SUSITNA
HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
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MARCH 1985 SNOW DEPTH SURVEY IN THE MIDDLE SUSITNA RIVER BASIN, ALASKA

PREPARED BY

LGL
Alaska Research Associates

UNDER CONTRACT TO

HARZA-EBASCO
SUSITNA JOINT VENTURE

FINAL REPORT

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Report by

LGL Alaska Research Associates, Inc.

William D. Steigers, Jr., LGL
Warren B. Ballard, ADF&G
Earl F. Becker, ADF&G

Under contract to
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Final Report
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NOTICE

ANY QUESTIONS OR COMMENTS CONCERNING THIS REPORT SHOULD BE DIRECTED TO THE ALASKA POWER AUTHORITY SUSITNA PROJECT OFFICE

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1 INTRODUCTION

Depth and quality of snow in winter have the capacity to limit moose (Alces alces gigas) populations in Alaska. Snow depth, density, crust layers in the snow profile, and duration of the snowpack are probably the most important characteristics (Coady 1974, Kelsall and Telfer 1974). Deep, dense, and/or hard-packed snow increases energy required for locomotion to obtain food, and covers the food making it less accessible to foraging moose (Coady 1974, LeResche 1974). Studies have shown that moose can travel more or less freely through soft snow up to about 24 inches deep (Telfer 1970), but are increasingly restricted in their movements as snow becomes crusted, denser, harder, or as depths of soft snow increase beyond 24 inches. Moose are generally absent from areas in North America where snow depths greater than 28 inches persist for more than about 2 months each winter (Kelsall and Telfer 1974).

Construction of the Susitna Hydroelectric Project in the middle Susitna River basin of southcentral Alaska would make lower elevation habitats within the 2 impoundment zones unavailable to wintering moose. In the project area upstream of the Devil Canyon damsite moose generally occupy lower elevations (1,800-3,000 ft) from mid-winter through early spring (January-May) and then, in the post-calving period, move to higher elevations (< 4,000 ft) where they remain through the rutting period in fall (September-October) (Ballard et al. 1983). Many moose again decend to lower elevations at some time during the mid-winter to early spring period. As snow accumulates during the winter, many moose make their way to lower elevation habitats. They tend to remain there until ameliorating snow and weather conditions permit them to leave. Initiation of these movements often appears to be associated with recent increases in local snow accumulation. For moose whose range of movements overlap the project impoundments zones, movement to lower elevations can take them below the high pool levels.

Snow in the project area usually reaches its greatest cummulative depth near the end of March and generally begins receding thereafter. Although snow depths vary greatly

throughout the middle basin, they are known to increase from east to west. Historical snow survey records in this area of 20 inches near the Oshetna River (Square Lake), 23 inches at Fog Lakes near the Watana dam site, and 33 inches near Devil Canyon (SCS 1985) show that average snow depth increases from east to west. Snow depths are generally assumed to increase from lower to higher elevations. However, no reliable information was available for snow depths over elevational gradients within the project area, particularly within major tributary drainages. Movement patterns of most radio-collared moose investigated from 1976 through 1983 appeared to be related to the drainage patterns of Susitna River tributaries (Ballard et al. 1982, 1983, 1984). As a result, most movements in the middle basin approximate a general north-south pattern.

The objective of this snow survey study was to obtain preliminary data on snow depths by elevation along major tributaries of the Susitna River in the middle basin.

2 ACKNOWLEDGEMENTS

A number of individuals contributed ideas for this preliminary study. They include Jack Whitman, Craig Gardner, and Karl Schneider (Alaska Department of Fish and Game), Randy Fairbanks (Harza-Ebasco Susitna Joint Venture), and Robin Sener (LGL Alaska Research Associates, Inc). We also thank Dale Herter and Brian Cooper of (LGL Alaska Research Associates, Inc) for collecting snow depth data during their winter bird transects. Figures were prepared by Graphic Definitions and computer-generated.

3 STUDY AREA

The study area was located in the middle Susitna River basin in southcentral Alaska. The basin is generally oriented in an east-west direction between the Alaska Range to the north and the Talkeetna Mountains to the south. The basin is a broad U-shaped valley which has been dissected by the Susitna River, forming a relatively narrow V-shaped channel through the basin. Numerous stream and river tributaries enter the Susitna River along its course through the middle Basin. Elevations under study ranged from about 1,100 ft at the confluence of Devil Creek and the Susitna River to 3,600 ft near the headwaters of Coal

Creek. The wide range of environmental conditions in the basin has resulted in a complex mosaic pattern of plant communities. Plant community composition and physiognomy have been strongly influenced by fire history, topography, soil moisture, aspect, and browsing by large herbivores. Precipitation in the area averages about 20 inches and most falls during the frost-free period.

4 METHODS

Two separate late-winter snow surveys in the middle Susitna River basin were conducted simultaneously during March 27-30, 1985. Snow depth information was collected at sites based on prior knowledge of prosence or absence of wintering moose (Ballard et al. 1982, 1983, 1984) during March 29 and 30, 1985. Concurrent with a winter bird census during March 27-29, 1985, snow depth information was also recorded at points along transects. Sample methods varied by source, so each are discussed separately.

4.1 Snow Survey

During March 29 and 30, 1985, 31 sites were sampled for depth of accumulated snow. Site selection was based primarily on a priori knowledge of use or non-use of a specific area by wintering moose (Ballard et al. 1982, 1983, 1984) and on a concurrent moose stratification survey (Ballard et al. 1985). Site selection usually followed major tributary drainages of the Susitna River, or elevational gradients of the Susitna River canyon. Specific site locations were selected from the helicopter. Sites were usually grouped in sets of at least 3 to correspond with number of observers available for data collection.

One observer was placed at each site (except site 1) by helicopter. The observer then selected a non-random line of travel based on the local topography and drainage pattern if near a stream and began sampling snow depths at 5 step (approximately 15 ft) intervals along the line transect. As many different vegetation types and other physical or topographical features were sampled as possible in an effort to obtain representation of the

variation in snow depths within a site. Therefore, transect placement and length within a site were left to the discretion of the individual observer. Often several shorter, disjointed transects were conducted in lieu of a single, longer transect when site-specific requirements dictated. As most sites were selected within drainages, moderate and steep slopes were usually not sampled.

Snow depths were measured to the nearest inch using fiberglass rods marked at 3-inch intervals. Data was recorded on voice tape recorders or field data notebooks, and later transcribed to data sheets. Notes of interest, such as surface snow hardness, crust layers in the snow profile, shrub species present, relative past and present browsing pressure, plant condition, animal sign, type of vegetation, and a narration of topographical positioning were also recorded at stops along transects. Elevation, aspect, and slope were recorded, and the site location marked on U.S.G.S. topographical maps and 1:60,000 scale color-infrared photographs. A minimum of 20 measurements were taken at each site; the maximum number was governed only by allotted time before return of the helicopter.

4.2 Winter Bird Transects

During the March 27-29, 1985 winter bird census (Herter 1985), snow depth information was collected at systematic points along 6 line transects. Transects varied from 2.7-4.2 miles in length, and followed the form of triangles, 4-sided polygons, or 2 or 3 sides of 4-sided polygons (Herter 1985). Transects were placed through relatively large stands of homogeneous vegetation near the Susitna River channel, with most of their length within the Devil Canyon (2 transects) and Watana (4 transects) impoundment zones (Herter 1985).

Snow depths were sampled at 15 minute intervals (e.g., 0830, 0845, 0900, etc.) while the observer slowly walked along a previously flagged transect. Ten consecutive measurements spaced 2 short paces (approximately 3 ft) apart were taken in the direction of travel along the transect. Snow depth was measured to the nearest 0.39 inch (1 cm) using a wooden dowel marked in 0.39 inch (1 cm) increments. Vegetation classification

(Viereck et al. 1982) was recorded at ecotype edges along the length of the transect (Herter 1985).

5 RESULTS

Snow depth data was collected in a non-random sample scheme, where sites, placement of transects within sites, and number of points sampled along transects were determined by the individual observer. Topographical and environmental features such as slope, aspect, elevation, and vegetation classification that may have affected snow depths were not controlled for between sites nor within sites. This made comparisons between sites tentative and subject to individual interpretation. General trends appeared evident (given the aforementioned interpretive caution), however, especially when within-site variation was narrated by the observer taking the measurements.

Snow depth data has been presented as a series of points along the 1 or more disjoined transects conducted at each site. Sample points were presented in the order they were taken, and disjoined transects combined into a single series of points. The vertical axis portraying snow depth was standardized in all figures to facilitate comparison of relative variation within and among sites. Average snow depth was depicted as a solid horizontal line. A narrative of sampling conditions and other observations were included in the site descriptions when recorded by the observer.

5.1 Snow Site Descriptions

Snow Site 1

Site 1 was located in a tributary of Jay Creek near its headwaters approximately 11 miles upstream from its mouth (Figure 1). Site 1 was at 3,575 ft elevation with a northerly aspect and medium (15 degree) slope. Vegetation was an open shrub canopy of resin birch (Betula glandulosa) and willow (Salix). Most shrubs showed little evidence of browsing. Feltleaf (Salix alaxensis) willow growing to 15 ft in height near the stream had been heavily browsed in the distant past, although it showed little sign of recent browsing. No fresh moose sign was observed. Three observers collected snow depth data at site 1;

results were presented separately by observer as subsites and then summarized as a single site.

Snow Subsite 1(B).--Subsite 1(B) was first oriented parallel to and up the tributary stream. It then turned uphill toward a northeast-facing windblown ridge. Average snow depth was 26.0±3.8 (mean ± standard deviation) inches, ranging from 18-36 inches deep (Figure 2). Points 1-13 paralleled the stream; points 12 and 13 entered drifts overhanging the stream. Points 14-31 were measured as the transect turned up a gentle slope onto a ridge. Hard, layered, crusts at 3, 12, 15, and 25 inches depth from the snow surface were measured beginning at point 23 as the steeper crown of the ridge was approached. Crusting in the top layers and drifts were evidence of the effects of wind on snow deposition. Northerly winds appeared to be prevalent.

Snow Subsite 1(E).--Subsite 1(E) was oriented perpendicular to the stream, bisecting the small valley. Average snow depth was 28.8±4.8 inches, ranging from 22-42 inches deep (Figure 3). Surface crusting was evident as a result of wind-packing.

Snow Subsite 1(W).--Subsite 1(W) was oriented down the stream valley. Average snow depth was 28.3±4.5 inches, ranging from 17-37 inches deep. Points 1-5 showed increasing snow depths as the partially drift-filled stream was approached (Figure 4). Points 25-38 were measured from a distance approximately 30 m from and parallel to the stream.

Summary of Snow Site 1.--Average snow depth over all points taken at site 1 was 27.7±4.5 inches, ranging from 17-42 inches deep. Measured snow depths were heavily influenced by wind redeposition in this area.

Snow Site 2

Site 2 was located approximately 1 mile downstream in the same tributary of Jay Creek as site 1, and about 10 miles upstream of the mouth of Jay Creek (Figure 1). It was at 3,250 ft elevation with a northerly aspect and gentle slope. Vegetation was an open shrub community of resin birch and willow. The single transect extended down the stream

valley. Average snow depth was 26.1±6.0 inches, ranging from 14-44 inches deep (Figure 5). Snow depths varied substantially within this site. Feltleaf willow showed signs of heavy past use of current annual growth twigs. Only 2 moose tracks were observed.

Snow Site 3

Site 3 was located approximately 1 mile downstream in the same tributary of Jay Creek as sites 1 and 2, and about 9 miles upstream of the mouth of Jay Creek (Figure 1). Site 3 was at 2,880 ft elevation with a northerly aspect and gentle slope. Vegetation was an open shrub community of resin birch and willow. The single transect extended down the valley along the stream. Average snow depth was 27.9±4.4 inches, ranging from 20-36 inches deep (Figure 6). Points 1-20 were on the west side of the stream parallel to and 15 ft distant, points 21-40 were on the stream, and points 41-49 were on the east side of the stream parallel to and 15 ft distant. Willows showed evidence of light past use of current annual growth twigs. Only 2 moose tracks and few signs of moose were observed.

Snow Site 4

Site 4 was located in Jay Creek about 6.5 miles upstream from its mouth and approximately 2.5 miles downstream of site 3 (Figure 1). Site 4 was at 2,650 ft elevation with a westerly aspect and gentle (3 degree) slope. Vegetation was an open shrub community of willow. The single transect extended down the valley along Jay Creek. Average snow depth was 19.8±4.5 inches, ranging from 7-28 inches deep (Figure 7). Points 1-2 were on the overflow ice of Jay Creek, while points 3-47 were in willows growing adjacent to the stream. Snow was deeper in adjacent shrubs than on the stream where the underlying overflow ice had reduced snow depths. The snow had a light surface crust, but was not hard-packed. Willows showed evidence of heavy past use of current annual growth twigs. Diamondleaf (Salix pulchra) and feltleaf willows were very heavily browsed. Feltleaf willow was about 5 ft tall after browsing. Abundant moose sign was present, with fecal pellets lying on top of unmelted snow. Moose had been cratering or walking through snow to gain access to the willows. The willows had been browsed since the

last heavy snowfall. Snow depth appeared to be comparable to the past browsing line on the shrubs. Total transect length was about 900 ft.

Snow Site 5

Site 5 was located in a headwater tributary of Coal Creek approximately 20 miles upstream from its mouth (Figure 1). Site 5 was at 3,450 ft elevation with a southeasterly aspect and medium (15 degree) slope. Vegetation was a closed shrub community of willow. The several transects extended down the valley along the tributary stream flowing into Coal Creek. Average snow depth was 26.4±5.1 inches, ranging from 11-37 inches deep (Figure 8). Points 1-15 were on the west side paralleling the stream, points 16-30 were on the east side paralleling the stream, points 31-45 were on the stream, points 46-60 were on the stream but about 0.75 mile downstream of the start point, and points 61-70 were on the east side of the stream about 1 mile downstream of the start point. Willows showed little evidence of past use. Only 1 old moose track was observed.

Snow Site 6

Site 6 was located in the headwaters of Coal Creek approximately 18.5 miles upstream from its mouth and 1.5 miles southeast of site 5 (Figure 1). Site 6 was at 2,940 ft elevation with an easterly aspect and gentle (3 degree) slope. Vegetation was a closed shrub community of willow. The several transects extended down the valley along Coal Creek. Average snow depth was 22.9±7.7 inches, ranging from 7-38 inches deep (Figure 9). Point 1 was on overflow ice of Coal Creek; in many places the stream had overflowed to the point that only solid ice was present. Points 2-15 were on the east side paralleling the stream; snow was wind-packed with crust layers at 3 and 12 inches from the surface. Points 16-40 were on the west side of the stream; low-growing diamondleaf willow and resin birch were exposed and the hard crusts in the snow profile made walking difficult. Points 41-48 were on the east side of the stream in diamondleaf and feltleaf willows. Where exposed above the snow, both diamondleaf and feltleaf willows showed evidence of heavy browsing pressure. At least 50 percent of the current annual growth twigs appeared

to have been removed. A preference for feltleaf over diamondleaf willow seemed to be present, though the taller height of feltleaf willow may have just made it more available. Virtually no recent browsing or moose sign was present since the last major snowfall. Only 1 moose track was observed; its direction of travel was up Coal Creek.

Snow Site 7

Site 7 was located on Coal Creek approximately 14 miles upstream from its mouth and 3.5 miles southwest of Coal Lake (Figure 1). Site 7 was at 2,690 ft elevation with a northeasterly aspect and gentle slope. Vegetation was a closed shrub community of willow. The several transects extended down the valley along Coal Creek. Average snow depth was 27.3±3.9 inches, ranging from 21-38 inches deep (Figure 10). Points 1-17 were on the west side paralleling the stream, points 18-33 were on the stream, and points 34-53 were on the east side of the stream. Willows showed light to moderate evidence of past use. The direction of travel of most observed moose tracks was down Coal Creek.

Snow Site 8

Site 8 was located on Coal Creek approximately 9 miles upstream from its mouth and 5 miles downstream of site 7 (Figure 1). Site 8 was at 2,580 ft elevation with a northerly aspect and gentle slope. Vegetation was an open mixed forest community of spruce (Picea) and balsam poplar (Populus balsamifera). The several transects extended down the valley along Coal Creek. Average snow depth was 31.7±3.6 inches, ranging from 18-40 inches deep (Figure 11). Points 1-15 were on the east bank paralleling 10 ft away from the stream; feltleaf willow was heavily browsed (>75%) and diamondleaf willow was lightly browsed (5-10%). Points 15-30 were on the west bank paralleling 10 ft away from the stream; feltleaf willow was heavily browsed (>75%). Points 31-45 were on the west bank paralleling 40 ft away from the stream; diamondleaf willow was very lightly (<1%) browsed. Points 46-60 were on the east bank paralleling 10 ft away from the stream; feltleaf willow was heavily browsed (>75%) and diamondleaf willow was lightly browsed (5-10%). Points 61-75 were on the east bank paralleling 40 ft away from the stream;

diamondleaf willow was very lightly (<1%) browsed. Points 76-102 were on the east bank paralleling 10 ft away from the stream.

Snow Site 9

Site 9 was located on lower Coal Creek approximately 6 miles upstream from its mouth and 3 miles downstream of site 8 (Figure 1). Site 9 was at 2,500 ft elevation with an eastern aspect and gentle (1 degree) slope. Vegetation was an open shrub community of willow along Coal Creek and an adjacent closed community of spruce. The several transects extended down the valley along Coal Creek. Average snow depth was 26.8±6.0 inches, ranging from 15-36 inches deep (Figure 12). Points 1-17 were on the west bank paralleling the stream; feltleaf willow was heavily browsed with decadent and dead stems, and lack of cru-ts in the snow profile suggested that the area was protected from wind. Points 18-19 were on the ice overflow of the stream. Points 20-29 were on a small island within the stream banks; feltleaf willow were decadent and there were abundant old moose tracks. Points 30-53 left the stream and entered a stand of tall white spruce (Picea glauca); Richardson willow (Salix lanata) was exposed in moose tracks, recent moose tracks suggested they were just walking around because no cratering was evident, and the area appeared to be sheltered from the wind. Points 54-61 were on overflow stream ice. Points 62-69 were on a small island within the stream banks; there was little evidence of wind action on the snow in this area, and decadent feltleaf willow on the island had experienced removal of about 50% of its current annual growth twigs. Throughout the streamside area, shrubs showed evidence of very heavy browsing pressure in their past.

Snow Site 10

Site 10 was located at the mouth of Coal Creek (Figure 1). Site 10 was at 2,390 ft elevation with a easterly aspect and gentle slope. Vegetation was a closed shrub community of willow along Coal Creek and an adjacent open community of spruce. The several transects extended down the valley along Coal Creek and onto an adjacent island. Average snow depth was 24.9±5.2 inches, ranging from 15-33 inches deep (Figure 13). Points 1-17 were on

the east bank of the stream, points 18-35 were on a gravel bar on the stream, and points 36-52 were on a island dominated by spruce. Browsing pressure was variable, ranging from light to moderate. Moose tracks and sign were abundant.

Snow Site 11

Site 11 was located about 1.5 miles south of the mouth of the Oshetna River on the upland bench (Figure 1). Site 11 was at 2,550 ft elevation on a easterly aspect with a gentle (5 degree) slope. Vegetation was an open shrub community of resin birch and willow. The single transect travelled south through scattered black spruce (Picea mariana). Average snow depth was 22.3±2.7 inches, ranging from 18-30 inches deep (Figure 14). Several scattered moose tracks and pits where moose were cratering for diamondleaf willow and resin birch were observed. The tips of most shrubs were just protruding above the snow level. Only a light surface crust on the snow suggested that the area may not experience frequent winds. The general area appeared to receive moderate to heavy use, although caribou (Rangifer tarandus) tracks may have contributed to the sign observed.

Snow Site 12

Site 12 was located about 2 miles south of the mouth of the Oshetna River on the upland bench, and about 0.5 miles southwest of site 11 (Figure 1). Site 12 was at 2,550 ft elevation, which was the same elevation as site 11, with a flat aspect and slope. Vegetation was an open shrub community of resin birch and willow. The single transect travelled in a southeasterly direction. Average snow depth was 19.9±3.3 inches, ranging from 10-26 inches deep (Figure 15). A semi-hard surface crust was present in the snow profile. Evidence of light browsing (<10%) was observed on diamondleaf and Richardson willows. No fresh moose tracks were observed.

Snow Site 13

Site 13 was located about 0.75 mile southeast of the mouth of the Oshetna River on an old river terrace lower in elevation than sites 11 and 12 (Figure 1). Site 13 was at 2,200 ft elevation with a flat aspect and slope. Vegetation was an open forest community of spruce

and an open shrub community of resin birch and willow. The single transect travelled in a northerly direction. Average snow depth was 20.5±2.0 inches, ranging from 18-24 inches deep (Figure 16). Approximately 50% of the exposed tips of resin birch had been browsed.

Snow Site 14

Site 14 was located at the mouth of Jay Creek on an island along the Susitna River (Figure 1). Site 14 was at 1,725 ft elevation on a westerly aspect with a gentle (3 degree) slope. Vegetation on the island was an open shrub community of willow along the Susitna River and an adjacent open community of spruce and large balsam poplar. The transect extended downriver through the willows along the edge of the island, then turned into the adjacent spruce and balsam poplar. Average snow depth was 17.2±4.0 inches, ranging from 7-21 inches deep (Figure 17). Points 1-17 were through the willow band between the spruce to the south and the river channel to the north; feltleaf and diamondleaf willows and balsam poplar twigs were heavily browsed, some drifting of snow was observed, and most of the snow had been disturbed by cratering and walking moose. Points 18-25 were in thick white spruce trees with feltleaf willow in the understory. Points 26-33 were beneath a tall, closed white spruce canopy with scattered alder (Alnus) in the understory; moose tracks appeared to be just passing through as there was no browse present. Points 34-40 returned to the bank of the river into feltleaf willow and balsam poplar; both had been heavily browsed. Three moose were observed as we approached to land at site 14.

Snow Site 15

Site 15 was located on a terraced bench 0.5 mile southwest of the mouth of Jay Creek (Figure 1). Site 15 was at 2,050 ft elevation on a northerly aspect with a gentle slope. Vegetation was an open forest community of white spruce. The transect crossed the terraced bench. Average snow depth was 19.5±6.9 inches, ranging from 8-34 inches deep (Figure 18). Diamondleaf willow appeared to have been browsed in early winter, but was mostly under snow at that time. The understory was dominated by resin birch.

Snow Site 16

Site 16 was located on the upland slopes above the Susitna River 3.5 miles southeast of the mouth of Jay Creek (Figure 1). Site 16 was at 3,100 ft elevation on a northerly aspect with a gentle slope. Vegetation was a closed shrub community of resin birch, willow, and alder. Average snow depth was 22.3±3.6 inches, ranging from 13-30 inches deep (Figure 19). A surface crust was present in the snow profile. Feltleaf and diamondleaf willows showed evidence of moderate browsing pressure. Alder had been browsed on the tips of twigs. A few moose tracks were observed.

Snow Site 17

Site 17 was located in the Watana Creek floodplain approximately 1 mile upstream of its mouth (Figure 1). Site 17 was at 1,600 ft elevation on a southerly aspect with a gentle (3 degree) slope. Vegetation was an open shrub community of willow. The transect began by heading upstream through the willows, then turned into the open white spruce forest to the east. Average snow depth was 23.1±1.9 inches, ranging from 19-27 inches deep (Figure 20). Points 1-13 were in feltleaf willow within the floodplain; no crusts were present in the snow profile, and almost all current annual growth of feltleaf willow had been removed. The browsed condition of the feltleaf willow was much as would be expected if observed during late spring. Points 14-18 were on Watana Creek overflow ice. Points 19-43 were in white spruce; some feltleaf and diamondleaf willows were present in the understory and were heavily browsed. Moose tracks were observed travelling through, but no cratering was noted. No fresh moose sign was noted since the last major snowfall.

Snow Site 18

Site 18 was located on the terraced bench approximately 1.5 miles southwest of the mouth of Watana Creek (Figure 1). Site 18 was at 2,250 ft elevation with a flat aspect and slope. Vegetation was a dwarf forest community of white spruce with a graminoid understory. The transects criss-crossed a flat area dominated by graminoids and diamondleaf willow. Average snow depth was 18.0±5.9 inches, ranging from 6-33 inches

deep (Figure 21). Hard crusts in the snow profile and variability in snow depths were evidence of the effects of wind in this exposed area. Moose had been cratering for diamondleaf willow.

Snow Site 19

Site 19 was located on the uplands approximately 4 miles south-southwest of the mouth of Watana Creek (Figure 1). Site 19 was at 2,600 ft elevation with a northwesterly aspect and gentle slope. Vegetation was an open forest community of black and white spruce with an understory of resin birch and willow. Average snow depth was 17.4±11.2 inches, ranging from 3-45 inches deep (Figure 22). Hard crusts in the snow profile and variability in snow depths were evidence of the effects of wind in this higher elevation area. Snow was deeper in the more protected willow (points 6-12) and black spruce (points 21-27) stands. Feltleaf willow were large, decadent, and heavily browsed. Approximately 50% of the current annual growth of diamondleaf willow had been browsed.

Snow Site 20

Site 20 was located in the headwaters of the east fork of Watana Creek approximately 19 miles upstream from the mouth (Figure 1). Site 20 was at 3,300 ft elevation with a southerly aspect and gentle (5 degree) slope. Vegetation was an open shrub co mmunity of resin birch and willow. The transect travelled down the stream valley parallel to Watana Creek. Average snow depth was 44.4±9.8 inches, ranging from 21-55 inches deep (Figure 23). Points 1-15 and 20-25 were in and between 9 ft tall diamondleaf willows that had received virtually no browsing. Points 16-19 were on stream overflow ice. Numerous extremely hard crusts caused by wind-packing were present in the snow profile. Winds appeared to be predominantly from the north and east, and had blown the snow from exposed ridges. No moose sign was observed.

Snow Site 21

Site 21 was located in the headwaters of the east fork of Watana Creek approximately 17 miles upstream from its mouth and 2 miles downstream of site 20 (Figure 1). Site 21

was at 3,000 ft elevation with a southerly aspect and gentle slope. Vegetation was an open shrub community of resin birch and willow. The transect travelled down the stream valley parallel to and about 20-40 ft from Watana Creek Average snow depth was 30.8±4.1 inches, ranging from 21-38 inches deep (Figure 24). Snow hardness varied from hard to soft with no crust layers. Diamondleaf (about 20%) and Richardson willows were moderately browsed, but feltleaf willow had been heavily browsed by moose. The area was heavily utilized by wintering moose; about 50 animals were observed in this general area of Watana Creek.

Snow Site 22

Site 22 was located in the east fork of Watana Creek approximately 10 miles upstream from its mouth and 4 miles upstream of the confluence of the east and west forks of Watana Creek (Figure 1). Site 22 was at 2,800 ft elevation with a northerly aspect and gentle to moderate slope. Vegetation was an open forest community of black and white spruce. The transect was located on the valley slopes 0.25 mile above Watana Creek. It travelled around the hillside toward the west, paralleling Watana Creek. Average snow depth was 24.6±5.0 inches, ranging from 17-36 inches deep (Figure 25). A surface crust layer was present but variable. Diamondleaf willow was noted to be moderately to heavily browsed. Numerous moose tracks and other sign was observed. Alder had not been browsed.

Snow Site 23

Site 23 was located in Clark Creek approximately 4 miles upstream of the confluence of Clark Creek and Tsusena Creek (Figure 1). Site 23 was at 2,750 ft elevation with a southwesterly aspect and flat slope. Vegetation was a closed shrub community of resin birch, willow, and alder. Average snow depth was 43.0±3.2 inches, ranging from 35-49 inches deep (Figure 26). Only light to moderate browsing of current annual growth twigs of feltleaf willow had occurred, though the shrubs showed evidence of past heavy browsing pressure. No moose tracks were observed.

Snow Site 24

Site 24 was located on Tsusena Creek at the confluence of Clark Creek and Tsusena Creek, approximately 4 miles downstream of site 23 (Figure 1). Site 24 was at 2,380 ft elevation with a southerly aspect and gentle slope. Vegetation was a woodland forest community of white spruce. The transect paralleled Tsusena Creek. Average snow depth was 35.1±2.9 inches, ranging from 28-42 inches deep (Figure 27). Points 1-31 were along the west bank of Tsusena Creek; feltleaf willow was heavily browsed with 90-100% of the twigs removed. Points 32-57 were on a knoll 40 ft from Tsusena Creek, and points 58-71 were travelling from the knoll back to the bank of Tsusena Creek. Points 72-77 were again along the west bank of Tsusena Creek; feltleaf willow along the stream was all heavily browsed. Most browsing appeared to have occurred earlier during the winter as no fresh moose sign was observed.

Snow Site 25

Site 25 was located at the mouth of Tsusena Creek along the Susitna River (Figure 1). Site 25 was at 1,510 ft elevation with a westerly aspect and gentle (1 degree) slope. Vegetation was a woodland forest community of white spruce. The transect began on the bank ice paralleling the Susitna River crossing the mouth of Tsusena Creek, and then travelled into the forest on the west bank of the stream. Average snow depth was 28.6±2.6 inches, ranging from 23-34 inches deep (Figure 28). Points 1-16 were on ice along the north side of the Susitna River. Points 17-36 were in a white and black spruce forest on the west bank of Tsusena Creek; absence of crusts in the snow profile suggested a lack of wind in this area, snow was less deep directly beneath the crowns of spruce trees than between them, and moose tracks were noted to travel between spruce trees where evidence was found of moose feeding on mountain cranberry (Vaccinium vitis-idaea) and low-growing willows in the shallower snow beneath the tree crowns.

Snow Site 26

Site 26 was located at the mouth of Devil Creek along the Susitna River (Figure 1). Site 26 was at 1,110 ft elevation with a southerly aspect and gentle to 30 degree slope. Vegetation was a closed mixed forest community of spruce and paper birch (Betula papyrifera). The transect extended along the banks of the Susitna River and Devil Creek. Average snow depth was 27.9±9.9 inches, ranging from 9-55 inches deep (Figure 29). Points 1-9 were 10 ft off the north bank of the Susitna River; paper birch and alder had been lightly browsed. Points 10-20 were 30 ft off the north bank of the Susitna River; paper birch had been browsed and a single moose track was observed. Points 21-61 were along the east bank of Devil Creek. Points 62-96 were along the Susitna River; the shallow depths in the first part of this section suggested measurements were on overflow ice. Points 97-132 were on a hill adjacent to the north side of the Susitna River; paper birch and alder had been browsed. Points 133-158 were along the north bank of the Susitna River; the shallow depths in the first part of this section suggested measurements were on overflow ice, and the 2 points 150 and 151 were measured in a snow sluff off an adjacent rock cliff.

Snow Site 27

Site 27 was located 5.5 miles upstream of the mouth of Devil Creek (Figure 1). Site 27 was at 2,525 ft elevation with a easterly aspect and gentle (5 degree) slope. Vegetation was a closed shrub community of willow and resin birch. The transect extended along the banks of Devil Creek and then turned toward the distant western valley hillside. Average snow depth was 43.3±7.4 inches, ranging from 31-63 inches deep (Figure 30). Points 1-13 were oriented through the willows along the west bank of Devil Creek heading north; hard crusts were in the snow profile, feltleaf (90-100%) and diamondleaf (70%) willows were heavily browsed, the main stems of many feltleaf willow were broken off by foraging moose, and furrows formed by moose plowing through chest-deep snow were observed. Points 14-47 turned to the west away from the stream toward the valley hillsides; deep snow was present in depressions filled by blowing snow (e.g., points 21-25 and 46-47),

diamondleaf willow was less heavily browsed on the hillsides than nearer Devil Creek, and winds were primarily from the north or northeast.

Snow Site 28

Site 28 was located 9 miles upstream of the mouth of Devil Creek, and 3.5 miles upstream of site 27 (Figure 1). Site 28 was at 2,750 ft elevation with a south-southwesterly aspect and gentle slope. Vegetation was an open shrub community of willow and resin birch. The transect was adjacent to Devil Creek. Average snow depth was 42.9±11.4 inches, ranging from 22-64 inches deep (Figure 31). Feltleaf and diamondleaf (65%) willows were heavily browsed. No moose sign was observed.

Snow Site 29

Site 29 was located on the southwest shore of Stephan Lake (Figure 1). Site 29 was at 1,862 ft elevation with a flat aspect and slope. Shoreline vegetation was a closed forest community of spruce. The transect was on and adjacent to Stephan Lake. Average snow depth was 30.3±10.6 inches, ranging from 10-45 inches deep (Figure 32). Points 1-5 were on overflow ice of Stephan Lake. Points 6-30 were in the shoreline spruce forest; snow immediately became deeper as the observer moved from lake ice onto the shore (e.g., between points 5 and 6), snow depths stabilized around 39 inches deep within the trees, and not much evidence of drifting was observed. Points 31-51 were in a graminoid-dominated summer bog; points 32 and 33 were on overflow ice from a small stream, and there was some evidence of drifting. Points 52-59 were again on lake ice. No moose sign was observed. Winds appeared to be a rather infrequent event on this lake.

Snow Site 30

Site 30 was located along a tributary of Prairie Creek, 2 miles southeast of site 29 (Figure 1). Site 30 was at 2,200 ft elevation with a southwesterly aspect and gentle (5 degree) slope. Vegetation was a closed forest community of spruce and paper birch and an open shrub community of willow. The transect extended down the tributary stream. Average snow depth was 39.1±3.4 inches, ranging from 32-50 inches deep (Figure 33).

Points 1-80 were through a willow dominated shrub community; diamondleaf, feltleaf, and Richardson willows were all moderately to heavily browsed. Points 81-89 were in an adjacent spruce forest. Only old moose sign was observed, implying the area had primarily been used earlier during the winter.

Snow Site 31

Site 31 was located near upper Prairie Creek about 2 miles southeast of site 30 (Figure 1). Site 31 was at 2,500 ft elevation with a north-northwesterly aspect and gentle slope. Vegetation was an open shrub community of willow. The transect extended along the tributary stream. Average snow depth was 37.5±2.6 inches, ranging from 32-42 inches deep (Figure 34). Feltleaf willow was heavily browsed. Only old moose sign was observed, implying the area had primarily been used earlier during the winter.

5.2 Winter Bird Transect Site Descriptions

Bird Transect 1

Bird transect 1 was located on the north side of the Susitna River approximately 1 mile downstream of the mouth of Fog Creek (Figure 35). Elevations ranged from 1,370-1,700 ft with a southerly aspect and gentle to steep slopes. The transect began near the bank and ran parallel to the Susitna River to the west, then turned upslope to the north, then turned east contouring around the slope, and then turned southeast returning to the point of origin (Figure 35). Vegetation along the transect was primarily closed spruce and mixed spruce-paper birch forests. Average snow depth was 32.5±2.4 inches, ranging from 26-38 inches deep (Figure 36). Sample points from 0845-1130 and 1415-1515 were at elevations below the Devil Canyon maximum high pool level of 1,466 ft, while points 1145-1400 were above that elevation. A light surface crust was noted to be present. Snow depths remained relatively consistent throughout the closed forests crossed by this transect.

Bird Transect 2

Bird transect 2 was located on the north side of the Susitna River across from the mouth of Fog Creek (Figure 35). Elevations ranged from 1,370-1,900 ft with a

southwesterly aspect and gentle to steep slopes. The transect began near the bank and ran north along the Susitna River, then turned upslope to the west, then turned southwest contouring around the slope, and then turned southeast returning to the point of origin (Figure 35). Vegetation along the transect was primarily closed spruce and mixed spruce-paper birch forests. Average snow depth was 30.2±2.6 inches, ranging from 25-34 inches deep (Figure 37). Sample points from 0830-1200 and 1430-1445 were at elevations below the Devil Canyon maximum high pool level of 1,466 ft, while points 1230-1415 were above that elevation. Snow depths remained relatively consistent throughout the closed forests crossed by this transect. A light surface crust was noted to be present.

Bird Transect 3

Bird transect 3 was located on the north side of the Susitna River near the mouth of Watana Creek (Figure 35). Elevations ranged from 1,550-2,020 ft with a southerly aspect and gentle to steep slopes. The transect began near the mouth of Watana Creek and ran upslope to the northeast and parallel to the stream, then turned upslope to the southeast, then turned back downslope to the southwest returning to the point of origin (Figure 35). Vegetation along the transect was primarily mixed spruce-paper birch forests at the lower elevations and woodland spruce and resin birch at the higher elevations. Average snow depth was 25.0±2.5 inches, ranging from 19-30 inches deep (Figure 38). All sample points were at elevations below the Watana Stage III maximum high pool level of 2,200 ft. Snow depths remained relatively consistent throughout the area crossed by this transect. The snow was noted to be soft and powdery.

Bird Transect 4

Bird transect 4 was located on the north side of the Susitna River between Sally Lake and the mouth of Watana Creek (Figure 35). Elevations ranged from 1,550-2,100 ft with a southerly aspect and gentle to steep slopes. The transect began at the edge of Sally Lake and ran generally across the slope to the southwest toward the Susitna River, then turned westerly and contoured near the top of the steep slope above the canyon, ending at the mouth

of Watana Creek (Figure 35). Vegetation along the transect was primarily mixed spruce-paper birch forests at the lower elevations and woodland spruce and resin birch at the higher elevations. Average snow depth was 20.3±2.5 inches, ranging from 15-25 inches deep (Figure 39). All sample points were at elevations below the Watana Stage III maximum high pool level of 2,200 ft. Snow depths remained relatively consistent throughout the area crossed by this transect. The snow was noted to be soft and powdery.

Bird Transect 5

Bird transect 5 was located on the north side of the Susitna River northwest of the mouth of Kosina Creek (Figure 35). Elevations ranged from 1,620-2,600 ft with a southerly aspect and gentle to steep slopes. The transect began at the edge of a small lake situated on the uplands northwest of the mouth of Kosina Creek, travelled in a generally straight line to the west-northwest for about 3 miles, then turned south and ended on the banks of the Susitna River (Figure 35). Vegetation along the transect was primarily open and closed spruce forest. Average snow depth was 19.3±4.1 inches, ranging from 11-25 inches deep (Figure 40). Sample points from 1115-1300 were at elevations above the Watana Stage III maximum high pool level of 2,200 ft, while points 1315 -1530 were below that elevation. Snow depths were variable, but on the average appeared to be deeper at the higher elevations between points 1115-1315 than at the lower elevations nearer the river (Figure 40).

Bird Transect 6

Bird transect 6 was located on the north side of the Susitna River northwest of the mouth of Kosina Creek (Figure 35). Elevations ranged from 1,640-2,700 ft with a southerly aspect and gentle to steep slopes. The transect began at the edge of the same small lake situated on the uplands northwest of the mouth of Kosina Creek where bird transect 5 began but at the opposite end, travelled to the northeast, then turned south-southwest, and then turned west where it ended on the banks of the Susitna River (Figure 35). Vegetation along the transect was primarily open and closed spruce and mixed spruce-paper birch

forests. Average snow depth was 22.1±2.8 inches, ranging from 17-27 inches deep (Figure 41). Sample points from 1115-1330 were at elevations above the Watana Stage III maximum high pool level of 2,200 ft, while points 1345-1615 were below that elevation. Snow depths were variable, but on the average appeared to be deeper at the higher elevations between points 1115-1315 than at the lower elevations nearer the river (Figure 41).

5.3 Comparisons Among Sites

Snow sites were conducted in sets of 3 or more because there were 3 observers. Often, sites were selected following a drainage valley; this was the case for Jay, Coal, Watana, Clark/Tsusena, and Devil Creeks. Because sites located along drainages generally followed elevational gradients, average snow depths among adjacent sites within those drainages were compared. Snow depths were averaged across all measurements taken at a site, including those in drifts and on overflow ice. For comparison, sites were plotted on figures by decreasing elevation within each drainage (see Figure 1).

Average snow depths in Jay Creek decreased from about 28 inches at site 1 to approximately 17 inches at site 14; a decline in elevation of about 1,850 ft (Figure 42). There appeared to be no difference by elevation along Coal Creek, averaging 27 inches for the 5 sites (Figure 43). Greatest difference in average snow depths by elevation occurred in the Watana Creek drainage, with 44 inches at elevation 3,300 ft and 23 inches at elevation 1,600 ft (Figure 44) Average snow depths in the Clark/Tsusena Creek drainage decreased from 43 inches at elevation 2,750 ft to 29 inches at elevation 1,510 ft, a decline of 1,240 ft. (Figure 45). Average snow depth was lower at site 26 at the mouth of Devil Creek than at either of the other higher elevation sites within that drainage (Figure 46).

When elevation of all 31 sites was compared with average snow depths, no trend was apparent (Figure 47). Selected sites covered a broad geographical range between Coal Creek and Devil Creek, and regional differences were expected. The maritime influence in the transitional climatic zone of the project area west of Tsusena Creek probably were a major

factor influencing snow depths relative to elevation at sites within that region. To the east of Tsusena Creek the project area appeared to become increasingly drier as the continental climatic zone was approached and the area entered the rain shadow of the Talkeetna Mountains. Other major factors that presumably could influence snow depth differences among the sites were movement of storm systems, topographic variation, and changes in latitude.

6 DISCUSSION

As anticipated, snow depths varied considerably within sites. Wind action, causing snow drifts and filling of depressions, resulted in variation. Snow depths were generally less when taken from atop overflow of frozen streams, lakes, or the Susitna River, where the underlying water had melted or incorporated snow in formation of the ice. Snow tended to be deeper in protected areas such as in denser vegetation (e.g., spruce forests and tall shrubs) than in open areas (e.g., low shrubs). Relatively little crusting was found at any site except those that had experienced wind-packing. Wind-packing was particularly evident in the exposed portions of the higher elevation sites such as upper ends of drainages and on exposed ridges.

Variation in snow depths was also affected by direction, distance, and length of transects placed within sites by individual observers. This was left entirely to the discretion of each observer, who was given only the guideline to obtain samples representing the variation present at a site. Variation among observers was apparent as each sought to sample portions of sites of particular interest to that individual. The samples were obviously not randomly distributed, but when all points were taken as a whole and averaged across all points sampled they may have approximated the mean snow depth at a site.

Variation among sites was not explainable by elevational differences alone. Other unmeasured variables may account for these differences. Within a drainage, snow depths generally decreased with decreasing elevation. Generally, average snow depths increased from east to west over the basin in spite of decreases in elevation over that same gradient.

The magnitude of increase in snow depths in the western portion of the study area was also probably affected by the year it was sampled; winter 1985 was a particularly deep snowfall year of record for the lower Susitna basin, the effects of which extended north of Talkeetna into Devil Canyon (SCS 1985).

7 PROJECT IMPLICATIONS

Given the limitations of the data collected from this single snow survey where sampling was by non-random techniques, conclusions drawn from this study must be viewed as tentative and subject to individual interpretation.

The results presented here suggest that snow depths decrease from higher elevations to lower elevations. These findings tend to support the hypothesis of Ballard et al. (1983, 1984) concerning patterns of moose movements over elevational gradients in the middle Susitna River basin. Snow depths also appear to decrease from west to east in the study area.

The importance of snow depths to moose are basically 2-fold: snow accumulation 1) restricts locomotion, and 2) covers food resources. The majority of tracks and other sign of the presence of moose were found along riparian drainages where forage resources of primarily willow were concentrated. This was particularly evident along upper Watana Creek (e.g., site 21) where numerous moose were concentrated around their similarly concentrated food source in spite of the almost 31 inches of snow. This suggests that moose concentrate during winter at locally available food sources even when snow depths approach those that would otherwise restrict movements. Other observational evidence collected during this study substantiates previous observations of Ballard et al. (1982, 1983, 1984) that moose will move from previously used areas to areas of lesser snow depths when accumulated snow restricts movements or covers forage resources (e.g., sites 7, 8, 9, 4, 24, 27, 28, 30, and 31).

Moose sign that we examined during late-winter 1985 appeared to be concentrated in areas occupied by feltleaf willow. Feltleaf willow usually grows in association with

riparian areas or on disturbed sites, and at all sites where notation was made it was always more heavily browsed than other willow species with which it grew in association. It is also the dominant willow species growing in riparian areas along the Susitna River. Feltleaf willow is tall-growing, and protrudes above the snow when other shorter willow species become covered. Moose movement and population data (Ballard et al. 1983, 1984), and subjective observations from this study suggest that during late winter moose concentrate in lower elevation riparian zones where snow is less deep and foods such as feltleaf willow protrude above the snow. Loss of lower elevation habitats supporting concentrated forage resources and having lower snow depth accumulations will have an adverse impact on wintering moose populations.

8 LITERATURE CITED

Ballard, W.B., C.L. Gardner, J.H. Westlund, and J.R. Dau. 1982. Big game studies, V III, Moose - Upstream. Susitna Hydroelectric Project. Phase I final report by the Alaska Dept. of Fish and Game to the Alaska Power Authority. Anchorage. 199pp. plus appendices.

_____, J.S. Whitman, N.G. Tankersley, L.D. Aumiller, and P. Hessing. 1983. Big game studies, Vol. III, Moose - Upstream. Susitna Hydroelectric Project. Phase II progress report by the Alaska Dept. of Fish and Game to the Alaska Power Authority. Anchorage. 141pp.

_____, _____, _____, _____, and _____. 1984. Big game studies, Vol. III, Moose - Upstream. Susitna Hydroelectric Project. Annual report by the Alaska Dept. of Fish and Game to the Alaska Power Authority. Anchorage. 147pp.

_____, _____, and C.L. Gardner. 1985. Moose - Upstream. Susitna Hydroelectric Project. Annual report by the Alaska Dept. of Fish and Game to the Alaska Power Authority. Anchorage. 48pp.

Coady, J.W. 1974. Influence of snow on behavior of moose. Can. Nat. 101:417-436.

Herter, D. 1985. Winter bird populations in forest habitats of the middle Susitna River basin, Alaska. Susitna Hydroelectric Project. Report by LGL Alaska Research Associates, Inc. under contract to Harza-Ebasco Susitna Joint Venture for the Alaska Power Authority. Anchorage. 24pp.

Kelsall, J.P., and E.S. Telfer. 1974. Biogeography of moose with particular reference to western North America. Can. Nat. 101:117-130.

LeResche, R.E. 1974. Moose migrations in North America. Can. Nat. 101:393-415.

SCS (Soil Conservation Service). 1985. Snow surveys and water supply outlook for Alaska. U.S. Dept. Agric. Soil Conser. Serv. Rep. March. 13pp.

Telfer, E.S. 1970. Winter habitat selection by moose and white-tailed deer. J. Wildl. Manage. 34:533-559.

Viereck, L.A., C.T. Dyrness, and A.R. Batten. 1982. Revision of preliminary classification for vegetation of Alaska. Unpublished report from Anchorage Workshop on Classification of Alaskan Vegetation, December 24, 1981. 72pp.

FIGURES

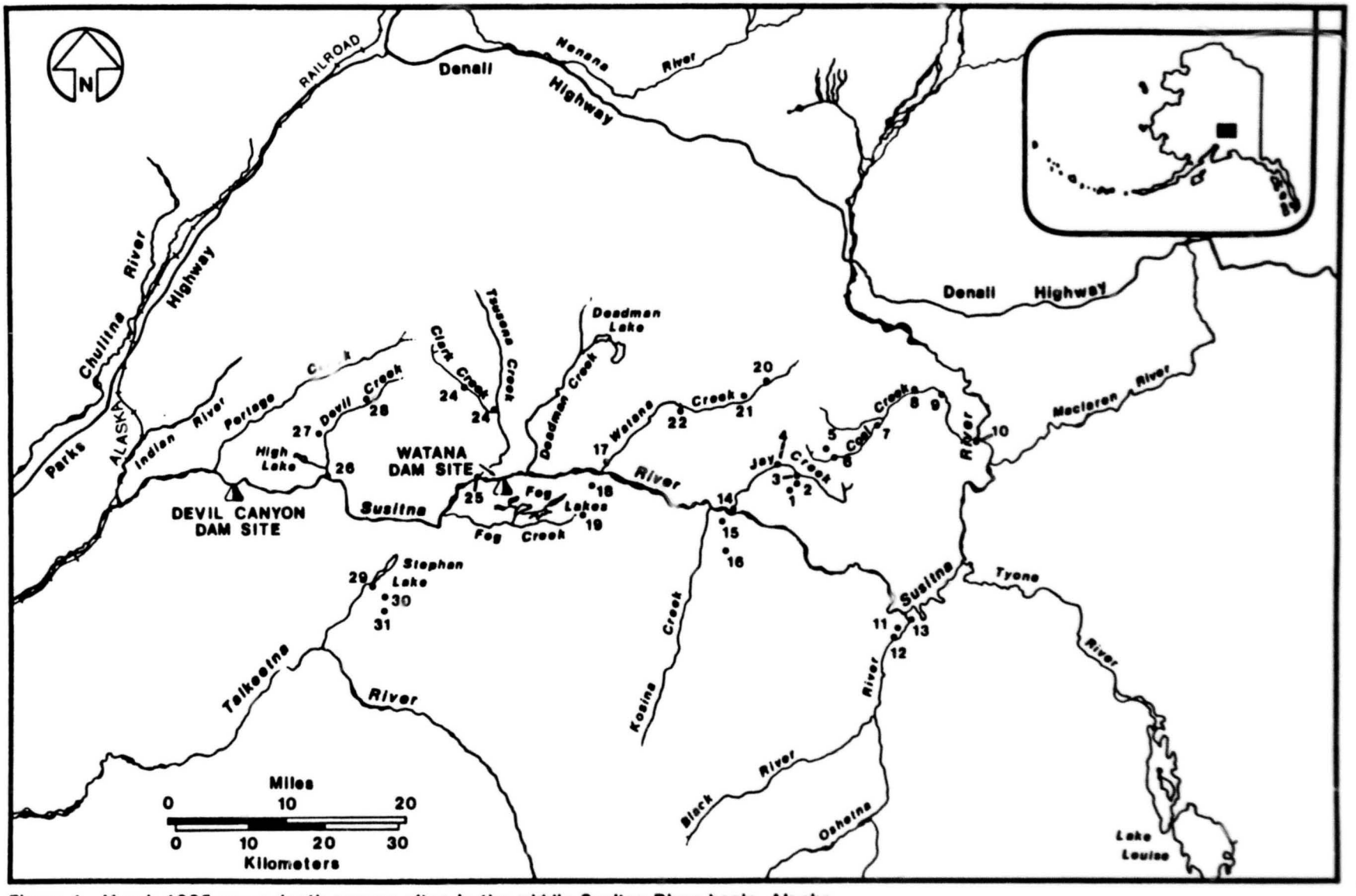

Figure 1. March 1985 snow depth survey sites in the middle Susitna River basin, Alaska.

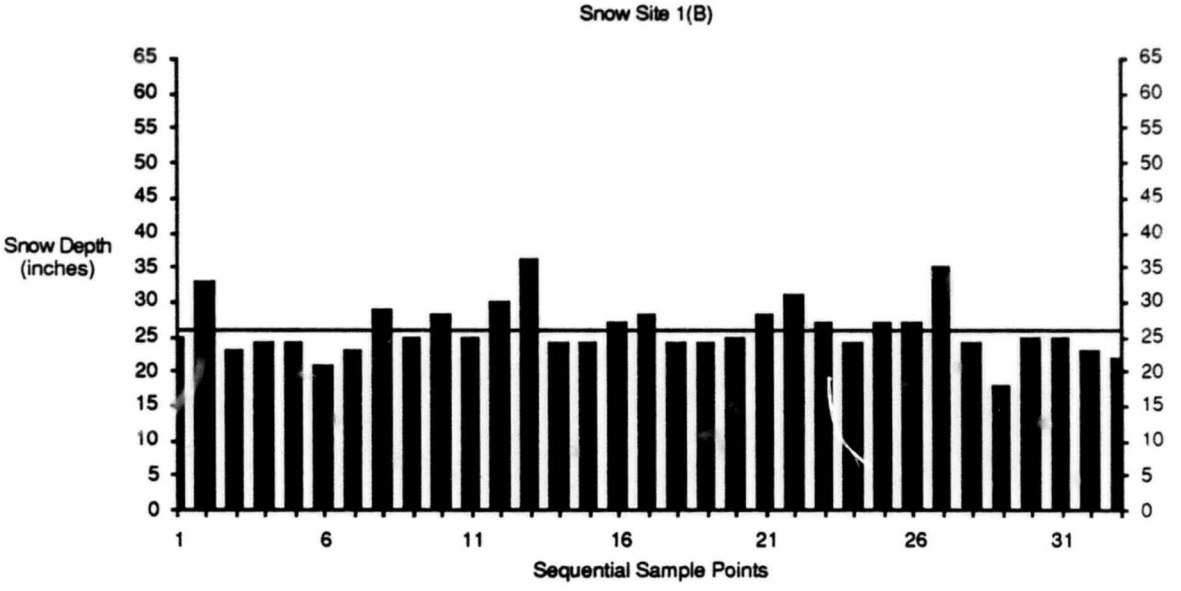

Figure 2. Snow depths at sequential sample points for snow site 1(B).

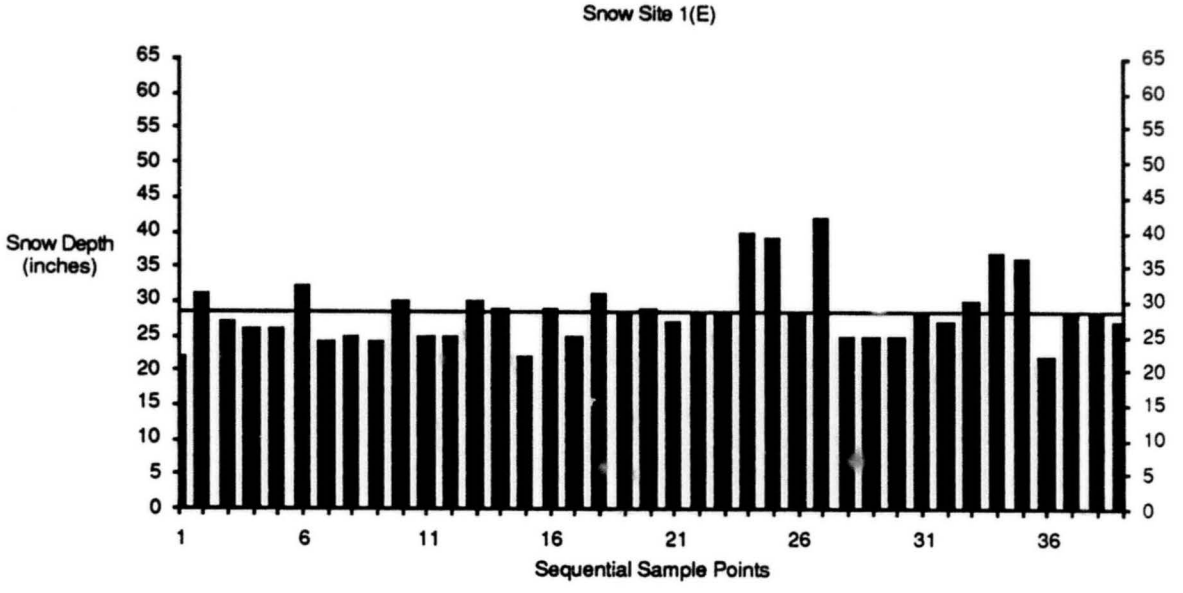

Figure 3. Snow depths at sequential sample points for snow site 1(E).

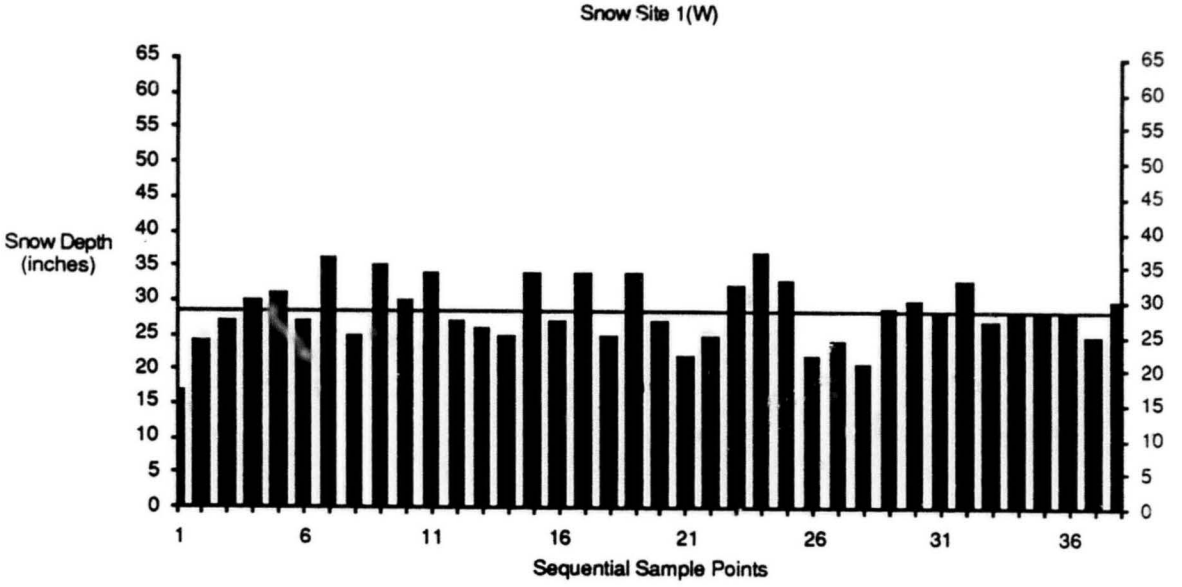

Figure 4. Snow depths at sequential sample points for snow site 1(W).

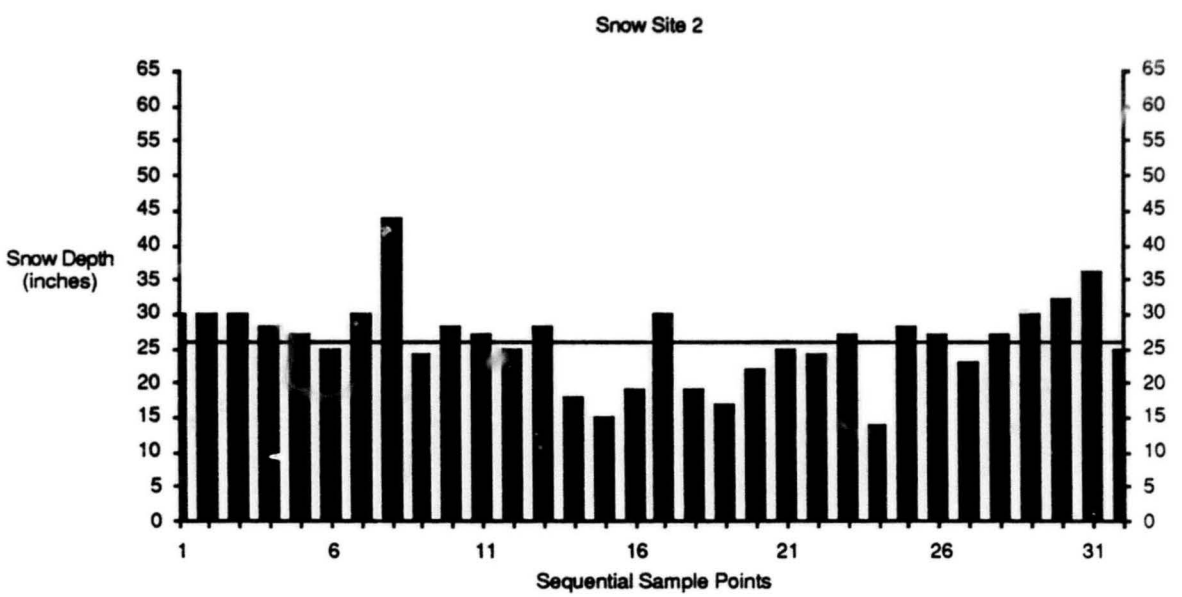

Figure 5. Snow depths at sequential sample points for snow site 2.

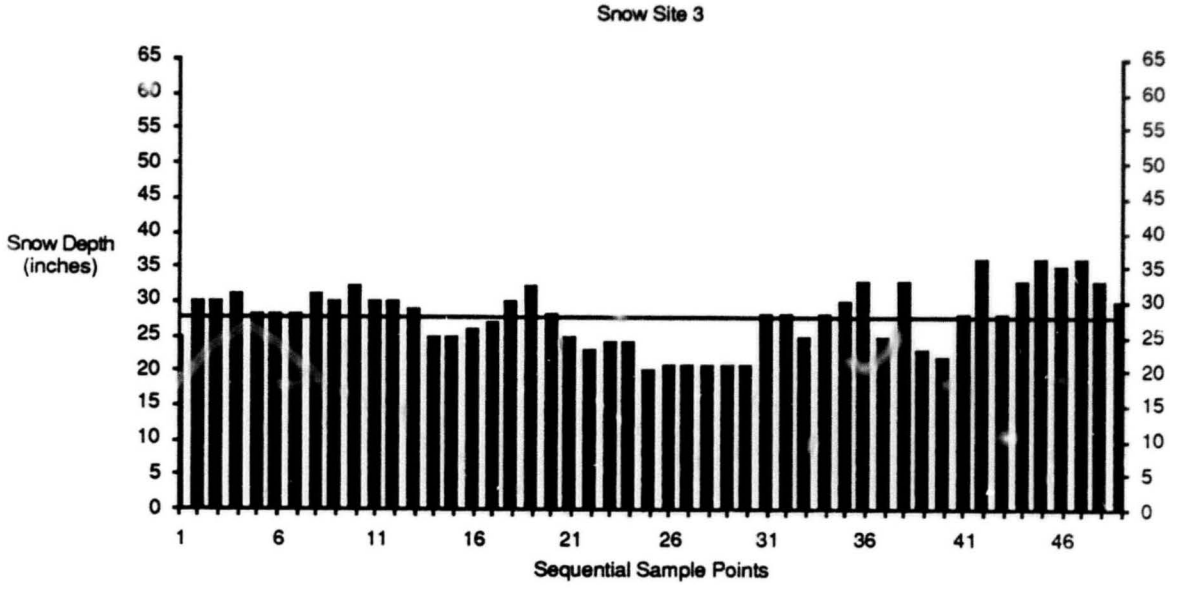

Figure 6. Snow depths at sequential sample points for snow site 3.

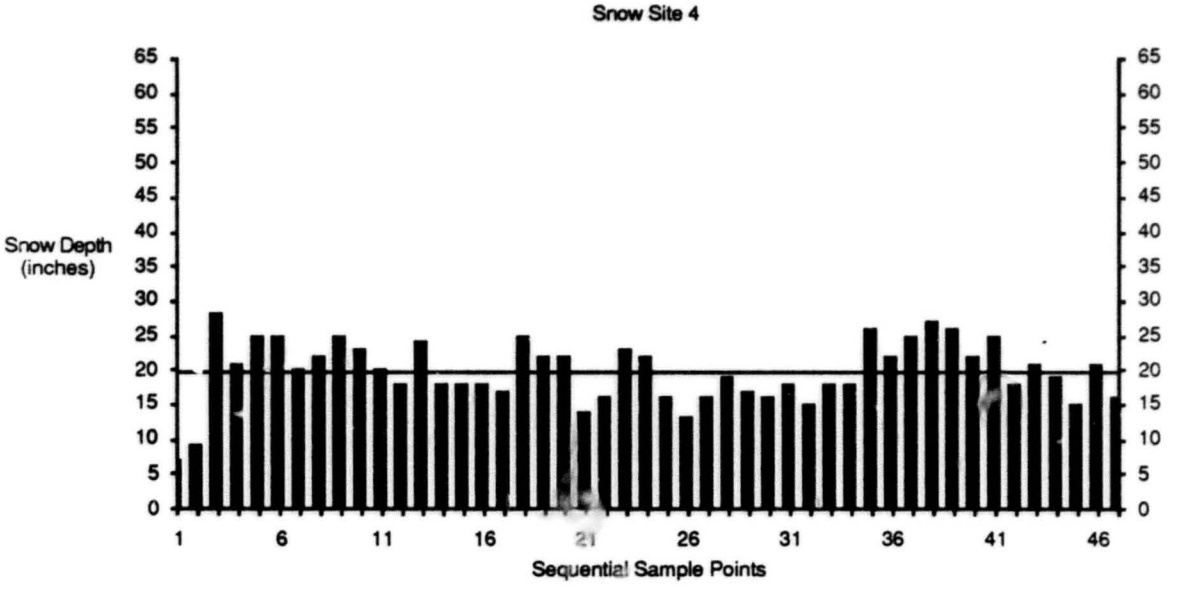

Figure 7. Snow depths at sequential sample points for snow site 4.

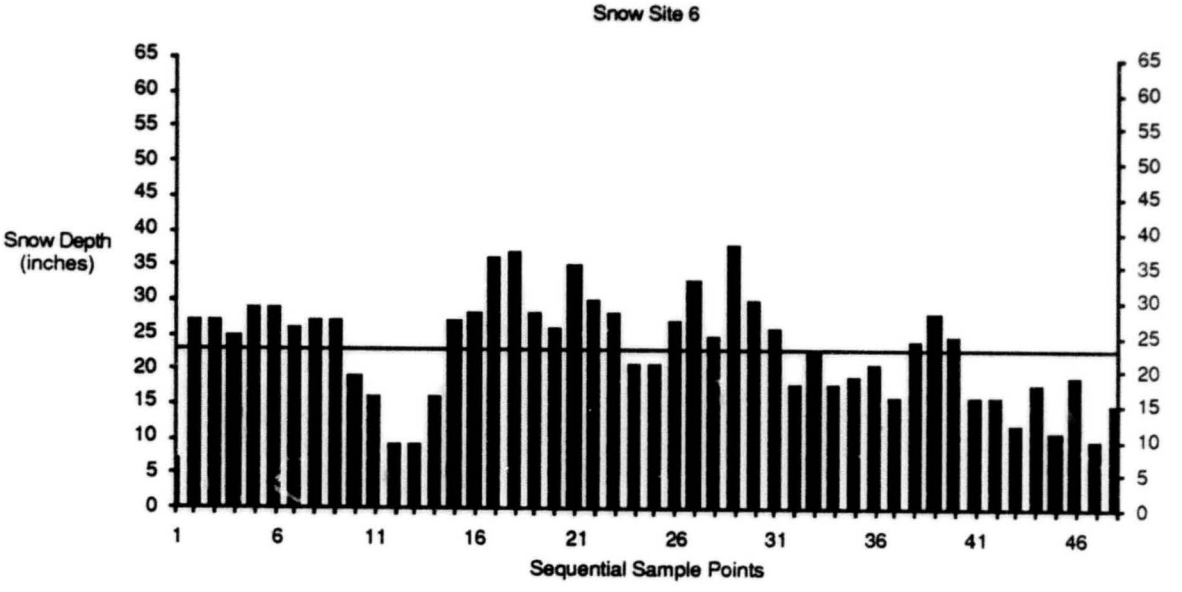

Figure 9. Snow depths at sequential sample points for snow site 6.

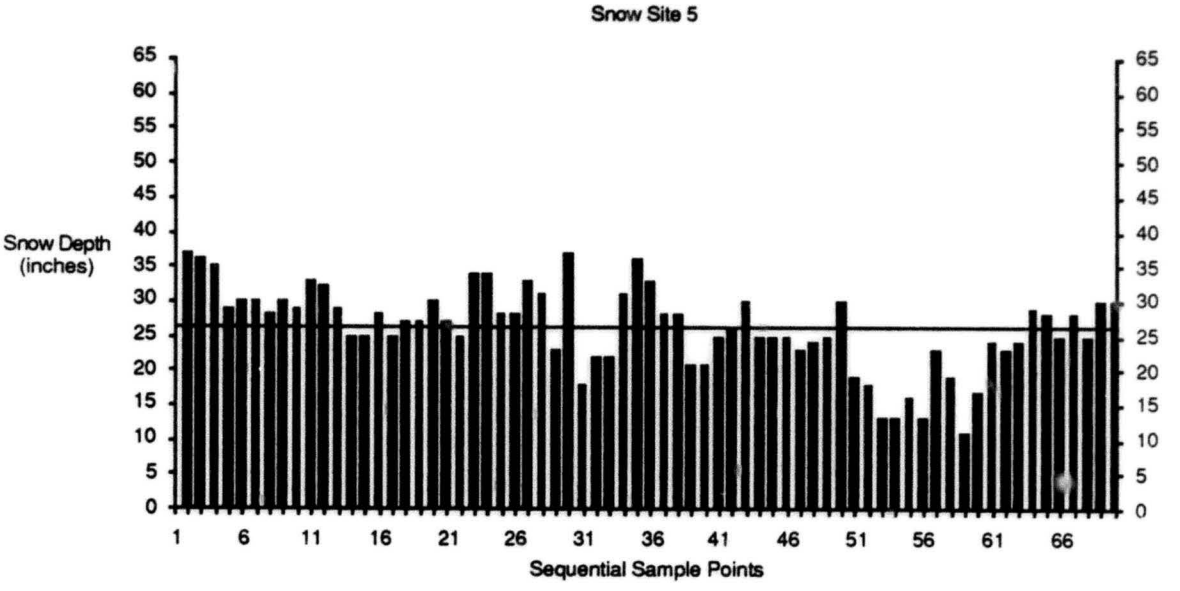

Figure 8. Snow depths at sequential sample points for snow site 5.

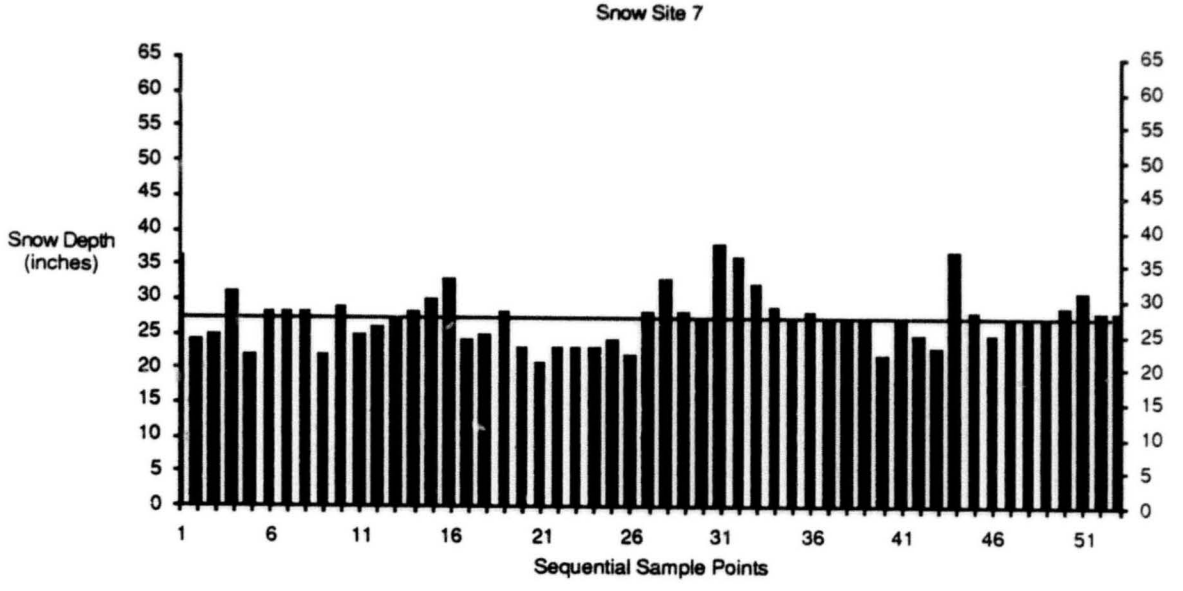

Figure 10. Snow depths at sequential sample points for snow site 7.

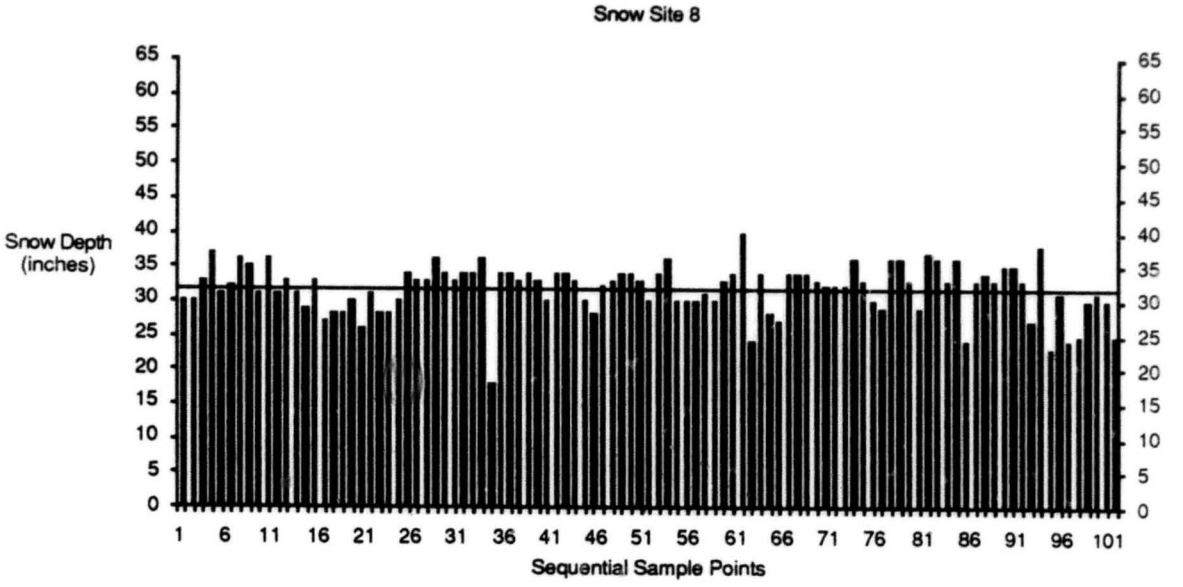

Figure 11. Snow depths at sequential sample points for snow site 8.

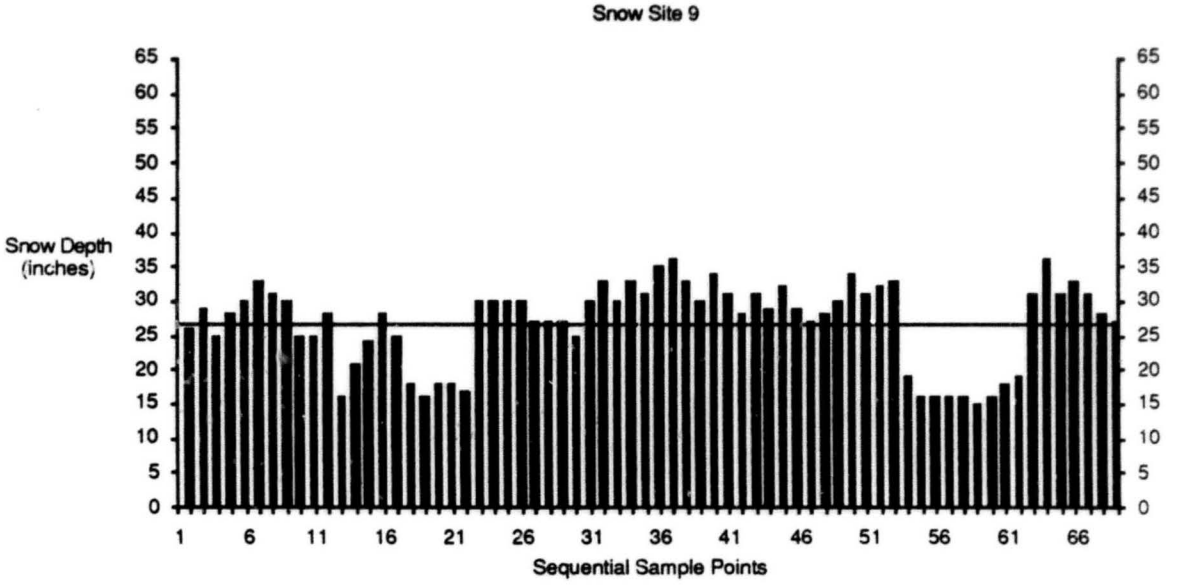

Figure 12. Snow depths at sequential sample points for snow site 9.

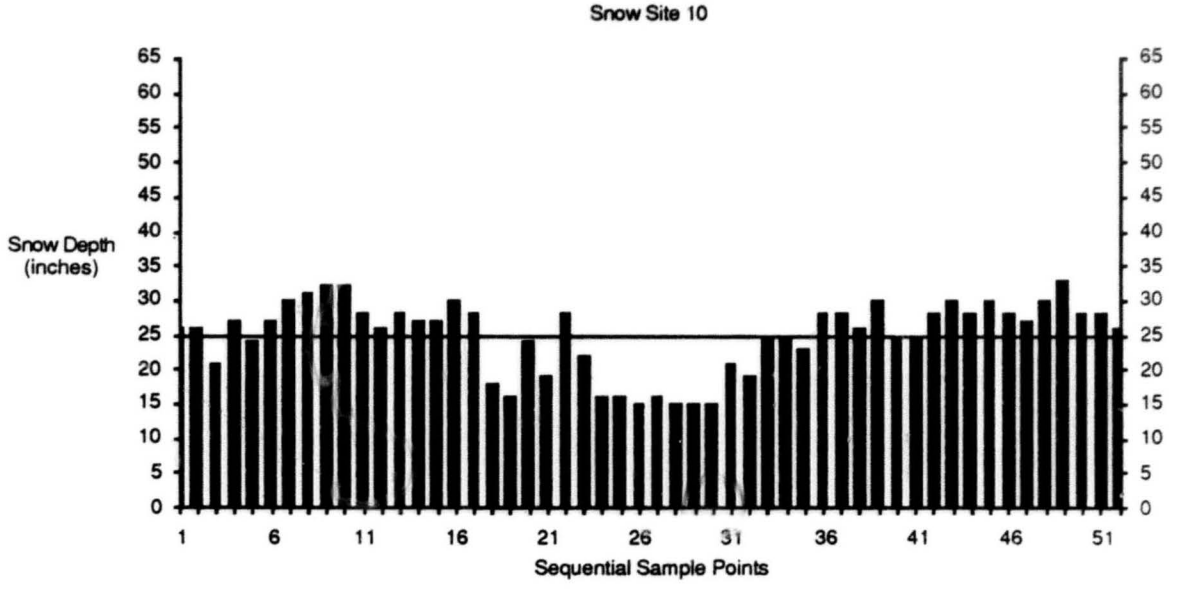

Figure 13. Snow depths at sequential sample points for snow site 10.

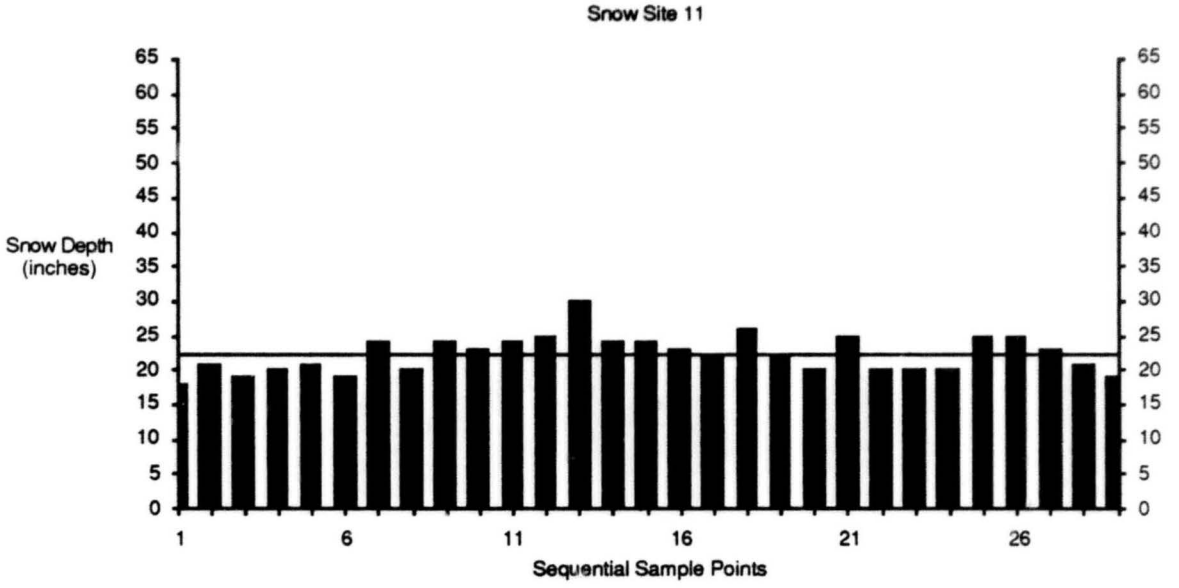

Figure 14. Snow depths at sequential sample points for snow site 11.

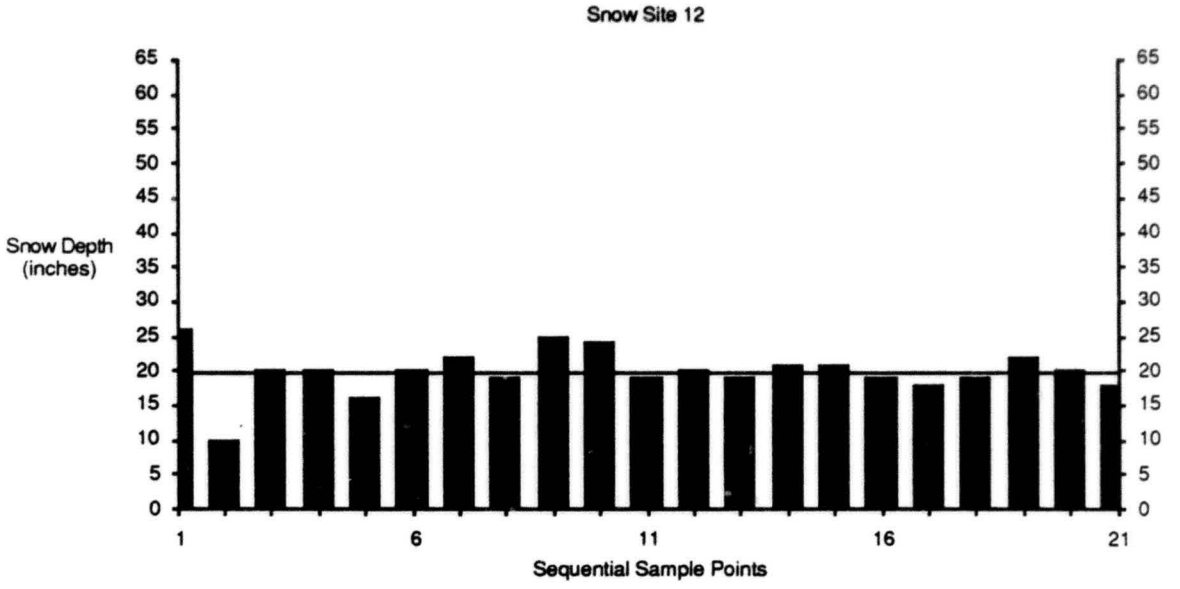

Figure 15. Snow depths at sequential sample points for snow site 12.

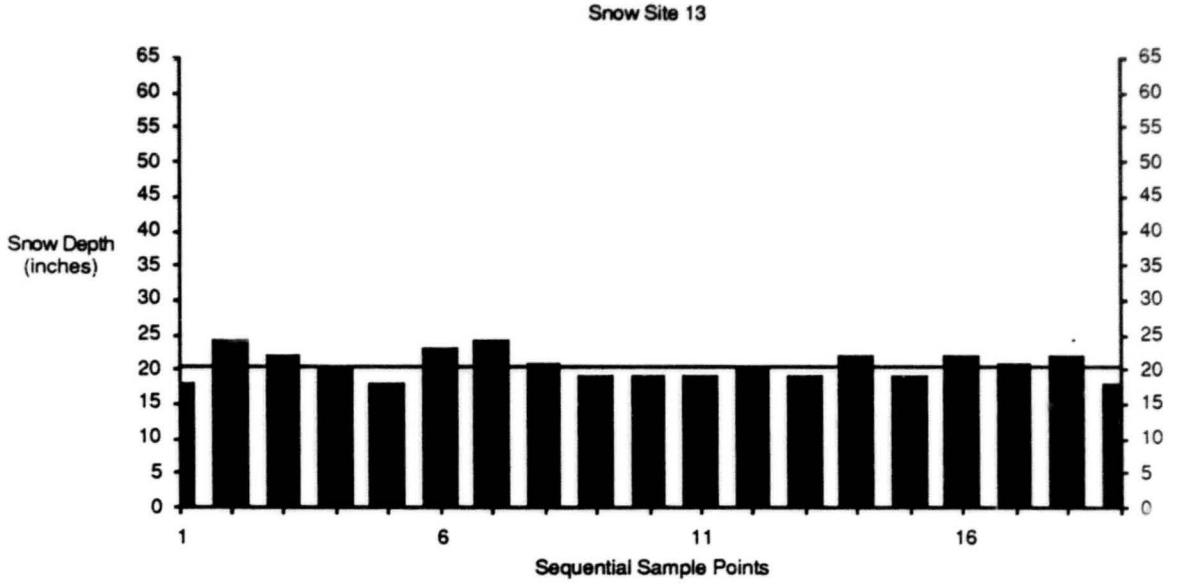

Figure 16. Snow depths at sequential sample points for snow site 13.

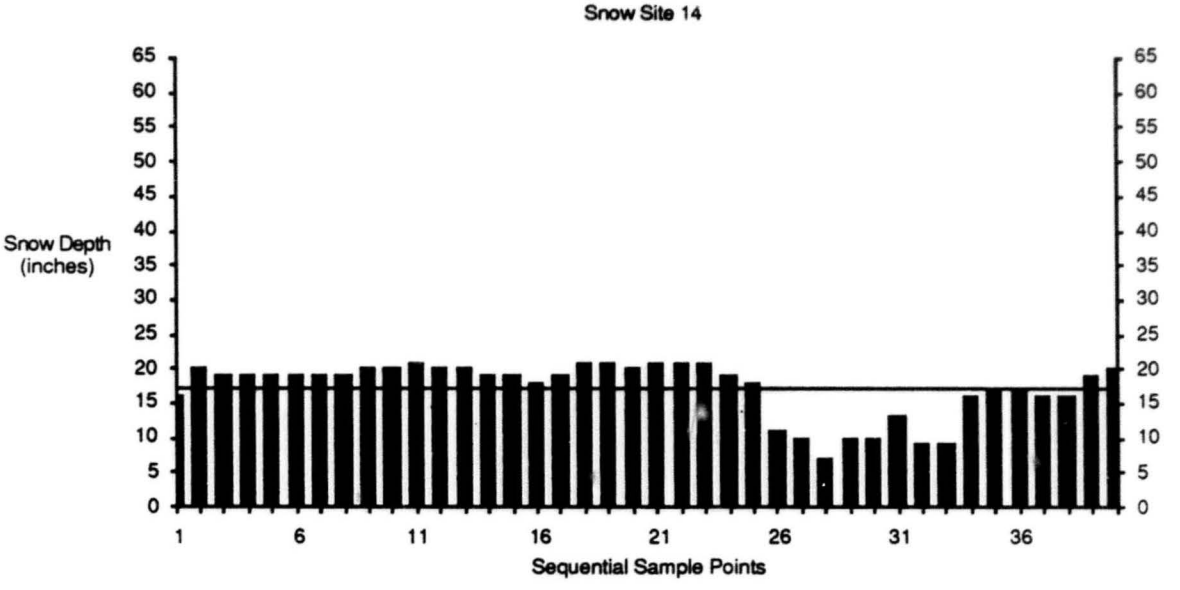

Figure 17. Snow depths at sequential sample points for snow site 14.

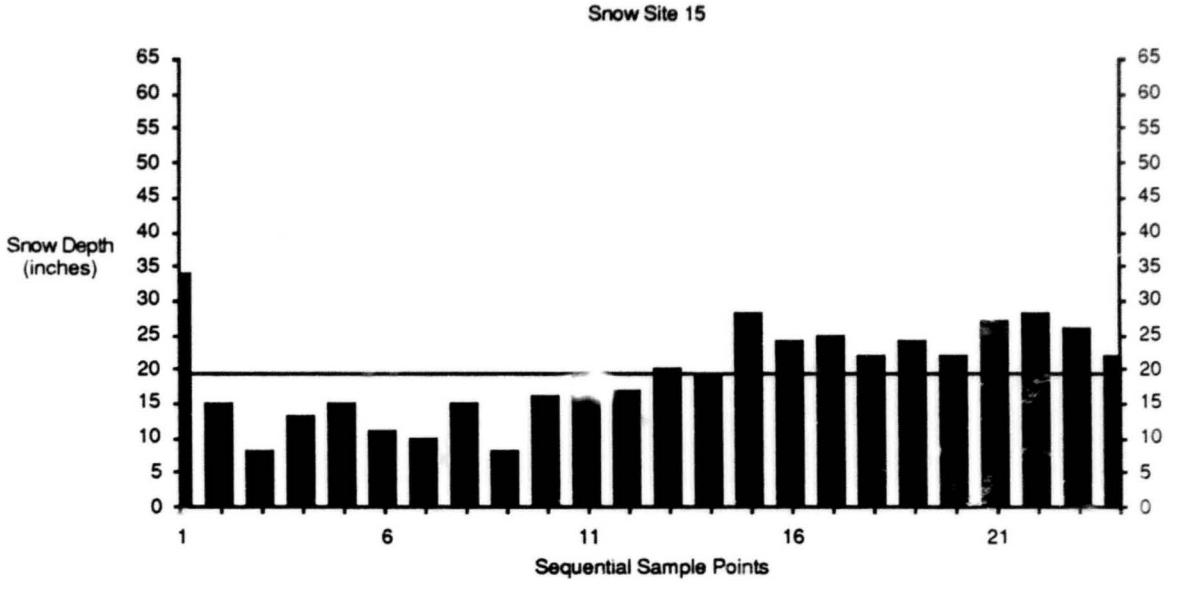

Figure 18. Snow depths at sequential sample points for snow site 15.

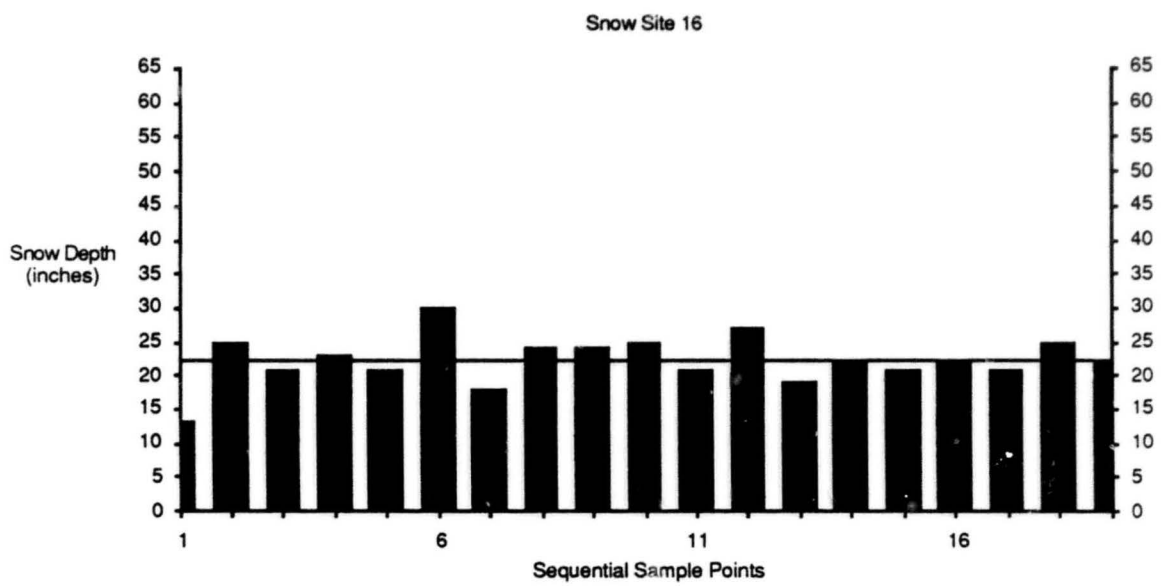

Figure 19. Snow depths at sequential sample points for snow site 16.

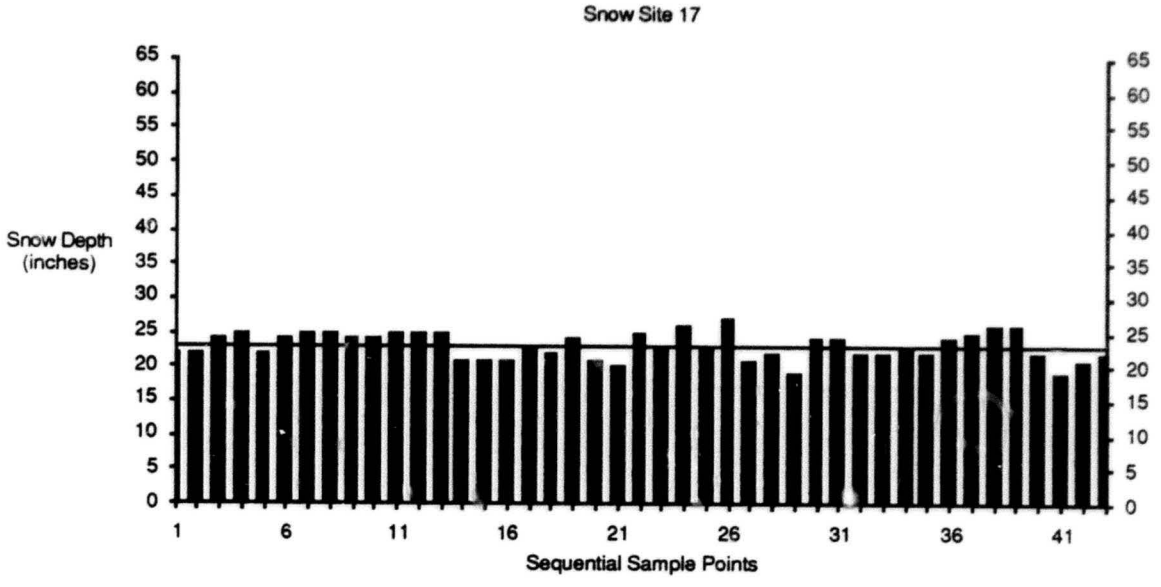

Figure 20. Snow depths at sequential sample points for snow site 17.

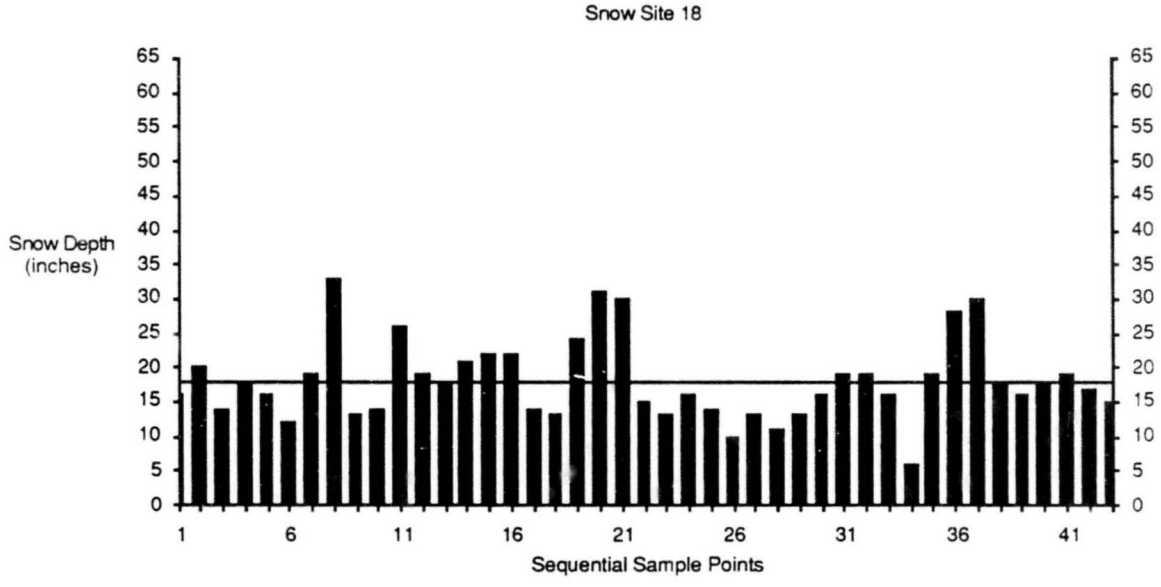

Figure 21. Snow depths at sequential sample points for snow site 18.

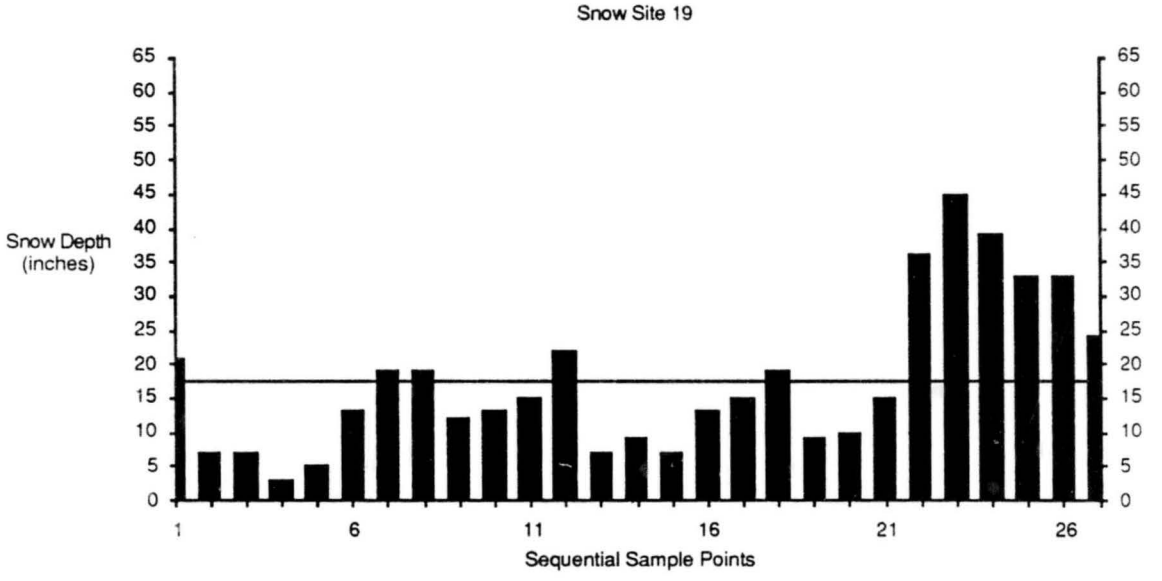

Figure 22. Snow depths at sequential sample points for snow site 19.

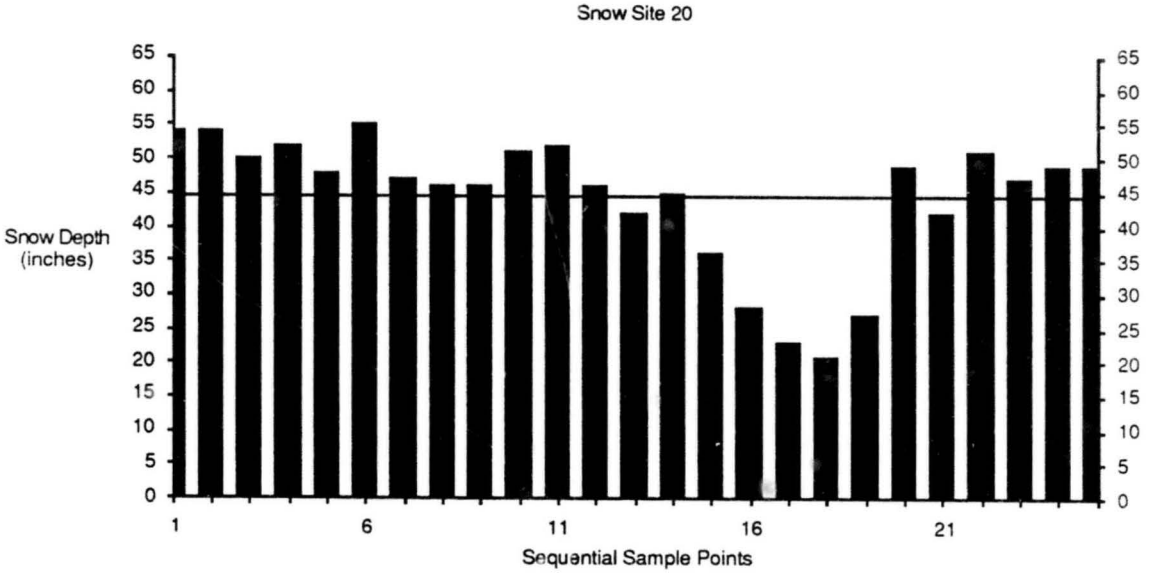

Figure 23. Snow depths at sequential sample points for snow site 20.

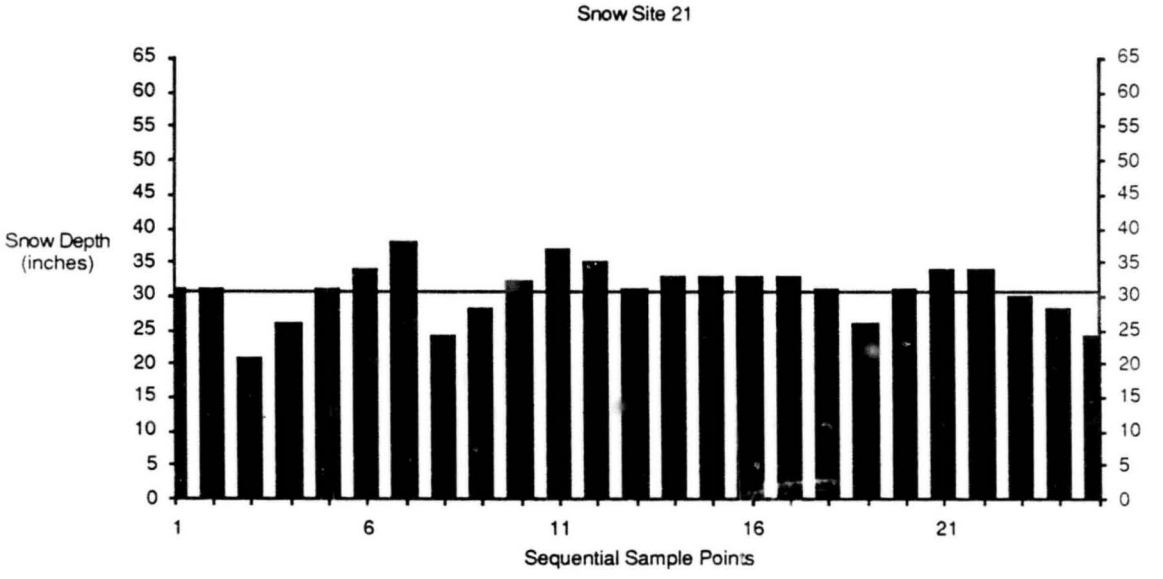

Figure 24. Snow depths at sequential sample points for snow site 21.

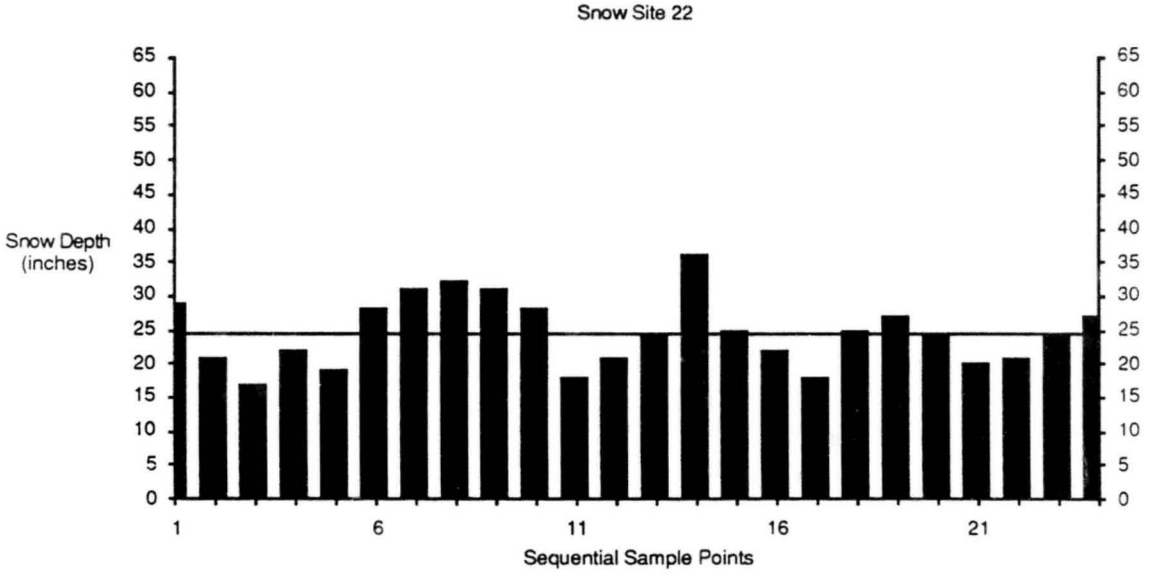

Figure 25. Snow depths at sequential sample points for snow site 22.

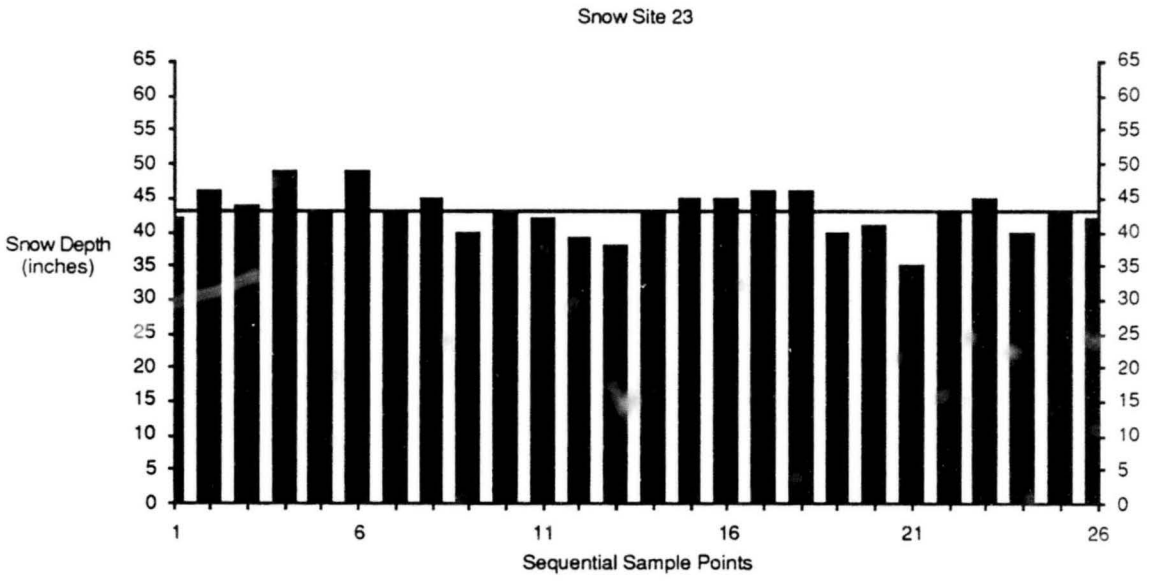

Figure 26. Snow depths at sequential sample points for snow site 23.

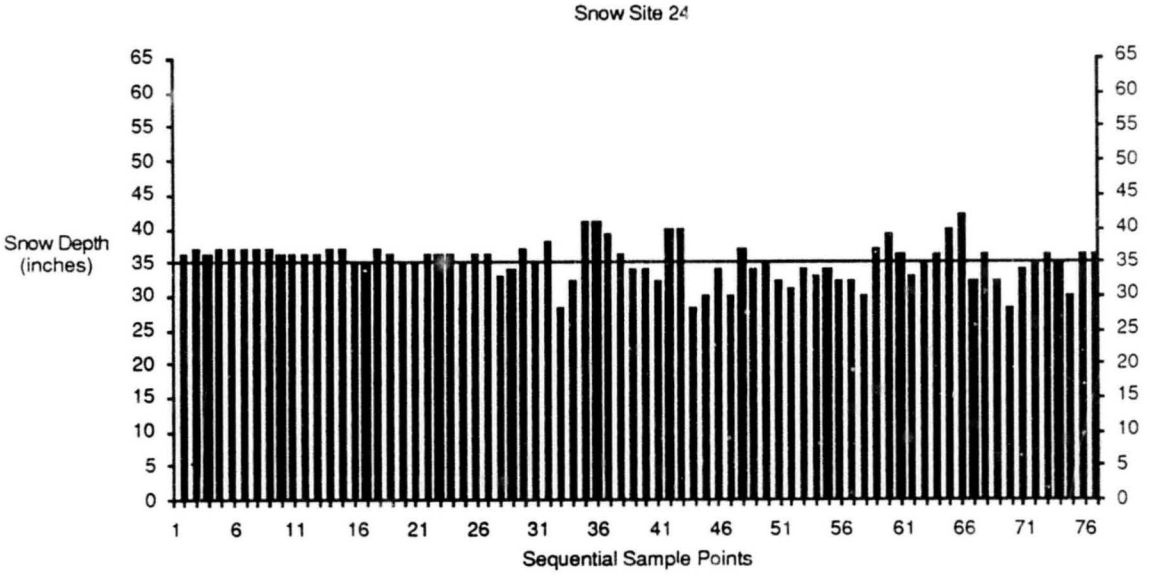

Figure 27. Snow depths at sequential sample points for snow site 24.

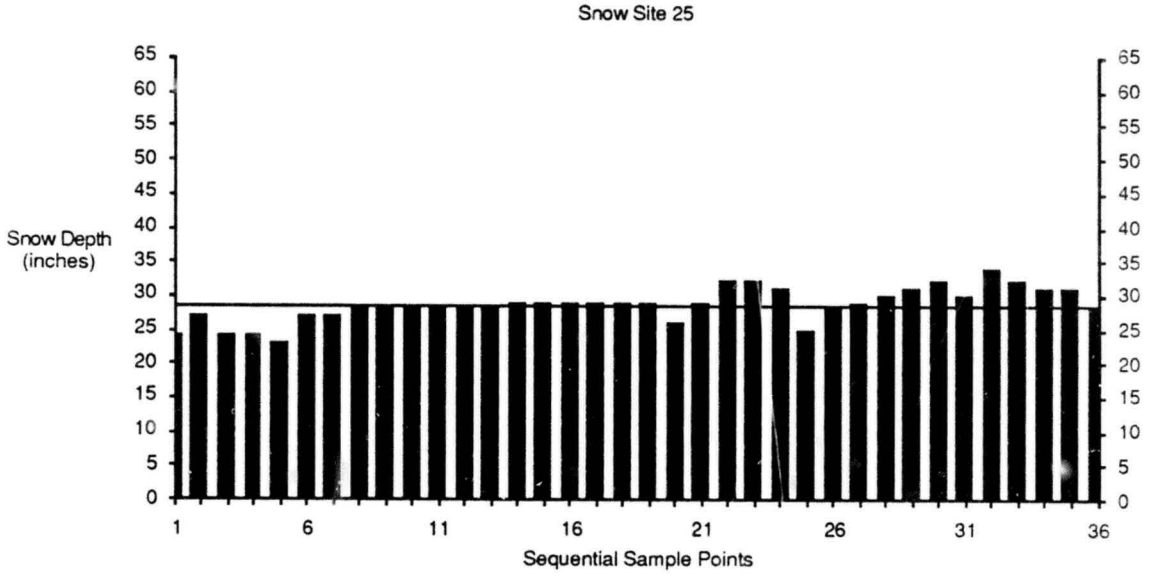

Figure 28. Snow depths at sequential sample points for snow site 25.

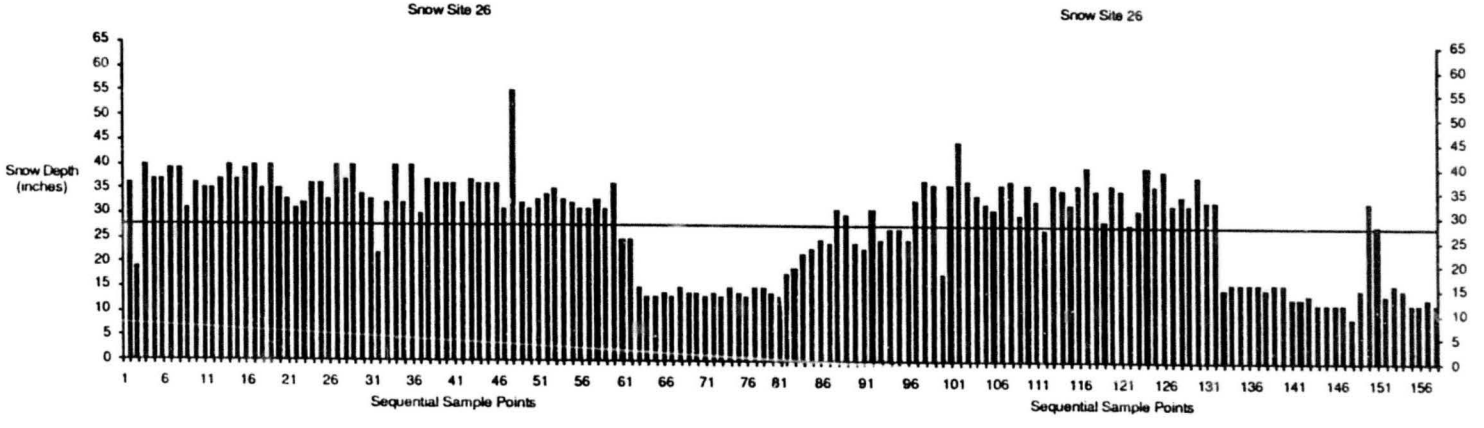

Figure 29. Snow depths at sequential sample points for snow site 26.

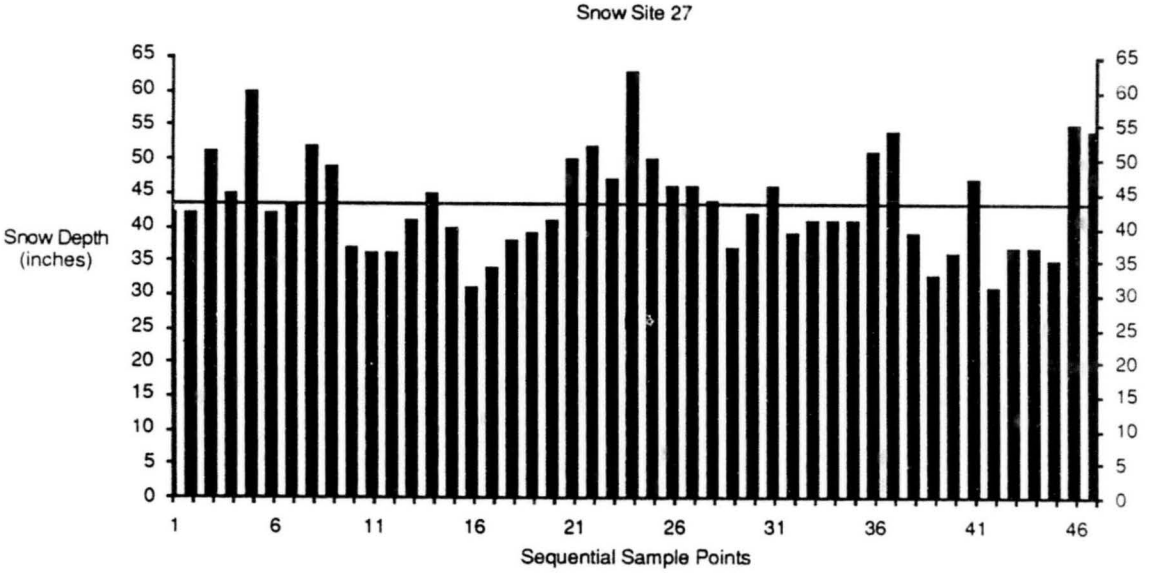

Figure 30. Snow depths at sequential sample points for snow site 27.

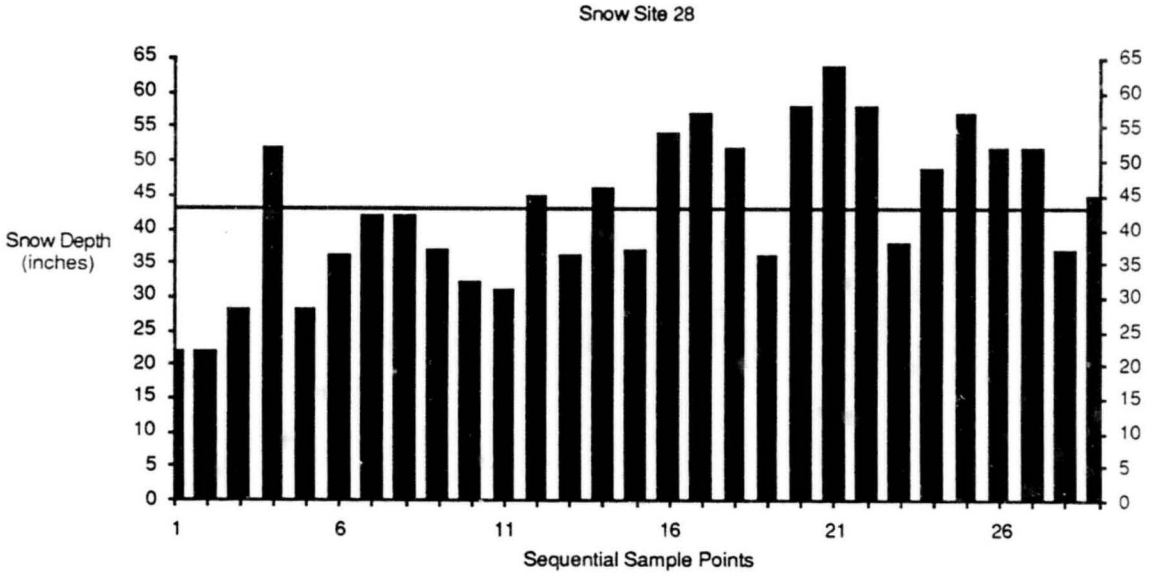

Figure 31. Snow depths at sequential sample points for snow site 28.

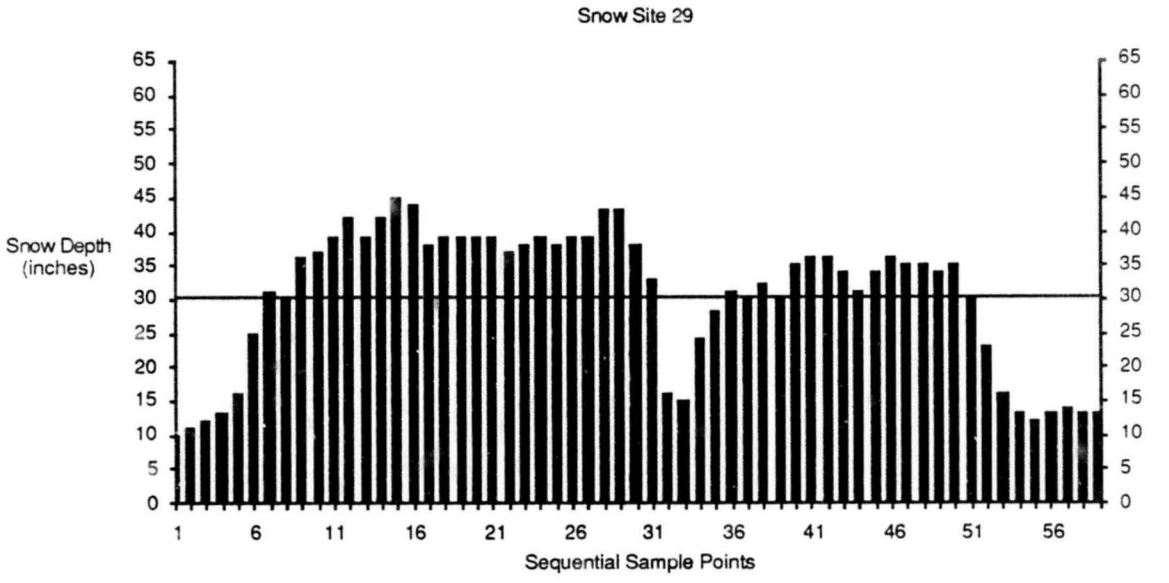

Figure 32. Snow depths at sequential sample points for snow site 29.

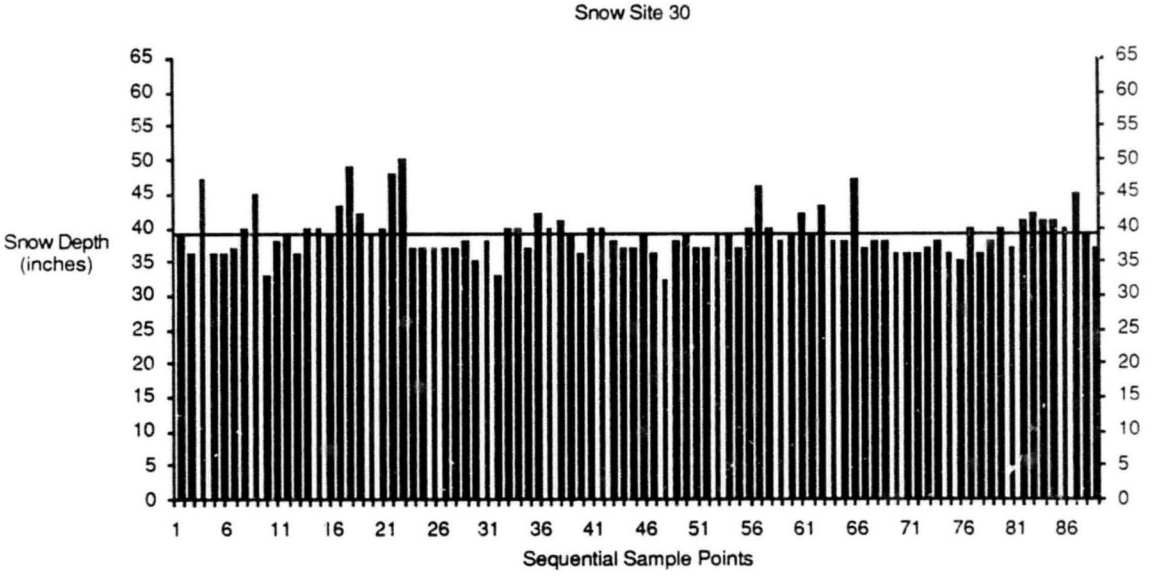

Figure 33. Snow depths at sequential sample points for snow site 30.

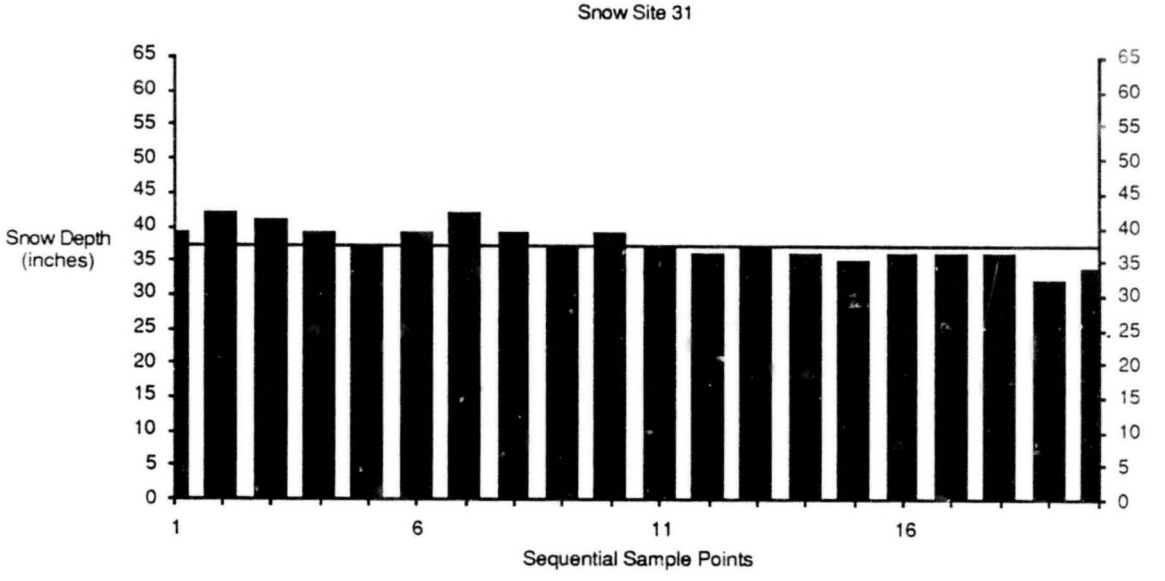

Figure 34. Snow depths at sequential sample points for snow site 31.

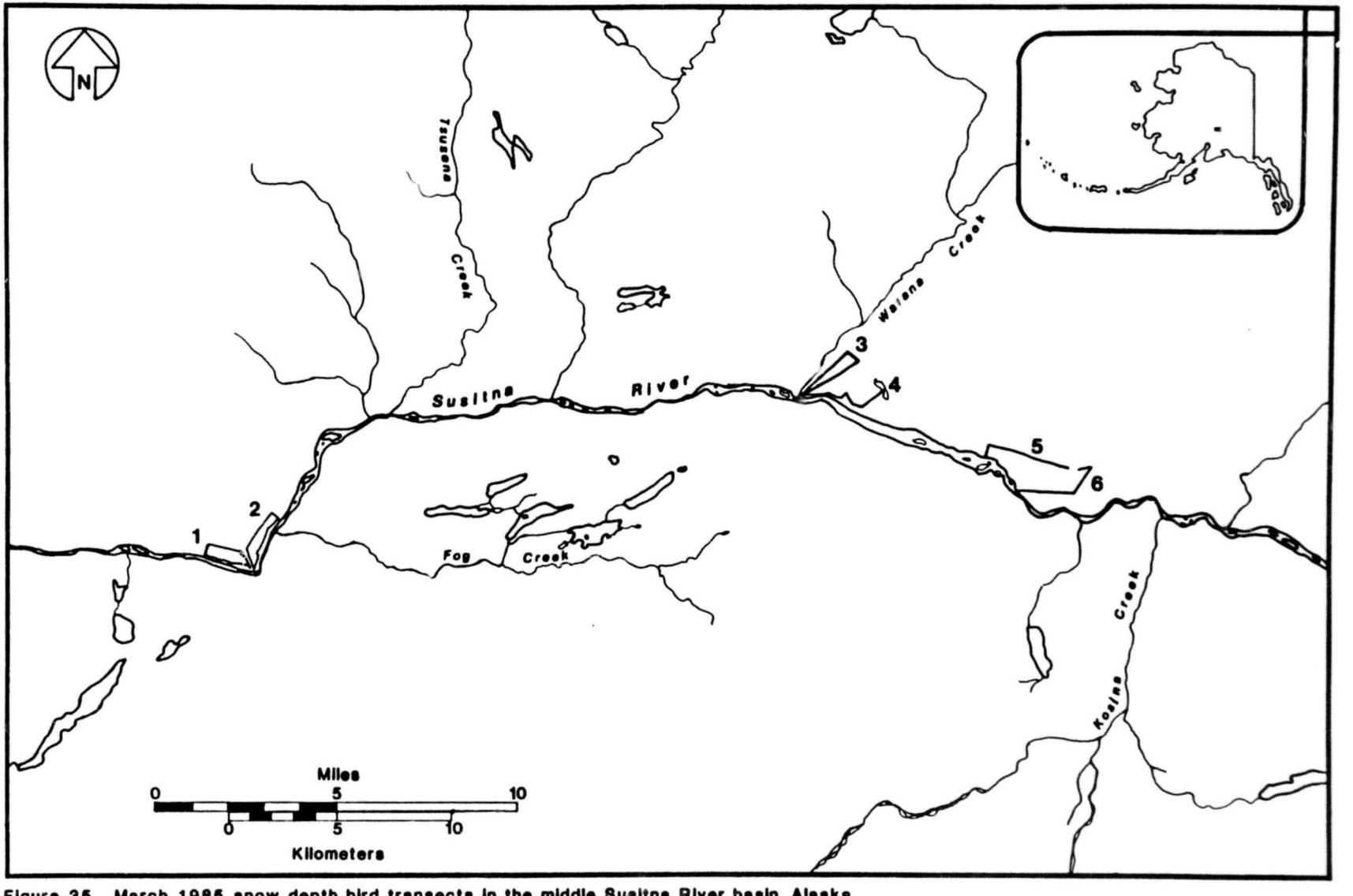

Figure 35. March 1985 snow depth bird transects in the middle Susitna River basin, Alaska.

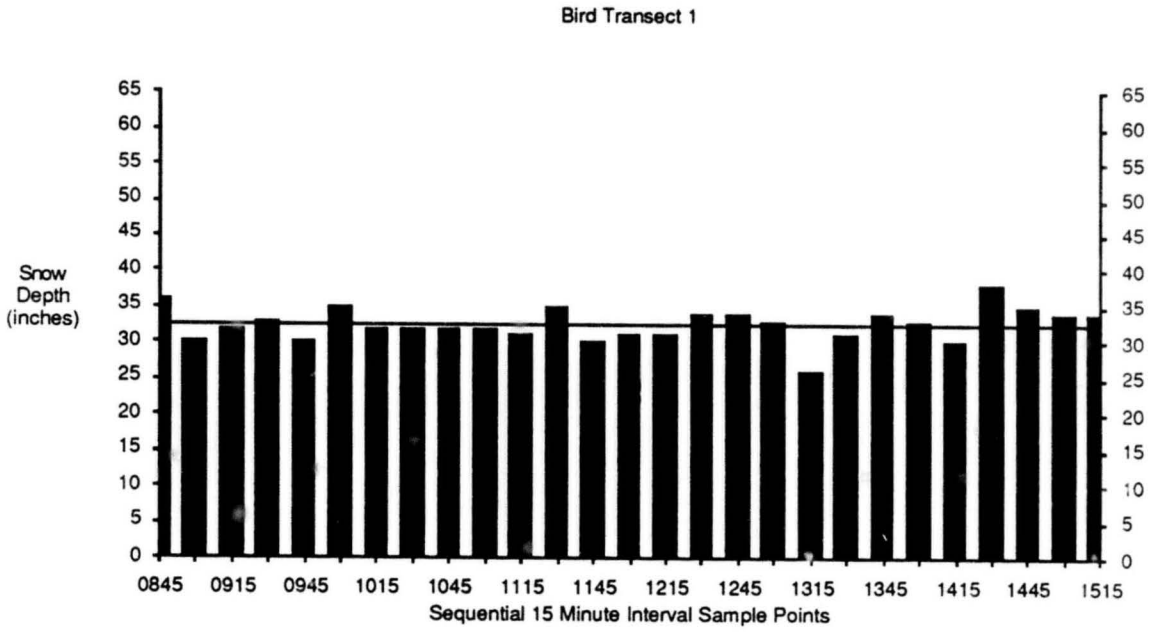

Figure 36. Snow depths at sequential 15 minute intervals for bird transect 1.

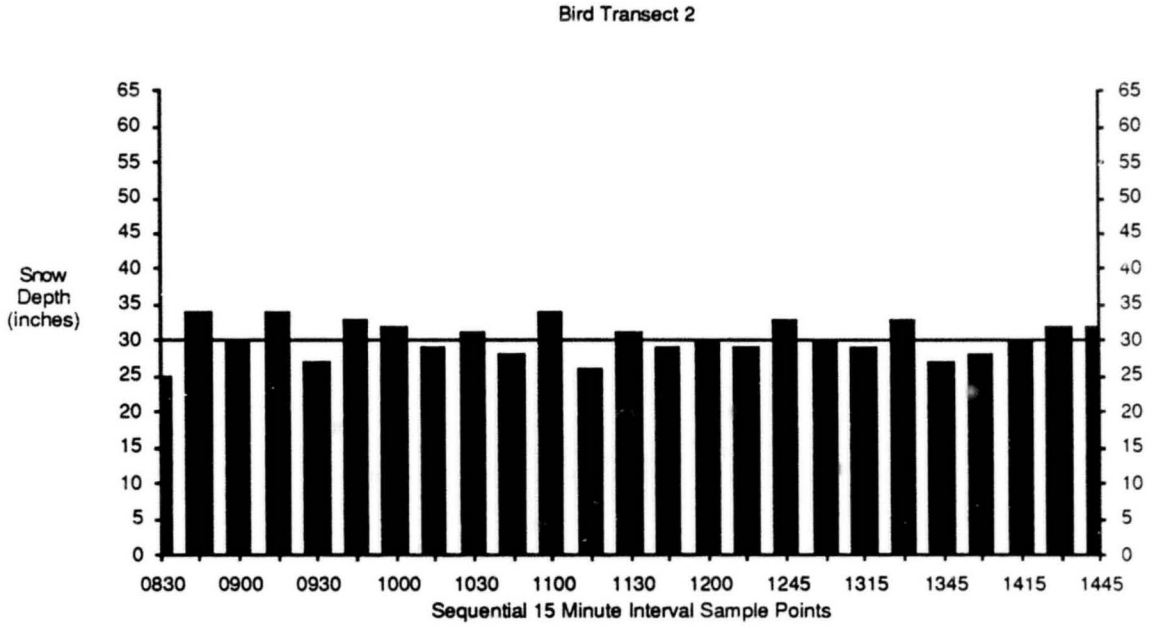

Figure 37. Snow depths at sequential 15 minute intervals for bird transect 2.

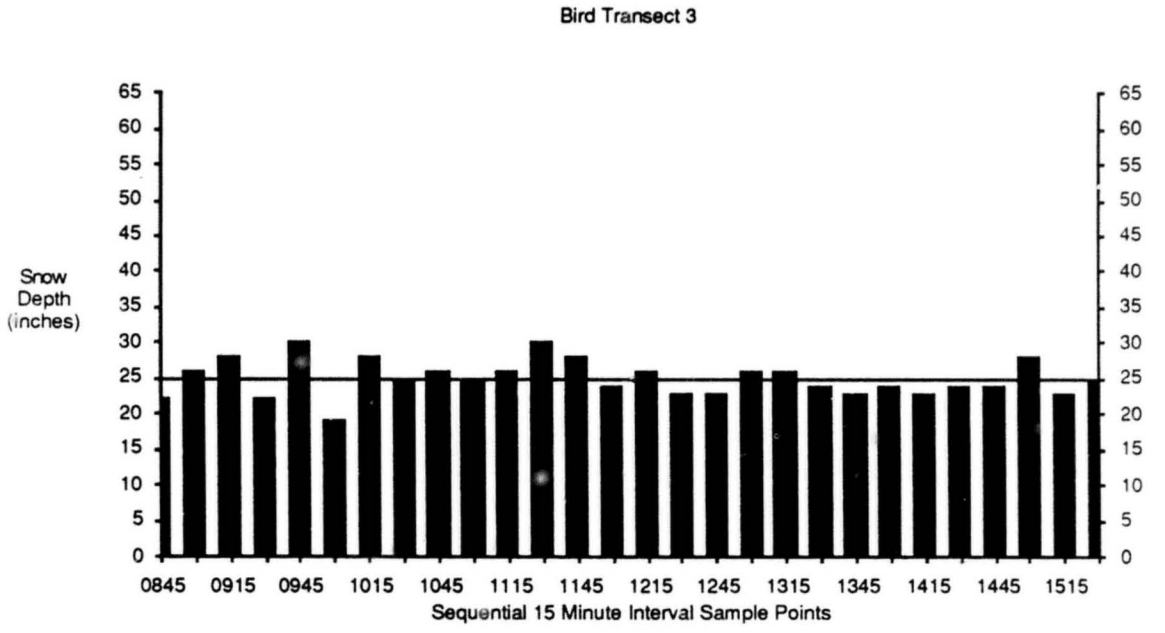

Figure 38. Snow depths at sequential 15 minute intervals for bird transect 3.

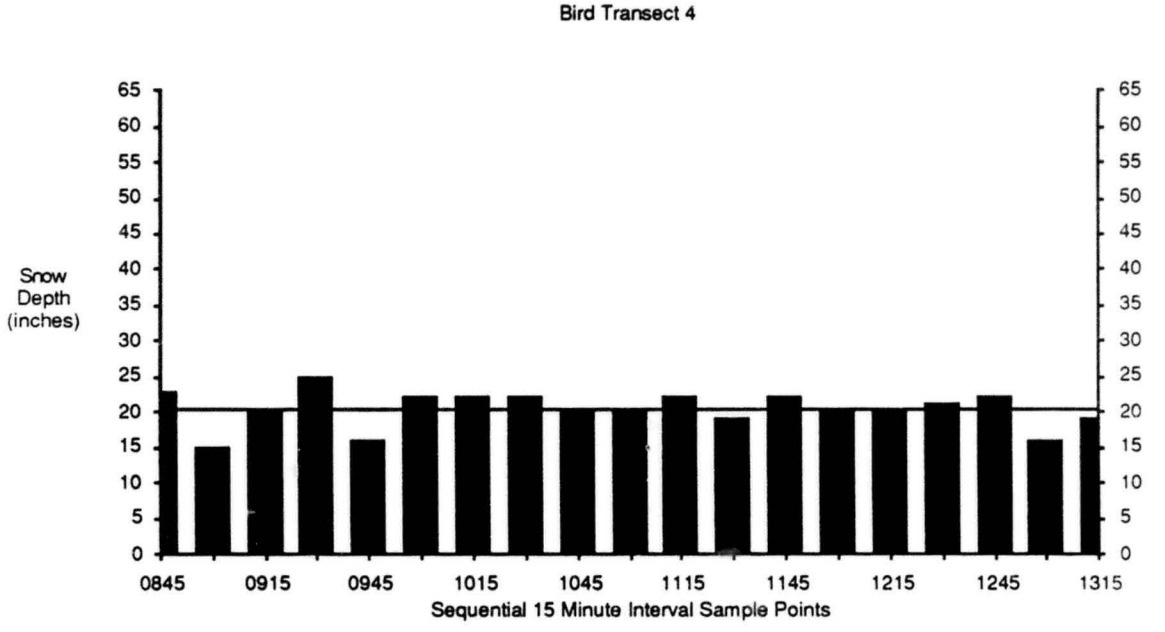

Figure 39. Snow depths at sequential 15 minute intervals for bird transect 4.

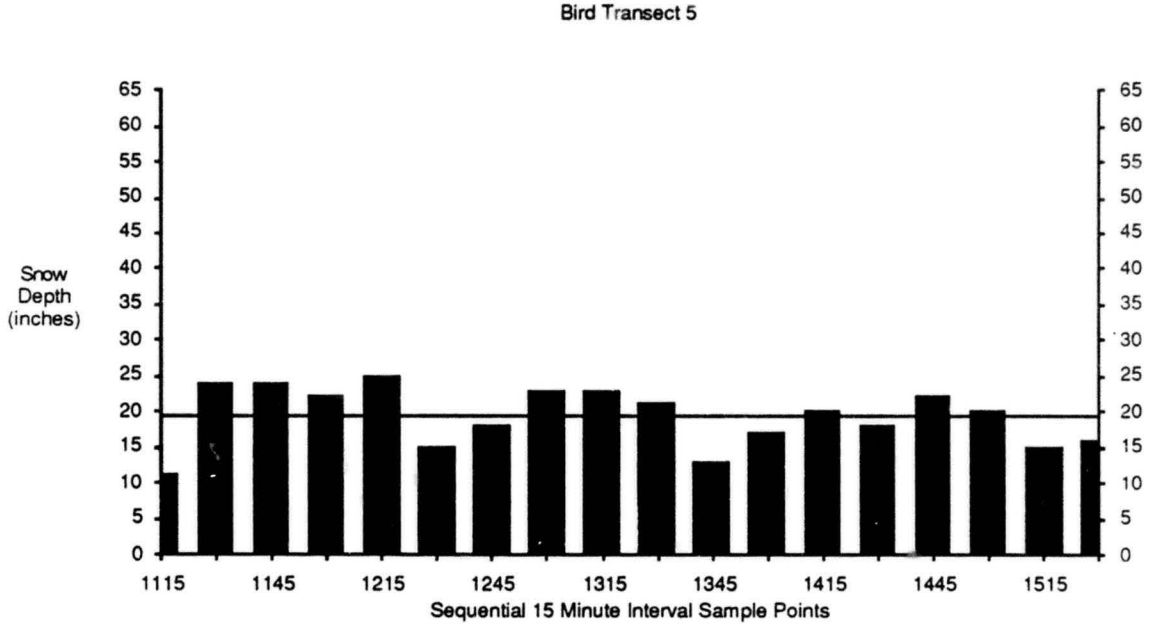

Figure 40. Snow depths at sequential 15 minute intervals for bird transect 5.

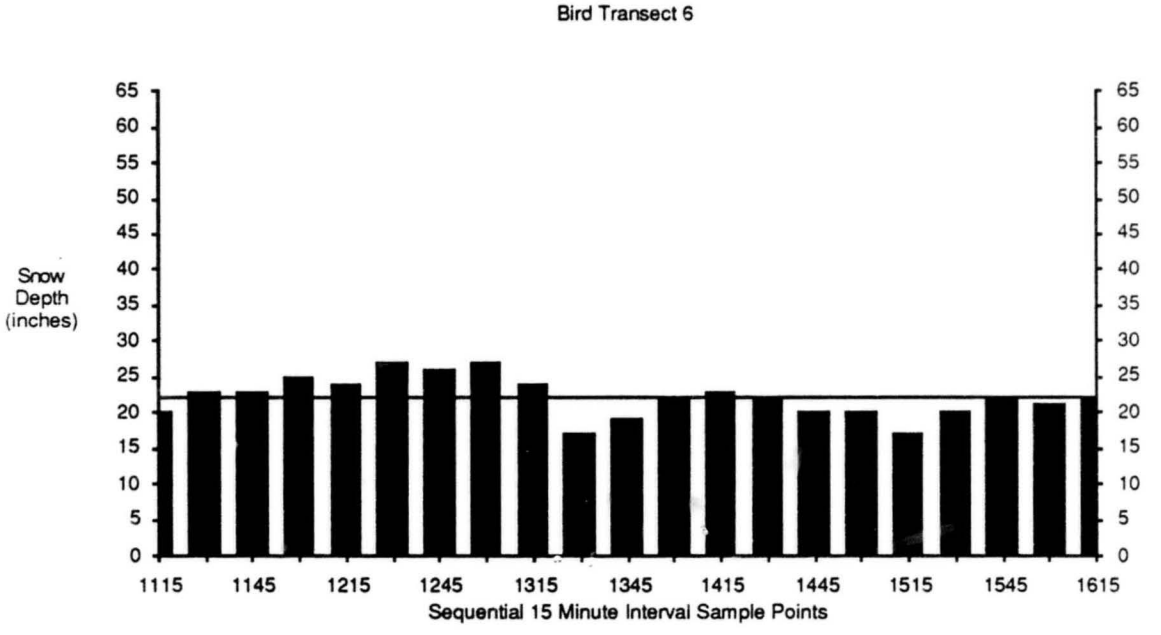

Figure 41. Snow depths at sequential 15 minute intervals for bird transect 6.

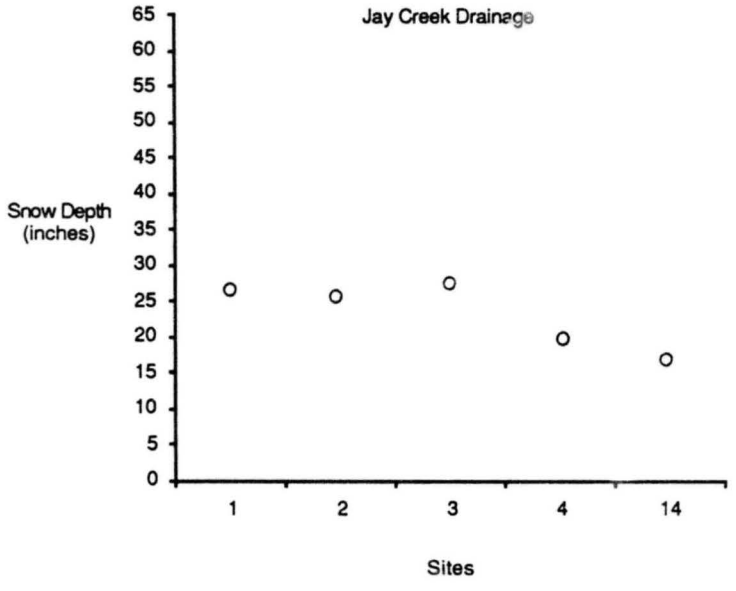

Figure 42. Comparison of snow depths for sites in the Jay Creek drainage.

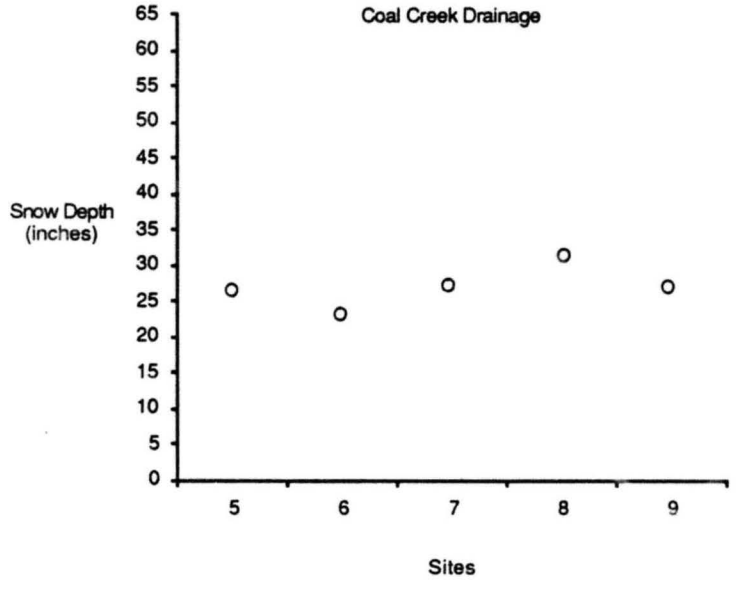

Figure 43. Comparison of snow depths for sites in the Coal Creek drainage.

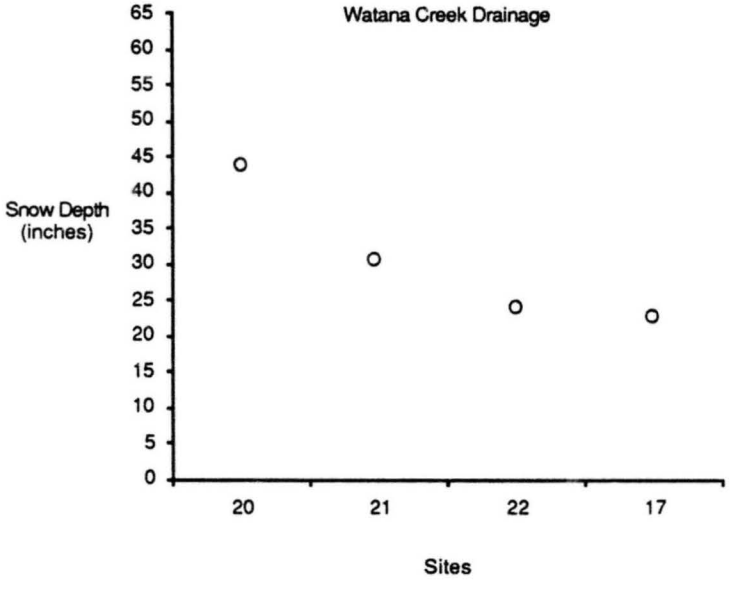

Figure 44. Comparison of snow depths for sites in the Watana Creek drainage.

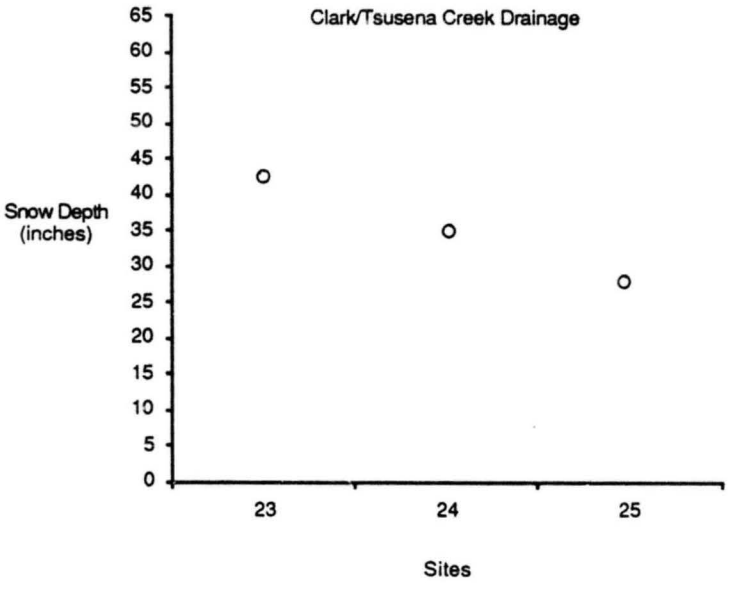

Figure 45. Comparison of snow depths for sites in the Clark/Tsusena Creek drainage

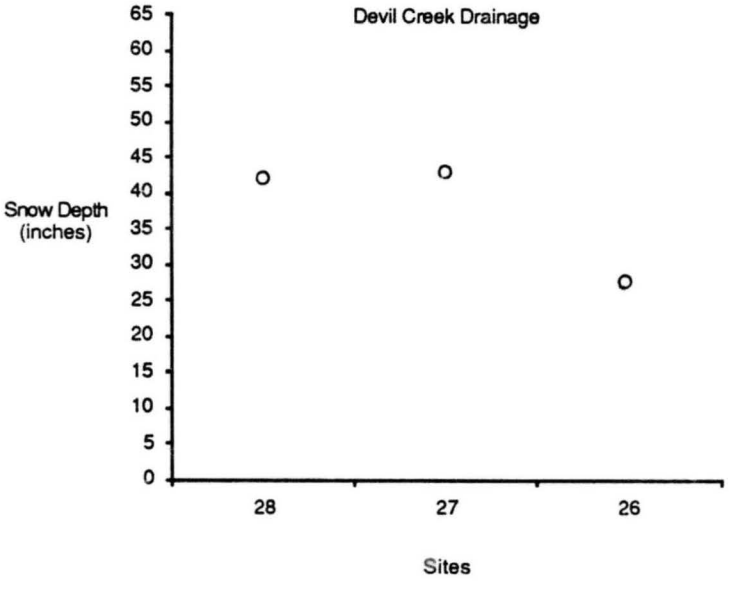

Figure 46. Comparison of snow depths for sites in the Devil Creek drainage.

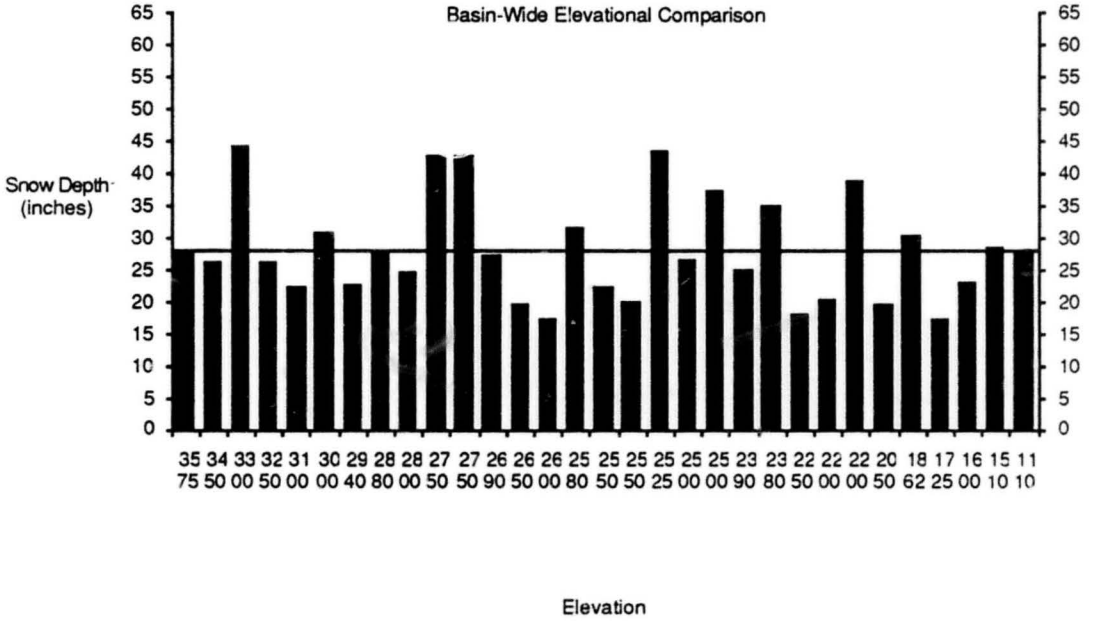

Figure 47. Comparison of snow depths and decreasing elevations for 31 snow sites.