table 4: Analytical techniques used in the (1981) quantitative determination of major ion and trace metal concentrations by Chemex Laboratories Ltd. (Source: Murray 1981).

Constituent	Method	Detection Limit[a]
Sulphate	Ion chromatography	0.01
Chloride	Mercury thiocyanate (colorimetric)	0.06
Nitrate	Cadmium reduction (colorimetric)	0.003
Ammonia	Alk. phenolphthalein (colorimetric)	0.001
Potassium	Flame photometric	0.06
Sodium	Flame photometric	0.02
Magnesium	Atomic Absorption	0.01
Calcium	Atomic Absorption	0.05
Aluminum (Soluble)	Solvent extraction (atomic absorption)	0.001
Iron (Soluble)	Solvent Extraction (atomic absorption)	0.002
Nickel (Soluble)	Solvent Extraction (atomic absorption)	0.001
Vanadium (Soluble)	Solvent Extraction (atomic absorption)	0.001
Aluminum (Insolu.)	Neutron activation[b]	1.0 ug
Vanadium (Insolu.)	Neutron activation[b]	0.1 ug
Manganese (Insolu.)	Neutron activation[b]	0.1 ug
Titanium (Insolu.)	Neutron activation[b]	50.0 ug
pH	Electrode	
Alkalinity	Tit. to pH 4, then back to 5.6 under N_2	

[a] mg/L unless otherwise stated

[b] filtered samples of the insoluble metals were analyzed by Nuclear Activation Services Ltd., Hamilton, Ontario.

situated at the sites removed from the river and the oil sands plants. For example, sulphate concentrations are relatively high at the stations immediately surrounding the two major emission sources, while sites on the periphery of the study area have concentrations that are much less (Figure 10). Fallout from the two plants and the occurrence of a low-level inversion in the Athabasca River Valley, which inhibits ventilation, generally account for this and the other areal distributions of the various compounds detected in the snow. There are few exceptions to these patterns, except for odd stations that appear to have anomalously high or low values for the particular constituents. This is evident in Figure 10 where SW5 has an apparent anomalous concentration. Without duplicates or replicates nothing can be conclusively determined about these anomalies.

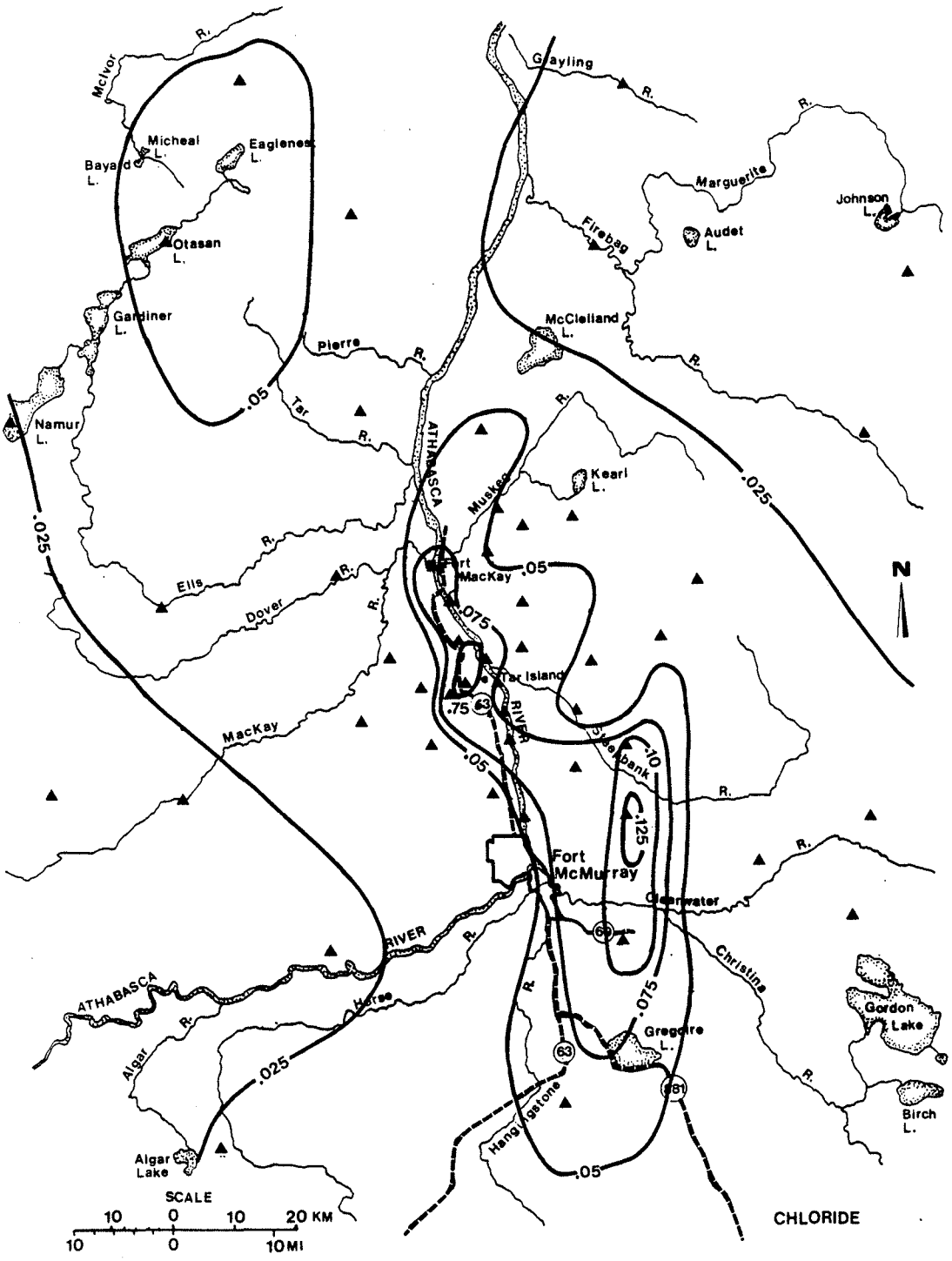

Figure 6: Areal distribution of the concentrations of chloride from snow samples collected between 4 and 8 February 1986 (ueq/L).

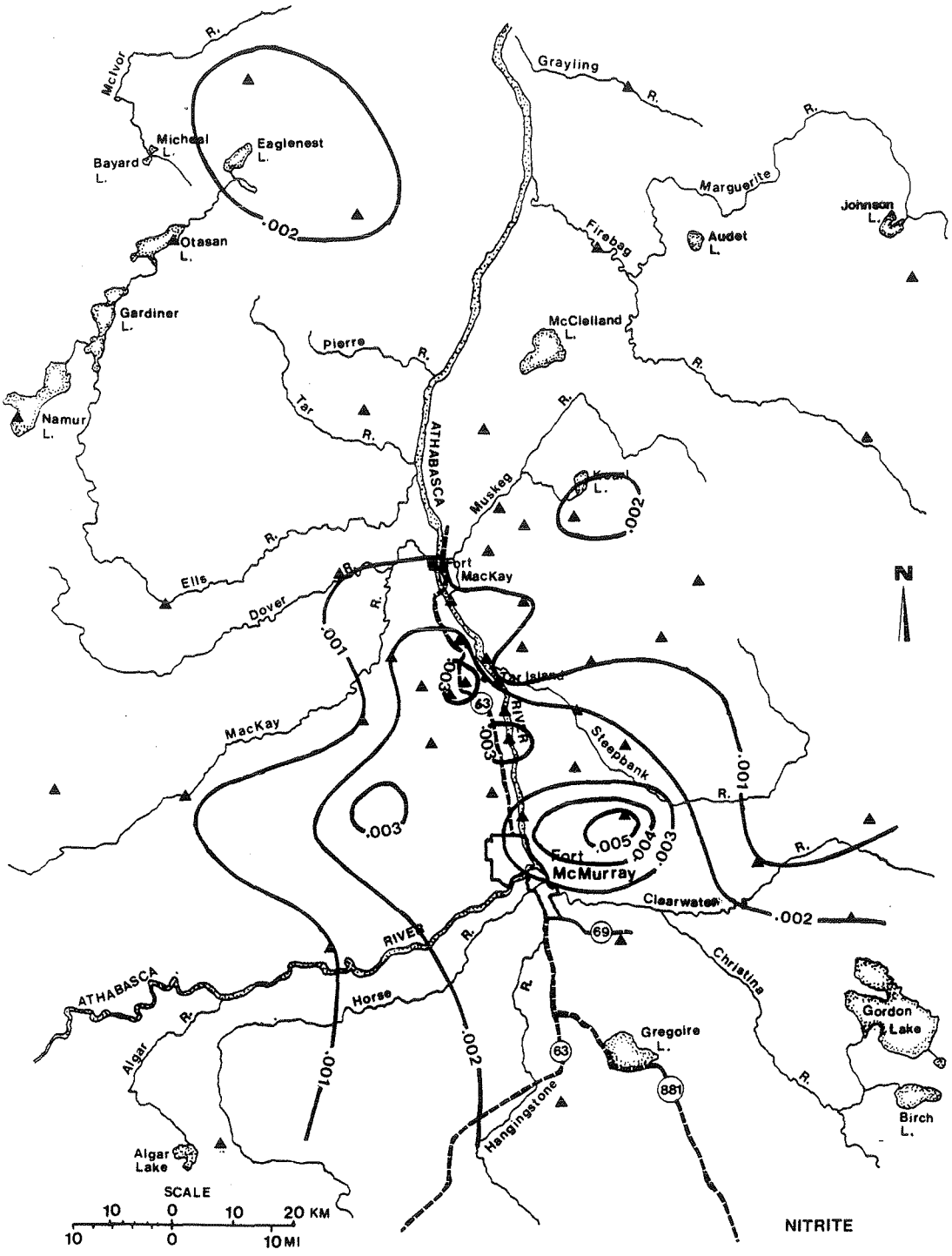

Figure 7: Areal distribution of the concentrations of nitrite from snow samples collected between 4 and 8 February 1986 (ueq/L).

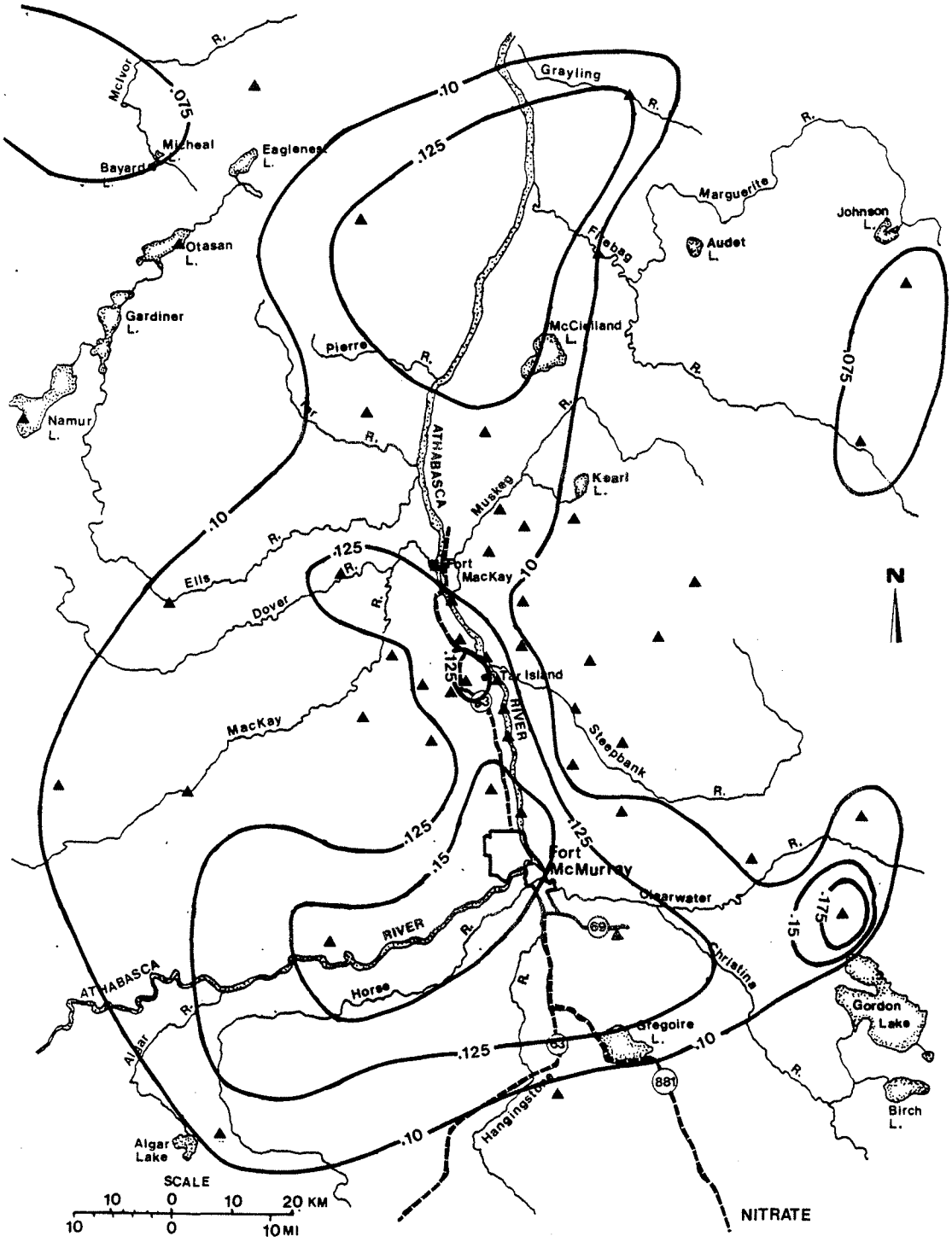

Figure 8: Areal distribution of the concentrations of nitrate from snow samples collected between 4 and 8 February 1986 (ueq/L).

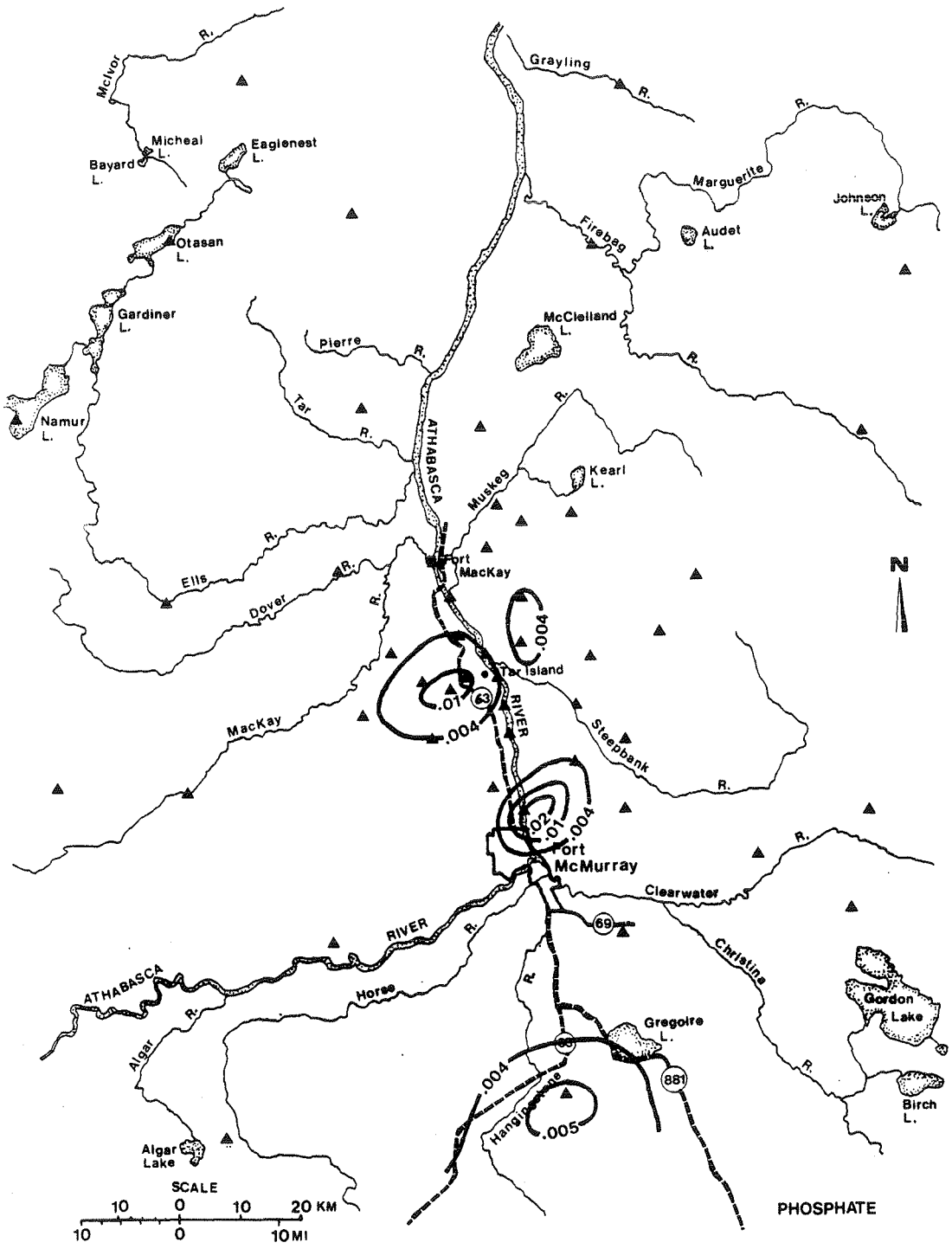

Figure 9: Areal distribution of the concentrations of phosphate from snow samples collected between 4 and 8 February 1986 (ueq/L).

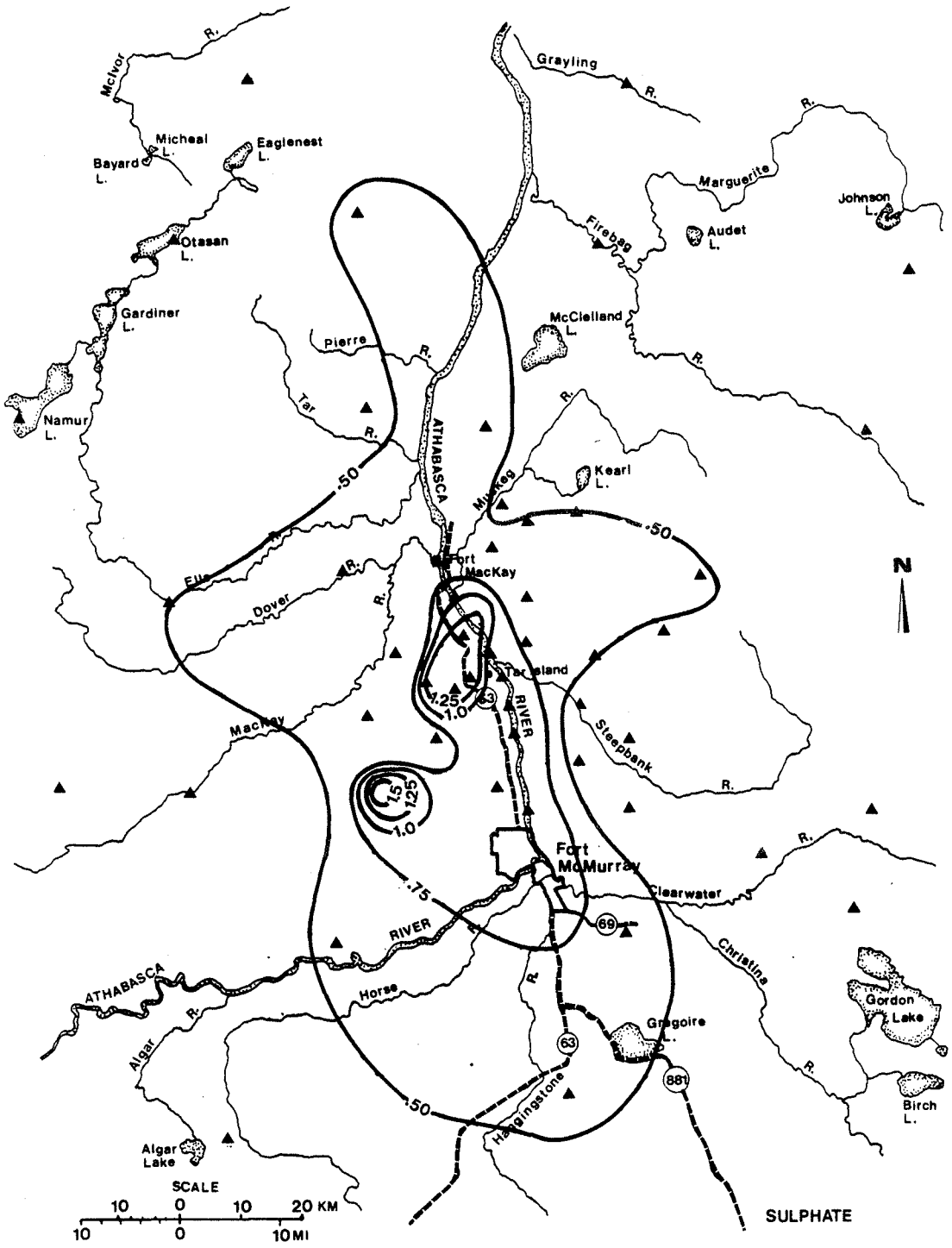

Figure 10: Areal distribution of the concentrations of sulphate from snow samples collected between 4 and 8 February 1986 (ueq/L).

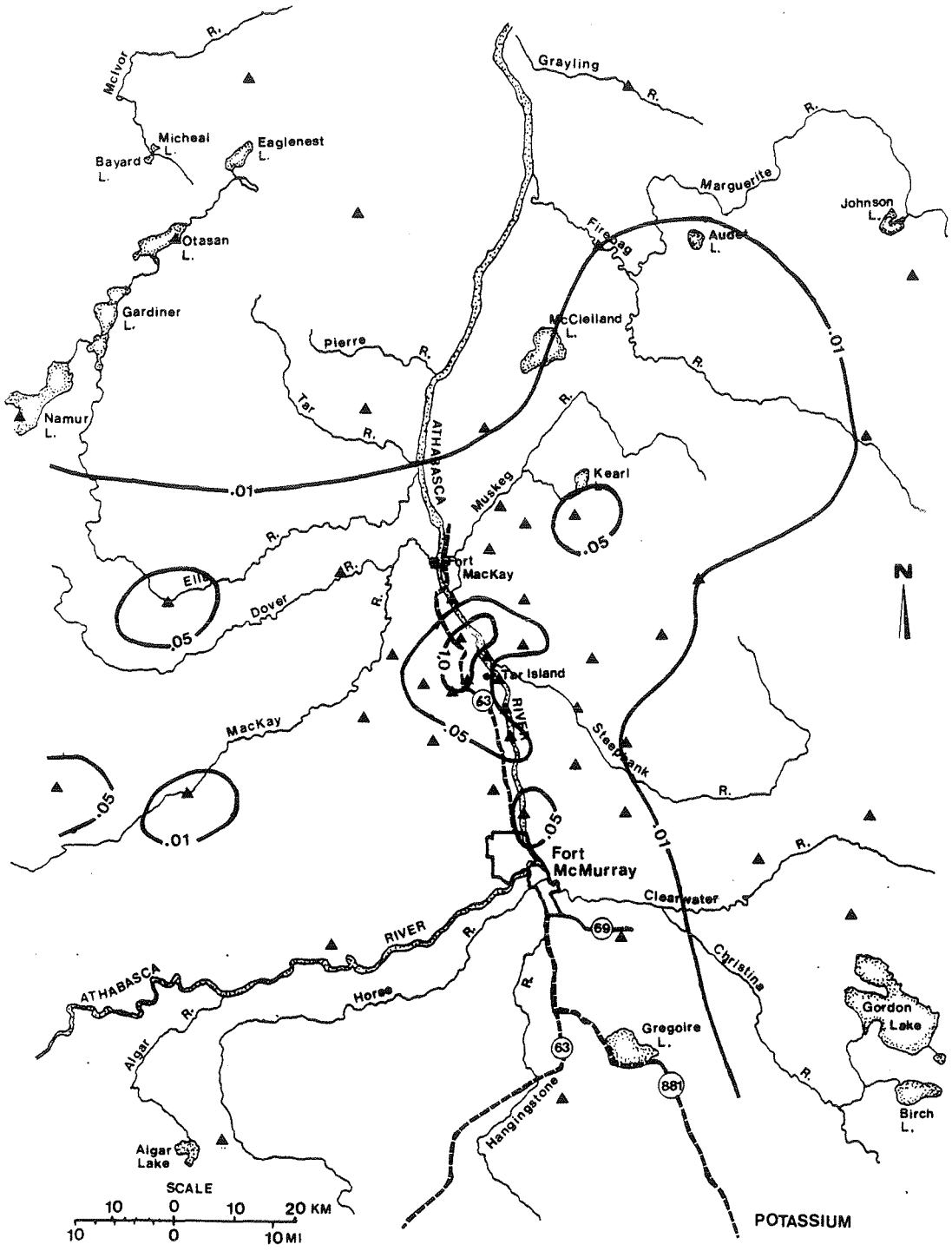

Figure 11: Areal distribution of the concentrations of potassium from snow samples collected between 4 and 8 February 1986 (ueq/L).

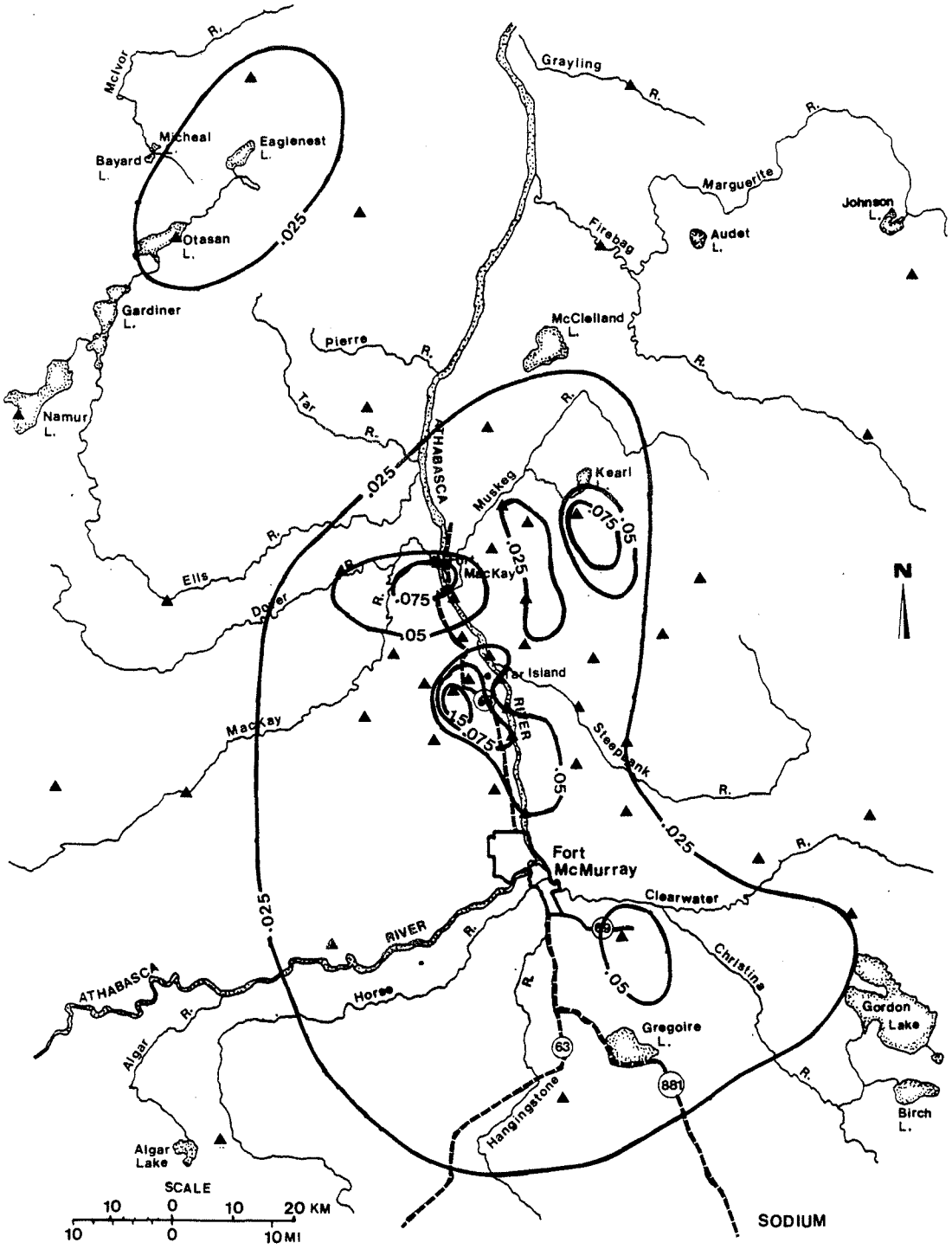

Figure 12: Areal distribution of the concentrations of sodium from snow samples collected between 4 and 8 February 1986 (ueq/L).

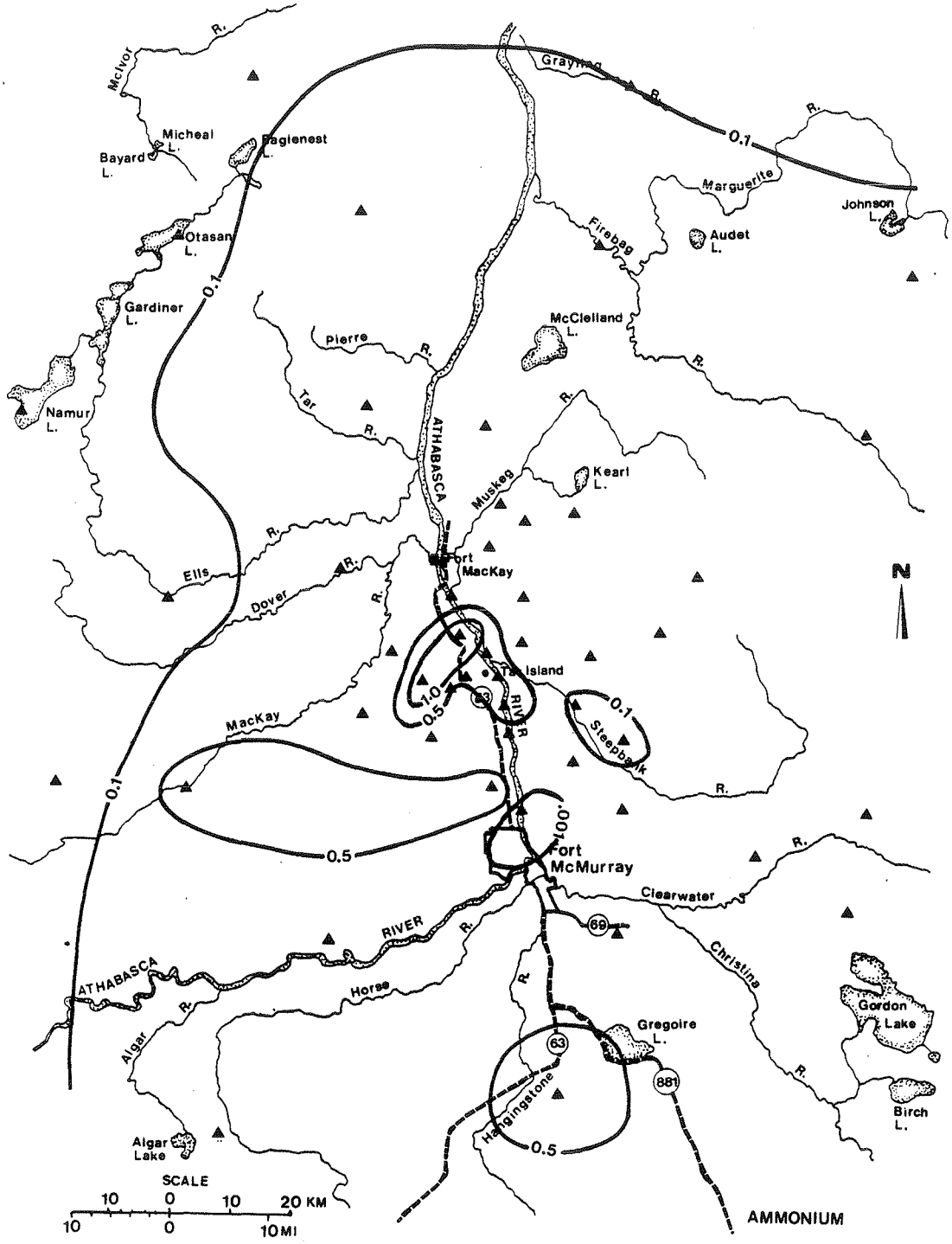

Figure 13: Areal distribution of the concentrations of ammonium from snow samples collected between 4 and 8 February 1986 (ueq/L).

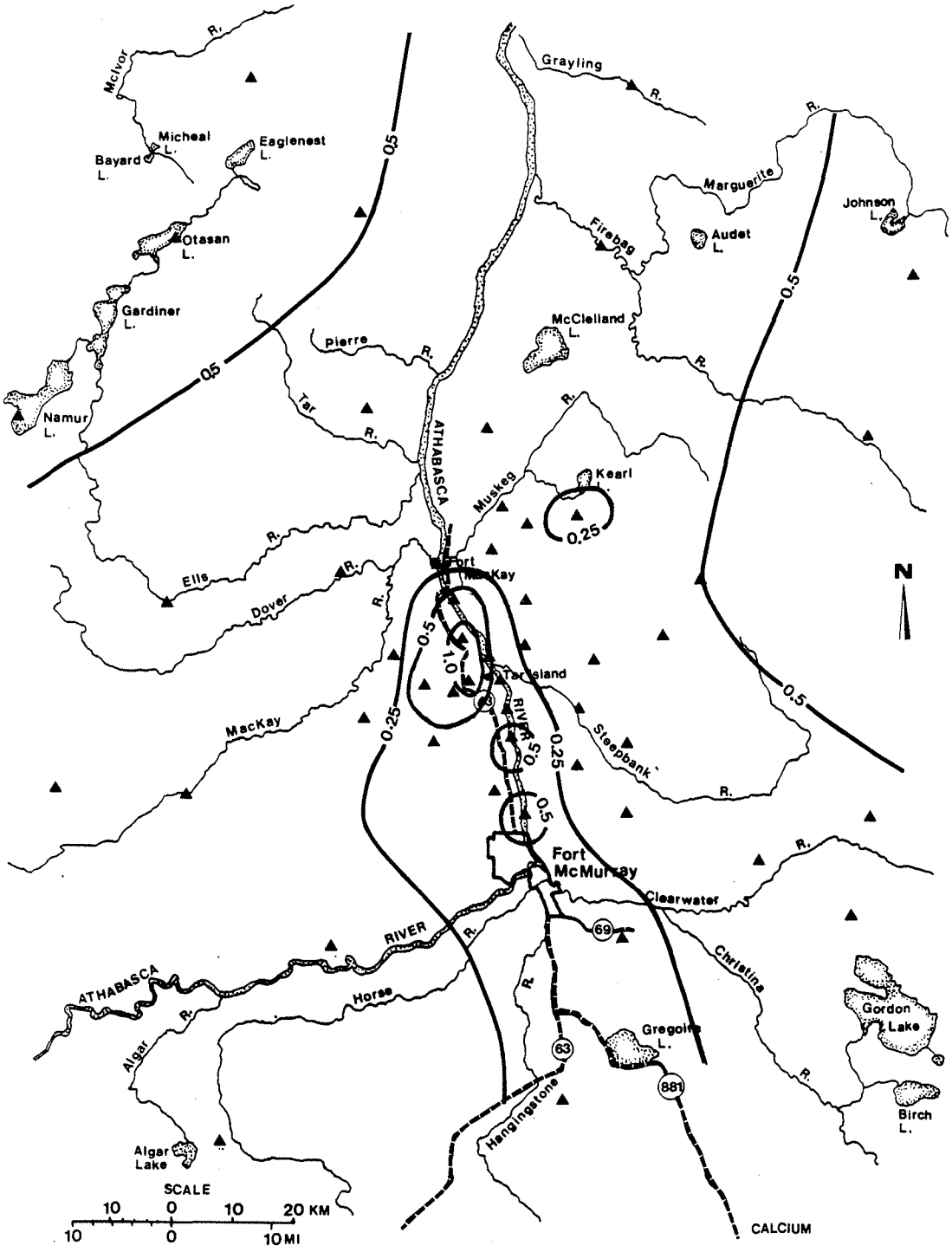

Figure 14: Areal distribution of the concentrations of calcium from snow samples collected between 4 and 8 February 1986 (ueq/L).

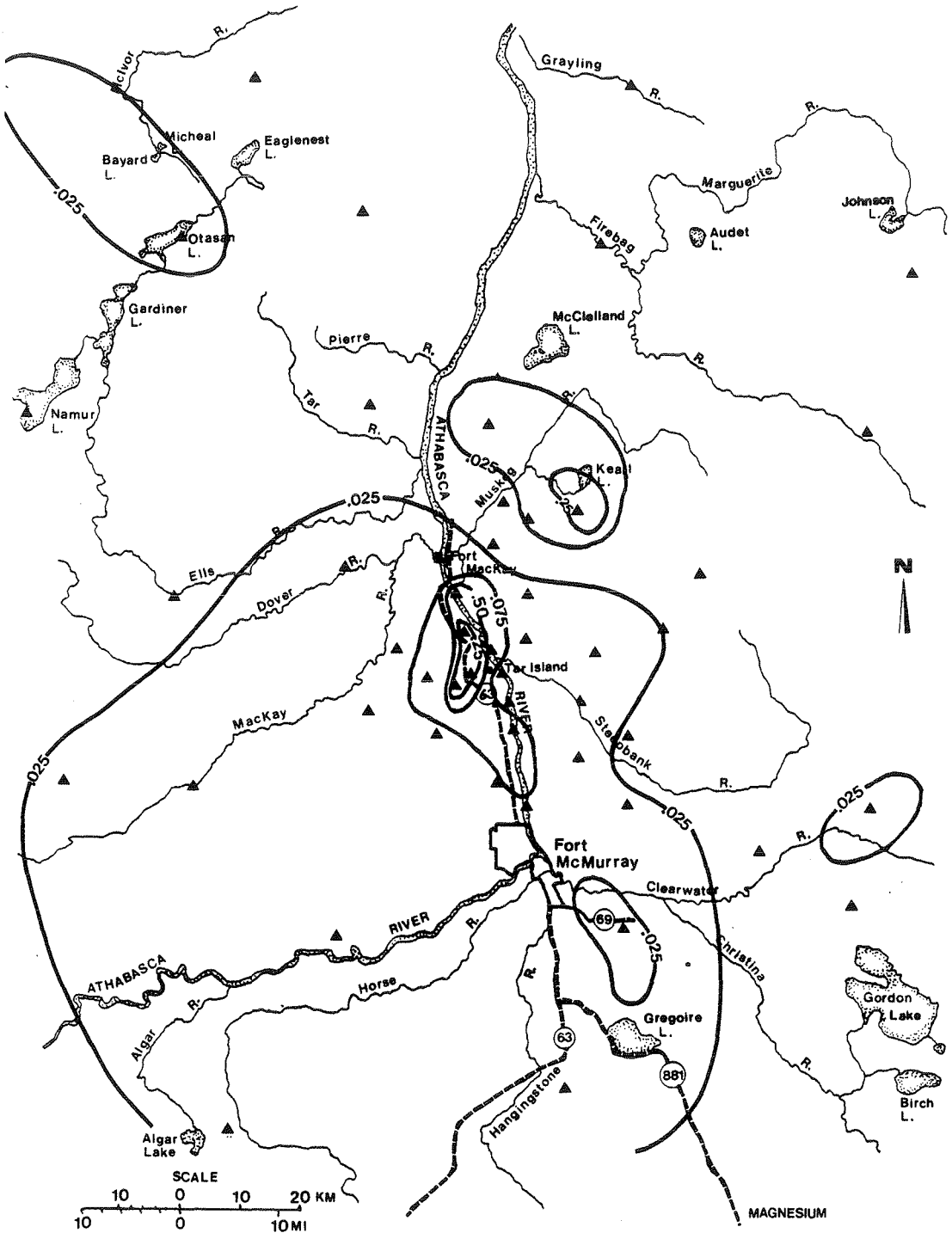

Figure 15: Areal distribution of the concentrations of magnesium from snow samples collected between 4 and 8 February 1986 (ueq/L).

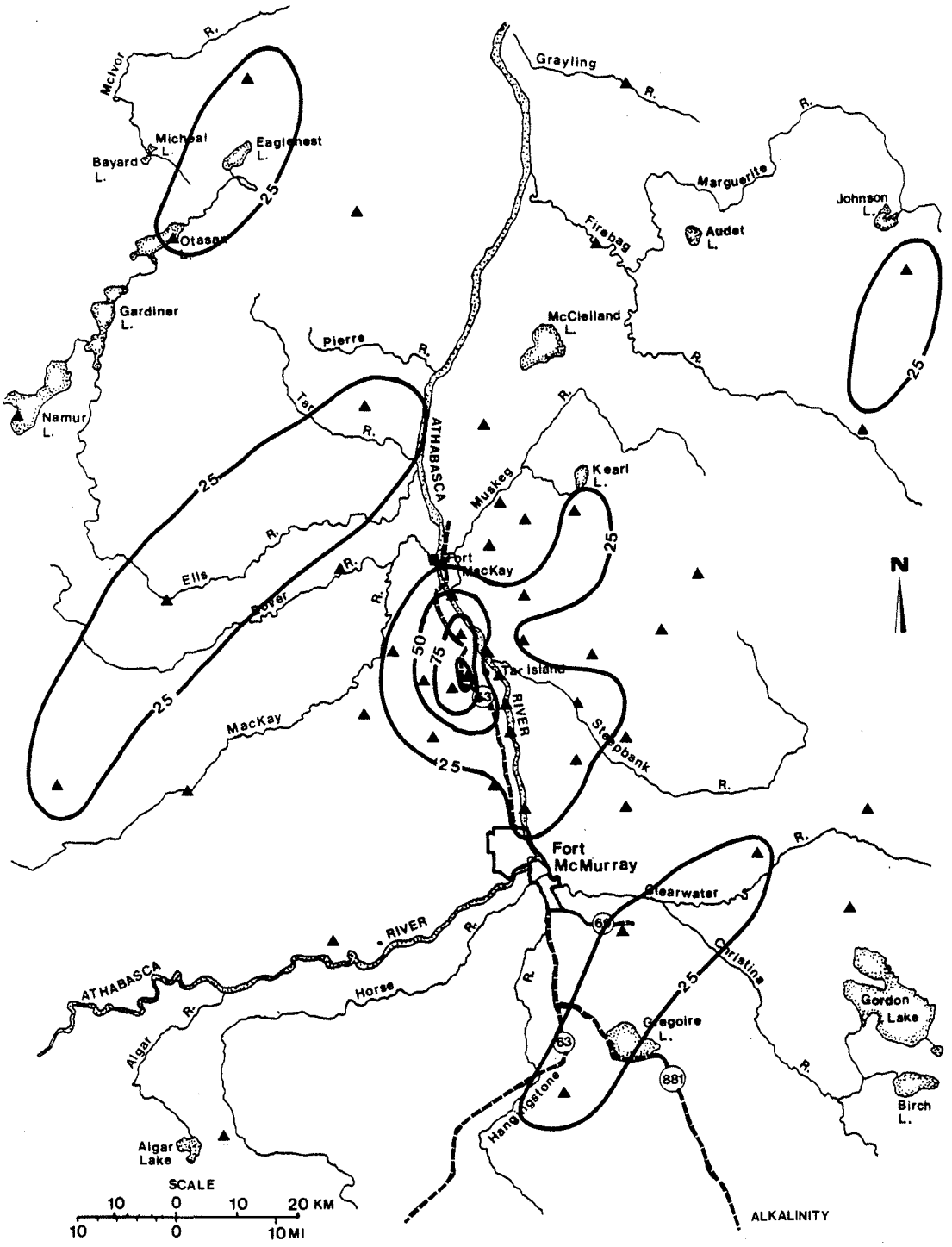

Figure 16: Areal distribution of the concentrations of alkalinity from snow samples collected between 4 and 8 February 1986 (ueq/L).

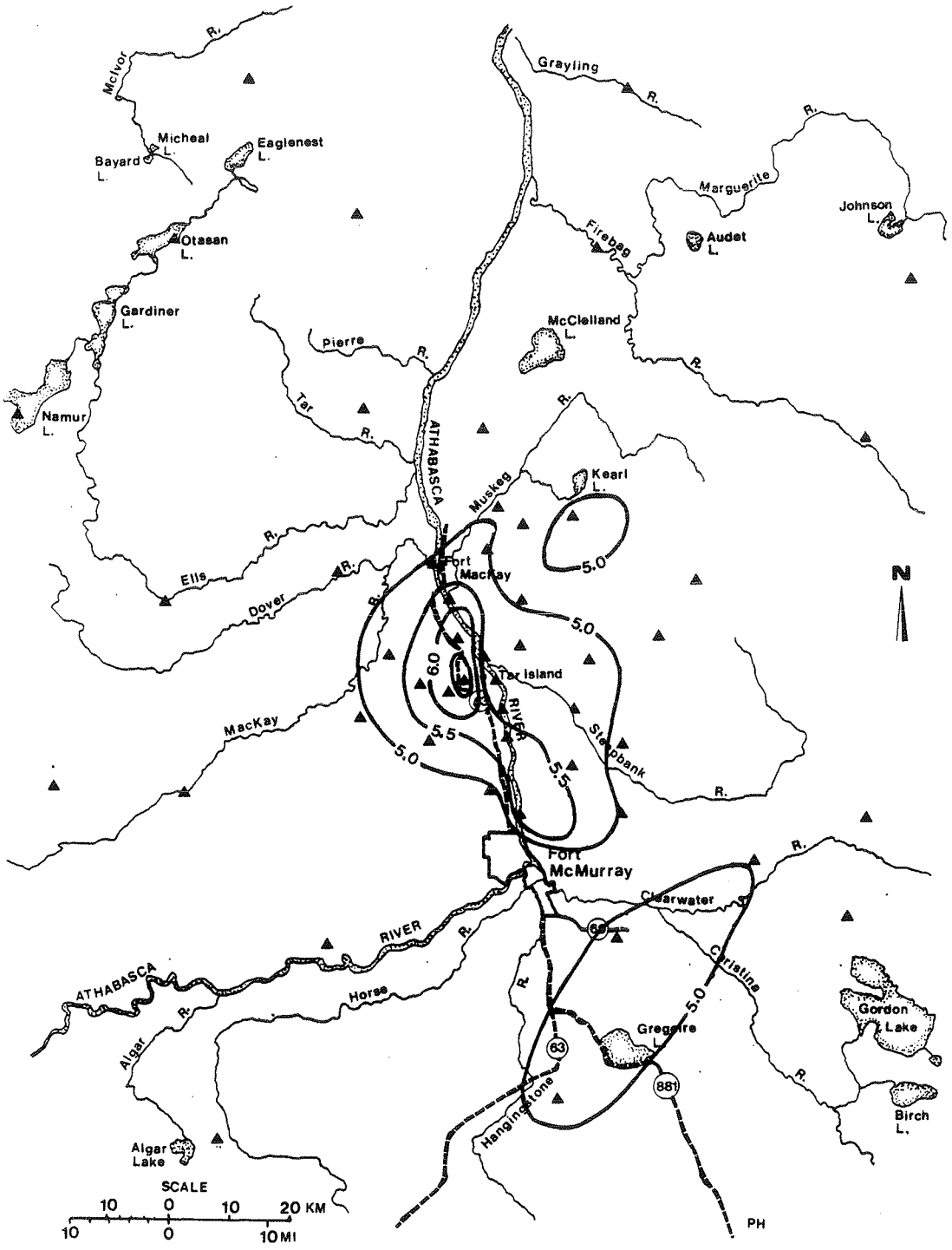

Figure 17: Areal distribution of the concentrations of pH from snow samples collected between 4 and 8 February 1986 (ueq/L).

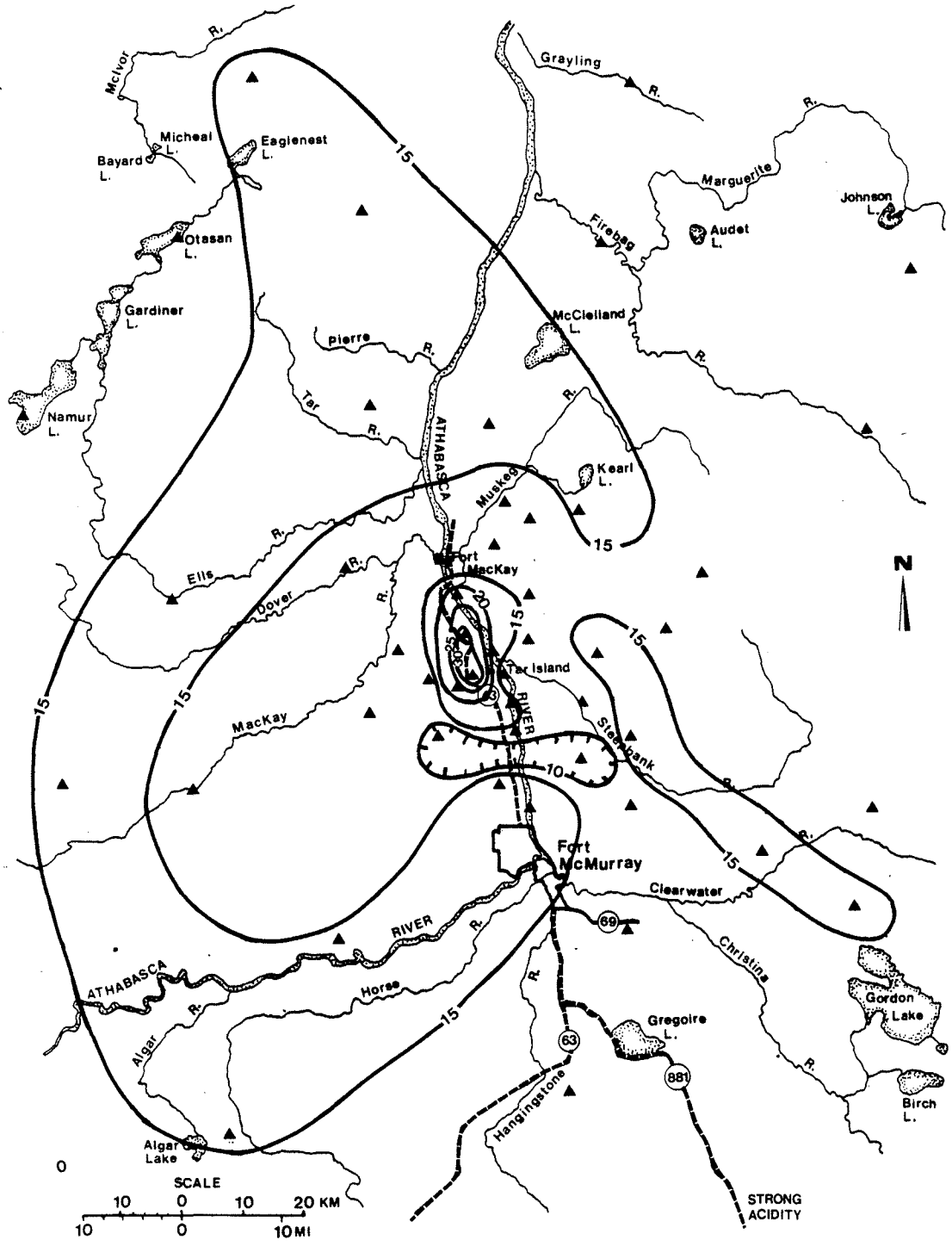

Figure 18: Areal distribution of the concentrations of strong acidity from snow samples collected between 4 and 8 February 1986 (ueq/L).

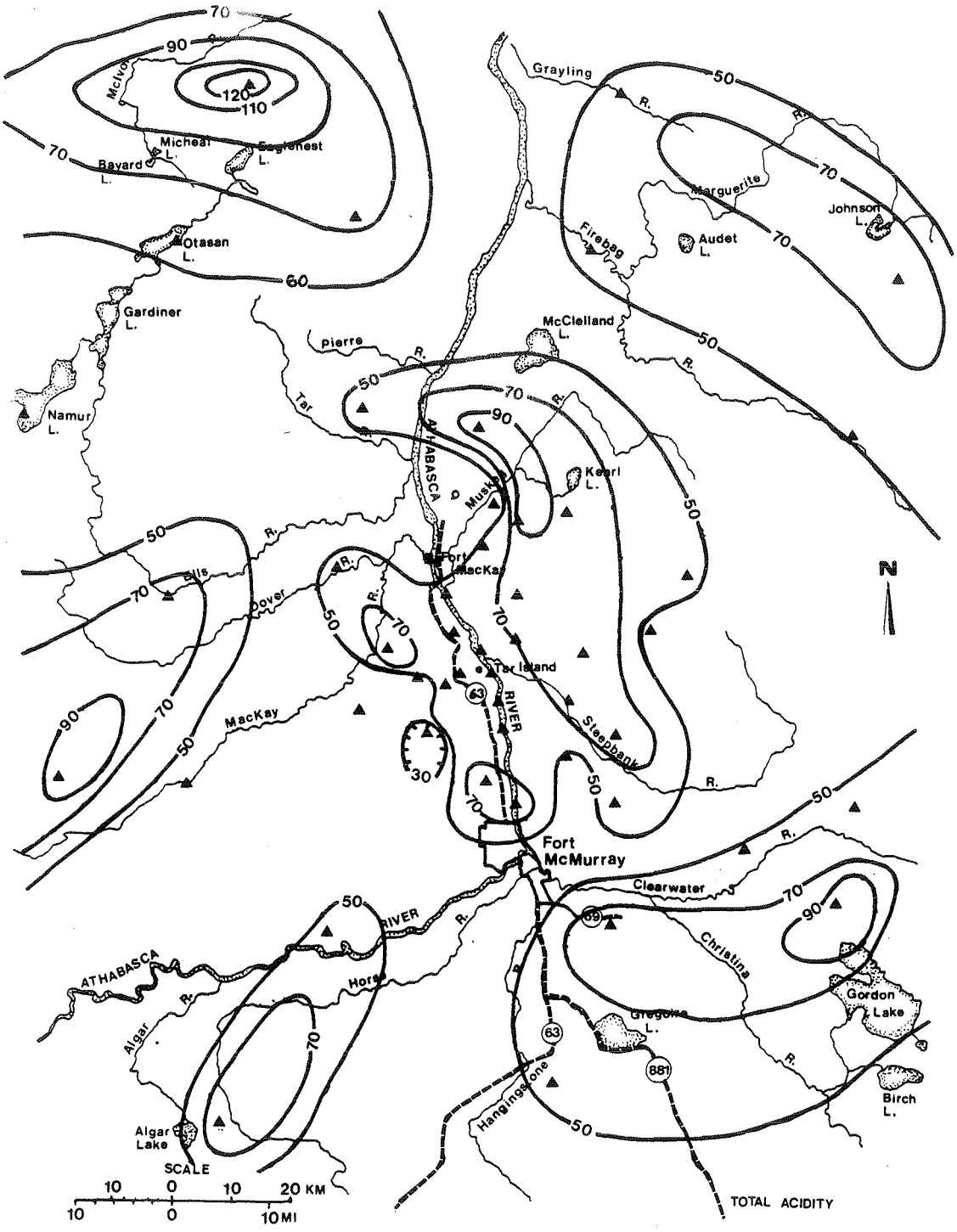

Figure 19: Areal distribution of the concentrations of total acidity from snow samples collected between 4 and 8 February 1986 (ueq/L).

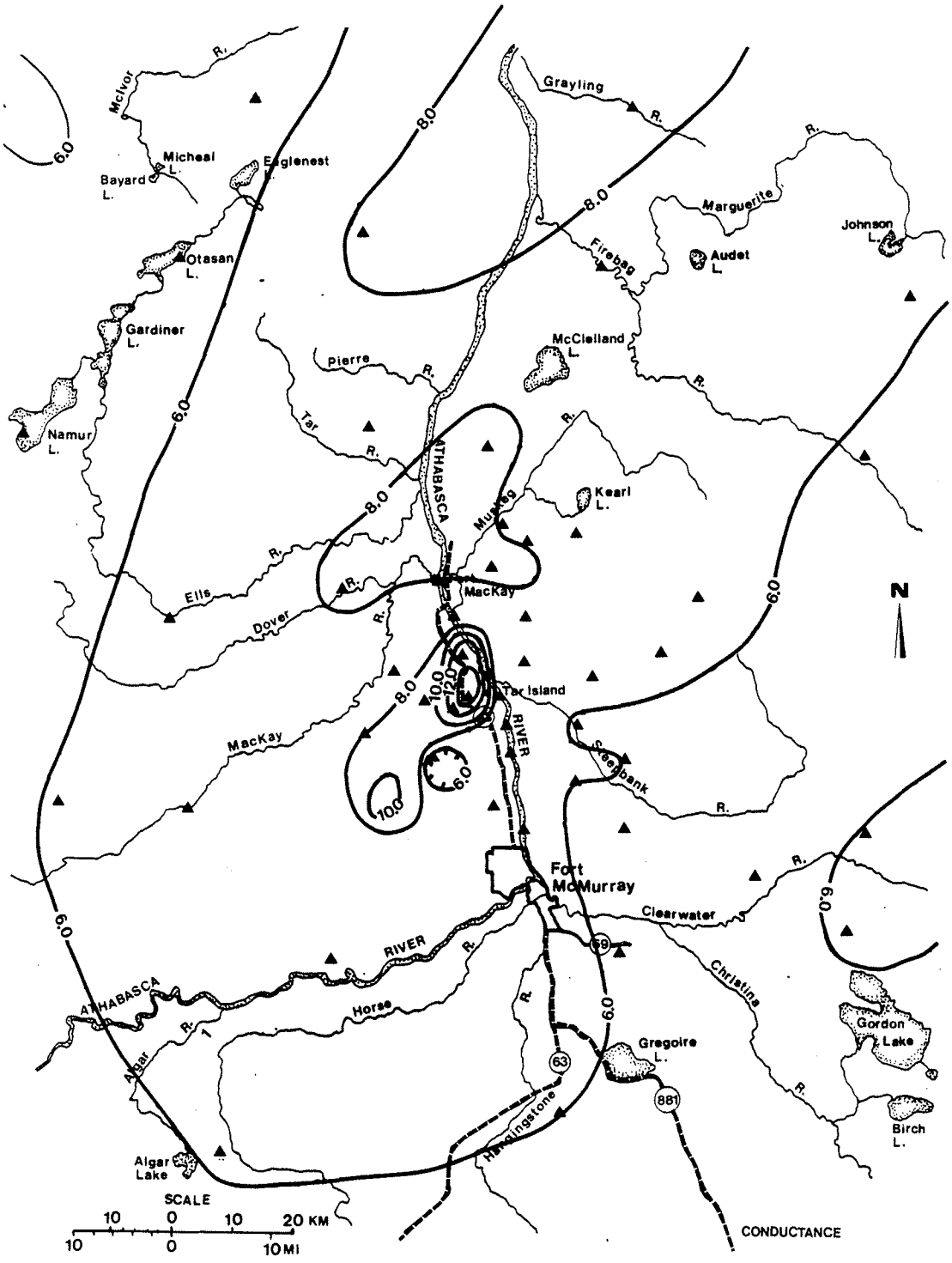

Figure 20: Areal distribution of the concentrations of measured conductance from snow samples collected between 4 and 8 February 1986 (us/cm).

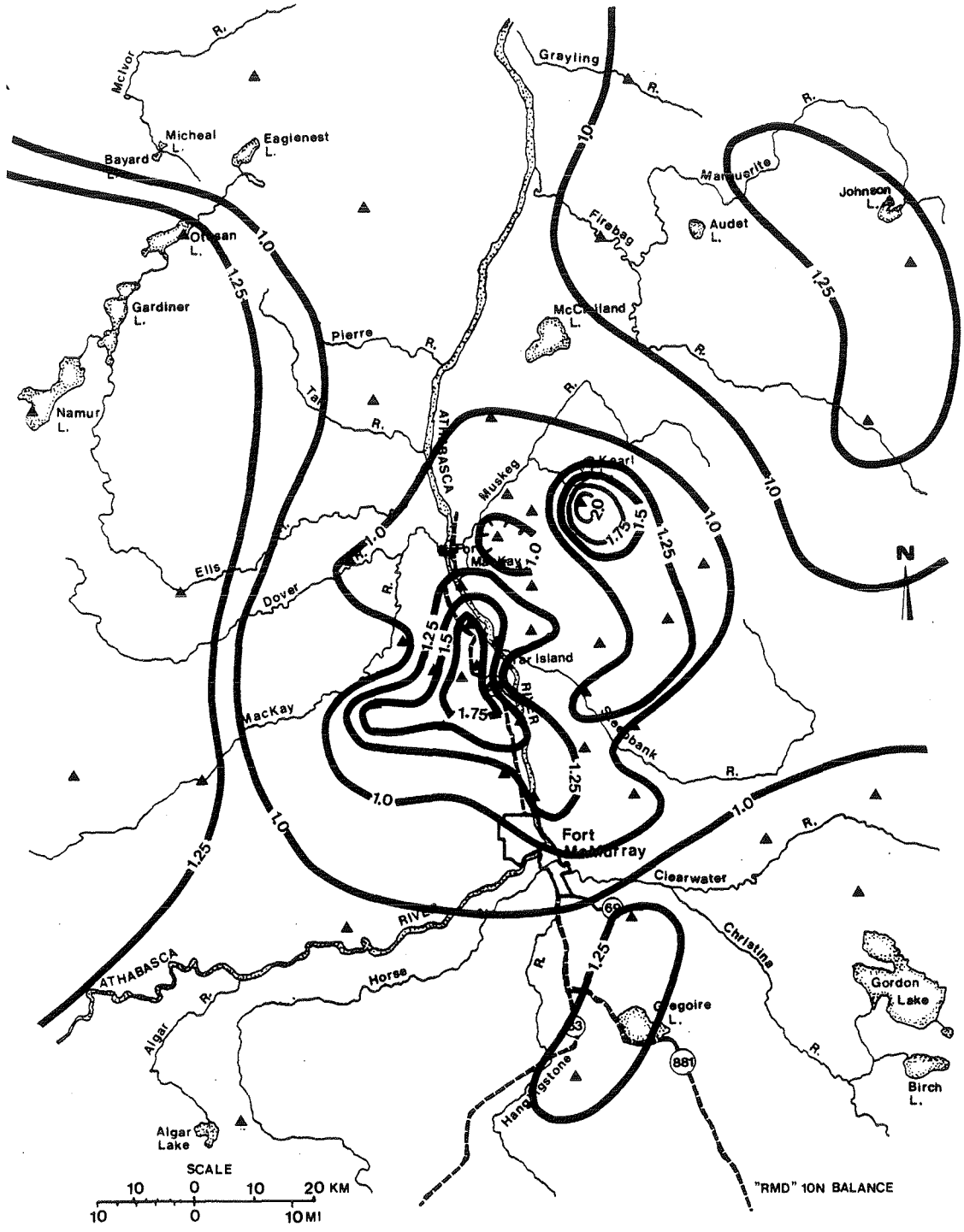

Figure 21: Areal distribution of ion balances calculated by "RMD" method from snow samples collected between 4 and 8 February 1986 (percentages).

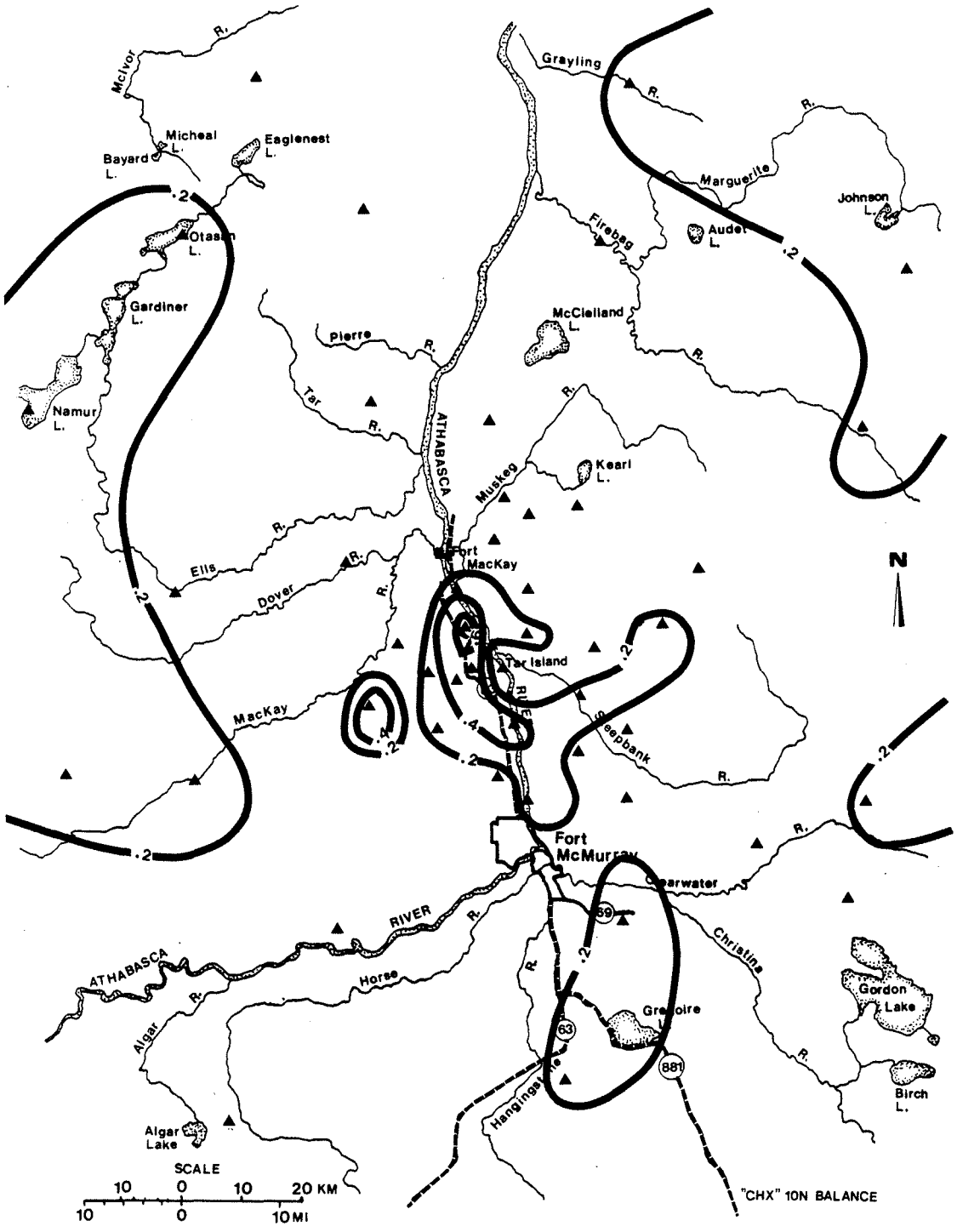

Figure 22: Areal distribution of ion balances calculated by "CMX" method from snow samples collected between 4 and 8 February 1986 (percentages).

5. SITE DOCUMENTATION

The purpose of the site documentation, photographs, and diagrams is to ensure that data users can assess the suitability of the sampling sites for their purposes. At each site detailed information on the location characteristics was compiled and photographs taken. Site diagrams were drawn in the field and later refined using the photographs, video-tapes, and field voice-recordings.

The site diagrams are in Appendix II. A legend is provided at the beginning of the appendix. Documentation for each site is located in Appendix III, while detailed site locations are plotted on sections of Alberta Energy and Natural Resources maps at the 1:250 000 scale in Appendix IV. Photographs of the four cardinal directions from the sampling sites and obliques are not included in the report but, are available from Research Management Division, Alberta Environment, Edmonton.

6. ASSESSMENT OF EXISTING SNOW SURVEY SITES

There are five siting attributes incorporated into evaluating the quality of each snow-survey site. They were adapted from a report prepared by Concord Scientific Corporation (Davis et al. 1985) after being discussed in committee with managers from Research Management Division. The main tenet of the site evaluations is that the chemistry of the collected snow should be affected as little as possible by local, site-specific influences.

These siting attributes include: (a) site description; (b) ground cover within 25 m; (c) ground-cover within 1 km; (d) distance to roads, overland routes, or air access; and (e) the ratio: distance separating sample site and obstruction to height of the obstruction. For each sampling location these attributes have been assigned to one of five categories. Category one indicates the least desireable in-situ condition for that particular attribute.

In terms of the site-description attribute a lake or large pond was rated as "5" while developments such as diesel-powered telephone relay stations were "1". Ground-covers within both 25 m and 1 km were rated highest if there was ice and lowest for combinations of ice/sedges/shrubs/forest. In the rating of the attribute distance to roads, overland routes, or air access, a site near a major road was categorized as a "1" while a site far removed would be "5". The ratio of the distance between the sample site and obstruction to the height of the obstruction was rated most favorably when the ratio was greater than five and least favorably when it was less than five tenths. Appendix V is a reprint of the actual site attribute form, while Table 5 is a summary of the attribute values assigned to each of the five categories for all sampling sites.

The degree of influence that each siting attribute contributes to the over-all evaluation, in terms of the one to five ratings, is variable. Some of the attributes are more important than others regarding snow-sample integrity and quality. This necessitated using weighted site-attribute values. These weighted values were determined using the Concord Scientific Corp. report as a guideline. However, the final values were set in committee with managers from

Table 5: Attribute values assigned to each sampling site.

Sampling Site	Site Description	Ground Cover Within 25 m	Ground Cover Within 1 km	Distance to Air or Road Access	Ratio of Distance to Site/ Veg.Height
BCH	2	3	3	3	5
BKN	2	2	3	4	2
CLK	4	4	3	4	2
DNK	3	2	3	4	1
E2	3	2	3	4	1
E4	3	3	3	4	1
ELS	3	3	3	4	1
ERA	2	3	3	5	4
FBG	3	3	3	4	2
FMA	1	3	2	1	2
GLK	5	5	4	5	5
GND	4	3	3	3	3
HHR	3	2	3	5	3
HLS	1	2	3	2	1
JSN	2	3	3	5	3
LCK	3	3	3	4	1
LGR	4	4	4	5	5
MKG	3	3	3	2	3
MKR	3	2	3	4	1
N1	3	2	2	1	1
N2	2	3	1	1	3
N4	3	3	3	1	3
NE1	3	2	3	3	1
NE3	3	1	3	2	1
NE5	3	3	2	2	2
NLK	4	4	4	5	4
NNE1	3	2	2	3	1
NNE3	3	3	3	4	3
NNE4	2	2	3	3	1
NNW1	3	3	3	4	3
NW3	3	3	3	3	3
NW1	3	3	3	5	2
RO	4	3	4	3	4
R1	4	2	4	3	3
R2	4	2	4	2	3
R3	4	3	2	2	2
R4	4	2	4	2	2
RIC	5	5	5	5	5
SALT	2	2	3	3	2

Continued

Table 5 (Concluded): Attribute values assigned to each sampling site.

Sampling Site	Site Description	Ground Cover Within 25 m	Ground Cover Within 1 km	Distance to Air or Road Access	Ratio of Distance to Site/ Veg.Height
SE3	3	2	3	3	1
SE5	4	5	4	5	5
SMT	3	2	4	2	3
SSW1	3	3	4	3	3
SW1	3	3	2	1	2
SW3	3	2	3	4	1
SW5	5	5	3	3	5
UTL	5	5	4	5	4
W1	3	4	3	4	4
W3	3	2	3	4	1
WCK	3	1	3	4	1
WLK	4	3	3	1	3

Research Management Division. The over-all contribution that the site-description attribute made to the final ratings was 30%. Ground cover within 25 m was rated at 25% while ground cover within 1 km was 10%. The percentages that the siting attributes distance to roads and ratio of sample site to obstruction height were 15 and 20%, respectively.

As an example of the rating system, HLS (Figure 36 and Appendix II, page 65) is within the clearing of Alberta Government Telephones's communications tower. Power for the site is supplied by a continuously running, on-site, diesel-burning generator, which has two exhausts. There is a winter road immediately adjacent to the actual snow sampling site. Because it is a developed location, it received a "1" for the site description attribute. RIC (Figure 61 and Appendix II, page 90) is on a relatively large lake with no major deviations from the desired siting criteria. It received a "5" for the site description attribute. (Weighting factor = 30%.)

Ground cover within 25 m at HLS is predominantly shrubby aspen, with a forest cover of 8 m-high pine to the west. Wind-blown contaminants from within this radius may impinge upon the quality of the snow samples and so, the attribute rating assigned was "2". At RIC the surrounding ground cover is ice and it received a "5". (Weighting factor = 25%.)

Forest and shrubs cover the ground within 1 km of HLS and so it was assigned a value of "3". At RIC, ice covers much of the surrounding 1 km area and it was ascribed a rating of "5". (Weighting factor = 10%.)

At HLS the distance to roads, overland routes, or air access was rated as poor, with a value of "2", because a winter road is adjacent to the snow sampling site. At RIC, it is over 1 km to the nearest winter road so it received a "5". (Weighting factor = 15%.)

The ratio of the distance separating sample site and obstruction to the height of obstruction should be at least 2.5 according to the Concord Scientific study. At HLS it was less than one and, as such, the attribute rating was the lowest possible, at "1".

The ratio was very high at RIC and the assigned attribute rating was the highest possible, at "5". (Weighting factor = 20%.)

The resultant values calculated for these two sites are 32 and 100 points out of 100 for HLS and RIC, respectively. They represent the extremes for the sites sampled during the 1986 survey. The weighted site-attribute values for these two locations and the remaining sites are presented in Table 6. They are arranged in ascending order. Often, a single poor characteristic of the sampling site was enough to heavily bias the rating for that location. For example, the five river sites, R0, R1, R2, R3, and R4, were all very similar in their physical characteristics. They were all along the relatively wide Athabasca River so ground covers within 25 m and 1 km, ratio of distance to sample site/vegetation height, and distance to roads were nearly identical. However, the nearness of the sites to the exposed sediments of the actively eroding depositional islands played an extremely important role in separating the quality of the site specific characteristics.

Table 6: Values of weighted site-attributes for snow sampling sites. (See text and Appendix IV for derivation of the values.)

Snow Sampling Site - Rating Out of 100 Possible			
HLS - 32	DNK - 50	R3 - 57	ERA - 64
FMA - 36	E2 - 50	FBG - 59	GND - 65
NE3 - 39	MKR - 50	JSN - 60	CLK - 70
N1 - 39	SW3 - 50	NW3 - 60	W1 - 72
NNE4- 41	W3 - 50	R2 - 60	R0 - 72
N2 - 44	NE5 - 51	WLK - 60	NLK - 83
NNE1- 45	N4 - 54	HHR - 61	LGR - 87
SALT- 45	SMT - 54	BCH - 62	SW5 - 90
WCK - 45	ELS - 55	NW1 - 62	SE5 - 92
NE1 - 47	E4 - 55	SSW1- 62	UTL - 94
SE3 - 47	LCK - 55	NNE3- 63	GLK - 98
SW1 - 48	R4 - 56	NNW1- 63	RIC -100
BKN - 48	MKG - 57	R1 - 63	

7. CONCLUSIONS AND RECOMMENDATIONS

The 1986 snow survey in the Alberta Oil Sands area was limited due to unseasonably mild weather. Melt-periods prior to the first snow sampling survey may have caused leaching of ions out of the snowpack. This biases the results from the chemical analyses. The second survey could not be conducted due to a lack of a snow cover.

The areal distributions of the concentrations of ions and other parameters generally indicate relatively strong gradients across the Athabasca River Valley compared to weaker gradients in the north-south directions from the oil sands plants. Low-level inversions appear to have reduced the ventilation of the valley, resulting in somewhat higher concentrations near the Athabasca River.

The sampling sites used in the 1986 survey, which includes many of those used in previous studies, were documented and assessed for their quality as representative locations for snow sampling. However, there is a wide range in their quality as some of the sites impose their specific characteristics upon the snow samples. Other sites seem well suited for being used to collect snow.

As such, we recommend RMD should more clearly formulate the objectives of this monitoring project so that testable hypotheses can be generated. Researchers should be made fully aware of these objectives and hypotheses before proceeding with their fieldwork. If properly formulated objectives and hypotheses were developed it is reasonable to expect that the present monitoring network of 51 sites could be significantly reduced in size and still give statistically valid information. We recommend that the Alberta Oil Sands snow survey network be modified so that only the sites most suited for attaining the project objectives be used. Those sampling areas that are near developments such as major highways, airports, or exhausts from generators would probably be discarded.

Besides reducing the variance due to poor sample design, the reduction in site numbers would have additional benefits. For example, by reducing the time needed to complete any given survey it would then be possible to do more than two surveys per season. This

would allow the project to both effectively monitor intra-site variability over the season and it would reduce the probability of significant loss of seasonal data due to poor weather conditions. The benefits of improving the project objectives and hypotheses cannot be overstated.

We recommend that the present procedure of conducting replicate and duplicate samples be continued. The exact number of these sites and their locations would be dependent upon the objectives and hypotheses of the project. Replicate samples are one way to test intra-site spatial variation. Further, they may help to reduce the inter-site "bulls-eye" effect of what appears to be anomalously high ion values seen at some single sample sites. However, due to time constraints, it will probably not be possible to conduct replicate sampling at all the sites even in a reduced network. Again, their final number depends on the project objectives of Alberta Environment.

Duplicate samples provide a check on laboratory analytical results. The project should continue its practice of taking these samples.

If the above recommendations are implemented there should be a significant increase in the over-all quality of the snow monitoring project.

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8. APPENDICES

8.1 Appendix I - Snow Sample Data Collection Form

WINTER PRECIPITATION CHEMISTRY PROJECT
SAMPLE COLLECTION FORM

STATION: _____ SAMPLE NO.: _____
DATE COLLECTED: _____ TIME COLLECTED: _____
TYPE OF SAMPLER: _____ SAMPLER X-SECTION (cm^2): _____

PHYSICAL DESCRIPTION OF SAMPLE SITE: _____

APPROXIMATE DISTANCE TO NEAREST LARGE VEGETATION(m): _____

CORE NUMBER	1	2	3	4	5	6	AVERAGE
TOTAL SNOW DEPTH (cm)							
FRESH SNOW DEPTH (cm)							
ICE LAYER DEPTH(S) (cm) (from ground)							
CORE LENGTH REMOVED (cm)							
CORE LENGTH RETAINED (cm)							

TOTAL SAMPLE LENGTH RETAINED (cm) _____
TOTAL SAMPLE VOLUME RETAINED (cm^3) _____
TOTAL SAMPLE WEIGHT (gm) _____
TOTAL SAMPLE DENSITY (gm/cm^3) _____

CONTAMINATION IN RETAINED CORE (indicate approximate amounts):

CORE	GRASS	LEAVES	NEEDLES	INSECTS	ROCKS/DIRT	FIBRES	OTHER
1							
2							
3							
4							
5							
6							

WEATHER CONDITONS (estimated):

CLOUD COVER (1/10's) _____ PRECIPITATION TYPE: NONE _____
WIND SPEED (m/s) _____ RAIN _____
WIND DIRECTION (±5°) _____ SNOW _____
FOG _____ BLOWING SNOW _____ PRECIPITATION INTENSITY _____

SAMPLE THAWED DURING TRANSPORT: YES NO
SAMPLE ARRIVED AT LAB FROZEN: YES NO
SAMPLE ARRIVED AT LAB PUNCTURED: YES NO

DATE(S) SAMPLE ANALYZED: _____

OTHER COMMENTS: _____

SAMPLE COLLECTED BY: SAMPLE ANALYZED BY:

_____ _____

8.2 Appendix II - Site Diagrams

LEGEND

★ - Sampling Site

▲ - Tower

△ - Coniferous Trees

○ - Deciduous Trees

H - Helicopter

⊠ - Building

═══ - Aerial Cable

—x—x— - Trasmission Line

◄═══ - Direction of Flow

A - Aspen (*Populus tremuloides*)

Al - Alder (*Alnus* spp.)

BS - Black Spruce (*Picea mariana*)

P - Jack Pine (*Pinus banksiana*)

Sed - Sedges

Shr - Shrubs

T - Tamarack (*Larix laricina*)

W - Willow (*Salix* spp.)

WS - White Spruce (*P. glauca*)

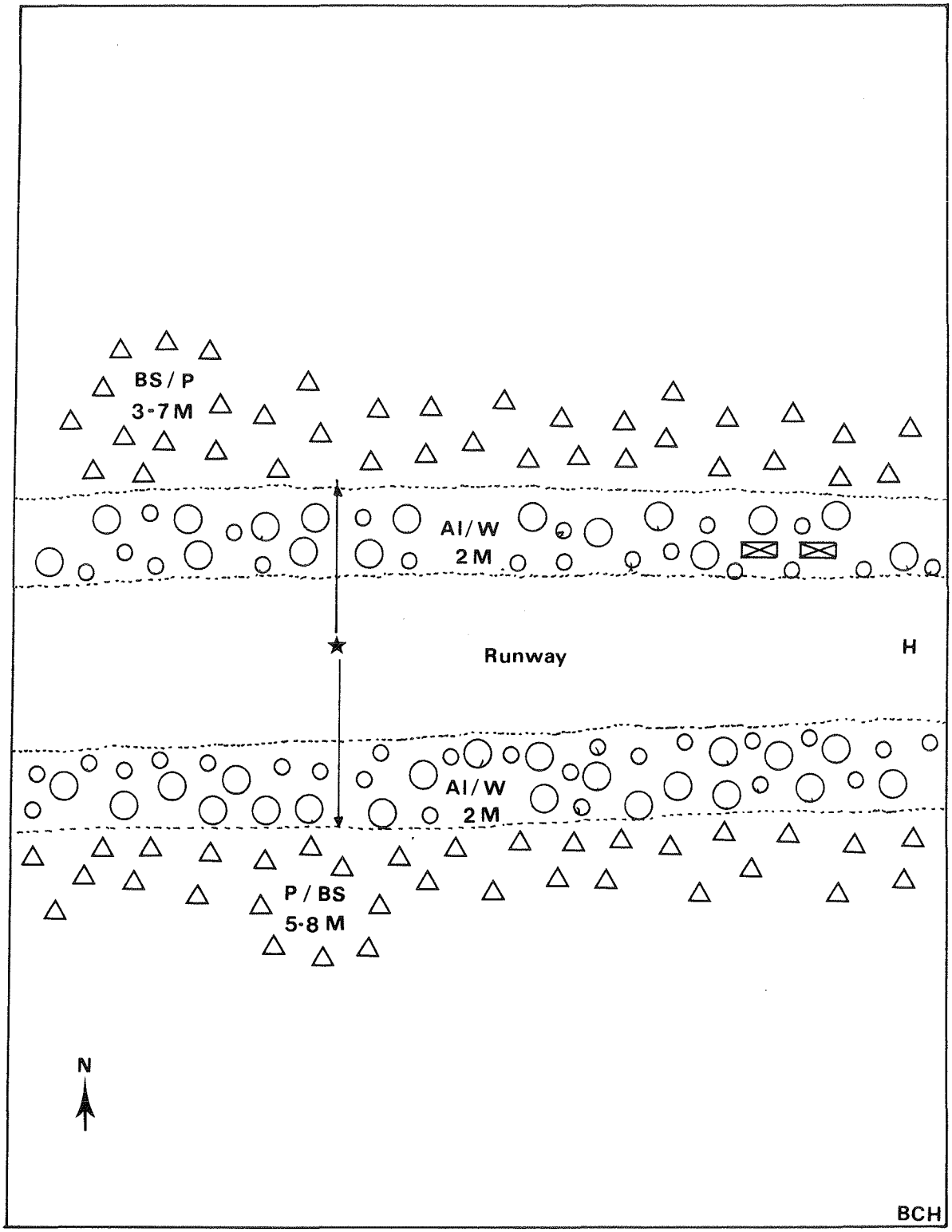

Figure 23: Site Diagram of BCH.

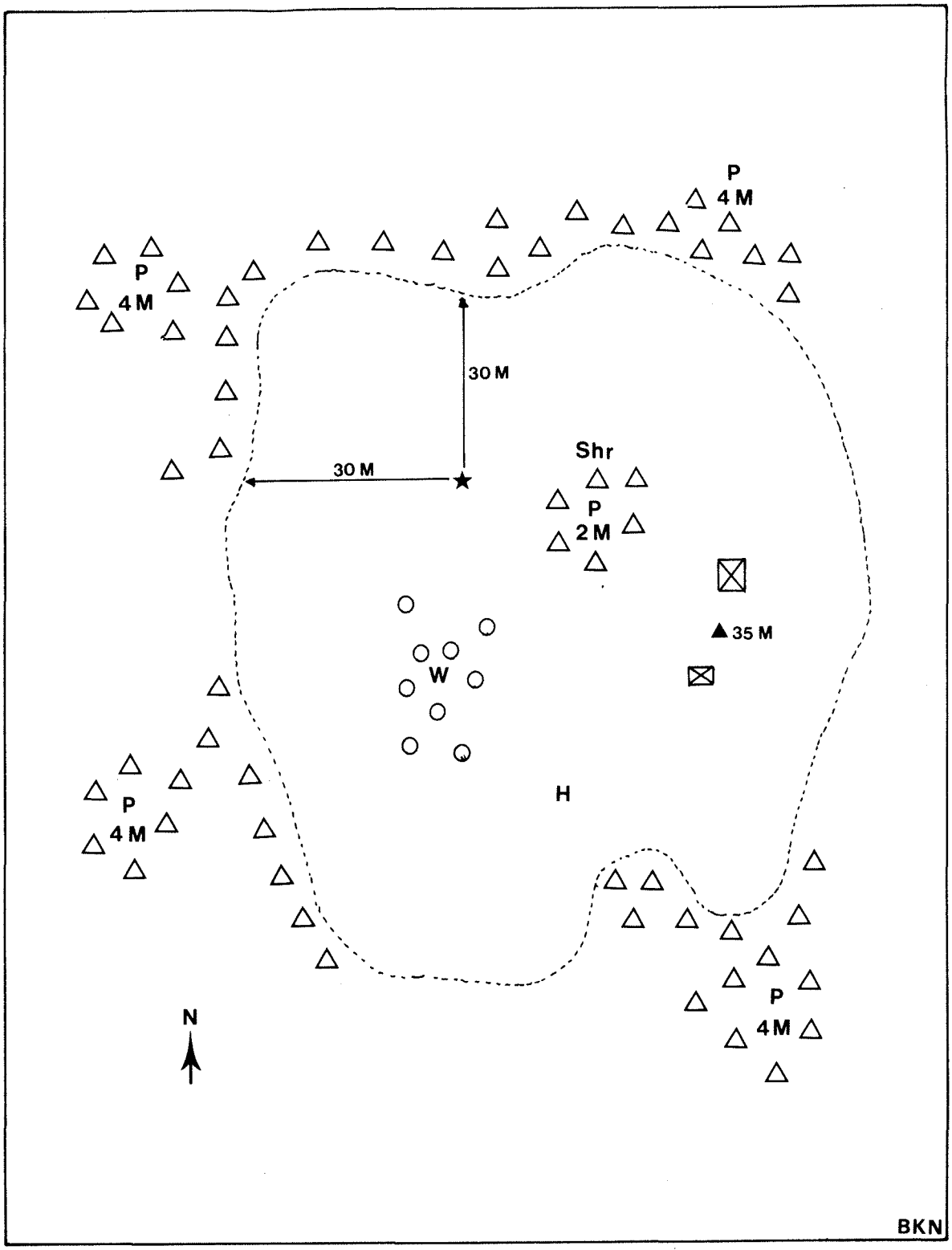

Figure 24: Site Diagram of BKN.

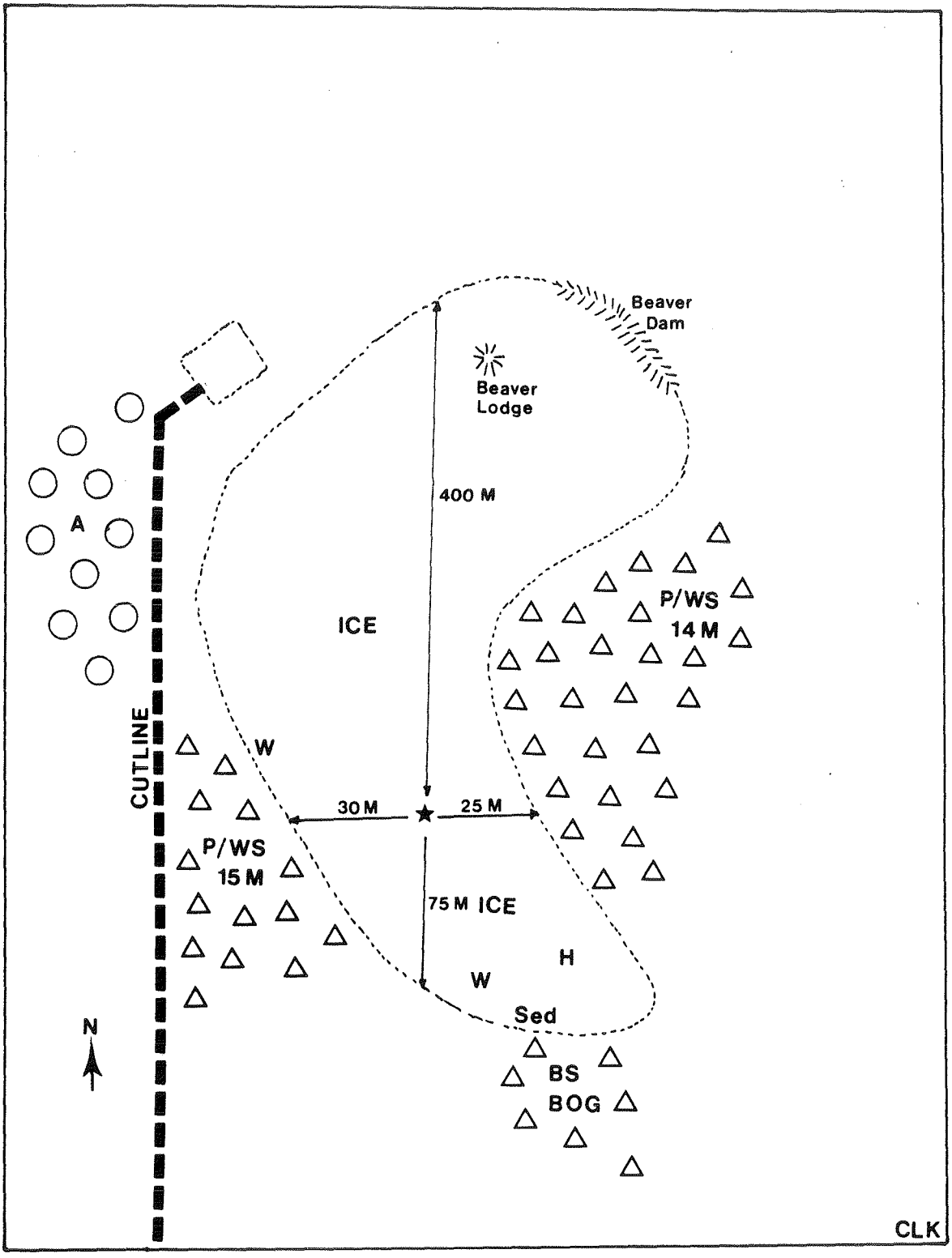

Figure 25: Site Diagram of CLK.

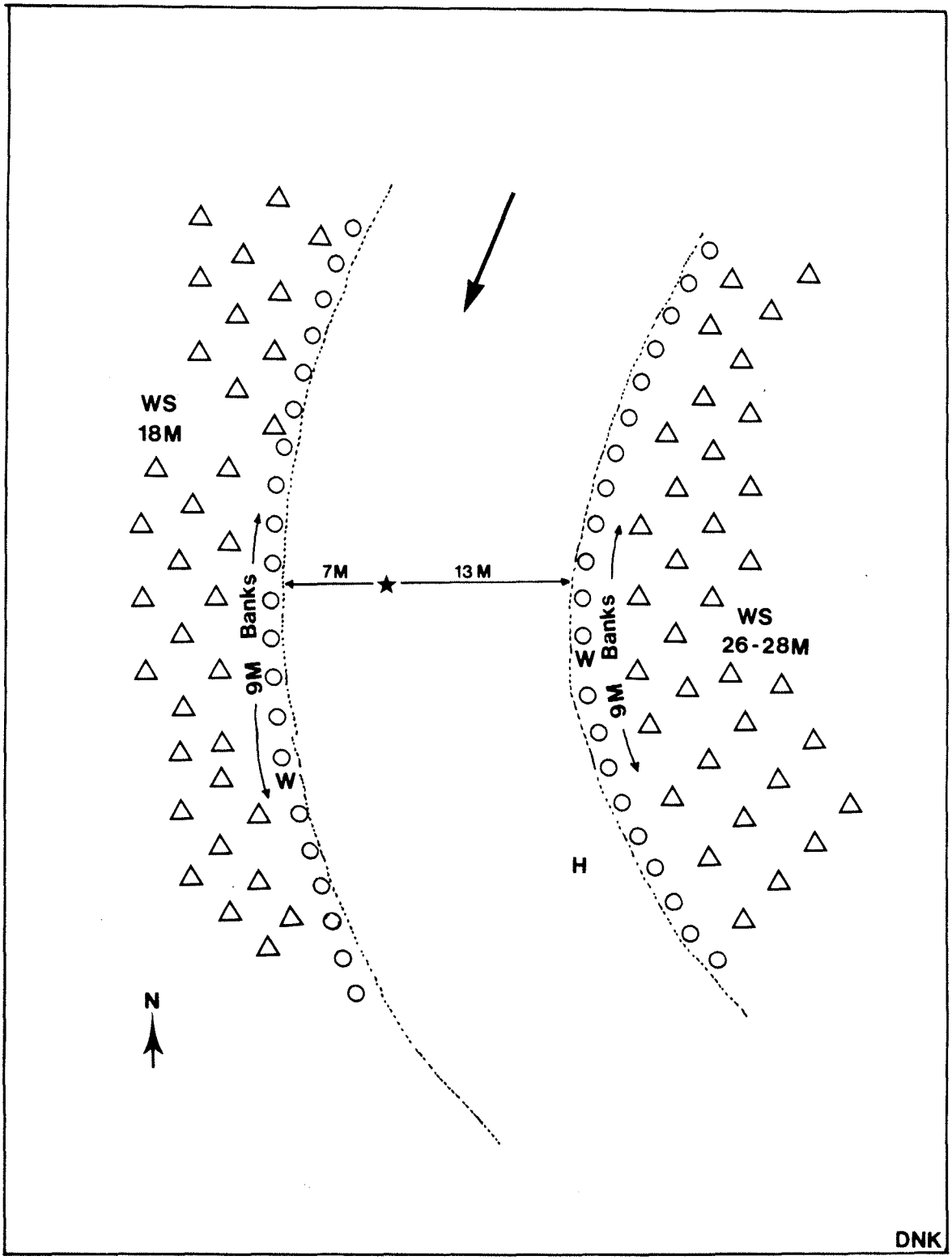

Figure 26: Site Diagram of DNK.

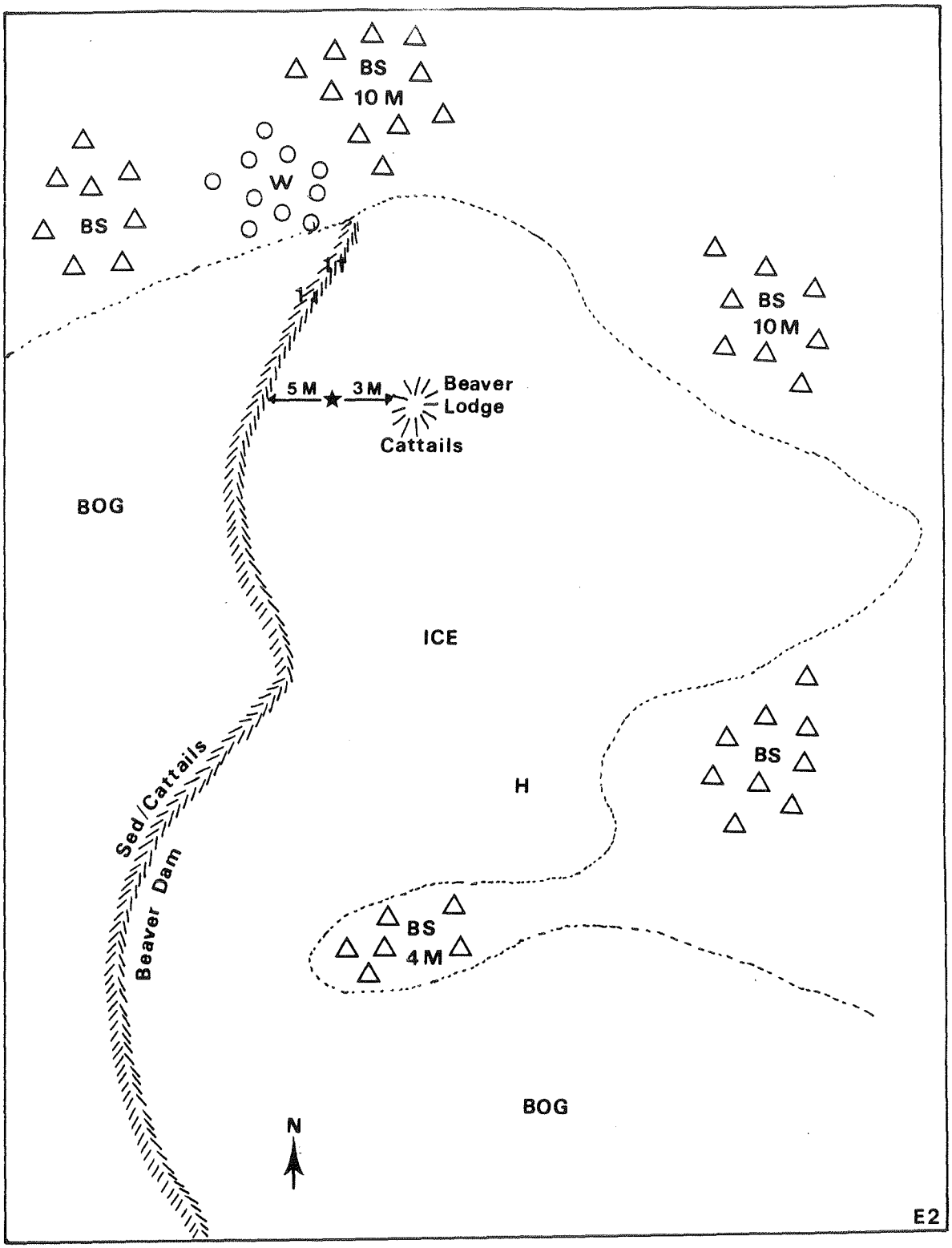

Figure 27: Site Diagram of E2.

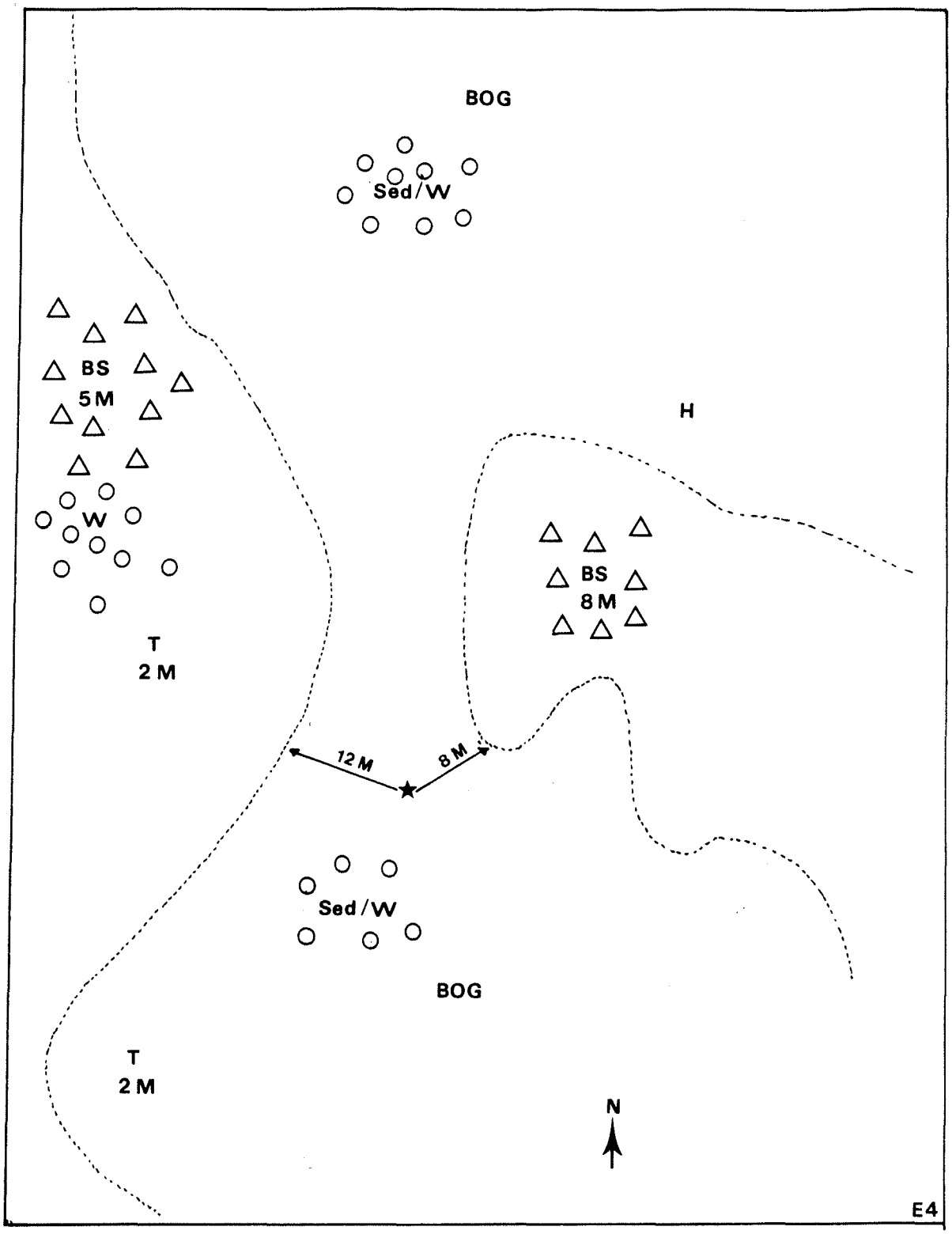

Figure 28: Site Diagram of E4.

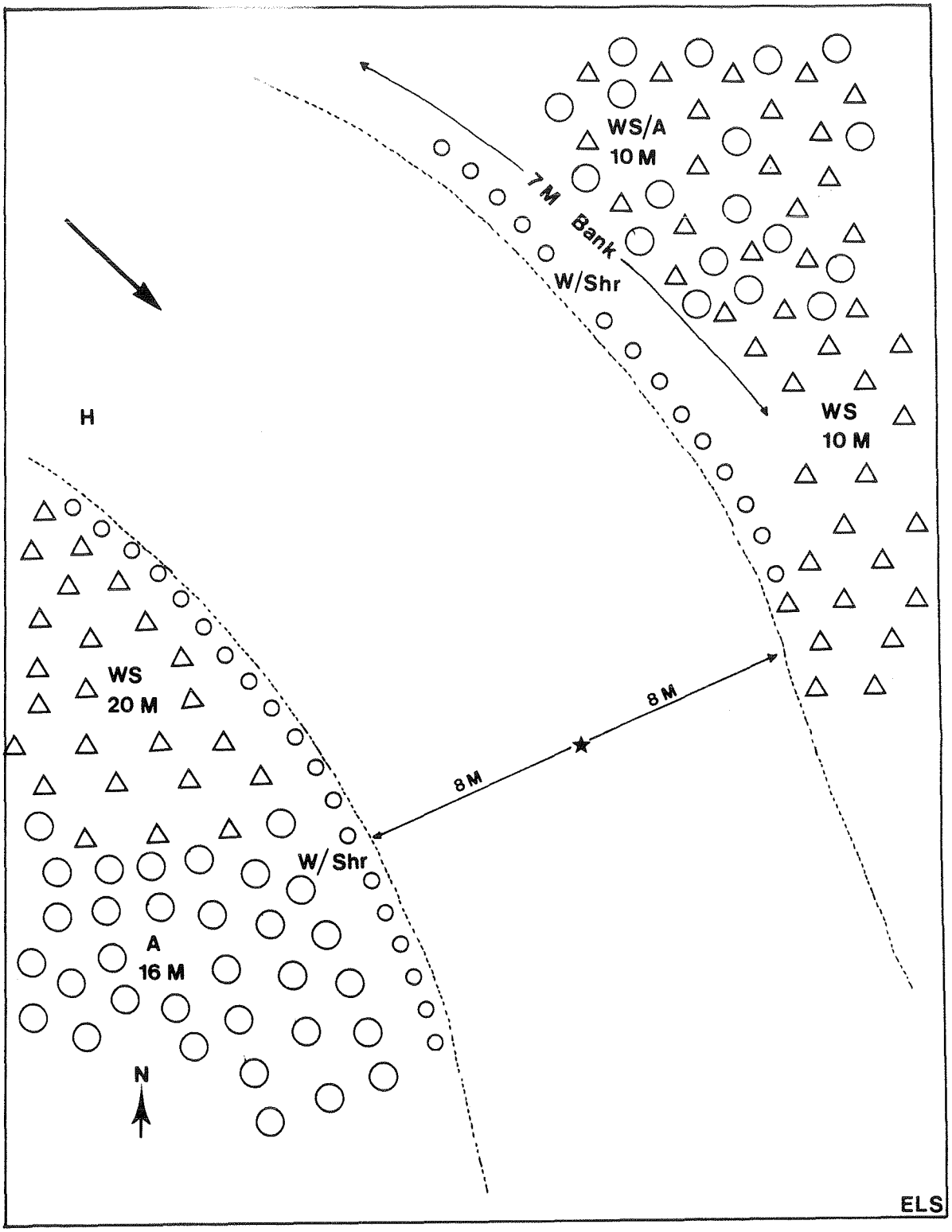

Figure 29: Site Diagram of ELS.

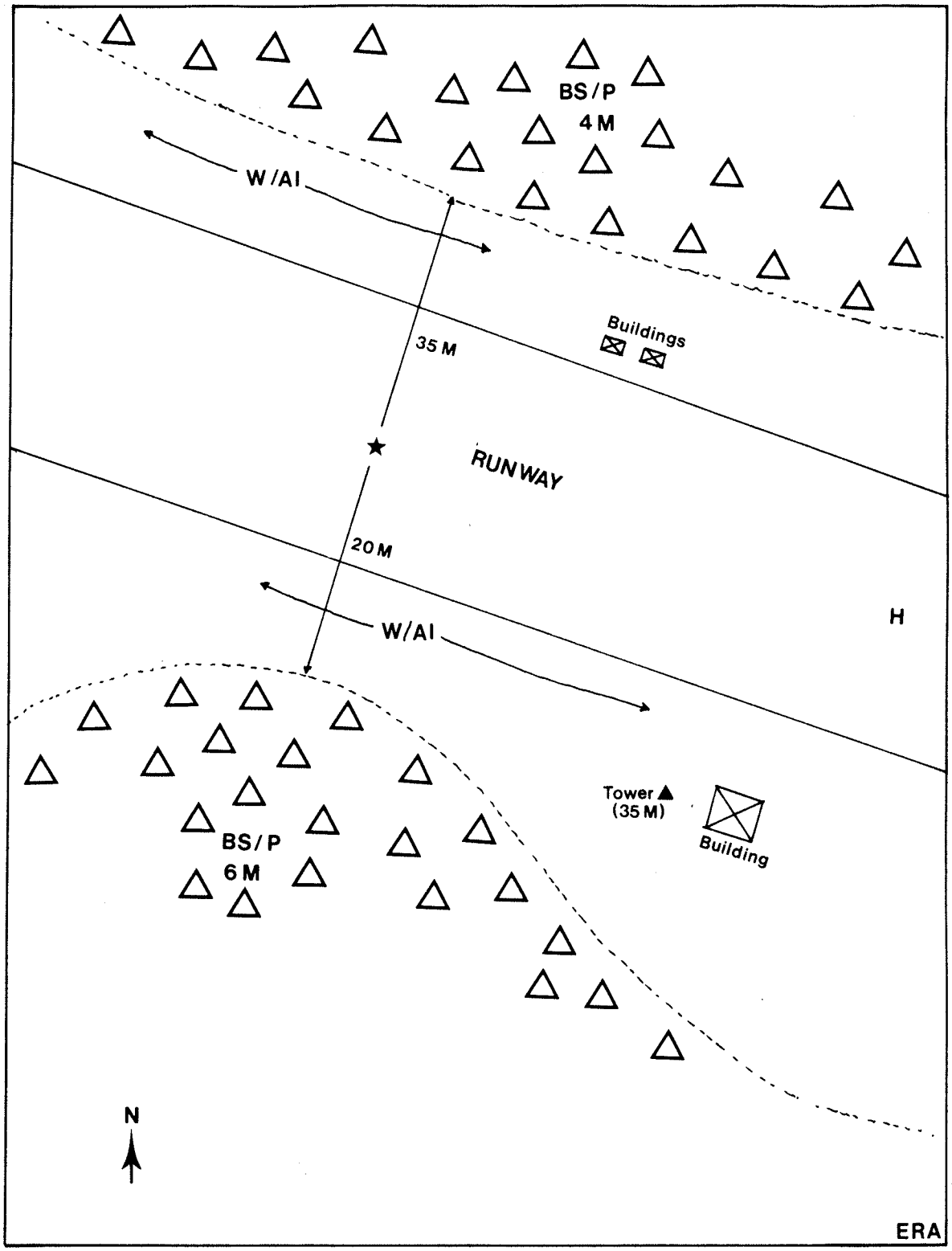

Figure 30: Site Diagram of ERA.

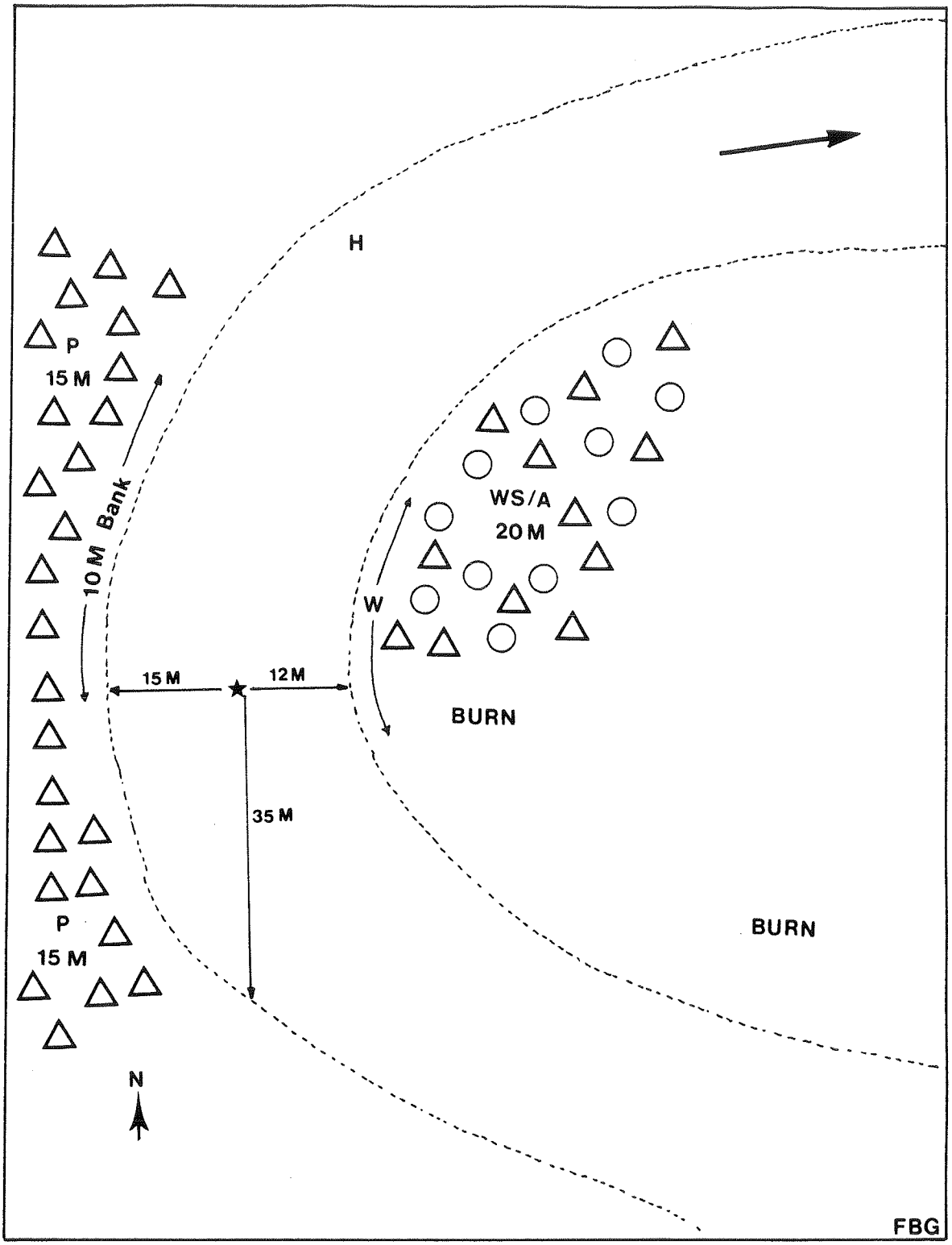

Figure 31: Site Diagram of FBG.

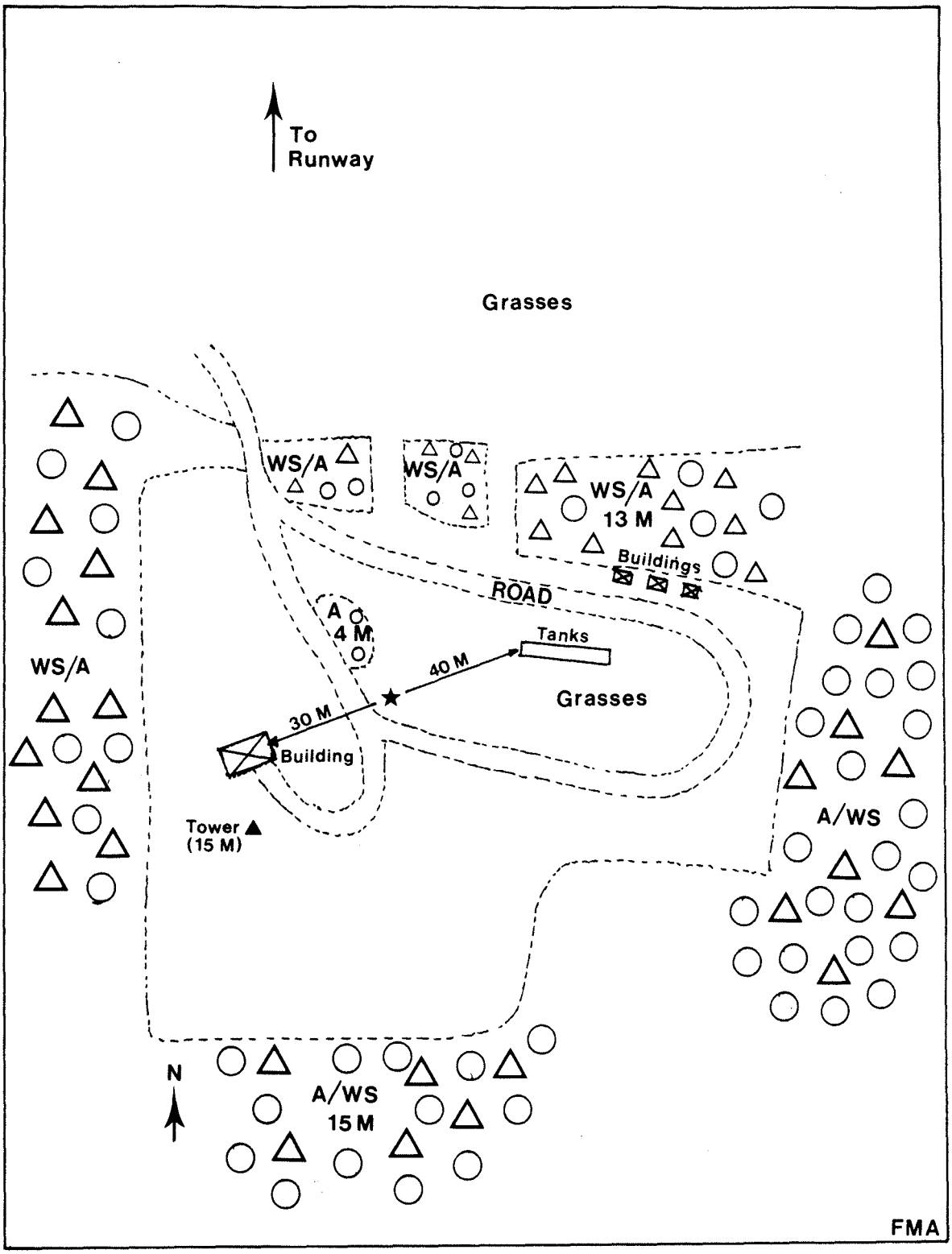

Figure 32: Site Diagram of FMA.

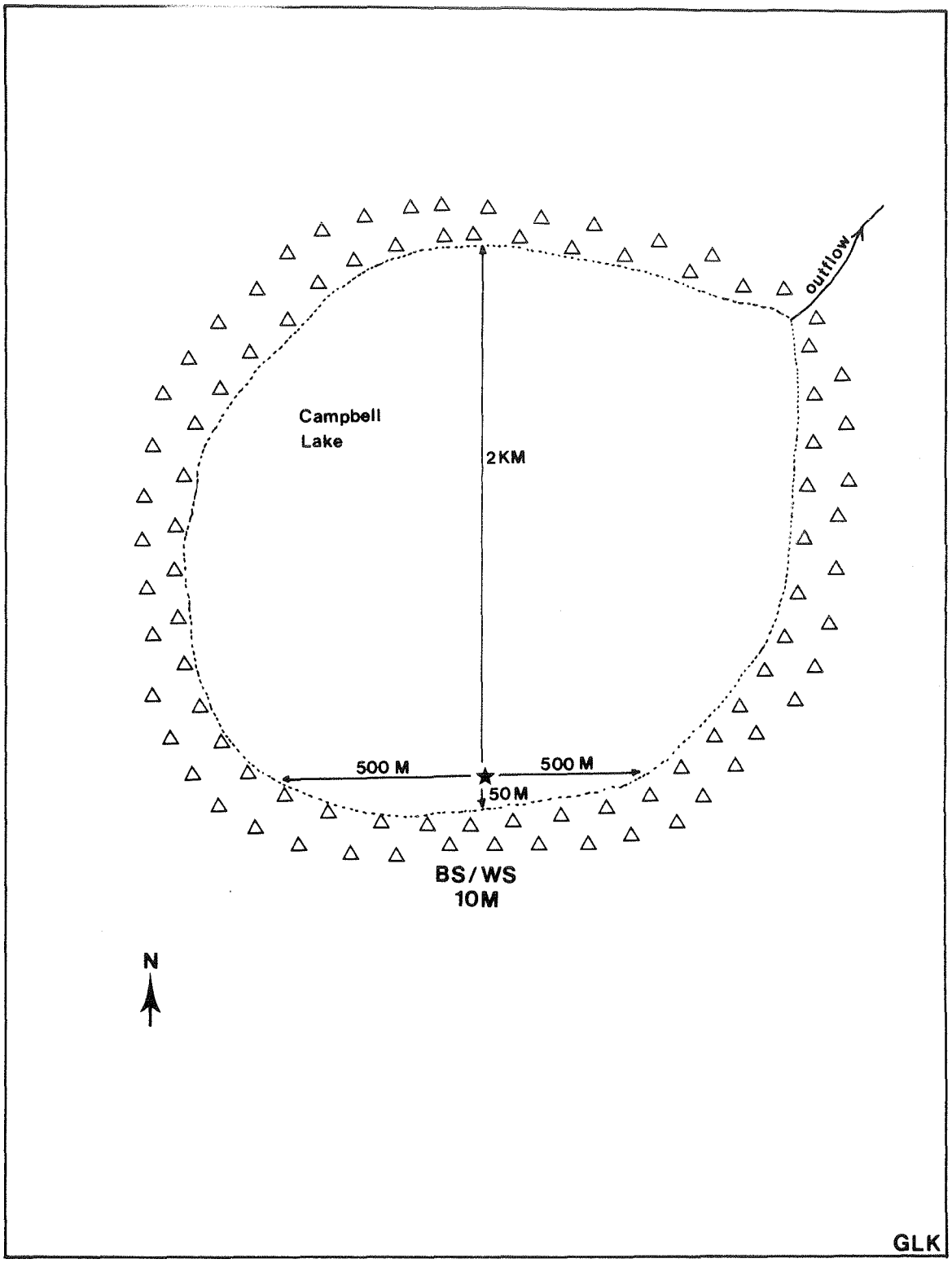

Figure 33: Site Diagram of GLK.

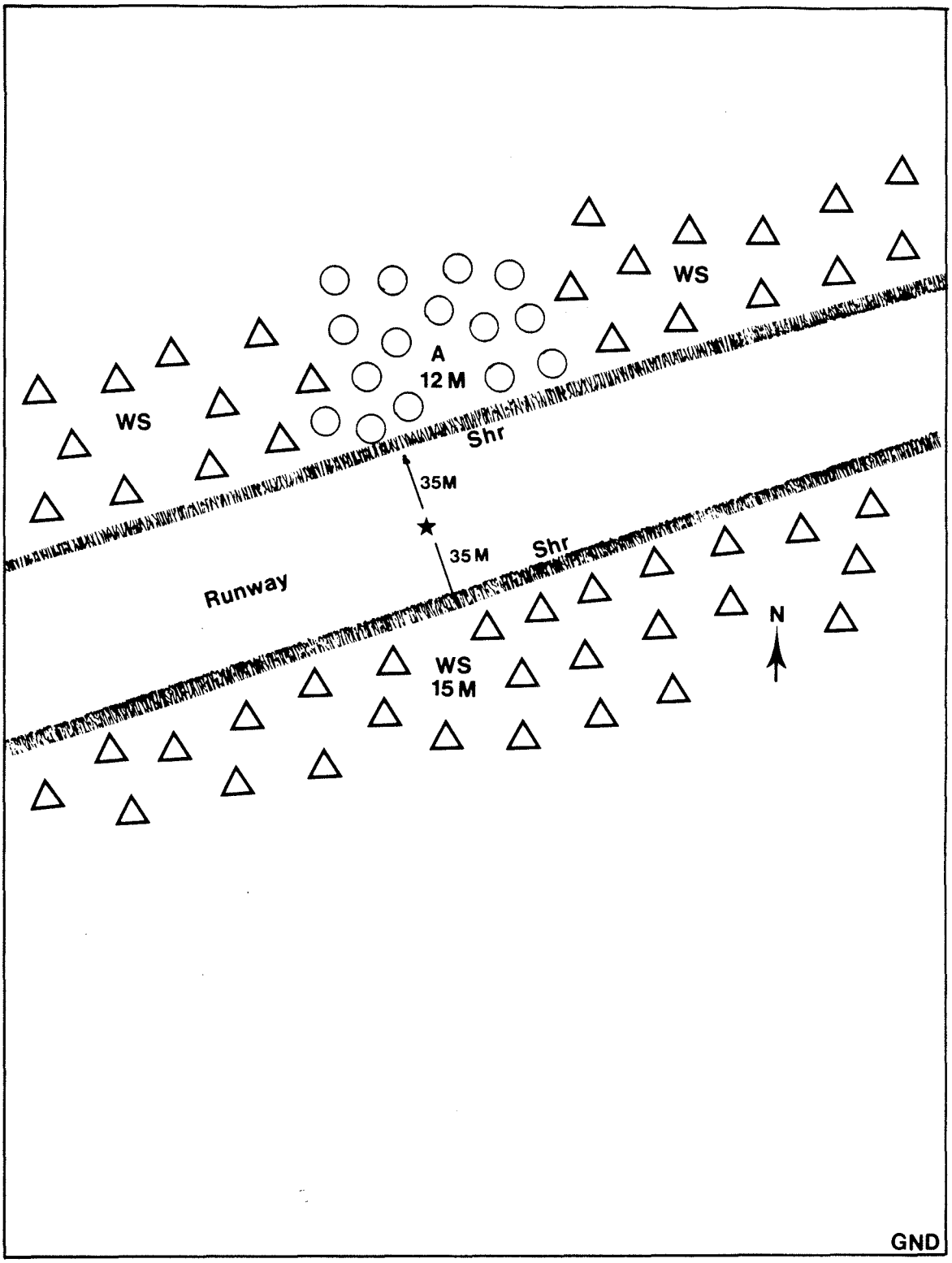

Figure 34: Site Diagram of GND.

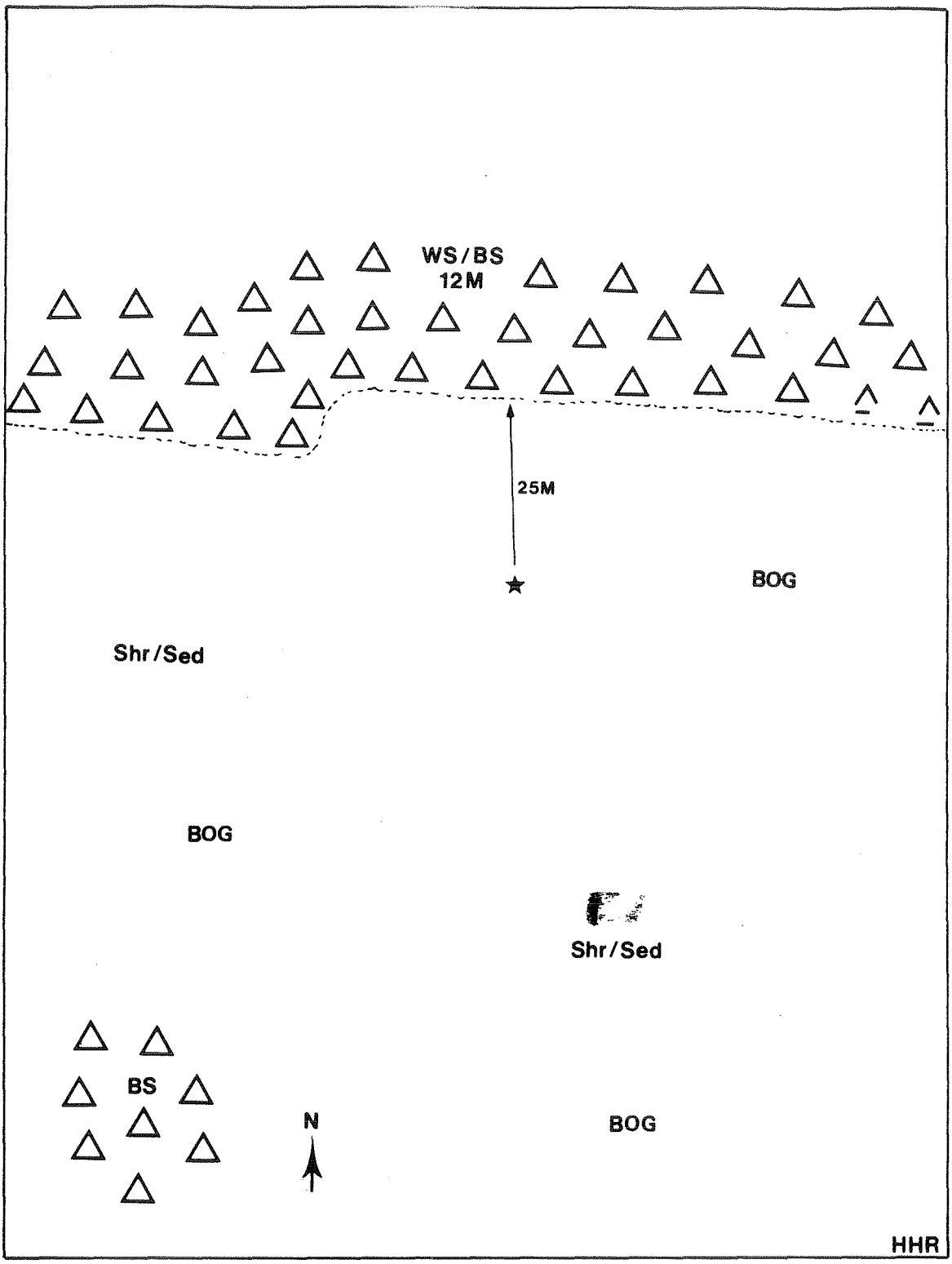

Figure 35: Site Diagram of HHR.

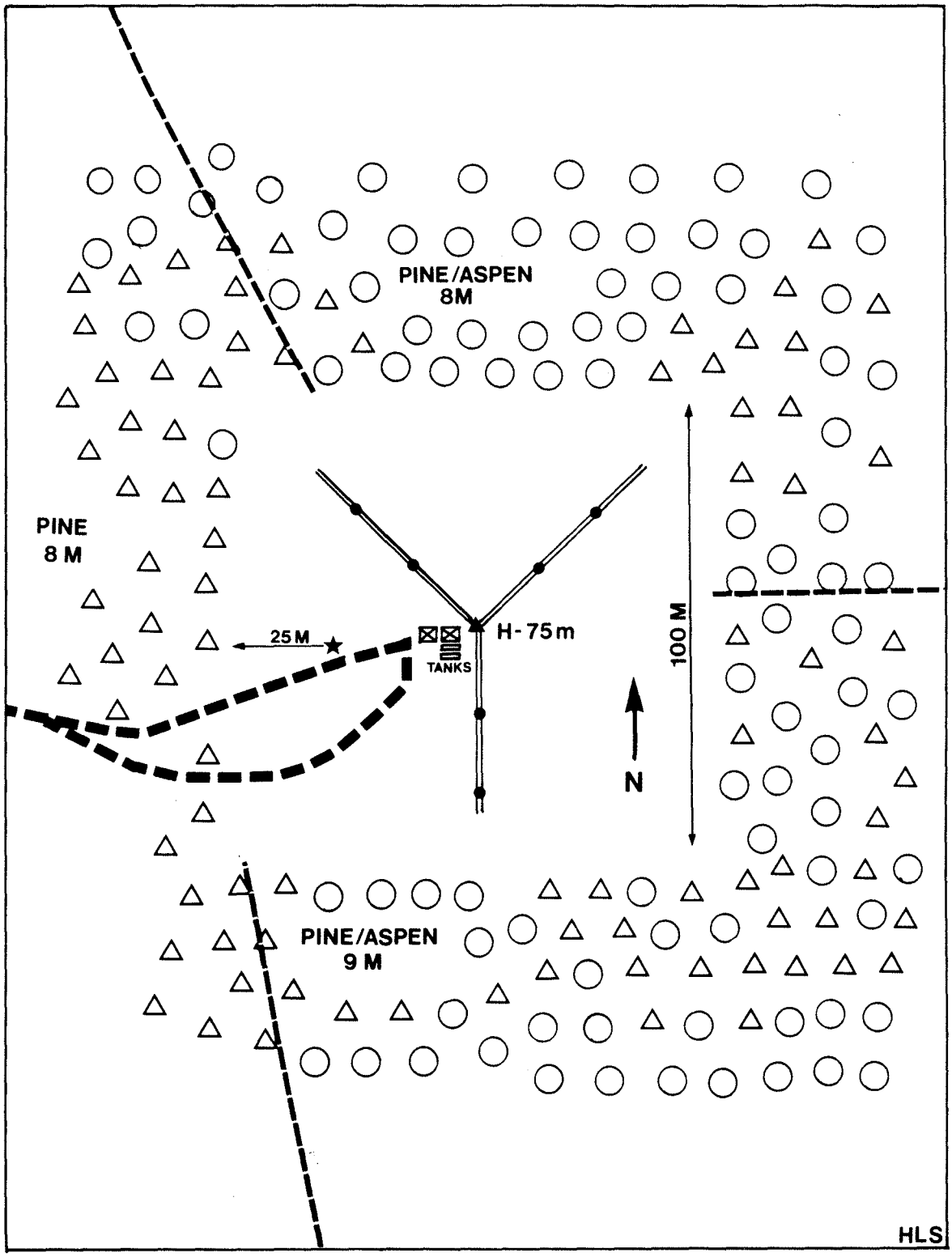

Figure 36: Site Diagram of HLS.

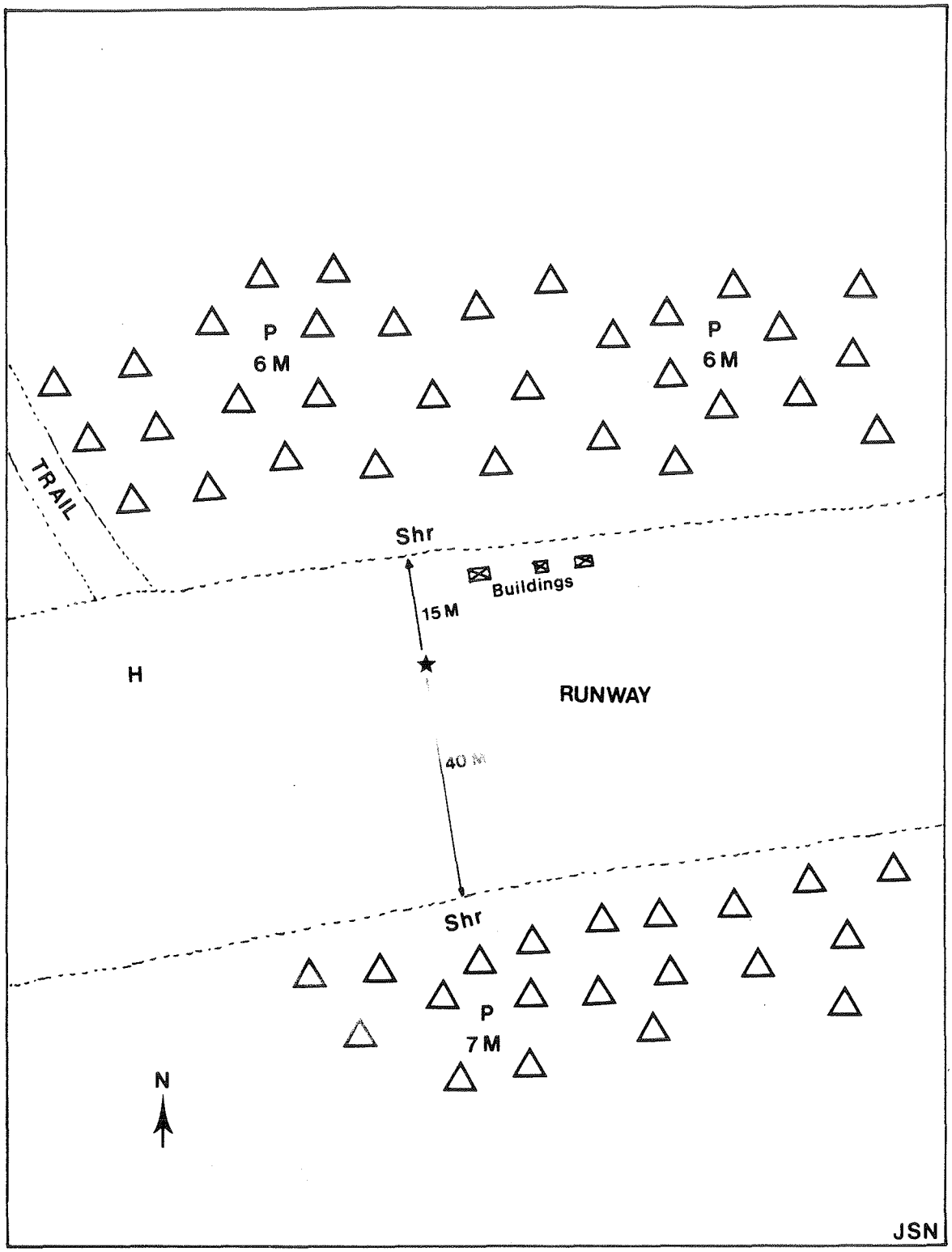

Figure 37: Site Diagram of JSN.

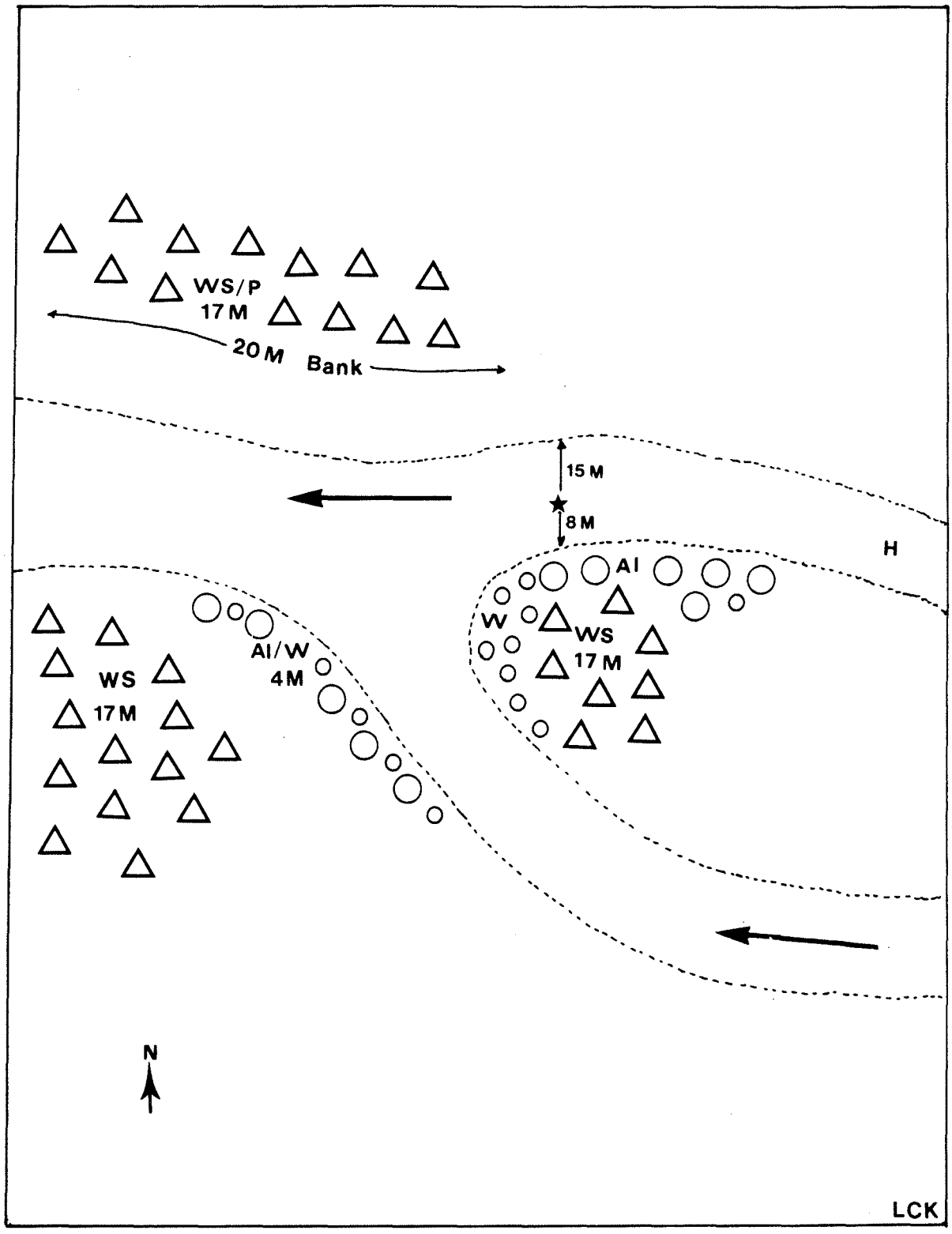

Figure 38: Site Diagram of LCK.

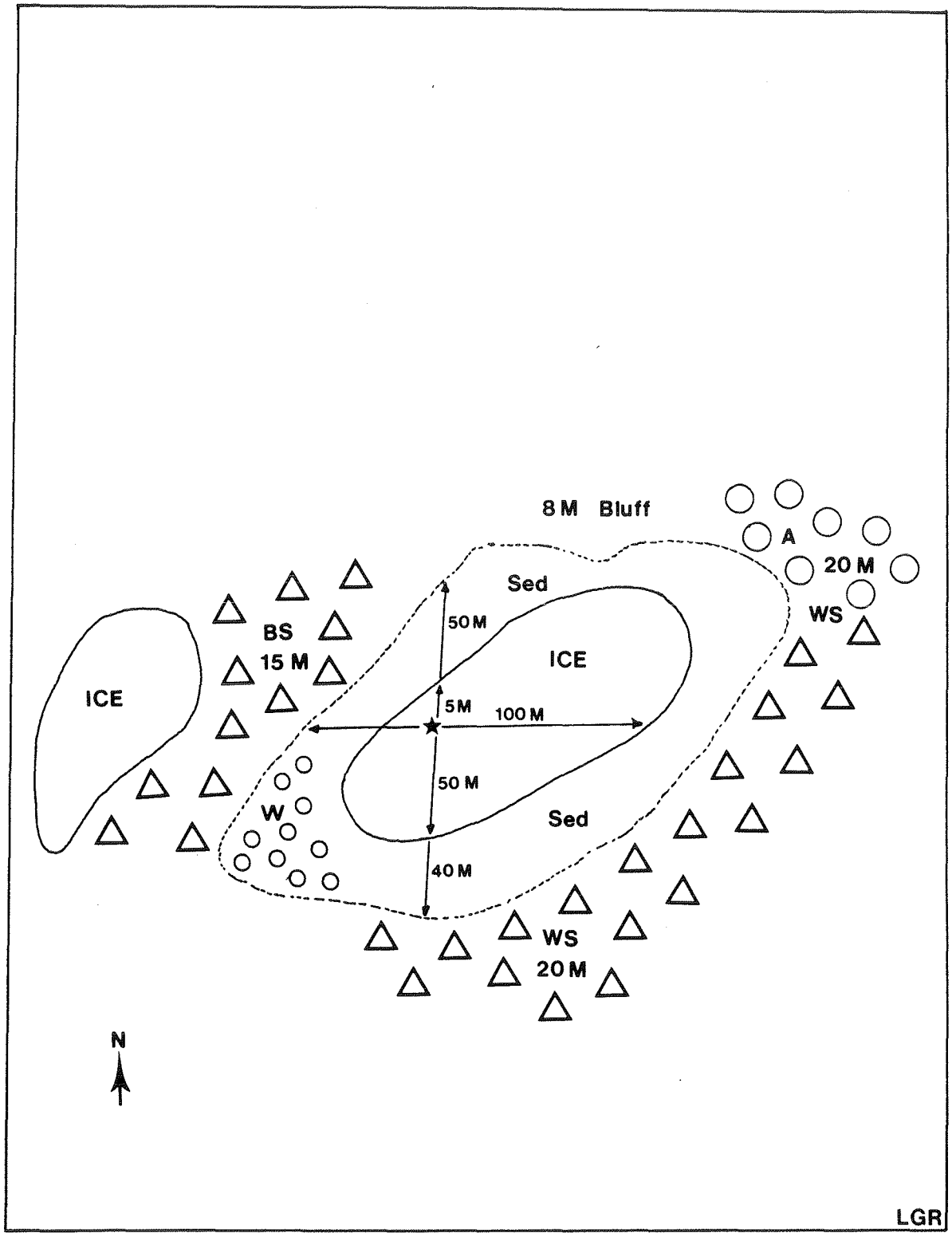

Figure 39: Site Diagram of LGR.

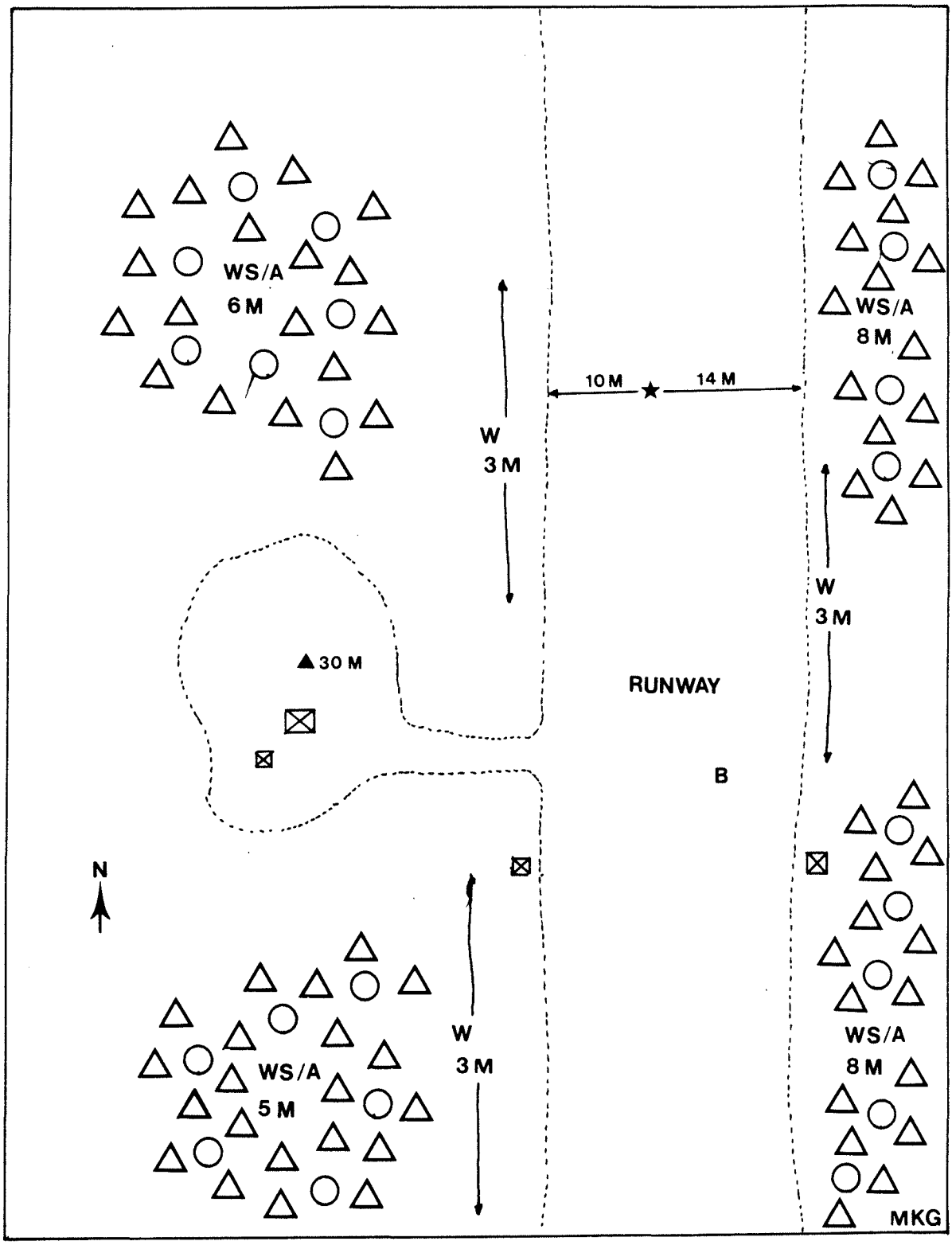

Figure 40: Site Diagram of MKG.

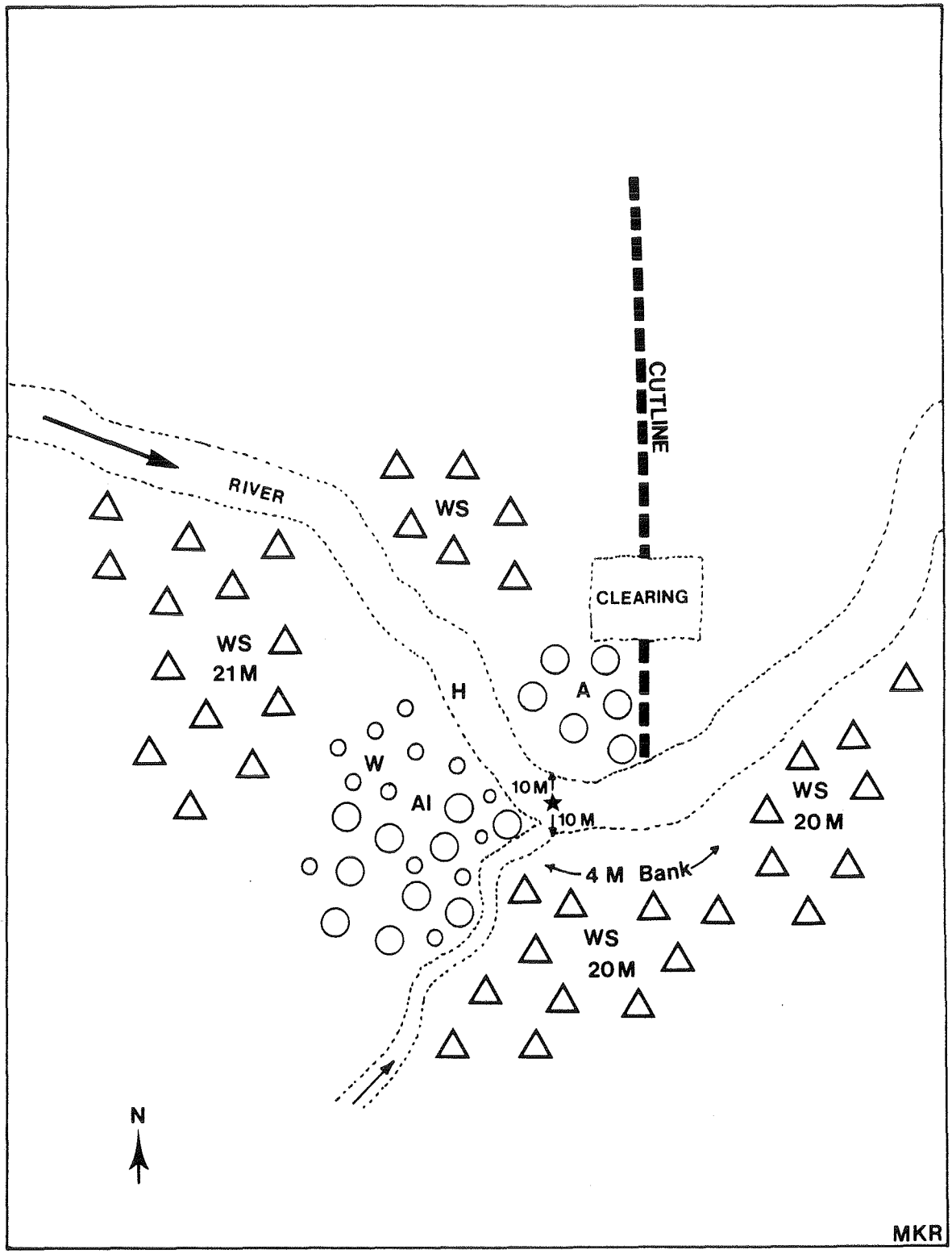

Figure 41: Site Diagram of MKR.

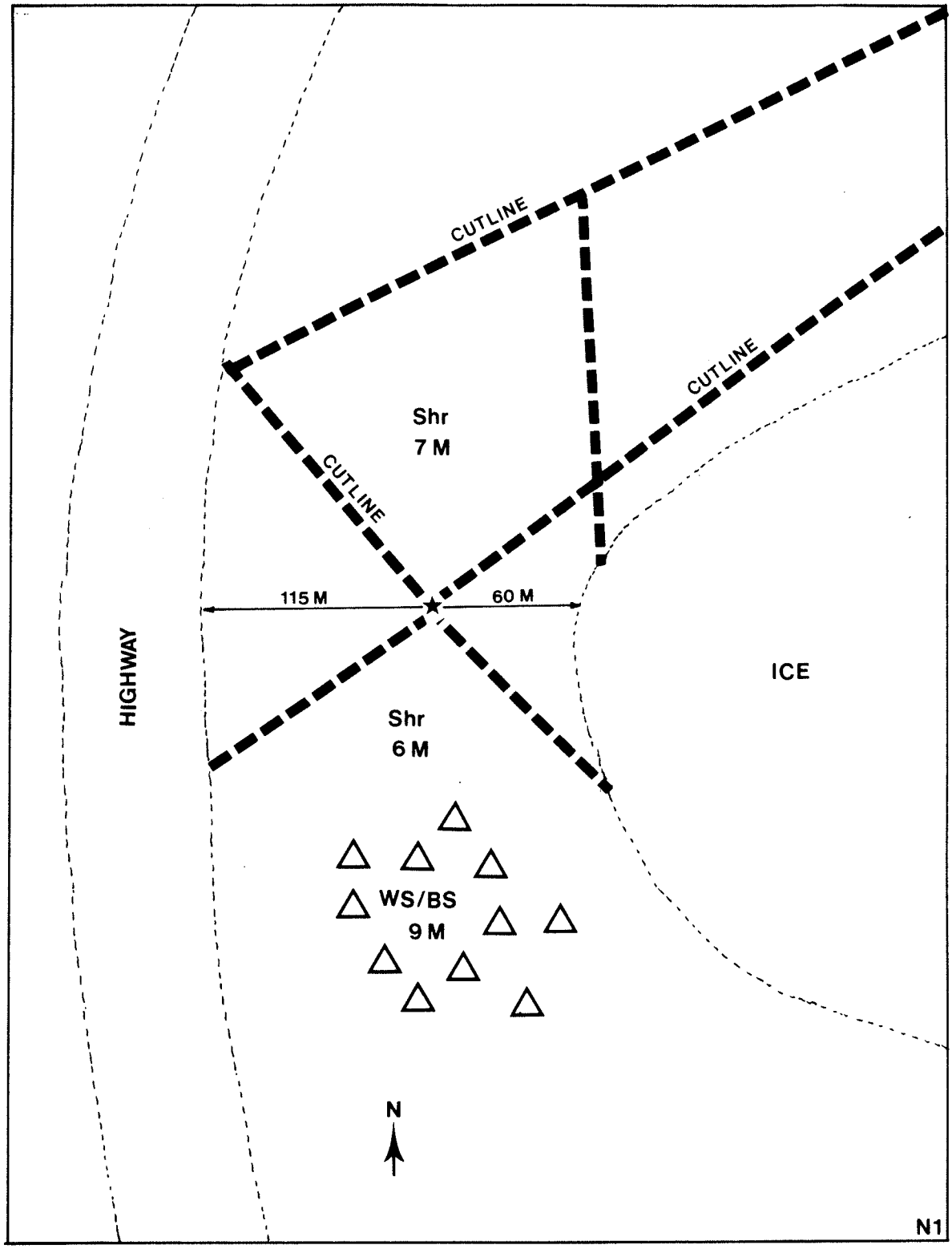

Figure 42: Site Diagram of N1.

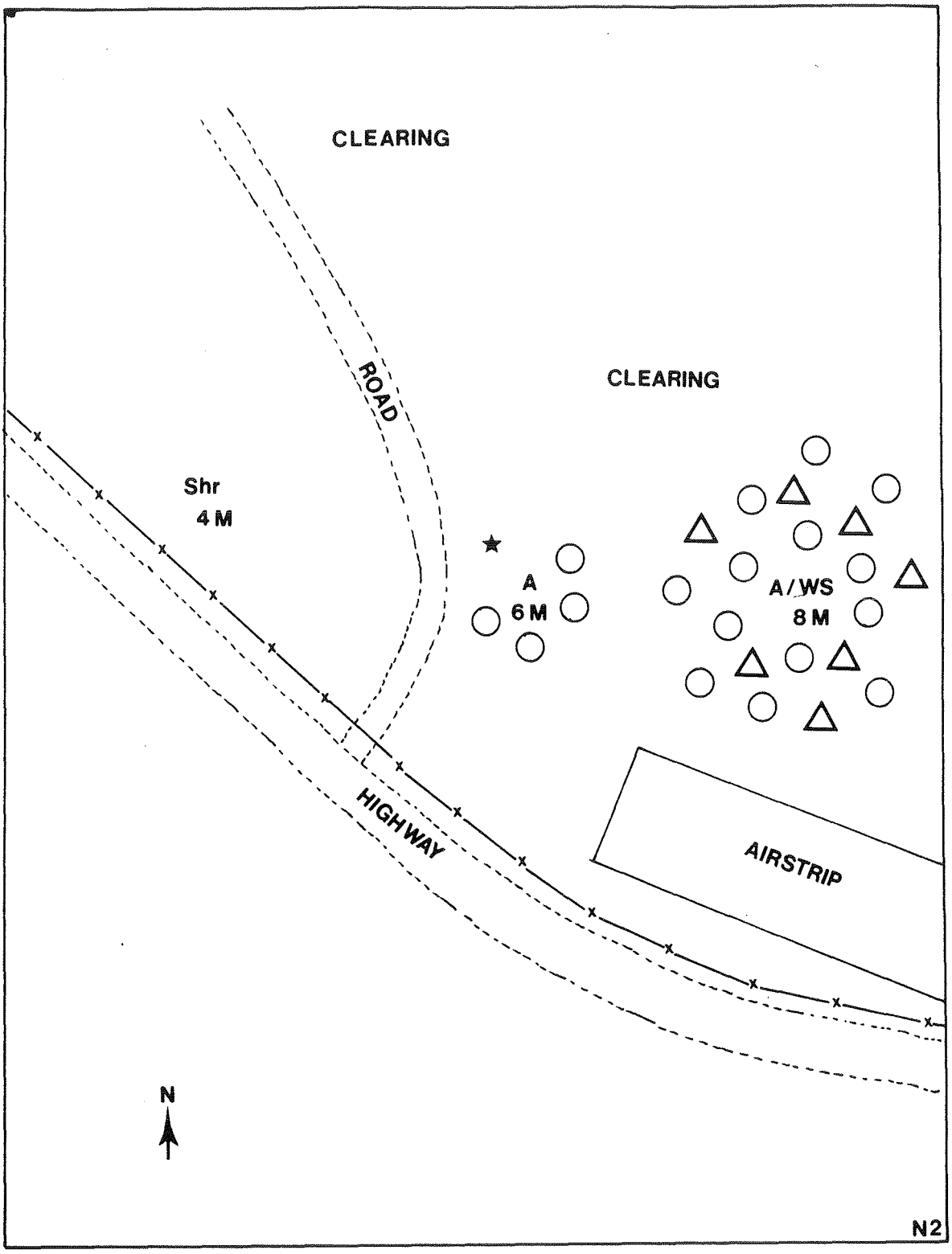

Figure 43: Site Diagram of N2.

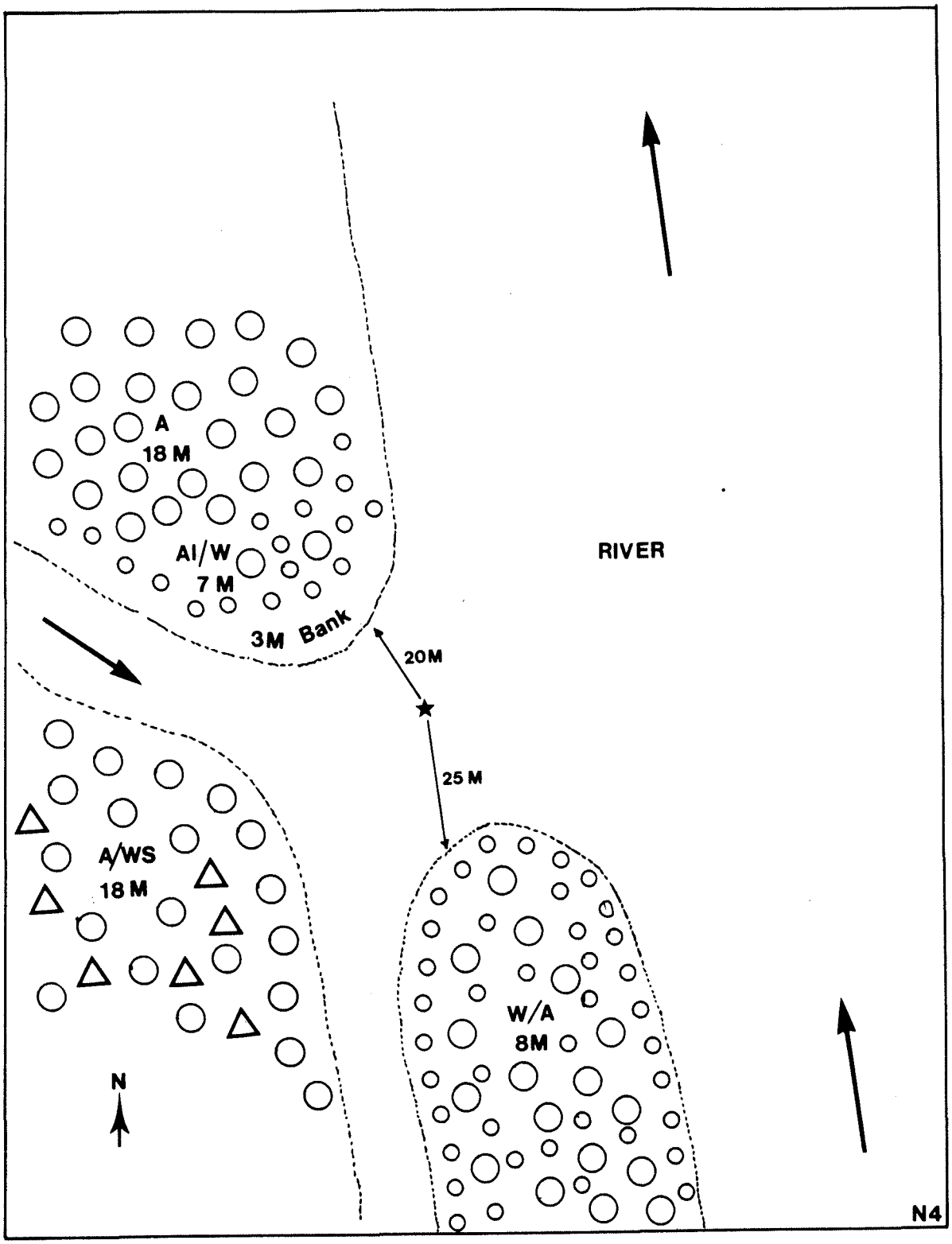

Figure 44: Site Diagram of N4.

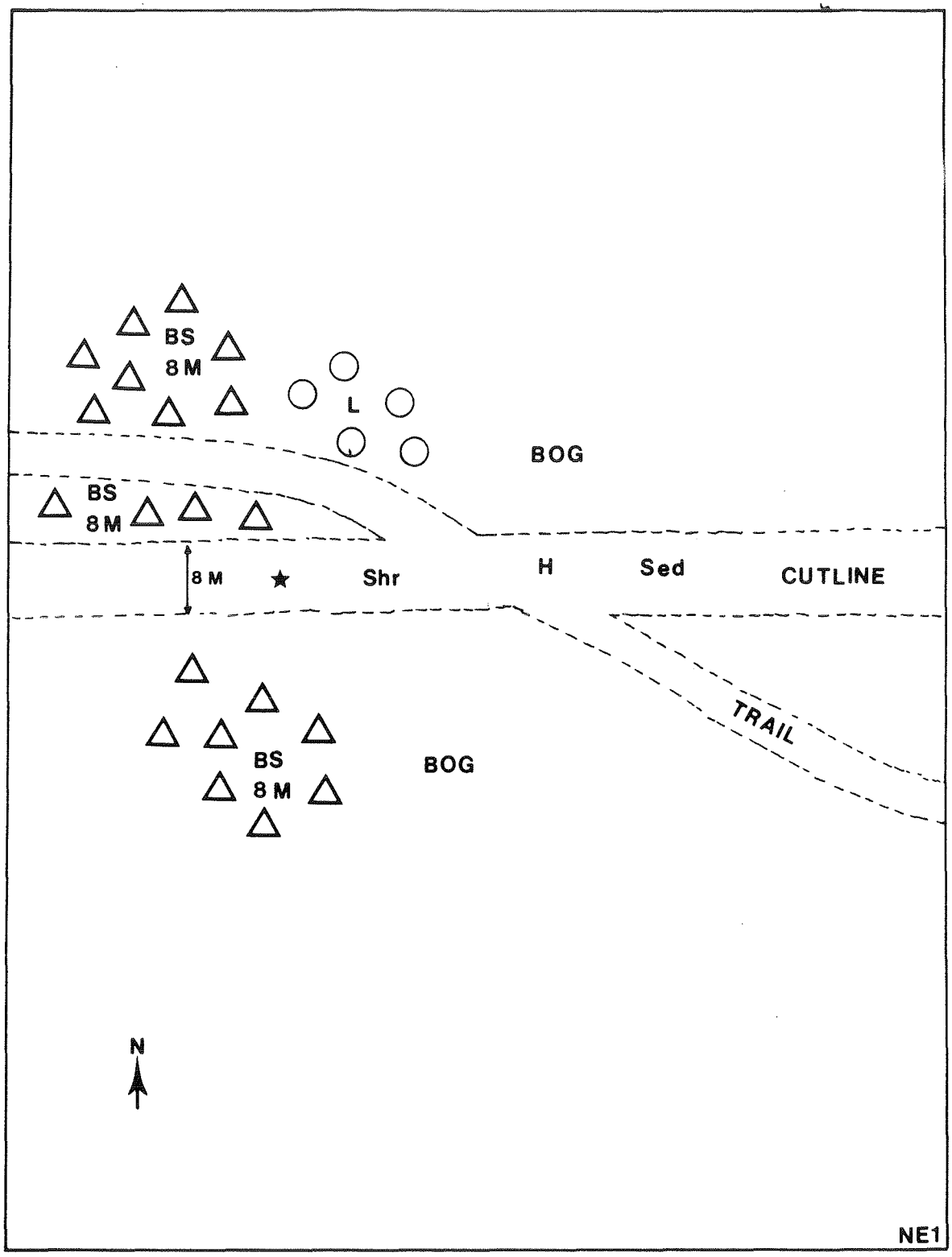

Figure 45: Site Diagram of NE1.

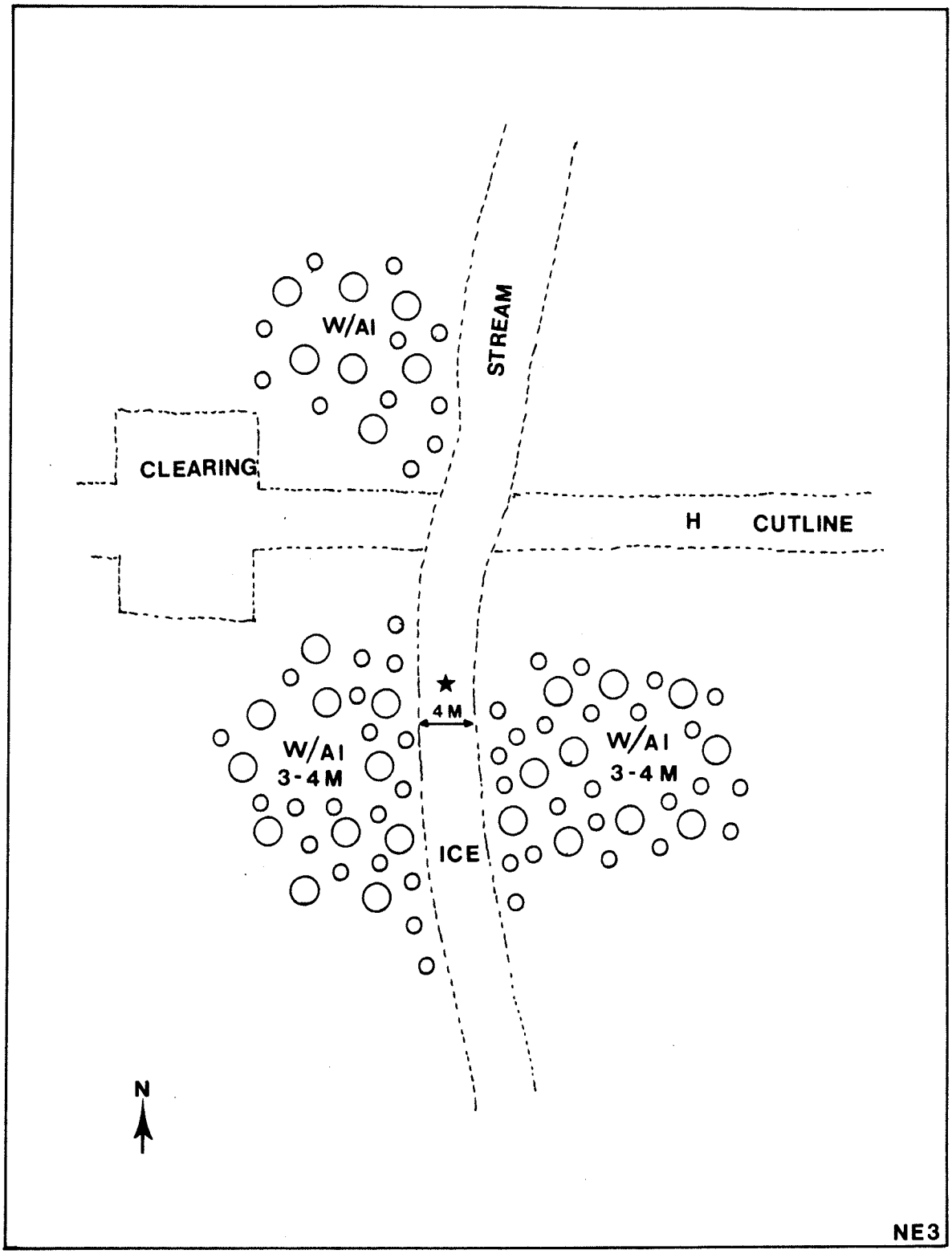

Figure 46: Site Diagram of NE3.

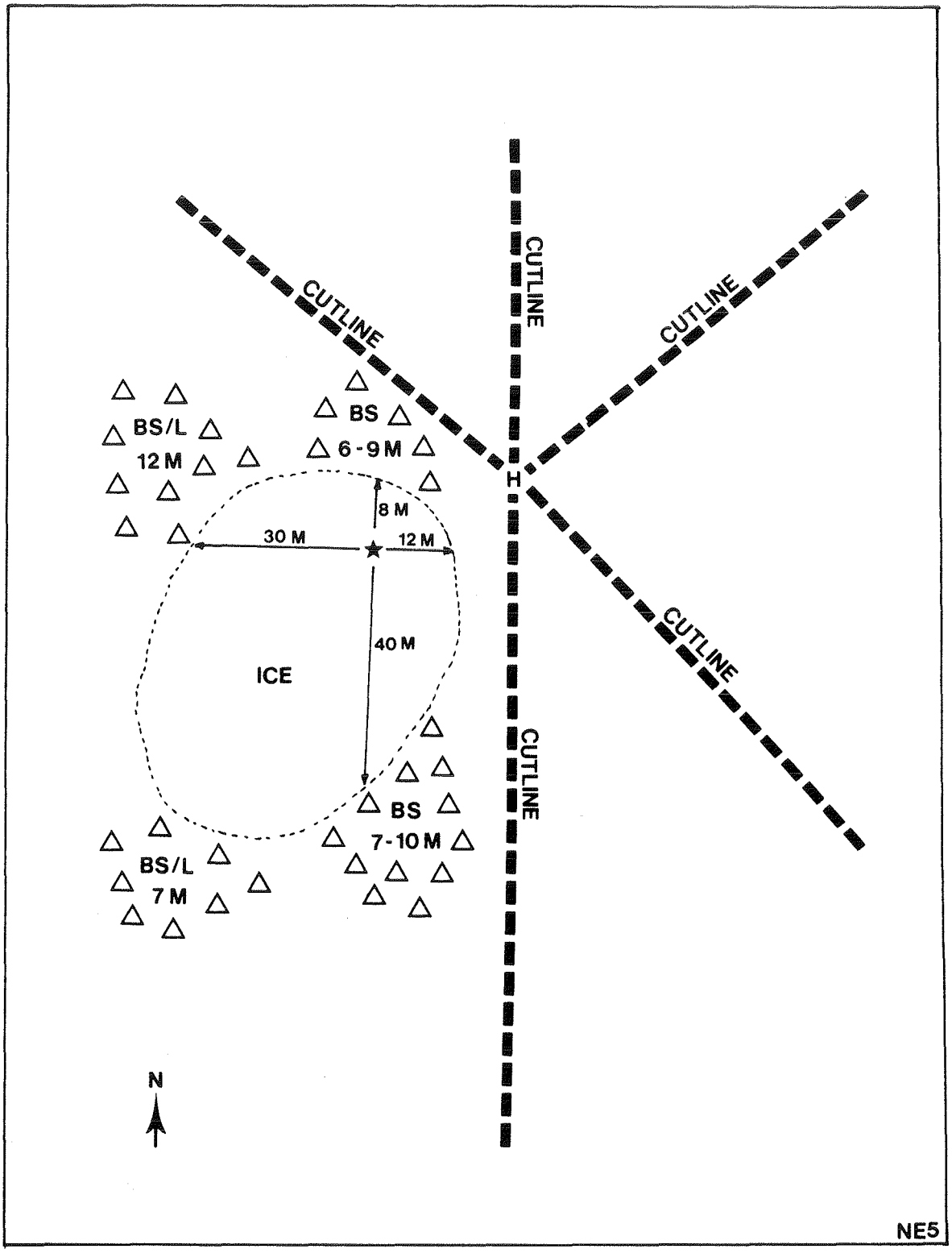

Figure 47: Site Diagram of NE5.

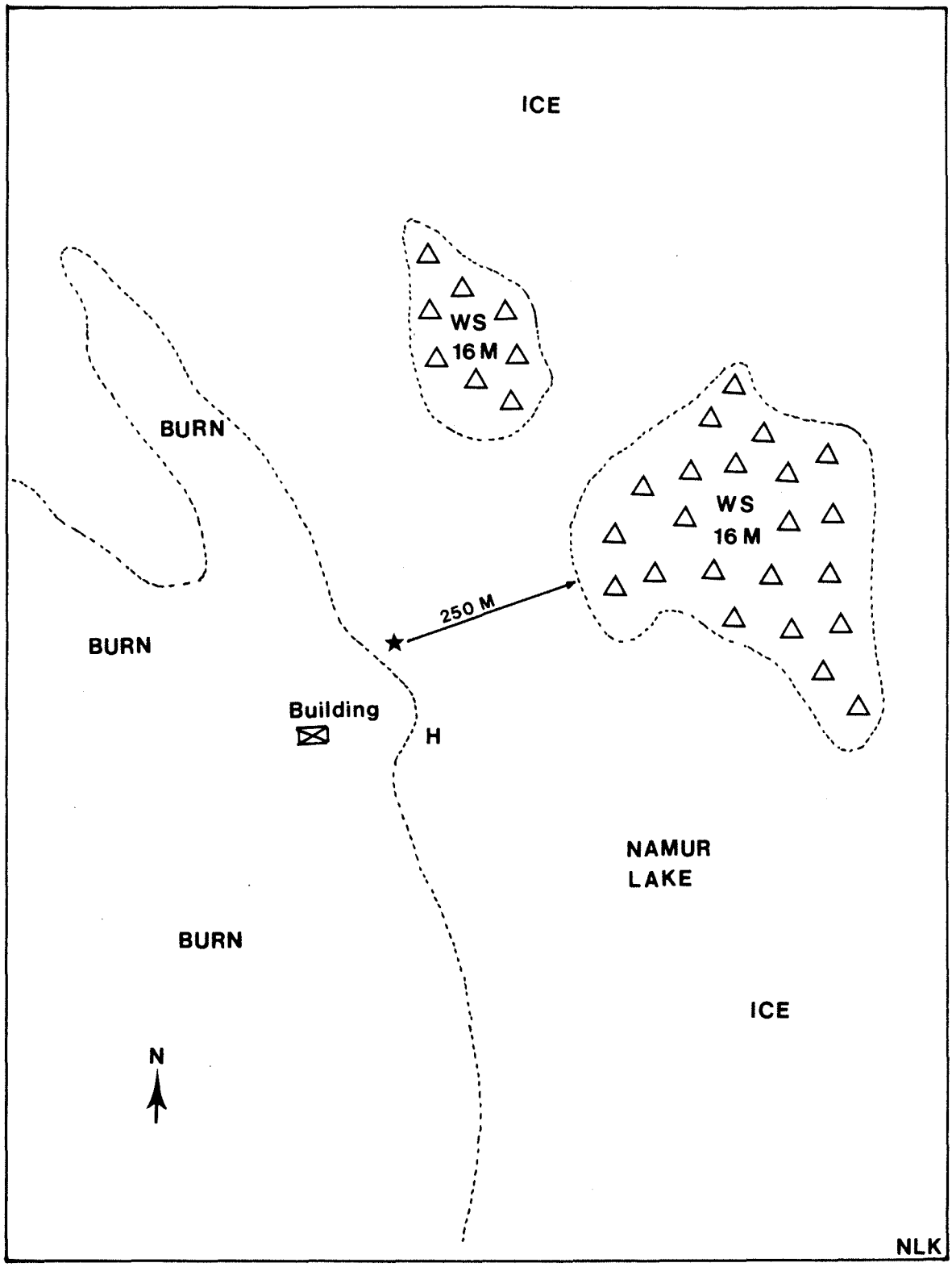

Figure 48: Site Diagram of NLK.

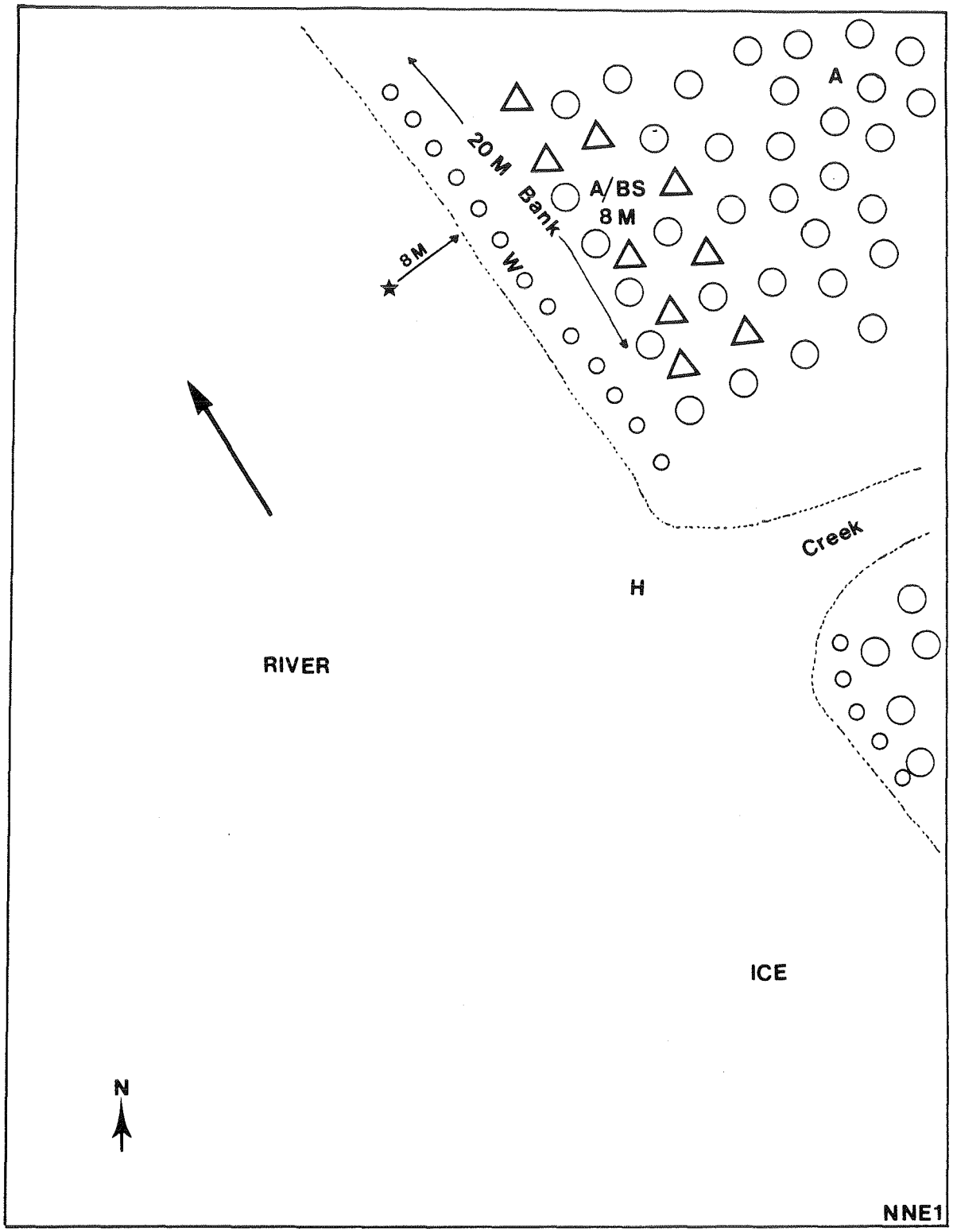

Figure 49: Site Diagram of NNE1.

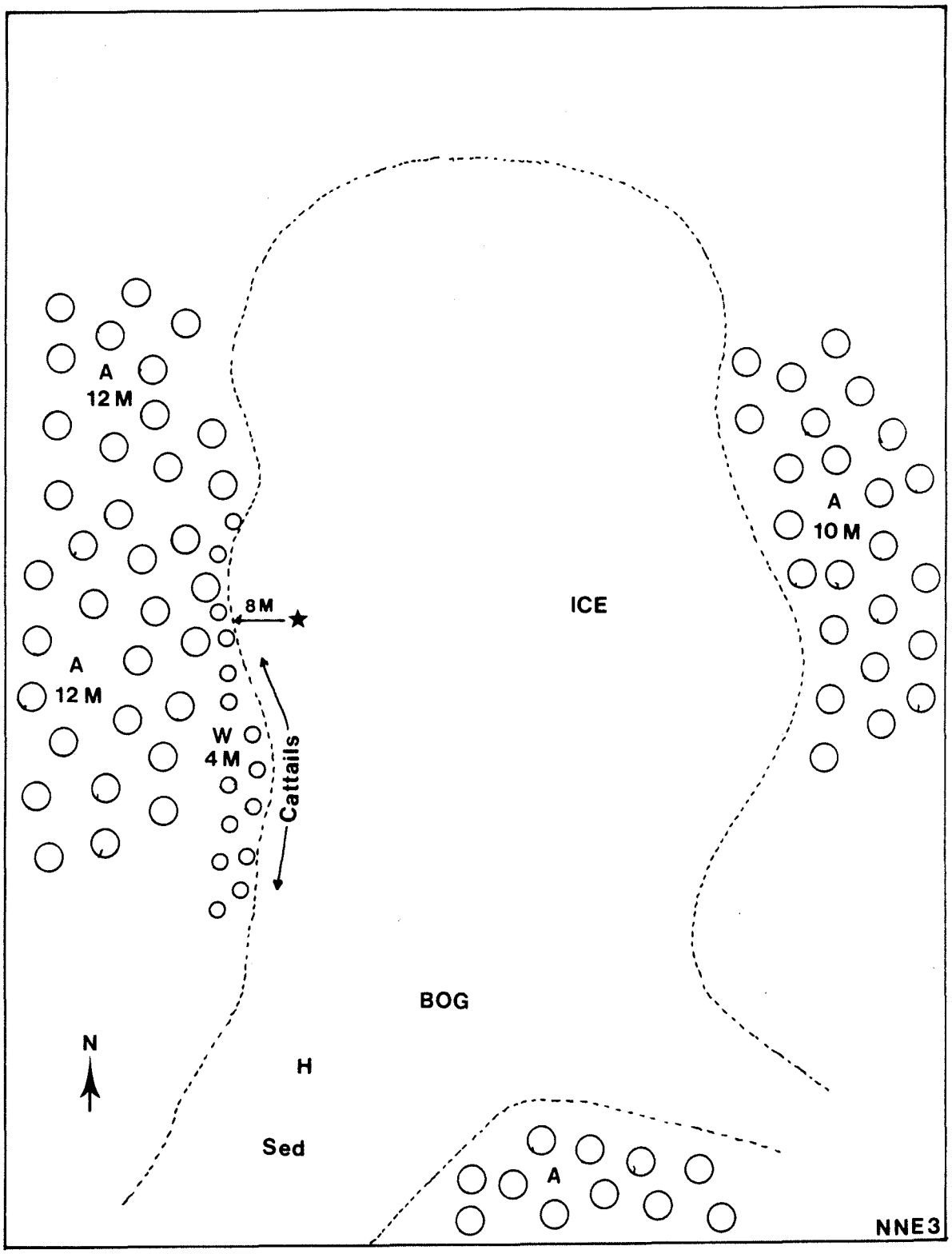

Figure 50: Site Diagram of NNE3.

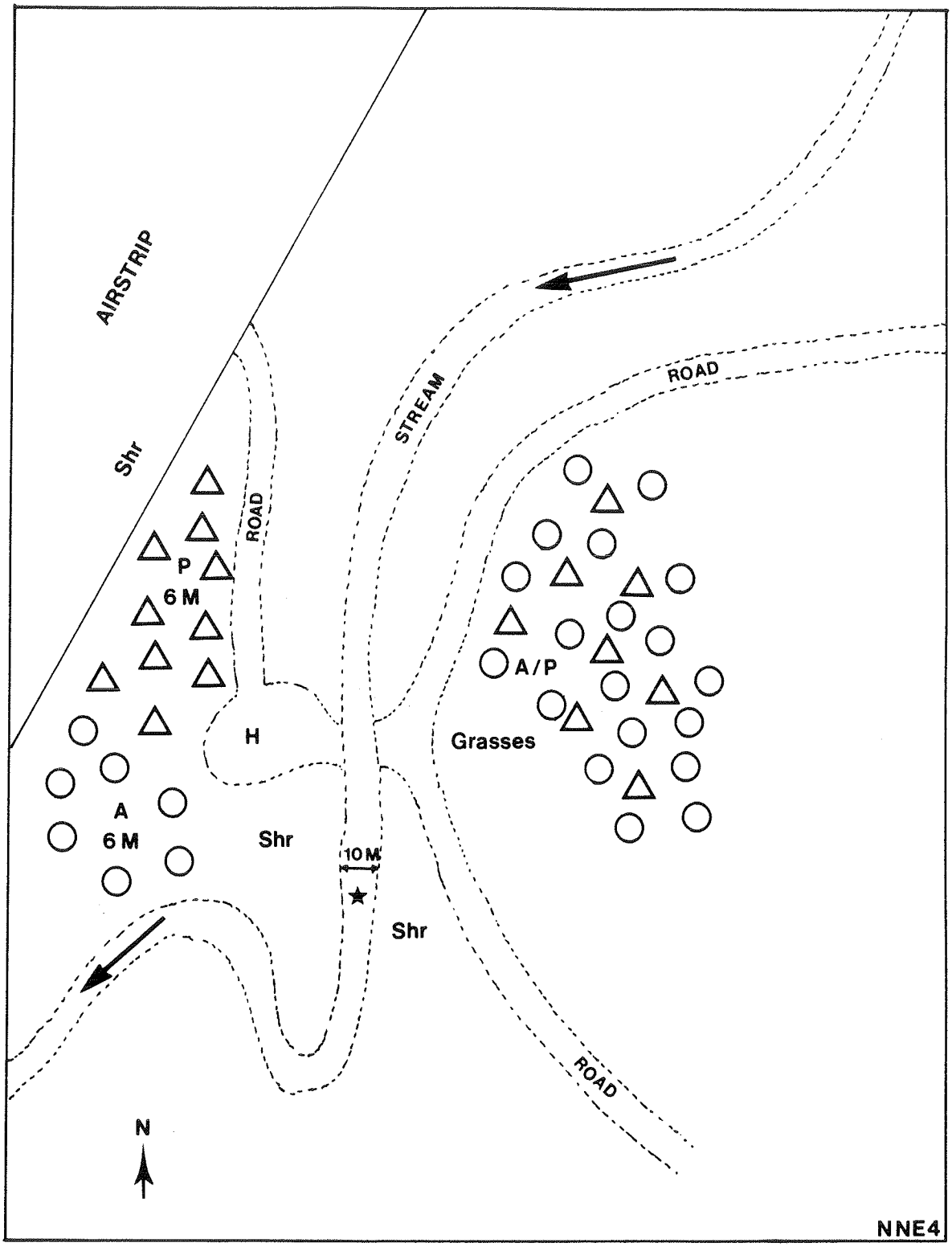

Figure 51: Site Diagram of NNE4.

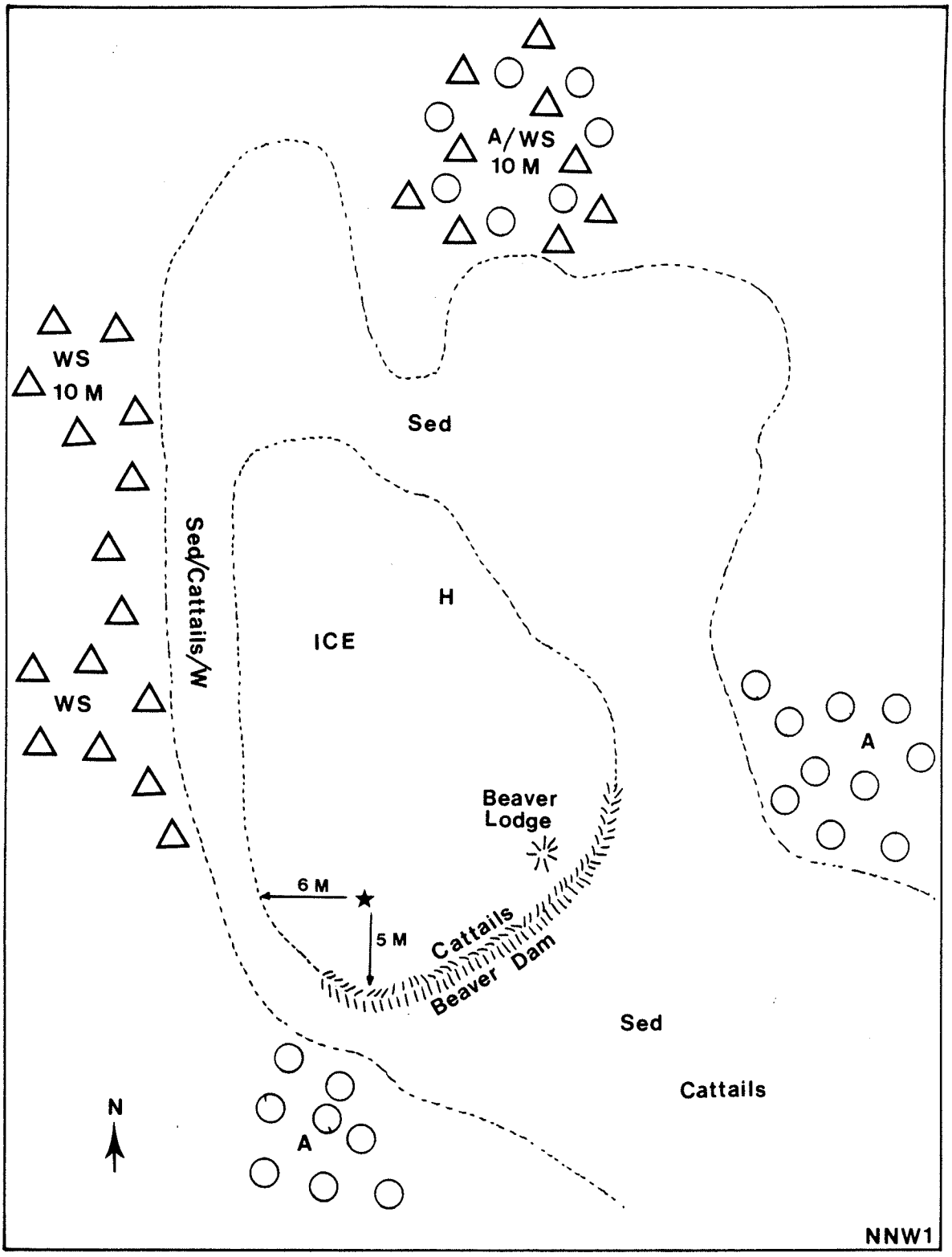

Figure 52: Site Diagram of NNW1.

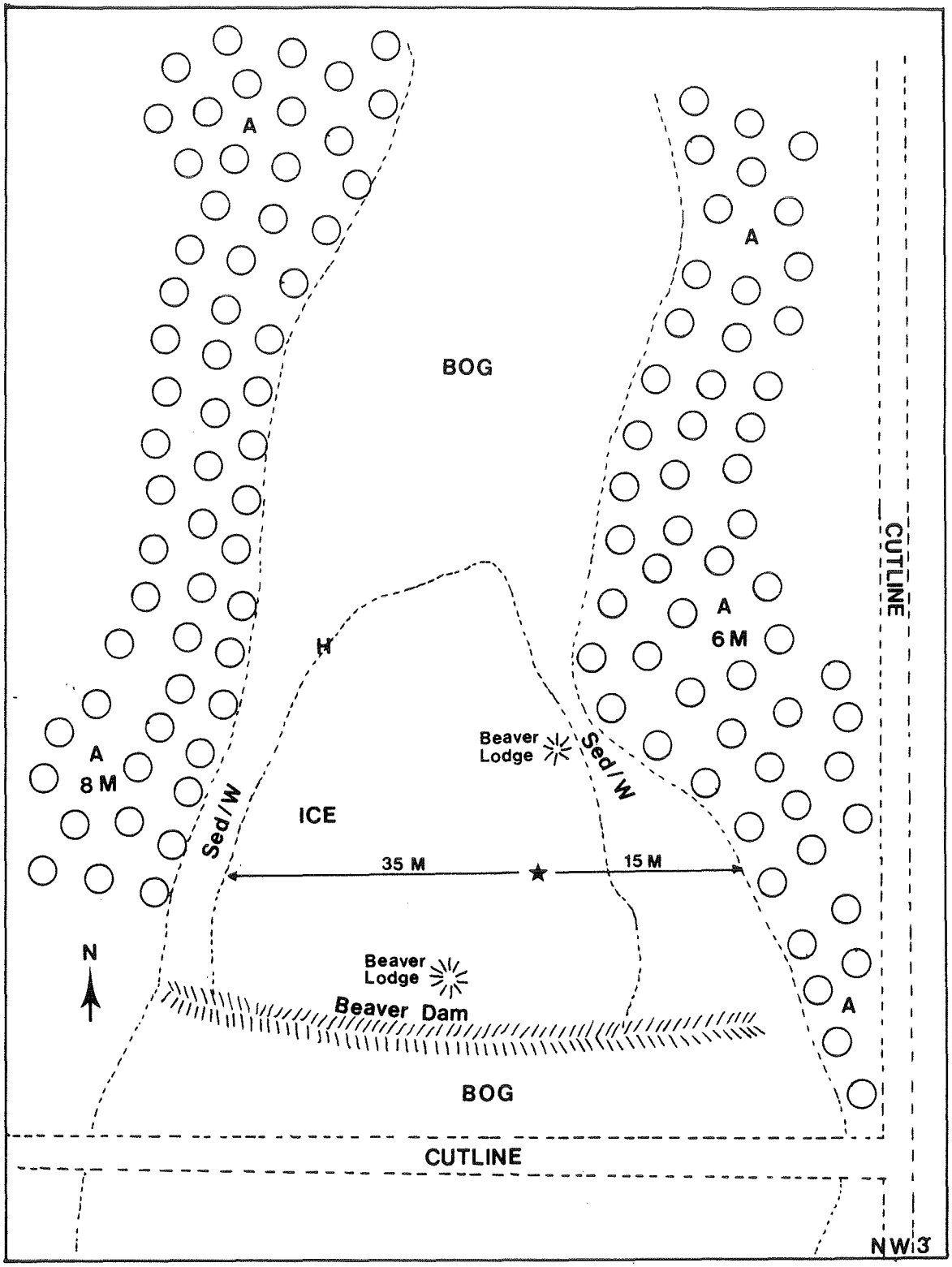

Figure 53: Site Diagram of NW3.

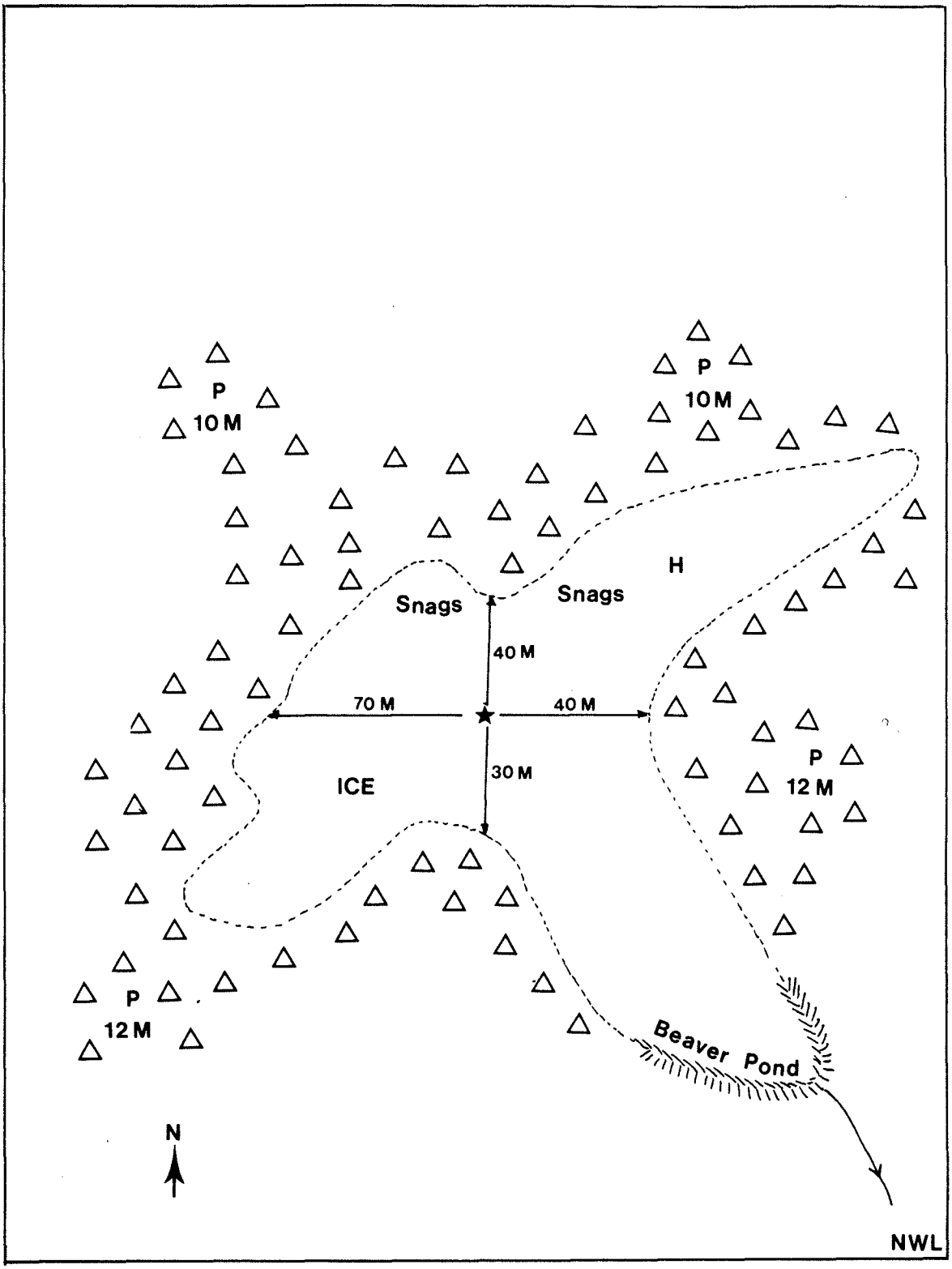

Figure 54: Site Diagram of NWL.

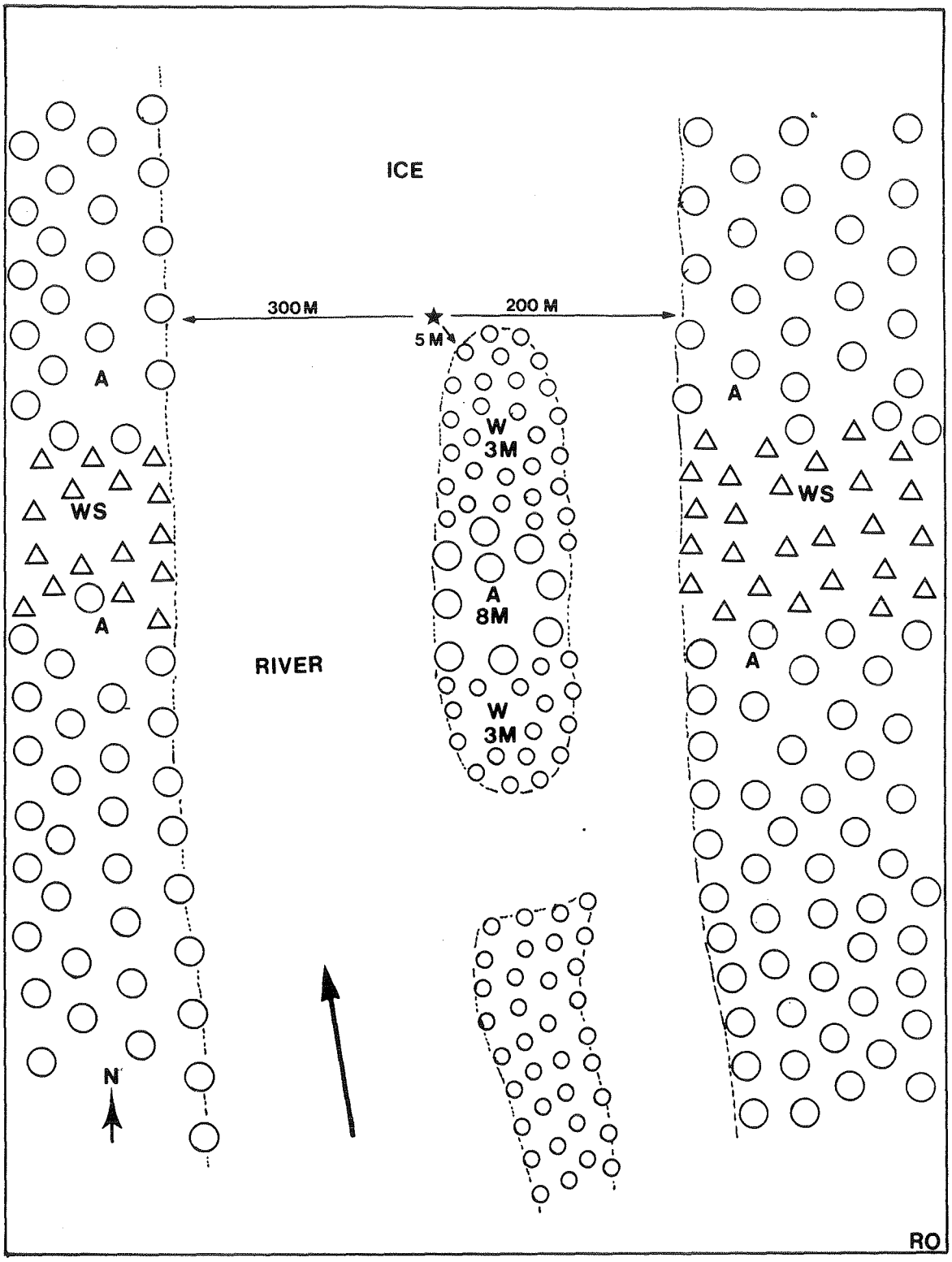

Figure 55: Site Diagram of RO.

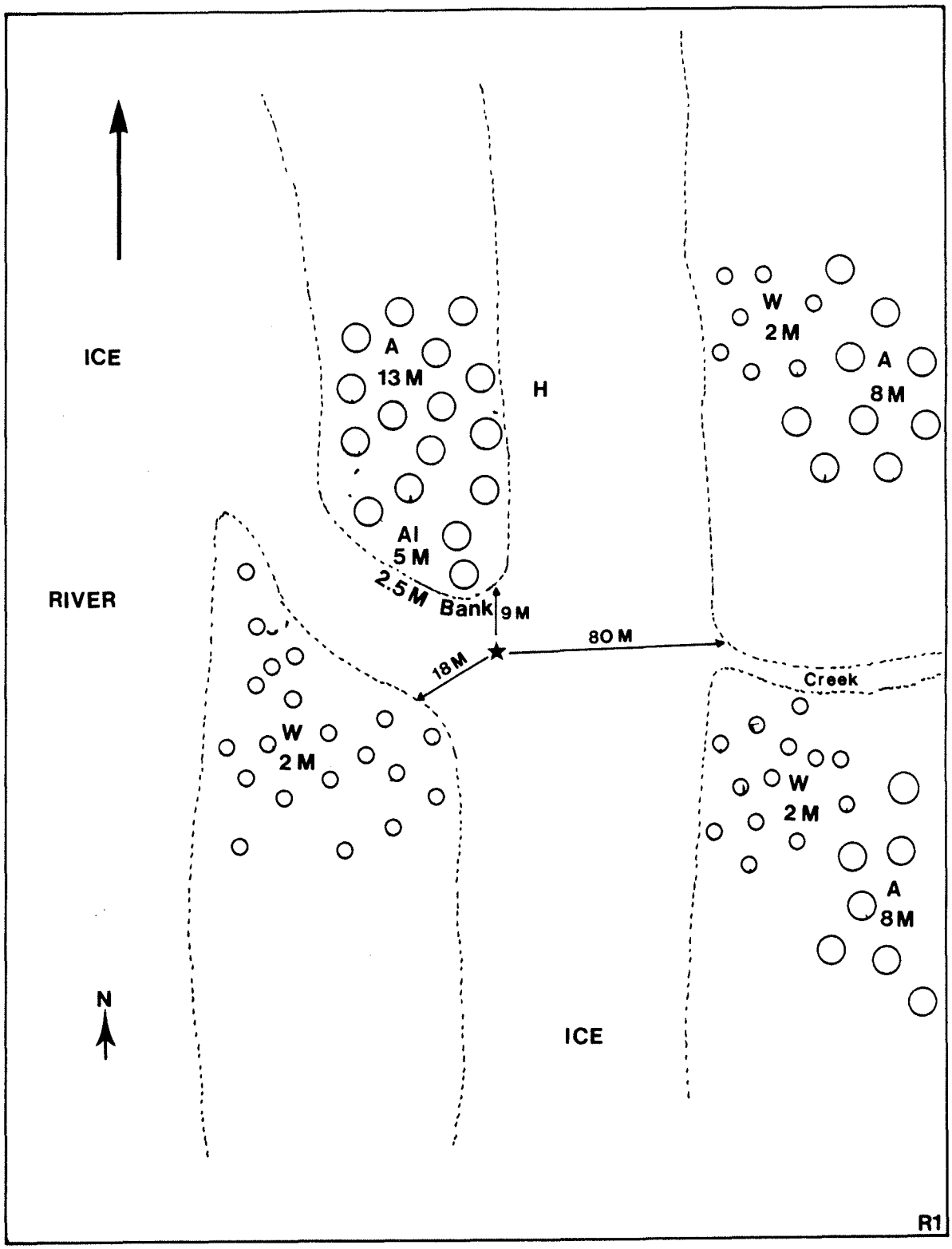

Figure 56: Site Diagram of R1.

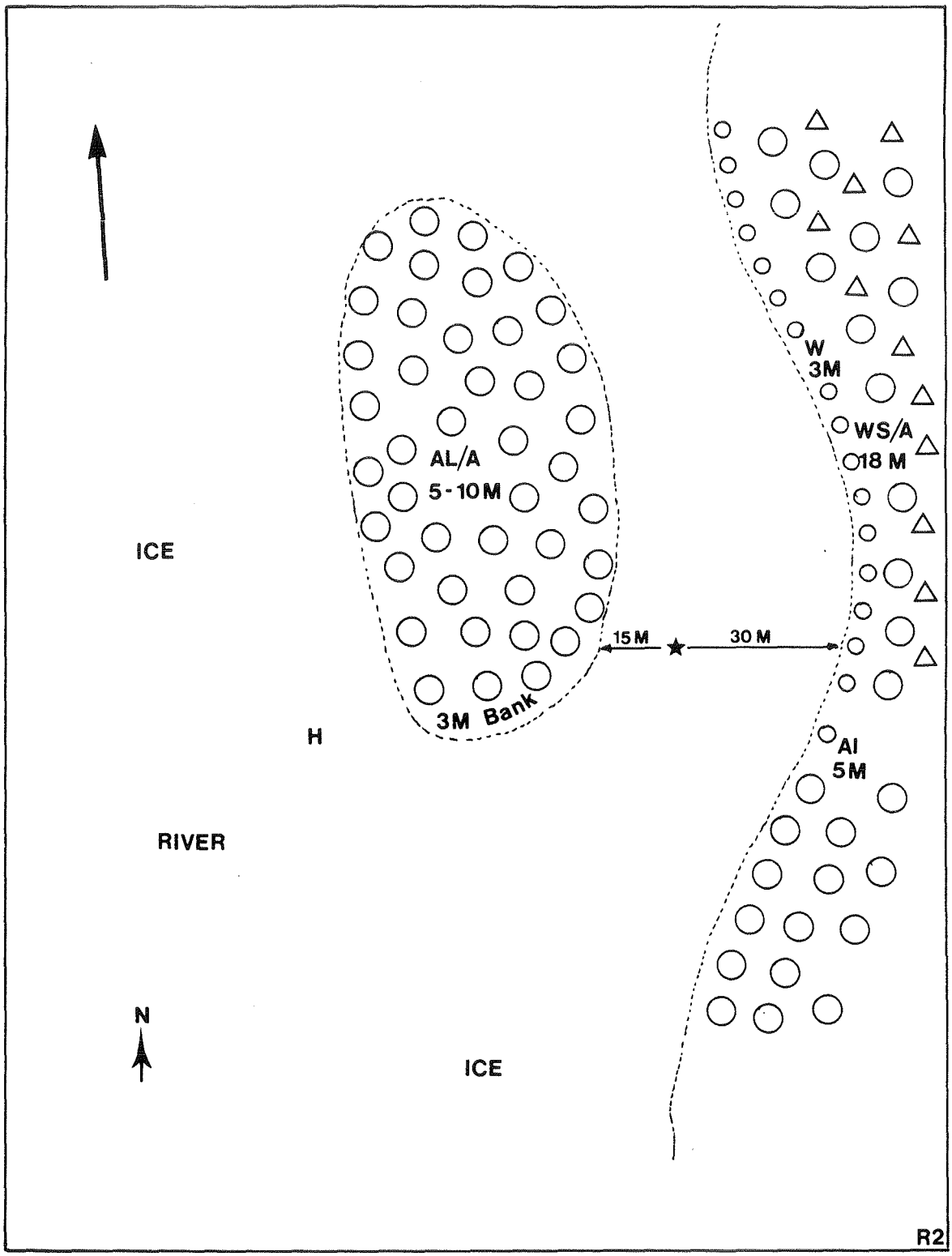

Figure 57: Site Diagram of R2.

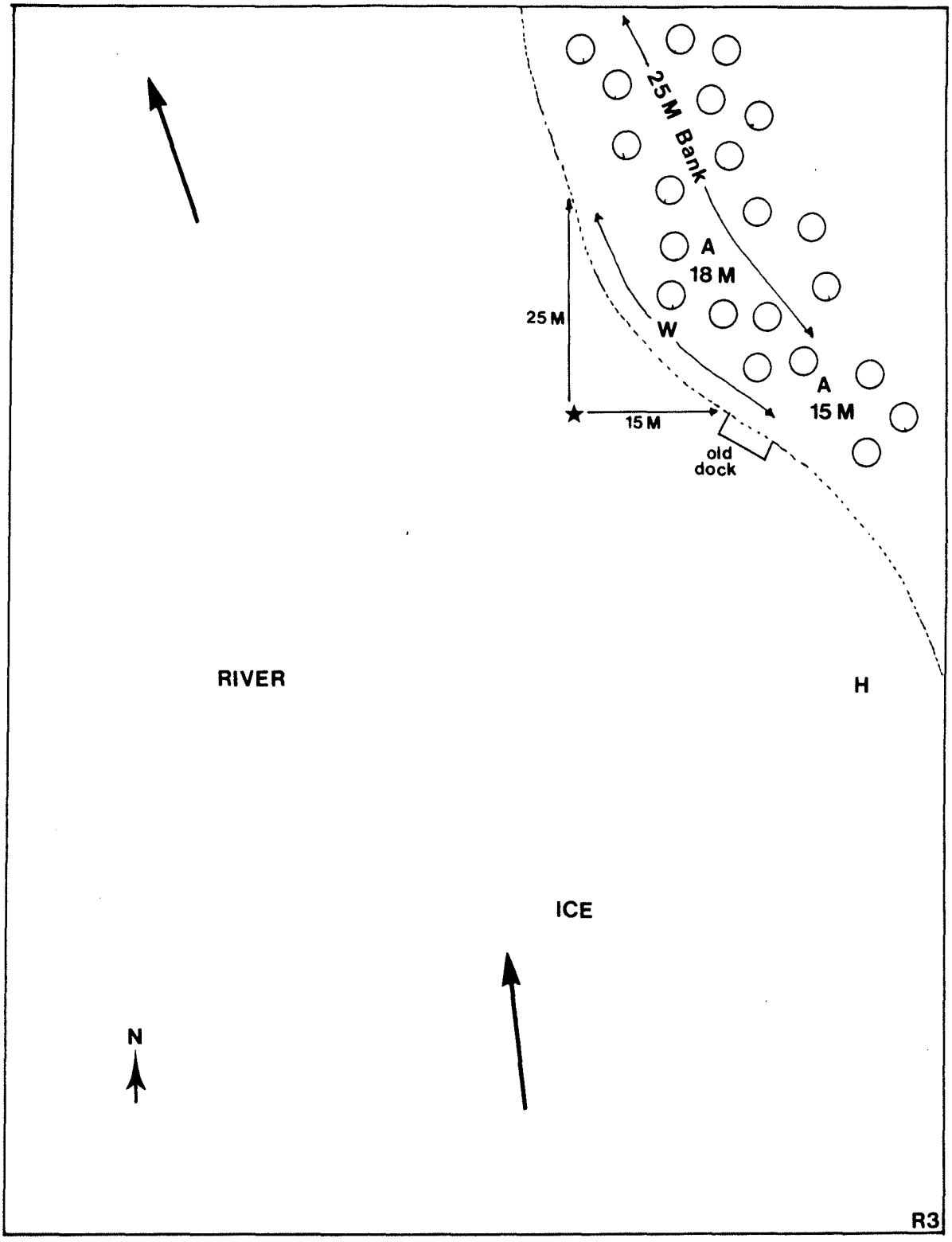

Figure 58: Site Diagram of R3.

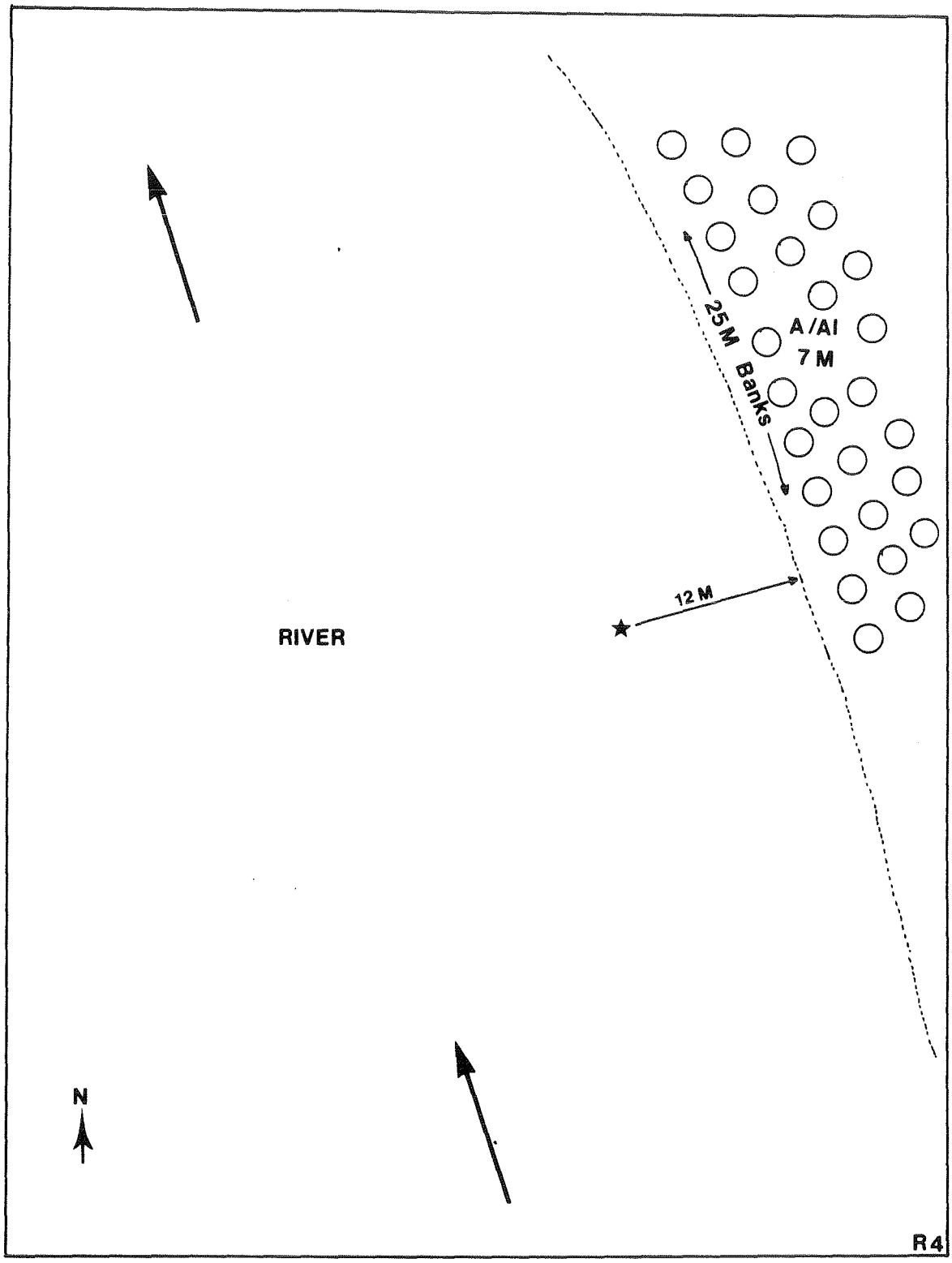

Figure 59: Site Diagram of R4.

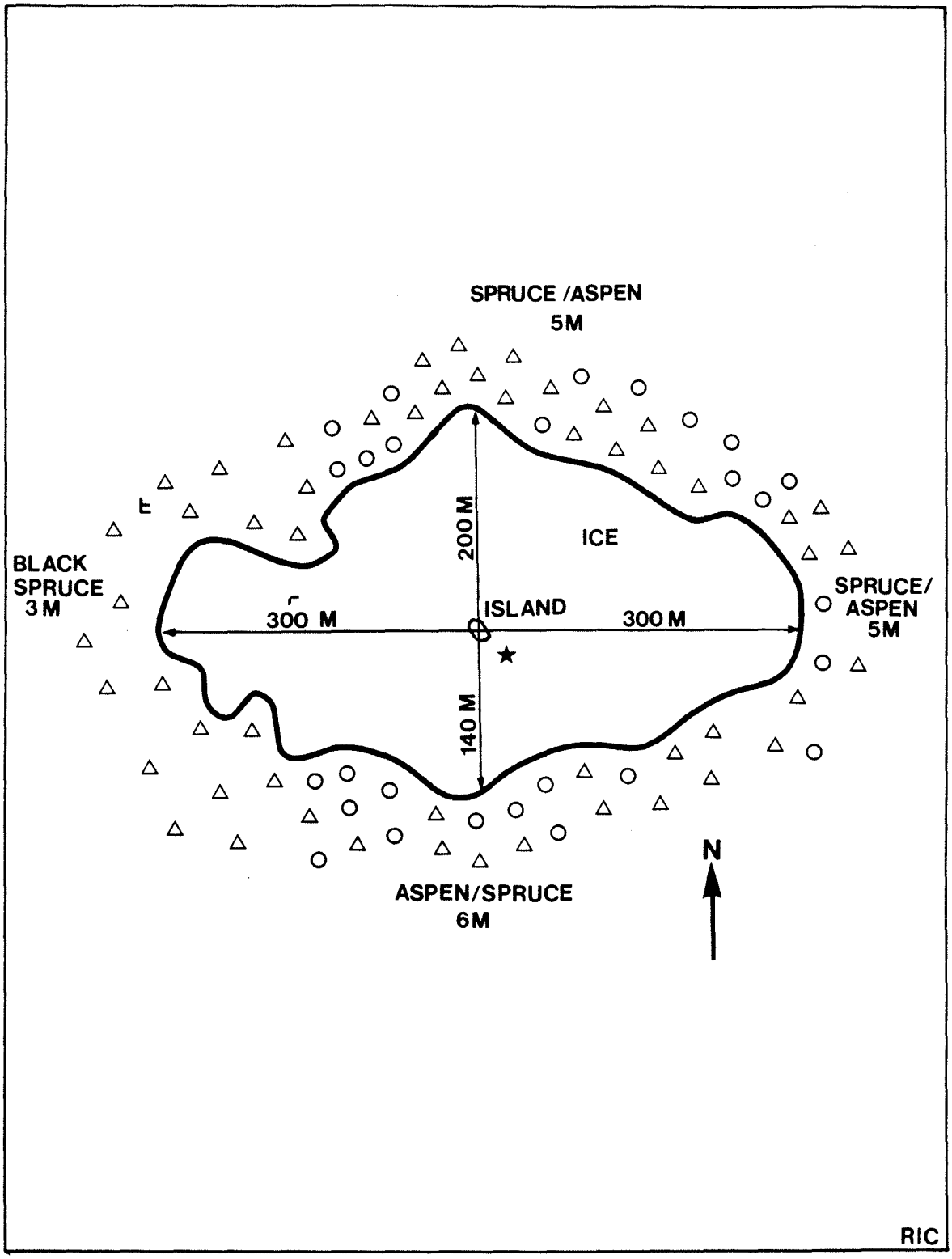

Figure 60: Site Diagram of RIC.

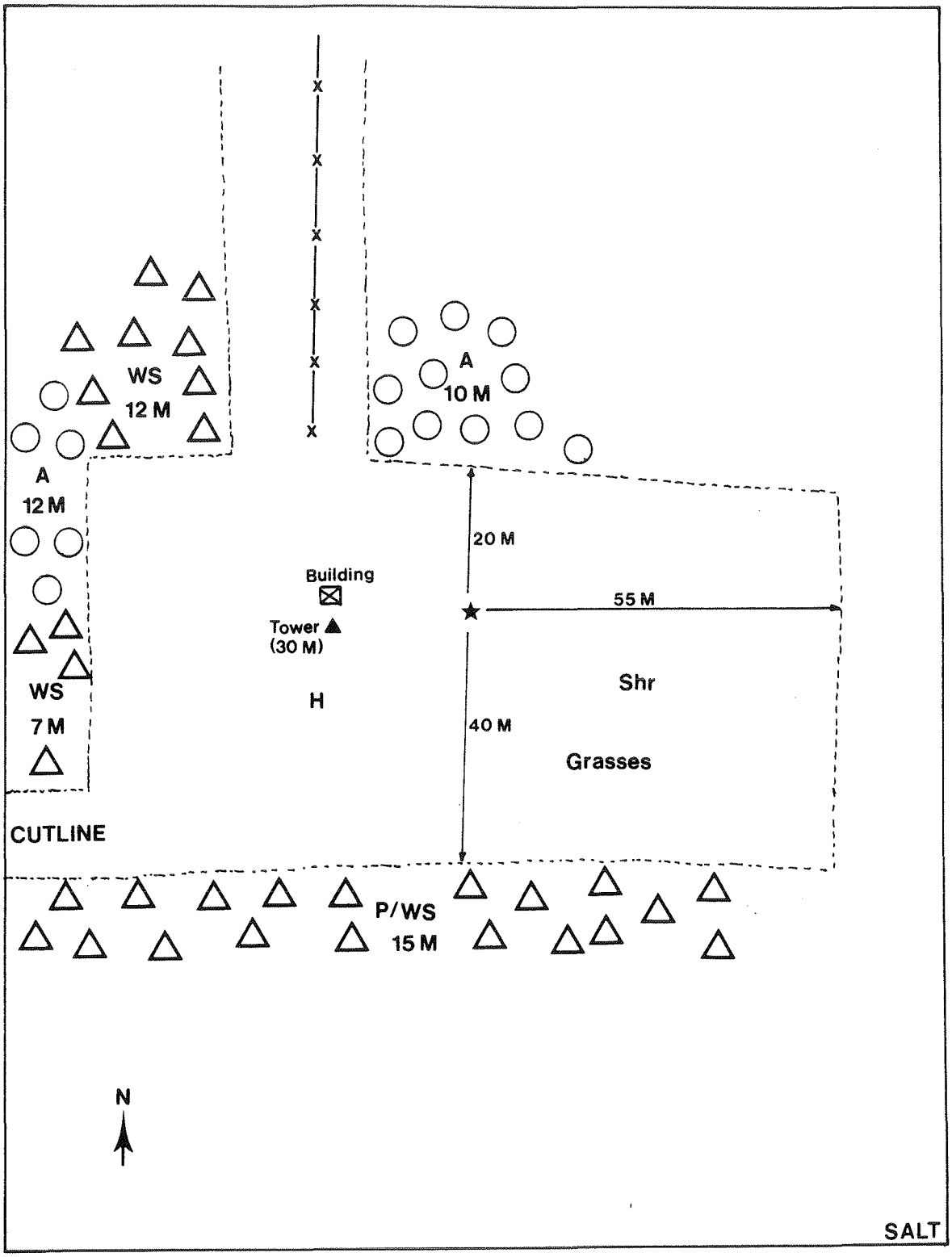

Figure 61: Site Diagram of SALT.

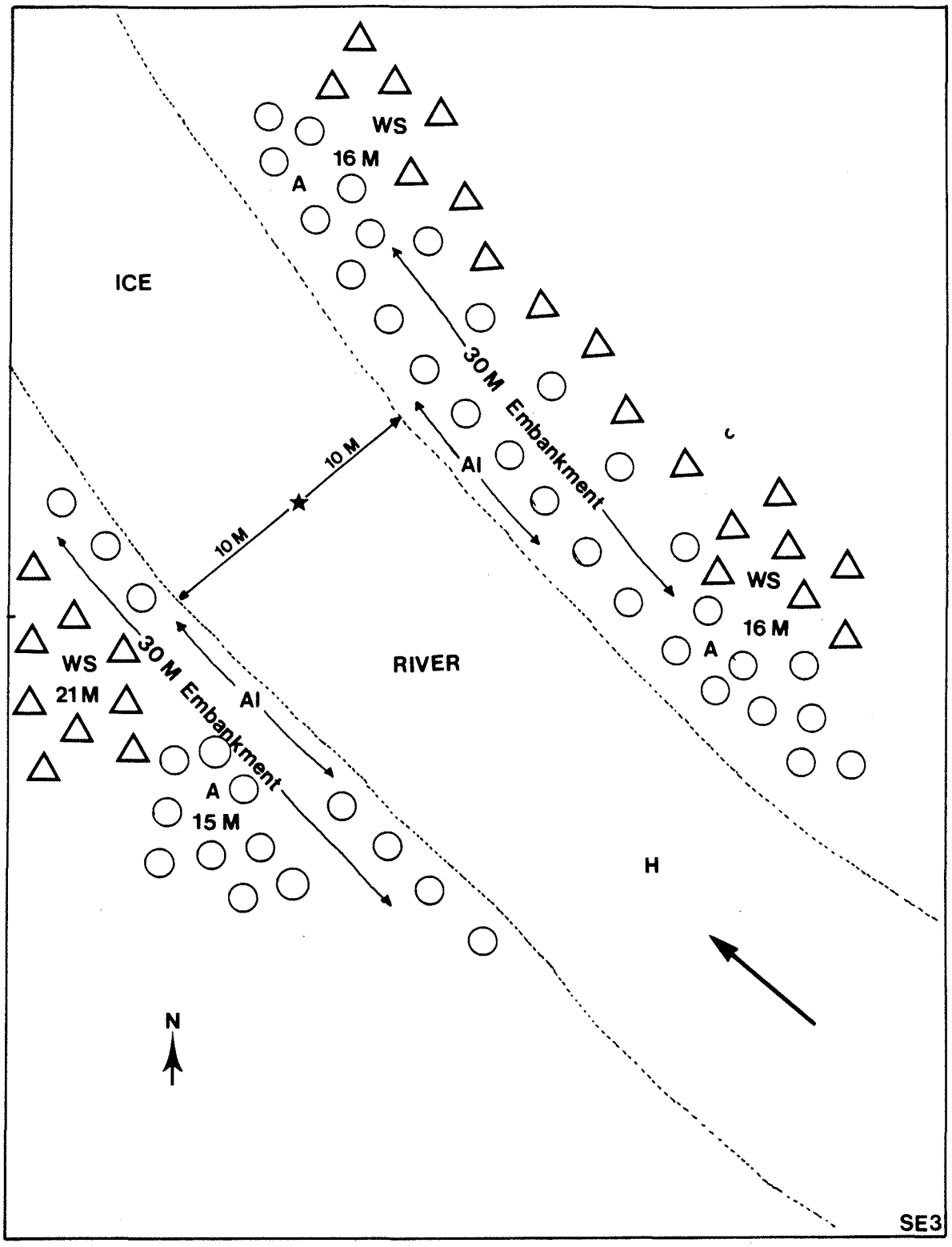

Figure 62: Site Diagram of SE3.

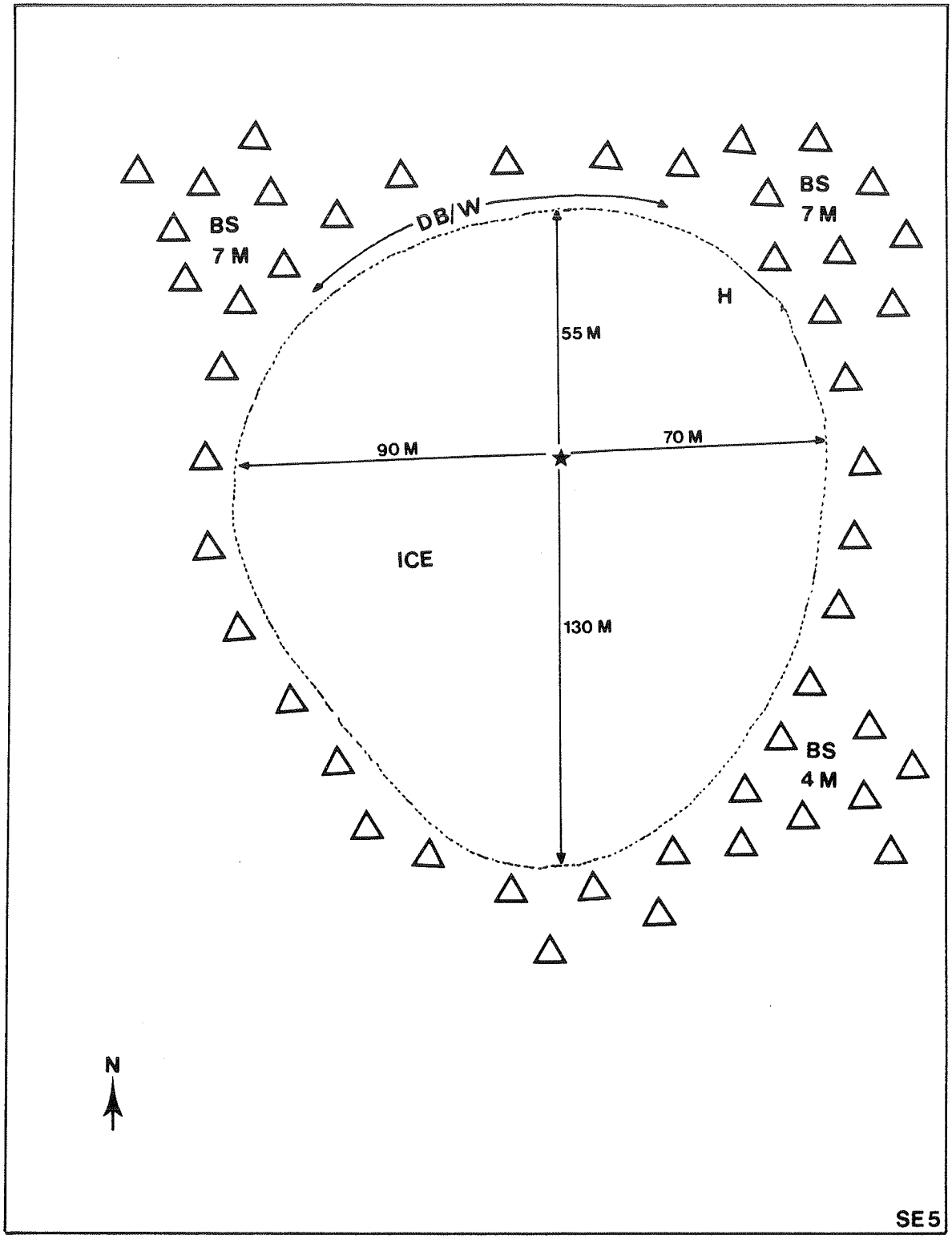

Figure 63: Site Diagram of SE5.

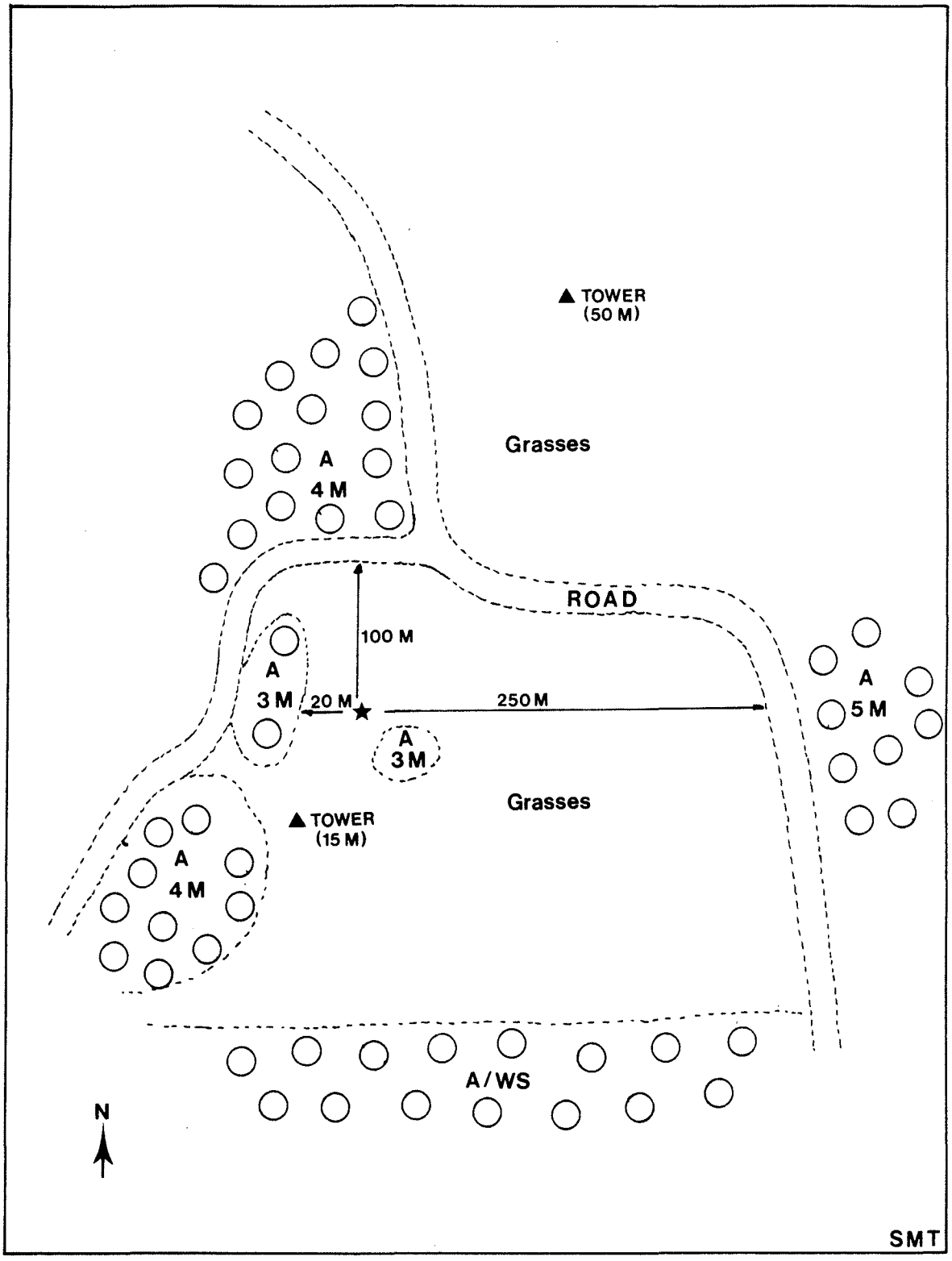

Figure 64: Site Diagram of SMT.

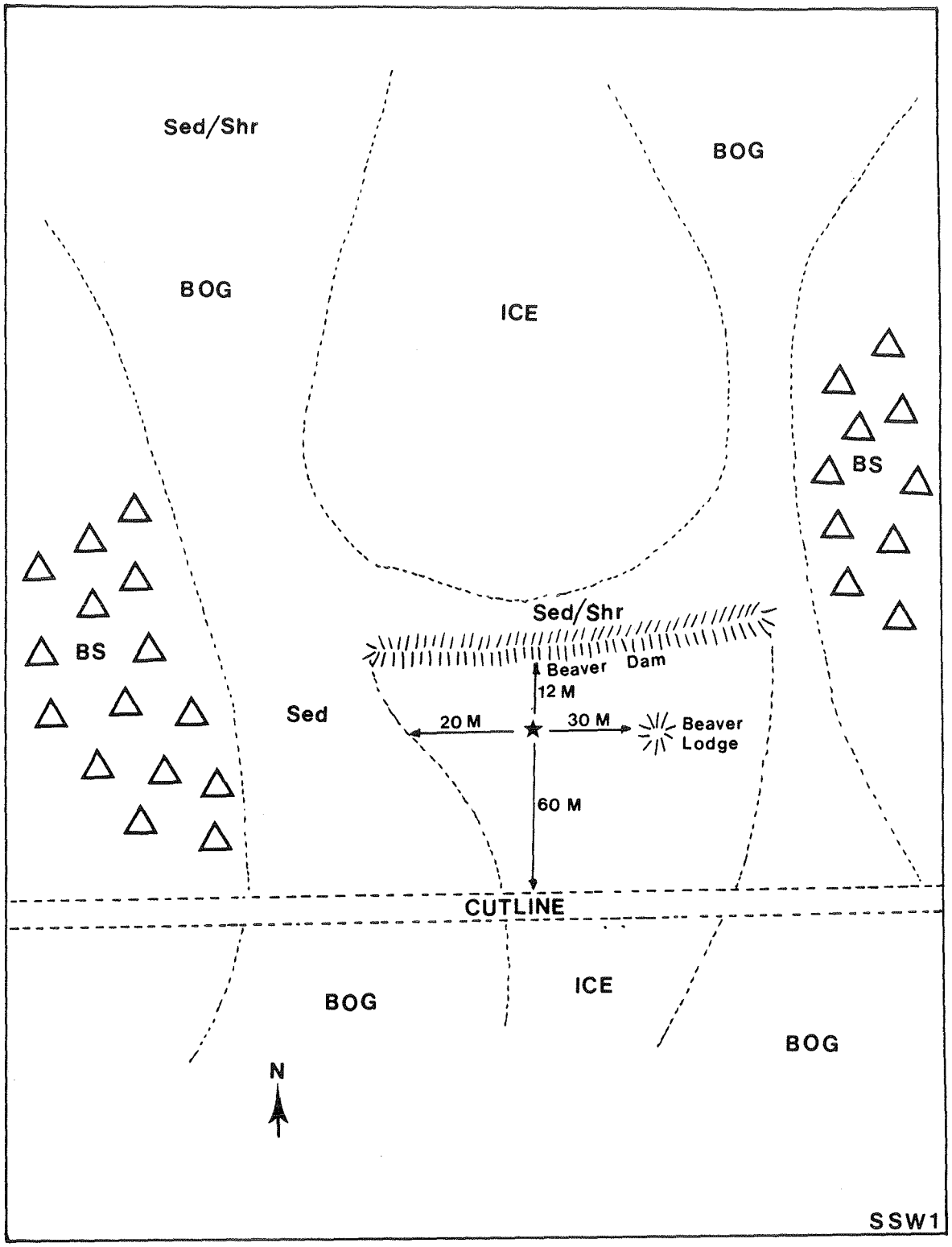

Figure 65: Site Diagram of SSW1.

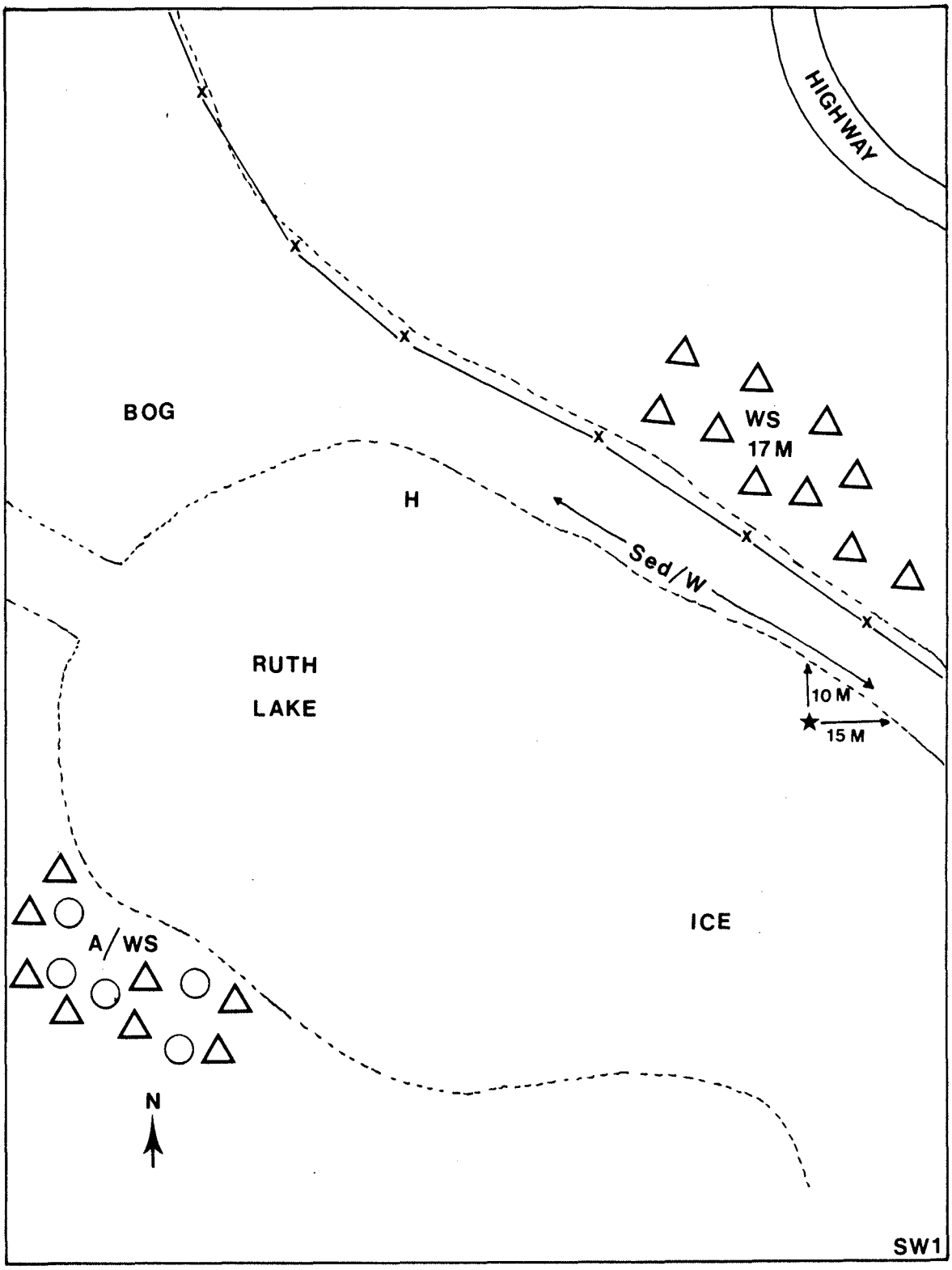

Figure 66: Site Diagram of SW1.

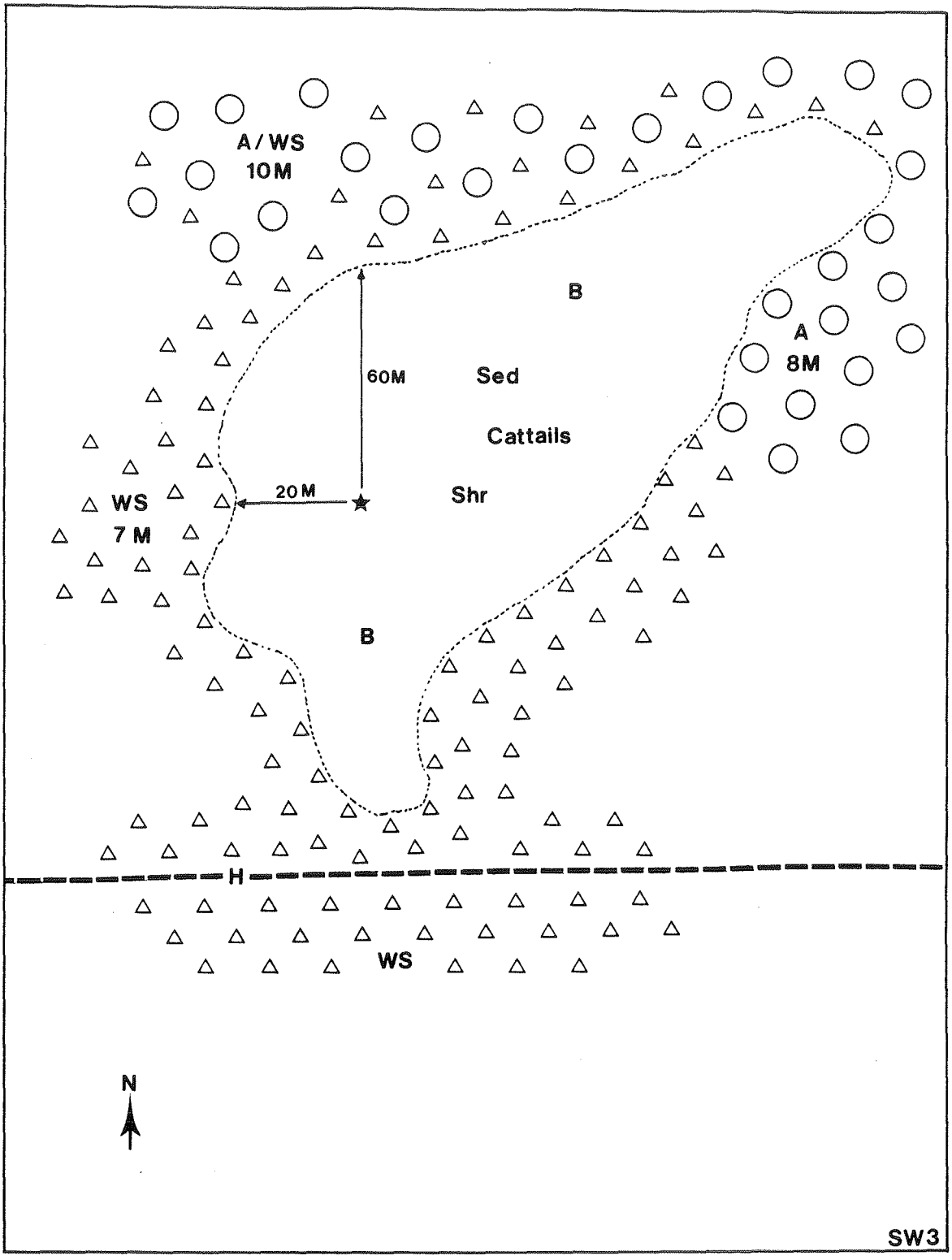

Figure 67: Site Diagram of SW3.

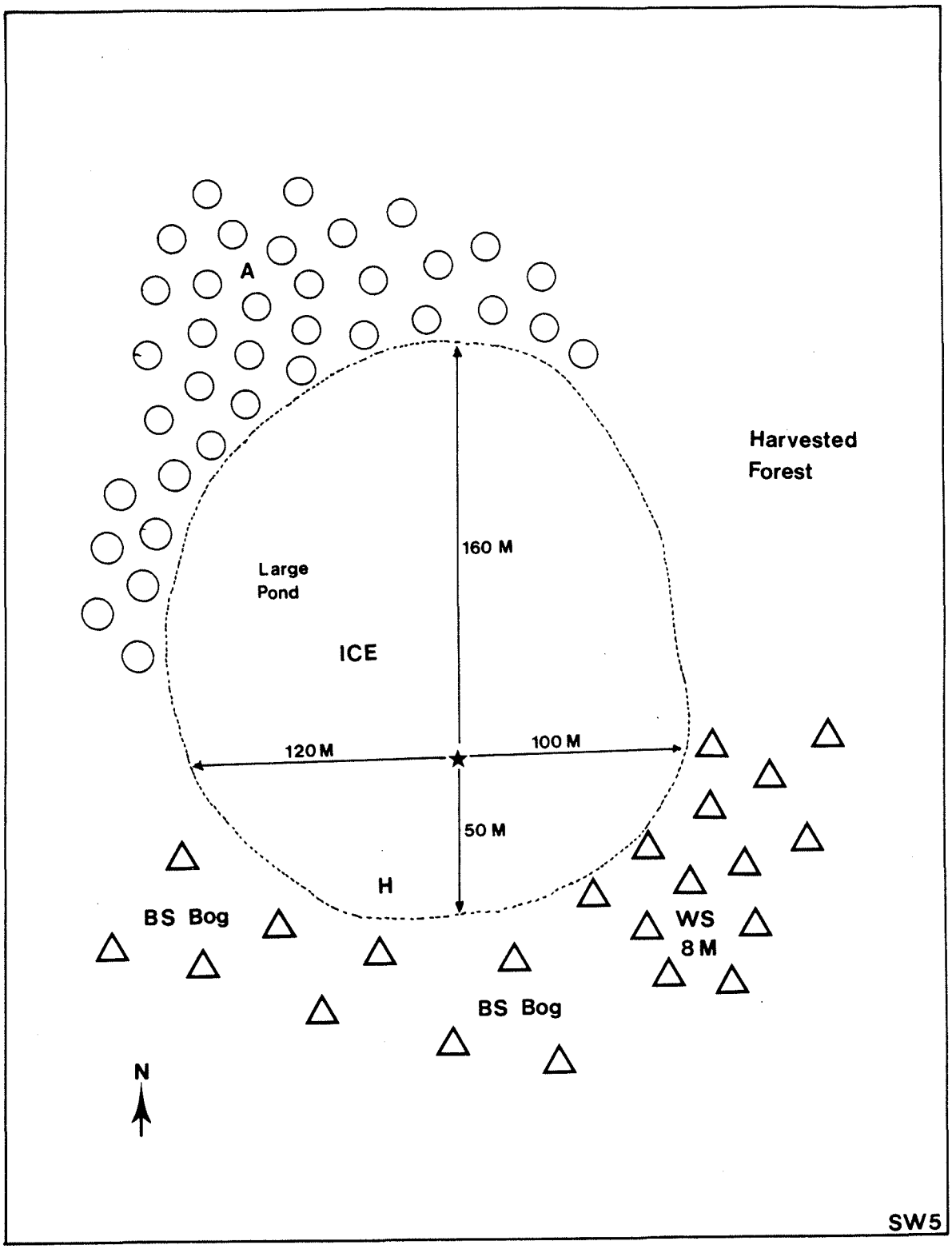

Figure 68: Site Diagram of SW5.

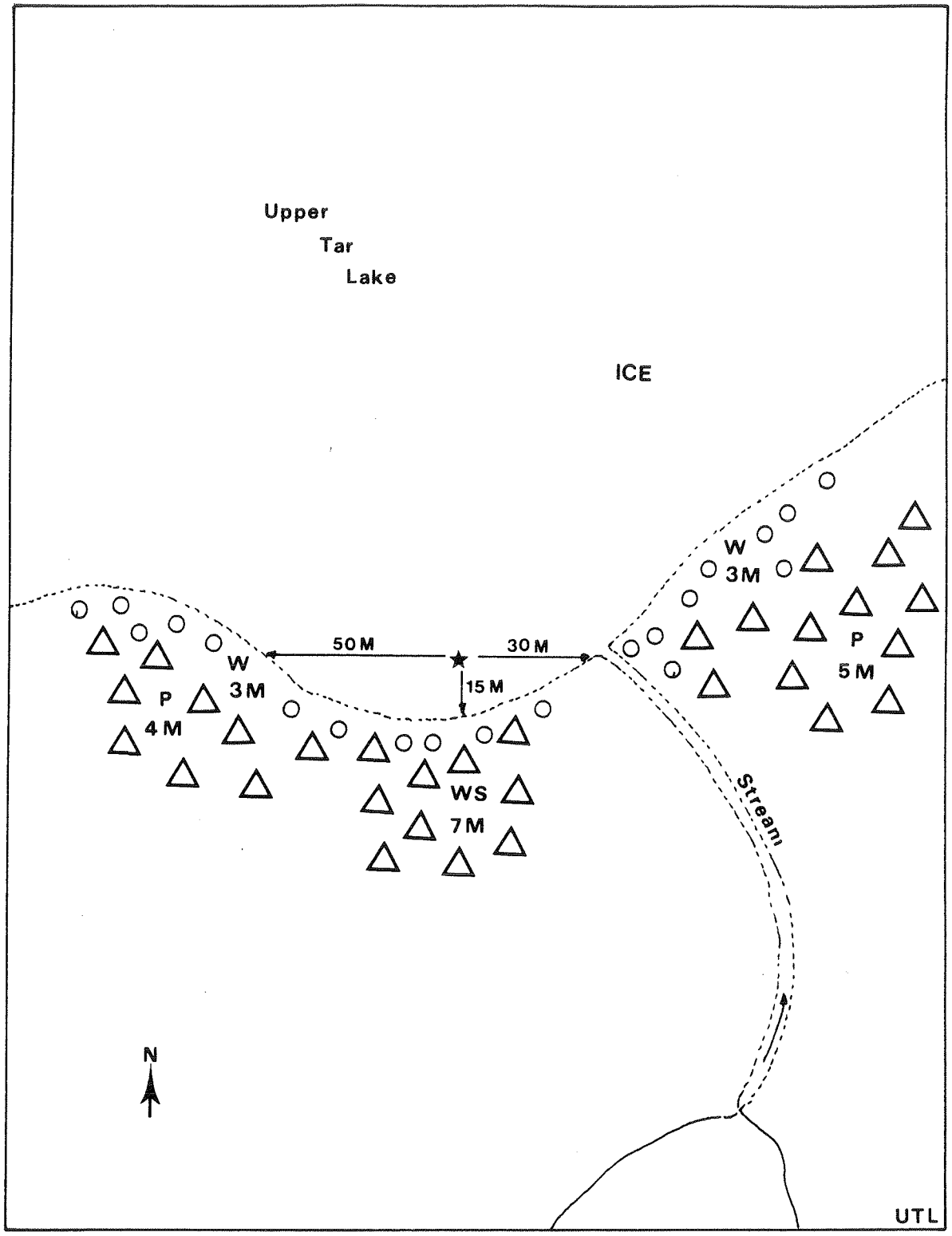

Figure 69: Site Diagram of UTL.

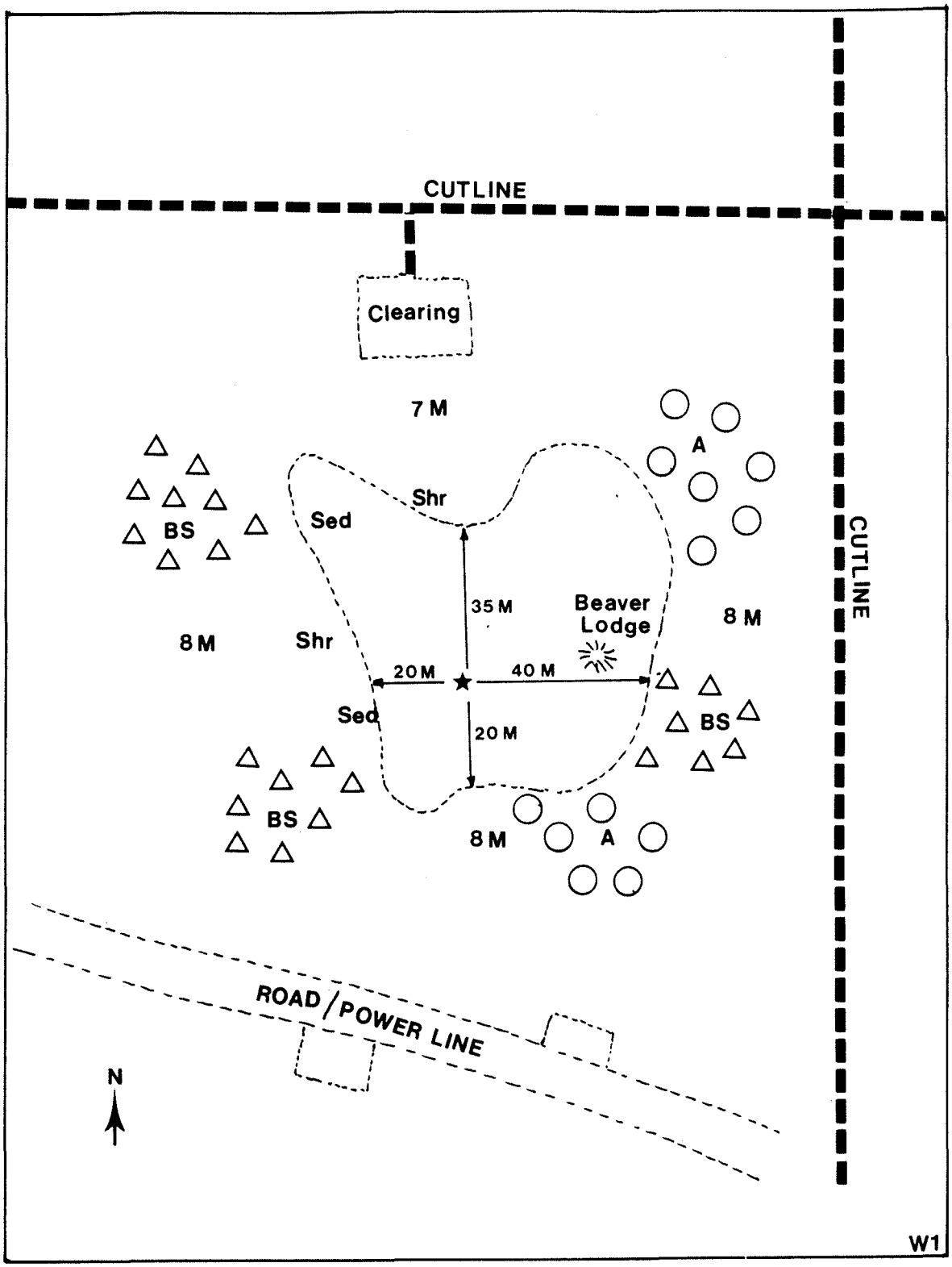

Figure 70: Site Diagram of W1.

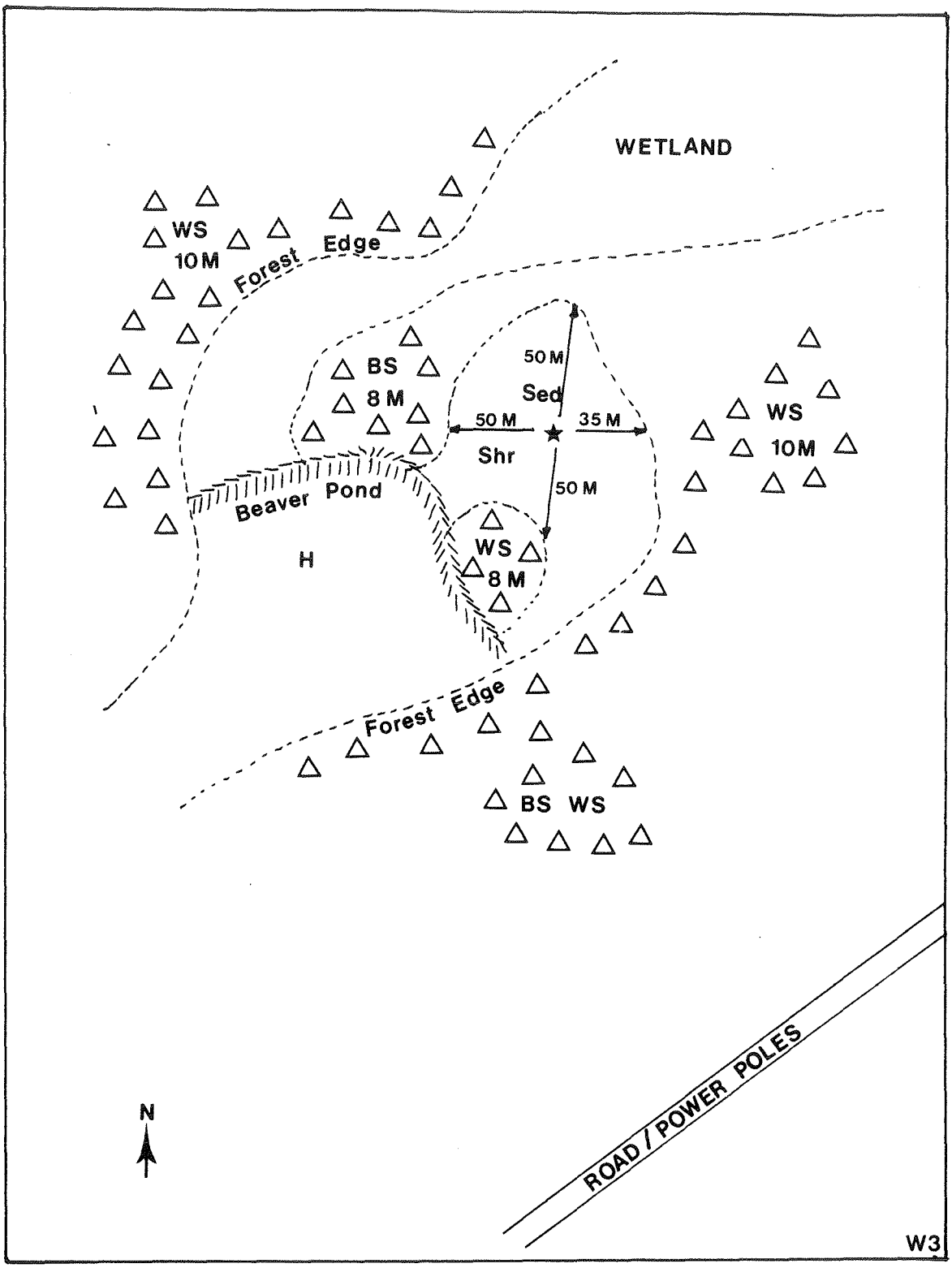

Figure 71: Site Diagram of W3.

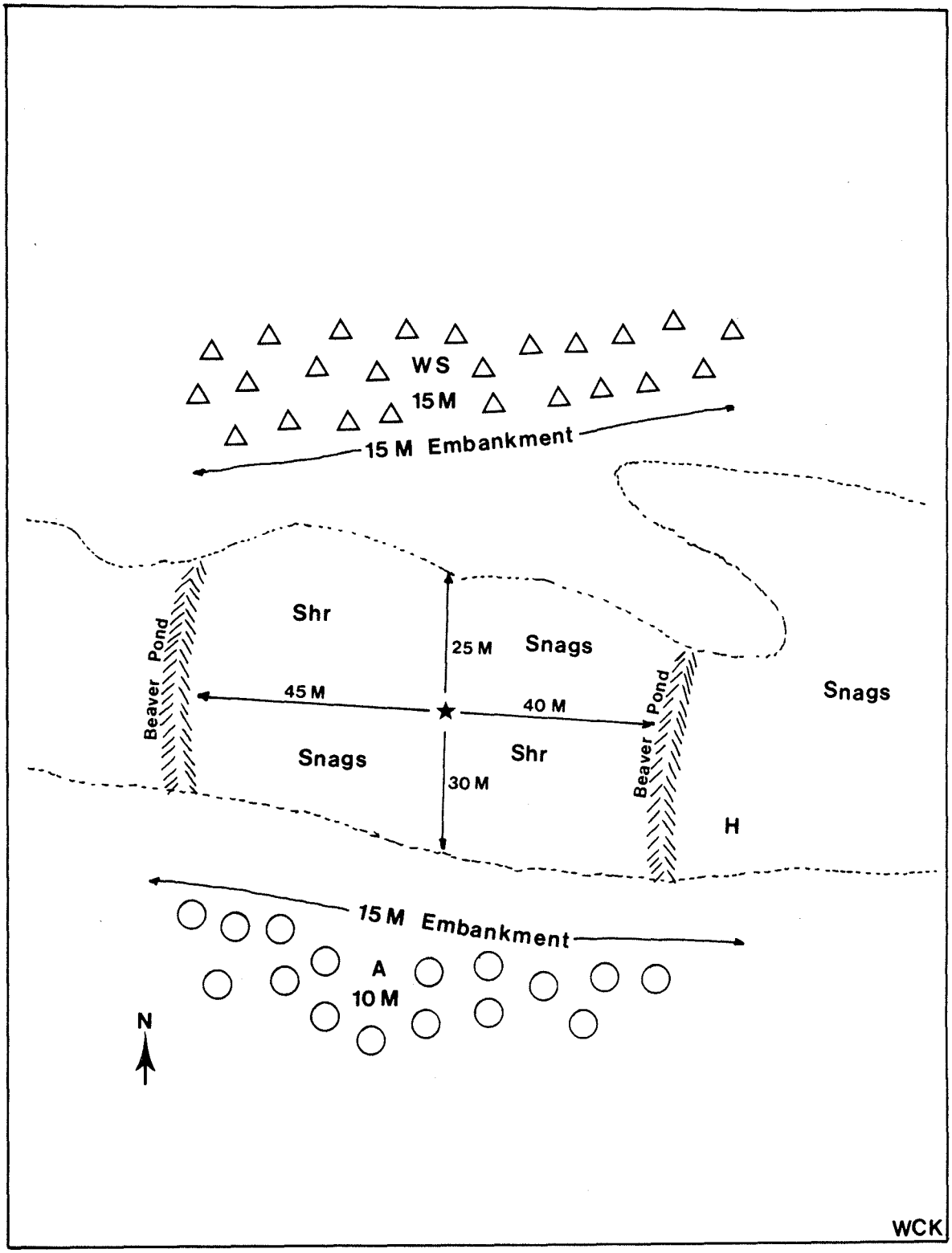

Figure 72: Site Diagram of WCK.

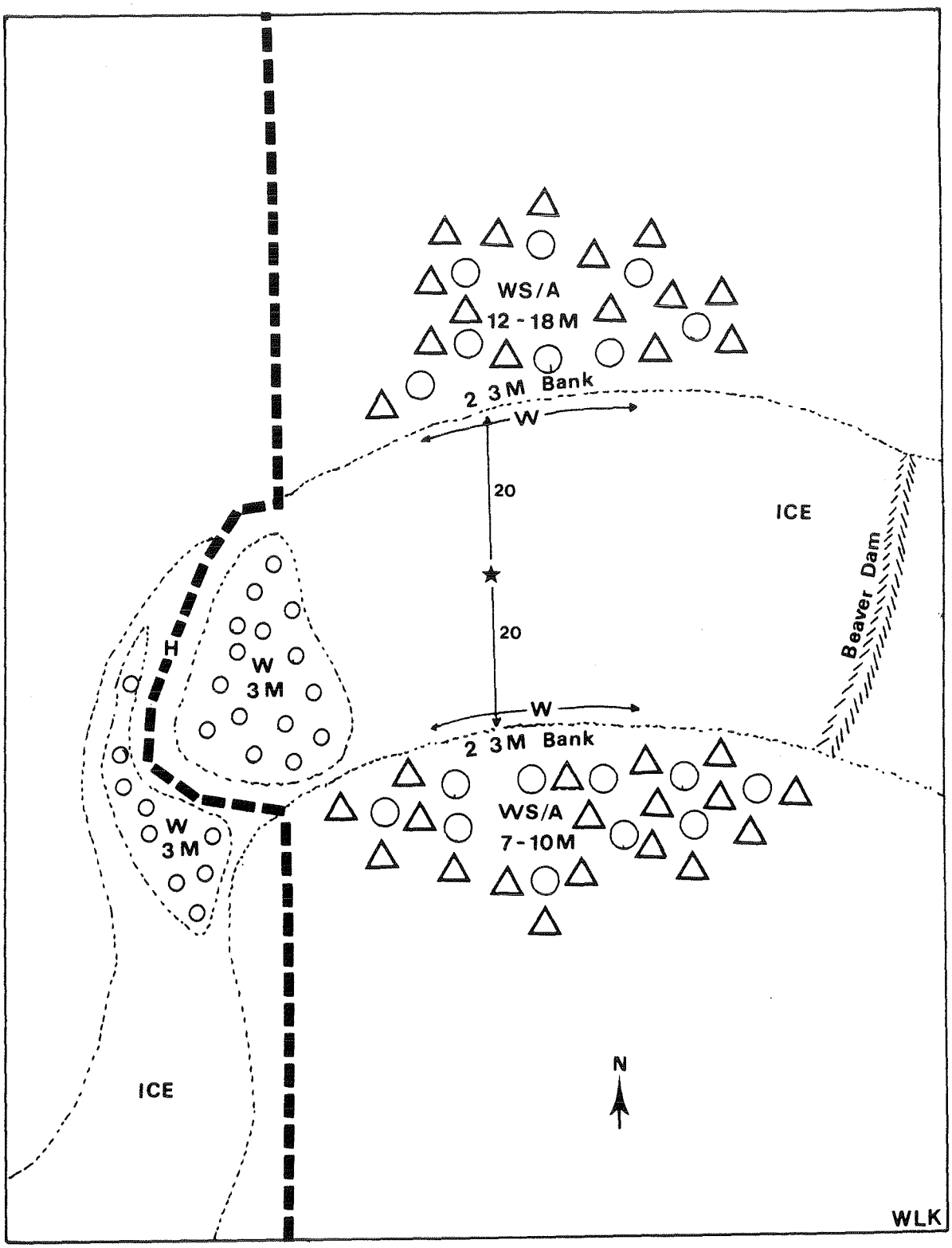

Figure 73: Site Diagram of WLK.

8.3 Appendix III - Site Documentation

Site Name: Birch Mountain Look-out Site Identifier: BCH

57 ^{0} 42 " N	111 ^{0} 51 " W	6394800 N 450000 E	799 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is situated on the middle of the landing strip at Birch Mountain Look-out.

Distance to Oil Sands Plants' Emissions: 74 km Direction: SSE

Distance to Fort McMurray: 111 km Direction: SSE

How Far to All-Season Road: 45 km Direction: S Surface: Gravel

How Far to Winter Road: 0.2 km Direction: E Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 200 m Direction: E

Site Characteristics:

The site is a landing strip for a forest-fire tower site. The surrounding topography is generally flat but, 1 km to the east there is a steep slope with about 500 m of relief. The forest cover is continuous pine and black spruce with an under-story of shrubs. Accessibility to the site is relatively easy as a winter road is maintained to allow service vehicles to reach the telephone relay station.

Site Influences on Integrity of Snow Samples:

The airstrip is aligned with the prevailing winds and drifting of snow occurs frequently. Additionally, there is a diesel generator, about half a kilometer away, that runs continuously to provide power for the relay station.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The redistribution of snow appears to be a deviation from ideal siting criteria. The alignment of the airstrip with the prevailing wind accounts for this but, even sites within the forest were observed to have drifted to a certain degree. The emissions from the generator may influence the snow chemistry but, the exhausts are downwind from the site.

Site Name: Buckton Look-out Site Identifier: BKN

57 ^{0} 52 " N	112 ^{0} 06 " W	6414000 N 435000 E	838 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Namur Lake 84 H Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The snow sampling site is located within the forest clearing occupied by Buckton Look-out forest tower. Specifically, it was to the northeast of the actual tower.

Distance to Oil Sands Plants' Emissions: 96 km Direction: SE

Distance to Fort McMurray: 136 km Direction: SE

How Far to All-Season Road: 67 km Direction: SE Surface: Gravel

How Far to Winter Road: 25 km Direction: SE Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: S

Site Characteristics:

The site is a natural forest clearing on a knoll that rises above the surrounding Birch Mountain uplands. The clearing is not flat but on-site relief is only several meters. The surrounding topography is gently rolling ground moraine with several distinct post-glacial features. The forest around the clearing is composed of pine and some white spruce. The on-site ground cover is pine, shrubs, and grasses. Accessibility by land is difficult because no cut-lines cross the site.

Site Influences on Integrity of Snow Samples:

There are no emissions from the buildings that are on the site but, splash from them and from the forest look-out tower and its support wires may exert an influence on the snow, especially considering that is was not possible to achieve the 2.5 ratio of object heights to sampling distance.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There are no large ponds or forest clearings near Buckton Look-out and so it provides the only reasonable sampling site within that locale. Thus, it is unavoidable about possible contamination from the overhead wires and the metal tower.

Site Name: Clark Creek Site Identifier: CLK

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56 0 48 " N	111 0 07 " W	6295400 N 491600 E	439 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

This site can best be located by following Clark Creek. Near its headwaters it bifurcates. The tributary that flows south should be followed. The site can be recognized because of its distinctive "J" shape and because there is a cut-line, with a "hook" on its end, that terminates along the northwest side of the pond.

Distance to Oil Sands Plants' Emissions: 31 km Direction: NW

Distance to Fort McMurray: 18 km Direction: SW

How Far to All-Season Road: 21 km Direction: W Surface: Paved

How Far to Winter Road: 5 km Direction: WSW Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 35 m Direction: W

Site Characteristics:

CLK is on a beaver pond near the headwaters of Clark Creek. The topography surrounding the site is flat and is composed of lake deposits. The forest cover is aspen, pine, and white spruce. Along the perimeter of the pond there are mainly willows. There is a cut-line along its west side.

Site Influences on Integrity of Snow Samples:

There was no evidence of drifting at the site so wind-blown organic debris accumulations should not be excessive. There is a cut-line about 35 m to the west which could potentially be used for off-road access, but there were no tracks at the time of sampling to indicate this.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There do not appear to be any significant deviations from ideal siting criteria that would adversely affect the quality of the snow sample.

Site Name: Dunkirk River Site Identifier: DNK

56 0 52 " N	112 0 43 " W	6301000 N	397000 E	478 m asl
Lat.	Long.	UTM Co-ordinates		Elevation

Map: Algar Lake 84 A Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

DNK is on the Dunkirk River. It is about 1 km downstream from an east-west cut-line/road that crosses the river. On the east side of the river there is a water-gauging station and a small man-made clearing. Another cut-line joins the east-west one from the north at a right angle. The specific snow sampling site is to the south of this "T" intersection.

Distance to Oil Sands Plants' Emissions: 70 km Direction: NE

Distance to Fort McMurray: 80 km Direction: ESE

How Far to All-Season Road: 54 km Direction: E Surface: Gravel

How Far to Winter Road: 0.5 km Direction: N Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

DNK is on the Dunkirk River. The river is about 20 m wide in the area and is about 9 m below the lacustrine plain above. White spruce is the dominant tree species surrounding the site with willow and other shrubs along the edge of the stream. Accessibility to the area is good in winter along a nearby cut-line/road and on the river, itself.

Site Influences on Integrity of Snow Samples:

The 2.5 ratio of tree heights to sampling distance could not be achieved at this site due to the relative narrowness of the river and the heights of the spruce. Fall through, splash, and organic debris may occur because of this. The river is well travelled using snow machines even though this site is 80 km from Fort McMurray. Drifting does not appear to be a consideration here.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The ratio of tree heights to sampling distance is less than desireable at this site. There do not appear to be alternatives to the site. Exhausts from snow machines also exert an influence of the quality of the snow.

Site Name: E2 Site Identifier: E2

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57 ^{0} 02 " N (Lat.) 111 ^{0} 16 " W (Long.) 6321000 N 485700 E (UTM Co-ordinates) 415 m asl (Elevation)

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

There are no prominent features that can be used to locate this site. The easiest method is to follow the eastward winding trail from NE1 for about 11 km and then connect with the north-south cut-line. The site is then about 3 km to the north and is the only large forest-opening in the area. The aerial oblique photograph should then be used to pinpoint the site.

Distance to Oil Sands Plants' Emissions: 15 km Direction: W

Distance to Fort McMurray: 36 km Direction: WSW

How Far to All-Season Road: 16 km Direction: SW Surface: Paved

How Far to Winter Road: 16 km Direction: SW Surface: Paved

How Close do Off-road Vehicles Regularly Approach: 1000 m Direction: SW

Site Characteristics:

The site is a low area within an extensive flat plain. A series of beaver dams have resulted in ponded water and created the forest opening. The forest cover is black spruce while willows and other shrubs grow along the pond edges and on the beaver dams. Cattails grow extensively on the beaver lodge. Accessibility to the site is not easy as no cut-lines traverse the opening.

Site Influences on Integrity of Snow Samples:

Snow, dust, and organic materials may accumulate on the pond's surface because of drifting behind the elevated beaver dams. Any contamination from off-road vehicles would be minimal as no snow-machine tracks were evident.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There do not appear to be any significant deviations from ideal siting criteria.

Site Name: E4 Site Identifier: E4

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57 ^{0} 04 " N (Lat.) 111 ^{0} 02 " W (Long.) 6324000 N 497600 E (UTM Co-ordinates) 506 m asl (Elevation)

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

This site can be difficult to locate if visibility is reduced. It is most easily located if a heading is taken from either MKG or E2. The site is along the North Steepbank River and directly west of two lakes which are about 11 km away. Once in the general region it can be located by following the cut line that runs east-west and ends in a square clearing. The sample site is then about 65 m to the southwest of the square. The helicopter can land in the north clearing and sampling can be conducted in the south clearing.

Distance to Oil Sands Plants' Emissions: 28 km Direction: W

Distance to Fort McMurray: 43 km Direction: SW

How Far to All-Season Road: 29 km Direction: WSW Surface: Paved

How Far to Winter Road: 21 km Direction: NW Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 65 m Direction: NE

Site Characteristics:

The site is a muskeg area with a black spruce bog surrounding it. As such, the tree cover is not extensive and is primarily composed of black spruce and tamarack. The shrubs are mostly small trees and dwarf birch. Sedges are also present. Accessibility is difficult because of the remoteness of the site but the nearby cut-line can be utilized by off-road vehicles.

Site Influences on Integrity of Snow Samples:

The site is one of the few forest openings in the area and snow will be trapped in the clearing due to the dynamics of air flow. Fall through, splash, and organic debris may also accumulate in the opening as the 2.5 ratio was not achieved.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There are very few forest openings or ponds in this part of the Oil Sands area and thus, there were no other sites that may have been better. Because of this the 2.5 ratio of heights to sampling distance could not be achieved.

Site Name: Ells River Site Identifier: ELS

57 0 07 " N	112 0 22 " W	6331500 N 417500 E	428 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Namur Lake 84 H Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

ELS is south of the Ells Tower and on the Ells River. It is the southern-most point of the river and it is near the Ells MAPS tower.

Distance to Oil Sands Plants' Emissions: 45 km Direction: ESE

Distance to Fort McMurray: 73 km Direction: SE

How Far to All-Season Road: 42 km Direction: W Surface: Gravel

How Far to Winter Road: 42 km Direction: W Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: N/A

Site Characteristics:

The site is on the Ells River. The surrounding topography is a flat lacustrine plain. The nearby vegetation is white spruce and aspen with shrubs along the edges of the stream. Accessibility to the site is possible along the river but, there were no tracks to indicate that snow machines had recently passed by.

Site Influences on Integrity of Snow Samples:

The 2.5 ratio of sampling heights to distance to sample site was not obtainable at this site as the river was too narrow and the trees too high. Because of this fall through and organic debris may influence the snow samples. Drifting did not appear to occur here. Occasionally helicopters land at the MAPS tower.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The 2.5 ratio could not be observed at this site. The tree and river characteristics did not change much near this site and so, there was no advantage to moving the site up- or down-river.

Site Name: Edra Look-out Site Identifier: ERA

57 0 52 " N	113 0 15 " W	6416000 N 366000 E	808 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Namur Lake 84 H Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The snow sampling site is in the middle of the landing strip at Edra Look-out.

Distance to Oil Sands Plants' Emissions: 134 km Direction: SE

Distance to Fort McMurray: 168 km Direction: SE

How Far to All-Season Road: 110 km Direction: SE Surface: Gravel

How Far to Winter Road: 85 km Direction: ESE Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: S

Site Characteristics:

The site is an airstrip at Edra Look-out. The area is ground moraine covered by black spruce and pine trees. Willows and alders grow on the edges of the strip. Accessibility to the site is very difficult by land because of the remoteness of the location.

Site Influences on Integrity of Snow Samples:

The airstrip is oriented close to the direction of the prevailing winds and, as such, drifting is common and the snow is very hard packed. The tower and its support wires may result in problems due to splash. There are buildings nearby but, there are no emissions from them during the winter.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The redistribution of snow and splash from the tower probably pose the most significant problems to snow sampling at this site. The remoteness of the site from the oil sands plants and from over-land traffic indicates that the snow should be relatively pristine.

Site Name: Firebag Site Identifier: FBG

57 ^{0} 37 " N	111 ^{0} 12 " W	6388800 N 488300 E	236 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The sampling site is near the junction of the Firebag River and the winter road that heads northeast and east of the Athabasca River. Specifically, it is upstream from the bridge over the Firebag about 1.7 km (along the fetch of the river) from where the Firebag makes a sharp 180^0 turn from west- to east-flowing.

Distance to Oil Sands Plants' Emissions: 71 km Direction: SSE

Distance to Fort McMurray: 103 km Direction: S

How Far to All-Season Road: 52 km Direction: SSW Surface: Gravel

How Far to Winter Road: 0.2 km Direction: S Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 200 m Direction: S

Site Characteristics:

The sampling site is on the Firebag River near the winter road that services northeast Alberta. The topography adjacent to the River is steeply sloping but, it is flat above the river valley with lacustrine deposits. There has been a burn to the southeast of the sampling site. The non-burned forest is primarily pine with some aspen on the alluvial flats. Accessibility to the site is possible by off-road vehicles.

Site Influences on Integrity of Snow Samples:

The winter road is about 200 m from the sampling site but, the road is not heavily used and so contamination from exhausts would not be excessive. The burned area may increase the ability of wind to transport materials because of the reduced canopy effect. The 2.5 ratio of heights to sample site was not obtained due to the heights of trees and relative narrow river.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There are no lakes or large ponds in the area that could have otherwise been used to achieve a desireable ratio of heights to sample site. The winter road does not have much traffic on it and locating the sampling site relatively near to it provides a means of locating the same site again.

Site Name: Fort McMurray Airport Site Identifier: FMA

56 ^{0} 44 " N	111 ^{0} 23 " W	6278300 N 486100 E	344 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The snow sampling site is south of the airport runway in a large clearing. There are several small buildings, a mock airplane fuselage that is used for fire drills, and a communications tower in the clearing. The specific site is half-way between the tower and the airplane fuselage.

Distance to Oil Sands Plants' Emissions: 42 km Direction: NE

Distance to Fort McMurray: 13 km Direction: NE

How Far to All-Season Road: 0.2 km Direction: N Surface: Paved

How Far to Winter Road: 0.1 km Direction: N Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

The site is part of the Fort McMurray Airport facility. It has been cleared of trees but, surrounding the sampling site are white spruce and aspen. There is a re-growth of aspen in these parts of the clearing that do not experience much use. Many airport service vehicles use the site on a frequent basis.

Site Influences on Integrity of Snow Samples:

Drifting does not seem to be a problem but, dust from the surrounding roads could be. Exhausts from automobiles and aircraft, smoke and chemical retardants used in fire drills, and splash from the communications tower and the fire-practice fuselage would influence the integrity of the snow samples.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The site does not offer pristine conditions, however, it should serve to test the sensitivity of the sampling and analysis procedures.

Site Name: Gordon Lake Site Identifier: GLK

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56 ^{0} 37 " N	110 ^{0} 33 " W	6276700 N 528900 E	473 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

GLK is located near the southeast shore of Campbell Lake, which is about 5 km north of Bunting Bay, on Gordon Lake. It is approximately 50 m from the shore.

Distance to Oil Sands Plants' Emissions: 71 km Direction: NW

Distance to Fort McMurray: 51 km Direction: WNW

How Far to All-Season Road: 36 km Direction: W Surface: Paved

How Far to Winter Road: 27 km Direction: W Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: N/A

Site Characteristics:

GLK is on a relatively large lake. The forest on the nearby south shore is dominated by spruce. There are willows near the shore. Snow accumulates along the edge of the lake but, drifting was not evident where the samples were taken. Accessibility to the lake is difficult as there are no cut-lines in the immediate vicinity.

Site Influences on Integrity of Snow Samples:

Drifting does not appear to be a problem at this site. Other factors that could potentially influence the snow are minor.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There do not appear to be any significant deviations from ideal siting criteria at this location.

Site Name: Grande Look-out Site Identifier: GND

56 0 17 " N	112 0 16 " W	6240000 N 424000 E	530 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Algar Lake 84 A Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

This snow sampling site is located on the air strip of Grand Look-out. It is near the center of the strip.

Distance to Oil Sands Plants' Emissions: 92 km Direction: NE

Distance to Fort McMurray: 71 km Direction: NE

How Far to All-Season Road: 33 km Direction: SE Surface: Paved

How Far to Winter Road: 33 km Direction: SE Surface: Paved

How Close do Off-road Vehicles Regularly Approach: 25 m Direction: N

Site Characteristics:

The site is on the landing strip of Grand Look-out. Its base is grass. The vegetation along the edge of the strip is shrubs, while the forest cover is aspen and white spruce. Accessibility to the site is good along a recently plowed cut-line that runs to the north of the strip.

Site Influences on Integrity of Snow Samples:

There is a cut-line nearby that has recently been plowed. Exhausts from the snow plow could affect the quality of the snow samples. Drifting does not appear to be extensive where the samples are collected. The forest look-out tower and buildings, which have no emissions during the winter, are about 200 m away. The air strip had not been used during the winter previous to the 1986 sampling.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The exhausts from the machine that plowed the cut-line could present a problem. Other than that there do not appear to be any significant deviations from ideal siting criteria.

Site Name: High Hills River Site Identifier: HHR

56 ^{0} 48 " N	110 ^{0} 30 " W	6302000 N 532000 E	469 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

HHR can be reached by following the Clearwater River and then the High Hills River. The site is 5 km north-northeast of the point where the two rivers meet and 2 km south of the re-curving High Hills River. A distinct forest edge will be noticed. The site is in the open area and on a vegetation-water drainage/flow line about 25 m south of the forest edge.

Distance to Oil Sands Plants' Emissions: 64 km Direction: NW

Distance to Fort McMurray: 57 km Direction: WSW

How Far to All-Season Road: 43 km Direction: SW Surface: Paved

How Far to Winter Road: 33 km Direction: SW Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: N/A

Site Characteristics:

The site is near a forest edge and is a very flat lacustrine plain. The forest to the north is white and black spruce while the vegetation adjacent to the sampling site is shrubs and sedges with some black spruce. The area has its water table on the surface, which is reflected in the response of the vegetation to the moisture conditions. Accessibility to the site is difficult.

Site Influences on Integrity of Snow Samples:

Drifting of snow does not appear to occur here to any great extent. Other factors that could potentially influence the integrity of the snow samples are not significant.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There do not appear to be any site-specific factors that would adversely affect the quality of the snow samples collected at this site.

Site Name: Bitumont Site Identifier: HLS

57 0 22 " N	111 0 30 " W	6358000 N 467800 E	349 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The snow sampling site is within the clearing of Alberta Government Telephones' communications tower which is located about 3 km to the southeast of Bitumont Look-out tower. Specific it is to the east of the tower, approximately half way to the edge of the clear-cut along a winter road, and near one of the stakes of the AOSERP snow-course.

Distance to Oil Sands Plants' Emissions: 34 km Direction: S

Distance to Fort McMurray: 68 km Direction: S

How Far to All-Season Road: 19 km Direction: SSE Surface: Gravel

How Far to Winter Road: 10 m Direction: S Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 10 m Direction: S

Site Characteristics:

The site is a cleared area for a 75 m communications tower. Power is supplied by a continuously running, on-site, diesel-burning generator. It has two exhausts that are about 4 m above the ground and pointed upwards. There is a winter road that is used to service the facility. The forest cover is predominantly aspen with some jackpine and the groundcover is shrubby aspen.

Site Influences on Integrity of Snow Samples:

The ratio of tower height to sampling-site distance is below the 2.5 limit. The guy-wires are not directly over the sampling site and they too would have an effect of fall-through or splash. Exhaust from the diesel generator is continually emitted and exhaust from helicopters may also affect the snow sample's integrity.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The height of obstruction/distance to sample-site ratio is less than the desired 2.5 limit. Emissions from the diesel generator and ground and air traffic could lead to anomalously high rates of dry deposition onto the snowpack. The snow analyses from this site are valuable, however, in that the results can be used to determine if in-situ emissions are detectable from background anthropogenic pollutants.

Site Name: Johnson Lake Look-out Site Identifier: JSN

57 0 34 " N	110 0 119 " W	6381000 N 541000 E	594 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The sampling site is located in the middle of the Johnson Lake Look-out airstrip. There are no defined streams that can be followed in inclement weather to find the site.

Distance to Oil Sands Plants' Emissions: 96 km Direction: SW

Distance to Fort McMurray: 113 km Direction: SW

How Far to All-Season Road: 58 km Direction: E Surface: Gravel

How Far to Winter Road: 45 km Direction: WNW Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: W

Site Characteristics:

The sampling site is on the runway of the Johnson Lake Look-out airstrip. The strip is covered by sand and gravel with some grass. The topography surrounding the site is gently-rolling moraine. The forest cover is all pine with a few shrubs along the edges of the airstrip. Accessibility to the site is difficult because of its remote location.

Site Influences on Integrity of Snow Samples:

All-weather and winter roads are long distances from the site. Thus, road dust and exhausts do not influence the samples. The airstrip had not been used by aircraft prior to sampling the winter's snow. The 2.5 ratio of heights to sample site was obtained as the pines are only about 7 m tall while the airstrip is approximately 50 m wide. Windblown contaminants could pose a problem as the site is elevated and winds are generally strong, as judged by the wind-crusted snow.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The only problem with the site is the redistribution of snow and the potential for the wind to transport organic and inorganic materials.

Site Name: Lost Creek Site Identifier: LCK

57 0 20 " N	110 0 27 " W	6346000 N 533000 E	451 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is located on the Firebag River near the junction with a major unnamed stream that rises off Muskeg Mountain upland. Specifically it is about 20 m up the Firebag from the junction.

Distance to Oil Sands Plants' Emissions: 74 km Direction: SW

Distance to Fort McMurray: 88 km Direction: SW

How Far to All-Season Road: 77 km Direction: WSW Surface: Gravel

How Far to Winter Road: 48 km Direction: WSW Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: W

Site Characteristics:

The sampling site is on the Firebag River. The surrounding area is steeply sloping within the river valley and gently rolling above the valley bottom. The forest cover is primarily white spruce and pine with some aspen. The lowest areas of the flood plain are occupied by willows and other shrubs. Accessibility to the site is very difficult because of the remoteness of the site.

Site Influences on Integrity of Snow Samples:

There are no roads near the sampling site and, as such, any influences from overland traffic are minimal. The 2.5 ratio of heights to distance to the sample site could not be observed because of the heights of the trees relative to the width of the channel.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The 2.5 ratio could not be observed but, there are no lakes or natural forest clearings that could have been used in place of this site.

Site Name: Long Rapids Site Identifier: LGR

56 ^{0} 37 " N	111 ^{0} 57 " W	6276500 N 442200 E	469 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

LGR is 3.5 km north of the Athabasca River. It is a distinctive pond which can be located while flying along the north rim of the Athabasca River Valley about 35 km SW of Fort McMurray.

Distance to Oil Sands Plants' Emissions: 46 km Direction: NE

Distance to Fort McMurray: 35 km Direction: ENE

How Far to All-Season Road: 18 km Direction: NE Surface: Gravel

How Far to Winter Road: 18 km Direction: NE Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: N/A

Site Characteristics:

LGR is on a pond that measures about 150 m across. Ice occupies the center of the clearing with sedges and willows along the edges. The area is covered by ground moraine and there is an eight meter bluff to the north of the pond. There are no cut-lines in the immediate area so access is limited.

Site Influences on Integrity of Snow Samples:

The clearing and pond are sufficiently large that some redistribution of snow is occurring.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There are no significant deviations from ideal siting criteria that might adversely affect the integrity of the snow samples.

Site Name: Muskeg Look-out Site Identifier: MKG

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57 ^{0} 07 " N (Lat.) 110 ^{0} 53 " W (Long.) 6332000 N 506000 E (UTM Co-ordinates) 563 m asl (Elevation)

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The snow sampling site is in the middle of the Muskeg Look-out airstrip.

Distance to Oil Sands Plants' Emissions: 38 km Direction: WSW

Distance to Fort McMurray: 57 km Direction: SW

How Far to All-Season Road: 41 km Direction: WSW Surface: Paved

How Far to Winter Road: 23 km Direction: WNW Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

The site is the airstrip of the Muskeg Look-out tower. Their are no features with significant relief near the tower but, it is on a gently sloping upland. The forest cover is dominated by white spruce and aspen while the ground cover is mostly willows along the edge of the airstrip and grasses on the strip itself. Accessibility to the site is possible as a snow-machine had recently gone by.

Site Influences on Integrity of Snow Samples:

Snow drifting does not seem to occur to any significant degree at this site, probably because the airstrip is oriented perpendicular to the prevailing winds. Exhausts from snow-machines cannot be ruled out for affecting the snow samples as a machine had passed very close to the sampling site. The 2.5 ratio of heights to sample site was observed here so fall-through, splash, and organic debris deposits should not be excessive.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There do not appear to be any major problems with using this site for snow sampling. The off-road vehicle tracks are located throughout the Muskeg Mountain upland as the area appears to be heavily used by trappers.

Site Name: MacKay River Site Identifier: MKR

56 0 50 " N	112 0 18 " W	6300000 N 421300 E	460 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Algar Lake 84 A Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is most easily reached by first locating the MacKay River and then following it until the distinctive southerly bend in its course is found. To aid in confirming the location there will also be an unnamed stream entering the bend from the south and a cut-line from the north. The specific sampling site was in the middle of the MacKay River, where the creek enters it.

Distance to Oil Sands Plants' Emissions: 47 km Direction: Ne

Distance to Fort McMurray: 57 km Direction: ESE

How Far to All-Season Road: 29 km Direction: ESE Surface: Gravel

How Far to Winter Road: 29 km Direction: ESE Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

The site is located on the MacKay River. The river valley is very shallow, being about 5 m. There is a cut-line with a seismic clearing just to the north of the sampling site. The topography is flat and composed of lake deposits. The surrounding forest cover is aspen and white spruce. Willow and alder are common along the river banks. Overland accessibility to the site is good via the cut-lines and river.

Site Influences on Integrity of Snow Samples:

There is little drifting along the river, probably due to the meandering nature of the stream. The 2.5 ratio of tree heights to sample site was attained. There was little evidence of off-road vehicles using the cut-line or river for transportation routes over the winter.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There are no significant deviations from ideal siting criteria at this snow sampling site.

Site Name: N1 Site Identifier: N1

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56 0 59 " N	111 0 32 " W	6320900 N 466400 E	320 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is to the east of the bend in Highway #63 that is adjacent to Ruth Lake. The specific site is at the intersection of two cut lines that are approximately 115 m from the highway and about 40 m from a pond to the northeast. Helicopters are not allowed onto the site.

Distance to Oil Sands Plants' Emissions: 4 km Direction: ENE

Distance to Fort McMurray: 31 km Direction: SSE

How Far to All-Season Road: 0.11 km Direction: SW Surface: Paved

How Far to Winter Road: 0.11 km Direction: SW Surface: Paved

How Close do Off-road Vehicles Regularly Approach: 115 m Direction: SW

Site Characteristics:

The site is an old burn on the Suncor lease. It is a flat, muskeg area with black spruce snags and an under-story of shrubs that are mainly black spruce. The ground cover has been disturbed due to the numerous cut-lines that intersect this corner of the lease. Accessibility to the site is limited because permission to enter is required from Suncor.

Site Influences on Integrity of Snow Samples:

The highway is very near the site and contamination of the snow pack is highly probably from vehicular exhausts and from road-sanding. Both Syncrude and Suncor are within short distances and so, emissions from them may appear in the snow samples. Immediately to the west of the highway and on the Syncrude lease there is a large area that has been cleared of trees. The trees are not within the 2.5 ratio of height to sample site and so fall through and organic debris may be present in the samples. Overhead wires are located about 160 m to the west

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The site is near the highway and so, access is relatively easy considering the sample site is on Suncor's lease. The results of the snow analyses should indicate whether vehicular and road sanding materials do, in fact, add to the total snow loading.

Site Name: Mildred Lake Site Identifier: N2

57 ^{0} 04 " N (Lat.) 111 ^{0} 35 " W (Long.) 6324400 N 464500 E (UTM Co-ordinates) 320 m asl (Elevation)

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The sampling site is approximately 100 m to the east of Highway #63 and within a forest clearing that is north of the southeast-northwest runway of Syncrude's airport.

Distance to Oil Sands Plants' Emissions: 3 km Direction: SW

Distance to Fort McMurray: 40 km Direction: SSE

How Far to All-Season Road: 0.1 km Direction: SW Surface: Paved

How Far to Winter Road: 0.05 km Direction: N Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 50 m Direction: N

Site Characteristics:

The site is a man-made forest clearing. The land is generally flat with a few undulations of several meters. The ground cover has been disturbed but, there is a recolonization of the natural vegetation where vehicular traffic has not been heavy. Site accessibility is very easy as the highway is nearby and an all-season road is used to service the site.

Site Influences on Integrity of Snow Samples:

Dust accumulations from the clearing and from winter sanding on the adjacent highway may occur. The settling pond of Syncrude is just to the west of the site and it has exposed materials year-round. Exhausts from vehicles on the highway and from the oil sands emissions also occur. There is a telephone line along the east side of the highway. In addition, the site is about 65 m from an end of the Syncrude landing strip and would, therefore, be subjected to airplane exhausts.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The site is very close to an major road and to a frequently used airstrip. Accumulations from wind-blown contaminants, such as dust, from the sanding on the highway and from the edges of the settling pond to the west may be excessive. The site does conform to the 2.5 ratio of vegetation height to sample site and it is easily accessible for sampling. This site could be used to determine if wind blown materials and other dry deposited materials are noticeable in the chemical analyses.

Site Name: N4 Site Identifier: N4

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57 0 10 " N	111 0 37 " W	6335800 N 461900 E	225 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

N4 is located at the juncture of the MacKay and Athabasca Rivers. Specifically, it is between the mainland and a small island on the Athabasca.

Distance to Oil Sands Plants' Emissions: 13 km Direction: S

Distance to Fort McMurray: 51 km Direction: SSE

How Far to All-Season Road: 0.5 km Direction: W Surface: Gravel

How Far to Winter Road: 0.5 km Direction: W Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

The site is on the ice of the Athabasca River. The MacKay River is about 25 m to the west. The vegetation on the mainland and on the small island to the south is white spruce and aspen, with willow and alder. Accessibility to the site is very good as the MacKay River is used extensively by snow-machines. Highway #63 is approximately half a kilometer to the west. The settlement of Fort MacKay is about the same distance.

Site Influences on Integrity of Snow Samples:

The major site influence is from the exhausts of snow machines. The MacKay River is heavily used for off-road access by residents of Fort MacKay. The highway to the west is gravel covered and sand is applied during the winter. Fort MacKay is nearby, and emissions from the buildings may influence the integrity of the snow samples. There is a helicopter landing pad in the settlement and so, low-level air traffic is common.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There are a number of site parameters that deviate from the ideal siting criteria, however, the location is very easy to locate, even in poor flying weather.

Site Name: NE1 Site Identifier: NE1

57 0 03 " N	111 0 24 " W	6322900 N 477800 E	311 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is relatively easy to find because of the distinctive nature of a nearby cut-line. However, it is easiest to start from 2 km north of Suncor (near the "tall tower") and fly east along the cut-line above the valley bottom for approximately 6 km. A meandering cut-line should be visible. Where it first intersects the original cut-line, while travelling east is where the helicopter can land. The specific sampling spot is on the straight cut-line about 100 m from the intersection.

Distance to Oil Sands Plants' Emissions: 7 km Direction: SW

Distance to Fort McMurray: 35 km Direction: S

How Far to All-Season Road: 6 km Direction: SW Surface: Gravel

How Far to Winter Road: 6 km Direction: SW Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

The snow sampling site is on a cut-line surrounded by black spruce and tamarack. The topography is flat, being on lacustrine sediments. Accessibility is relatively easy along the cut-lines.

Site Influences on Integrity of Snow Samples:

Drifting did not appear to be occurring at this site. The proximity of the oil sands plants presents the possibility that their contaminants will be present in the snow, however, no dust or ash layers were found. The 2.5 ratio of heights to sample distance could not be observed as the cut-line was narrow while the trees were relatively tall.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The 2.5 ratio could not be achieved so there may be an increase in organic debris in the samples. There are no other sites in the area, however, that offer better alternatives. Being close to the oil sands plants and downwind may serve to compare where the heavier air-borne materials are deposited relative to the river sampling sites.

Site Name: NE3 Site Identifier: NE3

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57 ^{0} 07 " N	111 ^{0} 22 " W	6330100 N 475700 E	343 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is a difficult one to locate because there are no distinct landmarks. The easiest method is to start from NNE1 and proceed east about 11 km. The area in this location is covered by numerous north-south and east-west cut-lines. As well, the vegetation patterns indicate drainage flows and/or old burns, both of which trend north-south. The sampling location is in the east burn, near a discontinuous east-west cut-line that has two closely spaced (within 20 m) seismic clearing. Specifically, the snow-sampling site is along the stream, about 30 m to the south of the cut-line.

Distance to Oil Sands Plants' Emissions: 12 km Direction: SW

Distance to Fort McMurray: 42 km Direction: S

How Far to All-Season Road: 13 km Direction: W Surface: Gravel

How Far to Winter Road: 13 km Direction: W Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 30 m Direction: N

Site Characteristics:

The site is on a small stream that is located within an old burn. The topography is flat, with the stream being less than a meter below the general surface. The surrounding vegetation is almost exclusively willow and alder. Accessibility to the site is good along the cut-lines.

Site Influences on Integrity of Snow Samples:

There is no significant drifting of snow due to the sheltering effect of the shrubs. Some of the nearby cut-lines are very recent. The one nearest the sample site was constructed using heavy machinery during the current winter. The 2.5 ratio of vegetation height to sample distance could not be observed because of the narrowness of the stream.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The site is not ideal in terms of siting criteria but, within the region there do not appear to be any alternative locations. That is, there are no large streams or ponds that could facilitate a helicopter while retaining snow that would be unaffected by the down-wash.

Site Name: NE5 Site Identifier: NE5

57 ^{0} 14 " N	111 ^{0} 15 " W	6343200 N 483600 E	341 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The easiest way to locate this site is to take a north-south bearing from Kearl Lake. There is a non-continuous cut-line that heads south from it. On the cut-line's southern leg from Kearl Lake, and about 6 km south of the lake, there will be other cut-lines that intersect the original, longer cut-line. The sampling site is the pond that is about 20 m to the southwest of the intersection.

Distance to Oil Sands Plants' Emissions: 28 km Direction: SW

Distance to Fort McMurray: 59 km Direction: SSW

How Far to All-Season Road: 13 km Direction: W Surface: Gravel

How Far to Winter Road: 3 km Direction: N Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 20 m Direction: NE

Site Characteristics:

The site is a small pond on lacustrine deposits. A number of cut-lines pass-by very close to the site. They are very fresh, some in the vicinity are being cleared. Besides seismic operations the surrounding forest within a 5 km radius is presently being harvested.

Site Influences on Integrity of Snow Samples:

Ideally the pond is an excellent site for sampling snow. However, seismic and forest operations are being conducted very close to the site. There is increased dust, exhausts, and airborne organic debris associated with these activities.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The commercial operations that are being conducted near the snow sampling site reduce the quality of this site for obtaining snow samples. However, the chemistry analyses of the snow should indicate relatively high concentrations of constituents emitted from these operations.

Site Name: Namur Lake 84 H Site Identifier: NLK

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57 ^{0} 24 " N (Lat.) 112 ^{0} 43 " W (Long.) 6362000 N 395000 E (UTM Co-ordinates) 707 m asl (Elevation)

Map: Namur Lake 84 H Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The snow sampling site is near the shore line between the peninsula and the two large islands on the eastern side of the lake. Specifically, it is near the building at the base of the peninsula.

Distance to Oil Sands Plants' Emissions: 80 km Direction: SE

Distance to Fort McMurray: 111 km Direction: SE

How Far to All-Season Road: 65 km Direction: WSW Surface: Gravel

How Far to Winter Road: 59 km Direction: W Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 100 m Direction: E

Site Characteristics:

The site is about 15 m from the shore on Namur Lake and about 250 m from the islands. The topography surrounding the lake is rolling, composed of ground moraine. There has been a burn from the west to the edge of the lake. Some of the trees on the peninsula escaped the fire. Accessibility to the site is relatively easy during the winter, even though no tracks were observed during the sampling.

Site Influences on Integrity of Snow Samples:

No drifting was noticed, probably because of the protection offered by the nearby trees, even though they were burned. Sastrugi formations were observed further offshore, however. There is a building about 50 m from the sampling site but, there are no emissions from it during the winter.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There are no significant deviations from ideal siting criteria except that the burned-out area would not reduce wind speed as much as an un-burned forest. The potential increase in wind speed may result in more drifting with associated wind-blown contaminates than would otherwise exist.

Site Name: NNE1 Site Identifier: NNE1

57 0 12 " N	111 0 35 " W	6330700 N 464400 E	228 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is along the east side of the Athabasca River about 2 km above the bridge over the river. There is a small stream nearby that has cut through the banks of the river.

Distance to Oil Sands Plants' Emissions: 9 km Direction: S

Distance to Fort McMurray: 45 km Direction: SSE

How Far to All-Season Road: 1.8 km Direction: N Surface: Gravel

How Far to Winter Road: 1.8 km Direction: N Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

The site is along the edge of the Athabasca River. The banks of the river are about 20 m high and there is little vegetation covering them. The top of the banks are covered by aspen and pine while willows are found along the edge of the river. Accessibility to the site is good as off-road traffic tends to stay near the edges of the river.

Site Influences on Integrity of Snow Samples:

The snow was largely transported away from the site, and thus, sampling was conducted relatively near the shore. The banks of the river are exposed and accumulations of wind-blown inorganic materials may occur. Exhausts from the off-road vehicles may affect the integrity of the snow samples. The site is close to the oil sands plants and emissions from them may be noticeable in the snow.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

A site more removed from the river banks would have been better but the transport of snow away from the river channel prevented this. The site is easy to find, however.

Site Name: NNE3 Site Identifier: NNE3

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57 0 13 " N	111 0 30 " W	6341600 N	468900 E	293 m asl
Lat.	Long.	UTM Co-ordinates		Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site can be found most easily by following the Muskeg River to where it branches to the right from where two large ponds will be located. The sampling site is along the west shore of the pond to the west. Or, there is an all-weather road that turns off Highway #63 that it can be followed to within about 1 km of the site.

Distance to Oil Sands Plants' Emissions: 21 km Direction: S

Distance to Fort McMurray: 55 km Direction: S

How Far to All-Season Road: 0.8 km Direction: S Surface: Gravel

How Far to Winter Road: 0.8 km Direction: S Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 500 m Direction: E

Site Characteristics:

The site is a large pond about 350 x 150 m. The topography surrounding the pond is gently rolling. Aspen is the main forest cover while alder and willows ring the pond with sedges and cattails around the edges. Accessibility to the site is primarily by air but, off-road vehicles could easily reach it.

Site Influences on Integrity of Snow Samples:

The nearest all-weather road is about 800 m to the south. It is covered with gravel and is sanded during the winter. Wind blown materials from it could affect the quality of the samples, as well as the exhausts from the vehicles. The road is relatively well-used by heavy equipment as there are logging operations about 15 km to the east. The 2.5 ratio of heights to sampling distances is easily observed at this site.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There do not appear to be any significant problems with this site in terms of siting criteria. Off-road vehicle tracks were not observed near the site but, they could easily gain access to the pond.

Site Name: NNE4 Site Identifier: NNE4

57 ^{0} 16 " N	111 ^{0} 28 " W	6346100 N 471900 E	274 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is to the southeast of the All-sands lease and then to the east of the northern end of the landing strip. Specifically, it is along the creek near the circular clearing (where the helicopter can land).

Distance to Oil Sands Plants' Emissions: 27 km Direction: SSE

Distance to Fort McMurray: 62 km Direction: S

How Far to All-Season Road: 11 km Direction: SW Surface: Gravel

How Far to Winter Road: 0.25 km Direction: W Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 50 m Direction: N

Site Characteristics:

The general site is near the All-sands development and its landing strip. Specifically, the sampling location is on the stream to the east of the northeast corner of the strip. The surrounding topography is sloping in the immediate area because of the banks of the stream but, above this, the land is flat. The forest cover is largely aspen, pine, and black spruce while the under-story is shrubs and grasses. Accessibility to the site is very easy by vehicles during winter but, the large distance to populated areas result in reduced traffic.

Site Influences on Integrity of Snow Samples:

The air strip and the All-sands development occupy large tracts of land that have been cleared of their natural vegetation. Because of this there is a greater likelihood for the redistribution of snow and the potential for wind-blown organic and in-organic contaminants. The creek is relatively narrow and therefore, the 2.5 ratio of heights to sampling distance could not be observed. Fall-through, splash, and organic debris could possibly influence the snow-chemistry results.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There are very few good sampling sites in this location due to few landing sites for the helicopter that offer the necessary distance separating it and the sampling spot. Because of this the 2.5 ratio of height of obstruction to distance of sampling site could not be observed.

Site Name: Thickwood Site Identifier: NNW1

57 ^{0} 11 " N	111 ^{0} 52 " W	6335700 N 446800 E	335 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is on a Beaver Pond about 200 m north of the Dover River. The most reliable method for finding it is to locate the meanders along the river, combined with the intersection of the long, angled cut-line north of the river, and the shorter cut-line that makes a jog where it crosses the river. Specifically, the sampling site on the highest beaver pond, by its southwest corner.

Distance to Oil Sands Plants' Emissions: 22 km Direction: SE

Distance to Fort McMurray: 57 km Direction: SE

How Far to All-Season Road: 13 km Direction: E Surface: Gravel

How Far to Winter Road: 11 km Direction: NE Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 50 m Direction: SE

Site Characteristics:

The snow sampling site is on the ice of a beaver pond. The topography is flat, on lacustrine sediments and aspen and spruce are the dominant tree species. In the shallow portions of the beaver dam there are sedges and cattails growing. Accessibility to the site is relatively easy along the river and the cut-lines.

Site Influences on Integrity of Snow Samples:

Wind transported materials collect on the lee side of obstructions, however, there was no drifting in the area. Tracks of off-road vehicles were not apparent.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The site has no significant qualities that would negatively affect the snow samples.

Site Name: NW3 Site Identifier: NW3

57 ^{0} 02 " N	111 ^{0} 45 " W	6321800 N 456800 E	341 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is between the MacKay River and Syncrude. It is about 5 km directly west of the cleared area on the western edge of Syncrude's lease. Near the site two cut-lines form a "T", while a long diagonal cut-line comes within 10 m of the cross on the "T". Specifically, it is on the beaver pond to the north of this cut-line intersection.

Distance to Oil Sands Plants' Emissions: 7 km Direction: E

Distance to Fort McMurray: 40 km Direction: SE

How Far to All-Season Road: 3 km Direction: E Surface: Gravel

How Far to Winter Road: 3 km Direction: E Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 30 m Direction: S

Site Characteristics:

NW3 is on a beaver pond to the west of Syncrude. The topography in the area is flat, with lacustrine sediments. The vegetation is predominantly black spruce and aspen. Willows, sedges, and cattails are found along the edges of the pond. Accessibility to the site is facilitated by the numerous cut-lines in the area.

Site Influences on Integrity of Snow Samples:

The site is within several kilometers of Syncrude and so, whenever there are easterly winds the location will be affected to some degree by the emissions and wind blown contaminants.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There are no significant deviations from ideal siting criteria to consider. The numerous cut-lines in the area do not necessarily mean that there are many off-road vehicles using the area as Syncrude's lease would have to be crossed to easily gain access to the site.

Site Name: New Lake Site Identifier: NWL

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56 0 44 " N	110 0 46 " W	6286000 N 509000 E	463 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is easily found by following the Clearwater River to where a small tributary stream can be followed to the pond. Or, a heading can be taken from the large (2 km diameter) lake to the east-southeast of the site.

Distance to Oil Sands Plants' Emissions: 42 km Direction: NW

Distance to Fort McMurray: 37 km Direction: W

How Far to All-Season Road: 25 km Direction: SW Surface: Paved

How Far to Winter Road: 16 km Direction: SW Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: N/A

Site Characteristics:

NWL is a beaver pond perched on the edge of the uplands above the Clearwater River Valley. The topography is flat on the plain and steeply sloping to the river below. Pine is the major tree species surrounding the pond but aspens are common on the slopes of the Clearwater River Valley. Forest harvesting has been conducted on the north-facing slopes across the valley.

Site Influences on Integrity of Snow Samples:

There are few influences that would compromise the quality of the snow samples taken at this site. The ratio of heights to sampling distance just makes the recommended value of 2.5. If the harvesting across the valley is current then there may be some anomalous concentrations in the samples.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There do not appear to be any significant deviations from ideal siting criteria other than the possibility that harvesting operations are presently going on.

Site Name: RO Site Identifier: RO

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56 ^{0} 48 " N	111 ^{0} 24 " W	6295000 N 475000 E	231 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

RO is located on the Athabasca River near the north end of Poplar Island. It is about 8 km north of the Fort McMurray city center.

Distance to Oil Sands Plants' Emissions: 16 km Direction: NNW

Distance to Fort McMurray: 8 km Direction: S

How Far to All-Season Road: 2 km Direction: W Surface: Paved

How Far to Winter Road: 2 km Direction: W Surface: Paved

How Close do Off-road Vehicles Regularly Approach: 50 m Direction: E

Site Characteristics:

The site is on the ice of the Athabasca River near Poplar Island. The flood plain is about 80 m below the top of the valley. The forest cover is primarily white spruce and aspen. Poplar Island is vegetated by willows and other shrubs. Accessibility to the site is good, but most off-road drivers stay to the shores of the river.

Site Influences on Integrity of Snow Samples:

There is a degree of drifting of snow at this site. A saw-mill is located nearby with its incinerator and associated smoke. The site is one of the closest to the city center. The main highway is about 2 km from the sampling site and exhausts from the vehicles may influence the integrity of the snow samples.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The site has many factors that could influence the quality of the snow samples. However, the presence of the nearby highway traffic, the city, and the incinerator should provide a check to determine if the emissions and exhausts from these can be detected in a relative sense.

Site Name: R1 Site Identifier: R1

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56 0 56 " N	111 0 25 " W	6309200 N 473300 E	229 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The sampling site is between two islands on the Athabasca River about 15 km below Fort McMurray's northern city limit and approximately 2.5 km northeast of Highway #63's "super-test" hill.

Distance to Oil Sands Plants' Emissions: 9 km Direction: NNW

Distance to Fort McMurray: 22 km Direction: S

How Far to All-Season Road: 1.9 km Direction: W Surface: Paved

How Far to Winter Road: 1.9 km Direction: W Surface: Paved

How Close do Off-road Vehicles Regularly Approach: 35 m Direction: E

Site Characteristics:

The site is on the Athabasca River between two islands. The surrounding flood plain and islands are vegetated by aspen and white spruce; willows predominate in the under-story. Accessibility to the site is good as the edges of the river are used by snow-mobilers.

Site Influences on Integrity of Snow Samples:

The snow on the river's ice is prone to drifting. Dust from the settling ponds of Suncor and from Highway #63 may also pose problems. The island to the north has a vertical bank that is snow-free and composed of fine alluvial deposits. Windblown materials from this may affect the chemistry of the snow. Emissions from off-road vehicles and from autos on Highway #63 could also influence the quality of the snow. Also, a sawmill, and its associated incinerator, are several kilometers upstream.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The major disadvantages of the site is its location at the bottom a large river valley. As such, winter inversions trap emissions from vehicular traffic, the sawmill's incinerator's smoke, and from Suncor's stacks and dust from the settling pond. The dry deposition from these should be evident in the chemical analyses. Also, the exposed bank on the island may locally increase the amount of contamination.

Site Name: R2 Site Identifier: R2

56 0 57 " N	111 0 27 " W	6313200 N 472700 E	229 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

R2 is a site along the Athabasca River near the first island above the holding pond of Suncor. It is approximately midway between the island's east side and the mainland.

Distance to Oil Sands Plants' Emissions: 4.7 km Direction: NW

Distance to Fort McMurray: 26 km Direction: S

How Far to All-Season Road: 1.9 km Direction: W Surface: Paved

How Far to Winter Road: 1.9 km Direction: W Surface: Paved

How Close do Off-road Vehicles Regularly Approach: 30 m Direction: E

Site Characteristics:

R2 is situated along the Athabasca River. It is approximately 2 km above Suncor's holding pond. It is almost midway between the island and the mainland. There is an exposed 2 m bank on the south end of the island. The vegetation on the island is predominantly aspen and alder.; on the floodplain it is white spruce and aspen, with willows along the shore. Accessibility by off-road vehicles is possible but, snow-mobilers tend to stay close to the shore.

Site Influences on Integrity of Snow Samples:

The exposed bank could present problems to the integrity of the snow samples collected as wind-blown materials could be transported onto the snowpack. The proximity of Suncor's holding pond and the emissions from the plant might also be reflected in the chemical analysis of the snowpack. Highway #63 is about 2 km from the site. Emissions from vehicular traffic using the road may have an effect on the quality of the snow.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The exposed bank on the upstream-side of the island, the smoke from the saw mill's incinerator, and the proximity of Highway #63 might pose problems in terms of deviations from ideal siting criteria.

Site Name: R3 Site Identifier: R3

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56 0 59 " N	111 0 25 " W	6316500 N 473400 E	228 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

R3 is located on the outside bend of the Athabasca River across from the settling pond at Suncor. There is an old abandoned dock near the specific site.

Distance to Oil Sands Plants' Emissions: 2.5 km Direction: NW

Distance to Fort McMurray: 29 km Direction: S

How Far to All-Season Road: 2 km Direction: W Surface: Gravel

How Far to Winter Road: 2 km Direction: W Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

The snow sampling site is situated on the east side of the Athabasca River, across from the dike of Suncor's settling pond. The forest cover along the east bank is aspen with shrubs immediately adjacent to the river. Accessibility is potentially easy via snow-machines, but thin ice due to Suncor's water discharge may discourage snow-machine use near the plant.

Site Influences on Integrity of Snow Samples:

Dust from the settling ponds and the heavy earth-moving equipment may affect the snow samples. Also, the snow on the river is prone to redistribution by wind. Fall-out from the stacks may pose a problem as the site is very close to the processing area. Downstream, about 1.5 km, sulphur, that has been scrubbed-out, is stored before being re-transported by trucks. In addition, a saw mill incinerator is in operation about 14 km upstream.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The snow chemistry results will probably result in anomalous concentrations of certain constituents because of the many site influences in operation near this site. Also, the site is in the river valley bottom so inversions and their associated reductions in ventilation could affect the chemistry results.

Site Name: R4 Site Identifier: R4

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57 ^{0} 03 " N (Lat.) 111 ^{0} 29 " W (Long.) 6321100 N 469800 E (UTM Co-ordinates) 226 m asl (Elevation)

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is situated along the Athabasca River near the south end of the island that is downstream from the mouth of the Steepbank River. Specifically, it is about 12 m west of the island in the main channel of the Athabasca River.

Distance to Oil Sands Plants' Emissions: 3 km Direction: S

Distance to Fort McMurray: 35 km Direction: S

How Far to All-Season Road: 1 km Direction: W Surface: Gravel

How Far to Winter Road: 1 km Direction: W Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 60 m Direction: E

Site Characteristics:

The site is near an island in the Athabasca River. The island has a three meter exposed bank. The vegetation cover on the island is aspen and alder. Accessibility to the site is limited for off-road traffic as the sample site is near the middle of the river and off-road vehicles tend to stay near the shore.

Site Influences on Integrity of Snow Samples:

The exposed river bank could pose a problem to the integrity of the snow samples due to wind-transported non-organic materials. With the site being close to the oil sands plants there could also be accumulations of materials from them. (There was, in fact, much dust in the snow during the 1986 sampling survey). There are a number of access roads nearby, too.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The exposed bank along the island could result in earth materials being transported by the wind. The proximity of the oil sands plants should also be evident in the analysis of the snow samples.

Site Name: Richardson Look-out Site Identifier: RIC

57 0 53 " N	111 0 03 " W	6415100 N 497700 E	297 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The sampling site is on a lake about 4.3 km to the WSW of Richardson Look-out tower and 1.0 km to the southwest of the landing strip. The specific location is approximately 25 m to the SE of the lone island in the middle of lake.

Distance to Oil Sands Plants' Emissions: 95 km Direction: SSW

Distance to Fort McMurray: 128 km Direction: SSW

How Far to All-Season Road: 79 km Direction: SSW Surface: Gravel

How Far to Winter Road: 1 km Direction: N Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 1000 m Direction: N

Site Characteristics:

The lake is approximately 700 m by 350 m and the island is near its center. The surficial materials of the surrounding area are composed of glacial outwash materials and eolian deposits. The general topography is made up of small undulating hills and depressions. The forest is open, park-like stands of jackpine with a ground-cover of lichens. A large forest fire has occurred recently to the south. A winter road passes about 1 km to the east and north.

Site Influences on Integrity of Snow Samples:

Snow and dust accumulations were not evident in the snowpack as the small island does not appear to affect the surface wind-flows. The height ratio between trees and the distance to the sample site is much greater than the recommended minimum of 2.5.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

This site is an ideal setting for obtaining snow samples. As such, there do not appear to be any major deviations from the desired siting criteria. Winters that have light snow covers and strong winds could result in contamination of the snow pack because of the nature of the surrounding surficial materials.

Site Name: Sandalta Site Identifier: SALT

57 0 13 " N	111 0 22 " W	6340100 N 476000 E	308 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is located along the Hartley Creek. The on-site tower is visible from many kilometers away.

Distance to Oil Sands Plants' Emissions: 24 km Direction: SW

Distance to Fort McMurray: 57 km Direction: S

How Far to All-Season Road: 3 km Direction: N Surface: Gravel

How Far to Winter Road: 3 km Direction: N Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 50 m Direction: N

Site Characteristics:

The site is a communications-tower forest clearing. The tower is about 25 m tall and a power line comes into the clearing from the north. The surrounding trees are primarily white spruce and aspen while the ground cover is dominated by a re-growth of aspen. The site is accessible along the power line right-of-way.

Site Influences on Integrity of Snow Samples:

The 2.5 ratio of heights to sampling site was observed at the site. The presence of the tower and the nearby power line may exert some influence on the snow chemistry. There is a building on the site but it appears that electricity is the power source, so there would be no emissions from the building.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The building, power lines, and tower may influence the quality of the snow samples. However, in this area there are no lakes or clearings that might otherwise be used.

Site Name: SE3 Site Identifier: SE3

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56 ^{0} 57 " N	111 ^{0} 15 " W	6311700 N 484300 E	360 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

SE3 is along the Steepbank River, about 16 km from the junction with the Athabasca River. The specific location is half-way between the two small tributary streams that enter the Steepbank from the east.

Distance to Oil Sands Plants' Emissions: 14 km Direction: WNW

Distance to Fort McMurray: 27 km Direction: SW

How Far to All-Season Road: 13 km Direction: W Surface: Paved

How Far to Winter Road: 13 km Direction: W Surface: Paved

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

The site is on the ice of the Steepbank River. The river valley is about 30 m below the surrounding plain, which is flat and composed of lake sediments. As the river's name suggests, its banks are steep. The forest cover in the valley is a mature stand of white spruce with some aspen along disturbed sites. Willows and alder are present along the edge of the river. Accessibility is good along the river.

Site Influences on Integrity of Snow Samples:

The site is downwind of and relatively close to the oil sands plants. This snow samples may reflect this. The narrowness of the river relative to the tall spruce did not permit the 2.5 ratio of heights to sampling site to be observed. The location is used quite heavily by off-road snow-machines.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The 2.5 ratio of tree heights to sampling distance could not be observed here. There were no alternatives as there are no other sites available in the near surroundings that offer room enough for a helicopter to land without disturbing the snow-pack. As such, the snow will be affected by fall through, splash, and organic debris. Snow machines pass by often. Their exhausts may have an effect on the samples.

Site Name: SE5 Site Identifier: SE5

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56 ^{0} 53 " N (Lat.) 111 ^{0} 07 " W (Long.) 6311700 N 484300 E (UTM Co-ordinates) 448 m asl (Elevation)

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is about 4 km east of the Steepbank River on a near-circular pond. The pond is the only one in the vicinity and so it can not be easily mistaken.

Distance to Oil Sands Plants' Emissions: 24 km Direction: NW

Distance to Fort McMurray: 23 km Direction: SW

How Far to All-Season Road: 20 km Direction: W Surface: Paved

How Far to Winter Road: 11 km Direction: SW Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: N/A

Site Characteristics:

The site is on a pond that is about 150 m in diameter. It is on a flat lacustrine plain surrounded by black spruce with some shrubs around the perimeter. There are no cut-lines in the immediate area and so, off-road traffic is light.

Site Influences on Integrity of Snow Samples:

The site is downwind of the oil sands plants. This may result in relatively high loadings in the snow. The 2.5 ratio was easily met as the pond is wide while the trees are not fully developed.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There are no significant deviations from ideal siting criteria that would adversely affect the integrity of the samples.

Site Name: Stony Mountain Site Identifier: SMT

56 0 22 " N	111 0 16 " W	6249100 N 482900 E	762 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is located on top of Stony Mountain, to the south of Fort McMurray. It about 4 km to the west of the forest-fire look-out tower. The easiest way to get there is to follow the road that goes up to the communications tower. The specific site, once on top, is to the south of the communications tower and in the clearing that is about 40 m to the north of the MAPS tower.

Distance to Oil Sands Plants' Emissions: 72 km Direction: NNW

Distance to Fort McMurray: 41 km Direction: N

How Far to All-Season Road: 0.1 km Direction: N Surface: Gravel

How Far to Winter Road: 0.1 km Direction: N Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

The site is a government facility that is used for a communications tower. It has been cleared but aspen and shrubs have begun to re-colonize. The surrounding forest is primarily aspen with some willows and alders. The top of Stony Mountain is relatively flat, but there is about 300 m of relief between it and Highway #63, below. Accessibility to the site is very easy. The area is extensively used by off-road vehicles.

Site Influences on Integrity of Snow Samples:

There is some drifting of snow on the plateau. Dust and vehicle exhausts could influence the chemistry of the snow samples as the site is heavily used by snow-machines. Sampling was conducted about 40 m from the smaller tower and about 250 m from the tall tower to minimize the effects of splash.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The amount of off-road vehicle activity in the area may pose a problem when interpreting the chemistry results. The redistribution of snow is also a concern but there are few sites on this elevated plateau that are large enough for a helicopter to land without affecting the snow with down-wash and at the same time small enough to inhibit drifting.

Site Name: SSW1 Site Identifier: SSW1

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56 ^{0} 51 " N 111 ^{0} 29 " W __ N __ E 347 m asl

Lat. Long. UTM Co-ordinates Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

This site can be difficult to find given limited visibilities and so, it may be less time consuming to start from a known point. The best way is to start from the Athabasca River from the unnamed island that is about 1 km to the south of Willow Island. From the southern end of this unnamed island proceed east along the cut-line. The site will be 1.5 km past the power line, and about 50 m to the north, in the beaver pond.

Distance to Oil Sands Plants' Emissions: 17 km Direction: N

Distance to Fort McMurray: 14 km Direction: SE

How Far to All-Season Road: 3.2 km Direction: E Surface: Paved

How Far to Winter Road: 3.2 km Direction: E Surface: Paved

How Close do Off-road Vehicles Regularly Approach: 50 m Direction: S

Site Characteristics:

The site is on the ice of a beaver pond. The surrounding topography is lacustrine flats. The forest cover is predominantly black spruce with sedges, cattails, and shrubs along the edges of the beaver pond. The beaver lodge is actively being trapped.

Site Influences on Integrity of Snow Samples:

There is some entrapment of snow by the beaver dam but drifting is not extreme. The beaver lodges are being actively trapped and so, there has been extensive snow-machine travel near the sampling site.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The relatively heavy use of the area by off-road vehicles is the most significant deviation from ideal siting criteria. As well, there is some redistribution of snow due the relatively large fetch of this and other connecting beaver ponds.

Site Name: SW1 Site Identifier: SW1

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56 ^{0} 59 " N	111 ^{0} 33 " W	6315800 N 466400 E	320 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterway 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

SW1 is located on the east side of Ruth Lake where Highway #63 makes its closest approach to the Lake.

Distance to Oil Sands Plants' Emissions: 5 km Direction: NE

Distance to Fort McMurray: 29 km Direction: SSE

How Far to All-Season Road: 0.1 km Direction: E Surface: Paved

How Far to Winter Road: 0.1 km Direction: E Surface: Paved

How Close do Off-road Vehicles Regularly Approach: 100 m Direction: E

Site Characteristics:

SW1 is on Ruth Lake, near its northeast end. It is close to Highway #63 and there is power line that runs between the highway and the sampling site. On the far side of the highway is the overburden from Suncor's open pit mine. Most of the vegetation has been removed from the surrounding area but, there is a stand of white spruce and aspen to the southwest of the sampling site. Accessibility is very easy as there is a service road off Highway #63 near where the snow samples are collected.

Site Influences on Integrity of Snow Samples:

The emissions and wind blown contaminants from both Syncrude and Suncor impinge upon the sampling site. In addition, there are power lines and a major highway nearby.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

Many of the site selection considerations deviate from the ideal at this site. Contaminants from the open-pit mines, the highway, etc., would affect the samples.

Site Name: SW3 Site Identifier: SW3

56 ^{0} 53 " N	111 ^{0} 37 " W	6306500 N 461500 E	350 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

This site can be difficult to find in poor flying conditions. It is easiest found by locating the east-west cut-line that is 1.5 km south of the lake that is downstream of Ruth Lake. Follow it for 9 km to the west and the site will then be located about 30 m to the north of the cut-line.

Distance to Oil Sands Plants' Emissions: 15 km Direction: NE

Distance to Fort McMurray: 23 km Direction: SE

How Far to All-Season Road: 8 km Direction: NE Surface: Gravel

How Far to Winter Road: 8 km Direction: NE Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 30 m Direction: N

Site Characteristics:

SW3 is on a depressional area of a flat lacustrine plain. The water table is at the surface and so, there is some ice below the snow. There are cattails and sedges immediately around the sampling site with white spruce and aspen surrounding the opening. Accessibility is relatively easy along the cut-line to the south. There are a number of snags near the site, which indicate that a burn has occurred in the past.

Site Influences on Integrity of Snow Samples:

There is some drifting occurring among the cattails in the opening. The 2.5 ratio of heights to sampling sites was observed but, the distance to the low cattails was relatively close, so there may be some transport of organic debris. The cut-line to the south is about 30 m away but, there was no evidence that it has been used for off-road travel.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The cattails could present problems in terms of organic debris. Other than that, there do not appear to be any major deviations from ideal siting criteria that would adversely affect the snow samples.

Site Name: SW5 Site Identifier: SW5

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56 ^{0} 50 " N	111 ^{0} 43 " W	6296400 N 455900 E	462 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is on a large pond which is part of a tributary of the Beaver River. It is about 8 km to the NE of Thickwood Tower. A large (15 m wide) cut-line traverses the region to west.

Distance to Oil Sands Plants' Emissions: 26 km Direction: NE

Distance to Fort McMurray: 22 km Direction: SE

How Far to All-Season Road: 3 km Direction: SW Surface: Gravel

How Far to Winter Road: 3 km Direction: SW Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 300 m Direction: NW

Site Characteristics:

SW5 is on a large pond near the Thickwood forest tower. There is a large cut-line, which is a pipeline right-of-way, about 300 m to the NW. Immediately to the east there has been forest harvesting activities. A black spruce bog is located to the south and southeast of the pond. Accessibility to the site is relatively easy along the roads constructed for the forest operations and along the cut-line to the NW.

Site Influences on Integrity of Snow Samples:

The pond is sufficiently large that drifting of snow occurs. Access to the site is relatively easy but, there were no off-road vehicle tracks observed at the time of sampling. The forest operations on the east side of the pond may have an influence on the snow. An all-season gravel road passes to the SW, about 3 km away.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There do not appear to be any significant deviations from ideal siting criteria. The nearby logging took place in previous years so there may not be any influences on the snow chemistry.

Site Name: Upper Tar Lake Site Identifier: UTL

57 ^{0} 39 " N	112 ^{0} 18 " W	6391000 N 421800 E	693 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Namur Lake 84 H Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

UTL is within a small bay near its southeast shore on Otasan Lake (which is also refered to as Sand Lake on some maps).

Distance to Oil Sands Plants' Emissions: 80 km Direction: SE

Distance to Fort McMurray: 116 km Direction: SE

How Far to All-Season Road: 53 km Direction: SE Surface: Gravel

How Far to Winter Road: 31 km Direction: E Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: >1000 m Direction: W

Site Characteristics:

The sampling site is on a large lake which is situated on the Birch Mountain upland. The topography surrounding the lake is undulating ground moraine. The forest cover is white spruce and pine with shrubs in the under-story. Accessibility to the site by ground is possible as there are numerous cut-lines in the area.

Site Influences on Integrity of Snow Samples:

The size of the lake is conducive for drifting to occur, however, this had occurred previous to sampling, judging by the density of the snow. The actual site is in a small bay which may protect it from strong westerly winds. The 2.5 ratio of heights to sampling distance was easily observed and so fall through, splash, and organic debris accumulations should be minimal.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

There do not appear to be any significant problems with the site that would adversely affect the integrity of the samples.

Site Name: W1 Site Identifier: W1

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56 ^{0} 59 " N	111 ^{0} 41 " W	6316100 N 459700 E	302 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

W1 is on a beaver pond about 3 km to the west of the western-most lake on the south of Syncrude's lease. It can be reached by following the power-line/road that runs west from the said lake and then by turning north for about 60 m after going the required distance.

Distance to Oil Sands Plants' Emissions: 7 km Direction: NE

Distance to Fort McMurray: 34 km Direction: SE

How Far to All-Season Road: 3 km Direction: E Surface: Gravel

How Far to Winter Road: 0.1 km Direction: S Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 100 m Direction: S

Site Characteristics:

W1 is located on a beaver pond several kilometers to the west of the oil sands plants. The topography is relatively featureless. The forest cover is dominated by black spruce with some aspen. Shrubs and sedges are common along the edges of the beaver pond. There is a large beaver lodge on the pond. Accessibility is relatively easy along the power-line right-of-way.

Site Influences on Integrity of Snow Samples:

The snow sampling site is within a few kilometers of the oil sands plants and so, whenever there are easterly winds the emissions from their stacks and wind blown contaminants from the settling ponds and open-pit mines would have an effect on the snow chemistry.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The site is relatively close to the oil sands plants and to a road (which does not have major activity). Other than that, the siting appears to be well suited for taking snow samples.

Site Name: W3 Site Identifier: W3

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56 ^{0} 56 " N (Lat.) 111 ^{0} 52 " W (Long.) 6310300 N 447300 E (UTM Co-ordinates) 427 m asl (Elevation)

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

This site is relatively difficult to find. It is easiest to locate by following the power lines that run to the southwest from Syncrude. From where the right-of-way straightens out into the southwest-northeast orientation proceed 7 km. To the northwest of where two other cut-lines intersect at right angles the beaver pond that the site is situated on will be seen. The specific sampling site is in the snags to the northeast of the beaver pond (where the helicopter should land).

Distance to Oil Sands Plants' Emissions: 19 km Direction: NE

Distance to Fort McMurray: 37 km Direction: SE

How Far to All-Season Road: 13 km Direction: NE Surface: Gravel

How Far to Winter Road: 13 km Direction: NE Surface: Gravel

How Close do Off-road Vehicles Regularly Approach: 50 m Direction: S

Site Characteristics:

The site is in a seasonally wet area surrounded by black spruce. The ground cover is willows, cattails, and sedges. The surrounding topography has very little relief and is composed of lake deposits.

Site Influences on Integrity of Snow Samples:

The 2.5 ratio of heights to sample site is exceeded but, the willows, which are about one to two meters high, are not greater than two and half times their heights away from the sample sites. Fall through, splash, and organic debris could affect the snow samples. The power lines are about 100 m away, to the southeast.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The minimum ratio of heights to sampling distance was not achieved at this site. In the immediate area there do not appear to be any sites that would be more suitable for collecting snow samples.

Site Name: Wood Creek Site Identifier: WCK

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56 ^{0} 53 " N	111 ^{0} 15 " W	6304800 N 483300 E	396 m asl
Lat.	Long.	UTM Co-ordinates	Elevation

Map: Waterways 74 D Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

WCK is situated on a beaver pond along Wood Creek. It can be found by following the creek to where it is crossed by a meandering cut-line, which is approximately 9 km east of the Athabasca River and 4 km west of the Steepbank River.

Distance to Oil Sands Plants' Emissions: 19 km Direction: NW

Distance to Fort McMurray: 18 km Direction: SSW

How Far to All-Season Road: 12 km Direction: W Surface: Paved

How Far to Winter Road: 12 km Direction: W Surface: Paved

How Close do Off-road Vehicles Regularly Approach: 100 m Direction: SW

Site Characteristics:

WCK is on one of a series of beaver ponds across Wood Creek, which is about 10 m below the plain above. The larger trees are all dead, probably due to an old burn or to changes in the water lever from flooding by the beaver dams. The vegetation in the immediate area is willow and dwarf birch; around the pond white spruce and aspen dominate. Accessibility to the site is difficult as the nearest cut-line is about 100 m away.

Site Influences on Integrity of Snow Samples:

The 2.5 ratio of height to distance of sample site could not be observed here. This indicates that there will be fall-through and organic debris affecting the quality of the snow samples.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

The ratio of height of obstruction to distance of sample site was less than desireable at this site. There are no other sites available along the creek or at locations nearby that could have been used instead.

Site Name: Wolf Lake Site Identifier: WLK

57 0 24 " N	111 0 52 " W	6361600 N	450300 E	317 m asl
Lat.	Long.	UTM Co-ordinates		Elevation

Map: Bitumont 74 E Series: Alberta ENR Scale: 1:250 000

Description of How to Reach Site:

The site is most easily located by taking a bearing from Calumet Lake. The unique shape of the sampling site's pond and the distinct curve in the north-south cut-line around the pond make the site relatively easy to find.

Distance to Oil Sands Plants' Emissions: 41 km Direction: SSE

Distance to Fort McMurray: 78 km Direction: SSE

How Far to All-Season Road: 25 km Direction: SSE Surface: Gravel

How Far to Winter Road: 7 km Direction: NE Surface: Packed Snow

How Close do Off-road Vehicles Regularly Approach: 5 m Direction: N/A

Site Characteristics:

The site is located on a beaver pond within a drainage channel that comes off the Birch Mountains upland. The topography is sloping on the sides of the channel but, it is flat on the ground moraine above. The forest cover is predominantly white spruce and aspen while the shrubs are mostly willows and alders. A cut-line crosses the west side of the pond and it is relatively well used by off-road vehicles.

Site Influences on Integrity of Snow Samples:

The most significant site influence is the apparent heavy use of the cut-line and stream channel by off-road vehicular traffic. At the time of the sampling the channel had been used several times by snow-machines since the last snowfall. The 2.5 ratio of heights to sample distance was obtained at this site.

Site Selection Considerations and Deviations From Ideal Siting Criteria:

Off-road traffic is relatively heavy at this sampling site and in the region surrounding it. This is probably due to the ease of access in this part of the Oil Sands area with several good winter roads that have been used for forestry operations. Other alternative sites probably experience similar levels of off-road traffic.

8.4 Appendix IV - Location of Sites

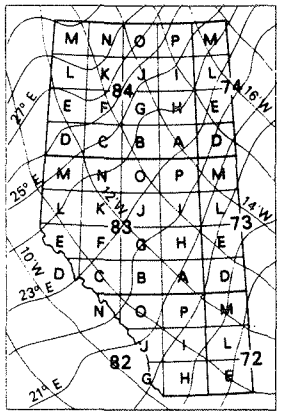
Legend for Figures 74 to 87:

CITY GRANDE PRAIRIE
TOWN BEAVERLODGE
VILLAGE
HAMLET
LOCALITY
POST OFFICE P
STATION
RAILWAY
TOWNSHIP LINE, SURVEYED
TOWNSHIP LINE, UNSURVEYED
SECTION LINE
PIPELINE

PRIMARY HIGHWAY 22
DIVIDED
PAVED
GRAVEL
SECONDARY ROAD 670
PAVED
GRAVEL
IMPROVED ROAD
UNIMPROVED ROAD
TRUCK TRAIL
TRAIL OR SEISMIC LINE
TRANSMISSION LINE

AIRSTRIP LENGTH & ELEVATION IN HUNDREDS OF METRES 13 9
REGULAR MAINTENANCE 13 9
OCCASIONAL MAINTENANCE 13 9
HELIPORT HELIPAD
FLOAT LANDING
FOREST HEADQUARTERS
RANGER STATION
FORESTRY CABIN
LOOKOUT PRIMARY
LOOKOUT SECONDARY
LOOKOUT POINT
CAMPGROUND

MAGNETIC CHART OF ALBERTA
FOR EPOCH 1980.0



AVERAGE DECLINATION OF THE COMPASS IN DEGREES
ANNUAL CHANGE OF DECLINATION IN MINUTES OF ARC

SCALE 1 : 250 000

km 5 0 5 10 15 20 km
miles 5 0 5 10 15 miles

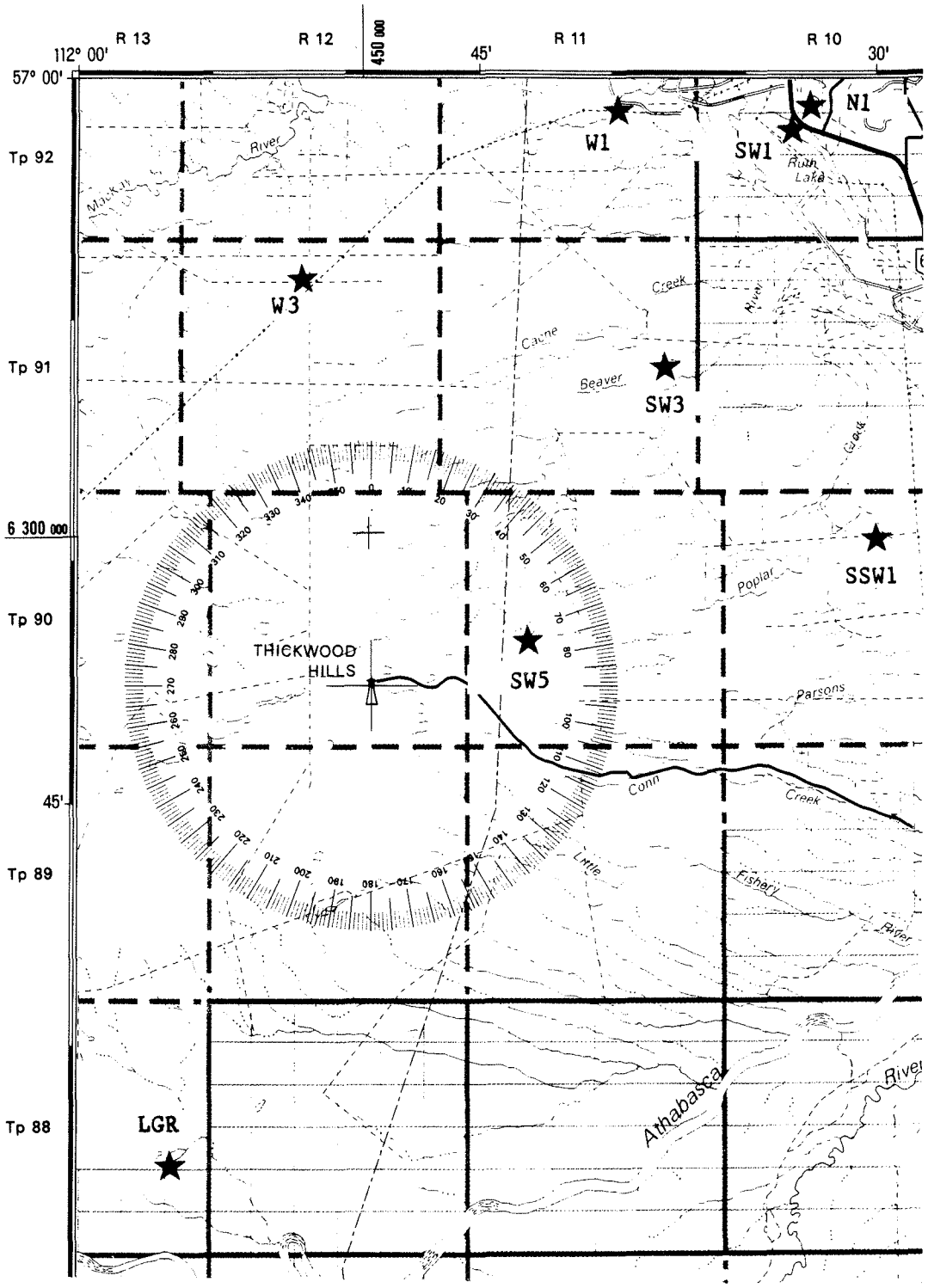


Figure 74: Site locations of N1, SW1, W1, SW3, W3, SSW1, SW5, and LGR. (Background map Alberta Energy and Natural Resources, 1:250 000, Waterways 74 D.)

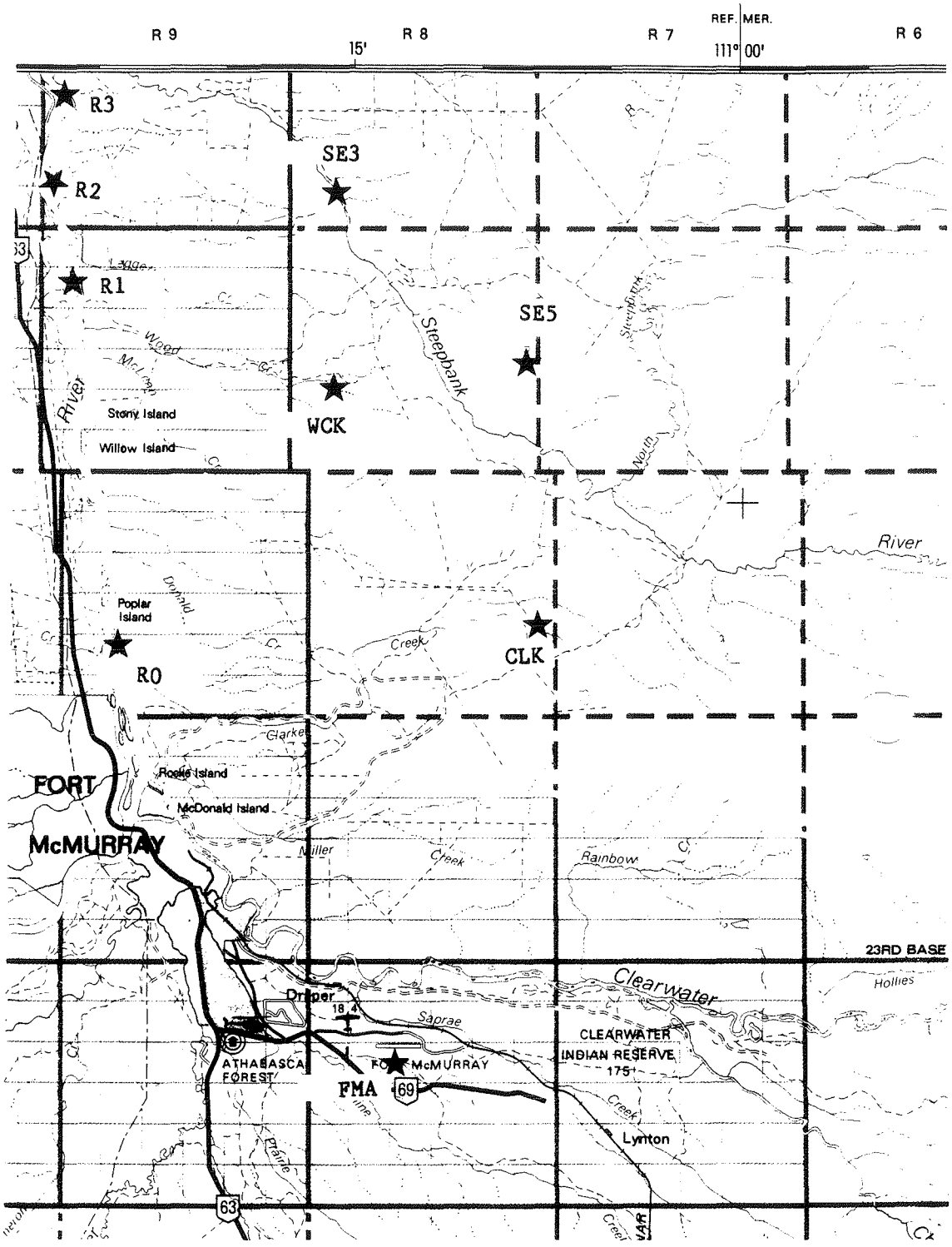


Figure 75: Site locations of R3, R2, R1, RO, SE3, WCK, SE5, CLK, and FMA. (Background map Alberta Energy and Natural Resources, 1:250 000, Waterways 74 D.)

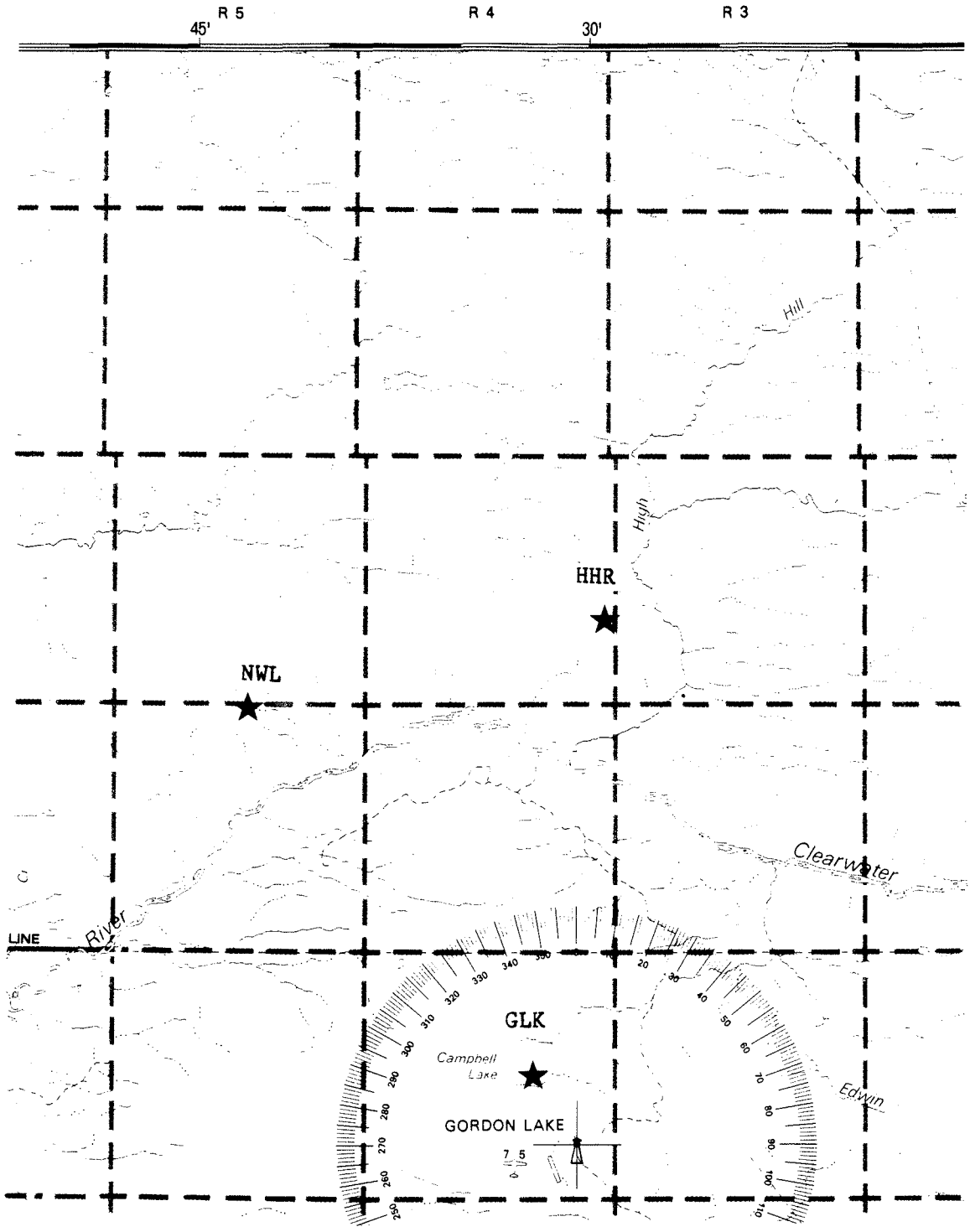


Figure 76: Site locations of NWL, HHR, and GLK. (Background map Alberta Energy and Natural Resources, 1:250 000, Waterways 74 D.)

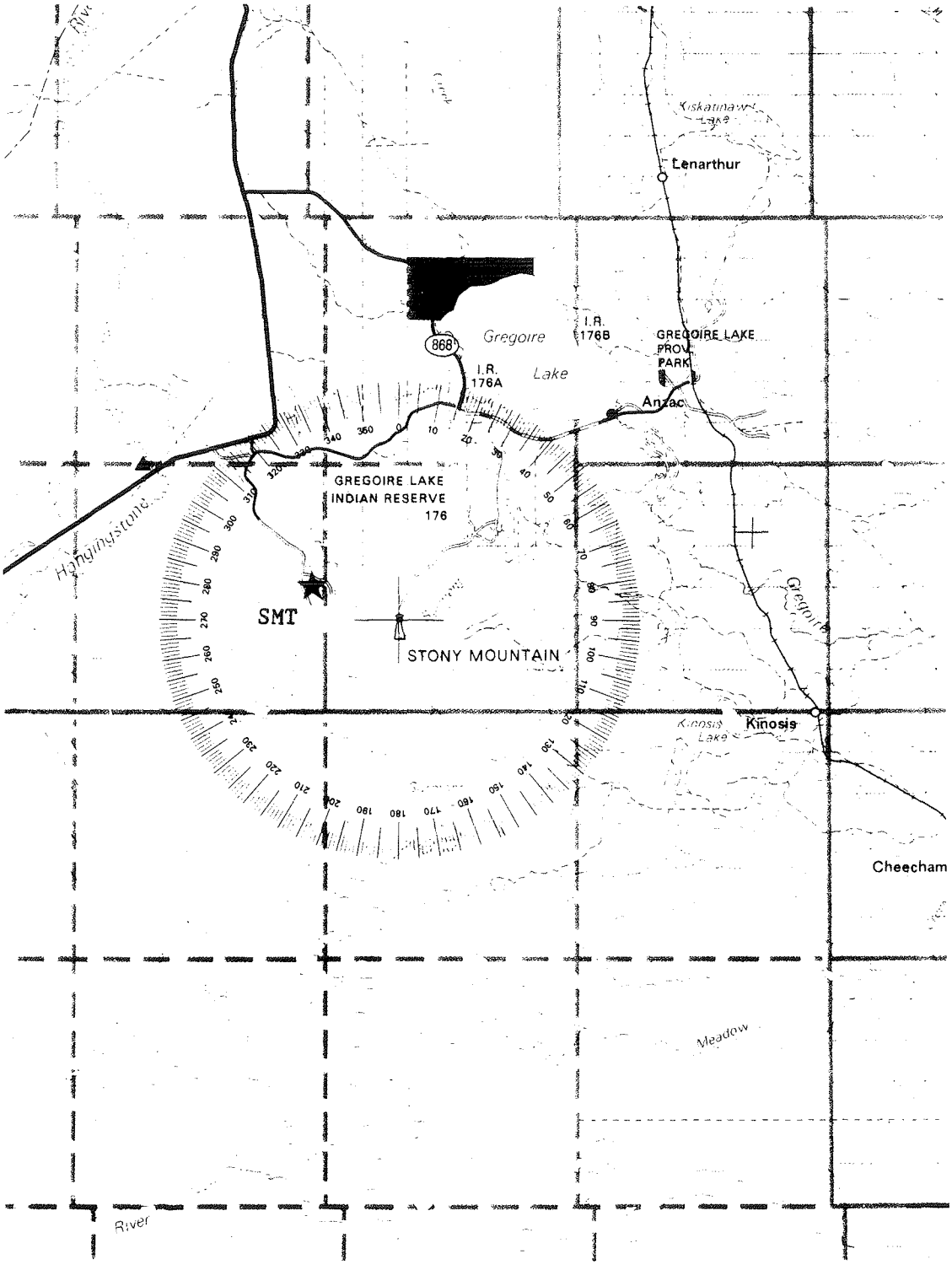


Figure 77: Site location of SMT. (Background map Alberta Energy and Natural Resources, 1:250 000, Waterways 74 D.)

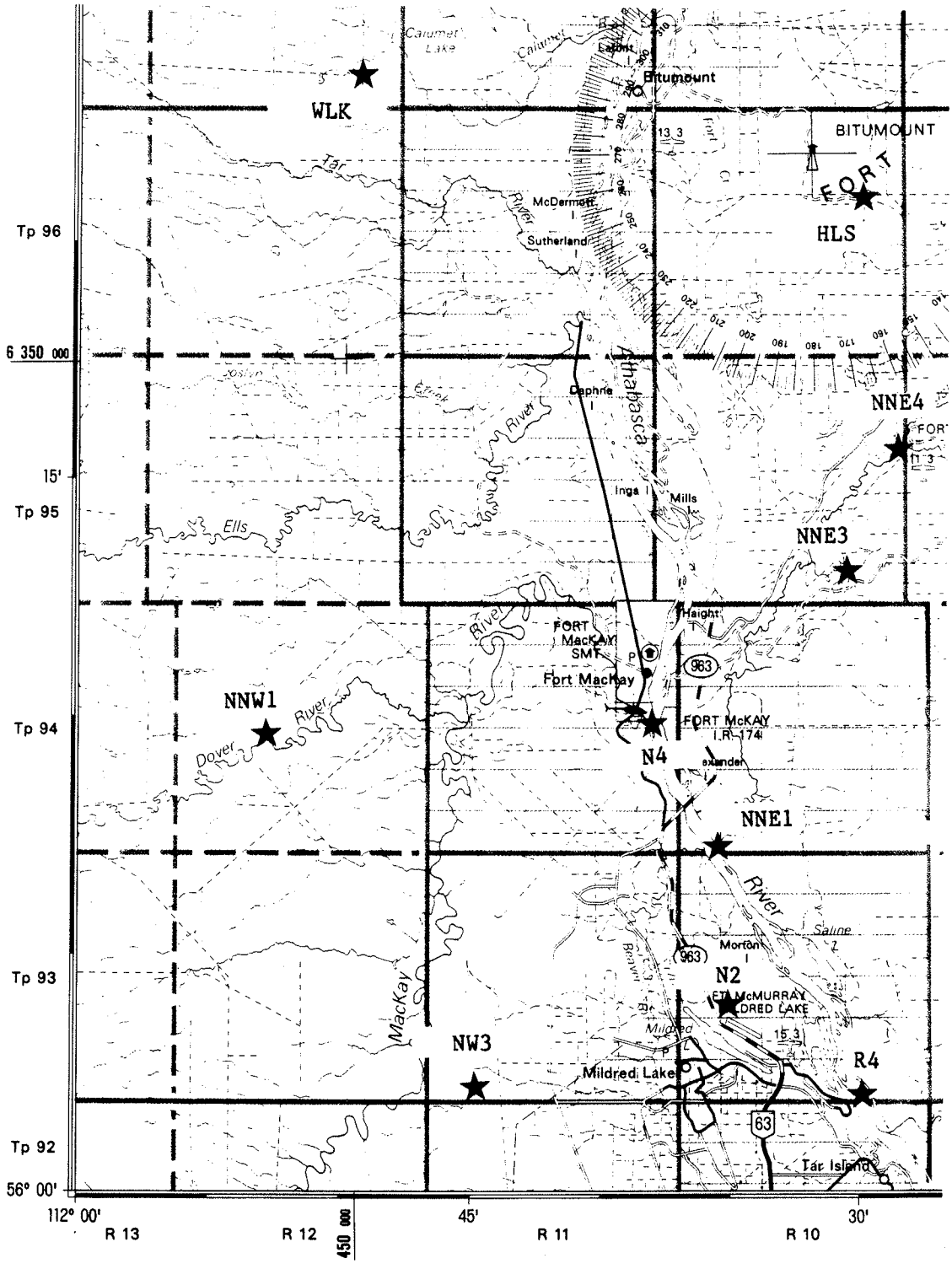


Figure 78: Site locations of WLK, HLS, NNE4, NNE3, NNW1, N4, NNE1, NW3, N2, and R4. (Background map Alberta Energy and Natural Resources, 1:250 000, Bitumont 74 E.)

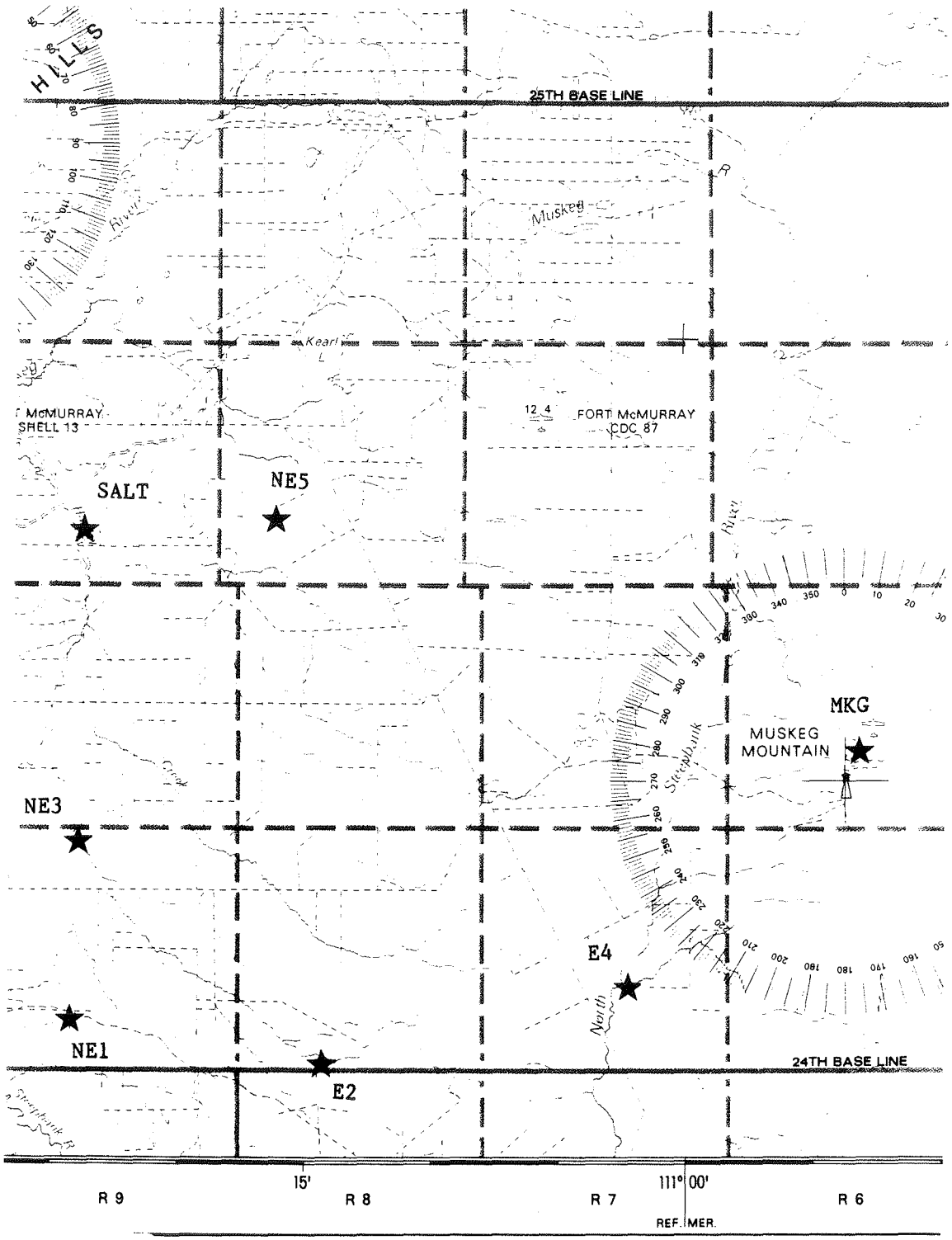


Figure 79: Site locations of SALT, NE5, NE3, NE1, E2, E4, and MKG. (Background map Alberta Energy and Natural Resources, 1:250 000, Bitumont 74 E.)

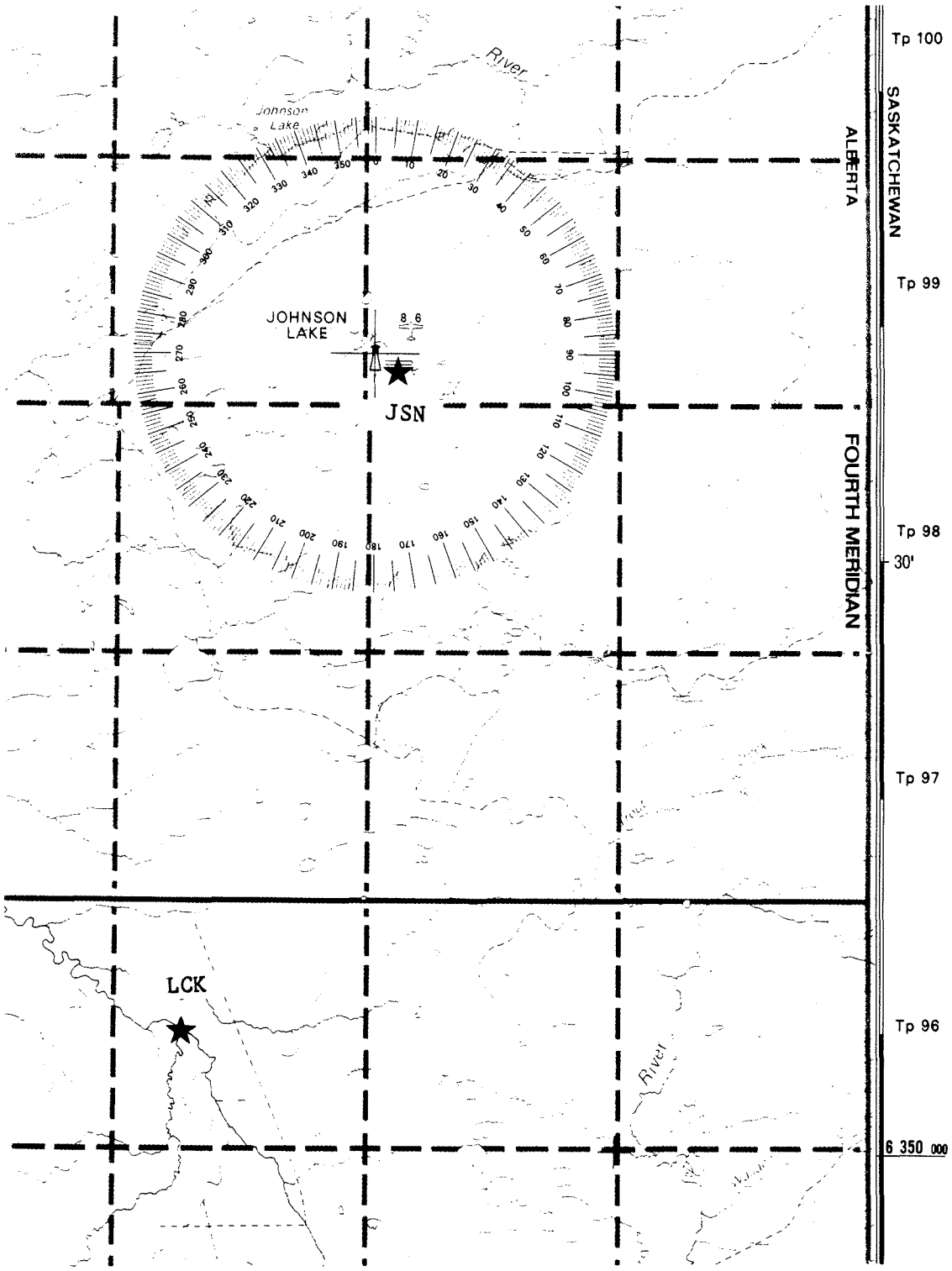


Figure 80: Site locations of JSN and LCK. (Background map Alberta Energy and Natural Resources, 1:250 000, Bitumont 74 E.)

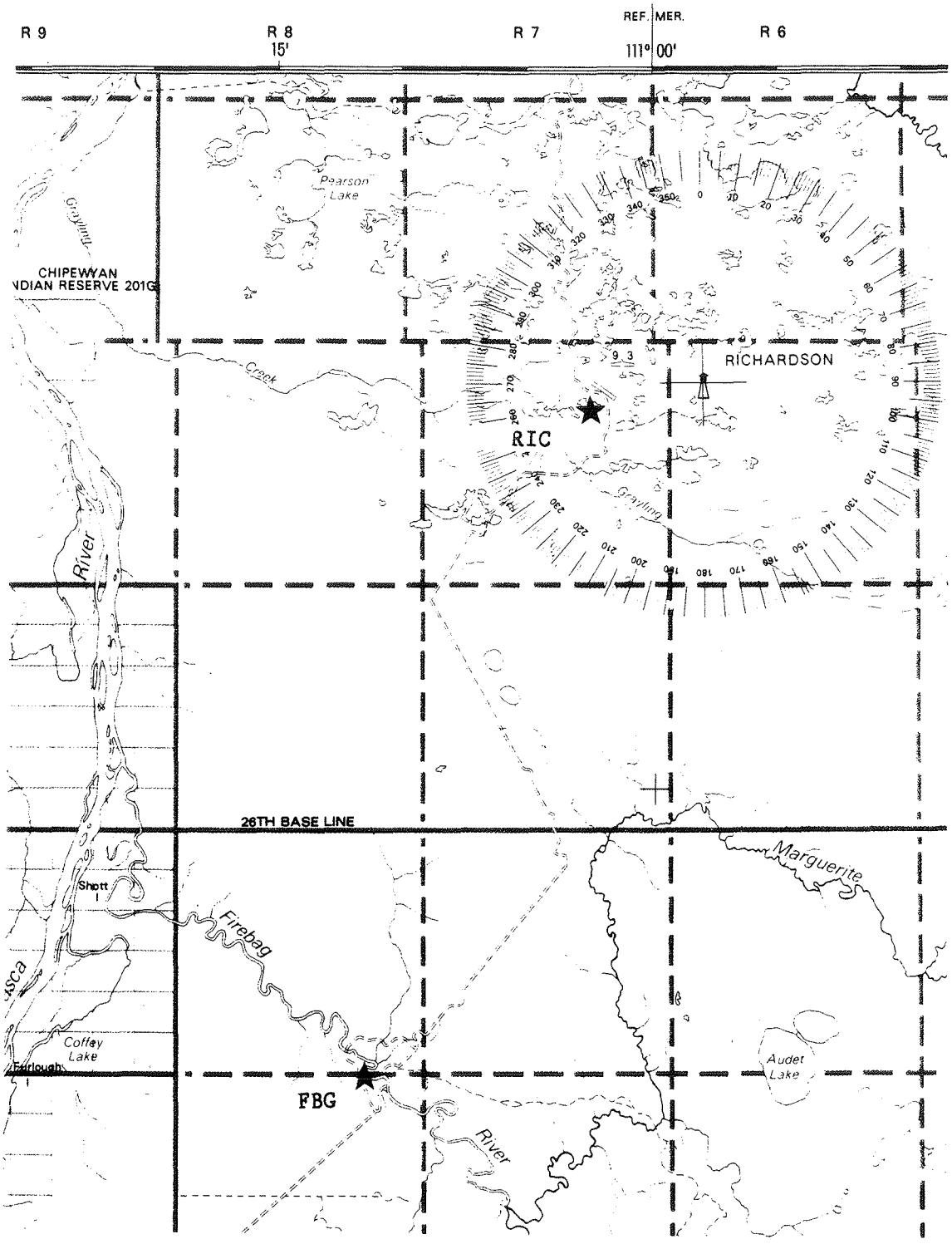


Figure 81: Site locations of RIC and FBG. (Background map Alberta Energy and Natural Resources, 1:250 000, Bitumont 74 E.)

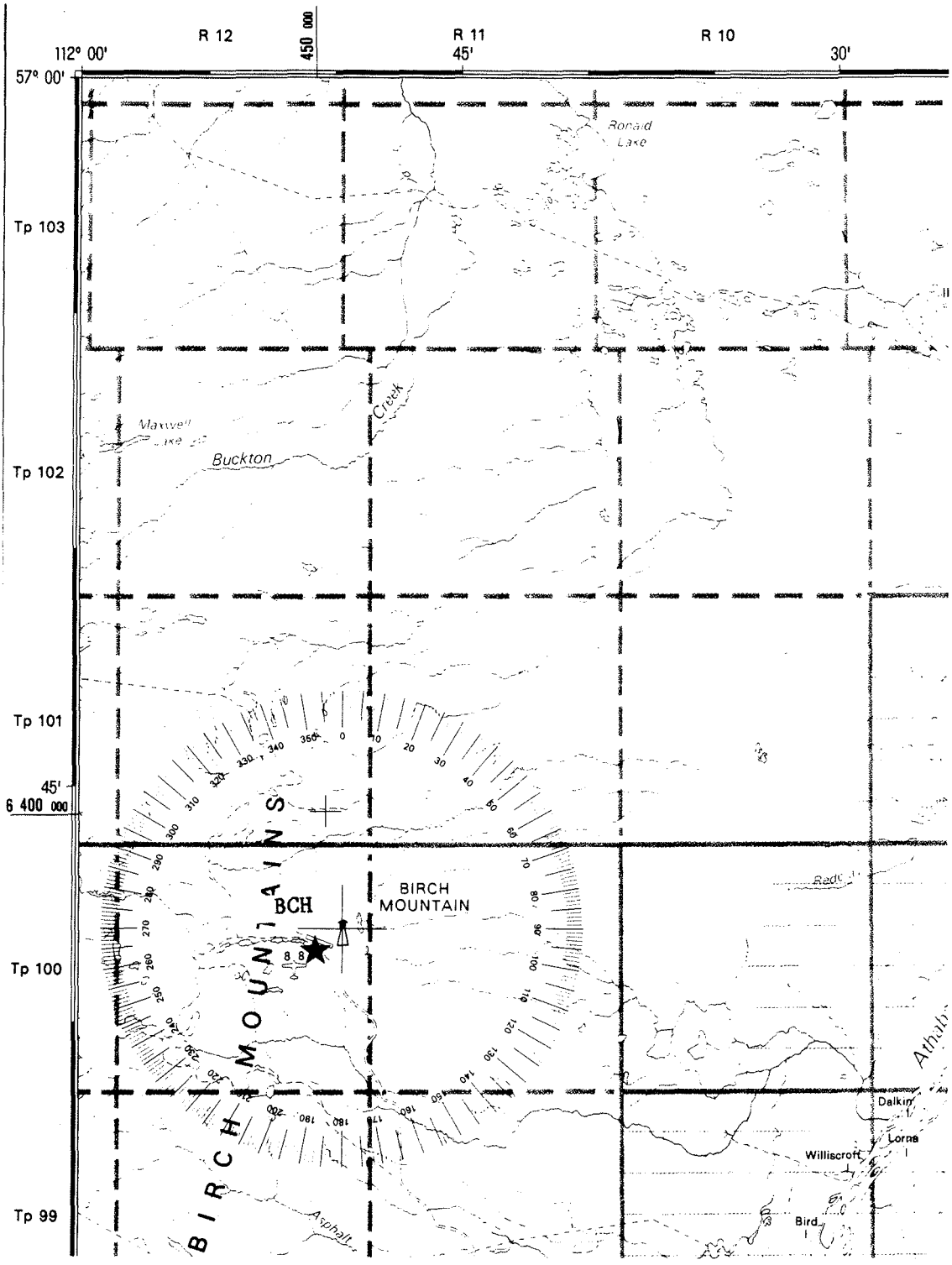


Figure 82: Site location of BCH. (Background map Alberta Energy and Natural Resources, 1:250 000, Bitumont 74 E.)

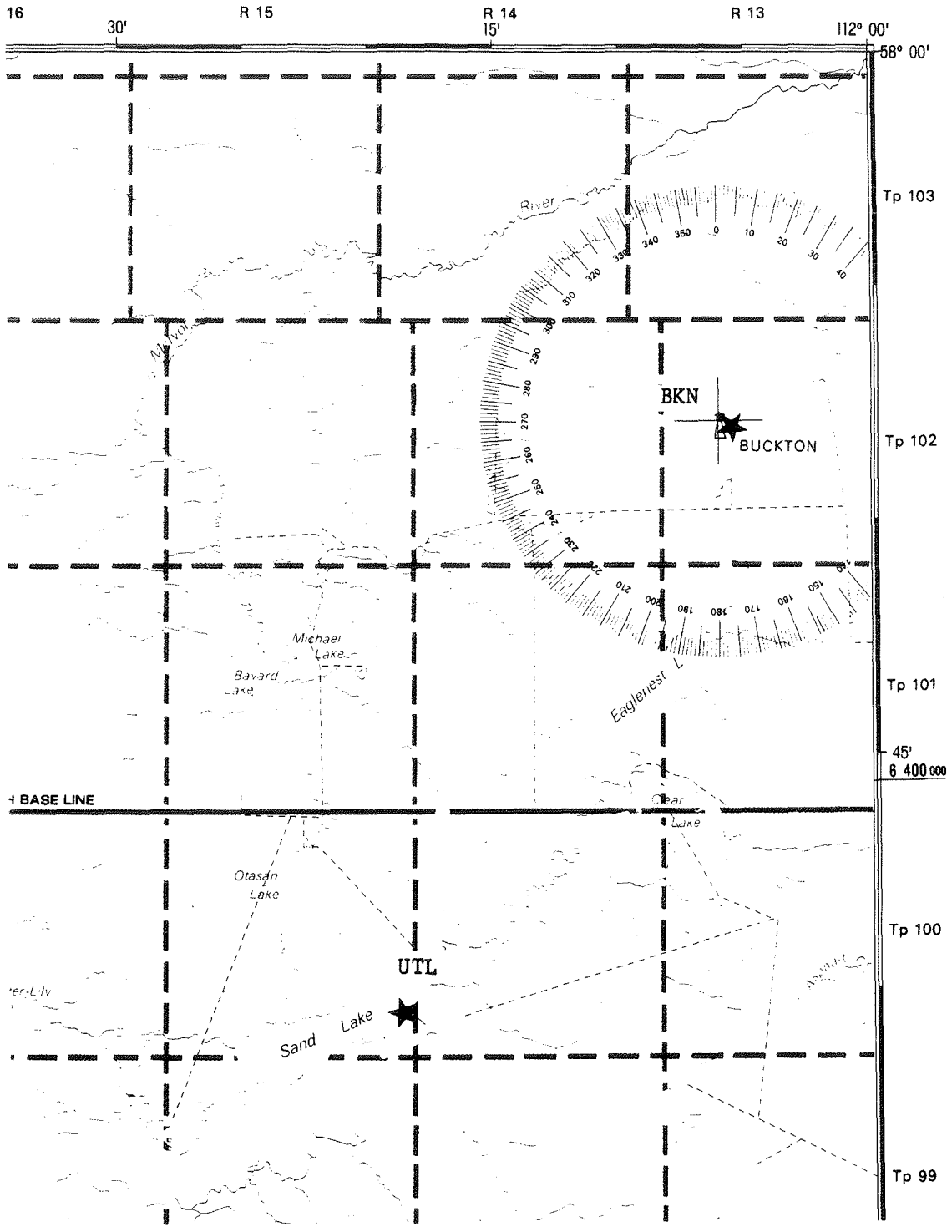


Figure 83: Site locations of BKN and UTL. (Background map Alberta Energy and Natural Resources, 1:250 000, Namur Lake 84 H.)

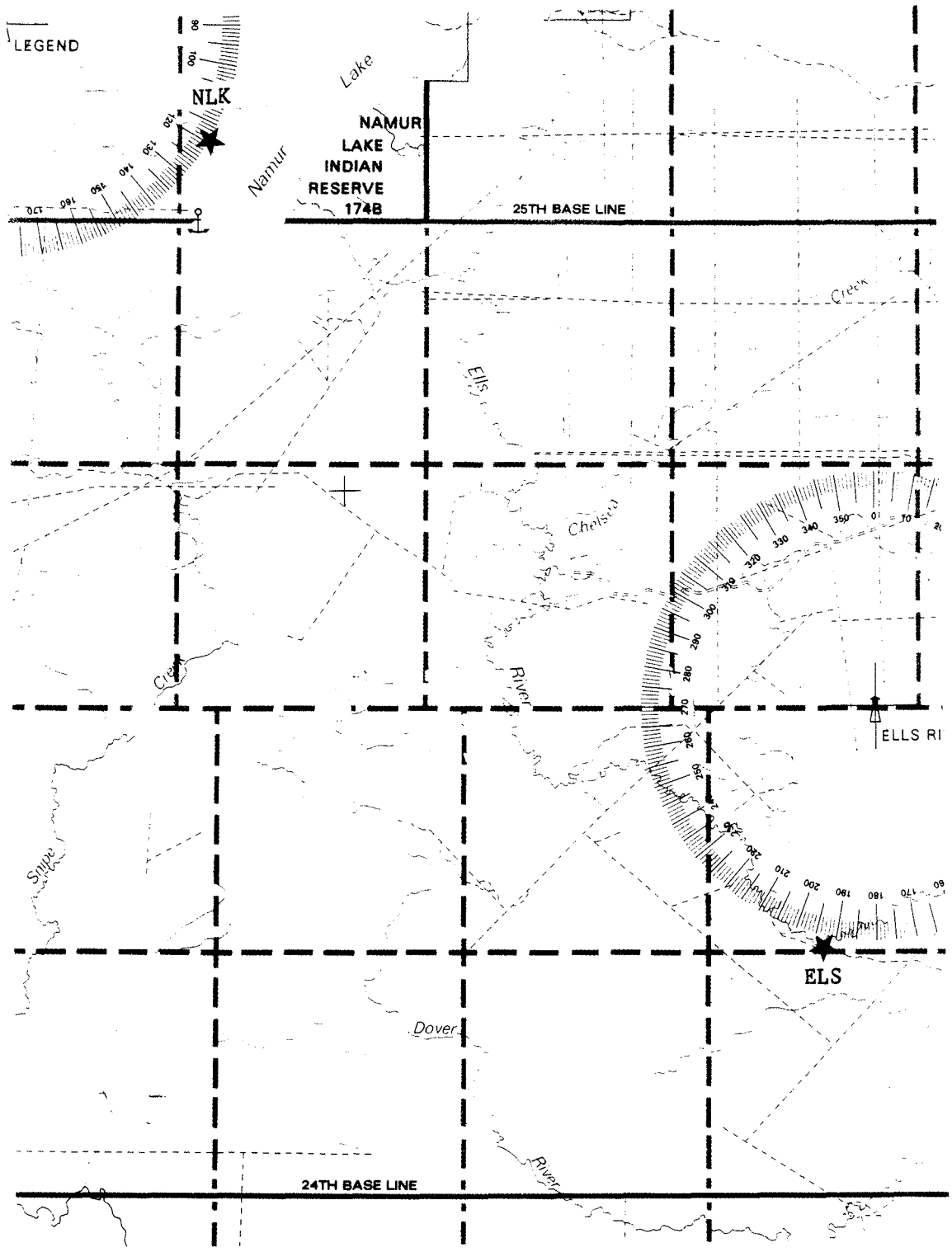


Figure 84: Site locations of NLK and ELS. (Background map Alberta Energy and Natural Resources, 1:250 000, Namur Lake 84 H.)

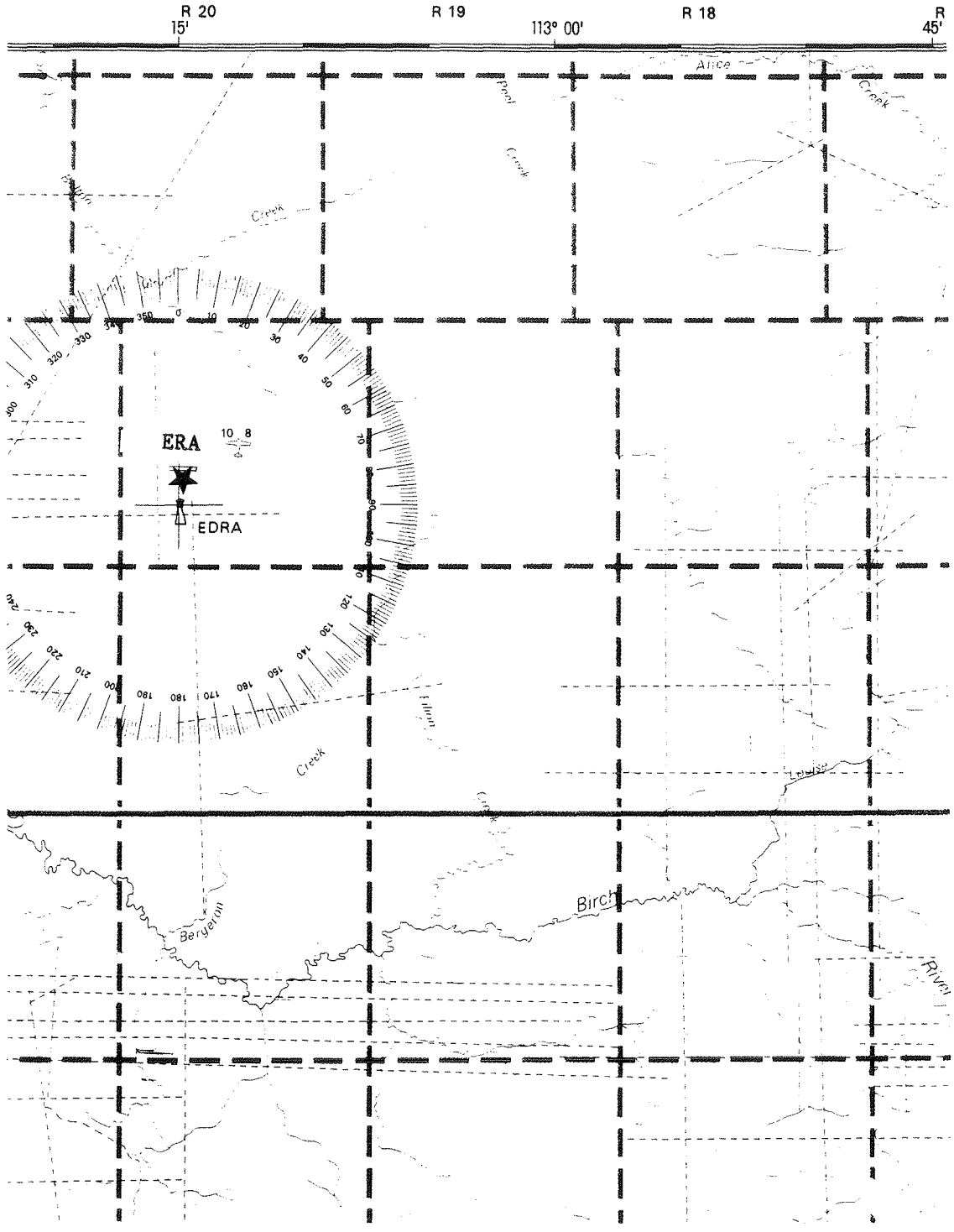


Figure 85: Site location of ERA. (Background map Alberta Energy and Natural Resources, 1:250 000, Namur Lake 84 H.)

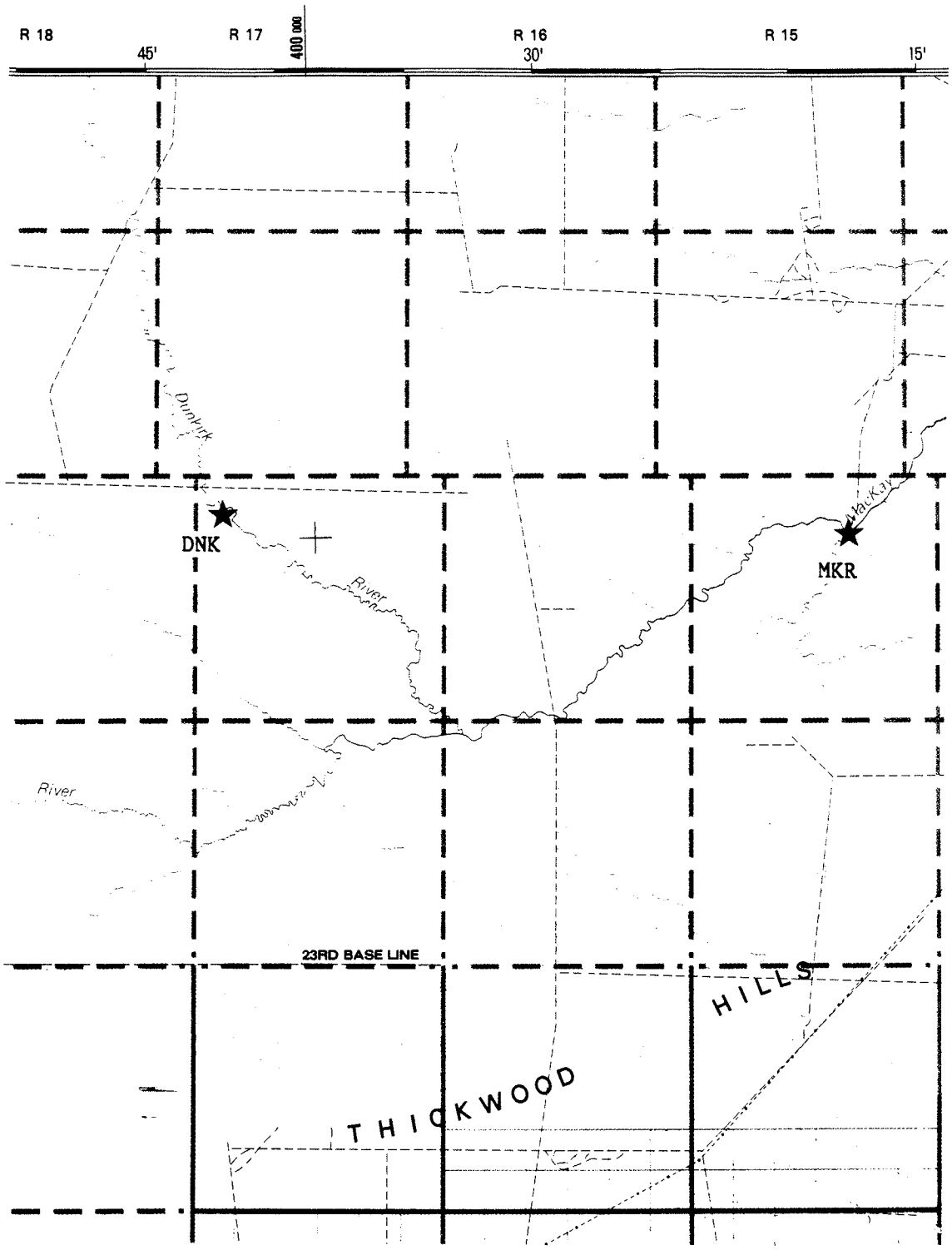


Figure 86: Site locations of DNK and MKR. (Background map Alberta Energy and Natural Resources, 1:250 000, Algar Lake 84 A.)

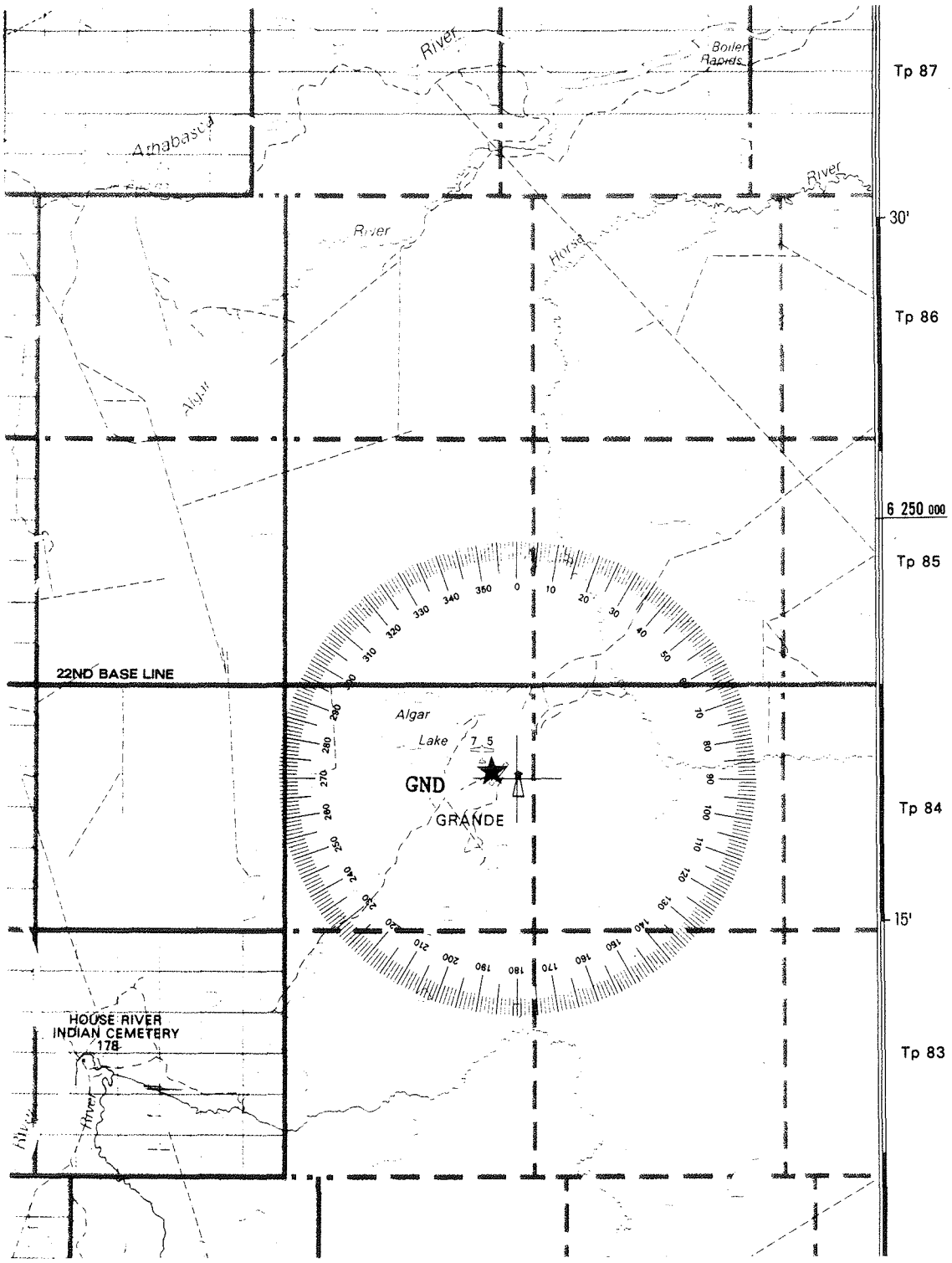


Figure 87: Site location of GND. (Background map Alberta Energy and Natural Resources, 1:250 000, Algar Lake 84 A.)

8.5 Appendix V - Rating Sheet of Site Attributes

RATINGS OF SITE ATTRIBUTES: Site_____

1.) Site Description:

Lake (4,5); Pond (3,4,5); River (3,4); Air Strip (1,2,3,4); Clearing (2,3,4); Cut Line (1,2,3,4); Development (1,2,3,4); Other_____(1,2,3,4).

Attribute value:___ Weighting factor: 30 % Resultant factor:____

2.) Ground Cover Within 25 m:

Ice (5); Ice/Sedges (2,3,4); Ice/Sedges/Shrubs (2,3,4); Ice/Sedges/Shrubs/Forest (1,2,3,4); Sedges (1,2,3); Sedges/Shrubs (1,2,3); Sedges/Shrubs/Forest (1,2,3); Shrubs (2,3); Shrubs/Forest (1,2); Other_____(1,2,3,4).

Attribute value:___ Weighting factor: 25 % Resultant factor:____

3.) Ground Cover Within 1 km:

Ice/Sedges/Shrubs (2,3,4,5); Ice/Sedges/Shrubs/Forest (1,2,3,4,5); Sedges/Shrubs (1,2,3); Sedges/Shrubs/Forest (1,2,3); Shrubs/Forest (1,2,3,4); Other_____(1,2,3,4).

Attribute value:___ Weighting factor: 10 % Resultant factor:____

4.) Distance to Roads, Overland Routes, or Air Access:

<50 m (1,2,3); 50 to <200 m (1,2,3,4); 0.2 to <1 km (1,2,3,4,5); 1 to <5 km (2,3,4,5); >=5 km (4,5).

Attribute value:___ Weighting factor: 15 % Resultant factor:____

5.) Ratio of Distance to Sample Site/Vegetation Height:

<0.5 (1); 0.5 to <1 (1,2); 1 to <2 (2,3); 2 to <5 (3,4); >=5 (4,5)

Attribute value:___ Weighting factor: 20 % Resultant factor:____

Total out of Possible 500:_____

Site Percentage Rating:_____%