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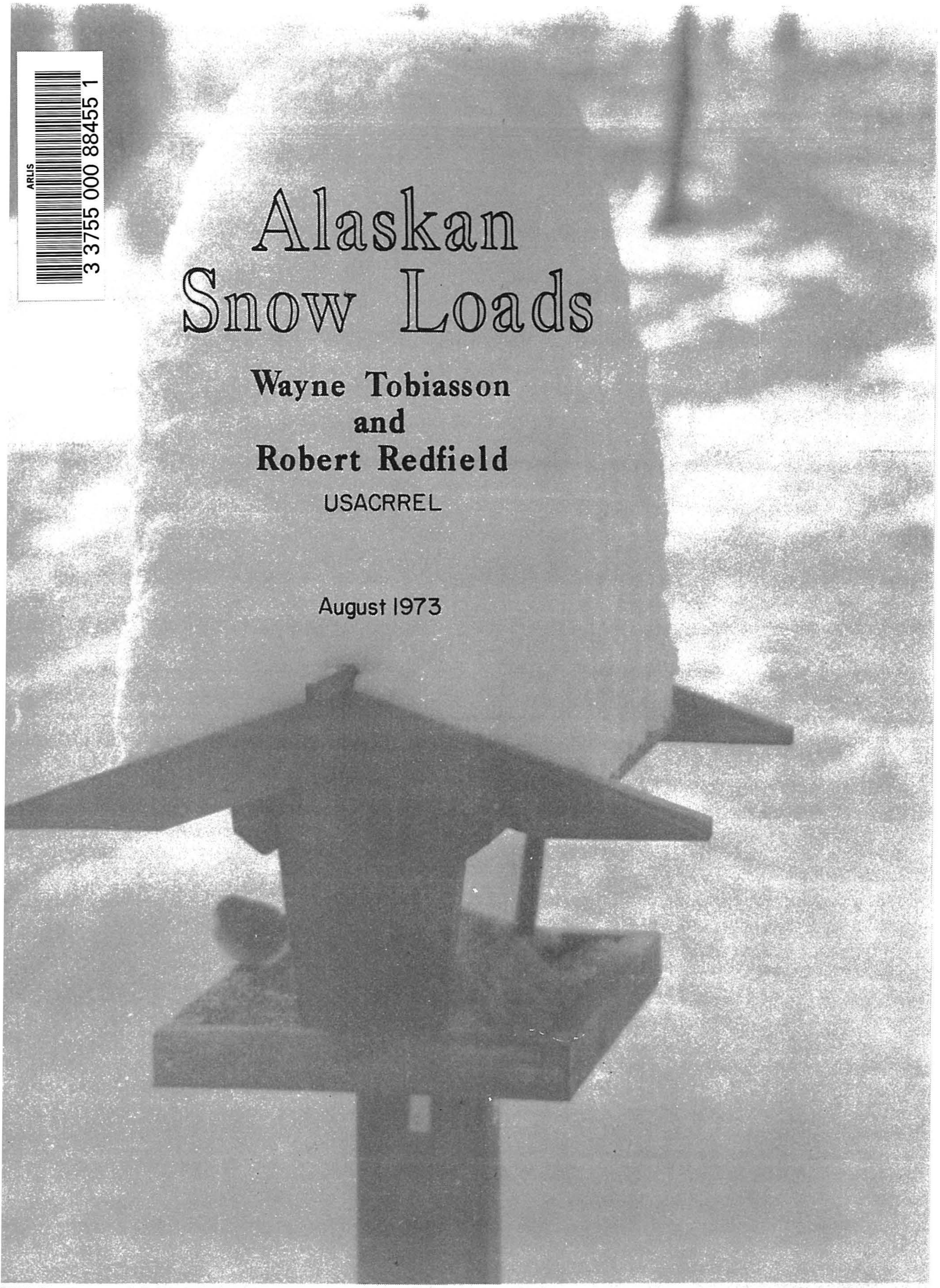

Alaskan Snow Loads

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and
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USACRREL

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ALASKAN SNOW LOADS

by

Wayne Tobiasson and Robert Redfield

Presented at the 24th Alaskan Science Conference
University of Alaska
August 1973

U. S. ARMY COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
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INTRODUCTION

Very little specific information on snow loads is available for Alaska even though for most of the state, snow loads are the maximum climatic loads induced on structures. The Uniform Building Code[17] is perhaps the most widely used building code in Alaska and it simply states that "snow loads shall be determined by the Building Official." A few large communities arm the Building Official with a specific snow load. The Building Code of the City of Fairbanks[9] adopts the Uniform Building Code, replacing the quoted sentence above with "The snow load is hereby determined to be 40 pounds per square foot". While on the subject of Fairbanks it is interesting to note that current design snow loads there vary from 30psf to 65psf depending on the reference chosen.[9,10,11,13] In most other Alaskan communities, lack of criteria, not variations depending on data source, is the problem.

Few Building Officials have direct knowledge of appropriate snow loads and snow load questions are frequently referred to engineers and architects who generally have never measured a snow load but through experience, have suggestions for design. Many refer to the map "Design Data for Military Construction in Alaska"[10] prepared by the Alaska District, Corps of Engineers in 1958 or the joint Army-Air Force Technical Manual "Load Assumption for Buildings"[11] issued in 1966. Both documents are currently under revision with significant changes anticipated.

Until recently the 1955 American Standards Association publication "Minimum Design Loads in Buildings and Other Structures"[2] was used to establish loads for the "lower 48" states. It did not contain loads for Alaskan areas. In 1972 that document was superseded by the American

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National Standards Institute (ANSI) publication, "Building Code Requirements for Minimum Design Loads in Buildings and Other Structures"[1] but again snow load criteria for Alaska were absent. National Weather Service records for Alaska were analysed for inclusion in the 1972 ANSI standard but they were not published since many of the ground snow load measurements were of questionable value.[24]

Most design snow loads currently in use in Alaska are essentially opinions based on experience. The vast majority of Alaskan structures hold up well under snow loads and in that light there is a tendency to believe that since structures are not collapsing, the proper loads are being used. Of course, wasteful overdesigns may also be occurring. When a sound building fails under snow loads, authorities generally react by increasing the design snow load for the region rather than introducing provisions to account for special loading conditions. Failures are seldom documented much beyond the point of stating that "the building collapsed under a heavy snow load".

Several snow load case histories and a few well-documented building failures indicate that most structures are significantly overdesigned but an occasional structure is underdesigned because attention has not been paid to special situations such as drifting and sliding snow.

To improve upon this situation new snow load criteria have been developed based on a statistical analysis of weather records and review of snow load case histories. The elevation, the local site conditions and the geometric, thermal and aerodynamic features of facilities have been considered.

INFORMATION SOURCES

Except for recent work by Isyumov[18] who is developing a method of predicting snow loads by considering daily snowfall, air temperature, windspeed, wind direction and roof properties, it is generally accepted that knowledge of the snow load on the <u>ground</u> is the first step in developing snow load criteria for roofs. Much of the weather data needed for Isyumov's approach is not available for Alaskan stations.

There are only 18 National Weather Service stations in Alaska that measure both the depth and load (i.e. water equivalent) of snow on the ground.[12] Depths are measured in inches of <u>snow</u> and gravimetric measurements of load are presented in inches of <u>water</u>. By multiplying inches of water by 5.2 the load can be converted to psf.

Unfortunately the ground snow load information collected at ten of the eighteen stations is either an estimated value based on the assumption that 10 inches of snow has a water equivalent of one inch (ie the specific gravity of the snow is 0.1) or is unreliable due to lack of trained observers.[22] The eight remaining stations report valuable ground snow load information but eight widely-separated stations do not provide much of a base on which to develop state-wide criteria. Fortunately a second source of snow load information is available. USACRREL initiated and has co-sponsored a program of detailed snow observations at 17 stations in Alaska for periods from 7 to 17 years. The United States Air Force, Air Weather Service and the United States National Weather Service (formerly the U. S. Weather Bureau) participated in the data collection.* The program and several relationships developed from the data are described by Bilello.[4,5] By combining the 8 National Weather Service stations and the 17 sites studied by USACRREL, 25 locations in Alaska with reliable ground snow load information were obtained.

Perhaps it would be possible to generate state-wide criteria using only these 25 stations but a far better job can be accomplished by also considering snow depth measurements available at these stations and at 112 additional smaller weather stations throughout the state. Periods of record range from 4 to 23 years depending on location. Where only snow depths are measured, the density of that snow must be estimated before snow loads can be computed.

The climatological series of the maximum annual depth of snow on the ground at 137 locations has been analysed statistically. Then, using the combined depth and load information available at 25 of these locations, conversion densities were developed, regionalized and applied to all 137 locations to generate ground snow loads at each site.

STATISTICAL ANALYSIS OF DEPTHS

Extreme value statistical studies by Thom[23] indicate that climatological series of annual maximum snow depths on the ground closely follow log-normal distributions (ie when plotted on log-normal probability paper the distribution is linear). He uses the mean and standard deviation of the logarithms of the series to establish confidence intervals, then aids the reader in visualizing his complex statistics by presenting results using Blom plotting positons.[6] Where a series consists of 10 or fewer values Blom's positions are preferred over the more common positions of Gumbel[15,16]. Both plotting positions are defined below:

$$\text{Probability (Blom)} = \left(\frac{m - 3/8}{n + 1/4}\right) 100.$$

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*We are indebted to Mr. Michael Bilello, Research Meteorologist, USACRREL, for permitting us to utilize the snow load information collected under his direction and to Mr. Roy Bates, Meteorological Technician, USACRREL, for guidance in the reduction and analysis of this information.

$$\text{Probability (Gumbel)} = \left(\frac{m}{n + 1}\right) 100.$$

where: n = number of years of record

m = rank of a particular annual extreme value. For the smallest value, m = 1; for the largest, m = n.

Probability is in percent.

All statistical results in this report are based on the use of Blom's plotting positions since a third of the locations have fewer than 10 years of snow depth records. Representative log-normal probability plots of the annual climatic series of maximum snow depths on the ground are shown in Figure 1.

Return periods can be used to relate probabilities to the "design life" of a facility. Return periods for annual series are defined as follows:

$$\text{Return period} = \frac{100}{100 - \text{Probability}}$$

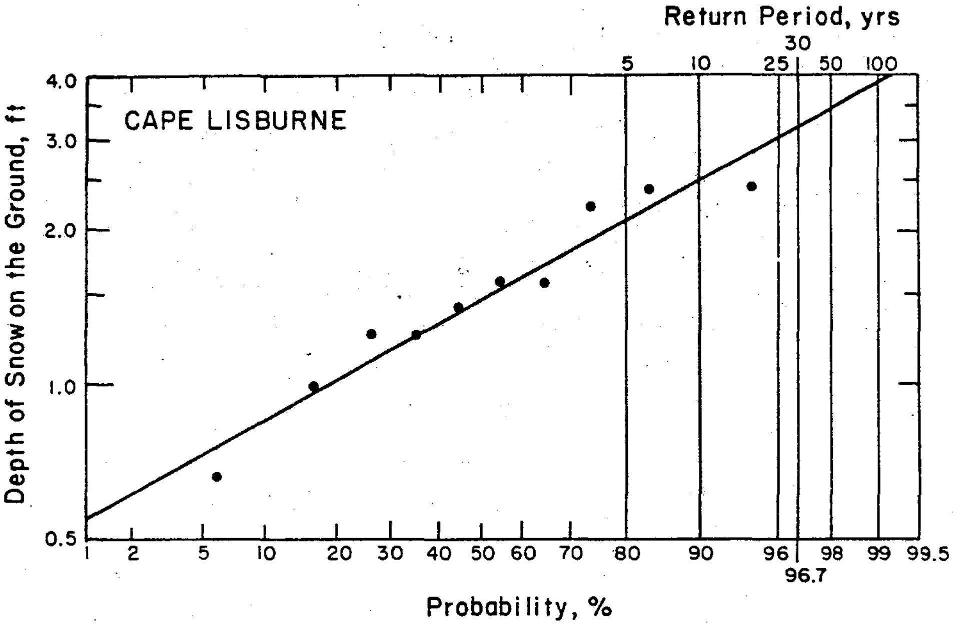
where probability is in percent and return period is in years.

A return period scale is superimposed on the probability scale of Figure 1. The snow depth from a regression line at a specific return period is the depth that can be expected to be equalled or exceeded once during that period. For example in Figure 1 the snow depth for a 25-year return period at Cape Lisburne would equal 3.1 ft.

The snow depth corresponding to 5, 10, 25, 30, 50 and 100-year return periods have been determined for 137 locations in Alaska using a digital computer. The Fortran II program developed for this task is presented in Appendix A of this report. Samples of computer tabulations of both the input data and results are presented in Appendix B. Periodic updating of the data and revision of results will be relatively easy tasks.

RELATING DEPTHS AND LOADS

An annual record of snow depth and load for two representative locations is presented in Figure 2. In the simplest case, such as at Cape Lisburne, both the depth and load maximize on the same date.



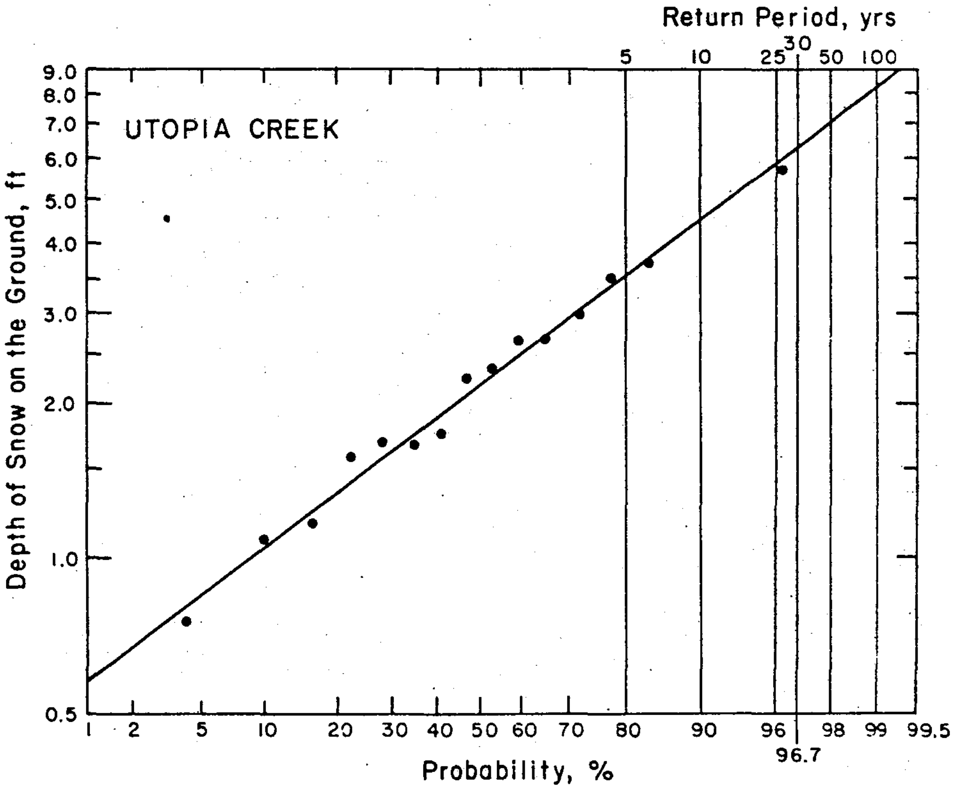


Figure 1. Log-normal probability plots for Cape Lisburne and Utopia Creek

However for many locations, such as Utopia Creek, the maximum load occurs at a later date than the maximum depth. When the load and depth maximize concurrently, the ratio of the maximum load, in psf, to the maximum depth, in feet of snow, is equal to the density of the snow in pcf on that date. When they maximize on different dates the ratio is not a physically-measurable density, simply a convenient conversion factor relating depth and load. This factor has been termed conversion density. If the depth and load maximize on different dates, the conversion density will always be less than the density measured at the time of maximum load but greater than that measured at the time of maximum depth.

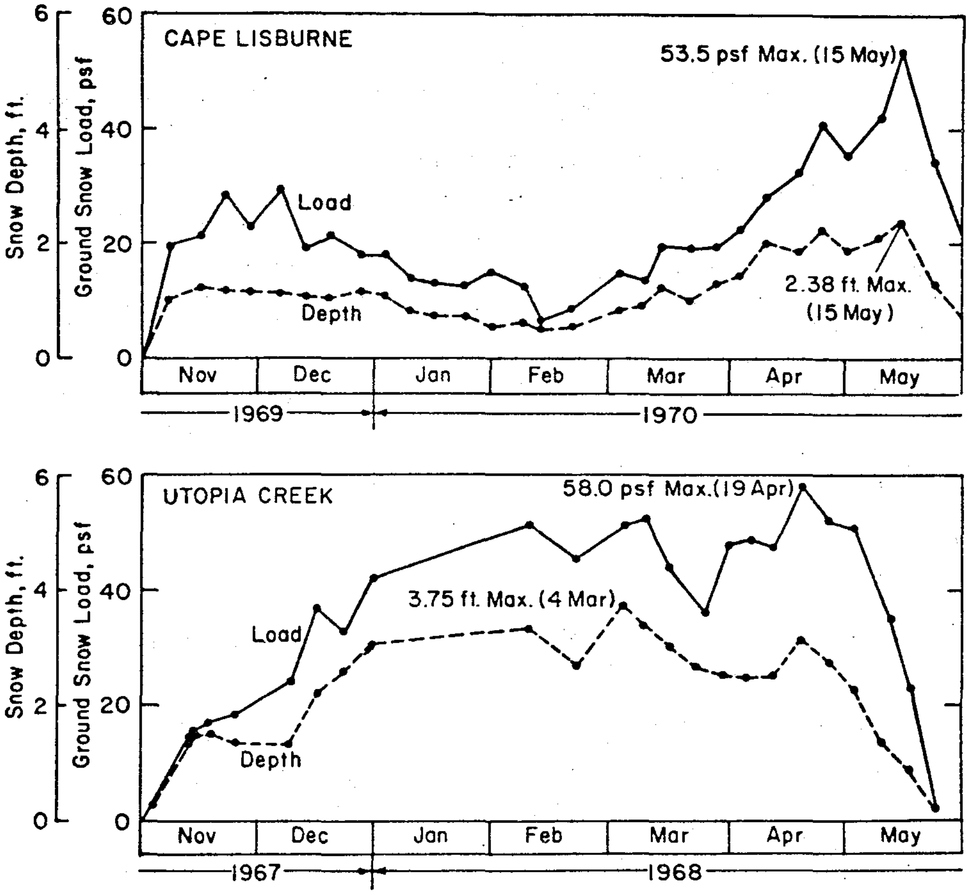
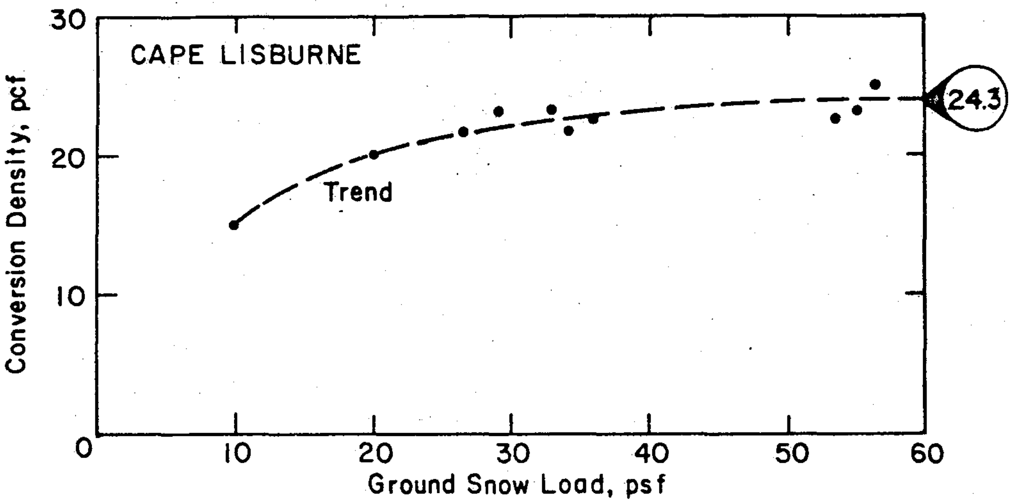


Figure 2. Record of snow depth and load for one season for Cape Lisburne and Utopia Creek.

DEVELOPING CONVERSION DENSITIES

For the 25 locations where both snow depth and water equivalent are measured, each annual conversion density was determined. Perhaps the most useful grpahical presentation, of the many investigated, was the relationship between each annual conversion density and its associated maximum annual snow load for a particular location. Two such graphs are shown in Figure 3. The density trend varies but for each station it is possible to extrapolate to a constant density for heavy snow loads. Similar curves were produced for all locations where ground snow loads were measured. The results indicated that a single conversion density could be established for each location regardless of the length of the return period. The conversion densities thus developed are presented in Figure 4.



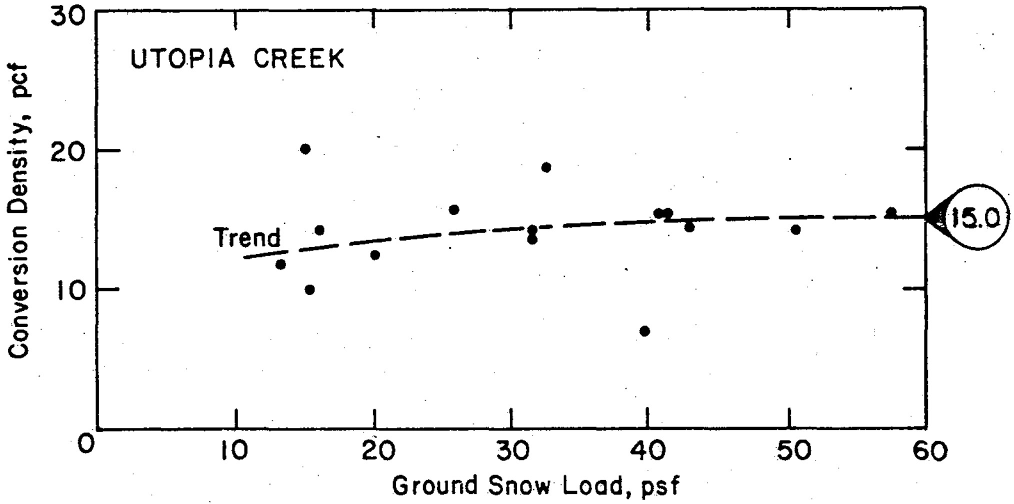


Figure 3. Graphs used to establish conversion densities for Cape Lisburne and Utopia Creek.

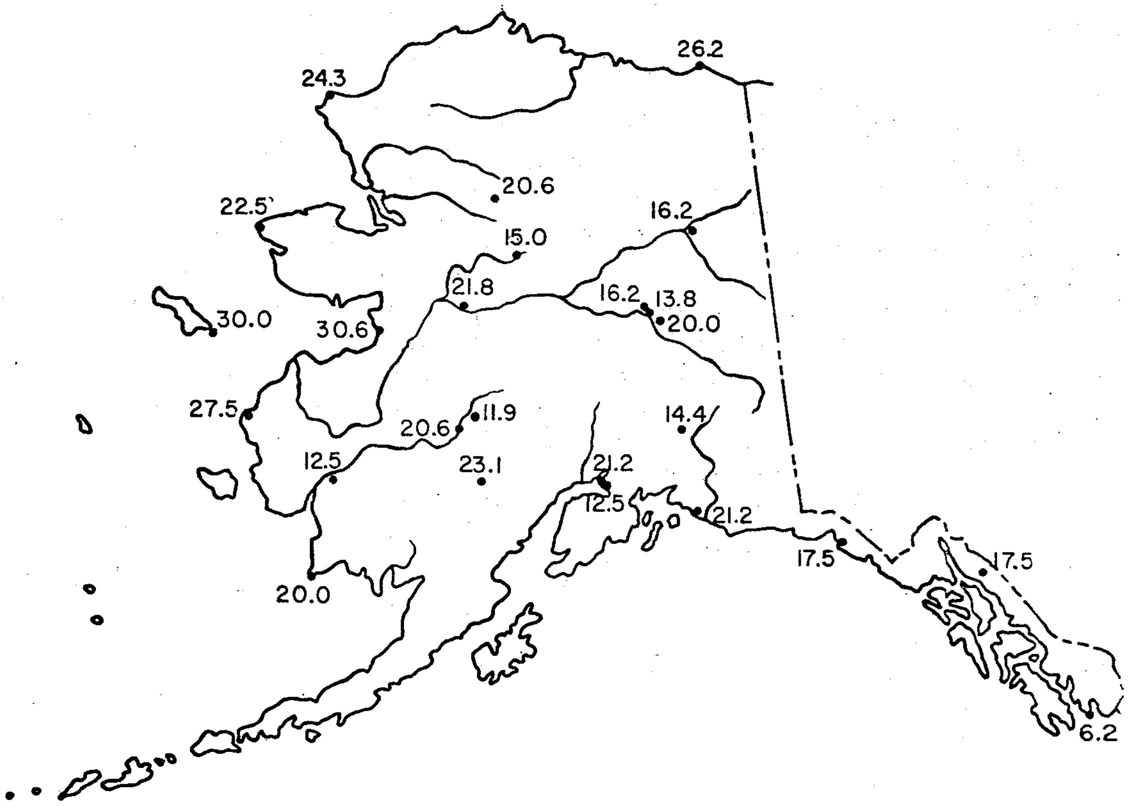
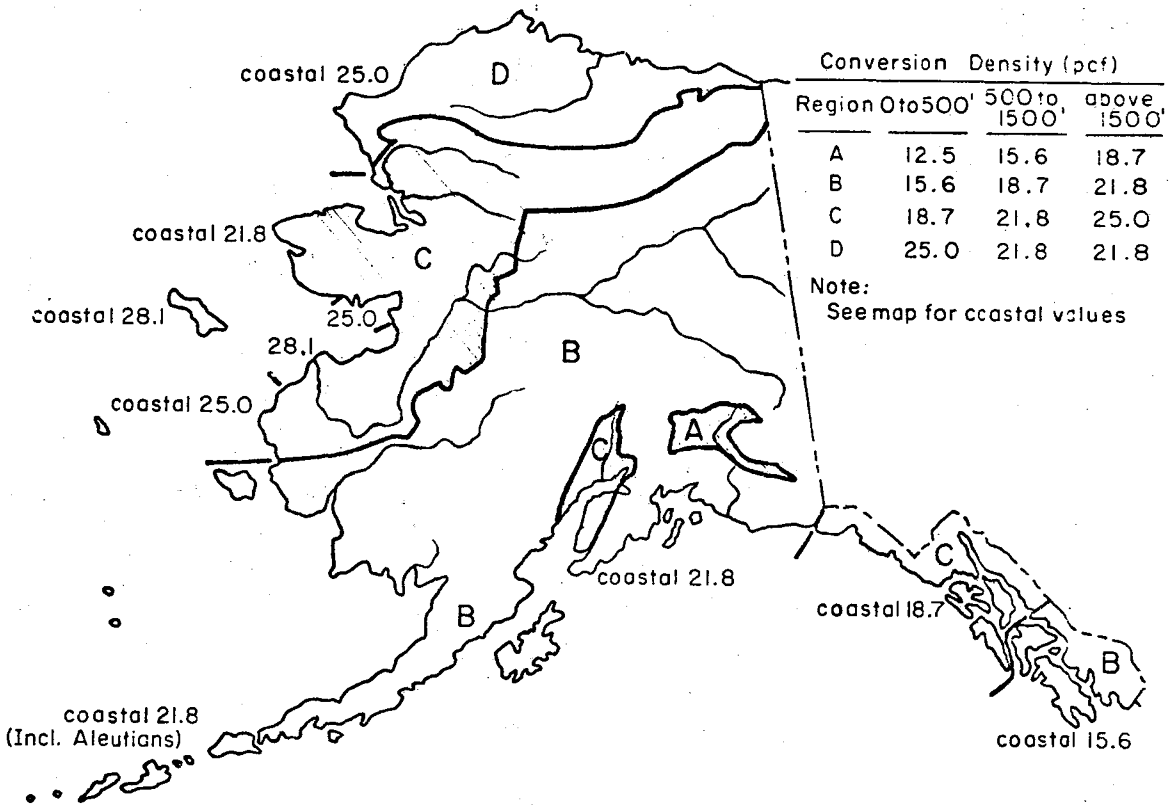


Figure 4. Conversion densities for 25 locations in Alaska.

Using information in "Snow Surveys for Alaska"[14], the U. S. Geological Survey physiographic map of Alaska[25], and Bilello's map of average seasonal snow-cover densities[5] as guides, conversion densities were regionalized. The conversion density in each region was further categorized according to site elevation and proximity to the coast. Regionalized densities are presented in Figure 5. These values were then applied to the design snow depths determined for 5, 10, 25, 30, 50 and 100-year return periods.

GROUND SNOW LOADS

The place name for each location, its latitude, longitude and elevation and the ground snow load in psf for 6 return periods are presented in Table I. For temporary facilities the 5-year return period snow load should be selected. For permanent facilities the 25-year return period is appropriate. However, as hazards to life and property increase in the event of a failure, design loads should increase toward the 100-year value. The snow load values for 23 locations are suspect



	Conversion Density (pcf)		
Region	0 to 500'	500 to 1500'	above 1500'
A	12.5	15.6	18.7
B	15.6	18.7	21.8
C	18.7	21.8	25.0
D	25.0	21.8	21.8

Note:
See map for coastal values

Figure 5. Regionalized conversion densities.

and are followed by an asterisk in Table I. Sixteen of the suspect locations have only 4 to 6 years of record. Since most of these limited records cover the heavy snow year of 1970-71, excessive statistical values generally result. Suggested 25-year return period values, based on comparisons with other stations in the vicinity and consideration of the 1970-71 snow loads as generally representing more than 15-year values, are shown in parentheses in Table I. Suggested values for other return periods can be obtained by multiplying the asterisked value for the desired return period by the ratio of the suggested 25-year value (in parentheses) to the asterisked 25-year value.

The National Building Code of Canada[3,8,20] uses a single conversion density of 12pcf (.19 gm/cm^3) throughout Canada to convert 30-year return period snow depths to ground snow loads. A surcharge equivalent to the weight of a one-day spring rainfall is added. The rainfall surcharge varies from less than 5psf in the Canadian prairies and Arctic to 25psf on Vancouver Island.[7] Such a surcharge is not needed for the Alaskan loads presented in this report since spring rains are already part of the maximum annual water equivalent observations.

Table I. Ground snow loads.

Station name	*Latitude*	*Longitude*	*Elevation, ft*	*Ground snow load, psf*					
				5 yr	*10 yr*	*25 yr*	*30 yr*	*50 yr*	*100 yr*
Adak	51°53'	176°38'	15	23	28	36	37	42	48
Adult Conservation Camp	61°42'	148°59'	825	30	41	57	60	71	86
Allakaket	66°34'	152°40'	600	61	80	111	113	131	156
Alpine Inn	61°43'	148°54'	455	19	22	27	28	30	34
Alyeska	60°58'	149°08'	251	98	122	154	159	180	206
Anchorage	61°10'	150°01'	114	52	64	80	82	92	105
Angoon	57°30'	134°35'	15	50	64	83	86	98	114
Aniak	61°35'	159°32'	81	50	63	79	82	92	106
Annette	55°02'	131°34'	110	20	30	43	45	54	67
Annex Creek	58°19'	134°06'	24	133	158	191	197	216	240
Attu	52°50'	173°11'E	70	51	66	86	89	102	119
Auke Bay	58°23'	134°38'	42	61*	79*	103* (100)	107*	123*	168*
Barrow	71°18'	156°47'	31	43	50	59	60	65	72
Barter Island	70°08'	143°38'	39	66	82	104	108	121	139
Beaver Falls	55°23'	131°28'	35	53	72	101	105	124	150
Bethel	60°47'	161°48'	125	36	46	61	63	73	88
Bettles	66°54'	151°31'	666	92	111	137	140	156	176
Big Delta	64°00'	145°44'	1268	43	59	82	86	102	124
Birch Road	61°08'	149°46'	460	62	66	72	72	75	78
Cape Decision	56°00'	134°08'	39	15	20	28	29	34	42
Cape Hinchinbrook	60°14'	146°39'	185	57	82	121	127	155	193
Cape Lisburne	68°52'	166°07'	45	62	74	90	92	101	114
Cape Newenham	58°38'	162°04'	475	60	78	104	108	125	148
Cape Romanzof	61°46'	166°03'	434	73	116	148	182	222	232
Cape Saint Elias	59°48'	144°36'	58	66	89	121	126	148	177
Cape Sarichef	54°36'	164°56'	175	15	21	29	30	35	43
Central	65°34'	144°49'	960	37	39	42	42	44	46
Chena Hot Springs	65°03'	146°03'	1195	59	77	101	105	120	141
Chignik	56°18'	158°24'	30	62*	83*	113* (80)	118*	138*	165*
Chitina	61°32'	144°27'	575	38*	60*	100* (80)	108*	139*	187*
Circle Hot Springs	65°29'	144°38'	935	30	33	36	36	38	41
Clear	64°18'	149°11'	580	52	65	81	83	93	106
Clearwater	64°03'	145°31'	1100	43	58	79	82	96	115
Cold Bay	55°12'	162°43'	96	20	24	29	29	32	35
College Magnetic Observatory	64°52'	147°50'	621	59	71	87	90	100	112
Cooper Lake Project	60°23'	149°40'	445	34	39	46	47	50	55
Cordova	61°58'	145°19'	1000	65*	79*	98* (110)	101*	112*	127*
Crooked Creek	61°52'	158°06'	125	42	49	58	60	65	72
Eagle	64°46'	141°12'	821	61	74	90	93	104	116
Eielson AFB	64°40'	147°06'	558	62	80	105	110	126	147

Table I (Cont'd).

Station name	Latitude	Longitude	Elevation, ft	Ground snow load, psf					
				5 yr	10 yr	25 yr	30 yr	50 yr	100 yr
Eklutna Lake	61°24'	149°09'	882	47	56	67	69	76	85
Elmendorf AFB	61°15'	149°48'	222	42	48	56	57	62	68
Fairbanks	64°49'	147°52'	436	52	63	78	80	89	101
Farewell	62°32'	153°54'	1499	38	48	60	62	70	79
Five Finger Light Station	57°16'	133°37'	30	24	38	64	69	89	120
Flat	62°29'	158°05'	309	55	68	85	87	97	110
Fort Yukon	66°33'	145°12'	443	50	57	65	66	71	77
Galena	64°44'	156°56'	120	52	59	69	70	76	82
Gilmore Creek	64°59'	147°31'	959	57*	78*	109* (90)	114*	135*	164*
Glacier Bay	58°27'	135°53'	50	85*	107*	137* (100)	142*	161*	187*
Glennallen	62°07'	145°32'	1456	29	34	41	43	47	52
Gulkana	62°09'	145°27'	1570	42	52	66	68	77	86
Gunsight	61°54'	147°18'	2960	56*	77*	108* (90)	113*	135*	164*
Haines Terminal	59°16'	135°27'	175	67	91	126	132	156	199
Holy Cross	62°10'	159°45'	200	68	82	100	103	113	127
Homer	59°38'	151°30'	67	45	57	74	76	86	100
Hughes	66°04'	154°15'	545	62	77	97	101	113	129
Iliamna	59°44'	154°57'	145	46	59	77	80	91	107
Intricate Bay	59°34'	154°28'	170	34	40	47	48	52	57
Juneau	58°22'	134°35'	12	46	60	79	83	95	112
Kasilof	60°19'	151°15'	75	61	72	85	87	96	106
Kasitsna Bay	59°28'	151°33'	12	82*	103*	131* (90)	136*	153*	176*
Kenai	60°34'	151°15'	86	55	68	84	86	96	109
Ketchikan	55°21'	131°39'	15	27	37	53	56	67	83
King Salmon	58°41'	156°39'	49	22	26	31	31	34	37
Kitoi Bay	58°11'	152°21'	15	43	60	86	91	109	134
Kobuk	66°54'	156°52'	140	87	106	132	136	152	172
Kodiak	57°45'	152°31'	21	31	38	49	51	58	66
Kotzebue	66°52'	162°38'	10	56	65	77	79	86	95
Lake Minchumina	63°53'	152°17'	701	52	60	70	72	77	84
Linger Longer	59°26'	136°17'	700	119	137	160	163	177	193
Little Port Walter	56°23'	134°39'	14	102	134	179	186	215	255
Mankomen Lake	62°59'	144°29'	3025	103*	130*	167* (120)	173*	197*	227*
Manley Hot Springs	65°00'	150°39'	300	50	59	70	72	78	86
Matanuska Agric. Exp. Sta.	61°34'	149°16'	150	19	24	31	32	37	43
McGrath	62°58'	155°37'	344	51	60	71	72	79	87
McKinley Park	63°43'	148°58'	2070	71	87	109	112	125	142
Moose Pass	60°28'	149°23'	485	78	98	126	130	148	171
Moses Point	64°43'	162°04'	15	105*	127*	156* (125)	161*	179*	202*
Nenana	64°33'	149°05'	356	45	58	76	79	90	106

Table I (Cont'd).

Station name	Latitude	Longitude	Elevation, ft	Ground snow load, psf 5 yr	10 yr	25 yr	30 yr	50 yr	100 yr
Nikiski Terminal	60°41'	151°23'	110	57*	75*	99* (80)	103*	118*	140*
Nome	64°30'	165°26'	13	70	89	114	118	134	155
Northeast Cape	63°17'	168°41'	38	90	114	148	154	175	204
Northway	62°55'	141°56'	1713	51	61	74	76	84	94
Nunivak	60°23'	166°12'	44	57	74	98	102	117	137
Oil Well Road	61°14'	149°43'	370	40	45	51	52	56	60
Palmer	61°36'	149°06'	225	32	45	63	66	79	97
Paxson Lake	62°57'	145°30'	2750	67	79	95	97	106	118
Petersburg	56°49'	132°57'	50	60	84	120	127	152	186
Point Hope	68°20'	166°48'	15	56*	101*	189* (90)	207*	284*	410*
Point Lay	69°45'	163°03'	10	35	44	57	58	66	76
Point Retreat Light Station	58°25'	134°57'	50	40	58	87	92	112	142
Port Alexander	56°15'	134°39'	18	56	72	95	99	113	133
Port Alsworth	60°12'	154°18'	260	24*	29*	35* (75)	36*	39*	44*
Port Heiden	56°57'	158°37'	92	15	21	30	31	38	47
Puntilla	62°06'	152°45'	1832	79	90	102	104	112	121
Richardson	64°17'	146°22'	875	57	73	95	99	113	132
Russian Mission	61°47'	161°19'	50	52	70	95	99	115	137
Saint Marys	62°04'	163°11'	25	19*	23*	27* (100)	28*	31*	34*
Saint Paul Island	57°09'	170°13'	22	37	48	63	65	75	88
Seldovia	59°26'	151°42'	31	70*	103*	156* (90)	166*	204*	261*
Seward	60°07'	149°27'	70	50	63	80	83	93	107
Shemya	52°43'	174°06'E	122	16	20	26	26	30	34
Shishmaref	66°14'	166°07'	14	38*	40*	42* (90)	42*	43*	44*
Sitka	57°03'	135°20'	67	34	44	57	60	74	95
Sitkinak	56°33'	154°08'	53	25	37	56	60	74	95
Skagway	59°27'	135°19'	10	11*	13*	14* (100)	14*	15*	16*
Slana	62°43'	143°44'	2200	42	60	88	94	114	142
Snowshoe Lake	62°02'	146°40'	2410	43	49	56	57	60	65
Sparrevohn	61°06'	155°33'	1580	72	98	136	142	168	204
Summit	63°20'	149°09'	2401	122	148	180	186	205	230
Talkeetna	62°18'	150°06'	345	106	130	161	166	186	210
Tanacross	63°24'	143°19'	1549	48	57	69	71	77	86
Tanana	65°10'	152°06'	232	59	74	94	97	109	126
Tatalina	62°54'	155°58'	964	70	78	88	89	95	101
Teller	65°16'	166°21'	10	41	66	109	117	151	203
Thompson Pass	61°08'	145°45'	2500	176	223	288	299	340	394
Tin City	65°34'	167°55'	269	52	70	97	102	120	144
Tok	63°21'	143°02'	1620	42*	46*	50* (70)	50*	53*	55*
Tonsina Lodge	61°40'	145°11'	1500	35	37	40	40	42	43

Table I (Cont'd).

Station name	*Latitude*	*Longitude*	*Elevation, ft*	*Ground snow load, psf* 5 yr	10 yr	25 yr	30 yr	50 yr	100 yr
Trims Camp	63°26'	145°26'	2408	226*	299*	404*(200)	421*	491*	585*
Umiat	69°22'	152°08'	337	49	57	68	70	76	84
Unalakleet	63°53'	160°48'	15	62	82	110	115	134	159
University Experiment Station	64°51'	147°52'	475	46	56	68	70	78	87
Utopia Creek (Indian Mtn.)	65°59'	144°29'	1220	66	85	111	116	133	155
Valdez	61°08'	146°15'	49	136	159	187	191	207	228
Wainwright	70°40'	159°50'	315	26	29	33	34	36	39
Wales	65°37'	168°03'	9	49	64	85	88	102	121
Wasilla	61°37'	149°24'	500	51*	74*	108*(60)	115*	140*	176*
West Fork	65°28'	148°40'	425	39*	45*	54*(80)	55*	60*	66*
Whittier	60°47'	148°41'	15	190	250	334	349	404	478
Wild Lake	67°33'	151°33'	1190	46*	49*	54*(120)	55*	57*	60*
Willow Trading Post	61°47'	145°11'	1400	82*	99*	119*(90)	123*	135*	151*
Wiseman	67°26'	150°13'	1286	84	103	128	132	148	167
Wrangell	56°28'	132°23'	37	32	46	67	70	85	106
Yakataga	60°05'	142°30'	27	80	102	132	138	157	182
Yakutat	59°31'	139°40'	28	122	149	184	190	212	240

The conversion densities developed for Alaska vary from a low of 12pcf (0.19 gm/cm^3) in the Copper River lowland to a high of 28pcf (0.45 gm/cm^3) along the west coast below the Seward Peninsula. In the interior, on the Alaska Peninsula, on the Aleutians and on the "Panhandle," densities vary between 16 and 25pcf (.26 and .40 gm/cm^3) depending on location and elevation. For the wind-driven snow on the North Slope a density of 24pcf (.38 gm/cm^3) is used.

Maps of Alaska overlaid with ground snow load isolines have not been made since they tend to obscure local variations and may result in hasty generalizations. To determine ground snow loads for sites not listed in Table I the loads reported at several sites in the vicinity should be inspected with attention paid to elevation and other geographical features. Such an approach will not only produce more meaningful criteria but will also alert the user to the extent of local variations in the vicinity. In some areas a 50-mile change in location has little influence on loads but in other areas loads might triple in the same distance.

Local variations are particularly significant in southeastern Alaska. The significant variation in the depth of snow on the ground for four locations all within an 11-mile radius of Juneau is shown in Figure 6.

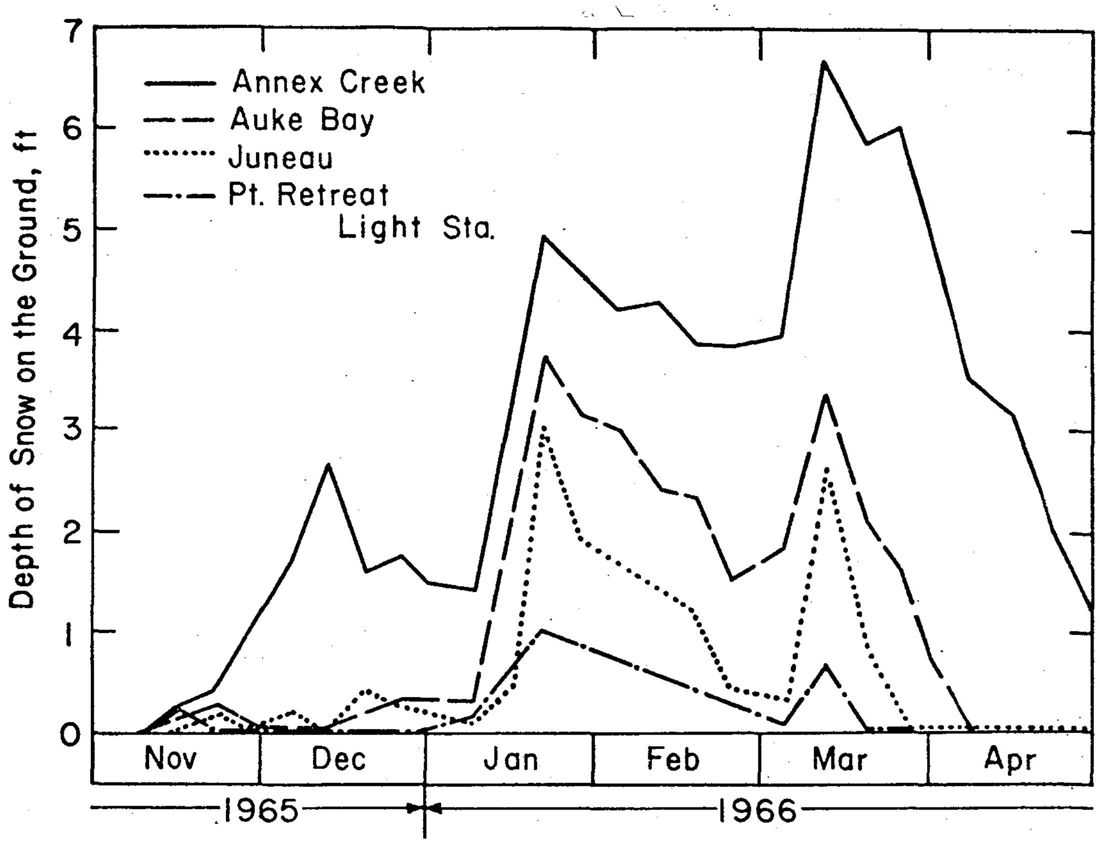


Figure 6. Depth of snow on the ground for four locations all within an 11-mile radius of Juneau.

Most snow depths reported for mountainous regions were measured in the populated valley areas. Such depths are often significantly less than those at high elevations in the area.

A few measurements of the depth or water equivalent of snow on the ground are of little direct value in establishing design loads. However, if such measurements are also obtained at one or more of the locations listed in Table I at the same time, the ratios can aid in the transfer of criteria from one location to another. Such measurements should be taken at intervals during the late winter and early spring when the snow load is near its seasonal high.

ROOF LOADS

Ground-to-roof conversion

Snow loads on roofs are affected by local winds and temperatures, the exposure of the structure, its thermal characteristics and geometry and its aerodynamic position. Factors have been developed to consider these variables. The factors are based on "Commentary No. 2 Snow Loads" in the Canadian Structural Design Manual[20] with modifications based on snow load observations in Alaska by the U. S. Army Engineer District, Alaska and USACRREL and in Canada by the National Research Council.[19,21]

The following equation has been developed to relate the "basic roof snow load" to regional winds, exposure of the structure, roof thermal characteristics, and ground snow loads.

$$p_r = C_r C_e C_t p_g$$

where:

p_r = basic roof snow load in psf

C_r = regional ground-to-roof conversion factor which considers local winds and temperatures

C_e = exposure of the structure

C_t = thermal characteristics of the roof

p_g = ground snow load in psf for the appropriate return period.

Appropriate values for C_r, C_e, C_t and p_g are listed in Tables II, III, IV and I respectively.

The "basic roof snow load," p_r, requires further modification to account for nonuniform and unbalanced loads, roof slope, extra snow collected in valleys, sliding of snow onto lower roofs and wind drifting of snow onto roofs located in areas of aerodynamic shade.

Minimum loads

All roofs should be designed to sustain a minimum uniform live load of 20psf except that a 15psf minimum load can be used for unobstructed metal roofs with a slope greater than 6 on 12 and fabric roofs with the vertical angle from the eave to the crown greater than 34°, since such roofs will shed snow by sliding.

Table II. Regional ground-to-roof conversion factor, C_r.

Region	C_r
Arctic Slope	.4
Northwest	
Inland	.5
Coastal and mountainous	.4
Yukon	.5
Southwest	
Mountainous	.5
Other areas	.4
South Central	
Coastal	.5
Other areas	.6
Southeast	.5

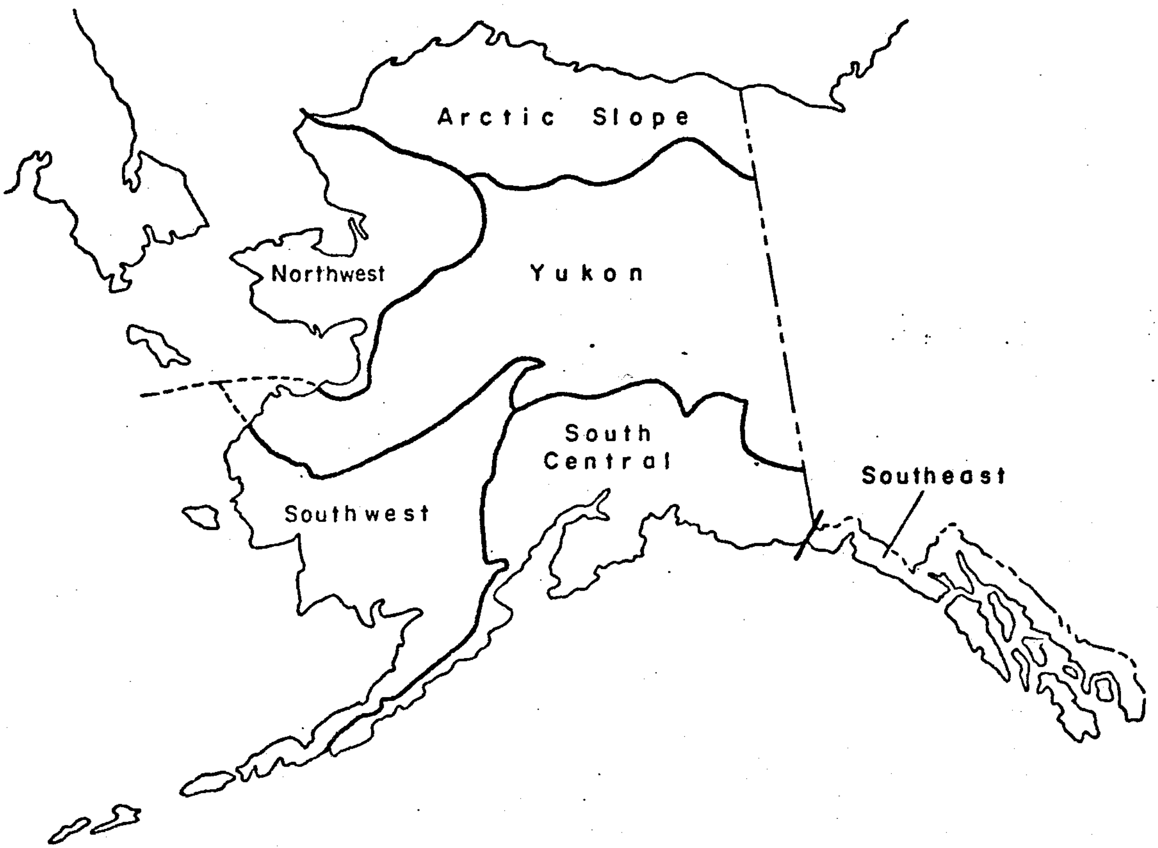


Table III. Exposure factor, C_e.

Siting of structure	C_e
Windswept	1.0
Suburbs with few trees	1.1
Near some trees or other windbreaks	1.2
In among trees	1.3

Table IV. Roof thermal factor, C_t.

Thermal condition	C_t
Heated building with unventilated roof having conventional insulation ($R < 15$)	1.0
As above, but ventilated	1.1
Heated building with unventilated, well-insulated roof ($R > 15$)	1.1
As above but ventilated	1.2
Building kept just above freezing	1.3
Unheated building	1.4

Full and zero loads

For all roofs the effect of removing the load from any portion of the loaded area should be investigated. In some instances, unloading certain areas will induce heavier stresses in the roof than with the entire roof loaded. Cantilevered roof joists are a good example: removing the load from the cantilevered portion will increase the bending stress and deflection at center span. In other situations undesirable stress reversals may result.

Roof slope

All loads acting on sloping surfaces should be considered to act on the horizontal projection of that surface.

The basic roof snow load, p_r, should be used without modification for simple shed, gable and hip roofs having a slope of 3 on 12 (14°) or less and for domed or vaulted roofs where the centerline rise is less than one tenth the span.

For unobstructed metal roofs where snow can slide off the eave, the flat roof snow load can be reduced by the roof slope factor, C_s, determined using the dashed line in Figure 7.

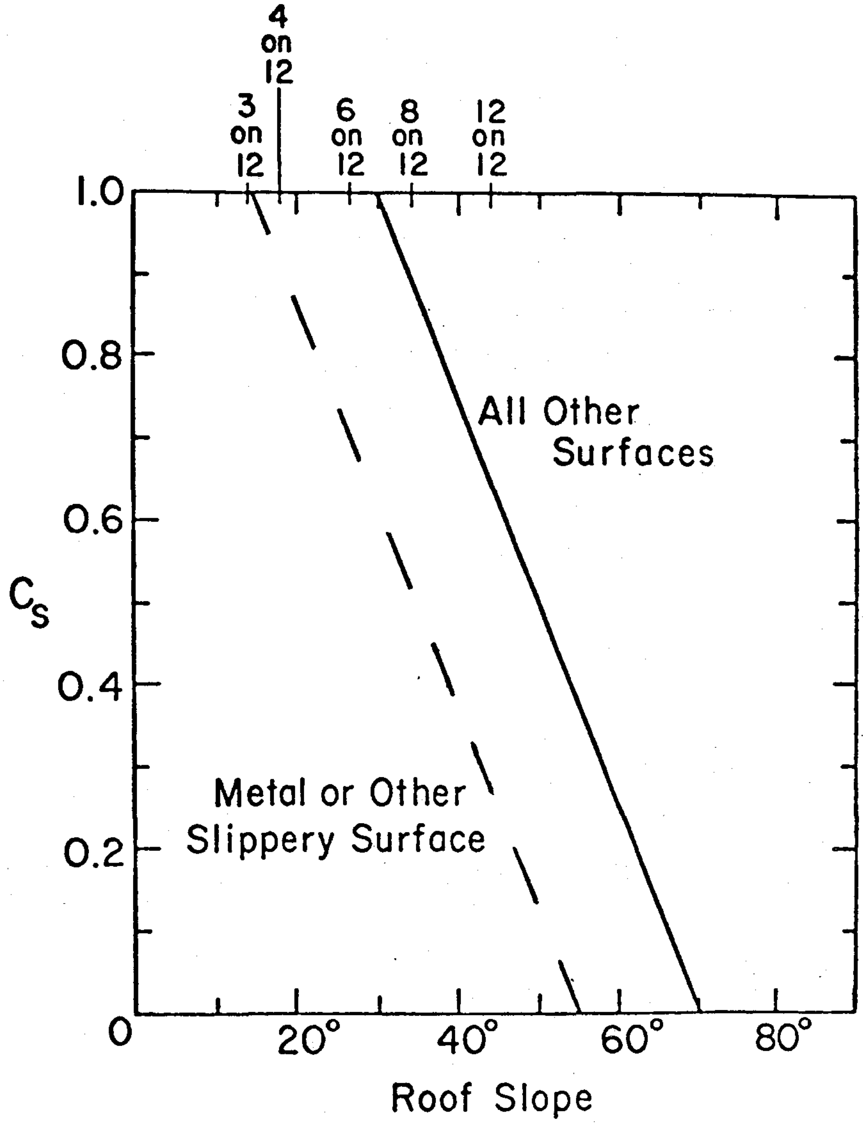


Figure 7. Graph for determining the roof slope factor, C_s

For other roofs that cannot be relied on to shed snow loads by sliding, the solid line in Figure 7 should be used to determine the slope factor, C_s.

For curved roofs with the rise greater than one tenth the span, the roof slope factor, C_s, should be determined from the appropriate curve in Figure 7 basing the slope on the vertical angle from the eave to the crown. The dashed line in Figure 7 should be used for fabric structures, including inflatables.

Unbalanced loads

For hip or gable roofs with a slope exceeding 4 on 12 (18°) the structure should also be designed to sustain an unbalanced uniform load on the lee side equal to 1.25 times the balanced load. In the unbalanced situation the windward side shall be considered clear of snow.

For domed and arched roofs with a rise greater than one tenth the span the lee side unbalanced load should be a triangular distribution increasing from zero at the crown to 2.0 times the balanced load at the eave.

Lower roofs (aerodynamic shade)

Snow drifts will accumulate on roofs in the wind shadow of higher roofs. The affected roof may be influenced by a higher portion of the same structure or by another structure nearby if the separation is 20 ft or less. When a new structure is built near existing structures drifting possibilities should be investigated for the existing structures and the new structures.

The drift load will decrease as the spacing between structures increases. The factor $\frac{20 - \text{spacing in feet}}{20}$ can be used to decrease drift loads for spacings to 20 ft. For spacings greater than 20 ft drift loadings need not be considered.

The surcharge load due to drifting can be approximated by a triangular distribution assuming that the drift rises to the level of the higher roof at the edge of the lower roof and tapers to zero at a distance along the roof equal to 2 times the clear height between the two roofs. The clear height is measured from the top of the balanced snow load on the lower roof to the closest point on the upper roof. If the clear height exceeds 5 ft the values for a 5-ft clear height will be used to establish the extent and magnitude of the surcharge load. To determine the thickness of the balanced snow load and the weight of snow in the drift, a density of 20pcf can be assumed. The drift load should be divided by the exposure factor, C_e, since the potential for drifting will also be influenced by site factors.

Multiple folded plate and barrel vault roofs

Such roofs collect excess snow in the valleys by wind drifting and by sliding. To account for the excess no reduction in load is allowed for slope as for shed, gable, hip and curved roofs.

The redistribution of load toward valleys also requires consideration of nonuuniform loading for all such roofs having a slope or equivalent slope exceeding 2 on 12 (10°).

The nonuniform load should decrease uniformly from a value two times the flat roof load p_r, at the valley to zero at the ridge. The total weight of snow on the roof is the same for the uniform and triangular loadings.

For sawtooth and similar roofs with one surface vertical or nearly so, uniform loads and nonuniform loads are developed in a similar manner.

Sliding snow

Snow may slide off metal, plastic or fabric surfaces but usually remains on wood, composition shingle or built-up surfaces unless the slope exceeds 45°. Situations which permit snow to slide onto lower roofs should be avoided. Where this is not possible the extra load added by sliding snow should be considered.

The final resting place of the sliding snow will depend on the size, position, and orientation of each roof. Distribution of sliding loads might vary from a uniform load 5 feet wide if a significant vertical offset exists between the two roofs, to a 20-foot wide uniform load where a low slope upper roof slides its load out over a second roof only a few feet lower much like a flowing glacier. For conditions where a portion of the sliding load is expected to also slide clear of the lower roof an appropriate percentage of the upper roof load should be used in the calculation. The Canadian Code[20] suggests using 50% of the upper roof load for the general case. Where all the upper roof load can be expected to remain on the lower roof after sliding, the full load should be considered.

If the upper roof surface is metal, the upper roof load for the sliding load calculation should be based on the solid line in Figure 7 not the dashed line.

Roof projections

A continuous obstruction longer than 15 ft may produce a significant drift on a roof. The loads caused by such a drift can be considered triangularly distributed on either side of the obstruction with a peak intensity 16 times the clear height of the projection. This value is based on the assumption that the drift reaches a maximum height equal to 80% the clear height and that the drift snow has a density of 20pcf. This load should be divided by the exposure factor, C_e, since the potential for drifting will also be influenced by site factors.

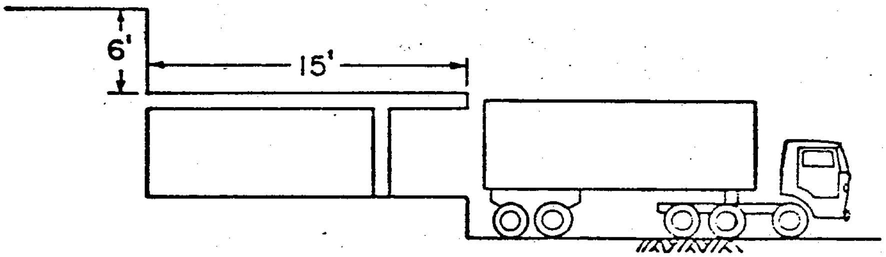
The lateral extent of the drift from a rectangular obstruction can be assumed equal to four times the clear height. L- or U-shaped obstructions (plan view) will increase snow loads to distances of 6 to 8 times the clear height respectively. For a four-sided obstruction such as a perimeter parapet the affected distance should be taken equal to 10 times the clear height.

Example

The following example is included to illustrate the snow load calculation technique.

KENAI EXAMPLE

Example: Determine snow loads for a large, conventionally insulated flat roof warehouse in an open area at Kenai. Also determine loads on the covered loading dock.



Kenai Solution

$p_r = C_r C_e C_t p_g$

For warehouse p_r = (.5)(1.0)(1.0)(84) = 42 psf.

For loading dock p_r = (.5)(1.0)(1.4)(84) = 59 psf.

Depth of snow on dock roof $= \dfrac{59 \text{ psf}}{20 \text{ pcf}} = 3$ ft.

Clear height = 6 ft – 3 ft = 3 ft.

Drift load at wall $= \dfrac{(20)(\text{clear height})}{C_e} = \dfrac{20(3)}{1} = 60$ psf.

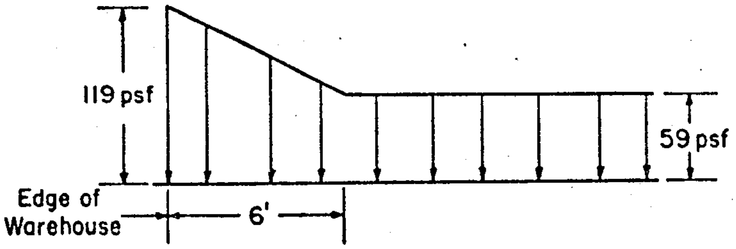
Total load at wall = 59 + 60 = 119 psf.

Lateral extent of drift = (2)(clear height) = 2(3) = 6 ft.

Design Snow Loads

Warehouse 42 psf

Loading dock



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APPENDIX A: FORTRAN II PROGRAM FOR ANALYSIS OF SNOW DEPTHS

```
C     LEAST SQUARES ANALYSIS OF LOG-NORMAL PROBABILITY PLOT
C     INCLUDES CALCULATION OF CORRELATION COEFFICIENT AND
C     COEFFICIENT OF DETERMINATION FOR THE REGRESSION LINE
C     USING BLOM'S PLOTTING POSITIONS
C     READ IN LIST OF VARIATES USED IN LAYING OUT PROBABILITY
C     PAPER AS THE FIRST SET OF DATA.
      DIMENSION Y(100), P(100),M(100),XSCALE(100),V(99),YLOG(100)
      READ PAPER TAPE 101, V
101   FORMAT(E20.0)
C     20 ANUM CHARACTERS PROVIDED FOR DATA LOCATION
4     READ PAPER TAPE 103, NA1, NA2, NA3, NA4, NA5, IDUM
103   FORMAT (5A4, I10)
C     8 ANUM CHARACTERS PROVIDED FOR DATA SOURCE
      READ PAPER TAPE 104, ISO1, ISO2, IDUM
104   FORMAT(2A4,I10)
C     8 ANUM CHARACTERS PROVIDED FOR DATA TYPE
      READ PAPER TAPE 104, ITYPE1, ITYPE2, IDUM
      N=0
1     N=N+1
C     Y VALUES READ IN IN ORDER FROM SMALLEST TO LARGEST.
C     LAST ENTRY MUST BE 9999.
C     IF THERE IS ANOTHER DATA SET, A NUMBER LESS THAN 99999999.
C     MUST BE ENTERED FOLLOWING THE 9999. ENTRY DESIGNATING THE
C     END OF THE PREVIOUS DATA SET.  IF NO MORE DATA SETS FOLLOW,
C     99999999. OR GREATER MUST BE ENTERED.
      READ PAPER TAPE 102, Y(N)
102   FORMAT(E20.0)
      IF (Y(N)-9999.) 1,2,2
2     N=N-1
      DO 10 I=1,N
      P(I)=((FLOAT(I)-.375)/(FLOAT(N)+.25))*100.
      M(I)=P(I)+0.5
      XSCALE(I)=V(M(I))
10    YLOG(I)=FLOG10F(Y(I))
      SUMX=0.0
      SUMY=0.0
      SUMXSQ=0.0
      SUMYSQ=0.0
      SUMXY=0.0
      DO 11 I=1,N
      SUMX=SUMX+XSCALE(I)
      SUMY=SUMY+YLOG(I)
      SUMXSQ=SUMXSQ+XSCALE(I)*XSCALE(I)
      SUMYSQ=SUMYSQ+YLOG(I)*YLOG(I)
```

```
11     SUMXY=SUMXY+XSCALE(I)*YLOG(I)
       ZN=N
       AVEX=SUMX/ZN
       AVEY=SUMY/ZN
       XYBIG=SUMXY-ZN*AVEX*AVEY
       XBIG=SUMXSQ-ZN*AVEX**2.
       B=XYBIG/XBIG
       A=AVEY-B*AVEX
       COCOR=XYBIG/((SUMXSQ-ZN*(AVEX**2.))*(SUMYSQ-ZN*(AVEY**2.)))
      1**0.5
       CODET=COCOR**2.
       Y101=10.**(A+B*2.674)
       Y5=10.**(A+B*5.842)
       Y30=10.**(A+B*6.817)
       Y50=10.**(A+B*7.054)
       Y100=10.**(A+B*7.326)
       Y10=10.**(A+B*6.282)
       Y25=10.**(A+B*6.750)
       PRINT 113
113    FORMAT(1H1,59HLEAST SQUARES ANALYSIS OF LOG NORMAL
      1PROBABILITY PLOT (BLOM))
       PRINT 105, NA1, NA2, NA3,NA4, NA5
105    FORMAT(1H0,9HLOCATION ,2X,5A4)
       PRINT 106, ISO1, ISO2
106    FORMAT(1H0,19HINFORMATION SOURCE ,2X,2A4)
       PRINT 107, ITYPE1,ITYPE2
107    FORMAT(1H0,9HDATA USED//2X,2A4,3X,4HPLOT)
       DO 3 I=1,N
       PRINT 108, Y(I), M(I)
108    FORMAT(F8.2,I8)
3      CONTINUE
       PRINT 109, B, A
109    FORMAT(1H0,6HSLOPE=,F10.5,2X,10HINTERCEPT=,F10.5)
       PRINT 110, ITYPE1,ITYPE2,Y101,Y5,Y10,Y25,Y30,Y50,Y100
110    FORMAT(1H0,13HRETURN PERIOD,2X,2A4,2X,8HPLOTTING/4X,
      15HYEARS,16X,8HPOSITION//7X,4H1.01,5X,F6.2,7X,1H1/
      17X,1H5,8X,F6.2,6X,2H80/6X,2H10,8X,F6.2,6X,2H90/6X,2H25,
      18X,F6.2,6X,2H96/6X,2H30,8X,F6.2,6X,4H96.7/6X,2H50,8X,
      1F6.2,6X,2H98/5X,3H100,8X,F6.2,6X,2H99)
       PRINT 111,COCOR,CODET
111    FORMAT(1H0,24HCORRELATION COEFFICIENT=,F10.5,5X,29HCOEFF
      1ICIENT OF DETERMINATION=,F10.5)
       READ PAPER TAPE 112, ZOOM
112    FORMAT(E20.0)
       IF(ZOOM-99999999.) 4,50,50
50     STOP
       END
```

APPENDIX B: COMPUTER PRINT-OUTS FOR CAPE LISBURNE AND UTOPIA CREEK

```
LEAST SQUARES ANALYSIS OF LOG NORMALPROBABILITY PLOT (BLOM)

LOCATION   CAPE LISBURNE ALASKA

INFORMATION SOURCE   BILELLO

DATA USED

 DEPTH      PLOT
   8.00       6
  12.00      16
  15.00      26
  15.00      35
  17.00      45
  19.00      55
  19.00      65
  27.00      74
  29.00      84
  29.00      94

SLOPE=    .18318  INTERCEPT=    .33194

RETURN PERIOD  DEPTH     PLOTTING
   YEARS                 POSITION

     1.01        6.63       1
     5          25.24      80
    10          30.39      90
    25          37.02      96
    30          38.08      96.7
    50          42.08      98
   100          47.20      99

CORRELATION COEFFICIENT=    .96821
COEFFICIENT OF DETERMINATION=    .93744
```

APPENDIX B

```
LEAST SQUARES ANALYSIS OF LOG NORMALPROBABILITY PLOT (BLOM)

LOCATION   UTOPIA CREEK, ALASKA

INFORMATION SOURCE   BILELLO

DATA USED

 DEPTH      PLOT
  9.00        4
 13.00       11
 14.00       17
 19.00       24
 20.00       30
 20.00       37
 21.00       43
 27.00       50
 28.00       57
 32.00       63
 36.00       70
 42.00       76
 45.00       83
 55.00       89
 69.00       96

SLOPE=    .25555  INTERCEPT=    .13644

RETURN PERIOD  DEPTH     PLOTTING
   YEARS                 POSITION

     1.01        6.60       1
     5          42.60      80
    10          55.18      90
    25          72.68      96
    30          75.60      96.7
    50          86.92      98
   100         102.00      99

CORRELATION COEFFICIENT=     .99498
COEFFICIENT OF DETERMINATION=     .98998
```