REPORT

OF

SNOW LOAD STUDY

OF

TRUCKEE QUADRANGLE

PORTIONS OF

NEVADA COUNTY, CALIFORNIA

JOHN WEBSTER BROWN

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INDEX

JUNE 1973

COMMENTARY NO. 2

SNOW LOADS

by

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This snow load study was undertaken at the request of the Nevada County Board of Supervisors as evidenced by Resolution No. 73-29, passed and adopted March 6, 1973. As a result of said resolution an agreement for services was entered into under date of March 6, 1973 by and between the COUNTY OF NEVADA and JOHN WEBSTER BROWN, CIVIL & STRUCTURAL ENGINEERS.

It is recognized that there are many variables to be valuated in the development of the loads that should be used as a representation of the snow on the roof of buildings and structures. At the present time there is insufficient information available as to the correlation of the snow loading on the ground versus the snow loading on adjacent roofs. Also, there is not enough data developed to correlate the snow loadings occurring on roofs with various pitches and with roofs of different surfacing materials. It is obvious that large differences in loadings occur by virtue of different exposures to sun and wind.

An inspection of the existing snow survey courses, which have been developed primarily for the prediction of runoff, shows that they are not generally located in places that will yield the greatest advantage in analyzing snow loads on buildings and structures. It is particularly significant that there was a definite lack of sufficient snow survey courses in the Truckee Quadrangle. Due to this reason, it was necessary to evaluate considerable data outside the study area to arrive at meaningful recommendations.

Due to the lack of finite information, it is normal to establish the loadings as a function of the anticipated maximum snow loading on the ground. In order to approximate the maximum snow loadings on the ground at various locations and at different elevations, two approaches were made. The first of these is based on projections of the snow loading on the ground derived from the existing snow survey courses which are read on January 1, February 1, March 1 and April 1 of each year. The second method used was to determine the approximate snow loadings on the ground as a function of the precipitation records from the various applicable weather stations.

Approximately twenty-nine (29) snow survey courses were evaluated in this study (refer table 1T and map 1M). Some of these snow courses have records as long as sixty (60) years and a few have records as short as six (6) years. Most of the snow course measurements and records thereof are made either by the Nevada Federal-State-Private Cooperative Snow Surveys under the direction of the Soil Conservation Service, U.S. Department of Agriculture in Reno, Nevada or by the California Cooperative Snow Surveys under the direction of the State of California Department of Water Resources in Sacramento, California. Four of the snow courses included in the study were started in 1964 by John Webster Brown and have subsequently been surveyed by Washoe County, Nevada. In addition to the above Mr. Harold Klieforth of the Desert Research Institute, University of Nevada Reno, has periodically taken snow samples at selected locations during 1970, 1971, 1972 and 1973 (refer table 2T). Also the Trimont Land Company has made records of snow depths for the snow years 1967-68, 1968-69 and 1969-70 in the Northstar ski area south of the Truckee Quadrangle (refer table 3T). Two additional snow survey measurements were made by John Roda of the Soil Conservation Service, Reno, Nevada, on March 14, 1973 and April 10, 1973 (refer table 2T).

Climatological data including precipitation records are available from the U.S. Department of Commerce, Weather Bureau for Soda Springs, Boca, Donner Memorial State Park, Squaw Valley, Tahoe City, and Truckee Ranger Station and these have been evaluated in this study (refer table 4T and 5T). Records of climatological observations including temperature extremes, precipitation, depth of new fallen snow, and depth of snow on the ground from November 1965 to date at the Tahoe-Truckee Airport (refer table 4T and 5T) were available and were evaluated in this study.

A graph of snow loading versus elevation above sea level was plotted for all the snow survey courses evaluated in this report (refer graph 1G). This graph shows rather good correlation for the courses that are deemed applicable to the study area. In setting a fitting curve to this graph it is obvious that the courses west of the summit must be discounted as not applicable to the study area. Similarly the courses a short distance east of the ridge of the summit must also be discounted, since they lay in the snow shadow of the summit and are strongly influenced by the higher terrain adjacent thereto. Examination of the long term snow course records as well as physical observation over the years of the snow pack on the ground, indicates that as the storms pass over the Sierras they start their heavy dumping on the west slopes and reach the greatest yield near the summit. The storms; however, continue a high yield for a few miles beyond the ridge of the summit. This predominate pattern s been fairly consistent over the years. In general the moisture laden cloud systems form over the Pacific Ocean and are blown to the east by the wind. When the clouds reach the influence of the Sierra Nevada Mountains they begin to rise and cool thereby causing snow to fall. As the storm clouds pass the summit they drop a large portion of their moisture content and consequently they do not have as much remaining to yield in the area east of the summit.

Similar to the above, a graph of snow loading versus elevation above sea level was plotted from the snow depth measurement data in the Northstar ski area (refer graph 2G). The largest values of the record of Northstar data occurred in the 1968-69 snow season. To convert the snow depth readings to water content, a plot was made of the densities of the comparable snow survey courses on the same dates to arrive at an appropriate density at the Northstar stations (refer graph 3G). The densities obtained from the snow survey courses were multiplied by the Northstar depths to yield the water content. While the 1968-69 snow season was one of the higher years of record, it was exceeded in the study area by the 1952 snow pack. Therefore a plot was made of the ratio of the 1969 snow load values to the maximum snow load values (usually 1952 values) for the comparable snow survey courses (refer graph 4G). The ratio of 1969 to maximum at the comparable snow survey courses was then used to convert the derived water content values at Northstar for 1969 to the water content that would represent the maximum of record (refer table 3T). The graph based on the Northstar area snow depths compares favorably with the graph prepared for the twenty-nine (29) snow courses.

The U.S. Army Corps of Engineers derived a map showing contours of normal annual precipitation for the Sierra areas under consideration in this report as a part of their studies in connection with the Washoe project. This map is shown as Chart No. 4 in the Appendixes of "Interim Survey Report for Flood Control Reno Area Truckee River and Tributaries", dated 1 March 1960 (refer map 2M). With the aid of this map, one can relate the normal annual precipitation to elevation. Since the normal annual precipitation is for the entire year, it is necessary to approximate the amount of this annual precipitation that would be cumulative in a snow pack. The above mentioned Appendixes indicate that approximately 86% of the annual precipitation occurs in the November to April period of time. From the climatological records for Tahoe City, Truckee Ranger Station and the Tahoe-Truckee Airport we have found in this study that an average of 85% of the normal annual precipitation will be in the snow pack and will be a measure of the snow loading (refer table 5T). In the normal and light snow years this 85% of annual will be too high for an indication of the snow pack; however, in the maximum snow years it is believed that this 85% is not out of line. In order to relate the maximum years of snow fall to the normal annual precipitation, the ratio of long term normal[1] water equivalent to the maximum water equivalent as shown by the existing snow survey courses was used. In the elevations below 8,000 feet the maximum snow loadings from the snow survey courses are approximately 200% of the long term normals. Above 8,000 feet the maximum snow loadings are approximately 170% of the long term normals (refer table 6T). Using the above set forth correlations, a curve was drawn with snow load versus elevation to plot the loadings derived from normal annual precipitation (refer graph 5G). In the 1964 Washoe County, Nevada Snow Load Study these curves showed reasonable consistency and compared favorably with the loads derived from the existing snow survey course data. In this study of the Truckee Quadrangle of Nevada County California the relationship to the snow courses is rather poor and this method is considered unreliable in this case.

To arrive at the recommended design snow loading on roofs, it is felt that 70% of the maximum snow loadings occurring would be satisfactory for safe construction. Of the normal building construction materials used, structural steel has the least factor of safety. This factor of safety is normally considered to be 1.65. By using 70% of the maximum snow loadings it would indicate that the stresses in structural steel would be approximately 1.43 times the normal allowable stresses. This would leave about a 22% margin to failure. Such a slim margin to failure is not desirable under normal circumstances but it is felt that for the purposes used herein it will yield satisfactory results. Since the maximum snow load level has a fairly long recurrence interval, it may be only equaled or approached once or twice in the useful life of a structure.

The gross amount of snow on a building or structure is nearly always less than that on the ground, even though the distribution of said snow loading from drifting together with melting and refreezing may produce loads on some areas considerably greater than that on the ground. This is due to the fact that some of the snow particles blow off the roof onto the ground, and seldom is the general level of the snow on the ground high enough so that snow can blow from the ground to the roof.

The National Building Code of Canada,[2] which was developed after considerable study for Canadian conditions by the National

1. "Snow Surveys for Forecasting Stream Flow in Western Nevada"; by Horace P. Boardman, C.E., the University of Nevada Agricultural Experiment Station, Reno, Nevada - Bulletin No. 184, Sept. 1949.

2. "Structural Information for Building Design In Canada 1965", Supplement No. 3 to the National Building Code of Canada, by the Associate Committee on the National Building Code, National Research Council, Ottawa, Canada - NRC No. 8331.

Research Council, uses 80% of the ground snow as a base value, with a reduction of this loading to 60% of the ground snow for roofs exposed to the wind. It appears that the recommendation herein of 70% of the ground snow compares favorably with the Canadian concept.

In order to illustrate the frequency of occurrence of the design snow loads, a graph showing maximum snow load for the year versus the year of occurrence was plotted for each of the twenty-nine (29) snow courses considered in this study (refer graph 1A thru 29A). Also plotted on the graphs are horizontal lines showing the value of 70% of the maximum snow load (approximate proposed code value) together with the value of the last 15 years of record (except that stations with less than 15 years of record show the average of all years). These graphs indicate that the occurrence of the 70% value is quite frequent even though the maximum recorded value is approached fairly infrequently.

An additional approach to the determination of base snow loadings has been developed by John Webster Brown and this approach has subsequently been adopted by the Soil Conservation Service of the U.S. Department of Agriculture. This approach is based on the recurrence interval of snow loads of different magnitudes at the site under consideration. For years Civil Engineers have been setting the level of flood protection for various facilities on the basis of return frequencies of floods of different magnitudes. It seems reasonable that this analogy could be extended to the levels of protection against snow loads. A simple representation of return frequencies has been in common use and is shown by the formula (Method #1) as follows:

$$R = \frac{N + 1}{K}$$

where R is return frequency in years.
N is the number of years of record.
K is the order of magnitude of the value in the series. (as an example: m = 3 for the value of snow load for the third heaviest year of record.)

Many more methods are available for the determination of return frequencies, but most of them are merely refinements that modify extreme values and deviations from the mean. The above formula gives results consistent with the reliability of the raw data if there are five or more years of record.

The Soil Conservation Service and many other federal agencies have adopted the "Log-Pearson Type III" method of determining the recurrence interval of hydrology phenomenon as recommended by the Water Resources Council, Washington, D.C. The basic formula for this representation of return frequencies (Method #2) is as follows:

$$\text{Log } L = M + KS$$

where L = computed snow load for a selected recurrence interval or percent chance of occurrence

and $M = \frac{\text{sum } X}{N}$ (Mean of the Logs)

and $S = \sqrt{\frac{\text{sum } x^2}{N-1}}$ (Standard Deviation)

where $x = X - M$

and K = Pearson Type III coordinates which are obtained from standard precomputed mathematical tables using the skewness (g) as a perameter

wherein: $g = \frac{N \text{ sum } x^3}{(N-1)(N-2)S^3}$

and N = number of events in the record being used

In general Method #1 is more consistent with the observed values of record when the number of years of record is short, and Method #2 seems more consistent when the number of years of record is long.

With the large amount of raw data observations available for the twenty-nine (29) snow courses of this study it would be prohibitive in time and effort to compute these return frequencies by hand. However, a computer program was developed during this study to accept the data and tabulate the results (for summary refer to table 7T and table 8T).

If the values calculated from the Method #1 and Method #2 formulas are plotted with snow load versus recurrence interval in years on a semilog graph, a fitting curve can be approximated. Then the snow load for any return frequency may be read from the curve. Plots of recurrence intervals for the twenty-nine (29) snow survey courses in the vicinity of the study area were made (refer graphs 1B thru 29B). From these curves it was found that the average recurrence interval of the maximum snow load of record is twenty-seven (27) years for Method #1 and forty-three (43) years for Method #2. Similarly it was found that the average recurrence interval of 70% of maximum is seven (7) years for Method #1 and eight (8) years for Method #2(refer table 8T). This illustrates that while the maximum snow load of record may only occur once or twice during the life of a structure, 70% of maximum will occur many times.

Emphasis should be made of the fact that in reality snow loads of a certain value will not reoccur at the intervals derived from recurrence interval formulae. Actually the values represent averages. A much better way of thinking of recurrence interval data is in regard to the percent chance of a snow load of a given value occurring in a given year. As an example, a 100 year return frequency means that there is a 1% chance that the 100 year snow load will occur next year. Therefore the relationship of typical recurrence intervals to the percent chance of occurrence in any given year is as follows:

RETURN FREQUENCY	% CHANCE
100	1%
50	2%
20	5%
10	10%
5	20%

To summarize the results of the graphs of each of the twenty-nine (29) snow course station recurrence intervals three plots of graphs were made for 5 year, 10 year and 20 years showing the snow load value for that interval for each course versus the elevation above sea level of each course. Fitting curves have been drawn on these three graphs (refer graphs 6G, 7G & 8G). To visually compare the recurrence interval summary graphs with what was happened in the past, a curve showing the average of the last 15 year snow load versus the elevation above sea level is presented herein for the twenty-nine (29) snow survey courses (refer graph 9G).

Since it is our understanding that the Tahoe-Truckee Airport District is contributing to the cost of this report and since substantial building improvements are contemplated at the airport in the near future, some additional special attention was given to the airport vicinity. There are no established snow survey courses in the Martis Valley portion of the study area. Periodic single snow survey measurements have been made at the airport since 1970 by the Desert Research Institute (DRI) and two spot snow surveys at the airport were made by the Soil Conservation Service (SCS) on March 14, 1973 and April 10, 1973. Climatological observations at the airport are available from November 1965 to date. Maximum snow loads of record at the airport were synthesized from the snow survey measurements using the method outlined above for the Northstar measurements to convert to an equivalent 1952 snow year (refer table 2T). Three maps were also drawn for 1938, 1952 and 1969 which show the relationship of the snow load in each of these years to the maximum load measured at each of the established snow survey courses considered in this study (refer maps 3M, 4M, & 5M). These maps amply represent that the 1969 snow loads in the study area were only about 79.2% of those experienced in 1952 (refer table 9T).

In addition to the above means of determining the loading at the airport, an approach to the problem through the climatological observation data was pursued. From the precipitation, temperature extreme, new fallen snow and snow on the ground records, a daily cumulative summation of water content possible in the snow was prepared at the airport for the snow years 1968-69 and 1972-73. To test the validity of this procedure, the same thing was done for Tahoe City, Boca and Truckee Ranger Stations (for summary refer to table 10T).

Most of the technical literature states that in general precipitation gages do not catch all of the water content from snow, but there is little published material showing how much is trapped. For several years now the Soil Conservation Service has operated some continuous recording snow pillows that yield the water content of the snow at any time. Two of these snow pillows at Independence Camp and at Sonora Pass are at sites which also have recording precipitation gages. The summation of the accumulated precipitation for the snow year was plotted on the same scale as the snow pillow water content (actual) at each station for the 1971-72 and the 1972-73 snow years (refer plots 1P, 2P, 3P, & 4P). These plots have an average value of about 70% of the actual precipitation in the snow being recorded by the precipitation gages (refer table 11T).

The snow load at the airport is then calculated from the maximum precipitation possible in the snow year 1968-69, adjusted for rain gage inaccuracy by dividing by 70%, and adjusted upward to the 1952 level by dividing by 79.2% (refer table 12T).

In any report of this type it is important to discuss the parameters involved, so that a broad perspective may be acquired. A maximum of about 60 years of record is all that is available for examination. This is in reality a rather short time when considering phenomenon of natural occurrences. It is known from geological studies and evidence that in the geologically recent past that the Great Lake Lahontan spread all the way across Nevada from about Pyramid Lake into Utah. One peak elevation of that lake was estimated to have been 25,000 years ago and the most recent peak was about 10,000 years ago. The quantity of water flowing from the Truckee River and other similar tributaries must have been enormous to maintain said lake against evaporation and seepage losses. Also there is considerable evidence still visible of glaciation in the Sierra Nevada Mountains, which adds to the presumption that precipitation in the form of snow had to have been many fold that which has been observed in historic times.

In fact from the accounts of the construction of the Central Pacific Railroad (in 1869-1869) over Donner Summit and from recorded snow depths on Donner Summit since 1878 it is obvious that snow loads at least 20% greater than the 1952 loads have occurred since the habitation of the area by the white man (refer graph 10G and table 13).

This snow load report and the recommendations contained herein are keyed to the maximum snow load of record which views only about the last sixty (60) years. For this study area, the 1952 snow loadings are the most severe. Attention should be directed to the fact that loads in excess of the maximum documented values are possible and probable. A balance between economics and risk must of necessity be judged in setting snow load values. While it is deemed that the risk in using the snow loads recommended herein is consistent with that contemplated from other hazards to the works of man, it must be kept in mind that these snow load values are minimum and can be exceeded.

Attention should be called to the point that the recommendations contained herein pertain only to Nevada County areas within the Truckee Quadrangle. The values are not applicable west of 120° 15' longitude. The Donner Summit ridge of the Sierras together with the snow shadow on the east slopes thereof (including the Donner Lake area) experience substantially heavier snow loads for any given elevation than do the regions of the study area.

As has been previously stated herein, the National Building Code of Canada in general allows a 25% reduction to a value of 60% of the ground snow when the roof is fully exposed to the wind on all sides and does not have projections, such as parapet walls, which prevent snow from being blown off. The Canadian Code does not; however, allow this further reduction due to wind in a mountainous area with heavy snow load and low wind speeds during the winter season. Most of Canada does not have snow loads as high as are experienced in the Sierra Nevada region. The mountainous areas of Western Canada (British Columbia - Near the Pacific Ocean) are similar to the Sierra Nevadas and the Canadian Code does not allow the additional wind reduction in that region. In the plains and desert regions of Canada the new fallen snow has a low density and is more susceptible to wind transportation than is the more dense snow falling from the moisture laden storms originating over the Pacific Ocean.

The recommendations in this report do not provide a general reduction for exposure to the wind; however, wind is taken into account in the reductions allowed for roofs with steeper pitches. Roofs with steeper pitches are raised higher above the general level of the snow on the ground and are thereby exposed to more wind action and velocity.

Traditionally the literature has given credit for steeper roof pitches on the assumption that sliding will occur from them. In general there is no assurance that sliding will occur in the Sierra Nevada Range until sometime later in the season than the time of anticipated maximum snow load.

It is frequently stated by casual observers that roofing erial types have a great influence on snow sliding from roofs. It is common to hear that metal roofing enhances sliding as compared to say wood shingles. This suggestion may indeed be valid late in the season when general thawing is established. Actual observations reveal that frequently the early heavy storms begin in the form of rain or very wet snow with somewhat mild temperature ranges. As the storm progresses the temperature drops and heavy snow begins. With the drop in temperature the moisture on the roof freezes to the roofing creating a bond that will persist throughout the season until a general thawing is established. Indeed specific observations have been made wherein metal roofing was still retaining the snow after other similar roofs of other materials have given up their load by sliding.

The snow loadings recommended by this report for the Truckee Quadrangle portion of Nevada County have been set forth herein after as an addendum to the Uniform Building Code. It is the opinion that the approach made herein and the loadings recommended represent a reasonable evaluation based on the current state of technology.

There are many variations of roof configurations that are possible and that are in common usage. It is felt that an addendum to the Uniform Building Code which would include all of the possible onditions would be too cumbersome. The National Research Council of nada has published "Commentary No. 2" to the National Building Code of Canada, 1970 which gives an excellent outline of snow load behavior in general. This commentary also includes figures showing snow load shapes for a variety of roof configurations. It is recommended that the Canadian "Commentary No. 2" be made available to those persons inquiring about snow loads and to building permit applicants for their guidance. Caution should be expressed in referencing to the "Commentary No. 2" that the 25% reduction to 60% of the ground snow does not apply to the Sierra Nevada Range.

As has been pointed out, the snow shadow on the east slopes of the Donner Summit ridge experiences substantially heavier snow loads than the region of this study. <u>Since the areas west of the Truckee Quadrangle have not been evaluated by this report</u>, the existing ordinance no. 510 should be continued in the westerly areas. To provide a realistic and orderly transition from the Truckee Quadrangle snow load values to those of ordinance no. 510 it is recommended that the values derived herein be used east of the east line of sections 5, 8, 17, 20, 29, and 32 of the T 16 E and that the values of ordinance no. 510 be used west of the west line of said sections. The values within said sections shall be on a straight line proportion between the two values based on the distance of the site from the boundary of this transition zone (refer map 1M).

CODE ADDENDUM

UNIFORM BUILDING CODE, VOLUME I

Addendum for Truckee Quadrangle [a]

Portions of Nevada County, California

CHAPTER 23 - Live and Dead Loads

Section 2305 - Delete Sec. 2305 and Delete Table 23-B.

Add the following:

Roofs shall sustain, within the stress limitations of this Code, all "dead loads" plus unit "live loads" as set forth in Table No. 23-B1. The live loads shall be assumed to act vertically upon the area projected upon a horizontal plane.

Unbalanced loads shall be used where such loading will result in larger members or connections. Trusses and arches shall be designed to resist the stresses caused by unit live loads on one-half of the span if such loading results in reverse stresses, or stresses greater in any portion than the stresses produced by the required unit live load upon the entire span.

Gabled, hipped, or curved roofs shall be designed to resist stresses caused by unit live loadings 1.2 times the values in Table 23-B1 on one-half of the roof if such loadings result in larger members or connections.

All roofs shall be designed with sufficient slope or camber to assure adequate drainage after the long-time deflection from dead load or shall be designed to support maximum loads including possible ponding of water due to deflection. See Section 2307 for deflection criteria.

a. Applicable east ~~of the~~ east section line of sections 5, 8, 17, 20, 29, and 32 of T 16 E Mt. Diablo B. and M.

R 16 E T 17 & 18 N

TABLE 23-B1 Roof Live Loads - Pounds Per Square Foot[4,5]

ELEVATIONS AT or ABOVE 5000 ft. Above Sea Level[3]

ELEVATION[1] Above Sea Level in Feet	SNOW LOAD IN lbs./Sq. ft.[2]
5,000	50
5,500	90
6,000	130
6,500	170
7,000	210
7,500	250
8,000	280

1. Intermediate Values may be interpolated by proportion.

2. Deviations from the above set forth snow loadings may be permitted by the Building Official provided the snow load and conditions in each individual case are derived, and certified to, by a Registered Structural Engineer who can show proper experience in snow load evaluation.

3. In the design of buildings and structures above the 5000 ft. Elevation, consideration shall be given to the following:

   a. Unbalanced loading on roofs.

   b. Drifting due to adjacent obstructions.

   c. Accumulation in valleys and adjacent to Parapet Walls and Chimneys.

   d. Ice Loadings on Cornices.

   e. Possible impact loadings from snow falling on structure from higher roofs.

   f. Effect on structure from dynamic loading caused by snow sliding off roof.

g. Snow sliding off roof and dynamically loading side walls by being forced against same due to the snow embankment adjacent to the structure.

h. Permanent automatic roof heating systems, with reliable power sources.

i. Protection of entrances and exits from danger of falling icicles and snow sliding off pitched roofs.

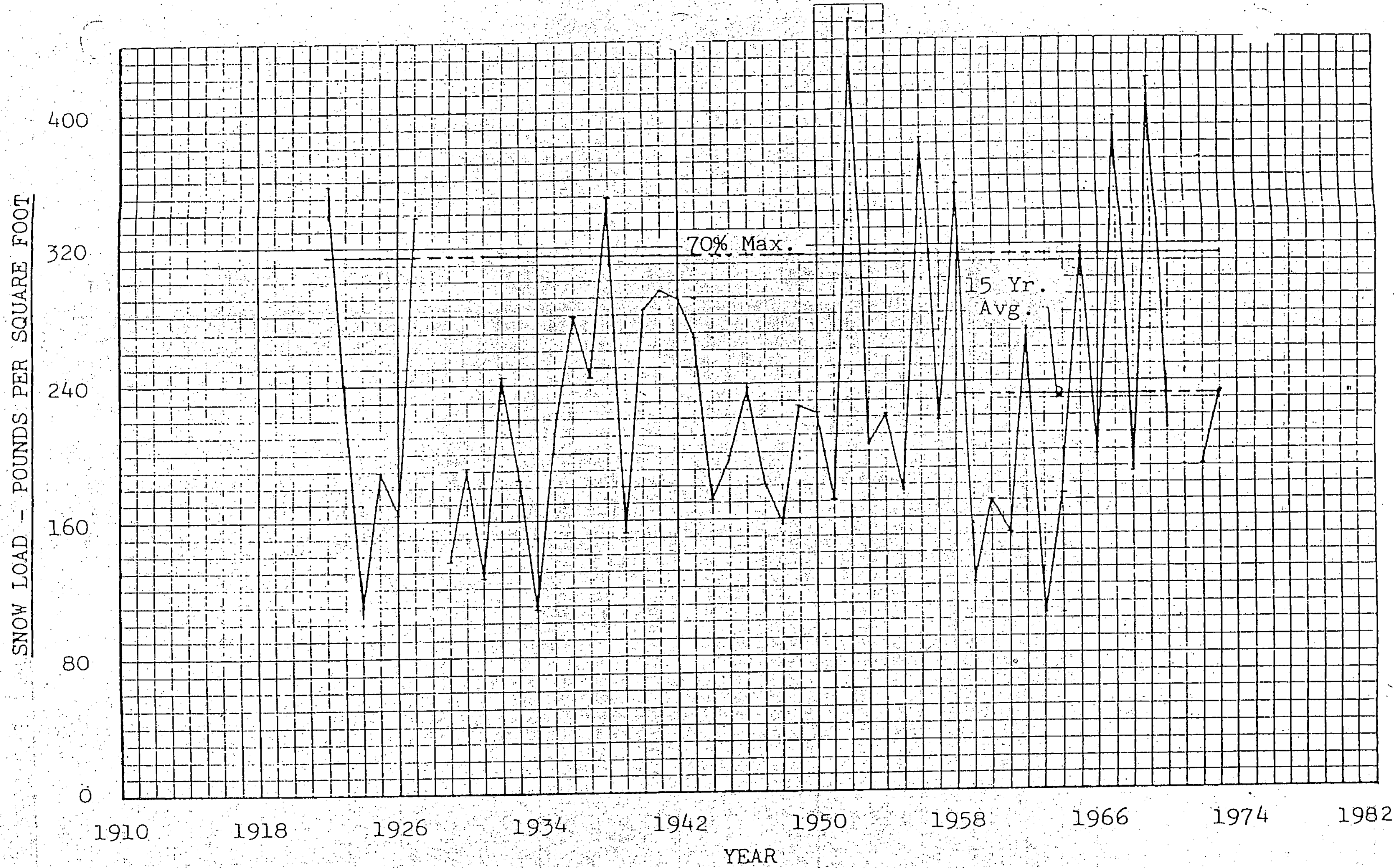
j. Ice weight where it will refreeze on unheated overhangs after having melted and run off from portions of roofs with heat below same.

k. Projections through the roof, such as ventilating and plumbing vent, which will be torn off or damaged by sliding snow.

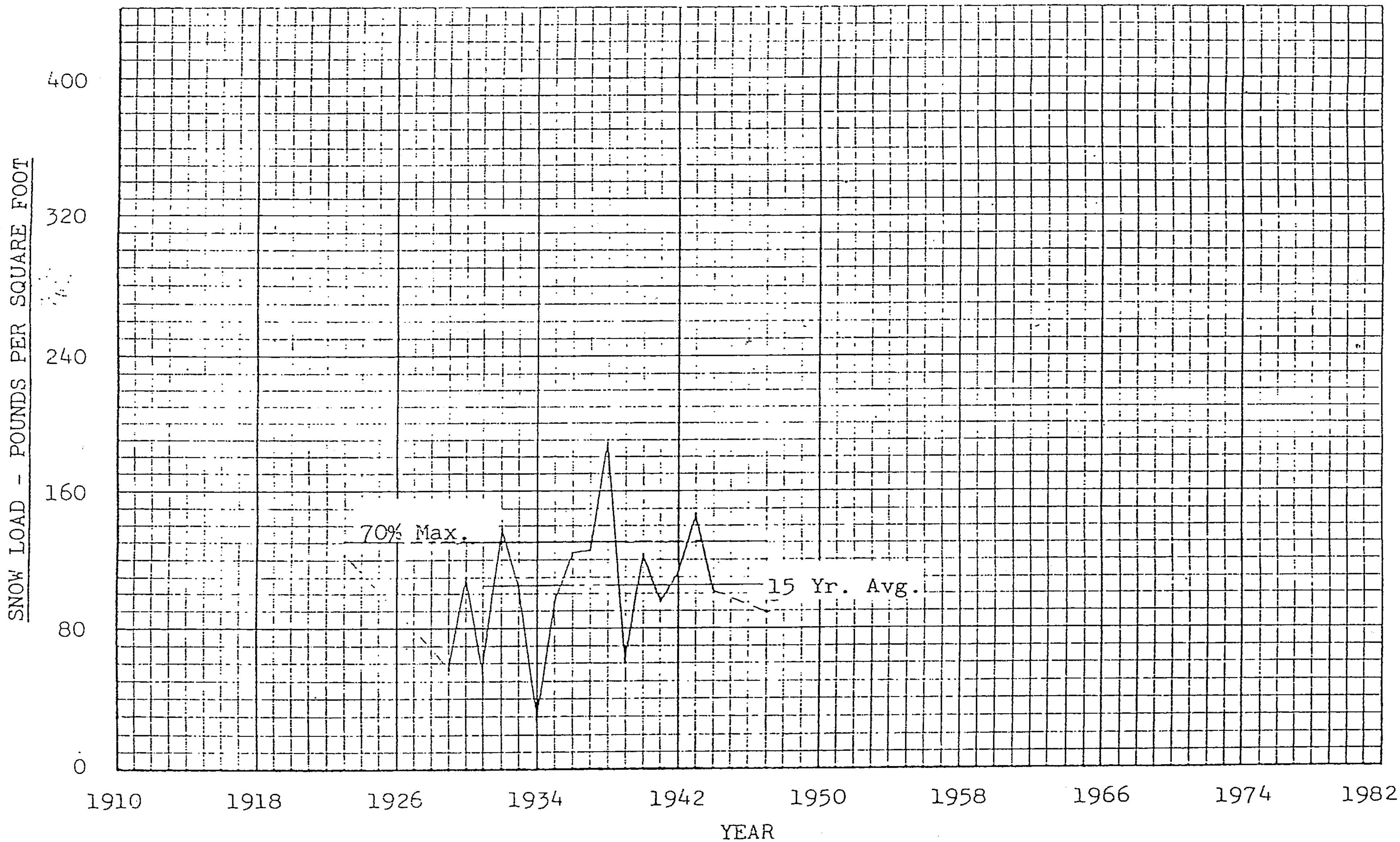
4. 80% of the tabulated values in Table 23-BI may be used with Roofs having a Pitch of between 7 in 12 and 12 in 12. 60% of the tabulated values in Table 23-BI may be used with Roofs having a Pitch in excess of 12 in 12.

5. These roof loadings are applicable only to roofs having an eave height above the anticipated general depth of snow on the ground. In the case of "A Frame" Buildings and other similar types wherein the roof extends below the depth of snow on the ground, a minimum of 1.4 times the tabulated values must be used on the roof below the ground snow level. Also special design consideration must be made for the stress condition wherein the snow from the upper portion of the roof slides down on top of the ground snow and consequently further increases the loading on the lower portion of said roof.

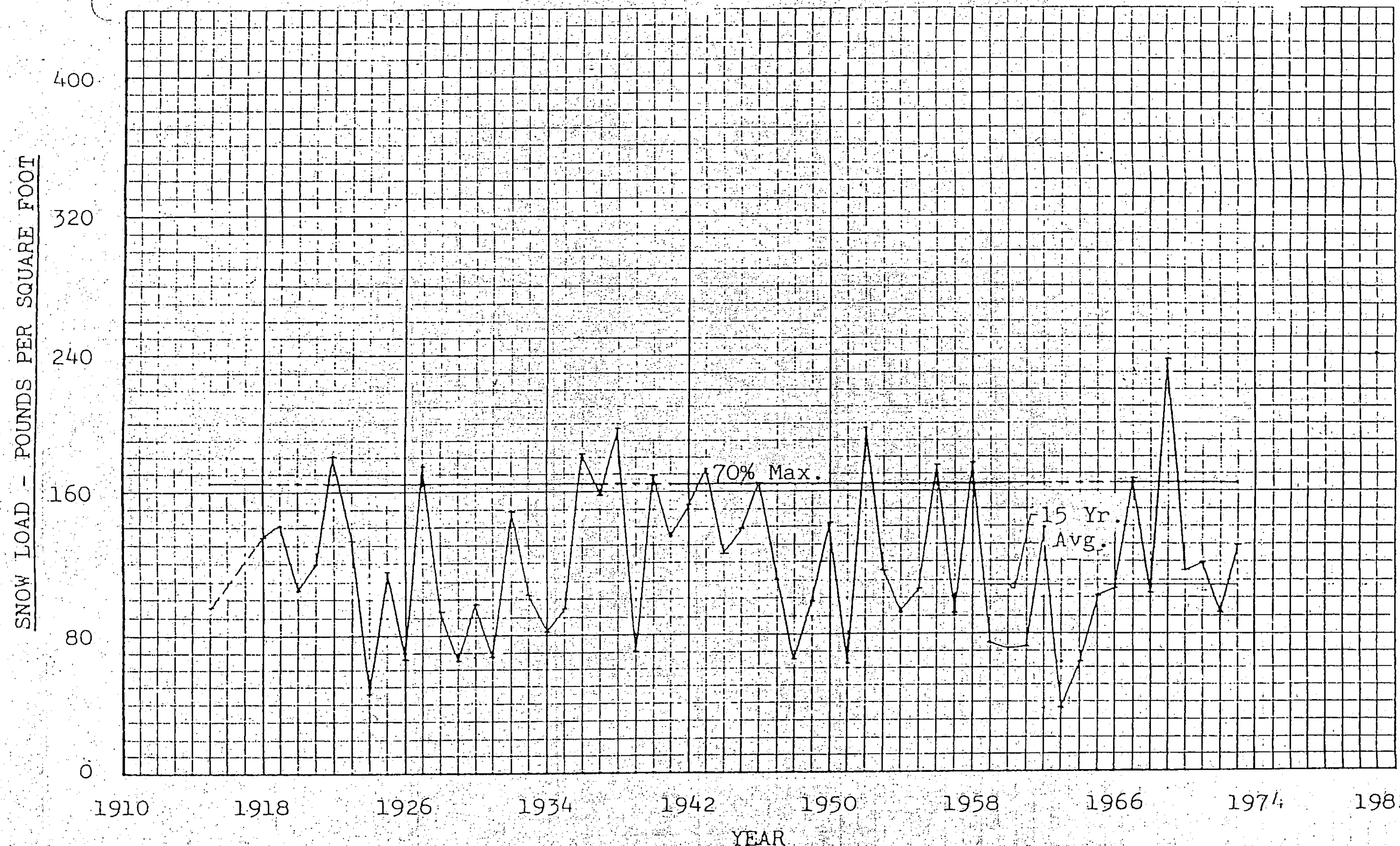
6. <u>NOTE:</u> Occasionally there may be large local deviations from the typical data from which this Code was developed. When applying these values to structures the designer should make every effort to determine if the tabulated values should be adjusted because of local orographic effects. Loads for structures which have an inherent need for a high degree of safety, or long life span, should be carefully evaluated, and the designer should always exercise his best professional judgement.



Webber Peak Elev. 7800 SCS No. 20K1 1922-1973

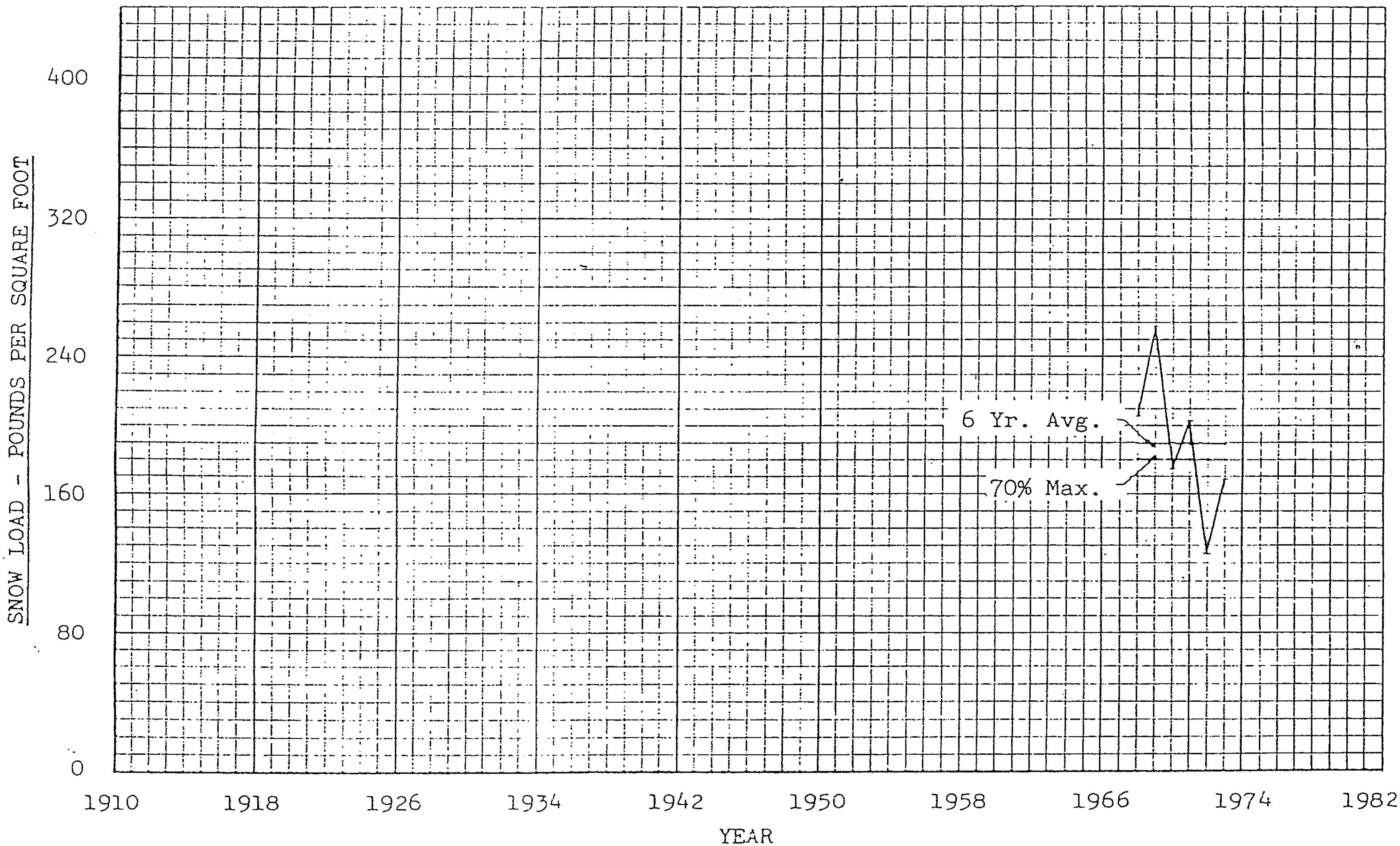


Granite Peak Elev. 8000 SCS No. -- 1923-1947



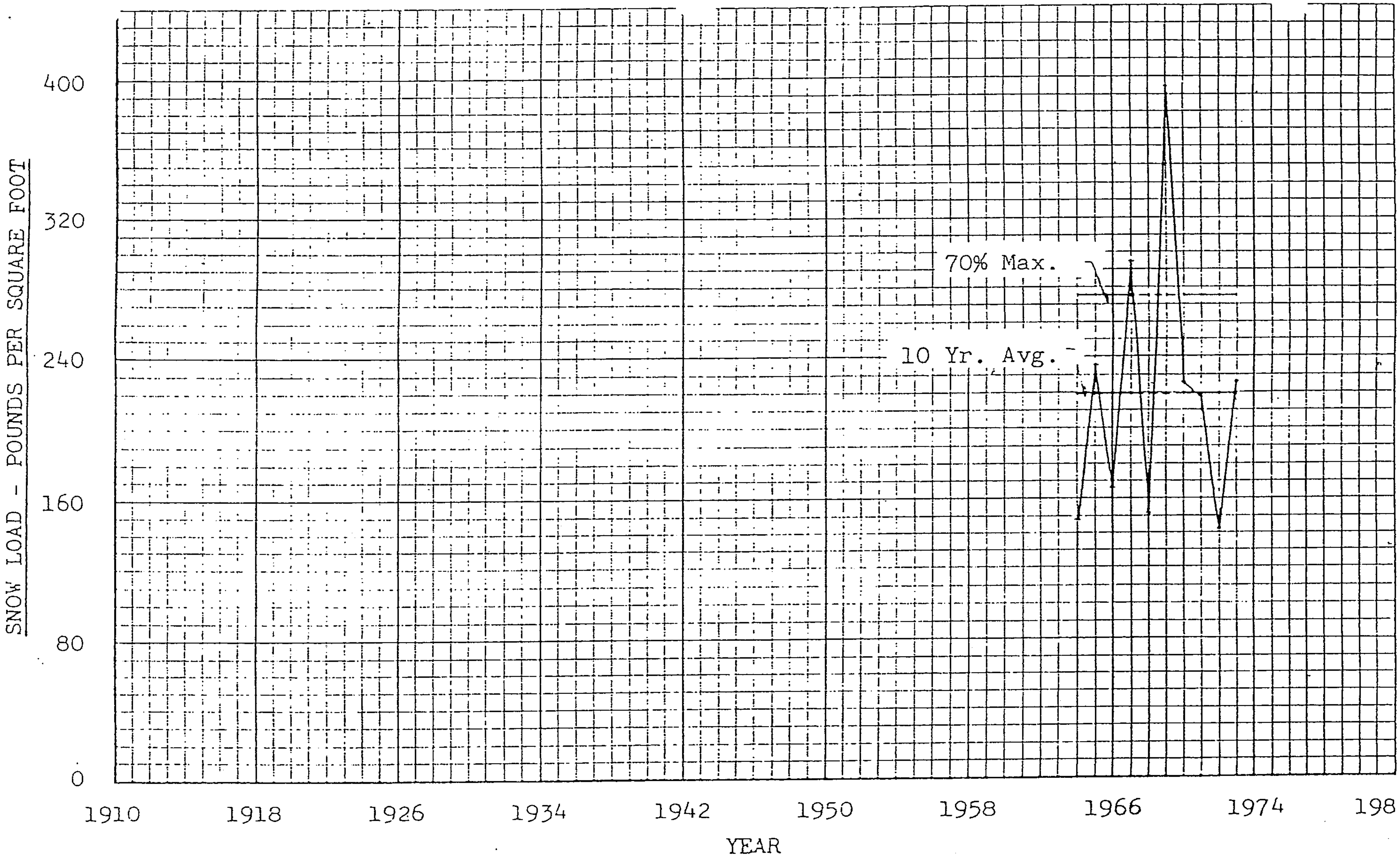
Marlette Lake Elev. 8000 SCS No. 19K4 1915-1973

6A

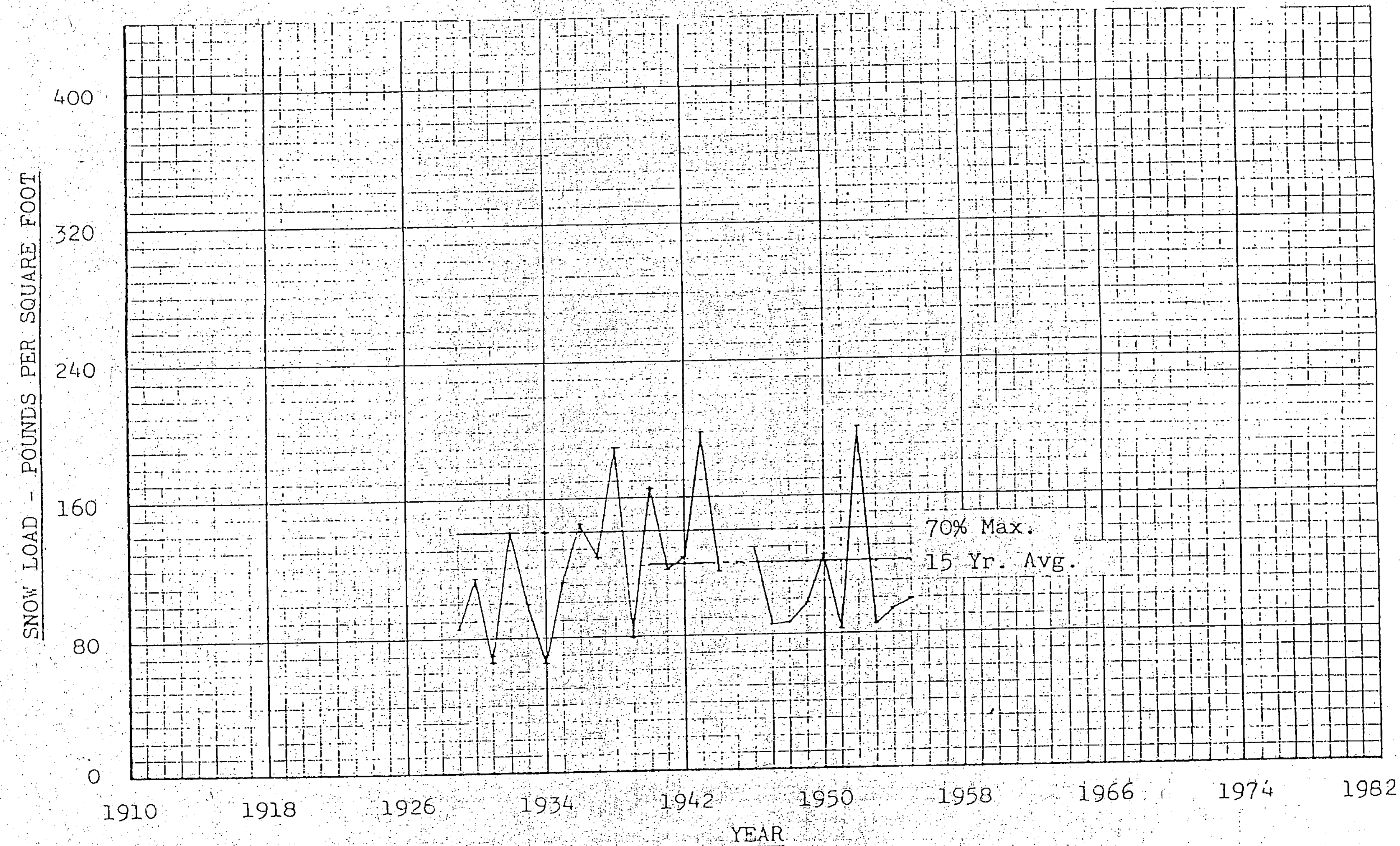


Mount Rose Lodge Elev. 8400 SCS No. -- 1968-1973

Independence Lake Elev. 8450 SCS No. 20K5 1937-1973

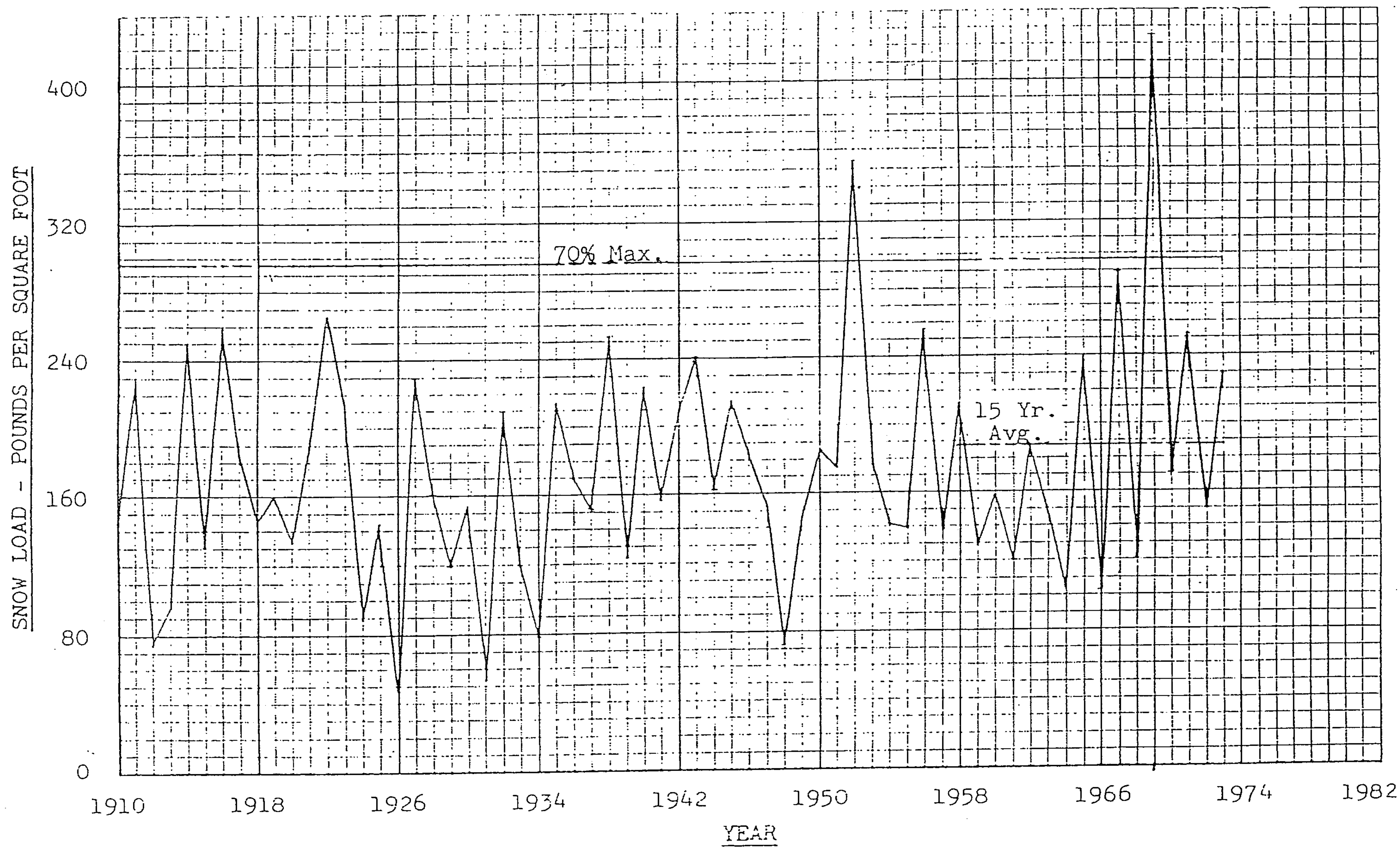


Third Creek Elev. 8600 SCS No. -- 1964-1973



Big Meadows Elev. 8800 SCS No. -- 1929-1955

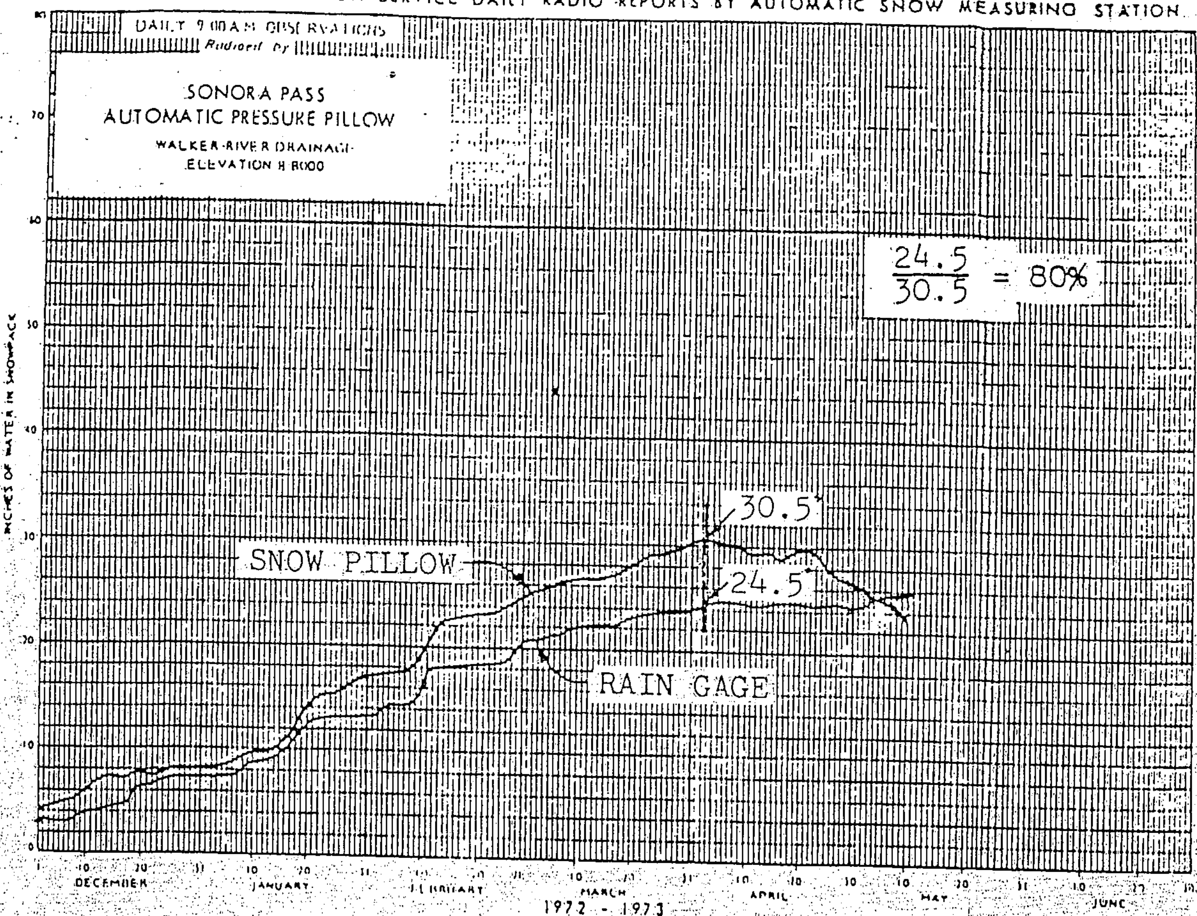
2A



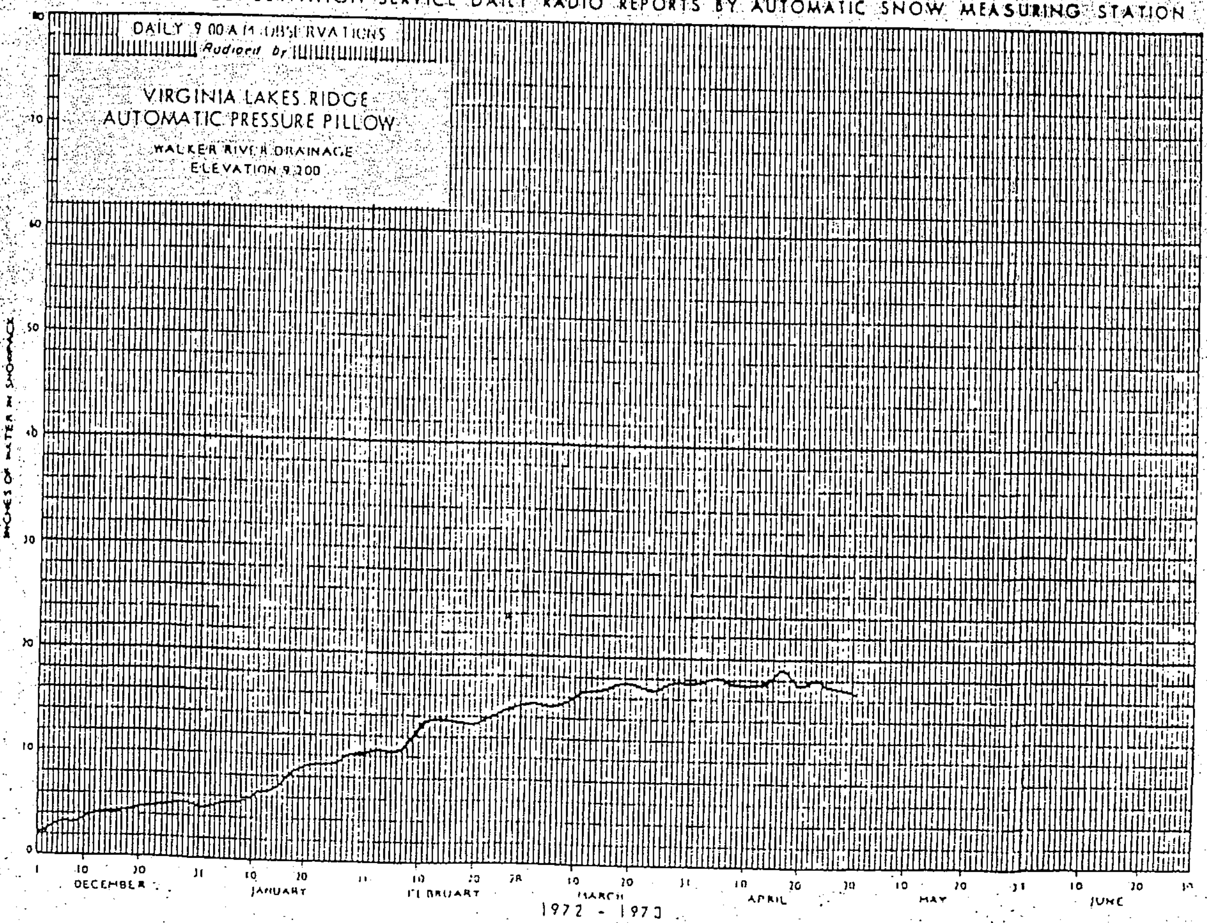
Mount Rose   Elev. 9000   SCS No. 19K2   1910-1973

GRAPH 1A

U.S.D.A. SOIL CONSERVATION SERVICE DAILY RADIO REPORTS BY AUTOMATIC SNOW MEASURING STATION

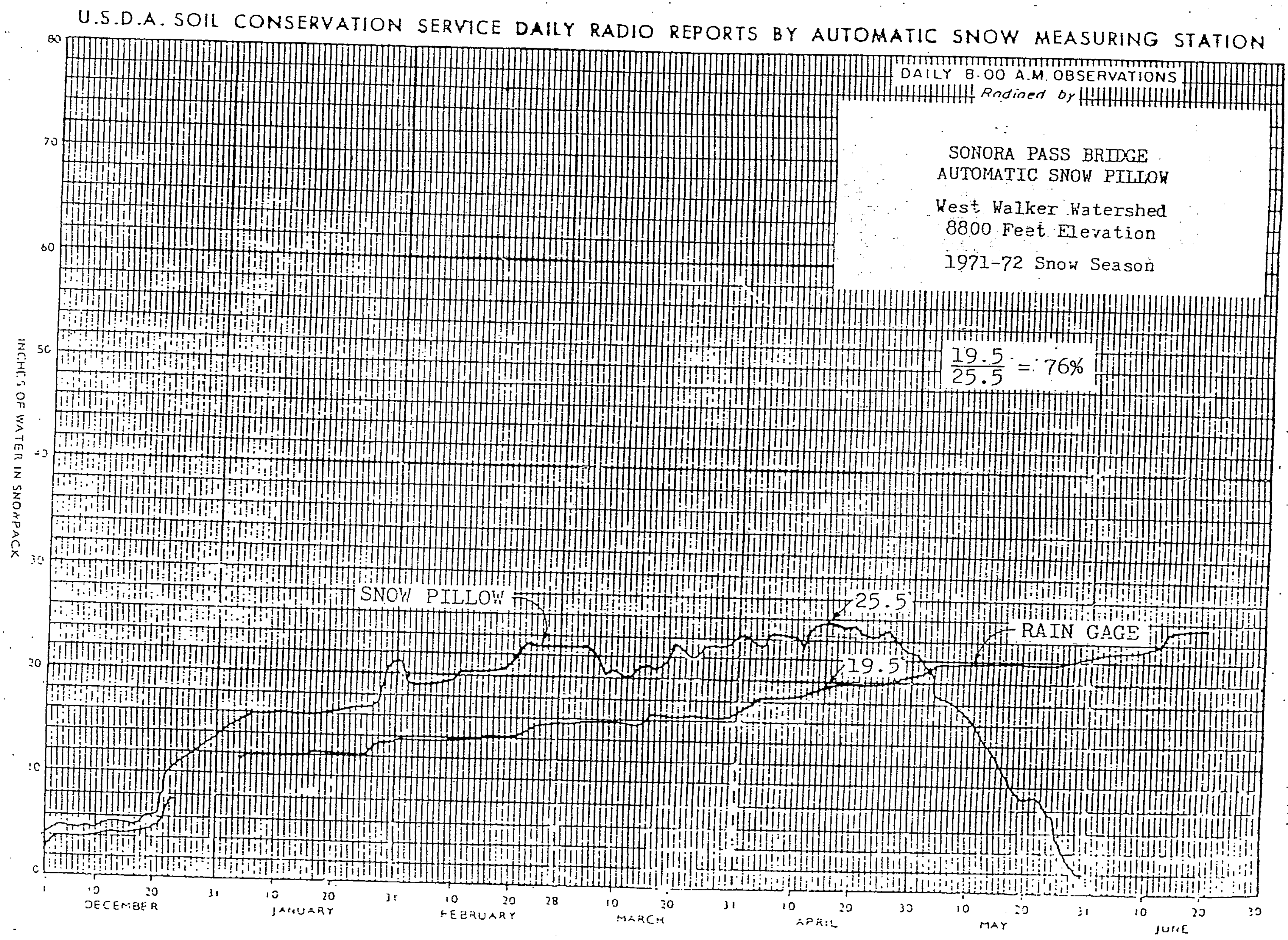


U.S.D.A. SOIL CONSERVATION SERVICE DAILY RADIO REPORTS BY AUTOMATIC SNOW MEASURING STATION

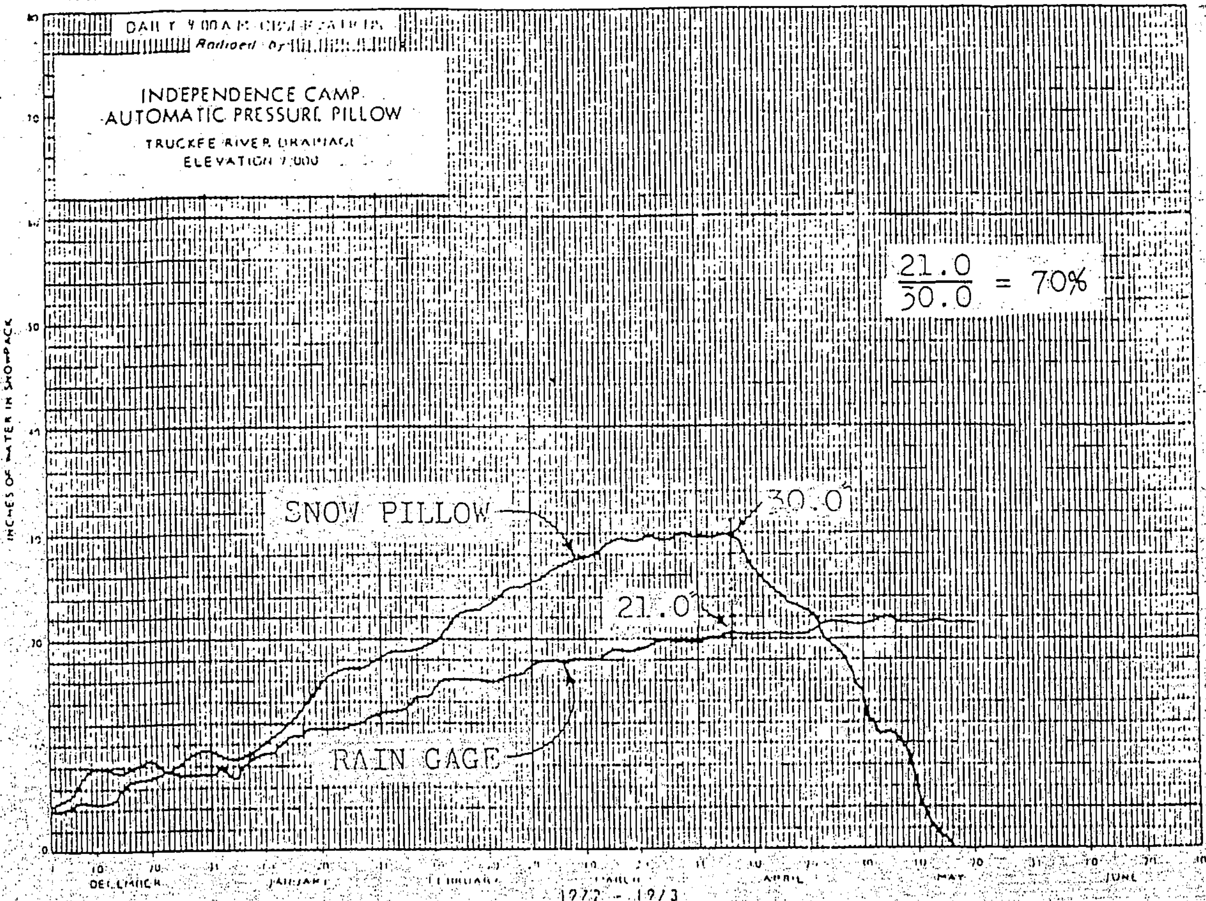


1A thru 29A

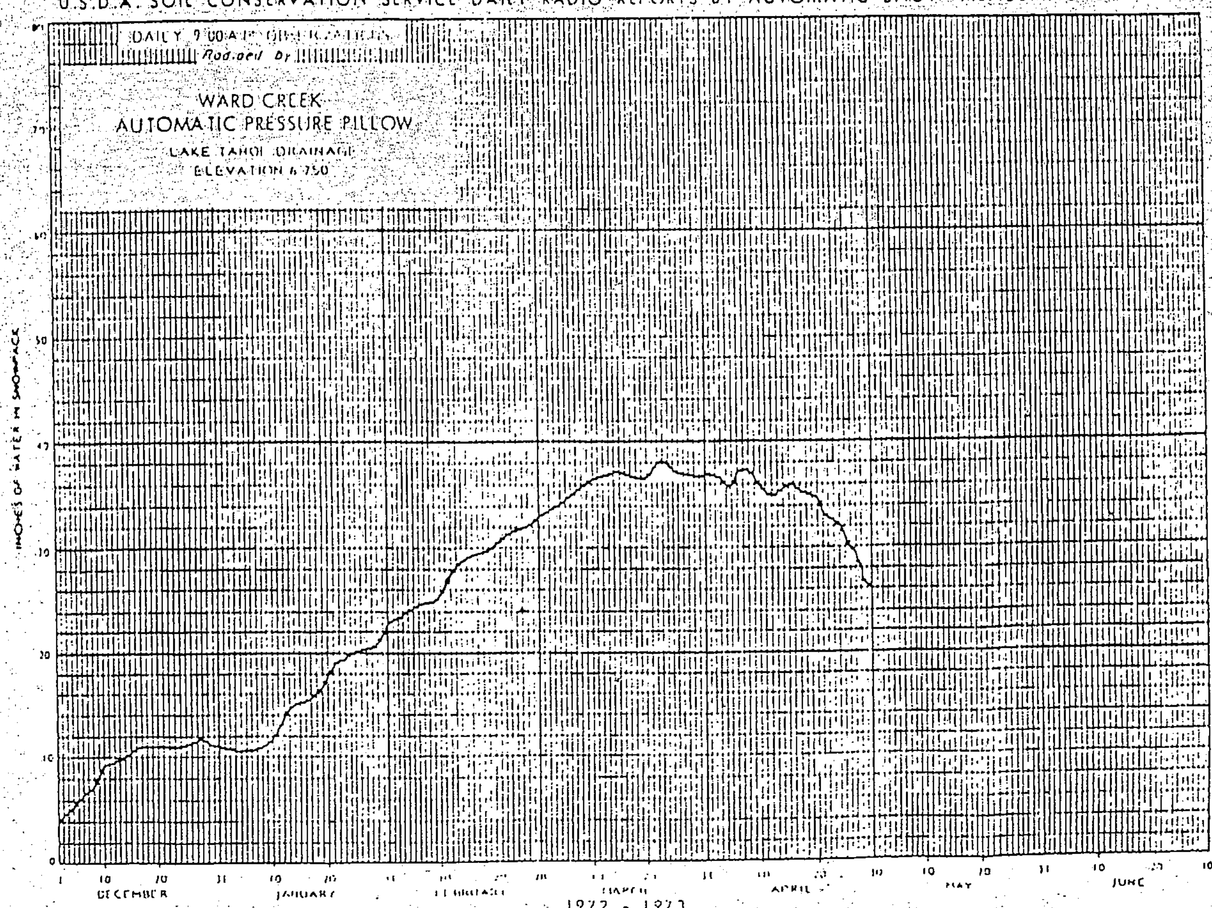
PLOT 4P


U.S.D.A. SOIL CONSERVATION SERVICE DAILY RADIO REPORTS BY AUTOMATIC SNOW MEASURING STATION
DAILY 8:00 A.M. OBSERVATIONS
Radioed by
SONORA PASS BRIDGE
AUTOMATIC SNOW PILLOW
West Walker Watershed
8800 Feet Elevation
1971-72 Snow Season
19.5 / 25.5 = 76%
SNOW PILLOW
25.5
19.5
RAIN GAGE
INCHES OF WATER IN SNOWPACK
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
PLOT 3P.
1A thru 29A

U.S.D.A. SOIL CONSERVATION SERVICE DAILY RADIO REPORTS BY AUTOMATIC SNOW MEASURING STATION

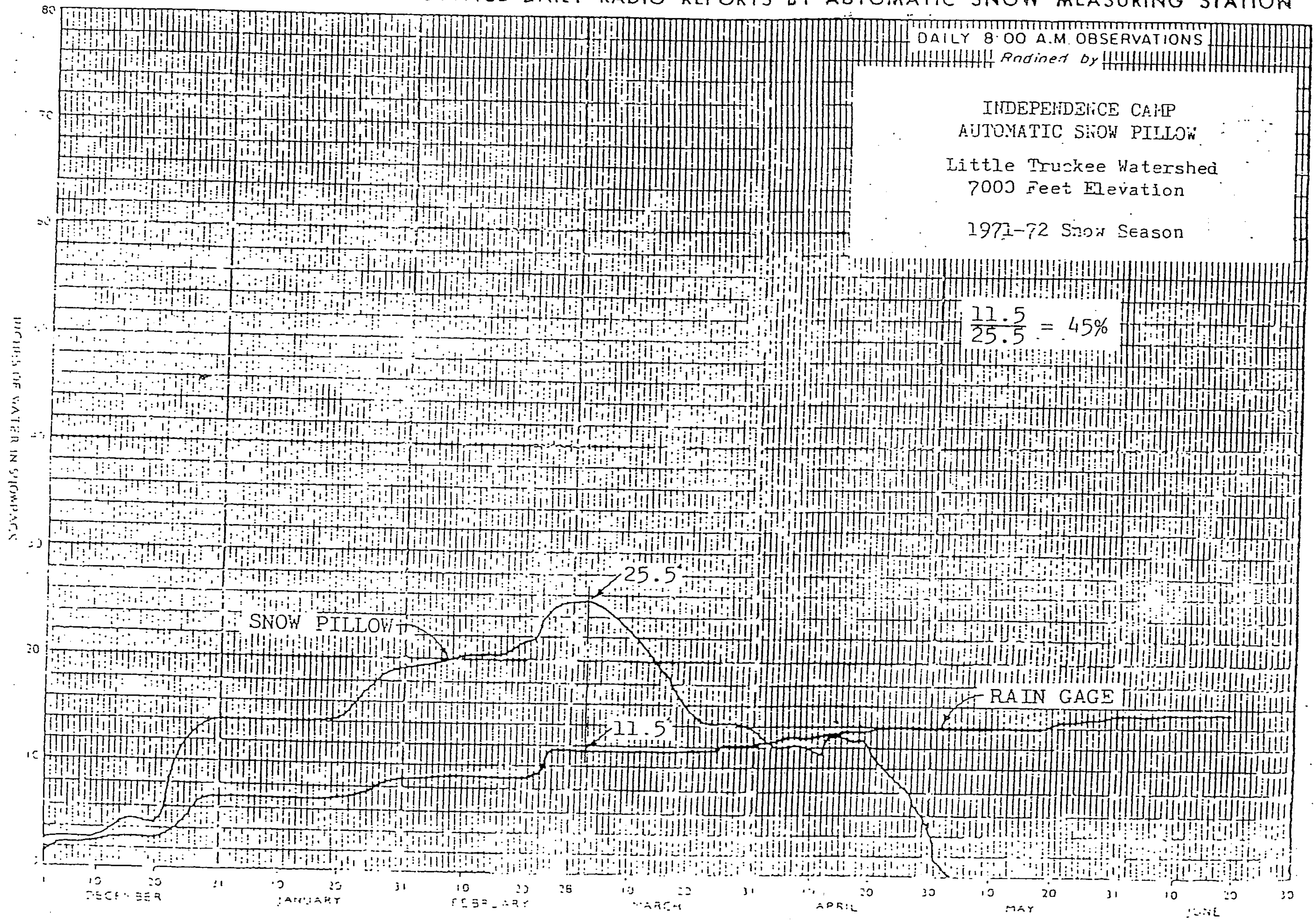


U.S.D.A. SOIL CONSERVATION SERVICE DAILY RADIO REPORTS BY AUTOMATIC SNOW MEASURING STATION



PLOT 2P

U.S.D.A. SOIL CONSERVATION SERVICE DAILY RADIO REPORTS BY AUTOMATIC SNOW MEASURING STATION



FROM CALIFORNIA COOPERATIVE SNOW SURVEYS

DONNER SUMMIT

SNOWFALL AND SNOWPACK

SINCE 1878

Year	Water Content Inches	Ratio to 1952 Value %
1880	375	119%
1890	370	117
1895	320	102
1907	308	98
1911	310	98
1938	235	75
1952	315	100%
1969	235	75

From the above information and from the accounts of the construction of the Central Pacific Railroad (in 1868-69) it is most probable that snow loads at least 20% greater than the 1952 loads have occurred since the white man's habitation of the area. 1952 is the maximum year of quantitative record in the study area.

TABLE 13T

TAHOE-TRUCKEE AIRPORT 5900 ELEV.
DERIVED MAXIMUM SNOW LOAD

PRECIPITATION

1969 Max. Precip. Possible in Snow		#/SF/" W.C.		Ratio Gage/Actual		1969/1952		Max. #/SF
17.35"	x	5.2	÷	.7	÷	.792	=	163

70% Max.--163 x .7 = 114#/SF

HAROLD KLIEFORTH OR JOHN RODA DATA

Year	Max. Snow Load From Snow Surveys #/SF		% Year Total Snow Load To Maximum for Comparable Snow Courses		
1971	59.8	÷	.423	=	141
1972	31.7	÷	.266	=	119
1973	42.1	÷	.336	=	125
				Average	128

	Max. #/SF	70% Max. #/SF
From Airport Precipitation Data	163	114
From Klieforth & Roda Data (Avg.)	128	90
From 5 Yr. Recurrence	132	92
From 10 Yr. Recurrence	160	112
From 20 Yr. Recurrence	195	137
From Snow Course Data	176	123
From North Star Data	173	121
From Average Annual Precipitation 24.29" x 5.2 x .85 x 2.11 ------	227	158

TABLE 12T

COMPARISON OF SNOW PILLOW WATER EQUIVALENT AND CUMULATIVE SUMMATION OF RAIN GAGE PRECIPITATION

Location	Elev.	Snow Year	Pillow H_2O Max. Inches	Rain Gage Sum Max. Inches	Gage/Pillow %
Sonora Pass Bridge	8800	1971-1972	25.5"	19.5"	76%
Sonora Pass	8800	1972-1973	30.5	24.5	80%
Independence Camp	7000	1971-1972	25.5	11.5	45%
Independence Camp	7000	1972-1973	30.0	21.0	70%
				Average -	67.75%
				Approx. Mean -	73%
				Say -	70%

COMPARISON OF SNOW SURVEY WATER EQUIVALENT AND CUMULATIVE SUMMATION OF RAIN GAGE PRECIPITATION TAHOE TRUCKEE AIRPORT

1972-1973
Snow Year

Date	Samples Taken By	Sum Precip. To Date Possible In Snow Pack Inches	Snow Survey Water Equiv. Inches	Gage/ Survey %
Jan. 2, 1973	Harold Klieforth D.R.I.	0	0	---
Feb. 1, 1973	"	2.69"	4.6	58%
March 1, 1973	"	3.41	7.2	47%
March 14, 1973	John Roda S.C.S.	4.34	8.1	54%
April 10, 1973	"	0	Trace	---
			Avg. =	53%

TABLE II T

STATION		DATE	MAX. W/C FOR YEAR SNOW SURVEY INCHES	SUM PRL P. POSSIBLE IN SNOW PACK MAX. INCHES	SUM PRECIP. TO DATE IN SNOW PACK INCHES	SNOW SURVEY WATER CONTENT INCHES	MAX. PRECIP. FOR THE YEAR	AVG. ANNUAL PRECIP.	AVG. PRECIP. NOV-APR
TAHOE CITY	6250	1968-69	27.9	30.2			30.75	30.90	26.29
		12/28/68			7.57	8.7			
		2/2/69			19.09	19.4			
		3/2/69			28.48	27.9			
		3/30/69			30.2	27.0			
TRUCKEE RANGER STATION	5995	1968-69	?	24.81			30.46	31.14	26.44
TAHOE-TRUCKEE AIRPORT	5900	1968-69	?	17.35			36.65	24.29	20.32
		1972-73	8.1	5.4					
		1/2/73			0	0			
		2/1/73			2.69	4.6			
		3/1/73			3.41	7.2			
		3/14/73			4.34	8.1			
		4/10/73			0	0			
BOCA		1968-69	16.6	16.22			19.25	?	?
		1/30/69			10.16	9.0			
		2/28/69			15.49	16.6			
		3/27/69			13.5	15.5			

TABLE IOT

SNOW YEARS - RATIOS TO MAXIMUMS

SNOW COURSE		MAX. #/SF	1938 LOAD #/SF	1938 % MAX.	1952 LOAD #/SF	1952 % MAX.	1969 LOAD #/SF	1969 % MAX.
Mount Rose	9000	424	251	59%	354	83%	424	*100%
Big Meadows	8800	200	190	95%	200	100%	---	---
Third Creek	8600	395	---	---	---	---	395	---
Indep. Lake	8450	410	328	80%	410	100%	353	86%
Mt. Rose Lodge	8400	258	---	---	---	---	258	---
Marlette Lake	8000	236	197	83%	188	80%	236	*100%
Granite Peak	8000	187	187	---	---	---	---	---
Webber Peak	7800	451	349	77%	451	100%	417	* 93%
Tahoe View Pt.	7700	---	---	---	---	---	223	---
Squaw #2	7500	436	---	---	---	---	436	---
Squaw #1	7500	431	---	---	---	---	---	---
Castle Creek	7400	508	---	---	508	100%	465	* 92%
Brockway Summit	7100	254	---	---	---	---	254	---
Lake Sterling	7100	570	450	79%	570	100%	437	77%
Webber Lake	7000	354	307	87%	354	100%	293	83%
Indep. Camp	7000	286	---	---	286	100%	242	85%
Donner Summit	6900	423	352	83%	423	100%	390	* 92%
Soda Springs	6750	420	325	77%	420	100%	---	---
Indep. Creek	6500	186	163	88%	186	100%	151	81%
Sage Hen Creek	6500	235	192	82%	235	100%	190	81%
Truckee #2	6400	199	199	100%	---	---	158	79%
Incline Golf urse	6350	91	---	---	---	---	91	---
ahoe City	6250	200	168	84%	200	100%	145	72%
Onion Creek	6100	346	280	81%	346	100%	283	82%
Donner Park #2	6000	179	---	---	---	---	179	---
Truckee Ranger Station	6000	177	---	---	177	---	---	---
Donner Lake	5950	288	---	---	288	---	---	---
Boca #2	5900	130	105	81%	130	100%	86	66%
Boca #1	5800	99	99	---	---	---	---	---

*Not Applicable - Not Used For Average

Sum - 792

Average = 79.2%

				Recurrence			Recurrence	
			Snow (in.)	#1	#2	Max Snow	#1	[illegible]
1	MT. ROSE	9000	425	82	—	293	15.0	23.0
2	BIG MEADOWS	8800	200	17	27	140	5.0	5.5
3	THIRD CREEK	8600	395	14	25	277	4.1	5.0
4	INDEPENDENCE LAKE	8450	411	25	45	288	5.6	6.0
5	MT. ROSE LODGE	8400	258	7	16	181	2.2	2.0
6	MARLETTE LAKE	8000	237	32	84	166	5.0	5.8
7	[illegible] PEAK	8000	183	13	—	132	5.0	—
8	WEBBER PEAK	7800	451	27	45	316	6.4	7.0
9	TAHOE MEADOWS	7700	[illegible]	10	19	156	3.8	4.3
10	SQUAW VALLEY #2	7500	437	14	26	306	3.5	3.5
11	SQUAW [illegible]	7500	432	11	30	302	3.5	5.0
12	CASTLE CREEK	7400	508	22	31	356	4.5	5.2
13	[illegible]	7100	252	17	34	[illegible]	[illegible]	[illegible]
14	[illegible]	7100	[illegible]	23	—	[illegible]	[illegible]	—
15	[illegible]	7000	[illegible]	23	—	[illegible]	[illegible]	[illegible]
16	[illegible]	7000	[illegible]	[illegible]	59	[illegible]	[illegible]	[illegible]
17	DONNER [illegible]	6900	420	33	55	[illegible]	[illegible]	[illegible]
18	[illegible]	6700	[illegible]	[illegible]	63	[illegible]	[illegible]	9.8
19	[illegible]	6500	[illegible]	[illegible]	50	[illegible]	8.0	8.0
20	[illegible]	6500	[illegible]	[illegible]	58	[illegible]	[illegible]	8.0
21	[illegible]	6400	[illegible]	4	—	[illegible]	9.8	[illegible]
22	INCLINE GOLF LODGE	6350	91	9	18	63	3.6	4.0
23	TAHOE CITY	6250	201	41	—	[illegible]	[illegible]	—
24	OPHIR CREEK	6100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	DONNER [illegible]	6000	180	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	TRUCKEE [illegible]	6000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.0
27	DONNER LAKE	5950	233	[illegible]	[illegible]	[illegible]	7.3	11.0
28	BOCA #2	5900	130	[illegible]	—	[illegible]	15.0	—
29	BOCA #1	5300	99	12	—	70	[illegible]	—
	— INDICATES LOG-PEARSON DOES NOT FIT DATA.	TOTAL	Σ	739	908		[illegible]	191.8
		AVERAGE	Σ/n	27.2	43.2		6.9	8.0

TABLE 8T

SHEET NO. ____ OF ____
JOB NO. ____
SUBJECT ____
DATE ____
CHKD. BY ____ DATE ____

SNOW LOADS

Snow Course	Elev.	Max. #/SF	70% Max. #/SF	15 Yr. Avg. #/SF	Recurrence Interval Yrs. Top #1-Bott #2: 5	10	20	50	100
Mt. Rose	9000	425	298	187.8	220	270	321	388	438
					228	264	293	327	349
Big Meadows	8800	200	140	120.4	147	177	208	249	280
					144	167	191	222	247
Third Creek	8600	395	277	220.5	296	370	444	542	616
					274	326	380	454	576
Independence Lake	8450	411	288	225.2	282	336	390	462	516
					279	321	362	415	46[illegible]
Mount Rose Lodge	8400	258	181	189.4	238	282	327	386	431
					228	248	266	286	299
Marlette Lake	8000	237	166	108.2	148	180	212	254	286
					155	178	199	223	240
Granite Peak	8000	188	132	104.9	133	163	193	233	263
					139	153	162	170	174
Webber Peak	7800	451	316	233	289	354	418	503	568
					291	341	390	454	502
Tahoe View Point	7700	223	156	122.7	174	222	271	336	385
					160	194	229	278	316
Squaw Valley #2	7500	437	306	257.9	335	408	481	577	651
					335	381	422	468	500
Squaw Valley #1	7500	432	302	134.7	337	417	496	601	681
					299	357	422	521	607
Castle Creek	7400	508	356	274.9	357	431	506	604	678
					346	405	466	552	622
Brockway Summit	7100	254	178	84.6	161	215	269	340	394
					148	187	224	273	311
Lake Sterling	7100	570	399	272	340	411	480	573	643
					350	392	427	465	490
Webber Lake	7000	354	248	162	208	257	307	372	422
					213	247	276	310	332
Independence Camp	7000	286	200	119.7	168	212	256	314	358
					166	199	233	276	312
Donner Summit	6900	423	296	210.5	268	325	381	456	513
					273	318	361	416	461
Soda Springs	6750	421	295	207.0	256	316	376	455	515
					253	299	344	404	450
Independence Creek	6500	186	130	73.5	108	138	169	209	240
					110	133	153	176	192
Sage Hen Creek	6500	236	165	99.5	139	174	208	254	289
					139	165	191	224	250
Truckee #2	6400	199	139	82.4	116	143	171	207	236
					120	140	158	179	194
Incline Golf Course	6350	91	63	52.6	68	92	115	146	170
					100	138	164	185	194
Tahoe City	6250	201	141	63.9	104	136	167	209	240
					101	103	103	103	103
Onion Creek	6100	346	242	128.1	186	241	296	370	425
					183	255	264	314	351
Donner Park #2	6000	180	126	96.3	132	168	205	252	288
					131	155	177	204	222
Truckee Ranger Station	6000	177	124	59.1	103	137	170	215	249
					90	116	146	192	232
Donner Lake	5950	288	202	114.1	169	222	274	344	397
					157	199	242	304	354
Boca #2	5900	130	91	34.8	61	82	103	130	151
					72	78	81	82	82
Boca #1	5800	99	70	45.2	69	93	116	147	171

PERCENT MAX. WATER EQUIVALENT IS TO NORMAL WATER EQUIVALENT (S)
(MAX/S)

NO.	NAME	ELEV. IN FT.	NORMAL WATER EQUIV. (S) INCHES	MAX. WATER CONTENT INCHES USUALLY 1952	% MAX/S
OK14	BOCA #2	5900		25.1	
)K11	DONNER LAKE #1	5950	(25.6)	55.4	216
---	TRUCKEE RANGER STATION	6000		34.1	
)K16	TAHOE CITY	6250	17.0	38.8	228
)K13	TRUCKEE #2	6400	18	38.3	213
)K6	SAGE HEN CREEK	6500	(20.8)	45.3	218
'K	INDEPENDENCE CREEK	6500	(15.4)	35.8	233
--	SODA SPRINGS	6750	41.1	80.9	197
K10	DONNER SUMMIT	6900	45.2	82.0	181
K2	WEBBER LAKE	7000	39.9	68.1	171
K4	INDEPENDENCE CAMP	7000	(23.0)	55.0	239
K19	SQUAW VALLEY #2	7500		76.8	
K1	WEBBER PEAK	7800	47.8	86.8	182
K4	MARLETTE LAKE	8000	26.3	45.5	173
K5	INDEPENDENCE LAKE	8450	49.3	79.0	160
--	BIG MEADOWS	8800	31.8	38.5	121
K2	MOUNT ROSE	9000	41.0	81.7	199

6000' - 7000' Avg. = 211 % of S

7000' - 8000' Avg. = 191 % of S

8000' - 9000' Avg. = 167 % of S

All Stations Avg. = 195 % of S

AVERAGE ANNUAL PRECIPITATION [1]

vs.

NOVEMBER 1 THRU APRIL 30 PRECIPITATION

	Elev.	Precip. Inches Annual Avg.	Precip. Inches Nov.-April	Avg. Nov.-April/Avg.
Tahoe City	6250	30.90"	26.29"	85.1%
Truckee Ranger Station	6000	31.14	26.44	84.9%
Tahoe-Truckee Airport	5900	24.29	20.32	83.7%
			Avg.	84.6%
			Say	85%

Tahoe-Truckee Airport [2]

Year	Precip. Nov. 1 Thru April 30	Precip. Total Annual	Nov. 1-April 30 Annual %
1965-66	9.72"	11.43"	85.0%
1966-67	30.35	35.11	86.4
1967-68	17.71	21.11	83.9
1968-69	31.25	36.65	85.3
1969-70	24.74	26.69	92.7
1970-71	17.93	23.62	75.9
1971-72	10.51	15.27	68.8
1972-73	19.33	—	—
Sum	142.21"	169.88"	83.7%
Average	20.32"	24.29"	

1. From map of Annual Average Precipitation by U.S. Army Corp. of Engineers for Washoe Project Studies.

2. From Climatological Observations, U.S. Weather Bureau, for Tahoe-Truckee Airport.

SNOW LOADS

DERIVED FROM

ANNUAL AVERAGE PRECIPITATION

	GENERAL ELEV.	MAX. SNOW OF RECORD #/SF	ANNUAL[2] PRECIP. INCHES	RATIO[3] MAX/AVG	SNOW SEASON ANNUAL %	MAX. SNOW #/SF	70% MAX.
	6000'		25" $\pm$	2.11	85%	233	163
	7000'		30" $\pm$	2.01	85%	267	187
	8000'		40" $\pm$	1.79	85%	316	222
QUAW VALLEY	7500'	437[1]	57.07	1.91	85%	482	337
OD' SPRINGS	6750'	421	57.31	2.11	85%	534	374
AHOE CITY	6250'	201	30.9	2.11	85%	288	202
ONNER PARK	6000'	180[1]	39.93	2.11	85%	372	261
RUCKEE RANGER STATION	6000'	177	31.14	2.11	85%	290	203
OCA	5800'	130	19.25	2.11	85%	179	126
AHOE-TRUCKEE AIRPORT	5900'	---	24.29	2.11	85%	227	159

OTE: 1" H_2O Equiv. = 5.2 #/SF

1. No Record for Big Year 1952
2. U.S. Army Corp. of Engineers - Washoe Project Studies
3. Interpolated Value for Elevations

TABLE 4T

SNOW SURVEY COURSE DATA

SNOW COURSE	ELEV.	APR. 1969 DATE	SNOW DEPTH (in.)	WATER CONTENT (in.)	DENSITY (%)	MAX. W/C	W/C % OF MAX.
. ROSE	9000	3/24	177.0	81.7	46.2%	81.7	100.0
INDEPENDENCE LAKE	8450	3/28	152.0	66.5	43.8%	79.0	84.2
MARLETTE LAKE	8000	3/26	108.0	45.4	42.0%	45.4	100.0
GRANITE PEAK	8000		N.R.	N.R.	N.R.	36.1	---
WEBBER PEAK	7800	3/27	175.7	80.3	45.7%	86.8	92.5
SQUAW VALLEY #2	7500	3/30	184.0	84.0	45.7%	84.0	100.0
SQUAW VALLEY #1	7500		N.R.	N.R.	N.R.	83.0	N.R.
CASTLE CREEK	7400	3/28	181.7	89.5	49.3%	97.7	91.6
BROCKWAY SUMMIT	7100	3/24	104.0	48.9	47.0%	48.9	100.0
LAKE STERLING	7100	3/25	188.0	84.2	44.8%	---	---
WEBBER LAKE	7000	3/27	129.9	56.5	43.5%	68.1	83.0
INDEPENDENCE CAMP	7000	3/28	101.0	46.7	46.2%	55.0	84.9
DONNER SUMMIT	6900	3/26	153.3	71.9	46.9%	81.4	88.3
SODA SPRINGS	6750		N.R.	N.R.	N.R.	80.9	N.R.
INDEPENDENCE CREEK	6500	3/28	68.0	29.1	42.8%	35.8	81.3
SAGE HEN CREEK	6500	3/28	84.0	36.6	43.6%	45.3	80.8
TRUCKEE #2	6400	3/30	71.0	30.4	42.8%	38.3	79.4
TAHOE CITY	6250	3/30	55.0	27.0	49.1%	38.6	69.9
ONION CREEK	6100	3/26	109.1	54.6	50.0%	66.6	82.0
DONNER PARK #2	6000	3/26	86.0	34.6	40.2%	34.6	100.0
TRUCKEE RANGER STA.	6000		N.R.	N.R.	N.R.	34.1	N.R.
DONNER LAKE	5950		N.R.	N.R.	N.R.	55.4	N.R.
BOCA #2	5900	3/27	38.0	15.5	40.8%	25.0	62.0

APRIL 1, 1969 NORTHSTAR DATA

STATION	ELEV.	SNOW DEPTH 4/1/73	ASSUMED DENSITY (ABOVE)	WATER CONTENT (CALC.)	W/C-% OF MAX.	MAX. W/C	MAX. SNOW LOAD	70% MAX.
7	8617	167.	.46	76.82	100.0	76.82	399.5	279.6
7A	8320	115.	.46	52.9	100.0	52.9	275.08	192.6
6	7880	133.	.458	60.9	98.0	62.2	323.2	226.3
5A	7820	87.5	.458	40.1	97.5	41.1	213.7	149.6
5	7800	121.	.458	55.4	97.5	56.8	295.6	206.9
8	7640	118.	.458	54.0	96.5	56.0	291.2	203.9
8A	7600	152.	.458	69.6	96.5	72.1	375.1	262.6
8B	7440	110.	.457	50.27	95.5	52.6	273.7	191.6
9A	7200	107.	.456	48.8	93.0	52.5	272.8	191.0
9B	7180	113.	.456	51.5	93.0	55.4	288.1	201.7
18	7000	88.	.456	40.1	91.0	44.9	229.3	160.5
9	6880	84.	.453	38.0	89.5	42.5	221.1	154.8
4	6460	53.	.435	23.1	80.5	28.6	148.9	104.2
10A	6420	79.	.435	34.4	79.0	43.5	226.2	158.3
3	6400	59.	.432	25.5	78.5	32.5	168.8	118.2
2	6340	33.5	.428	14.3	77.0	18.6	96.8	67.8
10	6320	72.	.427	30.7	76.5	40.2	201.0	146.3
11	6240	58.	.424	24.6	74.0	33.2	172.8	120.9
1	6240	32.	.424	13.6	74.0	18.3	95.3	66.7
12A	6220	62.	.424	26.3	73.0	36.0	187.3	131.1
12	6200	47.5	.422	20.0	72.5	27.6	143.8	100.6
13	6190	44.	.422	18.6	72.5	25.6	133.2	93.2
14	6090	49.	.417	20.4	69.5	29.4	152.9	107.0
15	6060	34.	.415	14.1	68.5	20.6	107.1	75.0
16	6020	7.	.414	2.9	67.0	4.3	22.5	15.7
17	5880	5.	.408	2.0	63.0	3.2	16.8	11.8

TABLE 3T

KLIEFORTH'S DATA (DRI)

TAHOE TRUCKEE AIRPORT (4TA) 5900 ELEV.

Jan.1	Depth	W.C.	Density	Feb.1				Mar.1				Apr.1			
				2/1	1.0	--	--	3/3	7.0	1.0	.14				
12/26	28.5	8.5	.30	1/31	29.0	10.8	.37	2/26	25.0	9.4	.38	3/31	15.	7.7	.51
1/22	32.0	11.5	.36												
1/1	22.0	5.4	.25	2/1	18.5	6.1	.33	3/1	12.0	5.8	.48				
1/2	0	0	--	2/1	14.5	4.6	.32	3/1	23.0	7.2	.31				
								3/14	23.0	8.1*					

*John Roda SCS

Max Values
ioe Truckee Airport

	W/C	DATE
1970	1.0	(3/3)
1971	11.5	(1/22)
1972	6.1	(2/1)
1973	8.1	(3/14)

% W.C. on Date to Max. of Record

	Truckee #2 % Max. 20K13	Brockway % Max. 20K22	Boca % Max. 20K14	Sage Hen % Max. 20K6
11.5"x5.2 = 59.8#/SF	41.5%	42.3%	44.4%	58.7%
6.1 x5.2 = 31.7#/SF	27.2%	26.6%	27.2%	41.5%
8.1 x5.2 = 42.1#/SF	38.5%	46.6%	33.6%	49.4%

1971 MAX. = 59.8/.423 = 141.4#/SF x .7 = 99.0#/SF

1972 MAX. = 31.7/.266 = 119.2#/SF x .7 = 83.4#/SF

1973 MAX. = 42.1/.336 = 125.4#/SF x .7 = 87.8#/SF

Avg. = 128.7 90.1 = Avg.

TABLE 2T

NAME	CAL. #	SCC	SEC	T	R	ELEV.	DTD	WC	%	DTD	WC	%	DTD	WC	%
TRUCKEE RIVER															
MOUNT ROSE	334	19K3	7	17N	19E	9000									
INDEPENDENCE LAKE	86	20K5	9	18N	15E	8450									
WEBBER PEAK	64	20K11	30	19N	14E	7800									
SQUAW VALLEY #1	* 317	ABAN	6	15N	16E	7500									
SQUAW VALLEY #2	318	20K19	6	15N	16E	7500									
INDEPENDENCE CAMP	88	20K4M	34	17N	15E	7000									
WEBBER LAKE	89	20K2	29	19N	14E	7000									
INDEPENDENCE CREEK	91	20K3	14	18N	15E	6500									
SAGE HEN CREEK	90	20K6	7	18N	16E	6500									
TRUCKEE RANGER STA.	* 93	ABAN	10	17N	16E	6000									
DONNER LAKE	* 94	ABAN	14	17N	15E	5950									
BOCA #2	95	20K14	23	18N	17E	5900									
GRANITE PEAK	* —	ABAN	24	19N	17E	8000									
TRUCKEE #2	92	20K12M	2	[illegible]	[illegible]	[illegible]400									
DONNER PARK #2	242	20K[illegible]	13	17N	15E	6000									
LAKE TAHOE BASIN															
MARLETTE LAKE	332	19K4	18	15N	[illegible]	8000									
BROCKWAY SUMMIT	285	20K22	3	16N	17E	7100									
TAHOE CITY	105		6	15N	17E	6200									
YUBA RIVER BASIN															
CASTLE CREEK	65	—	14	17N	14E	7400									
LAKE STERLING	70	—	1	17N	13E	7100									
DONNER SUMMIT	69	20K10	25	17N	14E	6900									
SODA SPRINGS	* 73	ABAN	22	17N	14E	6750									
AMERICAN RIVER BASIN															
ONION CREEK	120	—	1	16N	14E	6100									
DISCONTINUED STATIONS															
BOCA #1	* —	ABAN	23	18N	17E	5600									
BIG MEADOWS	* —	ABAN	15	15N	18E	8800									
INCLINE GOLF COURSE	—	—	15	16N	18E	6350									
MOUNT ROSE LODGE	—	—	7	17N	19E	8400									
THIRD CREEK	—	—	35	17N	19E	8600									
TAHOE VIEW POINT			11	15N	15E	7700									

SNOW COURSE LOCATIONS

TABLE 1T

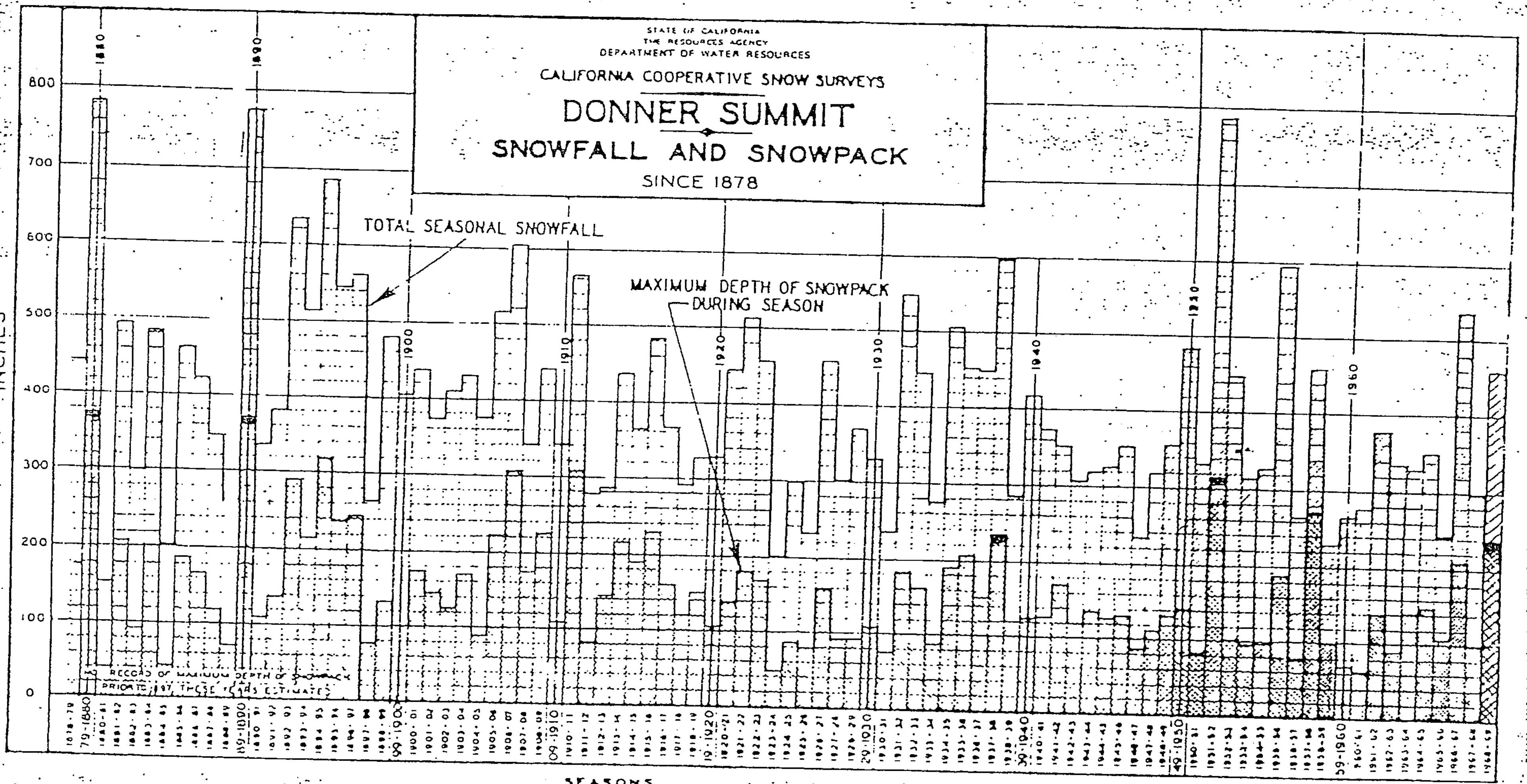
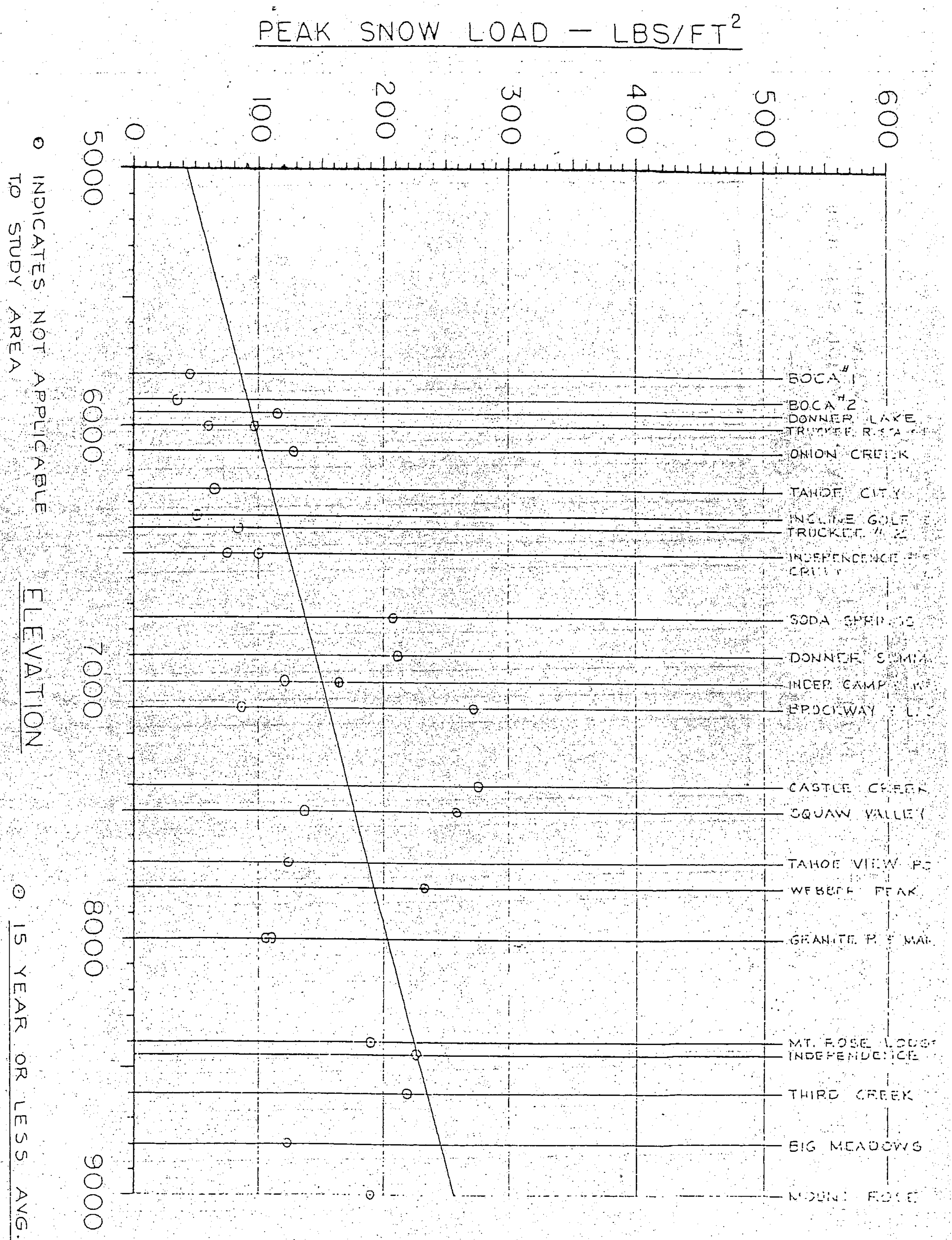
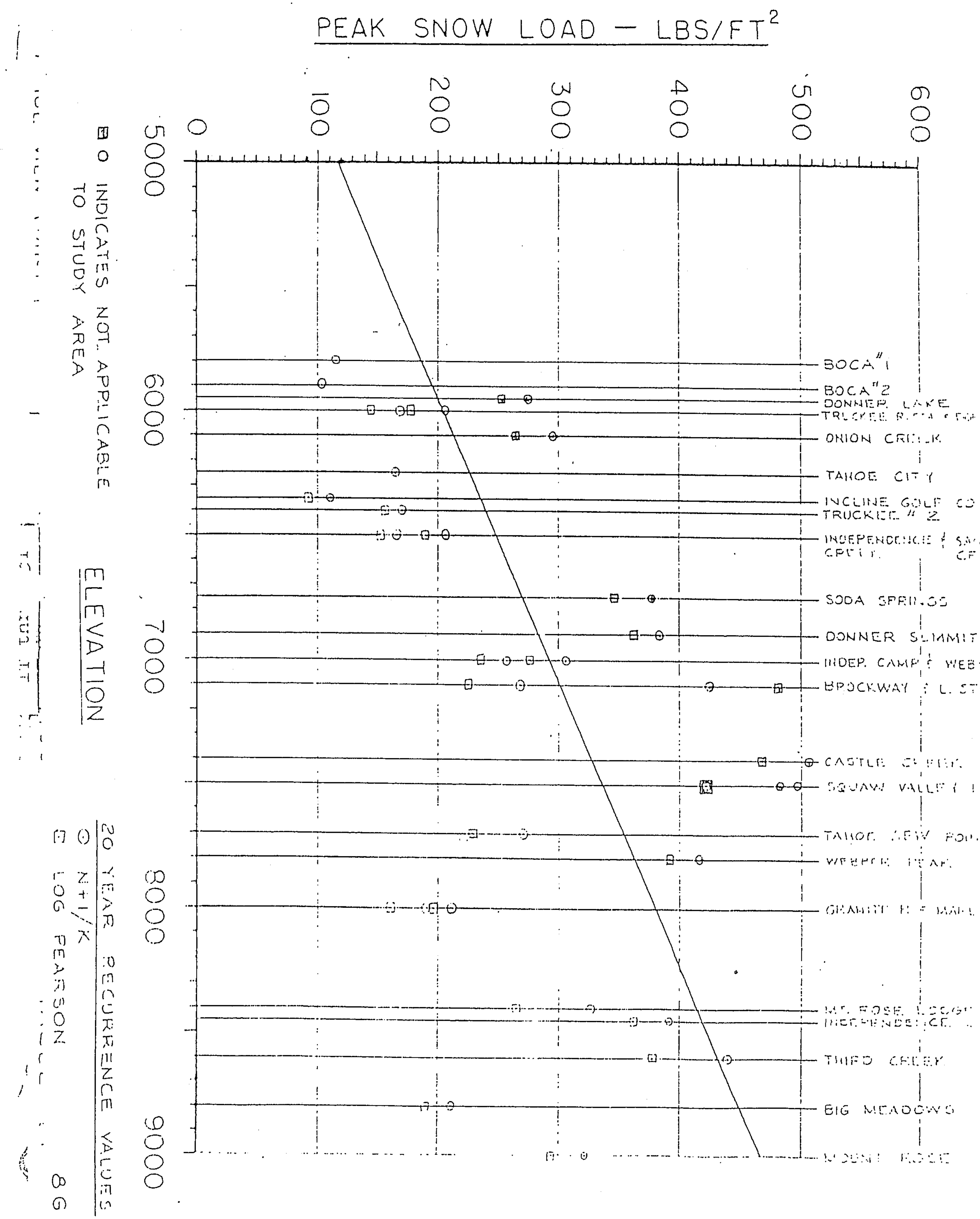
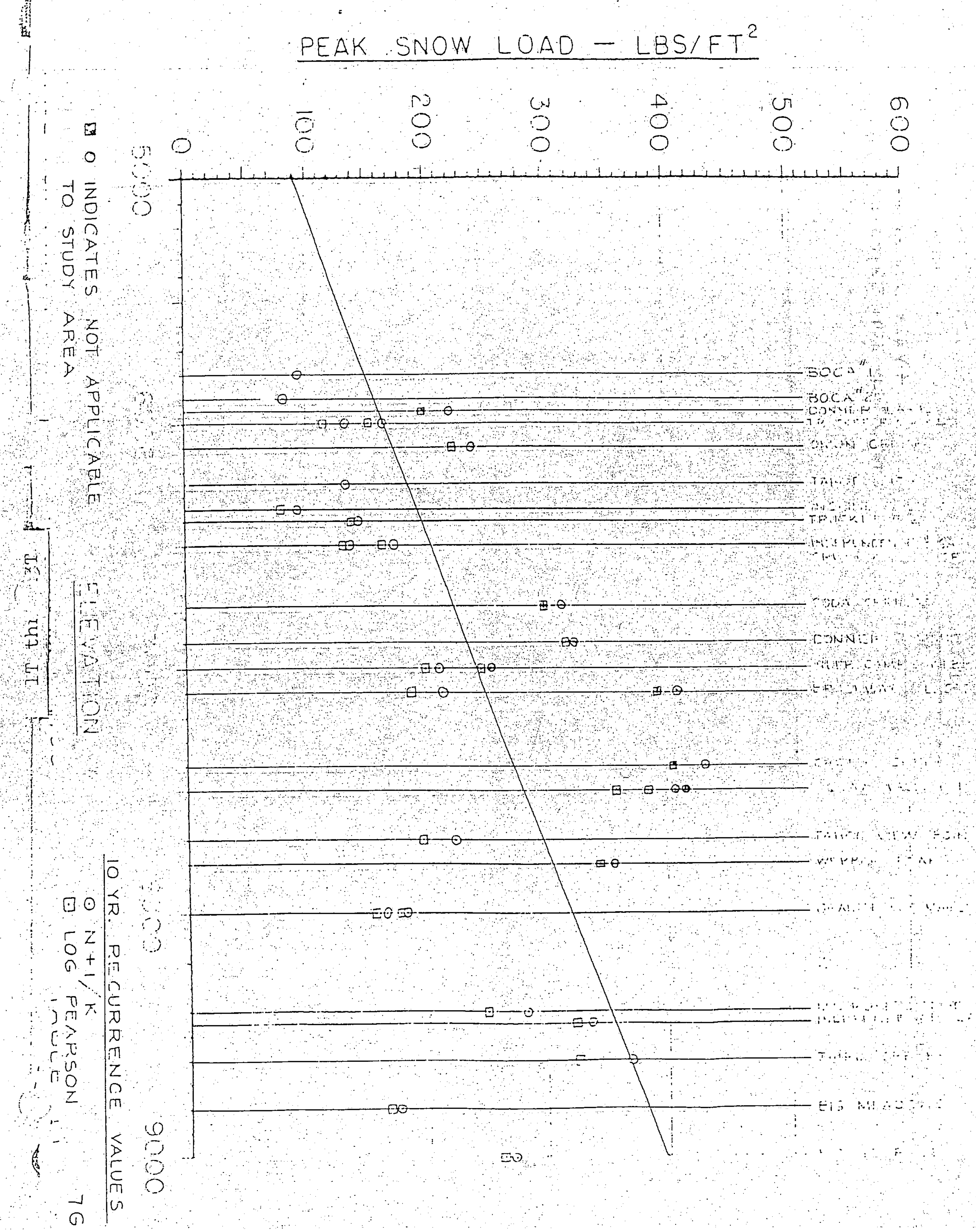


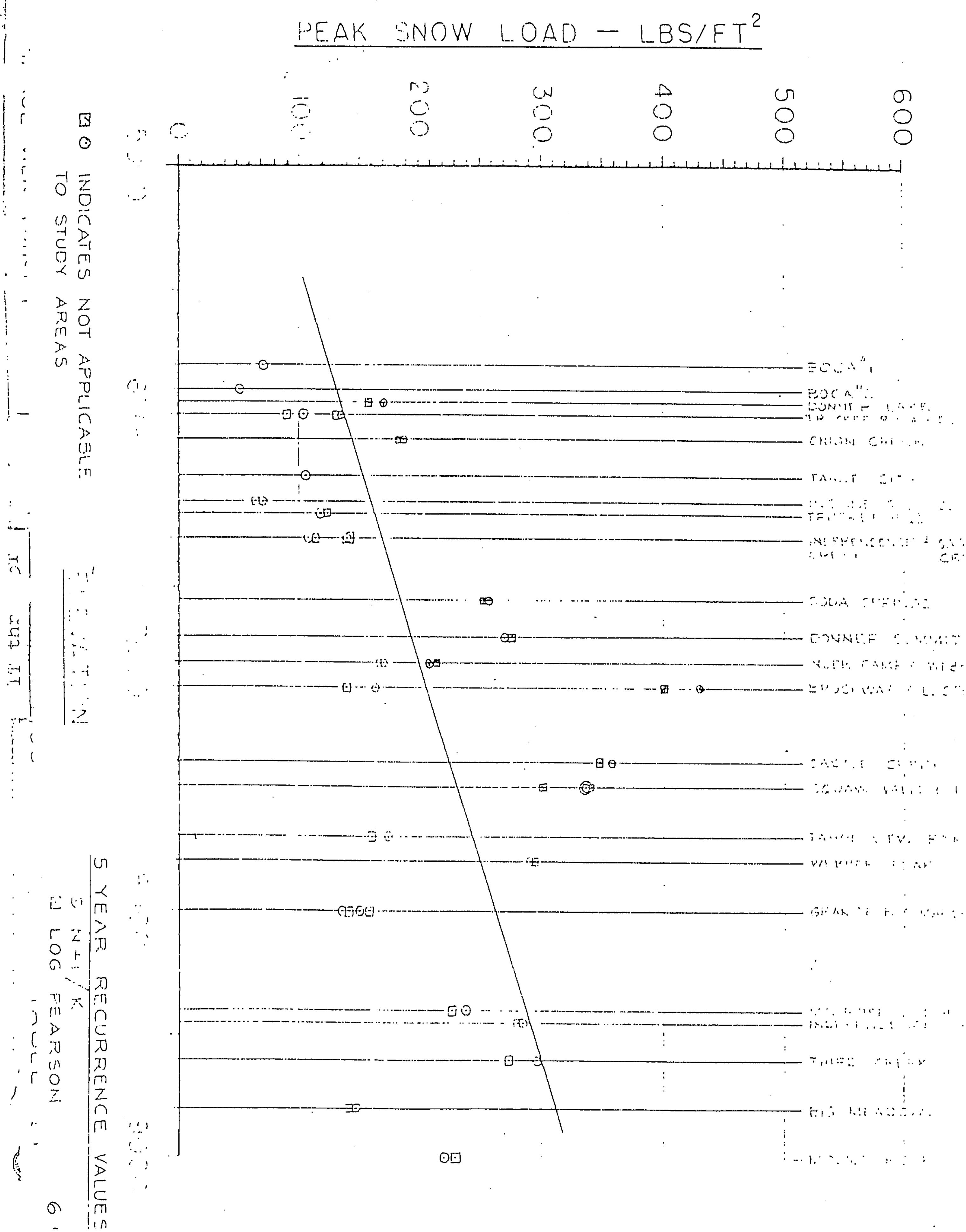
Fig. 9 — Snowfall and Snowpack at Donner Summit



TAHOE VIEW POINT I

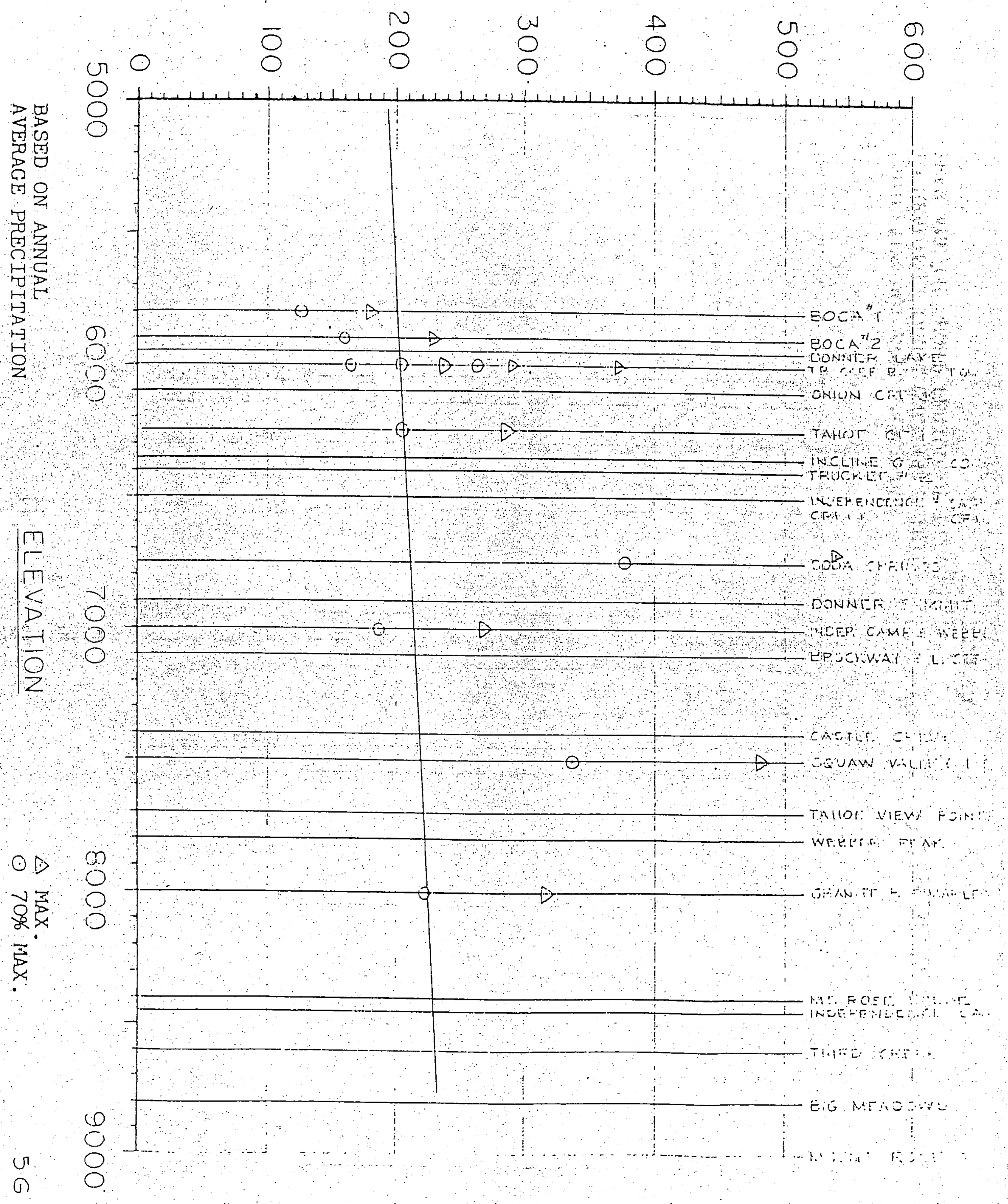

PEAK SNOW LOAD — LBS/FT2
0
100
200
300
400
500
600
ELEVATION
5000
6000
7000
8000
9000
O INDICATES NOT APPLICABLE TO STUDY AREA
20 YEAR RECURRENCE VALUES
N+1/K
LOG PEARSON
BOCA #1
BOCA #2
DONNER LAKE
ONION CREEK
TAHOE CITY
INCLINE GOLF CO
TRUCKEE # 2
SODA SPRINGS
DONNER SUMMIT
INDEP. CAMP
BROCKWAY
CASTLE
SQUAW VALLEY
TAHOE
WEBBER PEAK
MT. ROSE
INDEPENDENCE
THIRD CREEK
BIG MEADOWS
86


PEAK SNOW LOAD — LBS/FT²
0
100
200
300
400
500
600
5000
9000
ELEVATION
■ o INDICATES NOT APPLICABLE TO STUDY AREA
10 YR. RECURRENCE VALUES
⊙ N+1/K
⊡ LOG PEARSON
BOCA #1
BOCA #2
BIG MEADOWS
7G

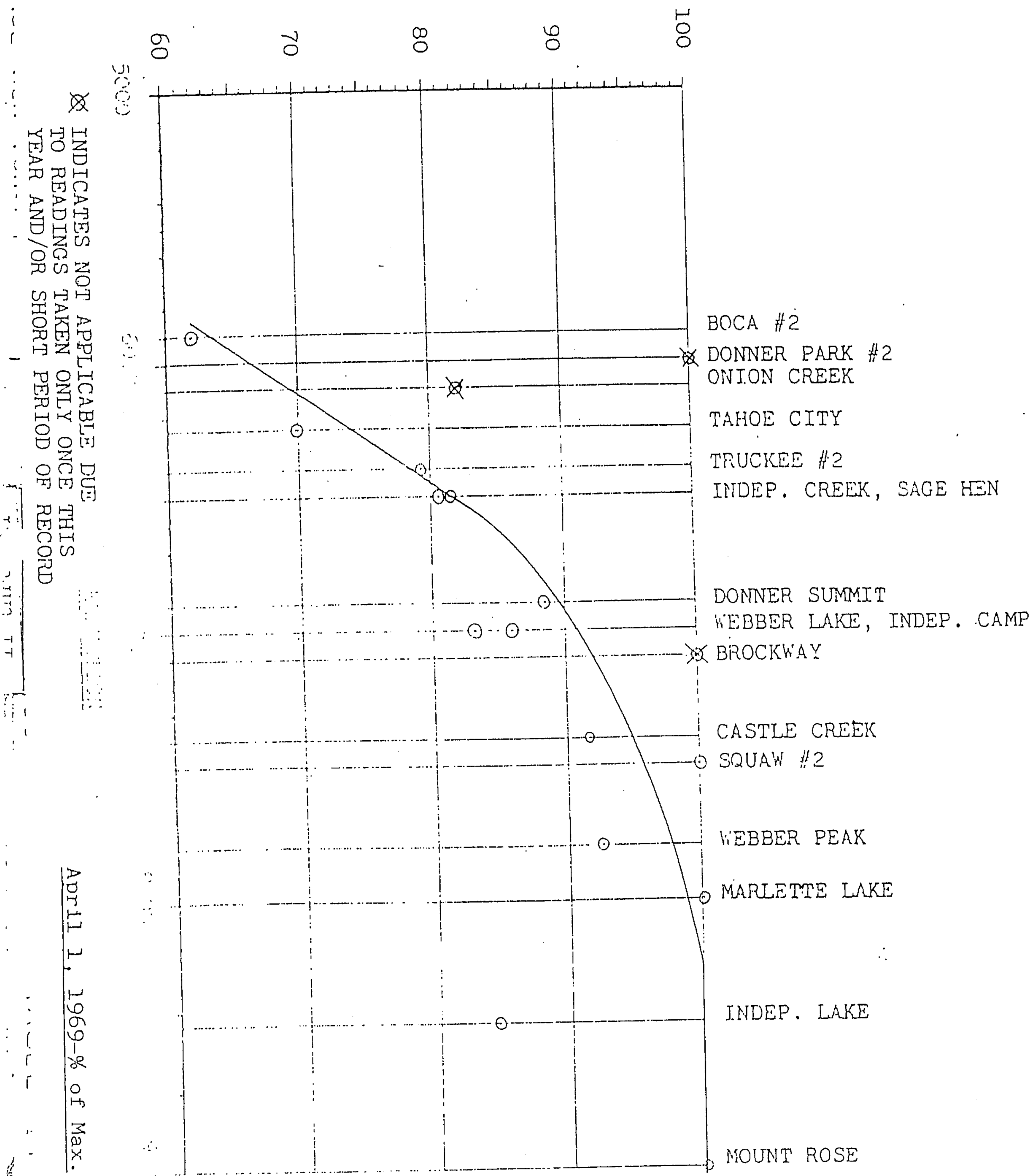


PEAK SNOW LOAD — LBS/FT²
0
100
200
300
400
500
600
INDICATES NOT APPLICABLE TO STUDY AREAS
SODA SPRINGS
DONNER SUMMIT
5 YEAR RECURRENCE VALUES
LOG PEARSON

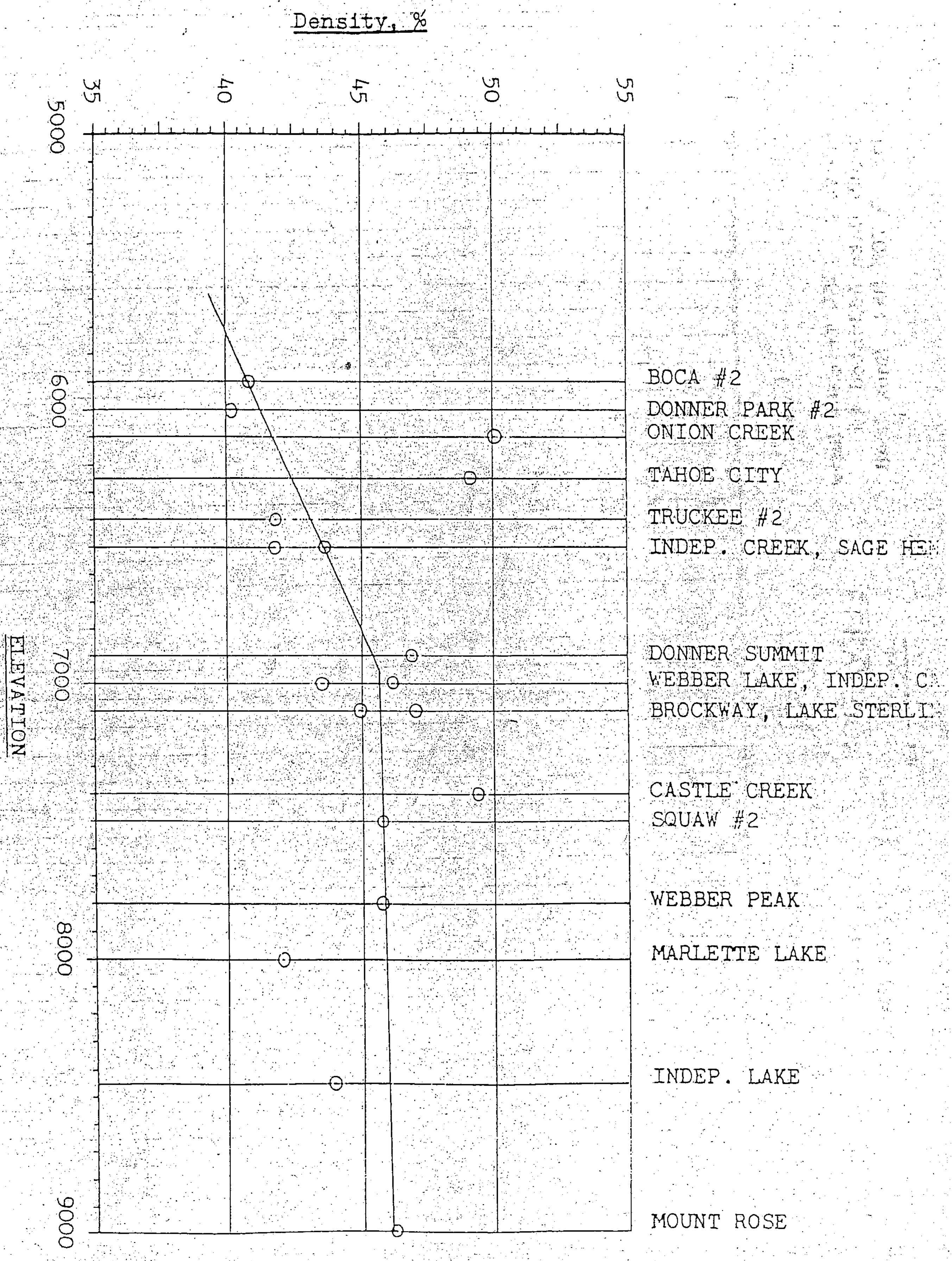
PEAK SNOW LOAD — LBS/FT²



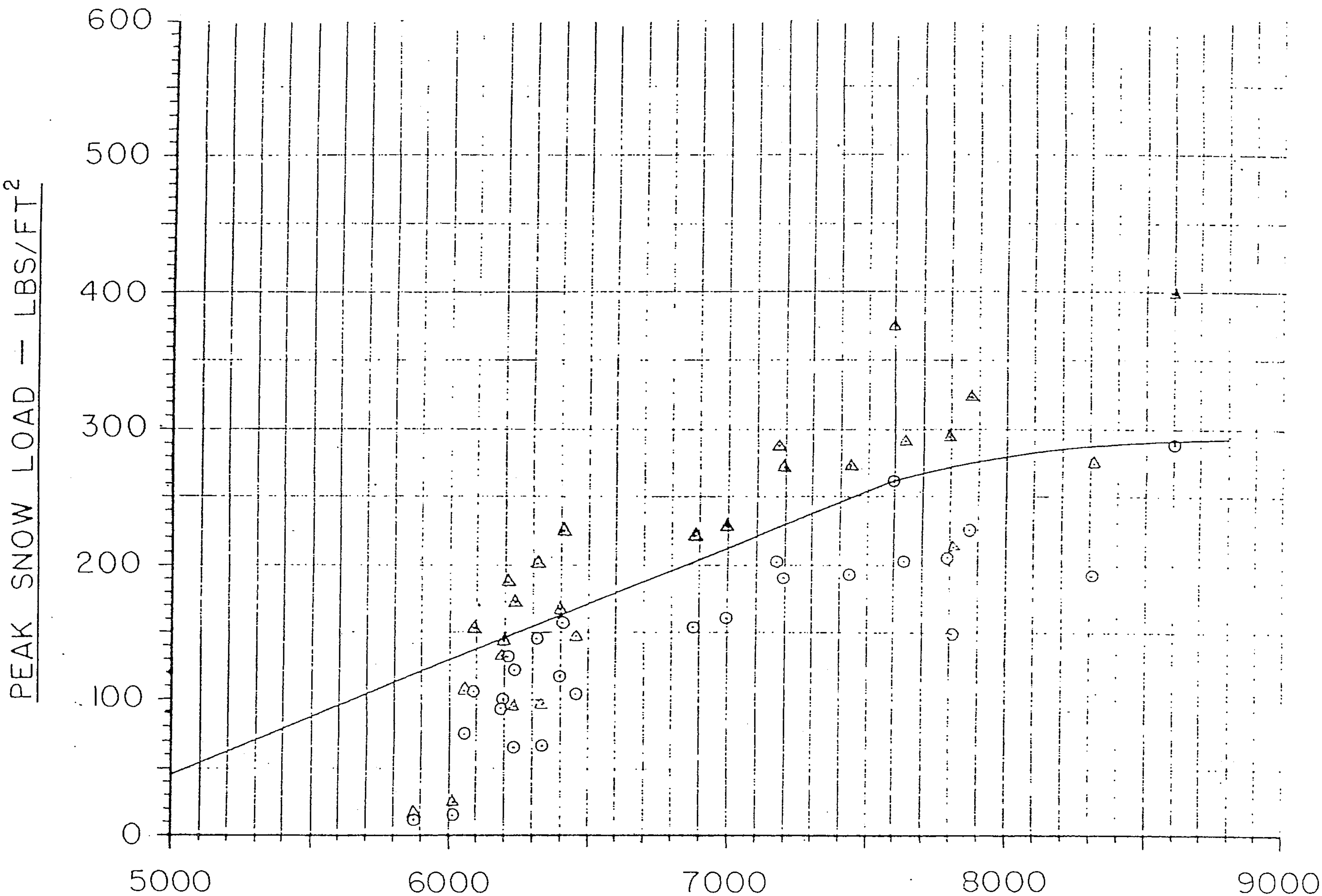
% of Max Snow Load (April 1, 1969)



April 1, 1969-% of Max.

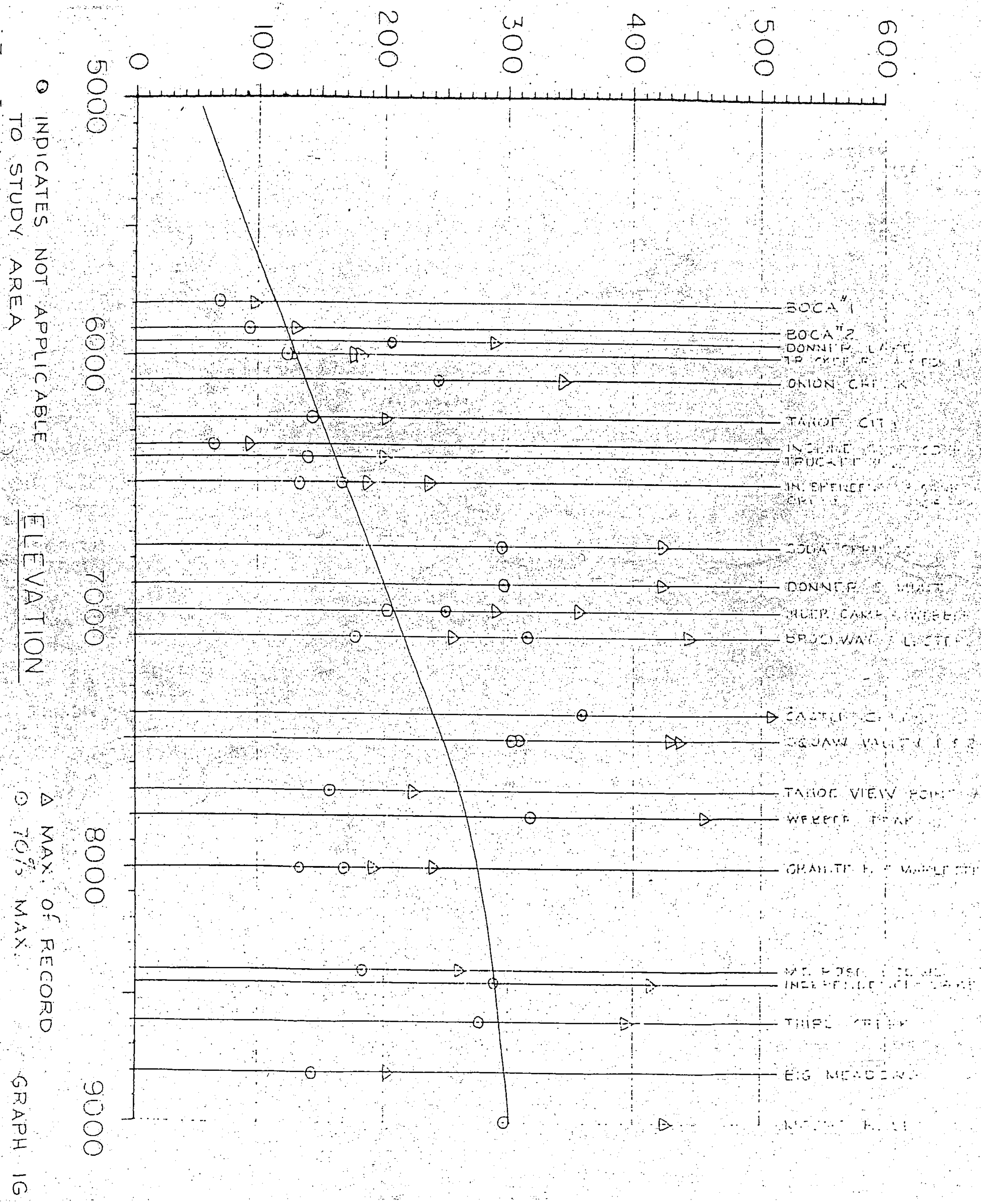


April 1, 1969 - Density, %

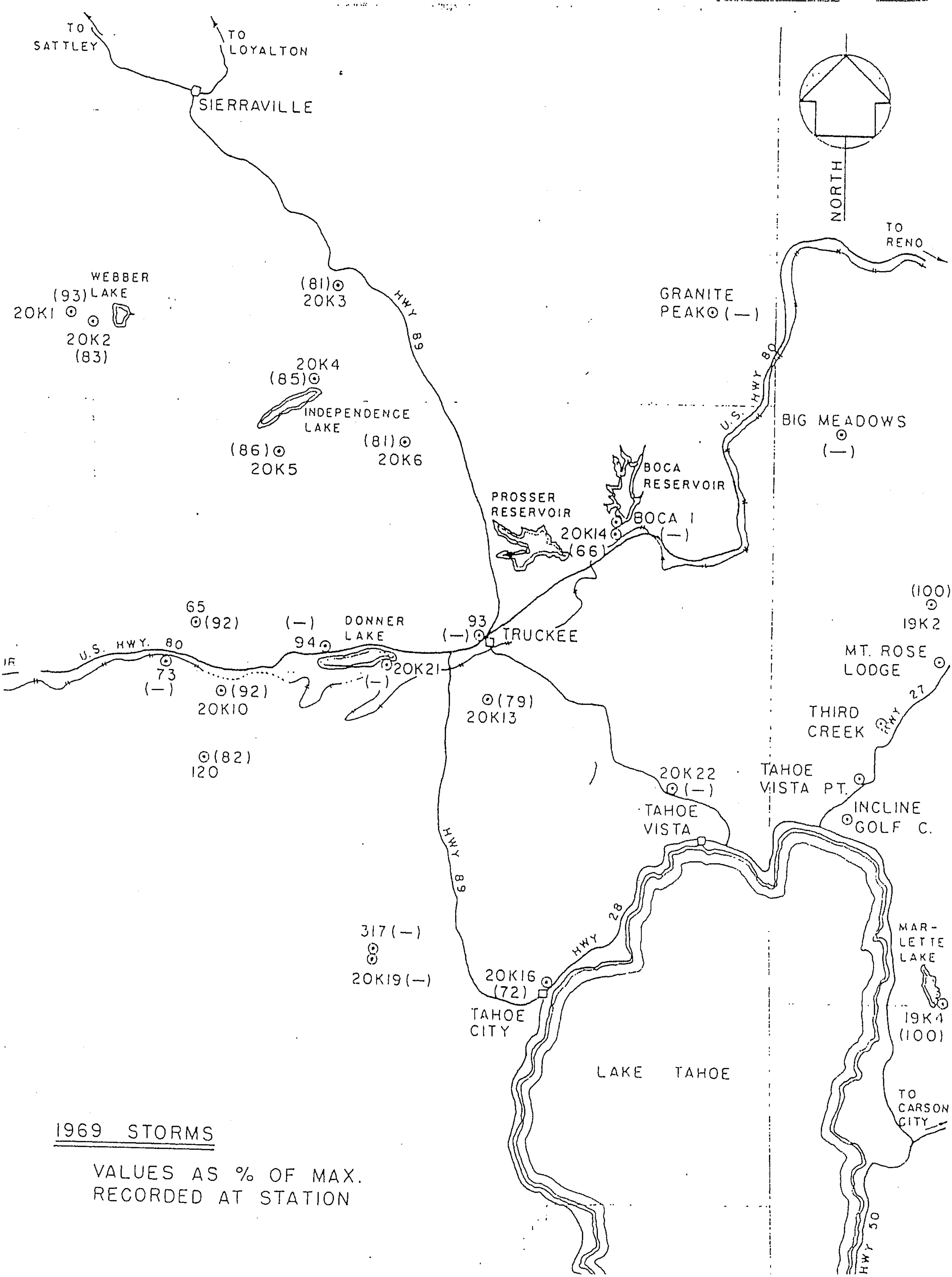


April 1, 1969 Trimont Snow Depth Data Adjusted to Max. & 70% Max. Snow Load

PEAK SNOW LOAD — LBS/FT²

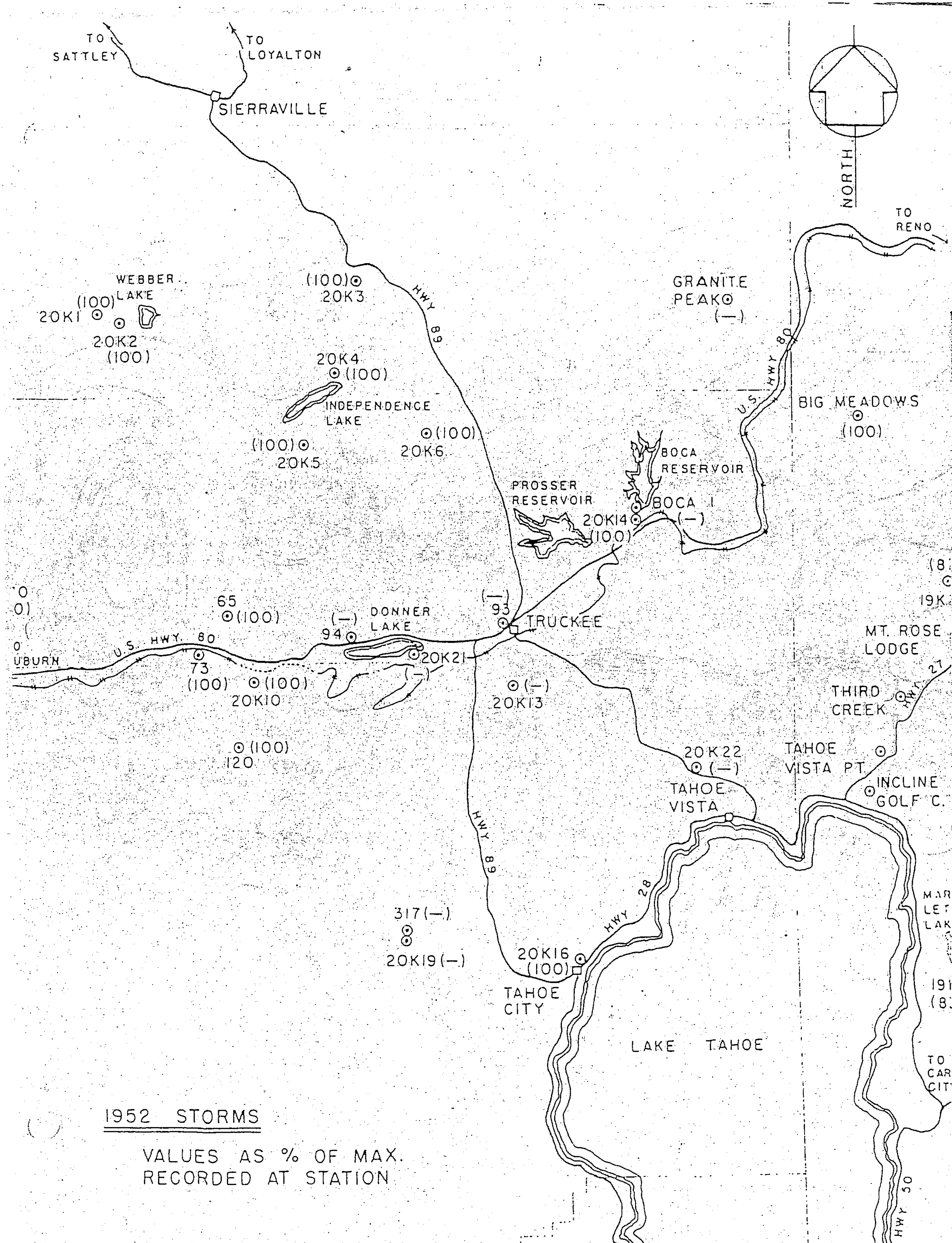


GRAPH 1G



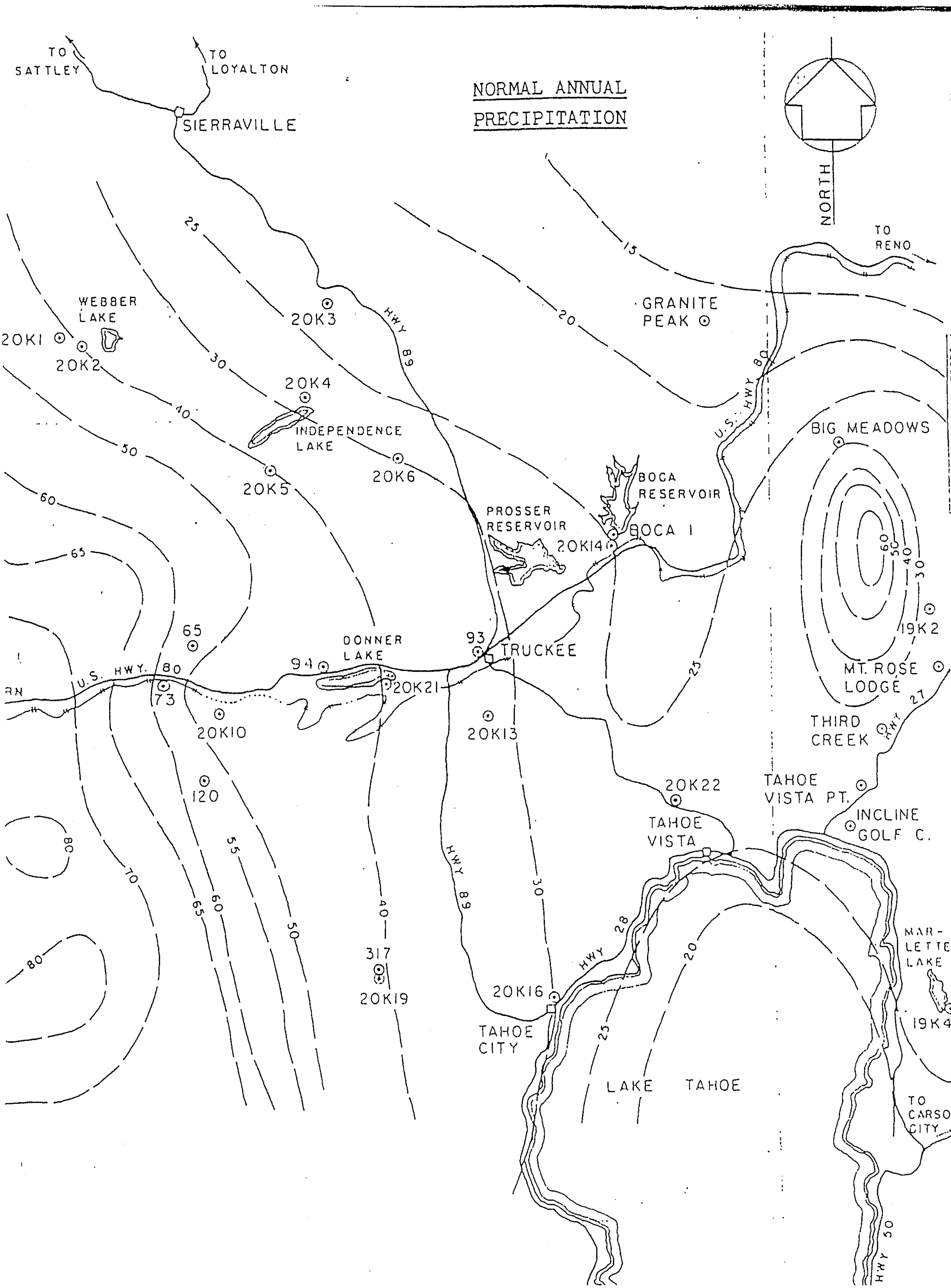
1969 STORMS

VALUES AS % OF MAX. RECORDED AT STATION

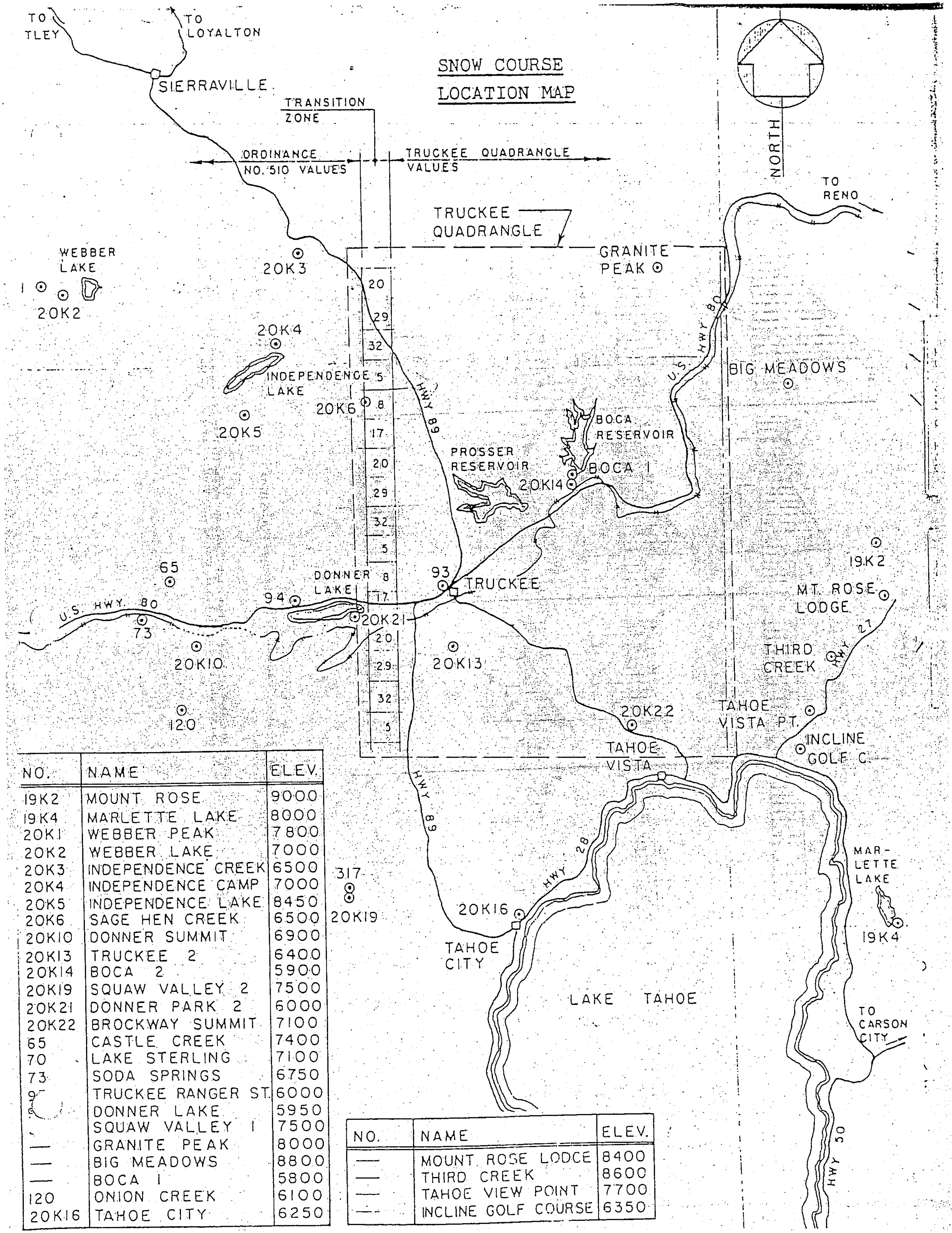


1952 STORMS

VALUES AS % OF MAX. RECORDED AT STATION


NORMAL ANNUAL PRECIPITATION
NORTH
TO SATTLEY
TO LOYALTON
SIERRAVILLE
TO RENO
WEBBER LAKE
20K1
20K2
20K3
20K4
INDEPENDENCE LAKE
20K5
20K6
GRANITE PEAK
BIG MEADOWS
BOCA RESERVOIR
PROSSER RESERVOIR
BOCA 1
20K14
HWY 89
U.S. HWY 80
65
93
94
73
DONNER LAKE
TRUCKEE
20K21
20K10
20K13
120
19K2
MT. ROSE LODGE
THIRD CREEK
HWY 27
20K22
TAHOE VISTA PT.
TAHOE VISTA
INCLINE GOLF C.
HWY 28
317
20K19
20K16
TAHOE CITY
MAR-LETTE LAKE
19K4
LAKE TAHOE
TO CARSON CITY
HWY 50
15
20
25
30
40
50
55
60
65
70
80

SNOW COURSE LOCATION MAP



NO.	NAME	ELEV.
19K2	MOUNT ROSE	9000
19K4	MARLETTE LAKE	8000
20K1	WEBBER PEAK	7800
20K2	WEBBER LAKE	7000
20K3	INDEPENDENCE CREEK	6500
20K4	INDEPENDENCE CAMP	7000
20K5	INDEPENDENCE LAKE	8450
20K6	SAGE HEN CREEK	6500
20K10	DONNER SUMMIT	6900
20K13	TRUCKEE 2	6400
20K14	BOCA 2	5900
20K19	SQUAW VALLEY 2	7500
20K21	DONNER PARK 2	6000
20K22	BROCKWAY SUMMIT	7100
65	CASTLE CREEK	7400
70	LAKE STERLING	7100
73	SODA SPRINGS	6750
9[illegible]	TRUCKEE RANGER ST.	6000
	DONNER LAKE	5950
	SQUAW VALLEY 1	7500
—	GRANITE PEAK	8000
—	BIG MEADOWS	8800
—	BOCA 1	5800
120	ONION CREEK	6100
20K16	TAHOE CITY	6250

NO.	NAME	ELEV.
—	MOUNT ROSE LODGE	8400
—	THIRD CREEK	8600
—	TAHOE VIEW POINT	7700
—	INCLINE GOLF COURSE	6350

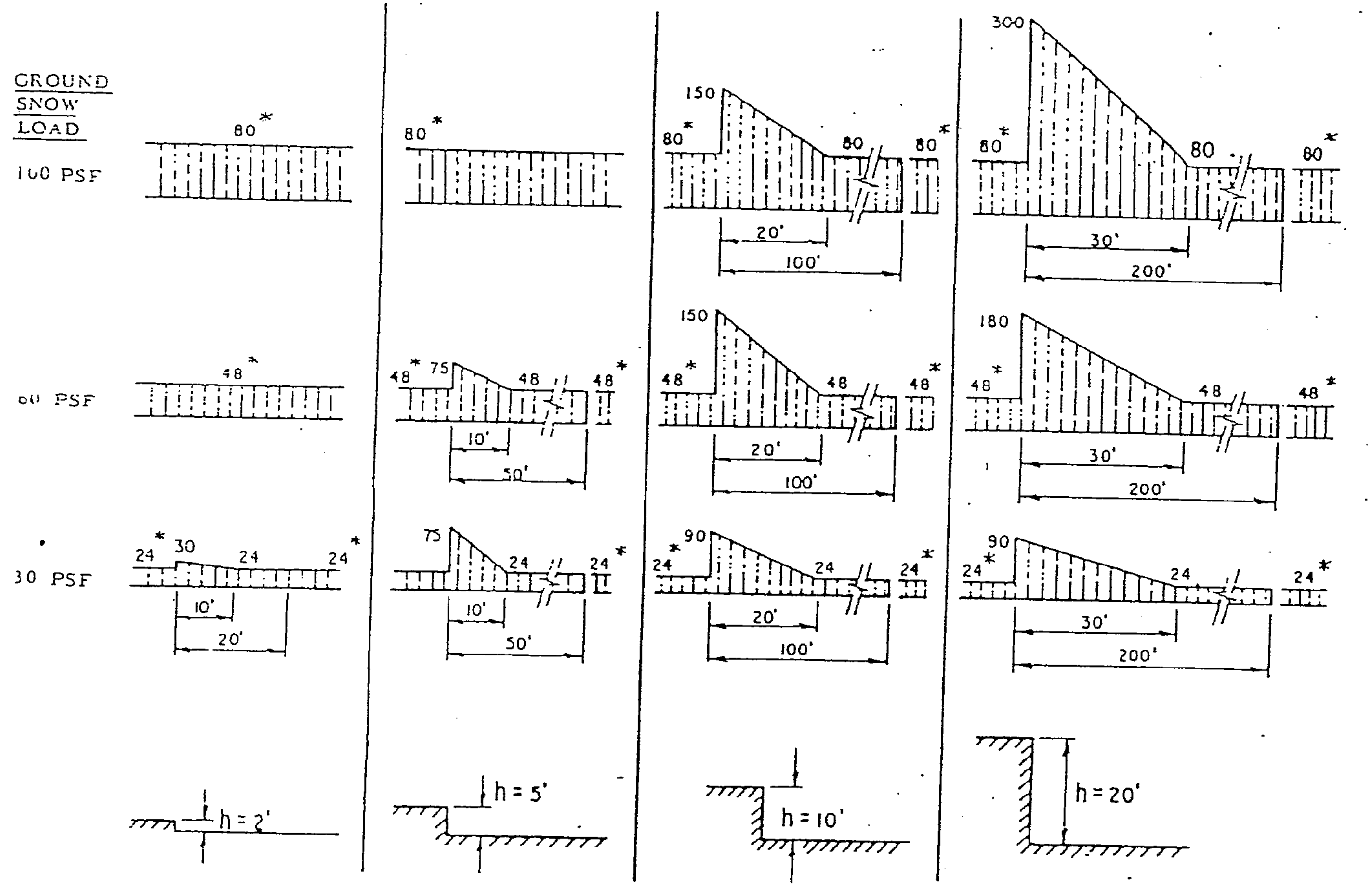


Figure C2-9 · Example Sheet 2: Design snow loads in psf for various differences in roof elevations for multi-level roofs with three typical ground snow loads.

Notes:
*For roofs exposed to the wind according to Article 4.1.5.4. all values marked with an asterisk (*) may be reduced by 25 per cent.
All load distributions shown in these Figures are also to be applied as alternating strip loading (full and zero load) according to Sentence 4.1.5.2.(2).

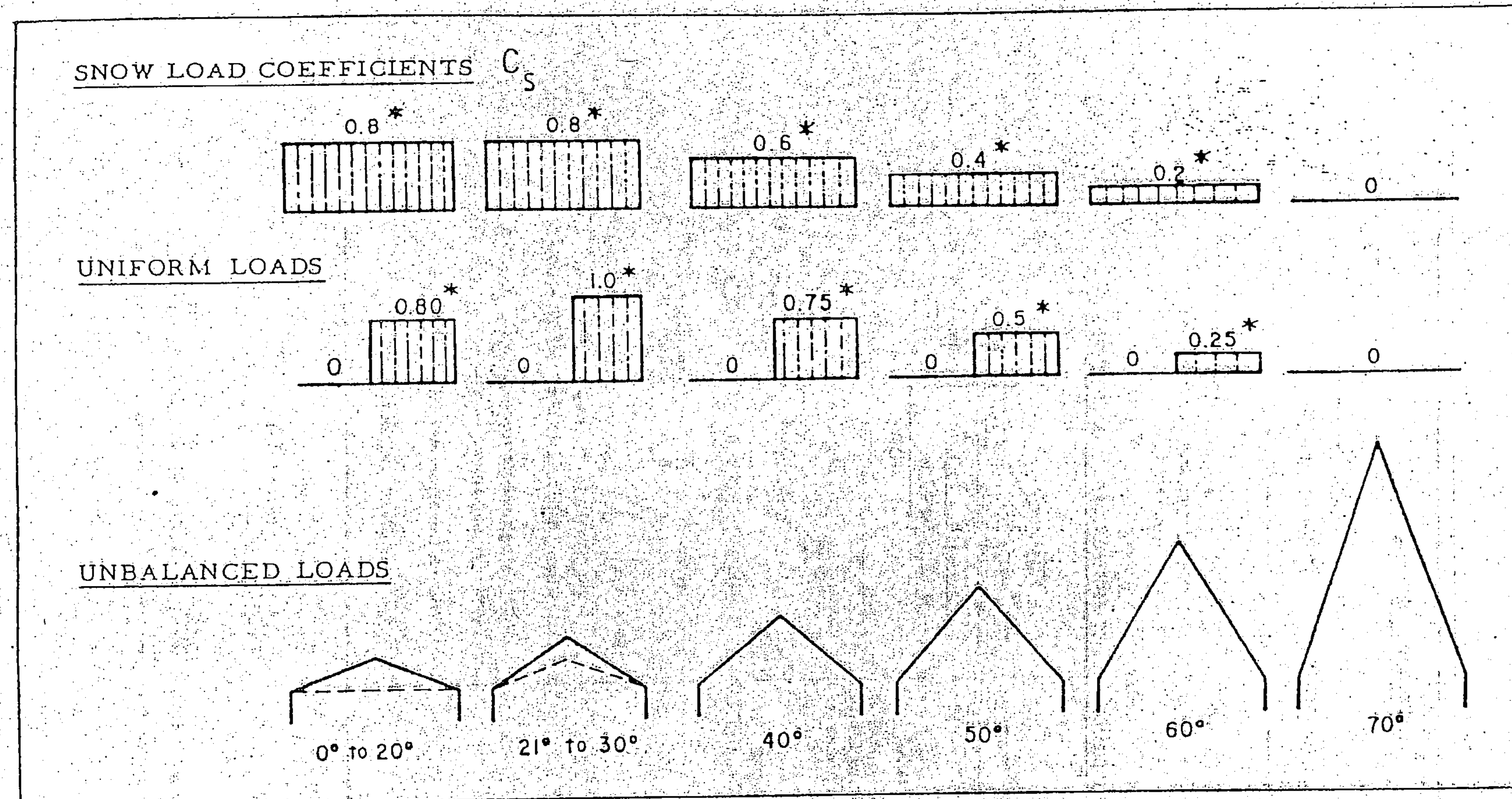
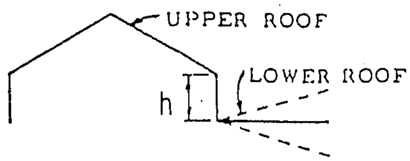


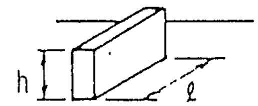
Figure C2–8 Example Sheet 1: Snow load coefficients C_s for uniform and unbalanced load conditions on gable and hip roofs with varying slopes.

Notes:
*For roofs exposed to the wind according to Article 4.1.5.4. all values marked with an asterisk (*) may be reduced by 25 per cent.
All load distributions shown in these Figures are also to be applied as alternating strip loading (full and zero load) according to Sentence 4.1.5.2.(2).

ROOF SHAPES

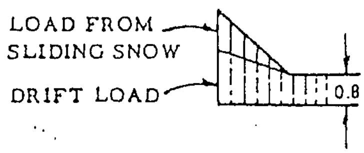


Lower of multi-level roofs with upper roof sloped towards lower roof



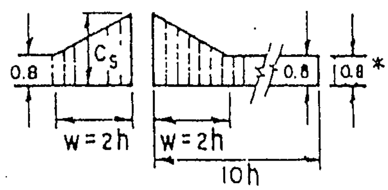
Roof areas adjacent to projections and obstructions on roofs

SNOW LOAD DISTRIBUTIONS AND COEFFICIENTS. LIMITATIONS



<u>Design lower roof</u> for loads according to Figure C2-5 plus a portion of the sliding snow from the upper roof according to text.

<u>Design upper roof</u> for loads according to Figures C2-1 to C2-4



$C_s = 10\frac{h}{g}$

when $10\frac{h}{g} < 0.8$* use $C_s = 0.8$*

when $10\frac{h}{g} > 2.0$ use $C_s = 2.0$

when $\ell < \frac{g}{6}$ use $C_s = 0.8$*

$W = 2h$

when $h < 5$ ft use $W = 10$

when $h > 15$ ft use $W = 30$

h = height of projection in ft

g = ground snow load in psf

W = width of snow drift in ft

ℓ = length of projection in ft

Figure C2-6
Lower of multi-level roofs with the upper roof sloped toward the lower roof

Figure C2-7
Areas adjacent to roof projections

Notes:

*For roofs exposed to wind according to Article 4.1.5.4., all values of C_s marked with an asterisk (*) may be reduced by 25 per cent.

All load distributions shown in these Figures are also to be applied as alternating strip loading (full and zero load) according to Sentence 4.1.5.2.(2).

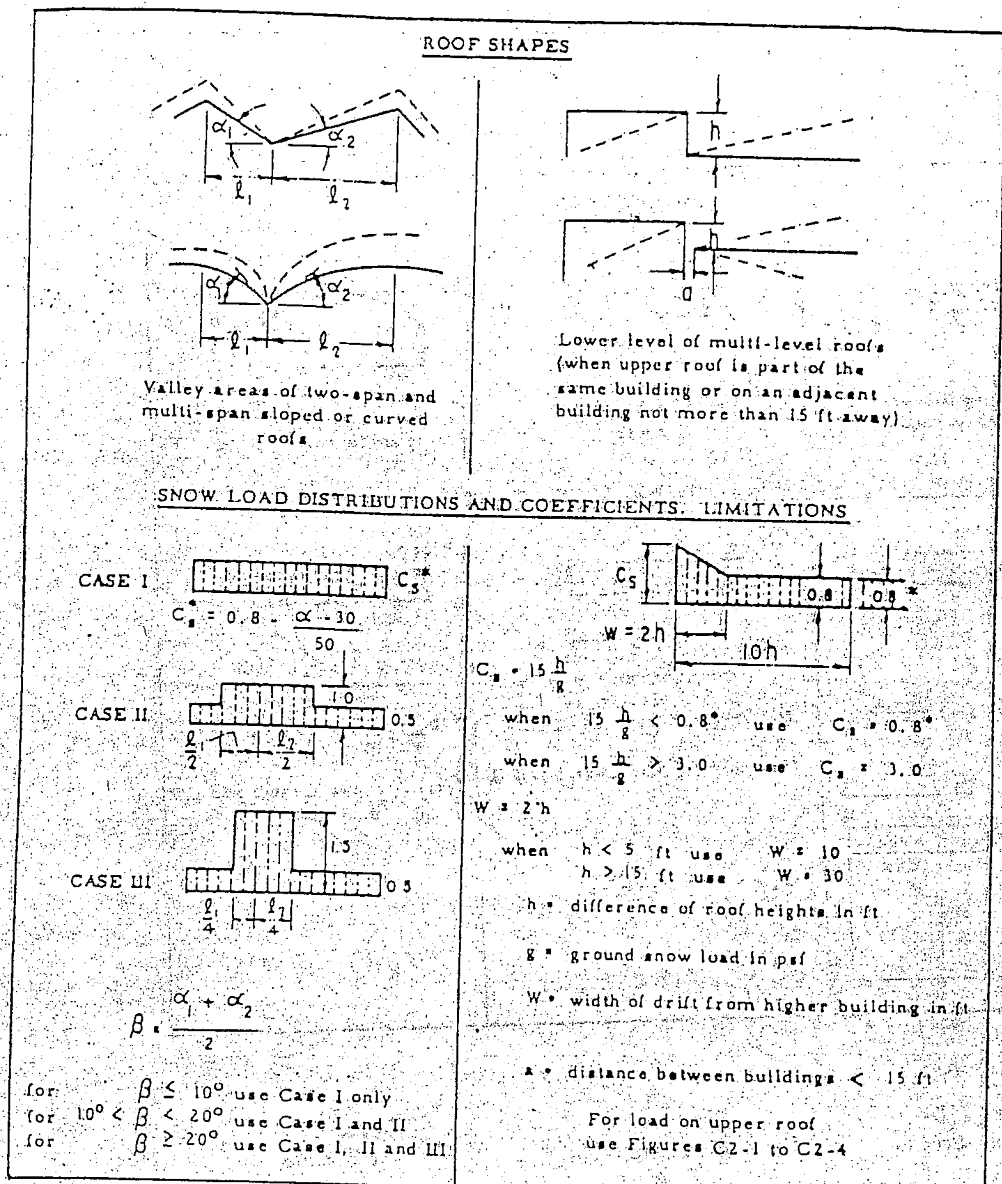


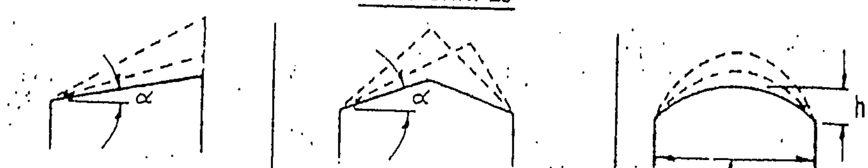
Figure C2-4
Valley areas of two-span and multi-span curved or sloped roofs

Figure C2-5
Lower roofs of multi-level roofs

Notes:

*For roofs exposed to wind according to Article 4.1.5.4., all values of C_s marked with an asterisk (*) may be reduced by 25 per cent.
All load distributions shown in these Figures are also to be applied as strip loading (full and zero load) according to Sentence 4.1.5.2.(2).
In Figure C2-4 note that the term $(\alpha - 30)/50$ is valid only for slopes α greater than 30° as provided in Sentence 4.1.5.3.(a).

ROOF SHAPES



Simple flat and shed roofs | Simple gable and hip roofs | Simple arch and curved roofs

SNOW LOAD DISTRIBUTIONS AND COEFFICIENTS. LIMITATIONS

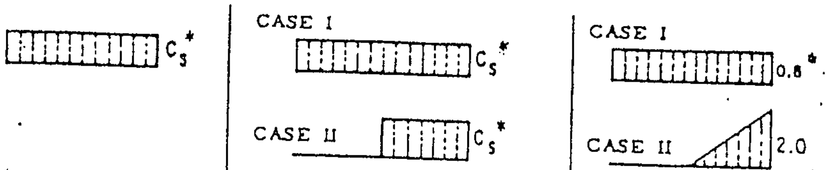


Figure C2-1 (Flat and shed roofs):

$$C_s^* = 0.8 - \frac{\alpha - 30}{50}$$

Typical values:

α	C_s shelt	C_s expd
0 to 30°	0.8	0.6
40°	0.6	0.45
50°	0.4	0.3
60°	0.2	0.15
70° to 90°	0	0

Figure C2-2 (Gable or hip roofs):

for $\alpha \leq 20°$ use Case I only

for $\alpha > 20°$ use Case I and II

Case I

$$C_s^* = 0.8 - \frac{\alpha - 30}{50}$$

Case II

$$C_s^* = 1.25\left(0.8 - \frac{\alpha - 30}{50}\right)$$

Figure C2-3 (Arch roofs):

for $\frac{h}{l} \leq \frac{1}{10}$ use Case I only

for $\frac{h}{l} > \frac{1}{10}$ use Case I and II

Figure C2-1
Flat and shed roofs

Figure C2-2
Gable or hip roofs

Figure C2-3
Arch roofs

Notes:

*For roofs exposed to wind according to Article 4.1.5.4., all values of C_s marked with an asterisk (*) may be reduced by 25 per cent.

All load distributions shown in these Figures are also to be applied as strip loading (full and zero load) according to Sentence 4.1.5.2.(2).

In Figures C2-1 and C2-2, note that the term $(\alpha - 30)/50$ is only valid for slopes α greater than 30° as provided in Sentence 4.1.5.3.(a).

Limits have been placed on the coefficients so that they will not be less than the basic coefficients nor greater than 2. The reduction of 25 per cent for exposed roofs should be considered applicable only to areas of the roof that are unprotected, i.e. some distance (estimated at 10 times the height h) away from the projection. Since narrow projections seldom produce significant snow accumulations, drift load from projections need only be considered when the length of the projection in feet exceeds one-sixth of the specified ground snow load in pounds per square foot.

(8) **Example Sheet 1 (Figure C2-8)**

Example sheet No. 1 has been added to show in graphical form the snow load coefficients C_s for uniform and unbalanced load conditions on gable and hip roofs with varying slopes according to the slope reduction formula of Figure C2-2. It will be noted that for the lower slopes (0 to 20 degrees) the imbalanced load is given by the requirements of Sentence 4.1.5.2.(2), i.e. with zero and full load, whereas for the steeper slopes (greater than 20 degrees) it is given by load case II of Figure C2-2.

(9) **Example Sheet 2 (Figure C2-9)**

Example sheet No. 2 shows the design snow loads in psf for various differences in roof elevation for multi-level roofs according to Figure C2-5 for three typical ground snow loads. It will be noted that 25 per cent reduction for exposed roofs according to Article 4.1.5.4. should be considered applicable only to areas of the roof that are unprotected, i.e. some distance estimated at 10 times the difference in elevation, away from the upper roof.

REFERENCES

(1) Climatic Information for Building Design in Canada, Supplement No. 1 to the National Building Code of Canada, issued by the Associate Committee on the NBC, National Research Council, Ottawa, Canada, 1970 (NRC No. 11153).

(2) National Building Code of Canada 1953, issued by the Associate Committee on the NBC, National Research Council, Ottawa, Canada (NRC No. 3188).

(3) Variations of Snow Loads on Roofs by Peter, B. G. W., Dalgliesh, W. A., and Schriever, W. R. Trans. Engineering Instit. of Canada, Vol. 6, No. A-1, April 1963 (NRC No. 7418).

(4) National Building Code of Canada 1960, issued by the Associate Committee on the NBC, National Research Council, Ottawa, Canada (NRC No. 5800).

(5) Maximum Snow Depths and Snow Loads on Roofs in Canada by Boyd, D. W. Proc. 29th Annual Meeting, Western Snow Conference, April 1961 (NRC No. 6312).

(6) Snow Accumulations in Canada: Case Histories: I, by W. R. Schriever, Y. Faucher and D. A. Lutes. National Research Council, Canada, Division of Building Research, January 1967 (NRC No. 9287).

(2) Gable or Hip Roofs (Figure C2-2)

For gable or hip roofs both uniform loads and unbalanced loads should be considered. A load 25 per cent greater than the uniform load on one side and no load on the other is recommended to account for the snow blown from the windward side over to the leeward side. An unbalanced load is also justified on this type of roof because of the possibility of snow being removed by sliding from one side only.

The same reductions as in Figure C2-1 in the coefficients for slopes exceeding 30 degrees are permissible.

When gable or hip roofs are adjacent to higher roofs or have projections, reference must also be made to Figures C2-5 to C2-7.

(3) Arch Roofs (Figure C2-3)

For arch roofs both uniform and unbalanced triangular loads are given. The coefficients for the unbalanced load are 0 at the ridge and 2.0 at the eave. The unbalanced load is based on the theoretical consideration of higher wind velocities at the peak and also from field observations of this type of load. The coefficients are based on the U.S.S.R. snow load requirements.

Where there are adjacent higher roofs or projections reference must also be made to Figures C2-5 to C2-7 for further coefficients.

(4) Valley Areas of Two-Span and Multi-Span Curved or Sloped Roofs (Figure C2-4)

For valley areas of two-span and multi-span roofs a uniform load with appropriate slope reductions is used, as well as two types of nonuniform load to account for drifting and sliding snow. Slope reductions of the coefficients for cases II and III are not allowed since melting or sliding snow will tend to accumulate in the valleys. These coefficients are based on field observations in Canada and the U.S.S.R. snow load requirements.

Should there be adjacent higher roofs or projections reference must also be made to Figures C2-5 to C2-7.

(5) Lower Roofs of Multi-Level Roofs (Figure C2-5)

The design load for roofs adjacent to higher roofs is recommended to be taken as a triangular load with a maximum (in pounds per square foot) equal to 15 times the difference in roof elevation (in feet) reduced to the normal snow load at a distance from the higher roof of twice the difference in elevation. This load is based on the assumption of a triangular snow drift extending to the top of the higher roof. Such drift loads occur not only when the upper roof is part of the same building, but also when it is on an adjacent building not more than some 15 ft away.

An upper limit of three times the basic snow load has been suggested in Figure C2-5. It should be noted, however, that higher loads have been observed where an upper roof was very long (measured perpendicularly to the step between the upper and lower roofs). On the other hand, for relatively short upper roofs (say less than 50 ft) a reduction below the value calculated from Figure C2-5 may be judged adequate by the designer.

The reduction of 25 per cent for exposed roofs should only be considered applicable to the areas of the roof further than 10 times the difference of roof height from the upper roof.

(6) Lower of Multi-Level Roofs with the Upper Roof Sloped Toward the Lower Roof (Figure C2-6)

Where snow is likely to slide onto a lower roof from an upper roof the lower roof should be designed for the load as provided for in Figure C2-5 plus an additional load produced by the snow that may slide from the upper roof. It is not possible at the moment to provide coefficients for this problem but the following guide is recommended. Because of the remote probability that both upper and lower roofs will have their full load over the full areas simultaneously when sliding occurs, it may be assumed that the lower roof would be carrying its full load according to Figure C2-5 and that sliding of 50 per cent of the design load from the upper roof would occur. The distribution should be made depending on the relative sizes, slopes and positions of the two roofs. If, because of a relatively small lower roof, all the sliding snow cannot be retained on it, appropriate reductions may be made. The density of sliding snow may be rather high.

(7) Areas Adjacent to Roof Projections (Figure C2-7)

Triangular drift loads are recommended adjacent to vertical projections from roofs, with a maximum (in pounds per square foot) equal to 10 times the projection height h (in feet), reduced to the normal load at a distance of twice the projection height. This is equivalent to a depth of snow of two-thirds of the projection height (See IV,(9)).

by the designer and the authority having jurisdiction to be more appropriate for the particular roof being designed and if based on applicable field observations or on model tests. In an effort to provide guidance to designers, the Division of Building Research has published a collection of case histories of interesting non-uniform snow loads[4].

Figures C2-1 to C2-3 are for the basic roof shapes. These are the simple flat and shed roofs, simple gable and hip roofs and thirdly simple arch and curved roofs. These roofs can be loosely classified as single span roofs. More complex roof shapes can then often be considered as combinations of these three roofs shapes. The basic roof shapes can be either combined with equal eave heights producing a valley or unequal eave heights resulting in a multi-level roof.

Valleys in two-span and multi-span roofs lead to increased loads in the troughs from the influence of the wind and, with steeper slopes, from sliding, creeping or melting snow. Coefficients for valley areas are presented in Figure C2-4.

On multi-level roofs the areas on the lower roofs that are adjacent to the higher roofs are subjected to heavier snow loads due to drifting. The coefficients for the increased load on the lower level of multi-level roofs are provided in Figure C2-5.

Where the upper roof is sloped towards the lower roof so that snow may slide or melt onto the lower roof, the lower roof should be designed for increased loads. This is specified in Figure C2-6.

Finally, the snow load distribution is influenced by vertical projections. The coefficients for this condition are provided in Figure C2-7.

Reduction of Snow Loads for Exposed Roofs

Numerous observations in most areas of Canada have shown that where a roof or part of a roof is fully exposed to wind, part of the snow is blown off under most conditions.

For such exposed roofs the coefficients may be reduced 25 per cent. The conditions permitting this reduction are given in Article 4.1.5.4. of the National Building Code.

It may be difficult for the designer in practice to make a clear distinction between those roofs that will be fully exposed to the winds and those that will not. To guard against the danger of a roof designed with the reduced coefficients becoming sheltered by future higher building and causing possibly higher loads, it would be prudent for the designer to require a distance of at least 15 ft from the property line to make the roof eligible for the reduction. This corresponds to the distance used in Article 4.1.5.3. for multi-level roofs. It should be noted that it is the designer's responsibility to use his own judgement in arriving at the best possible design snow load assumption.

Where a roof has projections, such as parapet walls, the reduction of 25 per cent should only be applied to roof areas that are relatively well exposed, i.e. those areas that lie outside a strip 10 times the height of the vertical projection.

Alternating Strip Loads (with Full and Zero Load)

It should be noted that on all roof areas, including those to be designed for increased or decreased loads according to Figures C2-1 to C2-7, the design snow load shall be applied

(a) with the full load on the entire area, or

(b) with the full load distributed on any portion of the area and zero load on the remainder of the area,

whichever produces the greatest effects on the members concerned (see Sentence 4.1.5.2.(2) of the NBC). The reasons for this overriding requirement are that snow very seldom accumulates evenly and to guard against unbalanced loading by snow removal from one side. Consequently, since certain structural members (such as certain diagonals of trusses) are subject to stress reversals or otherwise sensitive to changes in load distribution, non-uniform loading must always be considered by the designer in addition to uniform loading.

DETAILED EXPLANATION OF FIGURES C2-1 TO C2-9

(1) Flat and Shed Roofs—Slope Reduction (Figure C2-1)

Since, under most conditions, steeper roofs tend to accumulate less snow than flat and moderately sloped roofs because of sliding and better drainage, the coefficients are reduced for slopes exceeding 30 degrees as shown in Figure C2-1 and for slopes exceeding 70 degrees, no snow load need be considered.

For multi-level flat or shed roofs and for roofs with vertical projections, Figures C2-5, C2-6 and C2-7 should be referred to.

deflection) because usually the drains are located at columns (high points). This redistribution of load causes further deflection and can lead to a very dangerous situation.

Snow Removal

Although it is fairly common practice in some areas to remove snow from roofs after heavy snowfalls, the NBC does not allow a reduction of the design snow load to account for this for the following reasons:

(a) Snow removal cannot be relied upon. Experience in several countries has shown that during and after extreme snow storms traffic is at a standstill and snow removal crews cannot be obtained.

(b) Snow cannot be effectively removed from the centre of large roofs.

(c) Unbalanced loading can occur as a result of snow removal from one side although actually the NBC guards against this possibility by requiring each roof member and roof structural assembly to be designed for full load on any portion of the area and zero load on the remainder of the area.

DESIGN ROOF LOADS IN THE NATIONAL BUILDING CODE

Historical Notes

In the past, e.g. in the 1953 National Building Code of Canada[3], design snow loads were often considered to be equal to the ground snow load with reductions allowed for sloped roofs only. Such design load values were admittedly rough and have resulted in overdesign in some roofs while allowing underdesign in others, particularly in areas subject to high drift load. Information on which to base a more refined assessment of the loads was, however, not available until a countrywide survey of actual snow loads on roofs was undertaken by the Division of Building Research with the help of many volunteer observers[2]. This survey provided evidence on the relationship between ground and roof loads and enabled the committees responsible for the 1960 revision of the National Building Code[4] to make some changes in the roof loads compared with the ground load. The roof load was set at 80 per cent of the ground load, the ground load being based on a return period of 30 years and adjusted to allow for the increase in the load caused by rainwater absorbed by the snow (see Ref. 5).

With the advent of the 1965 Code some further changes were made by the Revision Committee on Structural Loads and Procedures which have led to a more rational approach to snow loads for the design of roofs. All roof loads were directly related to the snow load on the ground and consequently the column for the roof snow load in the table of Design Data for Selected Locations in Canada in Supplement No. 1 was omitted. The basic roof load was again 80 per cent of the ground load except that for roofs exposed to the wind a roof load of 60 per cent of the ground load could be used under certain conditions described further below. This reduction of roof load for exposed roofs to 60 per cent of the ground load was only made because at the same time allowance was made for a variety of influences causing accumulations of snow loads on roofs. This was done by means of "snow load coefficients" or shape factors which are shown in the form of diagrams and simple formulae in Figures C2-1 to C2-7. Explanations of the use of these coefficients are given in following sections.

Changes in the 1970 National Building Code

No major changes have been made in the snow load requirements for the 1970 Code.

DETERMINATION OF DESIGN SNOW LOADS ON ROOFS

Basic Snow Load Coefficients and Modifications to the Coefficients

The minimum design snow loads on a roof area or any other area above ground which is subject to snow accumulation is obtained by multiplying the snow load on the ground, g, specified for the municipality or area considered by the snow load coefficient, C_s, applicable to the particular roof area considered

$$s = C_s g$$

s = design snow load in psf
g = ground snow load in psf
C_s = snow load coefficient.

The basic snow load coefficient is 0.8, except that for roofs exposed to the wind, under certain conditions to be described, this value may be reduced to 0.6. These coefficients are to be further modified (increased or decreased) to account for the influences provided for in Article 4.1.5.3. of the NBC and discussed earlier in this commentary. Such modified snow load coefficients C_s are given in Figures C2-1 to C2-7 for various fairly common roof shapes. For other roof shapes, other coefficients may have to be used if considered

Effect of Wind on Snow Accumulation on Roofs

In perfectly calm weather falling snow would cover roofs and the ground with a uniform blanket of snow. If this calm continued, the snow cover would remain undisturbed and the prediction of roof loads would be relatively simple; the design snow load could be considered as a uniformly distributed load and equal to a suitable statistical maximum of the ground snow load.

Truly uniform loading conditions, however, are rare and have been observed only in certain areas of the British Columbia mountains and occasionally in other areas on roofs that are well sheltered on all sides by high trees. In most regions snowfalls are accompanied or followed by winds. Snowflakes, having a large surface area for their weight, are easily transported horizontally by the wind. Consequently since many roofs are well exposed to the wind little snow will accumulate on them.

Over certain parts of roofs the wind speed will be slowed down sufficiently to let the snow "drop out" and accumulate in drifts. This can be visualized by reference to the action of snow fences which cause the snow to "settle out". These areas on roofs could be called "areas of aerodynamic shade", and occur mostly behind vertical projections on the roof. An example of this is the area behind a penthouse on a flat roof where drifts often accumulate. Naturally, since the wind direction is not always the same drifts on all sides of a penthouse would generally have to be considered.

Lean-to roofs, i.e., roofs situated below an adjacent higher roof, are particularly susceptible to heavy drift loads because the upper roof can provide a large supply of snow. Canopies, balconies and porches also fall into this category. The drift loads that accumulate on such roofs often reach a multiple of the ground load and depend mainly on the difference of elevation of the two roofs and on the size of the upper roof. The distribution of load depends on the shape of these drifts which varies from a triangular cross-section (with the greatest depth nearest to the higher roof) to a more or less uniform depth.

Flat roofs with projections such as penthouses or parapet walls often experience triangular snow accumulations that reach the top of the projections on the building, but usually the magnitude of the load is less than on lean-to roofs.

Peaked and curved roofs subjected to winds at approximately right angles to the ridge provide aerodynamic shade over the leeward slope. This sometimes leads to heavy unbalanced loads, since most of the snow is blown from the windward slope to the leeward slope, producing loads that exceed the ground load on occasions. Curved roofs show similar or even more unbalanced distributions (little snow on top and heavy snow near the base of the arch). On the other hand it is true that many small peaked roofs on residences, in exposed areas, usually (but not always) accumulate little snow compared with that on the ground.

Solar Radiation and Heat Loss

Various other factors, besides wind, modify snow loads, although some of these factors are effective only under special conditions. It has been found, for example, that solar radiation has little effect in reducing loads in cold weather. Similarly, in cold weather, heat loss from the roof is not very effective in melting the snow particularly with the present trend to better insulated and ventilated roofs. These two factors cannot, therefore, be relied upon to reduce the snow load significantly during the colder periods. During thaws and toward the end of the winter, however, when the air temperature rises nearer to the freezing point, solar radiation and heat loss do contribute to the melting of the snow.

In special cases roofs have been designed with reduced design loads for areas with large snow loads by incorporating in the roof a method of clearing the roof of snow periodically during the winter by the deliberate heating of the roof ("thermal unloading").

Redistribution of Load from Melting Snow

Redistribution of snow load can occur not only as a result of wind action. On sloped roofs there are two problems connected with the melting of snow at temperatures slightly below freezing. Firstly, melt water can refreeze on eaves and cause high ice loads (also water back-up under shingles). This can at least partly be solved by taking steps to decrease the heat loss from the upper parts of the roof. Secondly, if a roof slopes and drains on to a lower one, melt water sometimes accumulates by refreezing on the lower roof or it is retained in the snow.

Since flat roofs in general do not provide as good drainage as that naturally obtained with sloped roofs, snow and ice will remain on flat roofs longer than on sloped roofs. On large flat roofs of industrial and commercial buildings, heavy loads are observed near projections such as air ducts (which sometimes act like snow fences in retaining snow). When this snow melts it may drain into the lower areas in the centre of bays (i.e., areas of maximum

COMMENTARY NO. 2

SNOW LOADS

by

W. R. Schriever, D. A. Lutes, and B. G. W. Peter

VARIATIONS OF SNOW LOADS ON THE GROUND AND ON ROOFS

Snow loads on roofs vary according to geographical location (climate), site exposure, shape and type of roof, and of course from one winter to another.

Before the roof snow loads can be discussed, however, the ground loads must be considered since they are the basis for the determination of the roof loads. Ground snow loads, forming part of the basic climatic information needed for building design in Canada, are dealt with in Supplement No. 1 to the National Building Code[1]. There, the snow loads on the ground are given both in form of a chart (Chart 9) and in form of a table of "Design Data for Selected Locations in Canada". This table is reproduced in Part D of this Supplement for the convenience of the user.

Climate Variation

The wide climate variations existing in Canada produce wide variation in snow load conditions across the country. Coastal regions (both Atlantic and Pacific), because of frequent thaws during the winter, are usually characterized by snow loads of short duration, often caused by a single storm. The mountainous regions of British Columbia and Alberta experience the heaviest snow loads in the country, lasting the entire winter and varying considerably with elevation. Prairie and northern regions have very cold winters, with small annual snowfalls; owing to frequent strong winds there is considerable drifting of snow both on roofs and on the ground. Finally, the central region, including Ontario and Quebec, is marked by varying winds and snowfalls, and sufficiently low temperatures in many places to allow snow accumulation all winter. In this area high uniform loads as well as high drift loads occur.

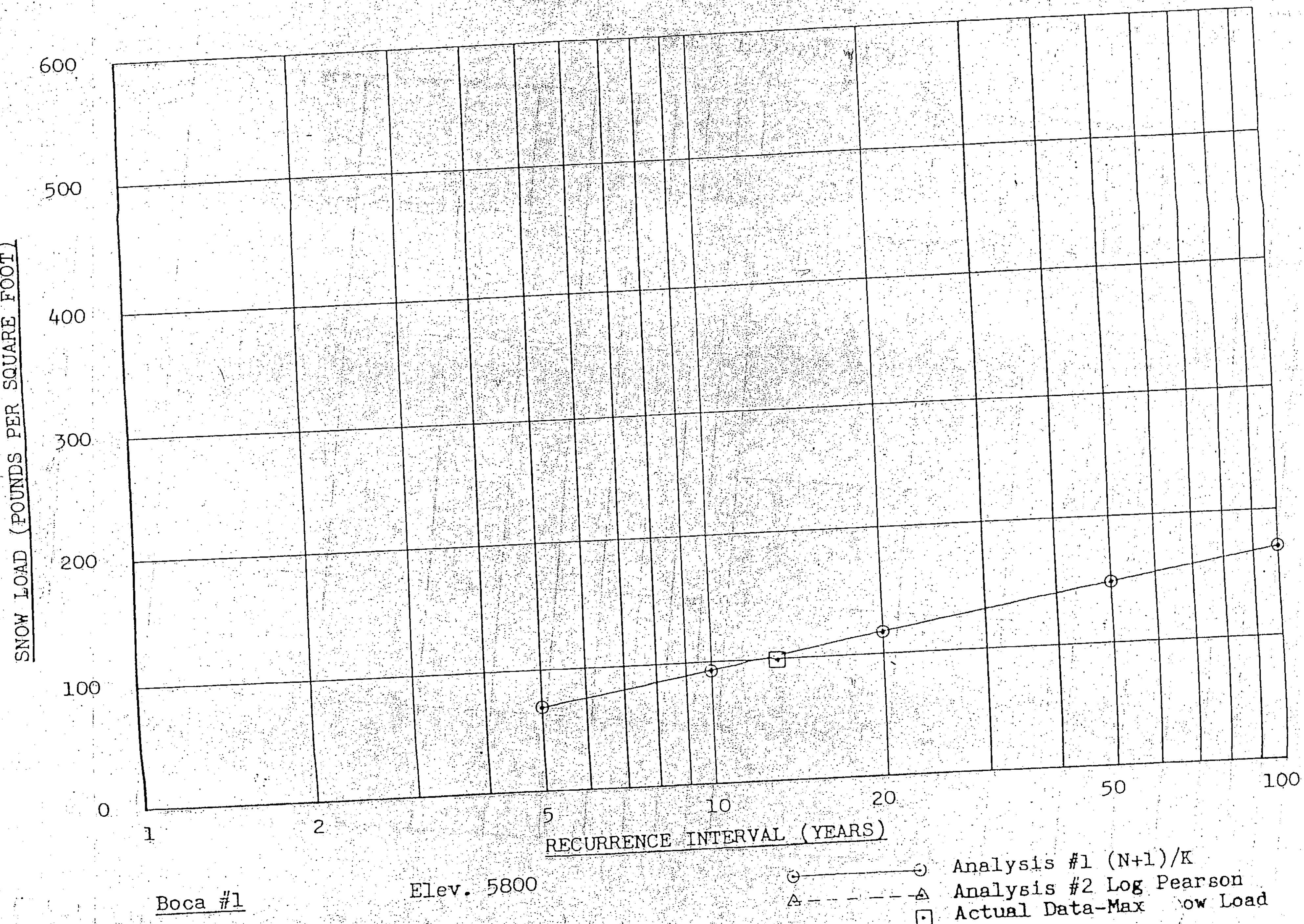
Local Variations. Mountain Areas

It should be noted that charts on such a small scale as those in Supplement No. 1[1] cannot show local differences in the weather elements even where these are known to exist. Practically all observations used in preparing Chart 9 were, of necessity, taken at inhabited locations and hence the Chart applies essentially to permanently populated areas. This should be noted by designers particularly for mountainous areas because ground snow loads are known to increase with elevation. In mountain areas therefore, the snow loads of Chart 9 and the Table apply only to the populated valleys not to the mountain slopes and peaks with higher elevations. For the latter areas, local experience should be taken into account. For some mountain areas water equivalent data, collected for hydrological purposes, are available from which the relationship between elevation and ground snow load can sometimes be determined for a given climatic zone.

Specific Gravity of Snow

Snowflakes of falling snow consist of ice crystals with their well-known complex pattern. Owing to their large surface area to weight ratio they fall to the ground relatively slowly.

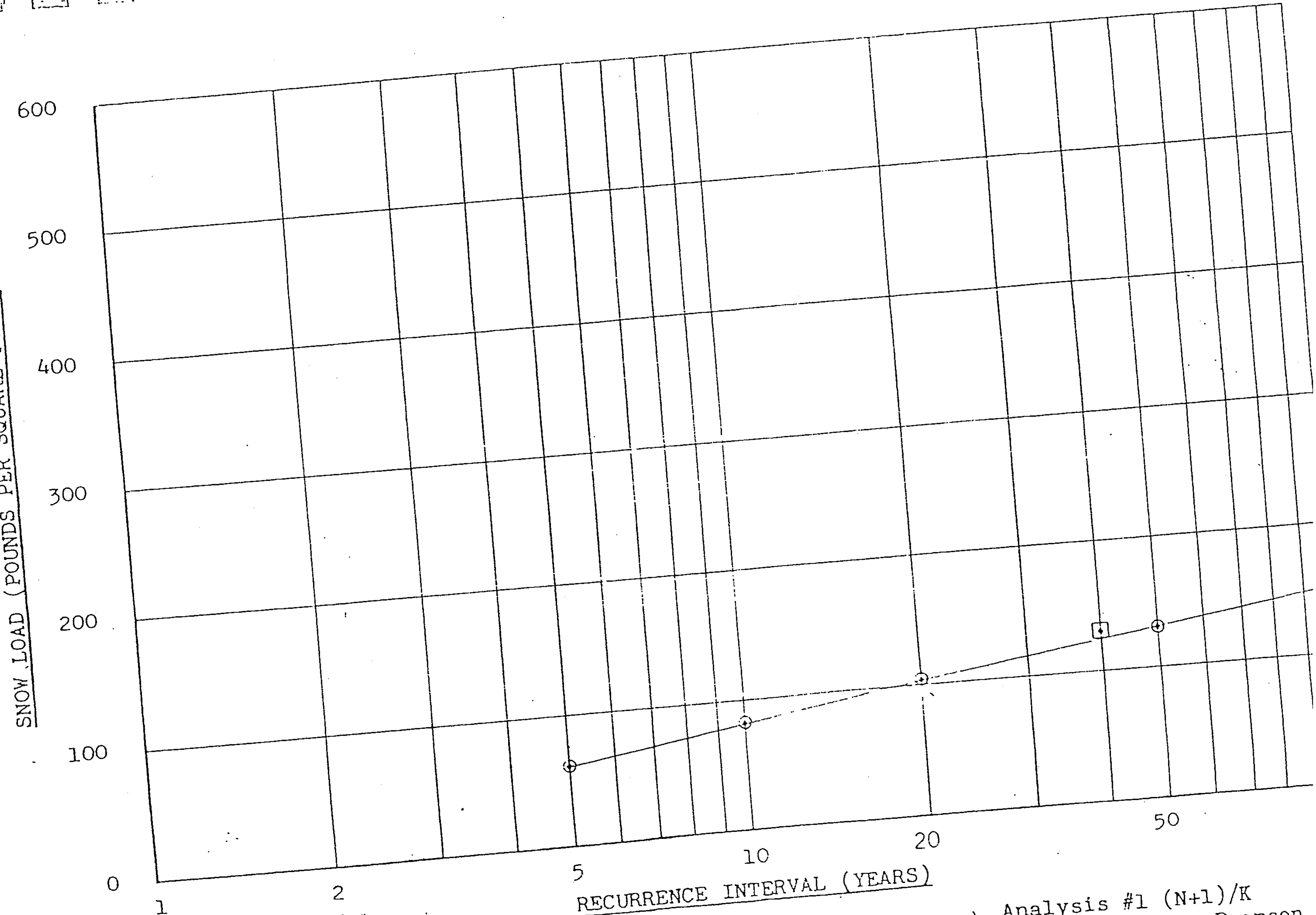
Freshly fallen snow is very loose and fluffy, with a specific gravity of about 0.05 to 0.1 (1/20th to 1/10th of water). Immediately after falling, however, the snow crystals start to change: the thin, needle-like projections begin to sublime and the crystals gradually become more like small irregularly shaped grains. This results in settlement of the snow and after a few days or weeks the specific gravity will usually have increased to about 0.2 or higher, even at below freezing temperatures. The specific gravity of old snow generally ranges from 0.2 to 0.4. Since maximum snow loads nearly always occur immediately after an unusually heavy snowfall and hence a large proportion of the snow has a low density, a mean specific gravity of about 0.2 was used to calculate the weight of the whole snow cover in Supplement No. 1. The actual value used was 0.192, since it was found convenient to assume that one inch of snow cover corresponds to a load of one pound per square foot. To this was added the weight of the maximum one day rainfall in the period of the year when snow depths are greatest.



Boca #1

Elev. 5800

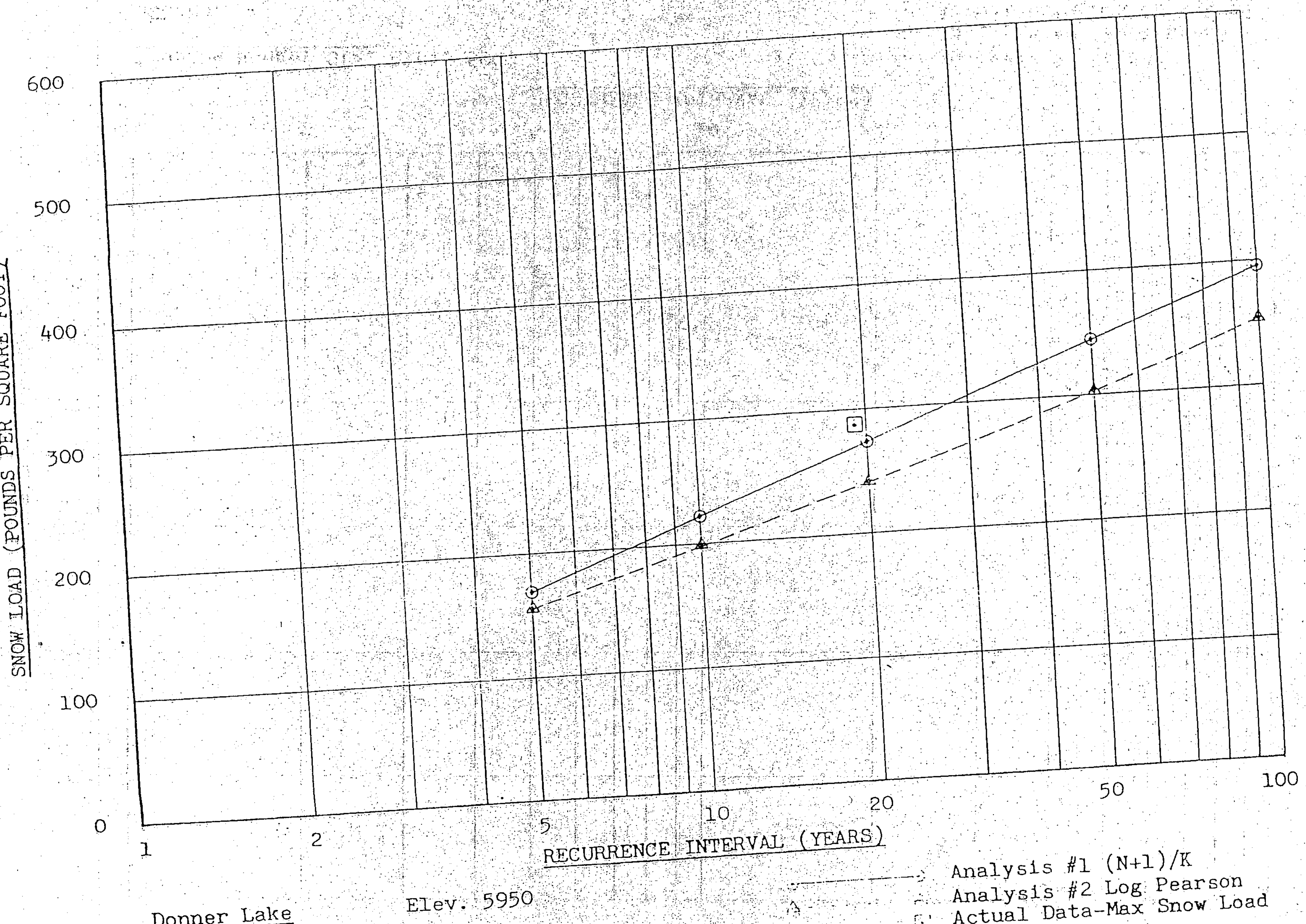
SCS No. --



Boca #2

Elev. 5900

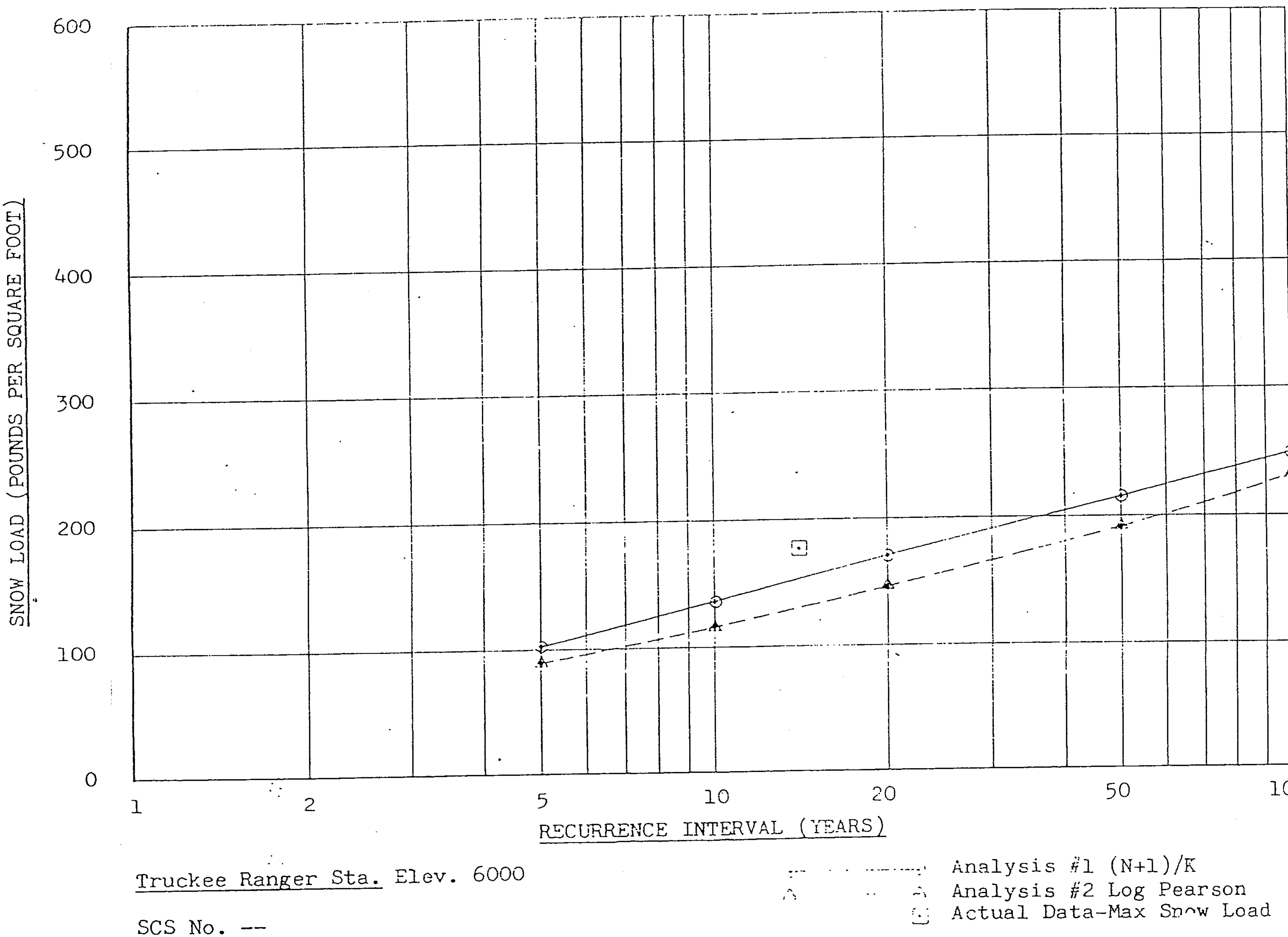
20K14



Donner Lake

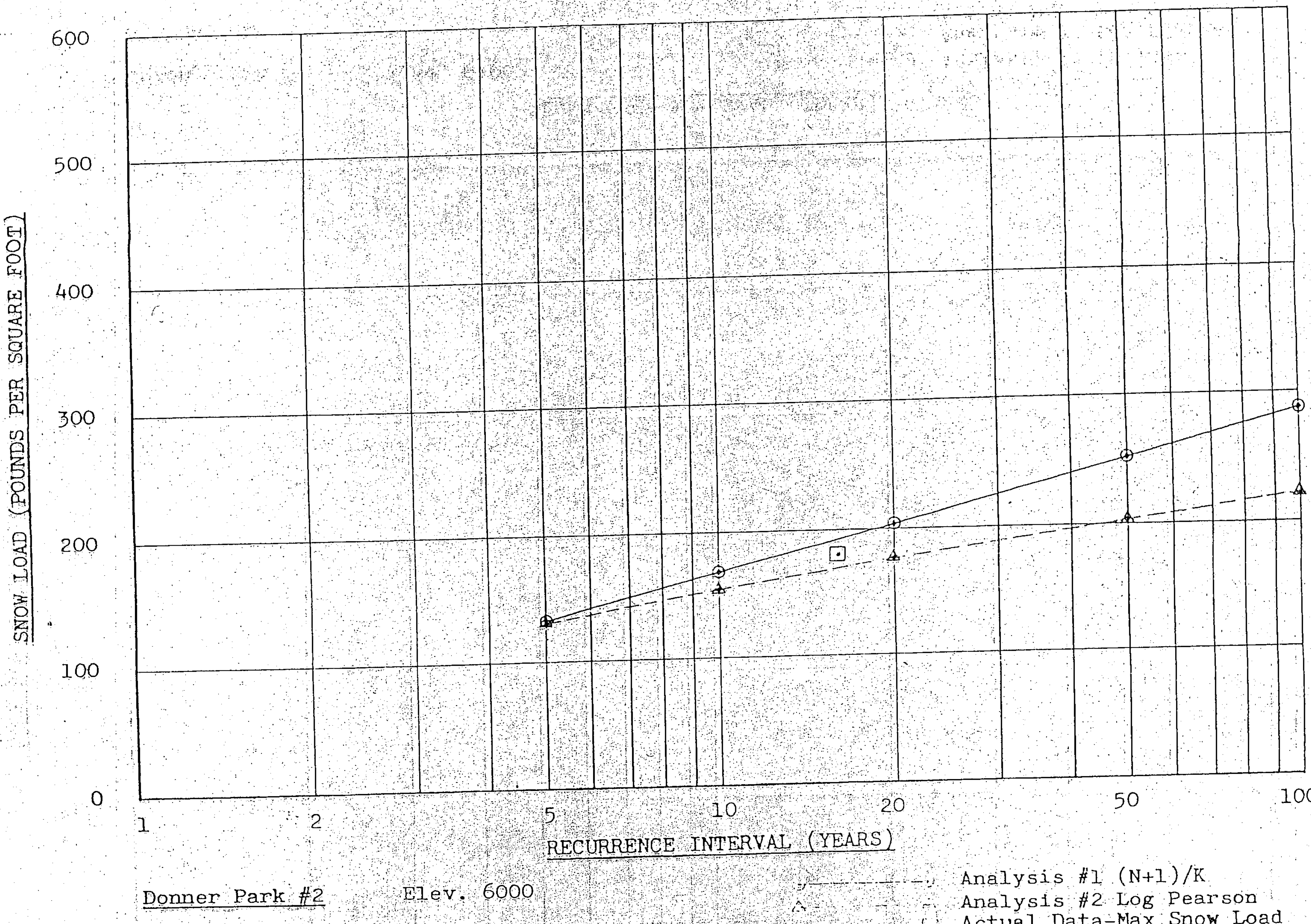
Elev. 5950

SCS No. --



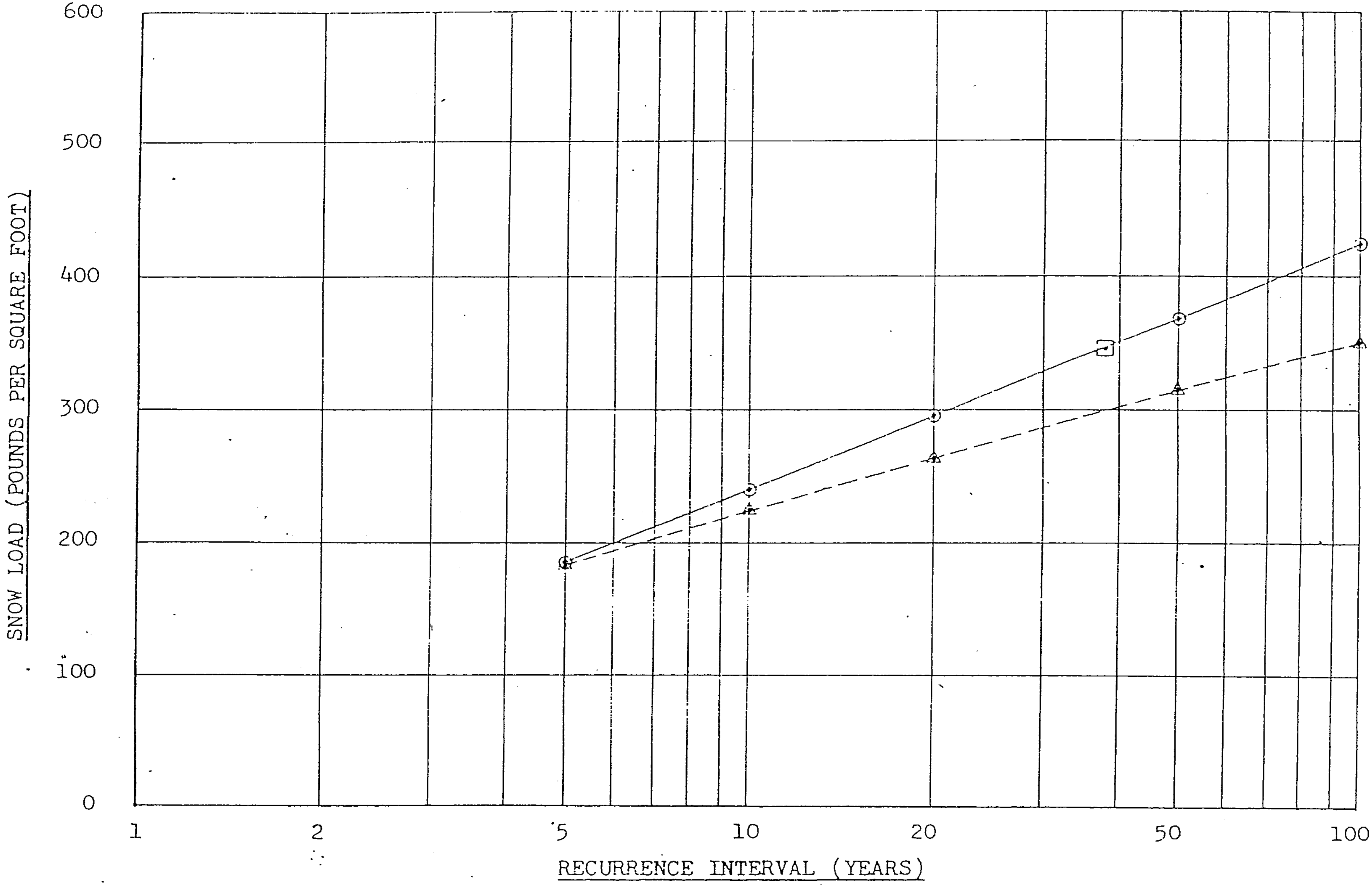
Truckee Ranger Sta. Elev. 6000

SCS No. --



Donner Park #2 Elev. 6000

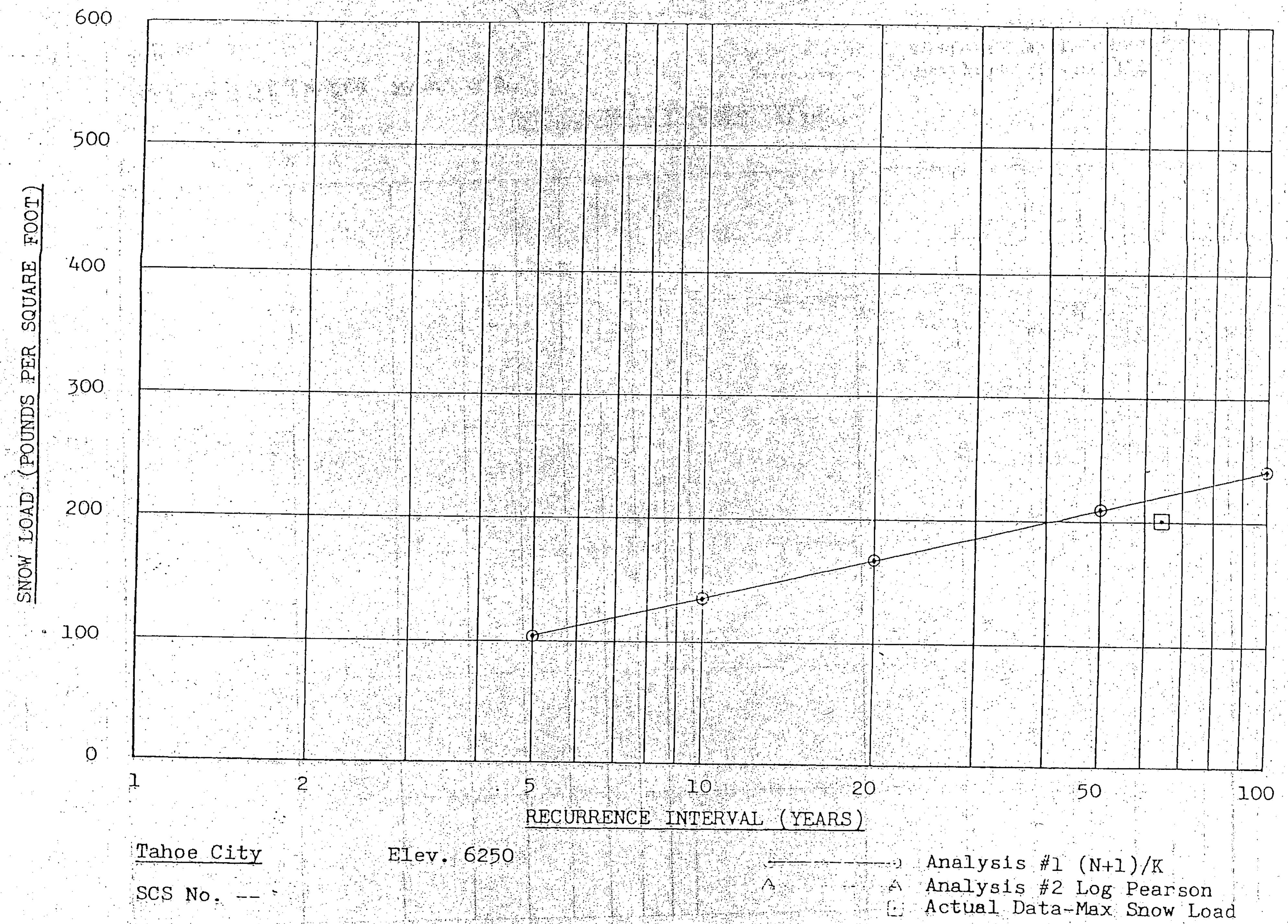
SCS No. 20K21



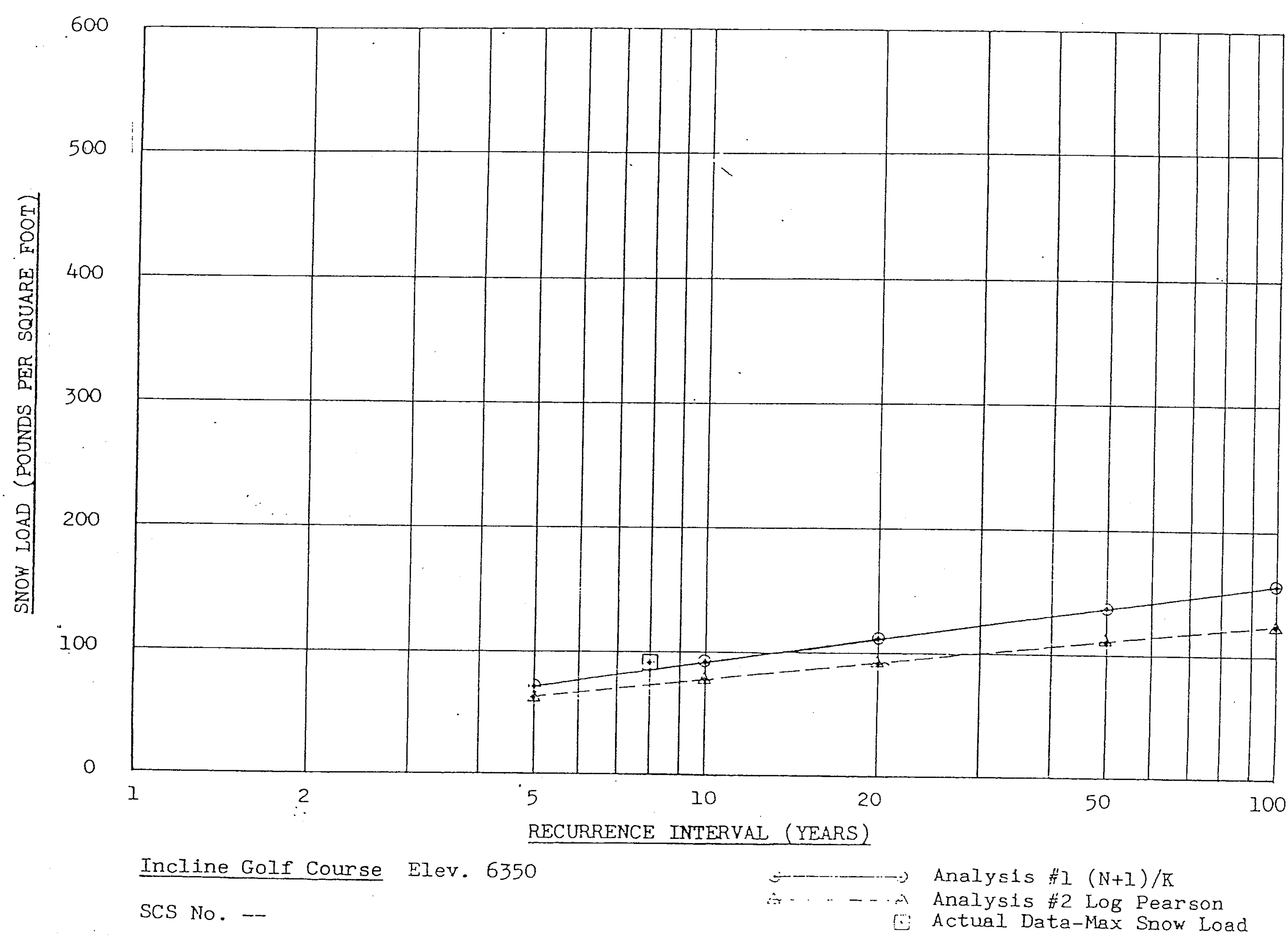
Onion Creek Elev. 6100

SCS No. --

Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow Load

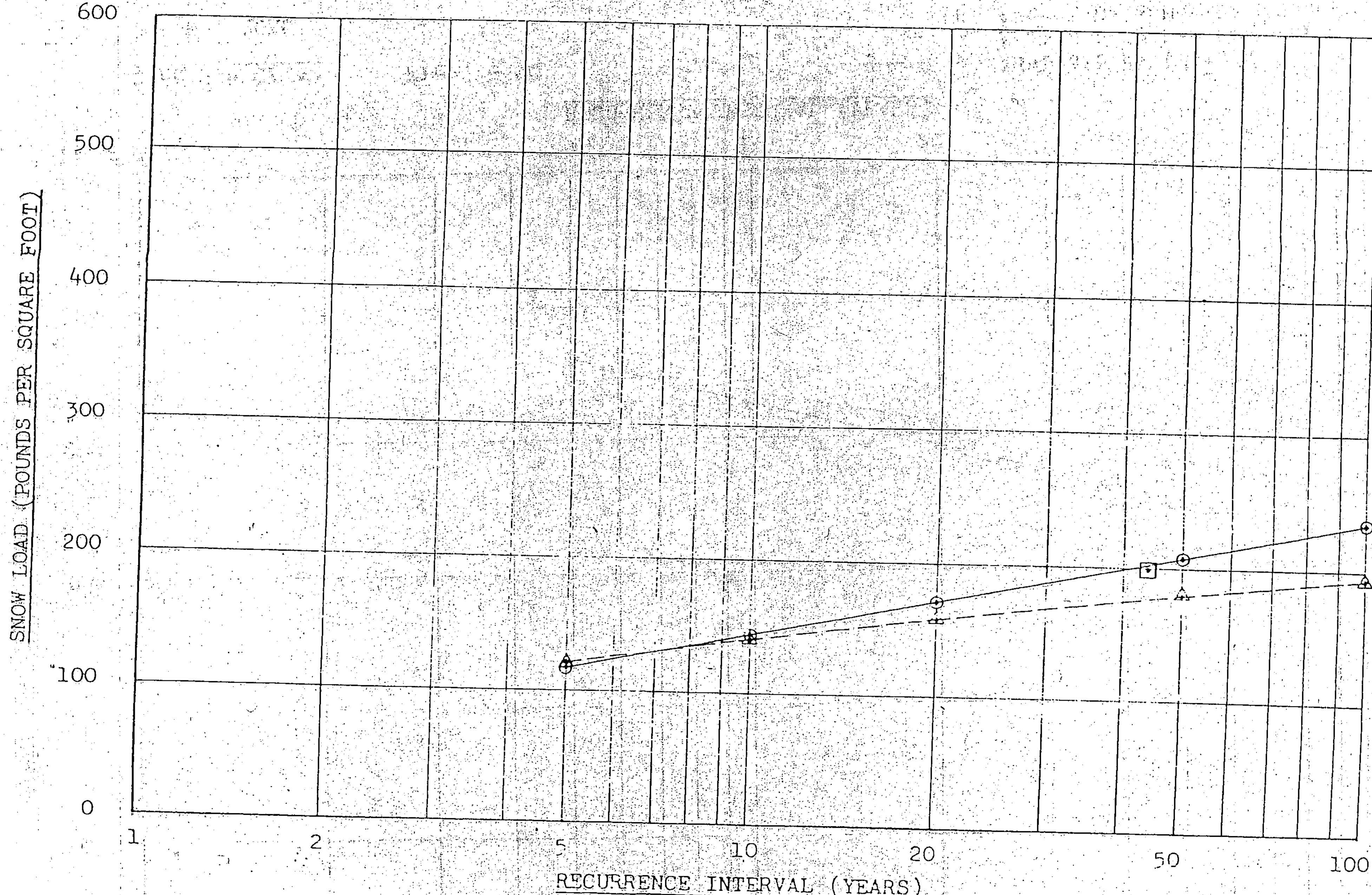


SNOW LOAD (POUNDS PER SQUARE FOOT)
600
500
400
300
200
100
0
1
2
5
10
20
50
100
RECURRENCE INTERVAL (YEARS)
Tahoe City
Elev. 6250
SCS No. --
Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow Load



Incline Golf Course Elev. 6350

SCS No. --

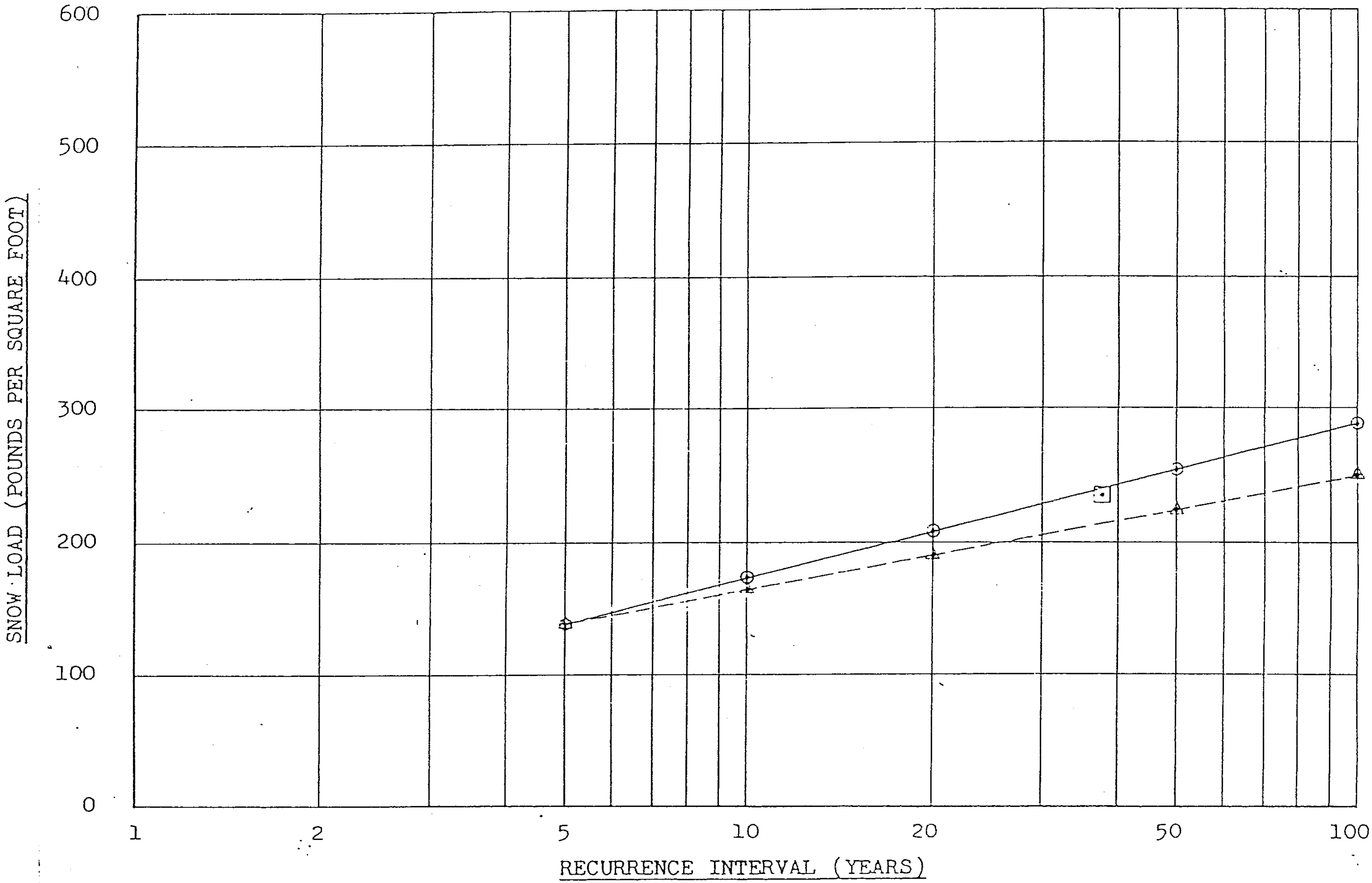


Truckee #2

SCS No. 20K13

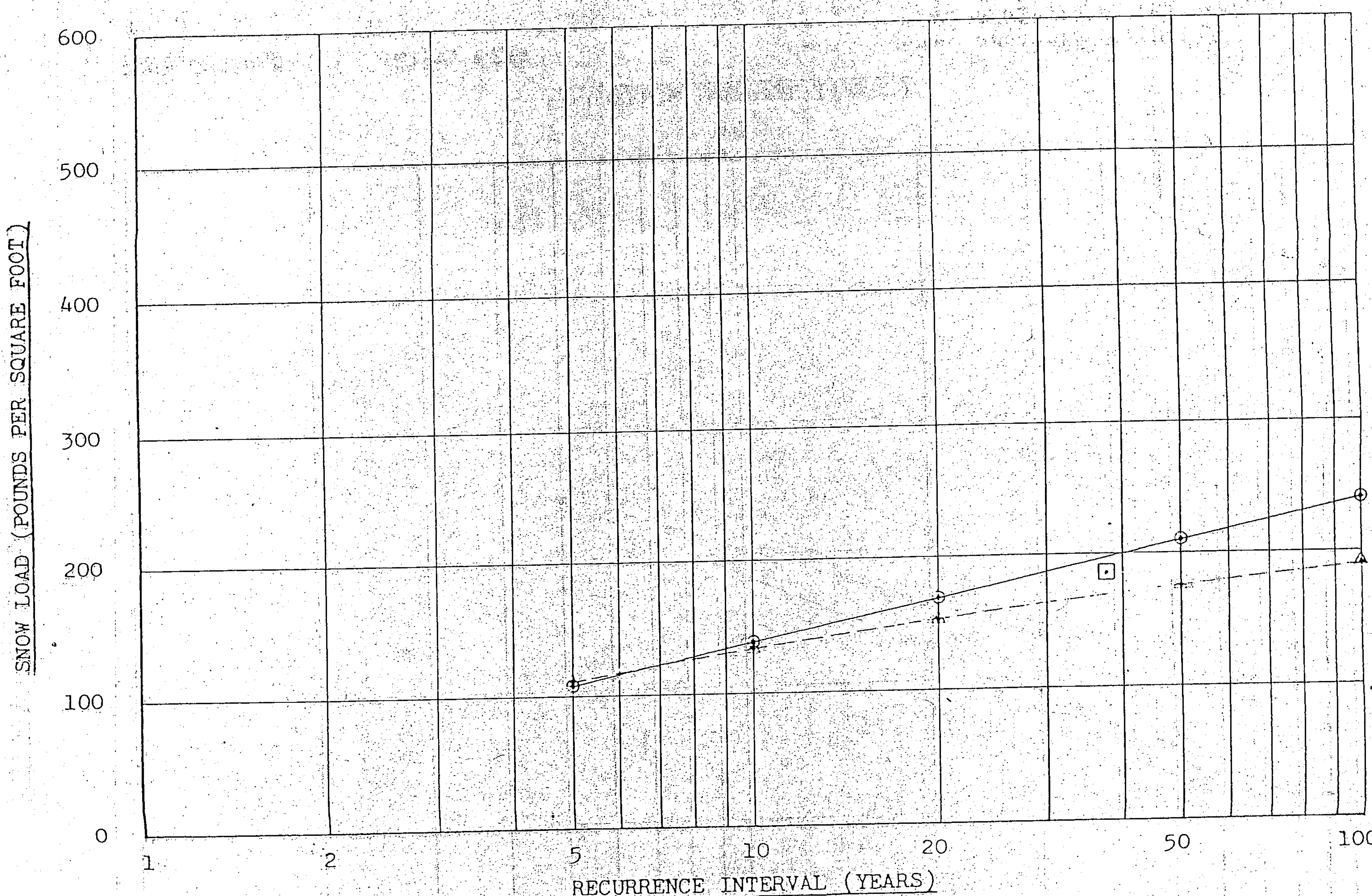
Elev. 6400

Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow Load



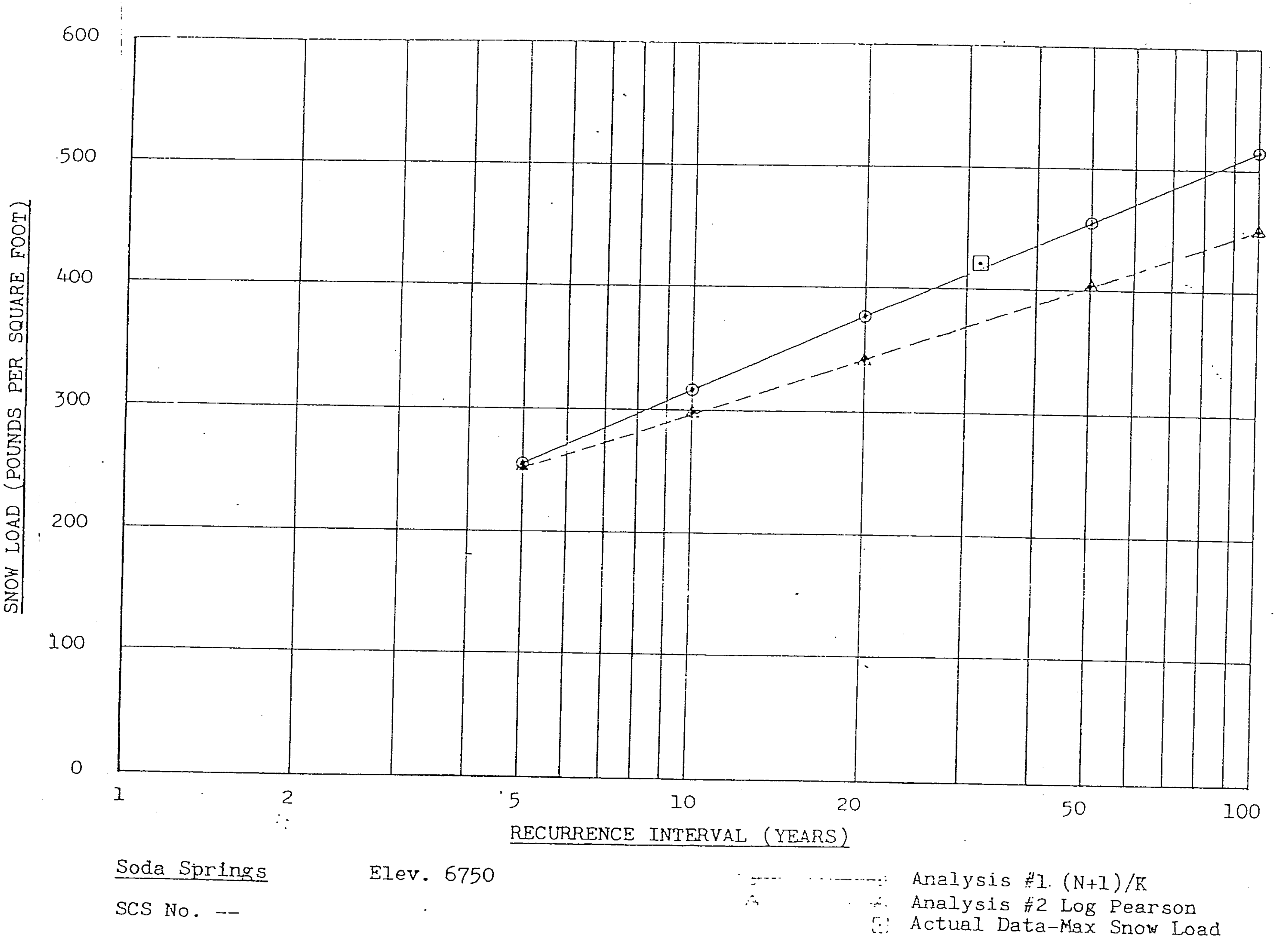
Sage Hen Creek Elev. 6500

SCS No. 20K6



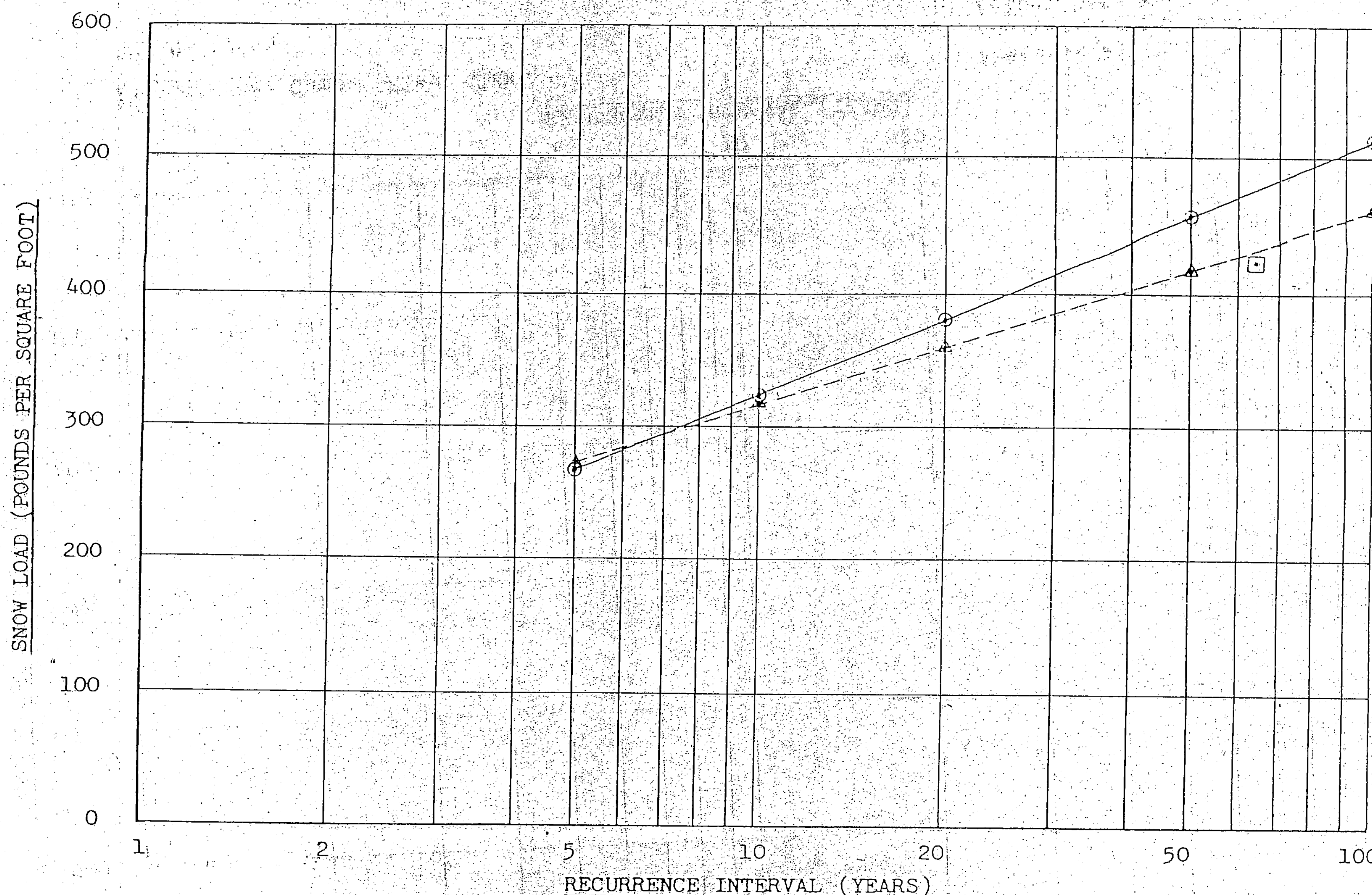
Independence Creek Elev. 6500

SCS No. 20K3



Soda Springs Elev. 6750

SCS No. --

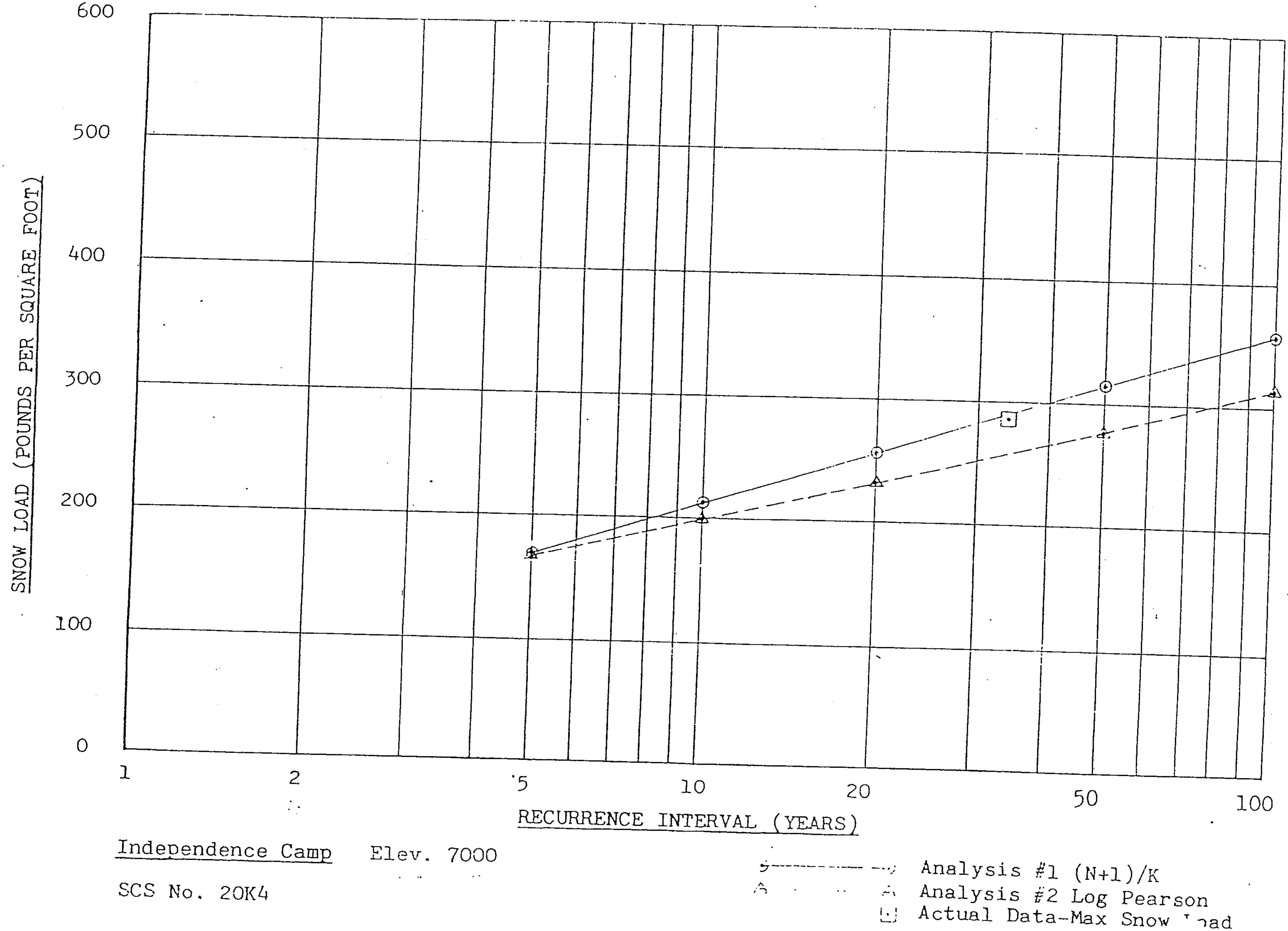


Donner Summit Elev. 6900

SCS No. 20K10

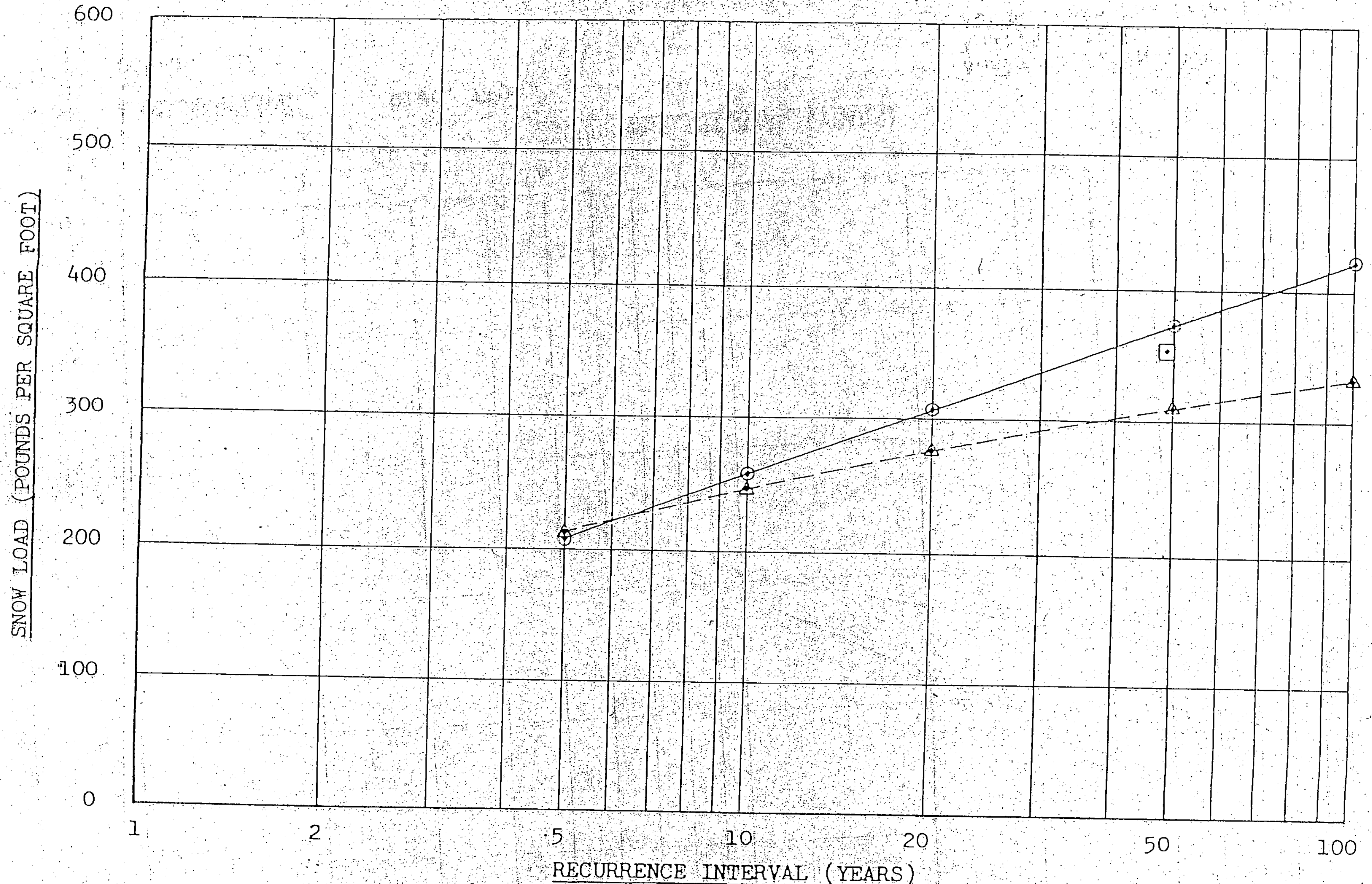
Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow Load

17B



Independence Camp Elev. 7000

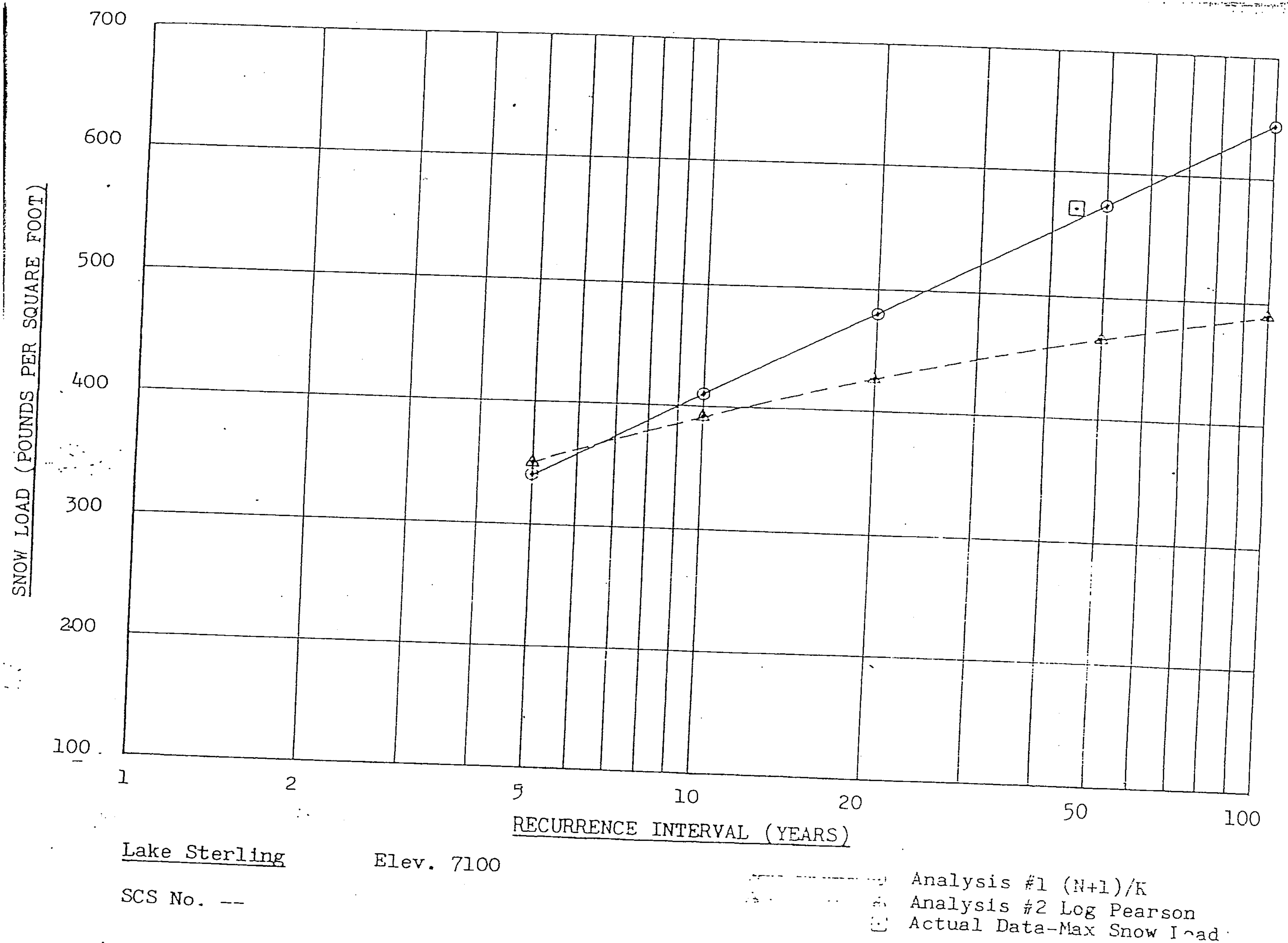
SCS No. 20K4



Webber Lake

Elev. 7000

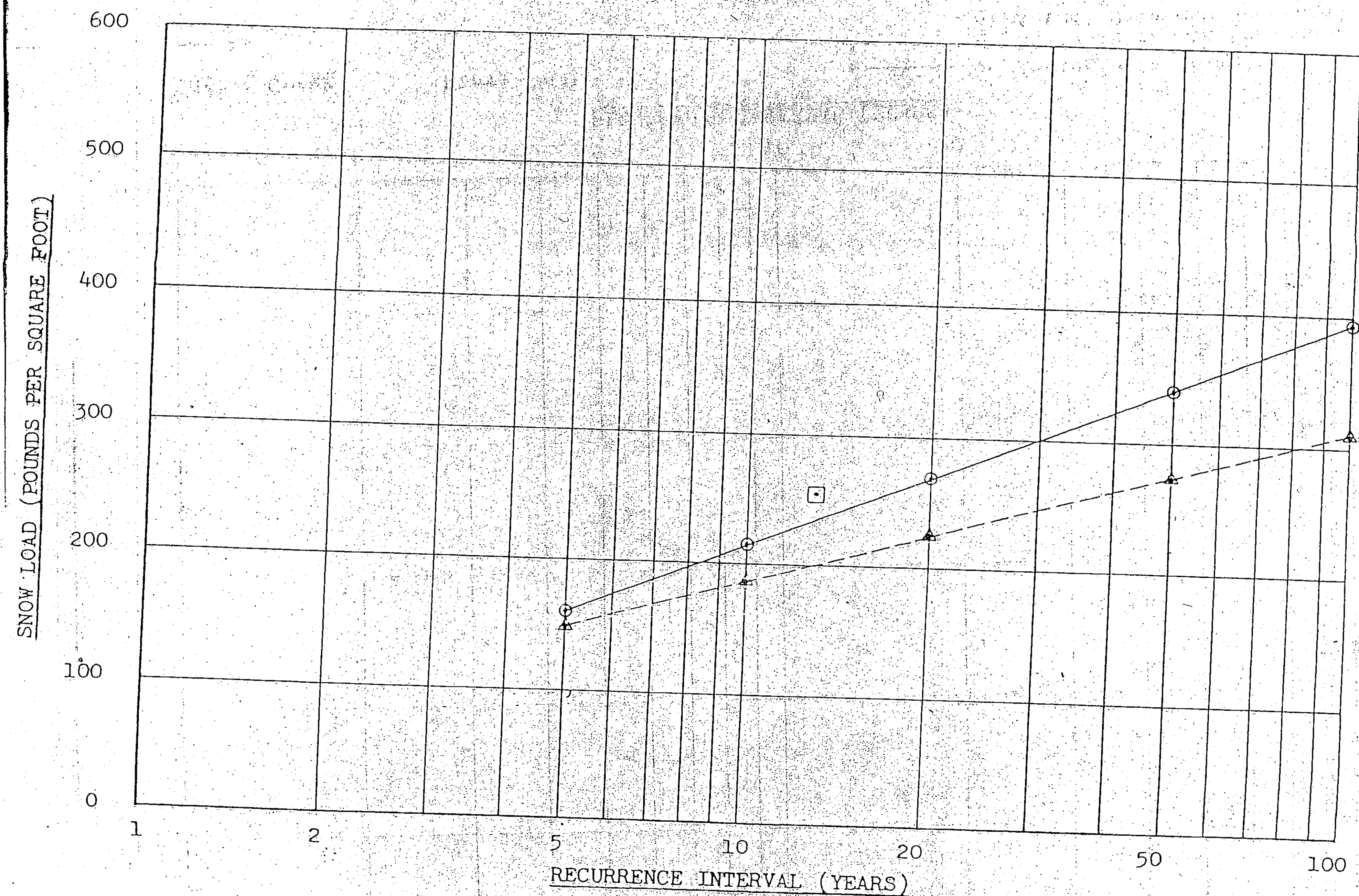
SCS No. 20K2



Lake Sterling Elev. 7100

SCS No. --

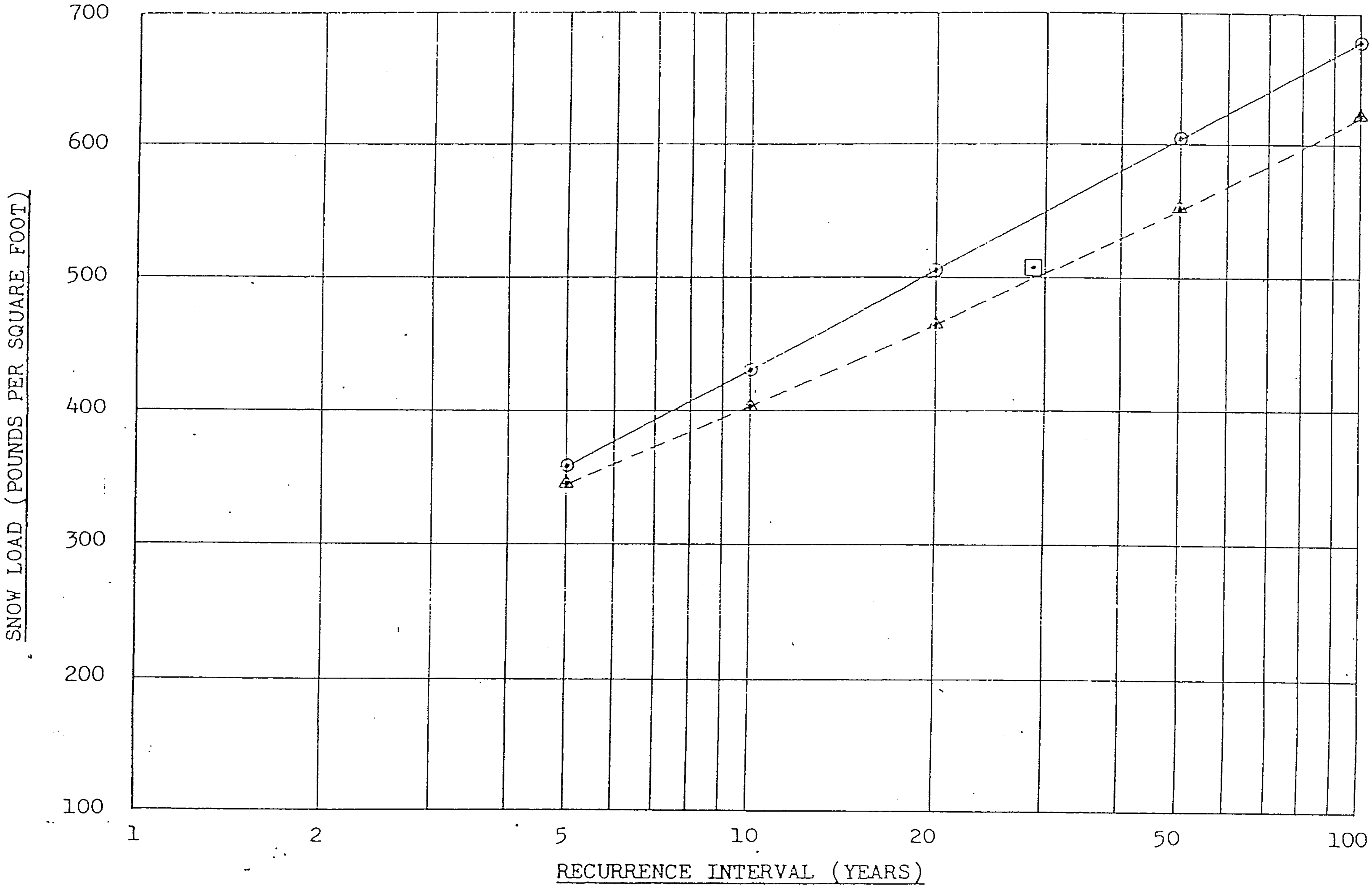
1+B



Brockway Summit Elev. 7100

SCS No. 20K22

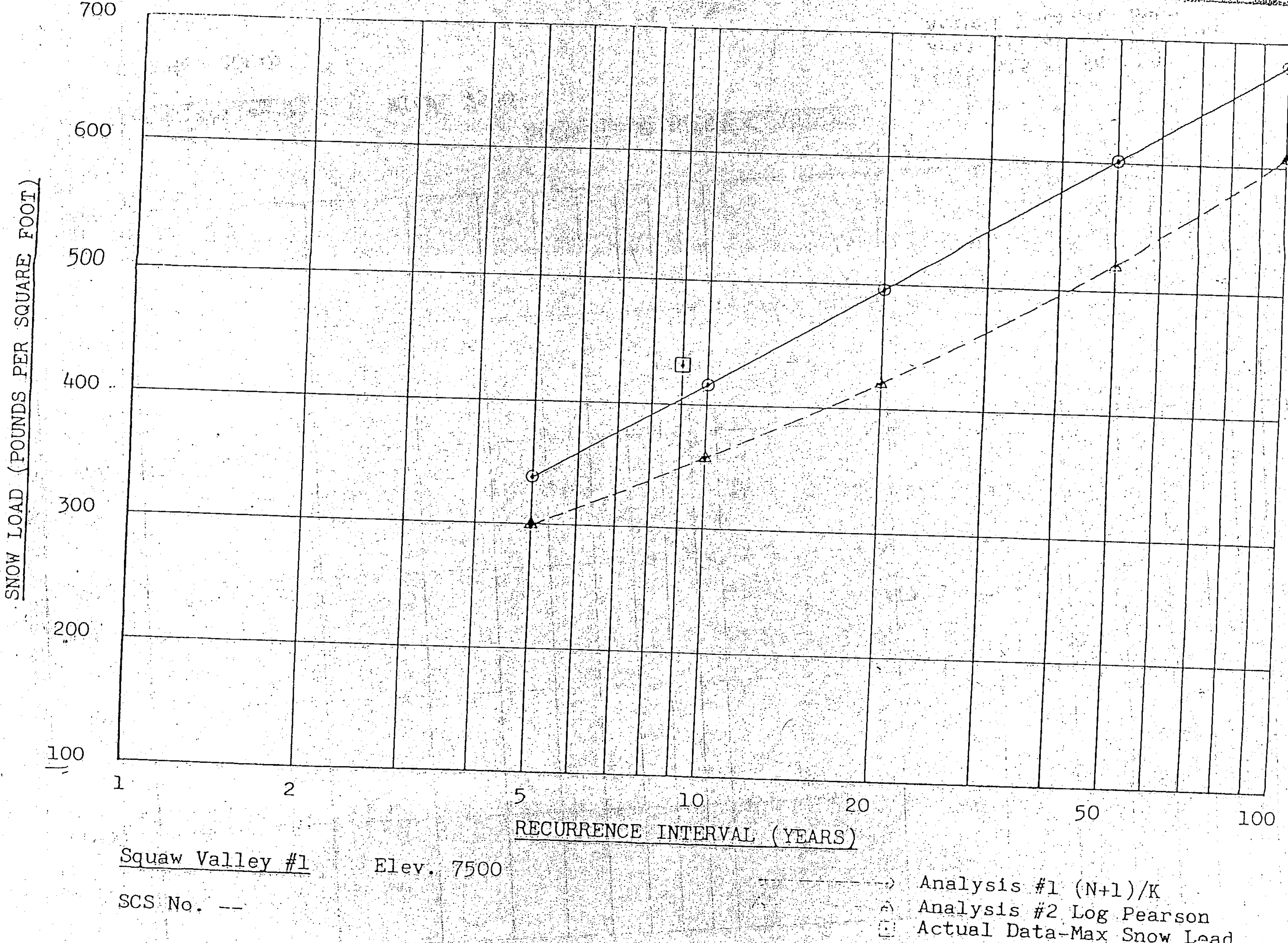
Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow 1

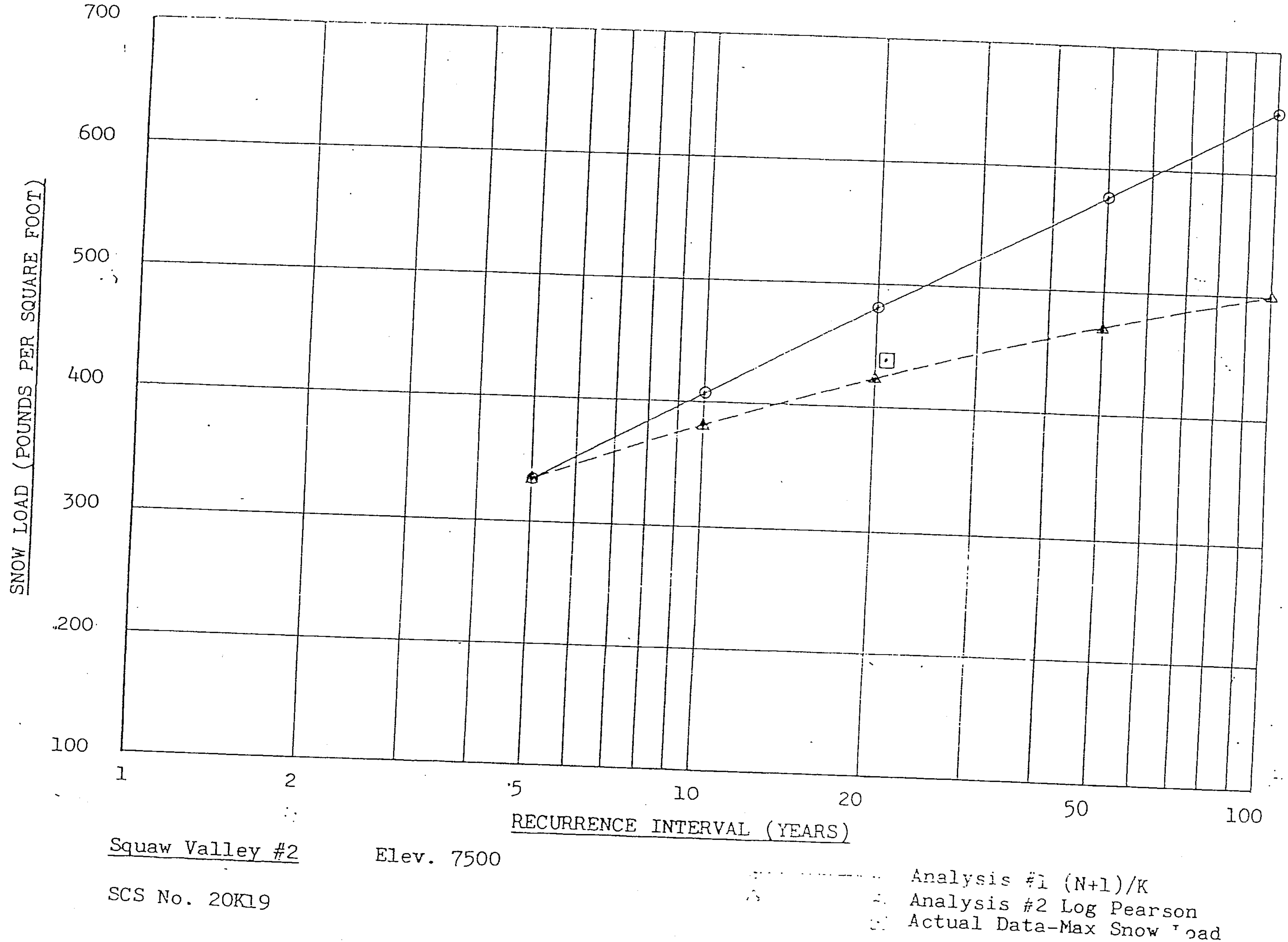


Castle Creek   Elev. 7400

SCS No. --

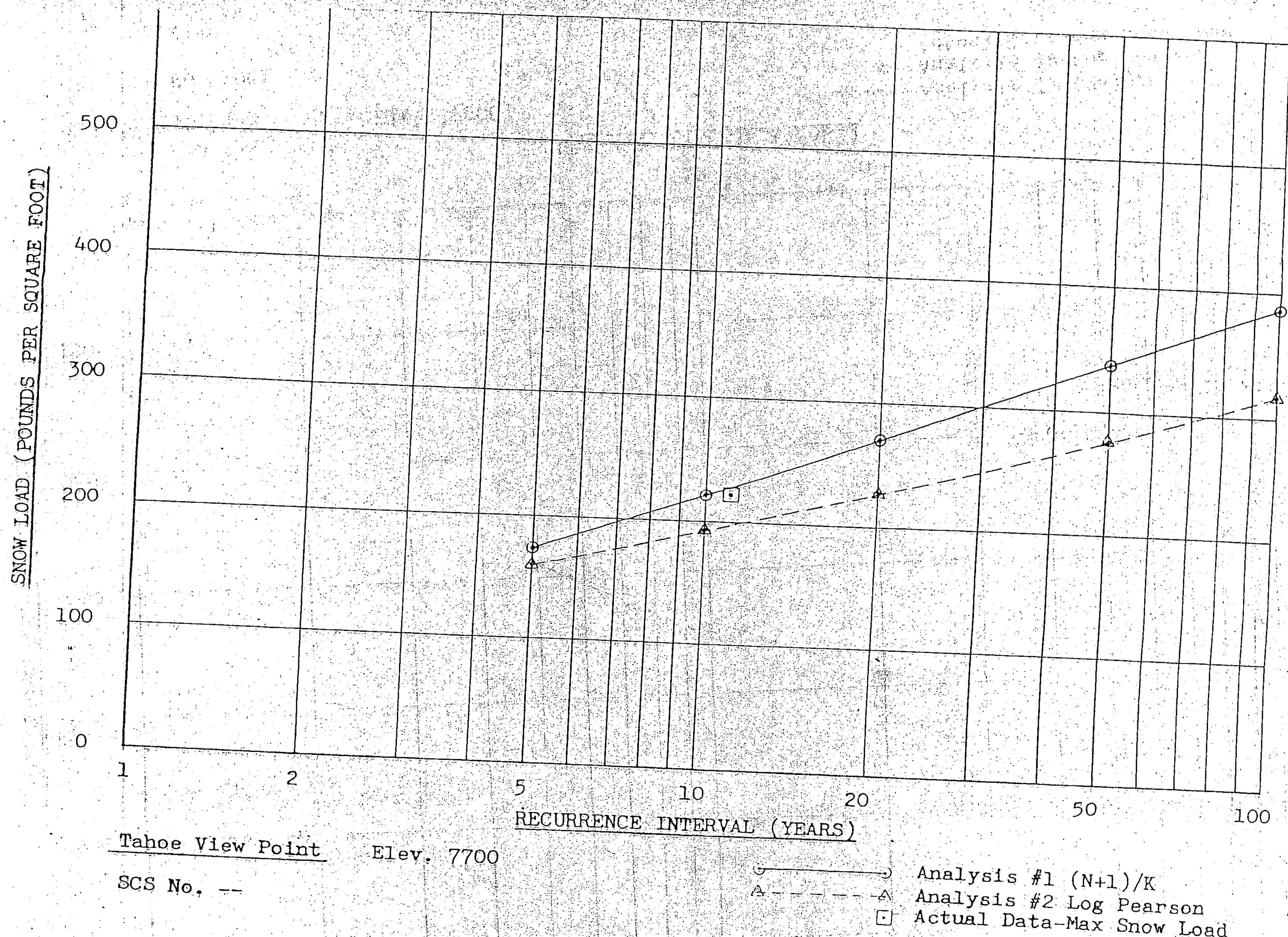
Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow Load


SNOW LOAD (POUNDS PER SQUARE FOOT)
100
200
300
400
500
600
700
1
2
5
10
20
50
100
RECURRENCE INTERVAL (YEARS)
Squaw Valley #1
Elev. 7500
SCS No. --
Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow Load



SNOW LOAD (POUNDS PER SQUARE FOOT)
700
600
500
400
300
200
100
1
2
5
10
20
50
100
RECURRENCE INTERVAL (YEARS)
Squaw Valley #2
Elev. 7500
SCS No. 20K19
Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow Load

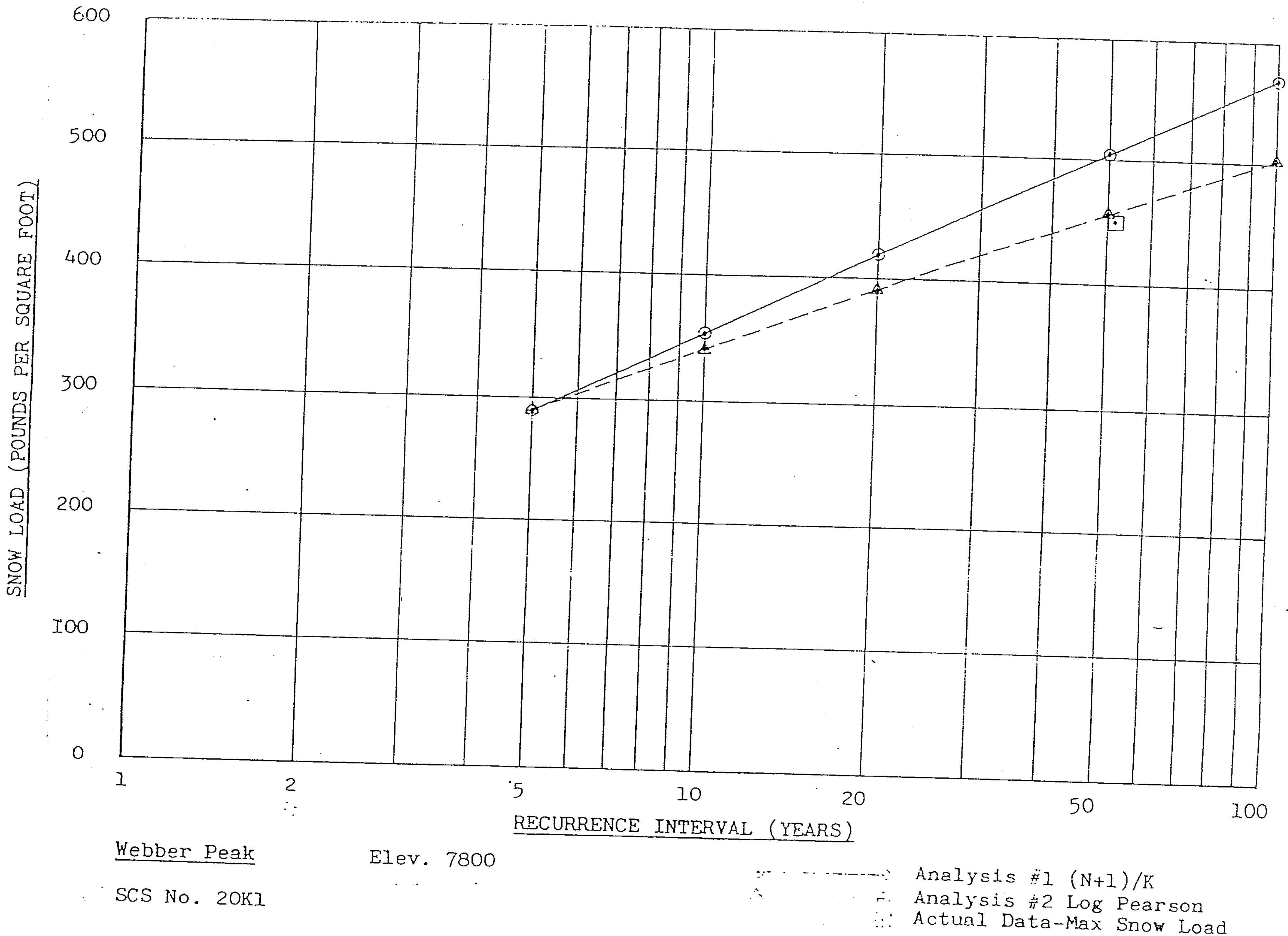
10B



Tahoe View Point   Elev. 7700

SCS No. --

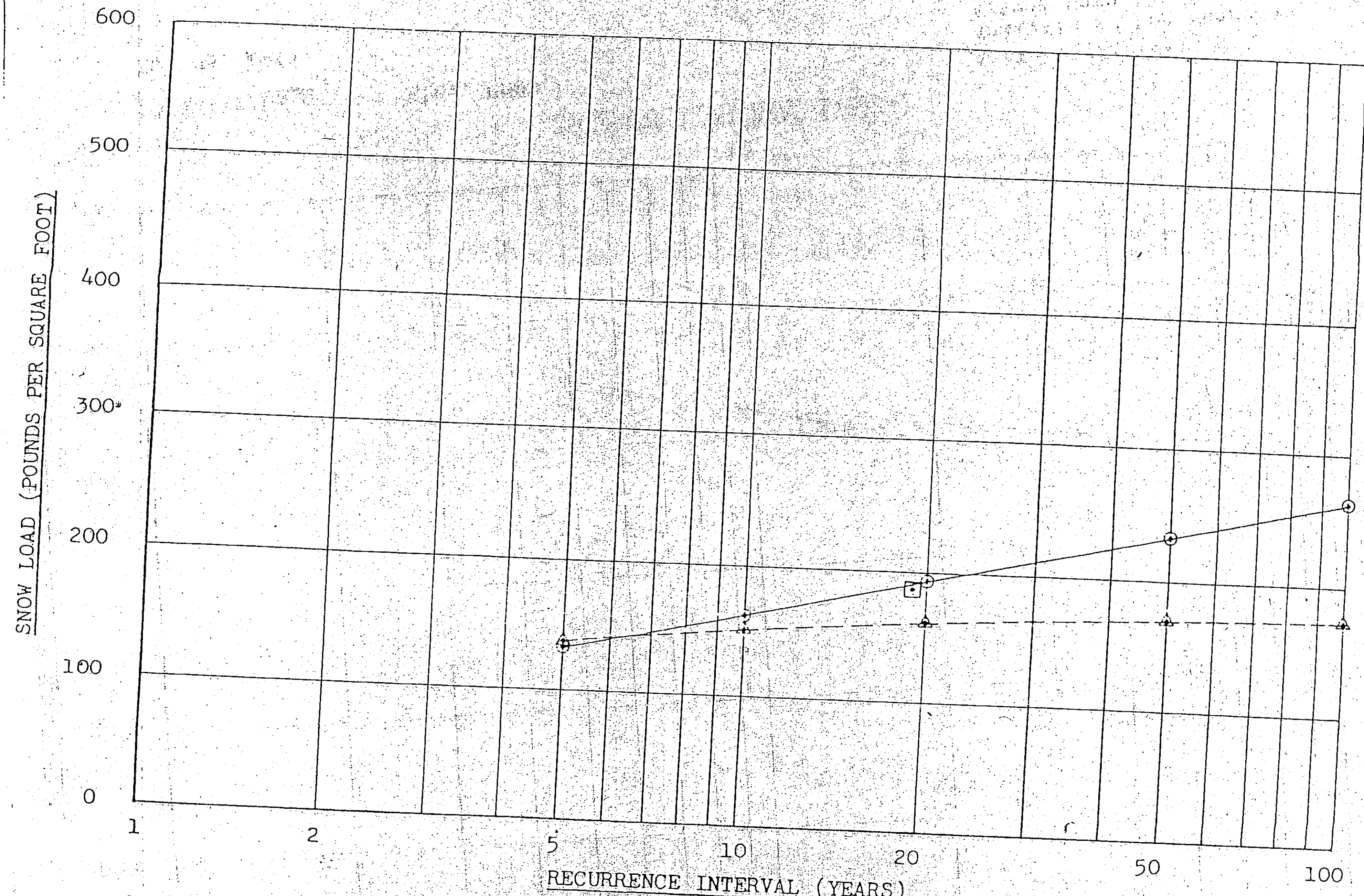
B



Webber Peak

Elev. 7800

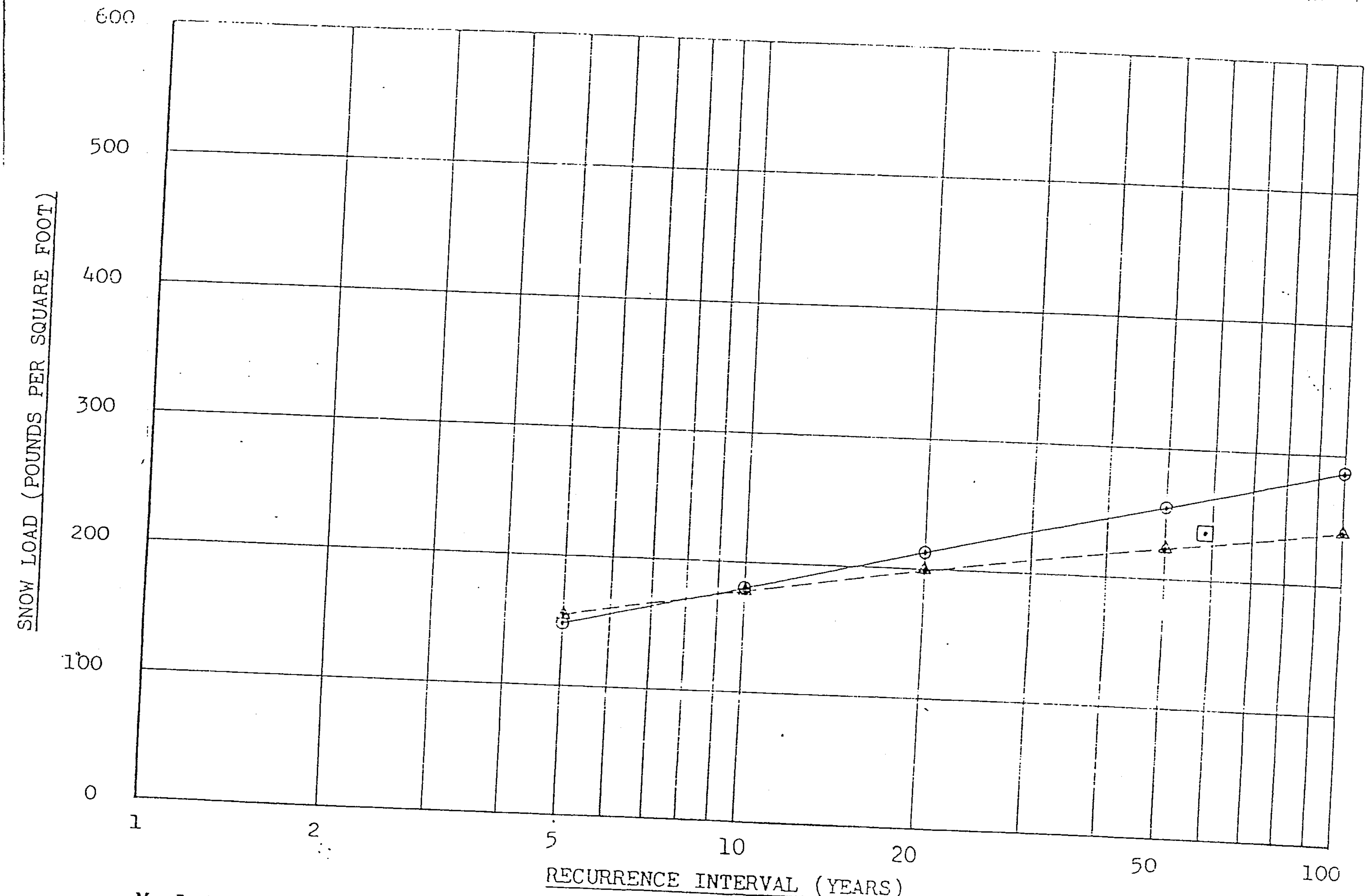
SCS No. 20K1



Granite Peak

Elev. 8000

SCS No. --



Marlette Lake

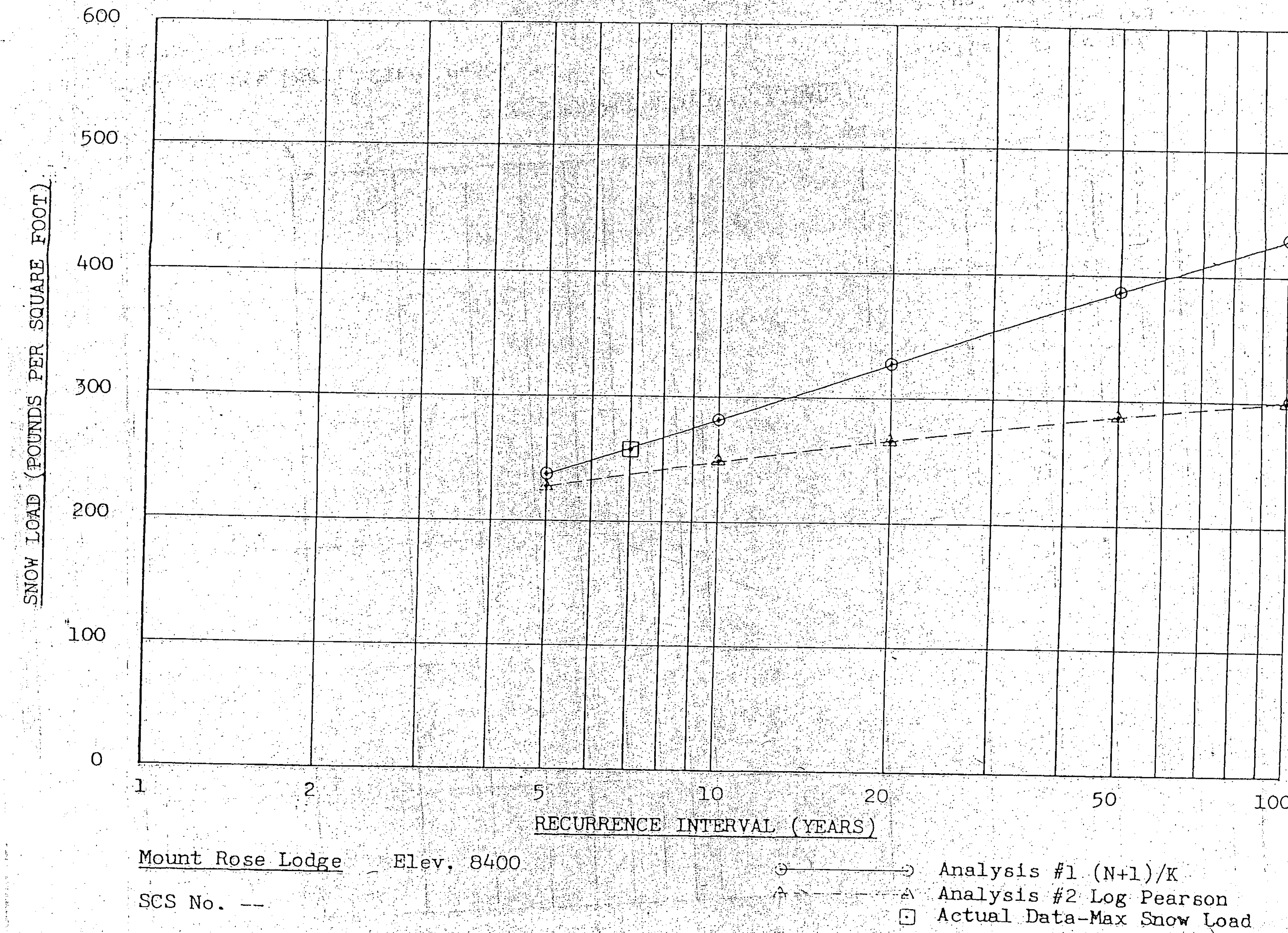
SCS No. 19K4

Elev. 8000

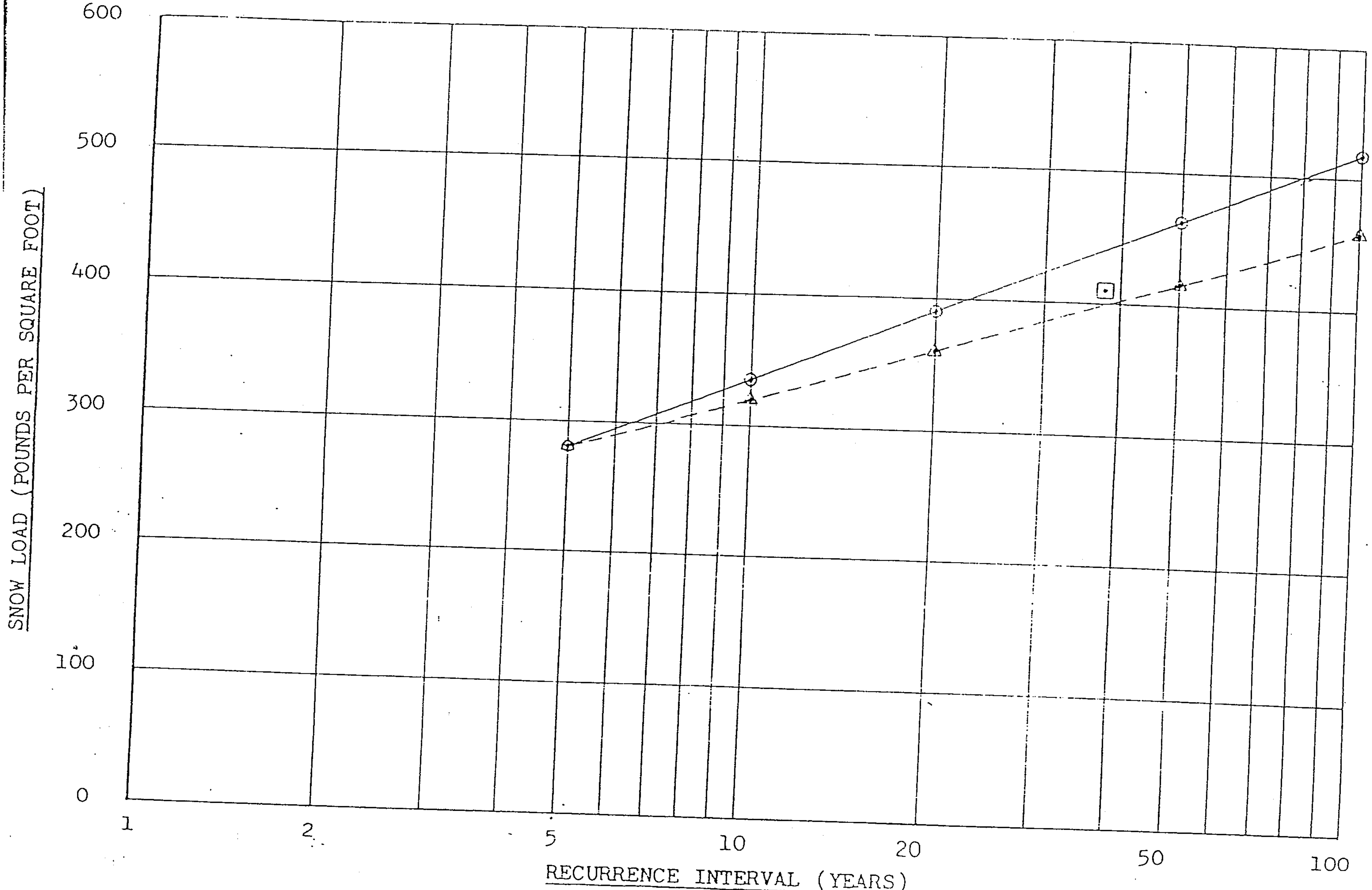
Analysis #1 (N+1)/K

Analysis #2 Log Pearson

Actual Data-Max Snow



SNOW LOAD (POUNDS PER SQUARE FOOT)
600
500
400
300
200
100
0
1
2
5
10
20
50
100
RECURRENCE INTERVAL (YEARS)
Mount Rose Lodge Elev. 8400
SCS No. --
Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow Load

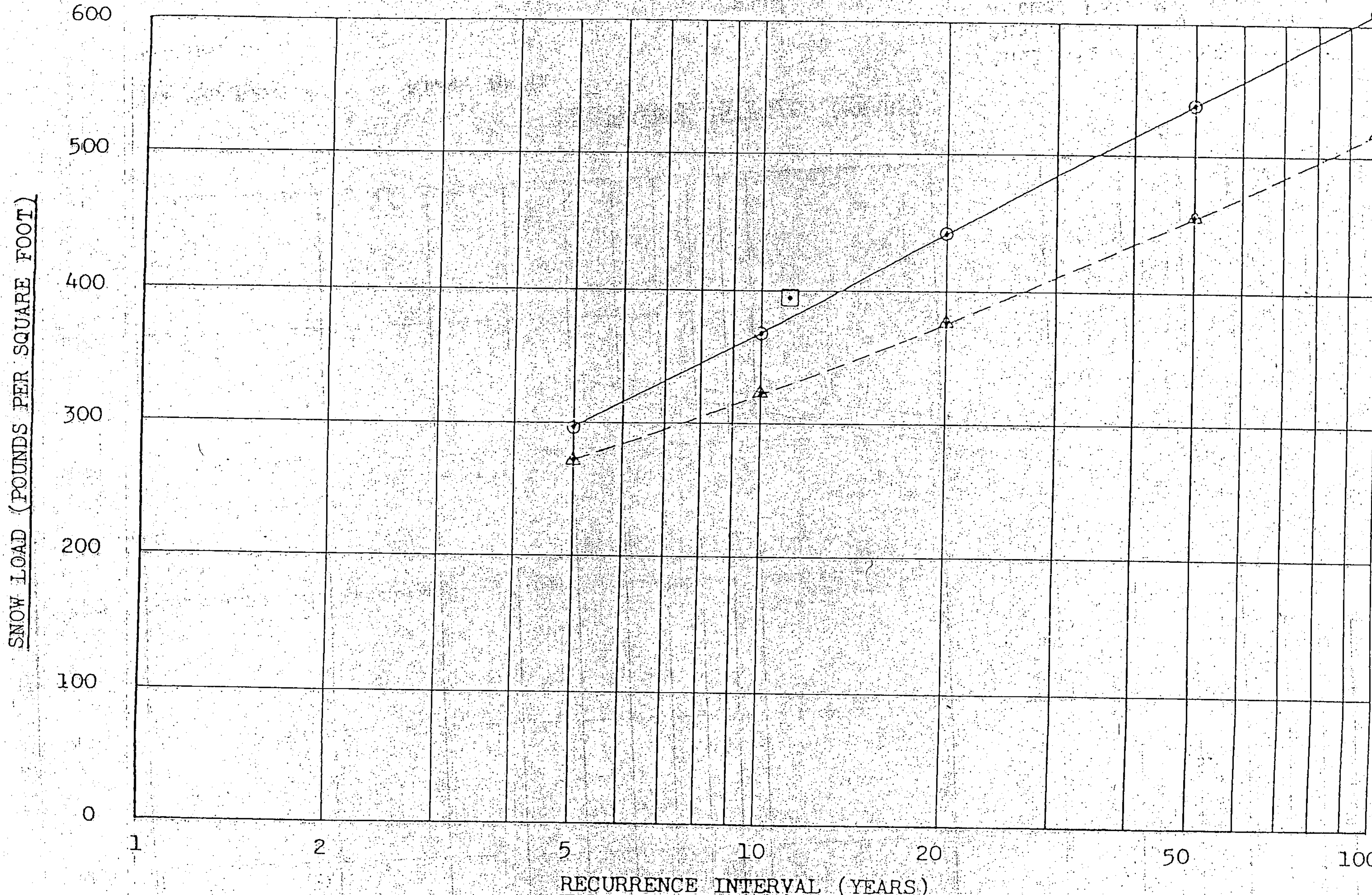


Independence Lake Elev. 8450

SCS No. 20K5

Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow ! ›d

4B



Third Creek

Elev. 8600

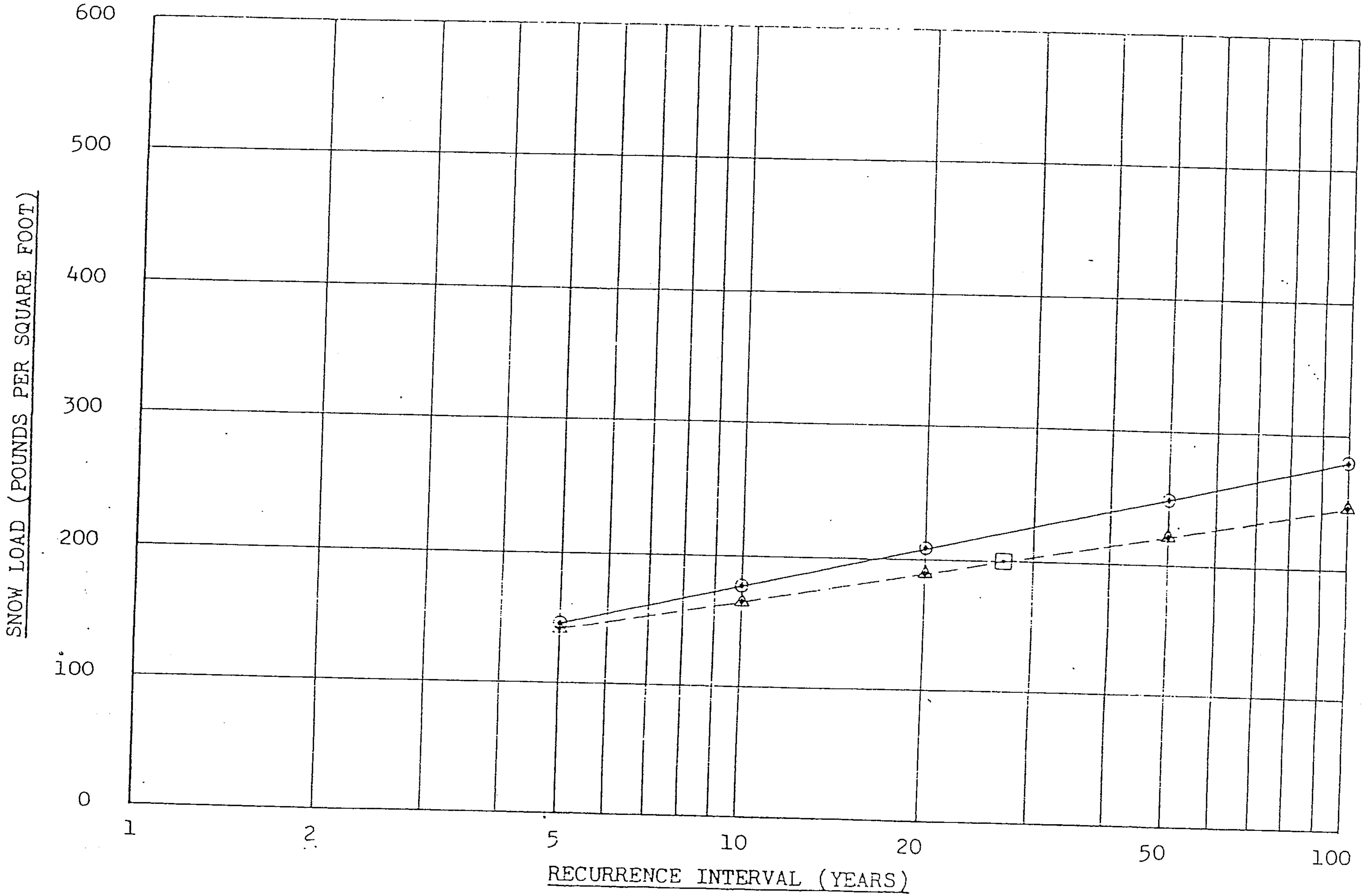
SCS No. --

Analysis #1 (N+1)/K

Analysis #2 Log Pearson

Actual Data-Max Snow Load

3B



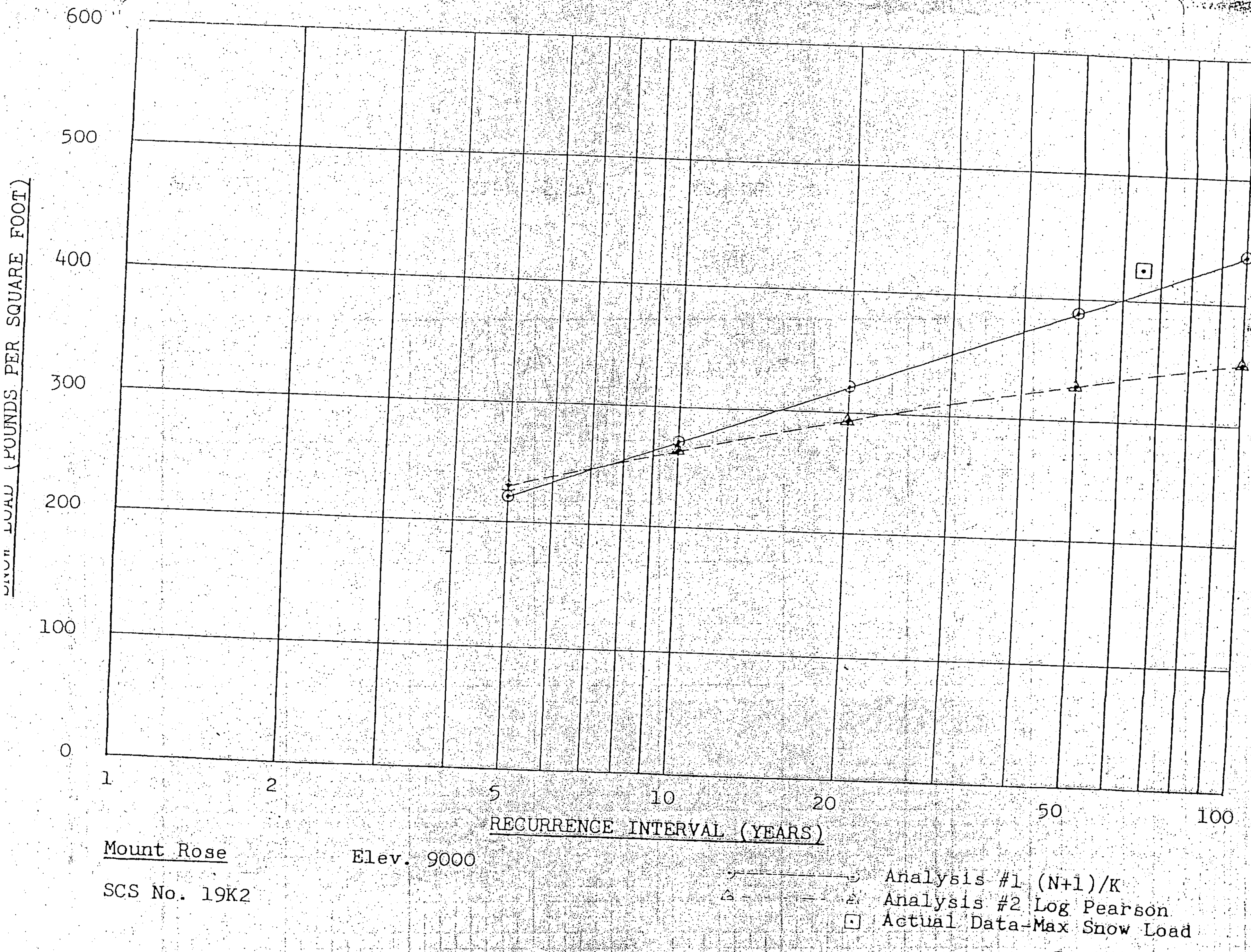
Big Meadows

Elev. 8800

SCS No. --

Analysis #1 (N+1)/K
Analysis #2 Log Pearson
Actual Data-Max Snow ˉad

2B

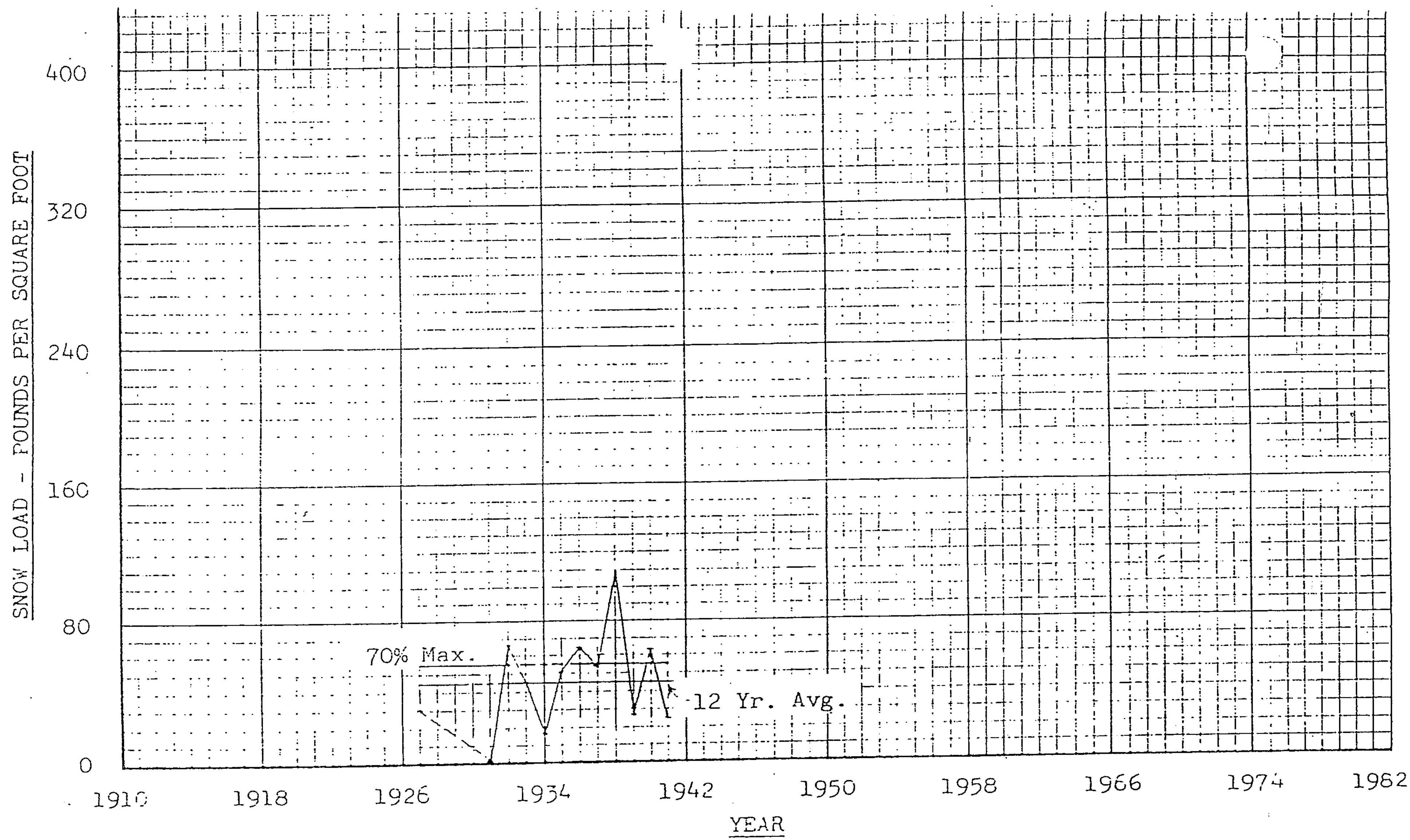


Mount Rose

SCS No. 19K2

Elev. 9000

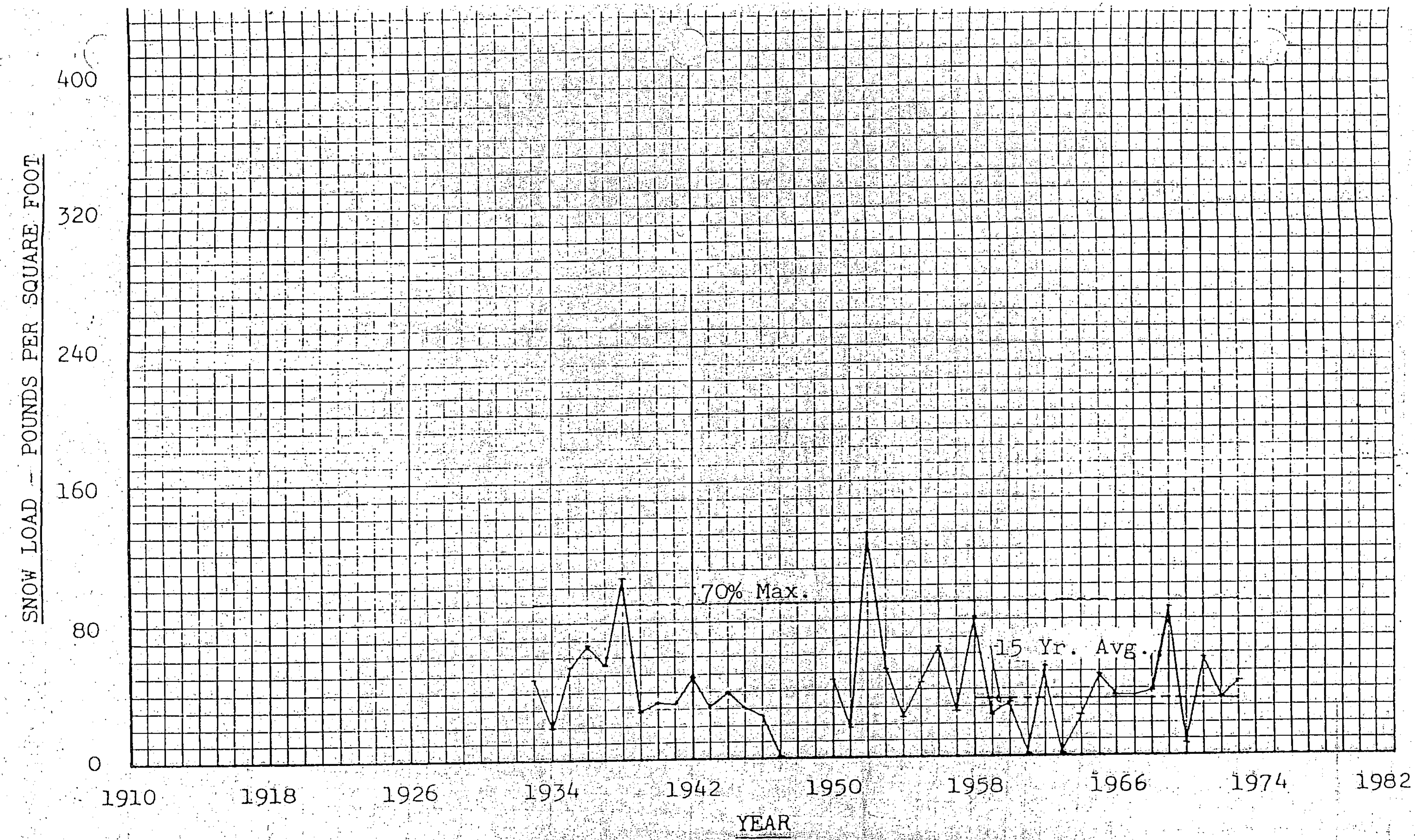
GRAPH 1B



Boca #1 Elev. 5800 SCS No. -- 1927-1941

29A

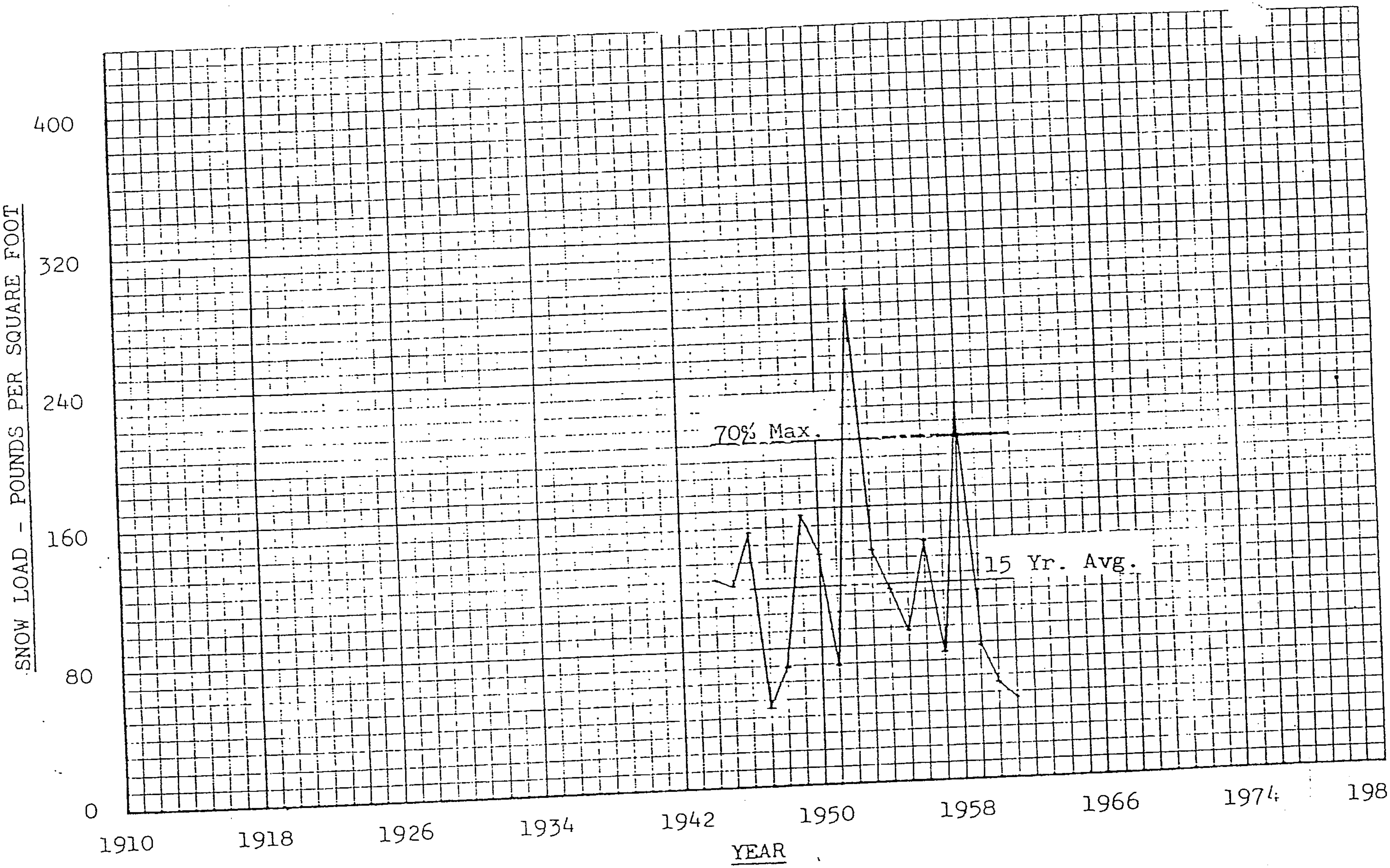
GRAPHS
1B thru 29B



Boca #2 Elev. 5900 SCS No. 20K14 1933-1973

28A

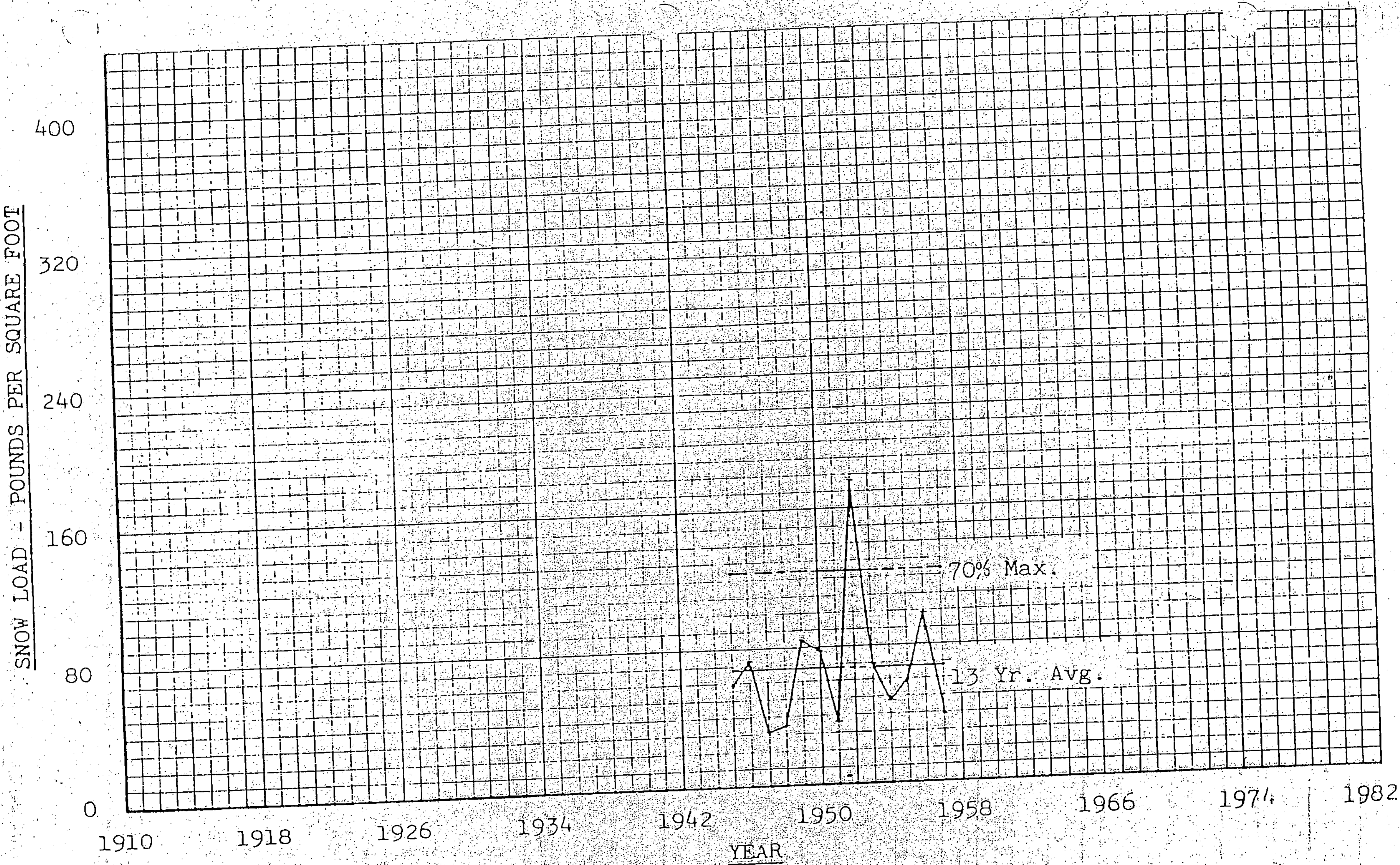
GRAPHS 1B thru 29B



Donner Lake Elev. 5950 SCS No. 1944-1961

27A

1B thru 29B

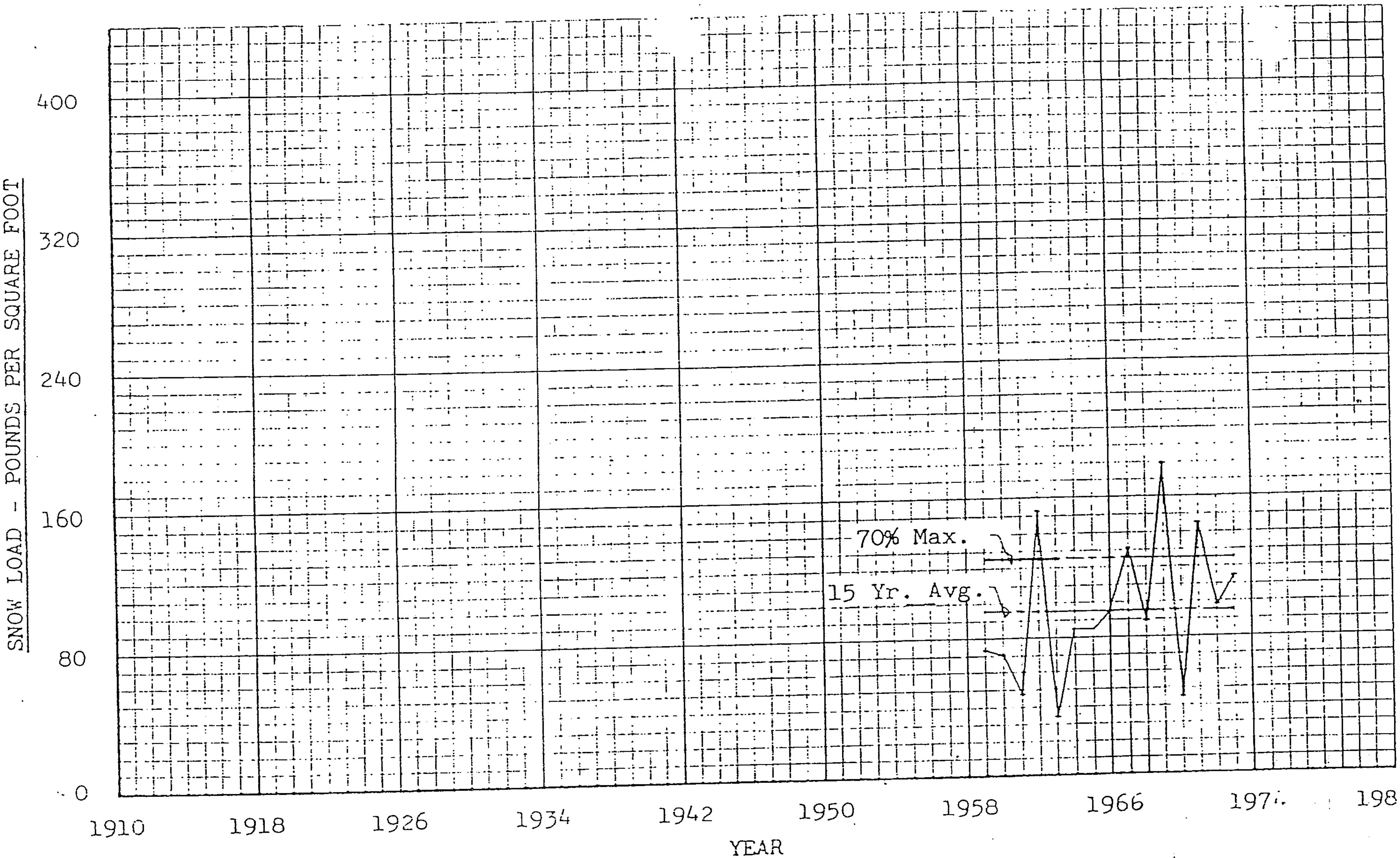


Truckee Ranger Station Elev. 6000 SCS No. --

1945-1957

26A

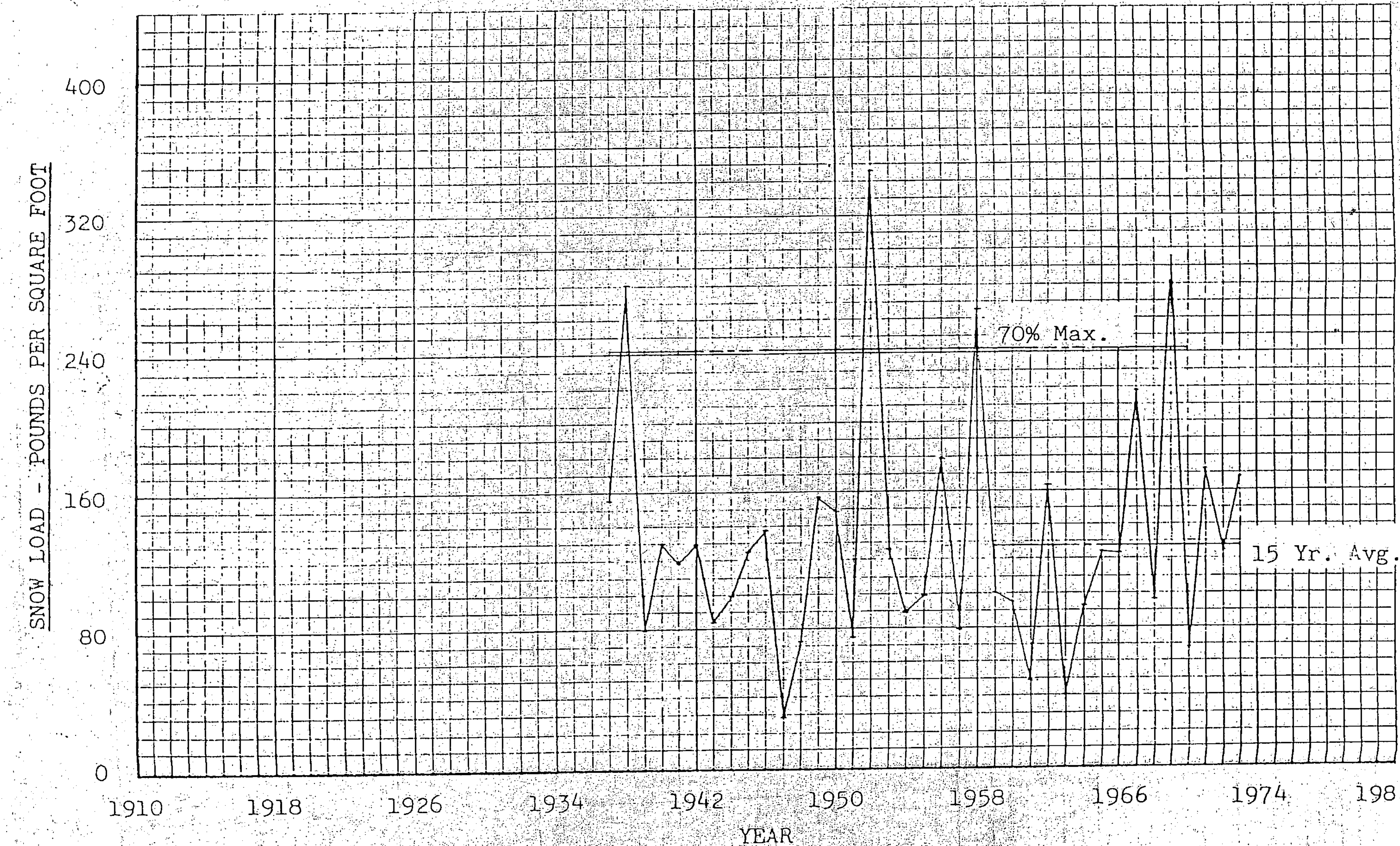
1B thru 29B



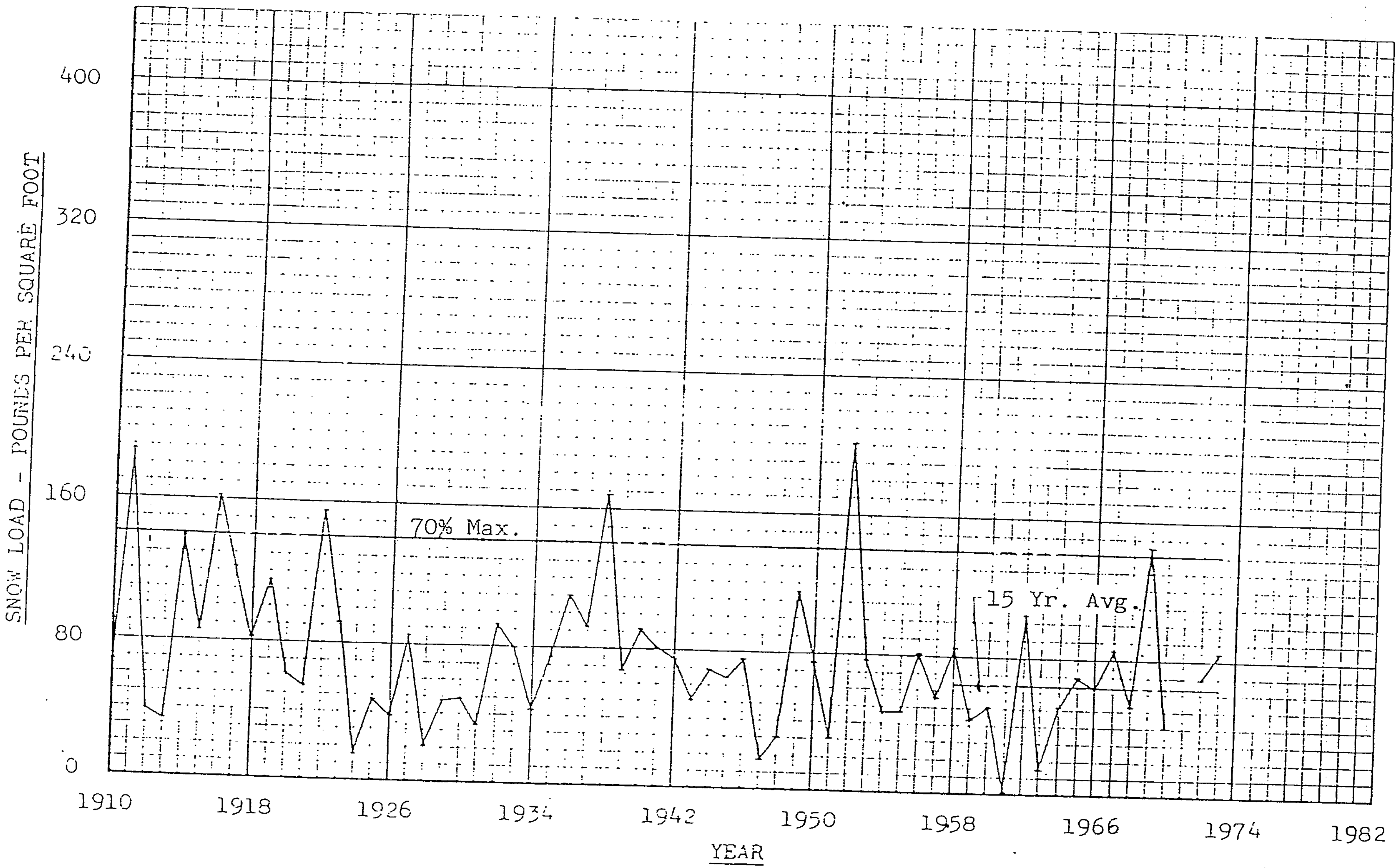
Donner Park #2 Elev. 6000 SCS No. 20K21 1959-1973

25A

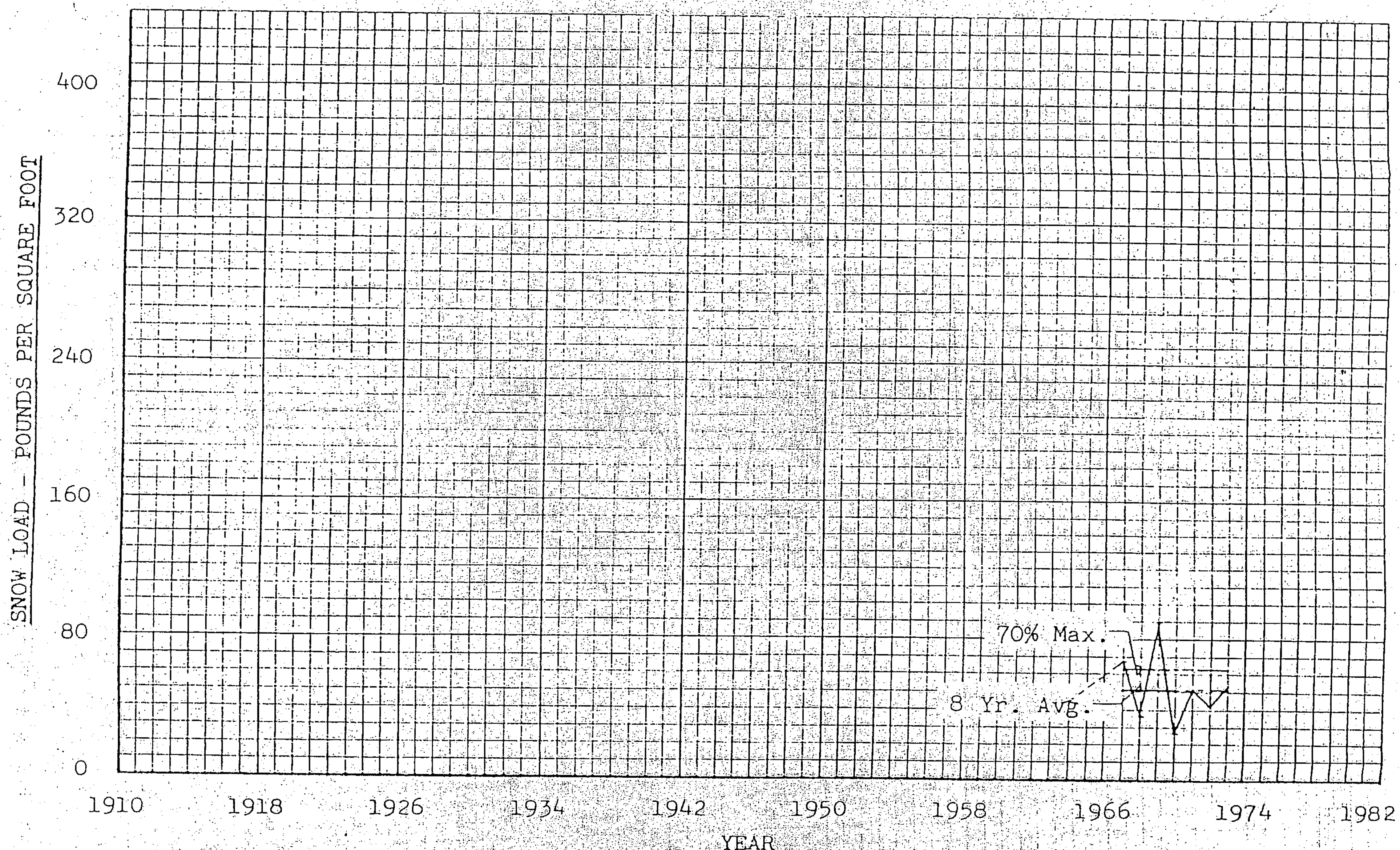
GRAPHS
1B thru 29B



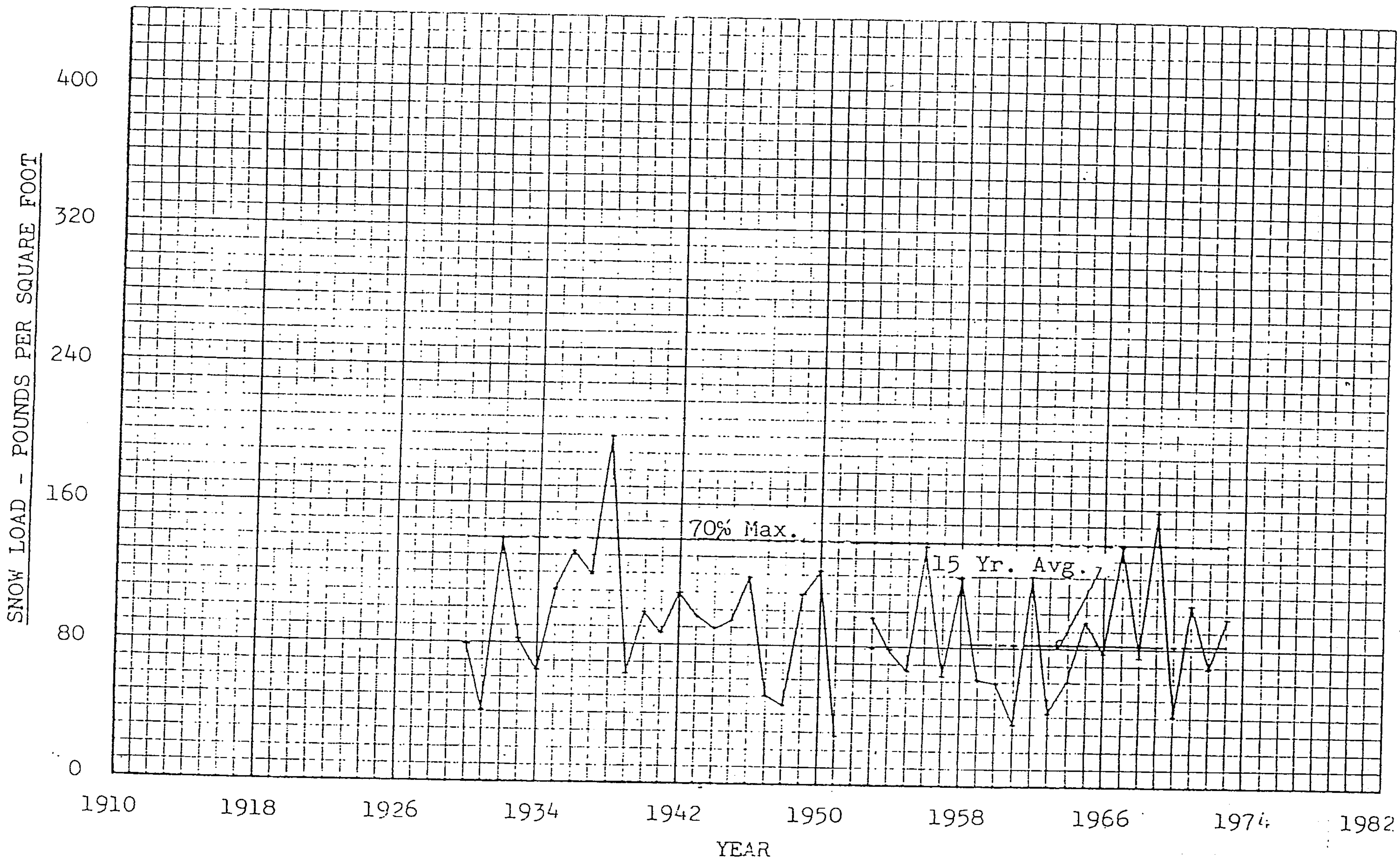
Onion Creek Elev. 6100 SCS No. -- 1937-1973



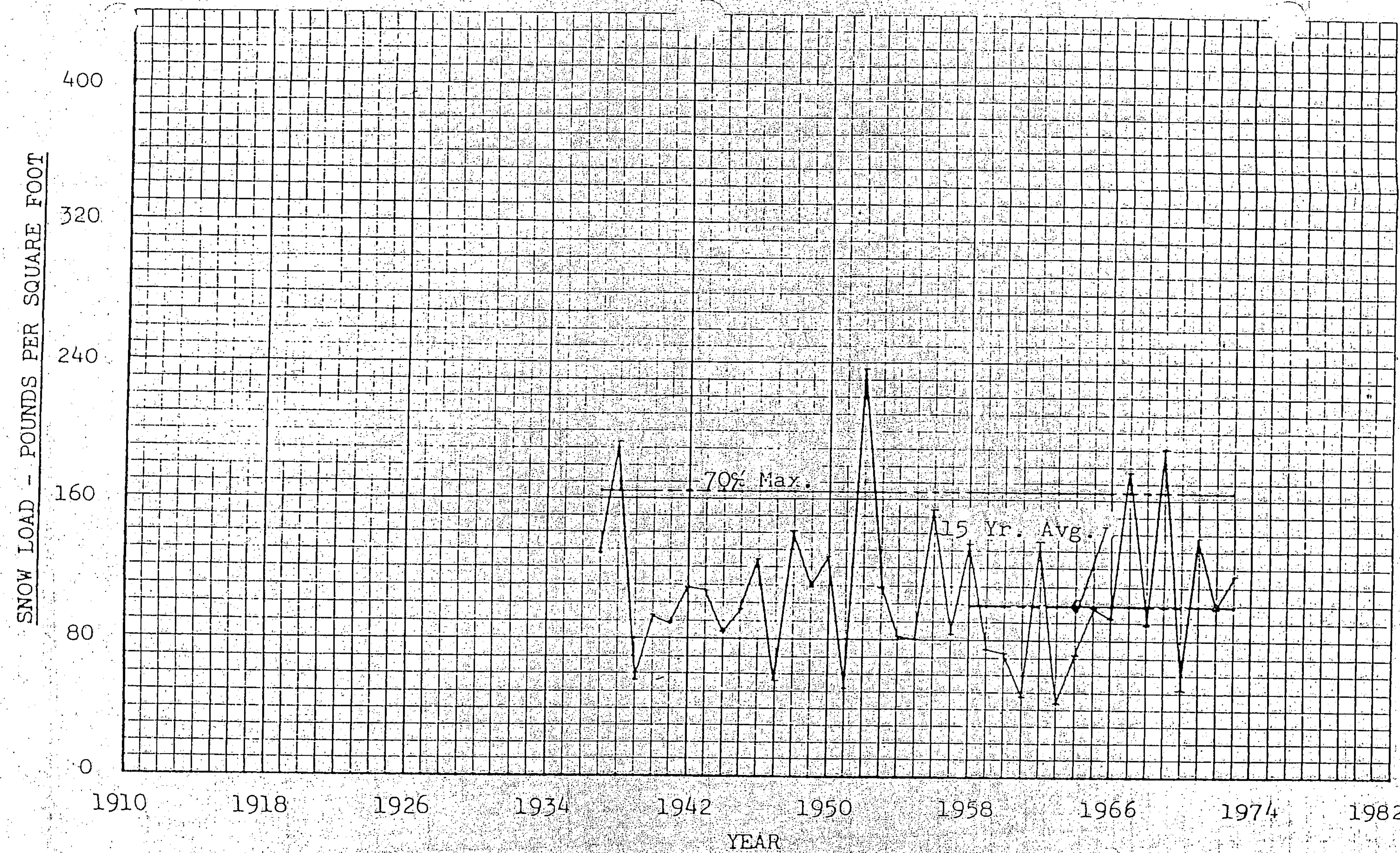
Tahoe City Elev. 6250 SCS No. 20K16 1910-1973



Incline Golf Course Elev. 6350 SCS No. -- 1964, 1967-1973



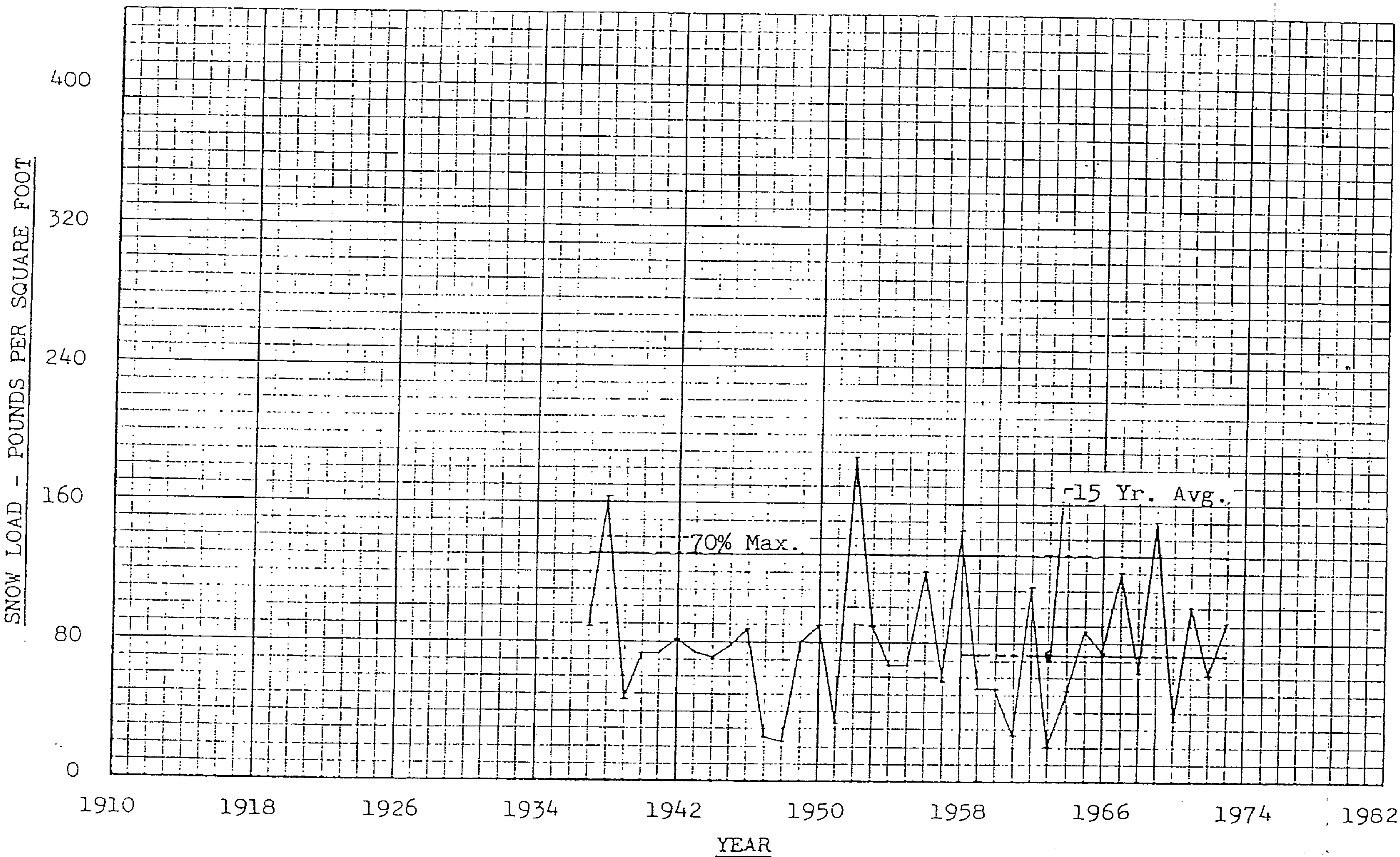
Truckee #2 Elev. 6400 SCS No. 20K13 1930-1973



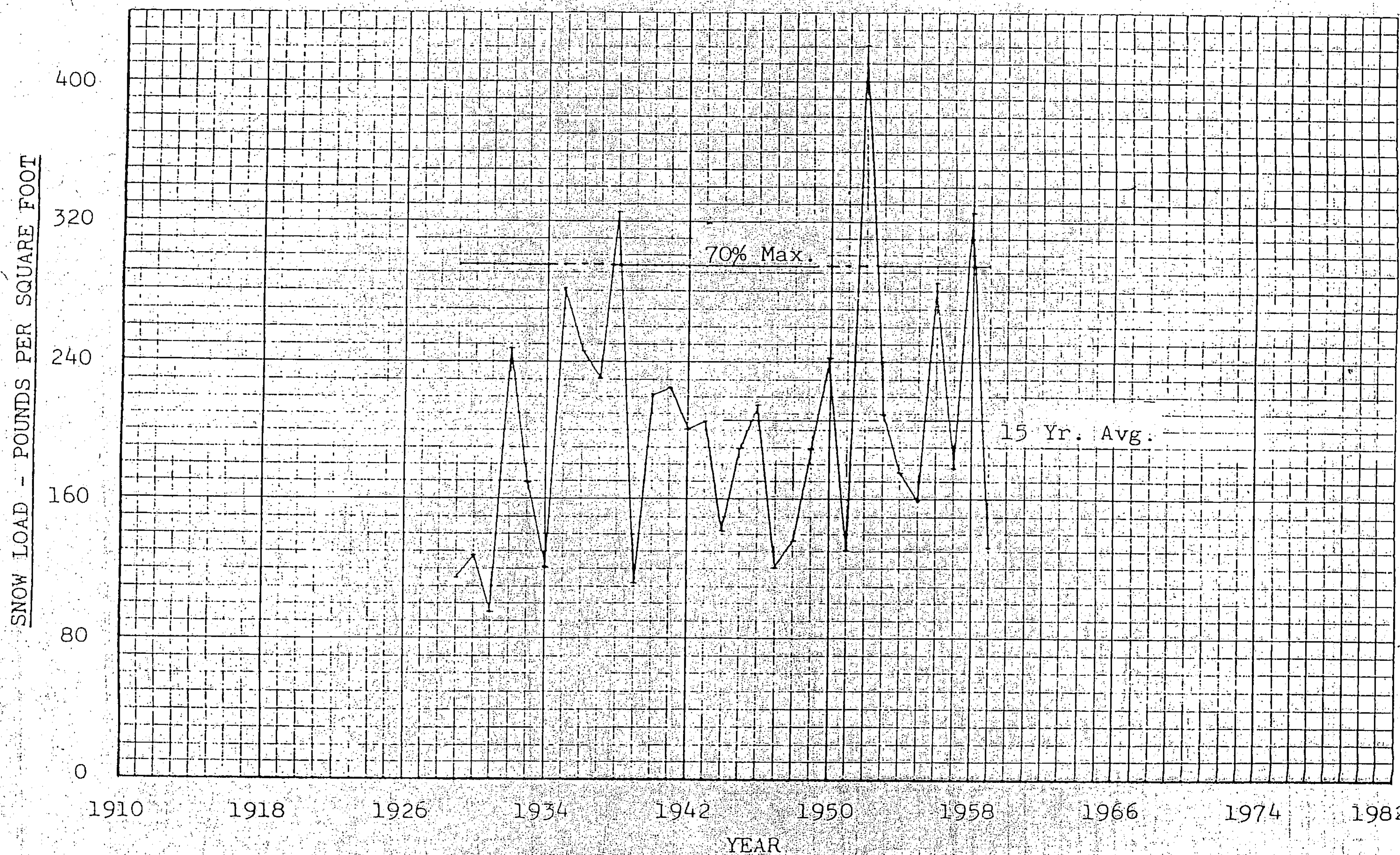
Sage Hen Creek Elev. 6500 SCS No. 20K6 1937-1973

20 A

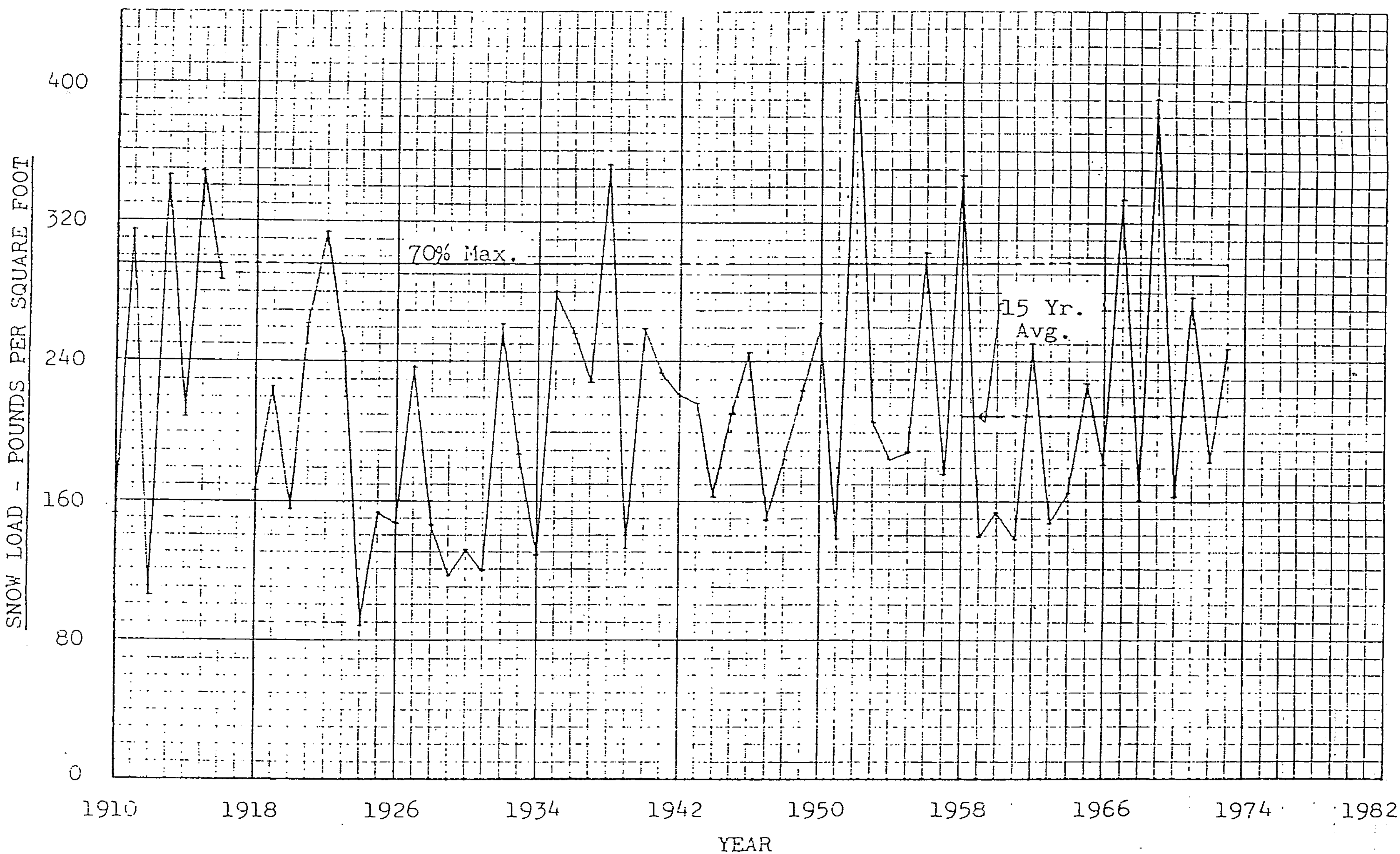
1B thru 29B



Independence Creek Elev. 6500 SCS No. 20K3 1937-1973

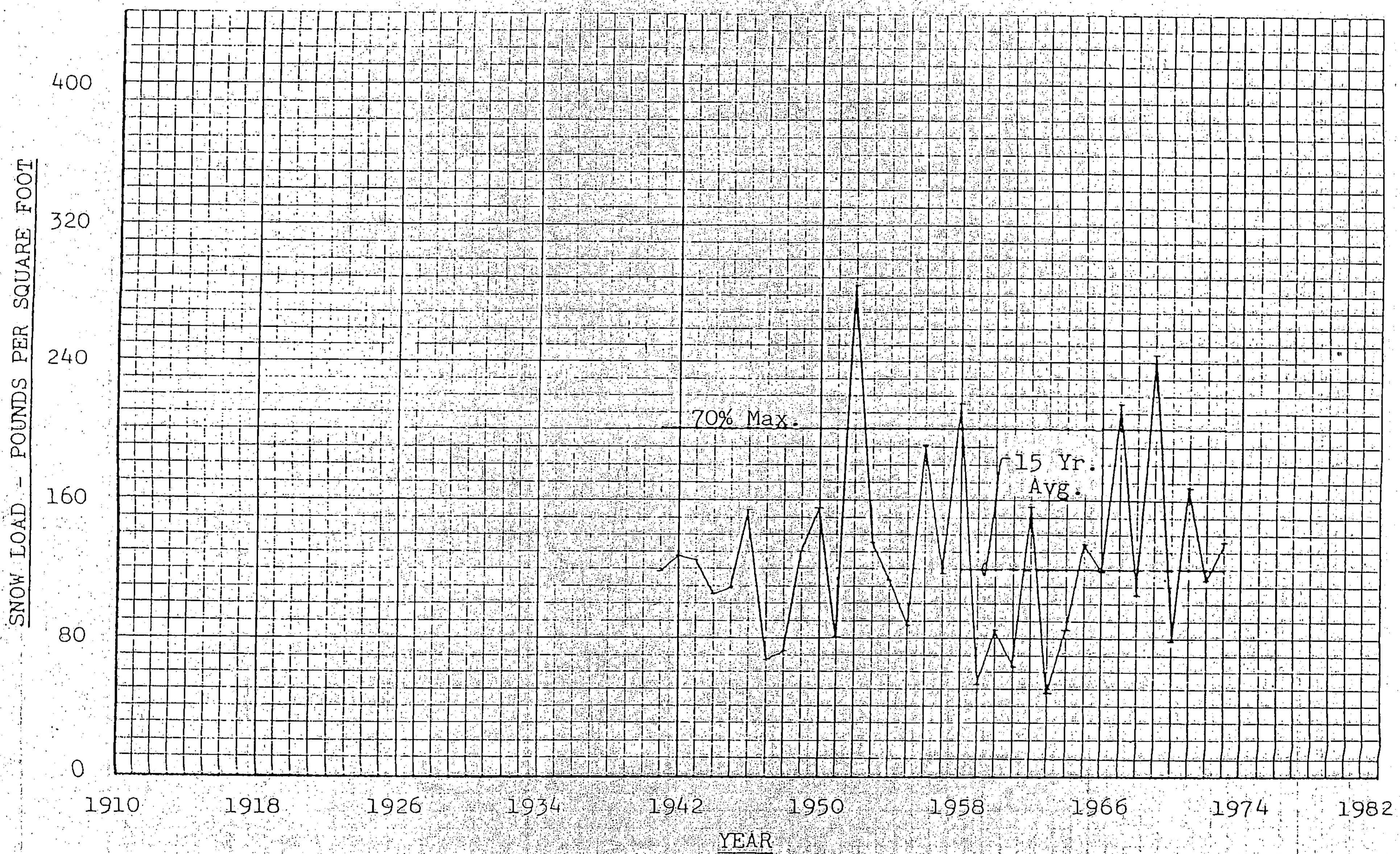


Soda Springs Elev. 6750 SCS No. -- 1929-1959

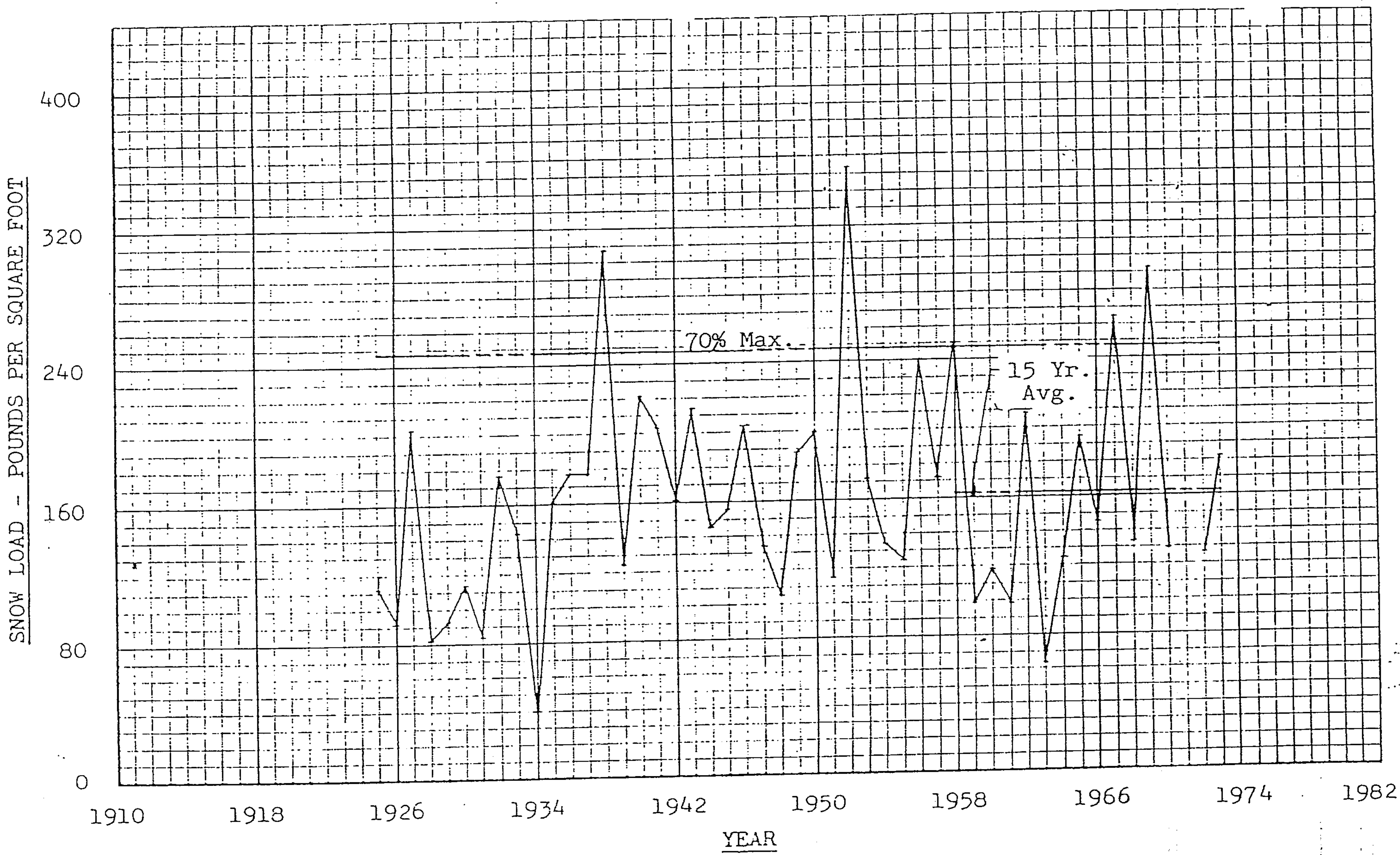


Donner Summit Elev. 6900 SCS No. 20K10 1910-1973

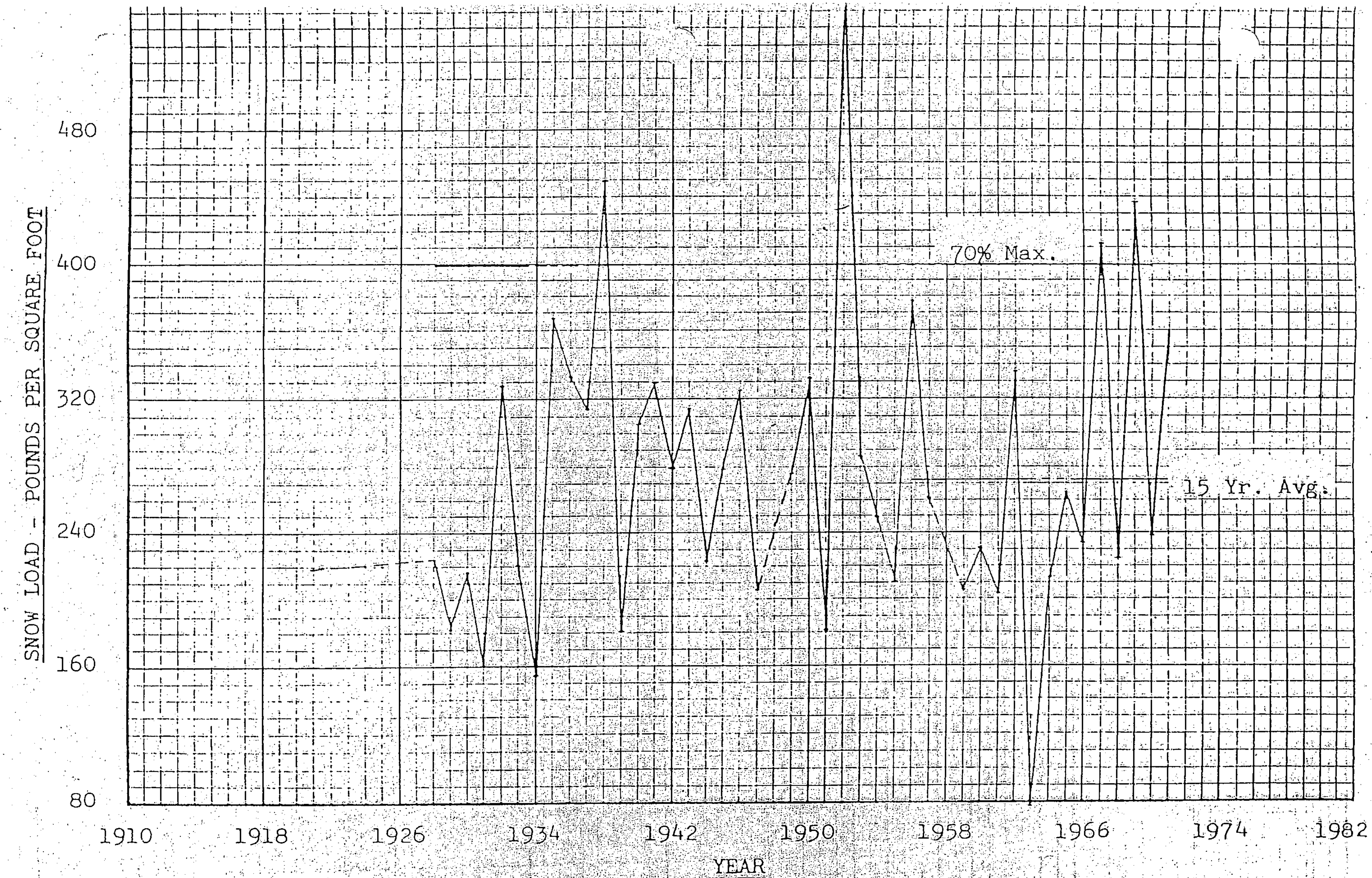
17 A



Independence Camp Elev. 7000 SCS No. 20K4 1941-1973

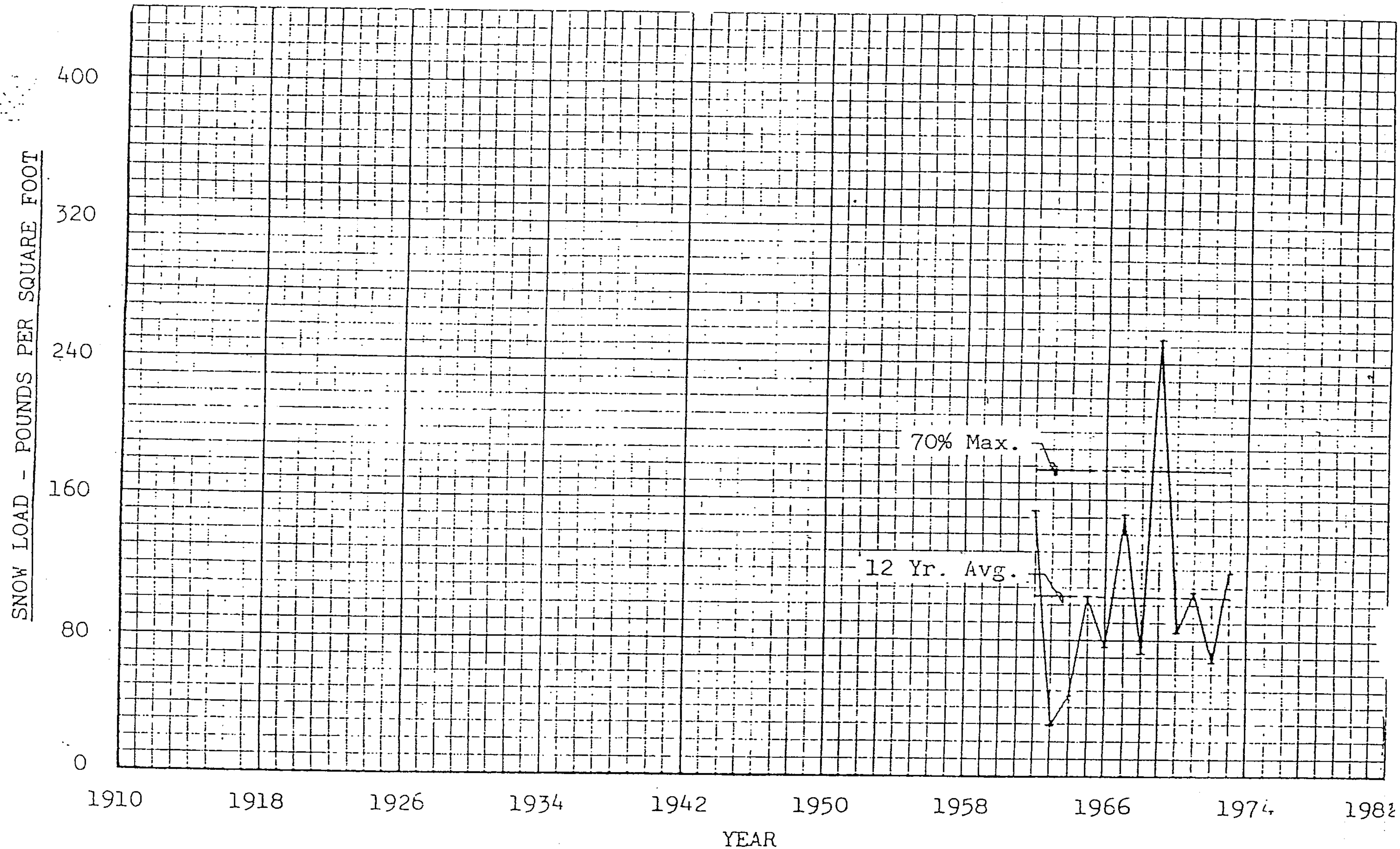


Webber Lake Elev. 7000 SCS No. 20K2 1925-1973



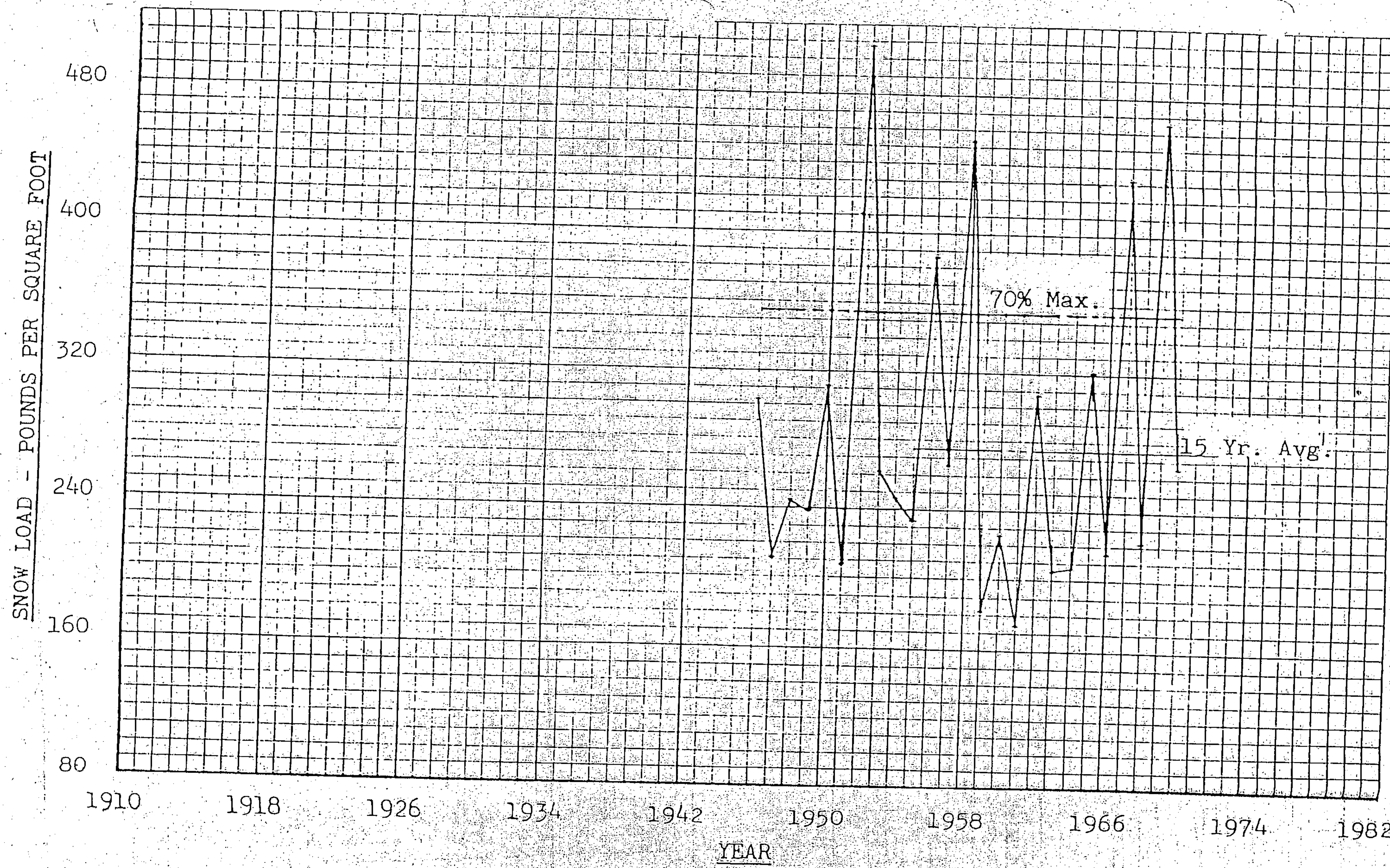
Lake Sterling Elev. 7100 SCS No. -- 1920-1971

14A



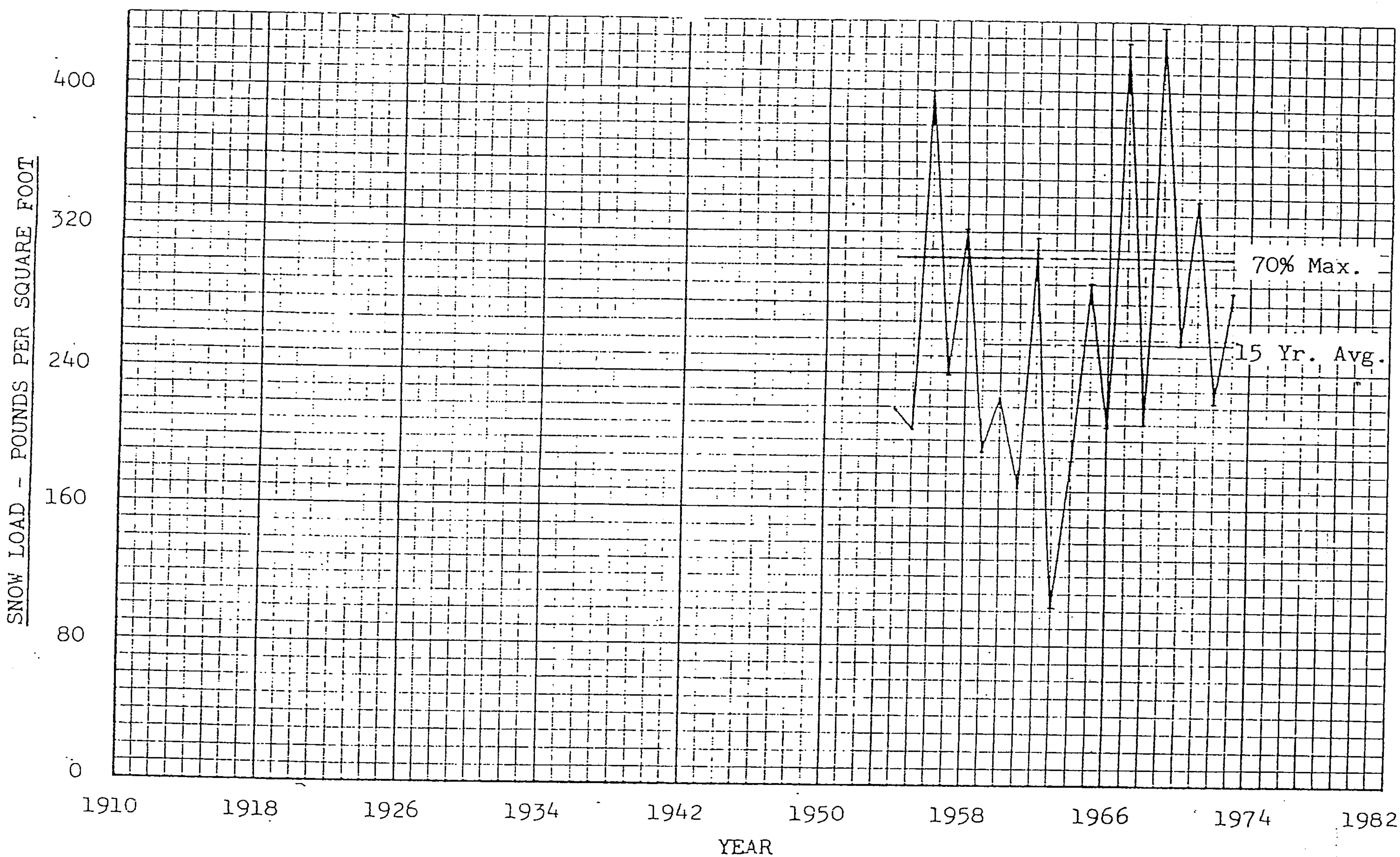
Brockway Summit Elev. 7100 SCS No. 20K22 1962-1973

13A

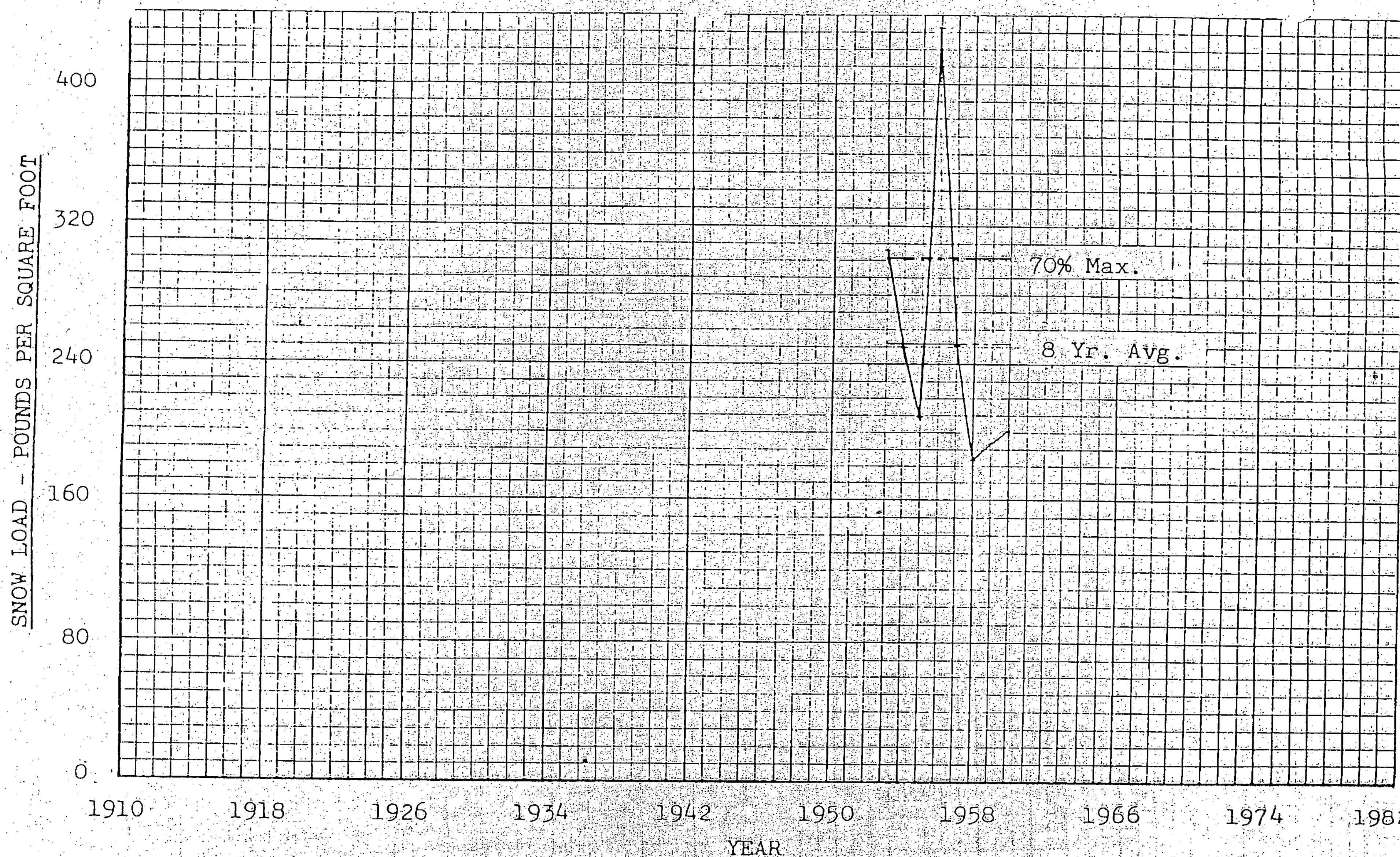


Castle Creek 5 Elev. 7400 SCS No. -- 1946-1970

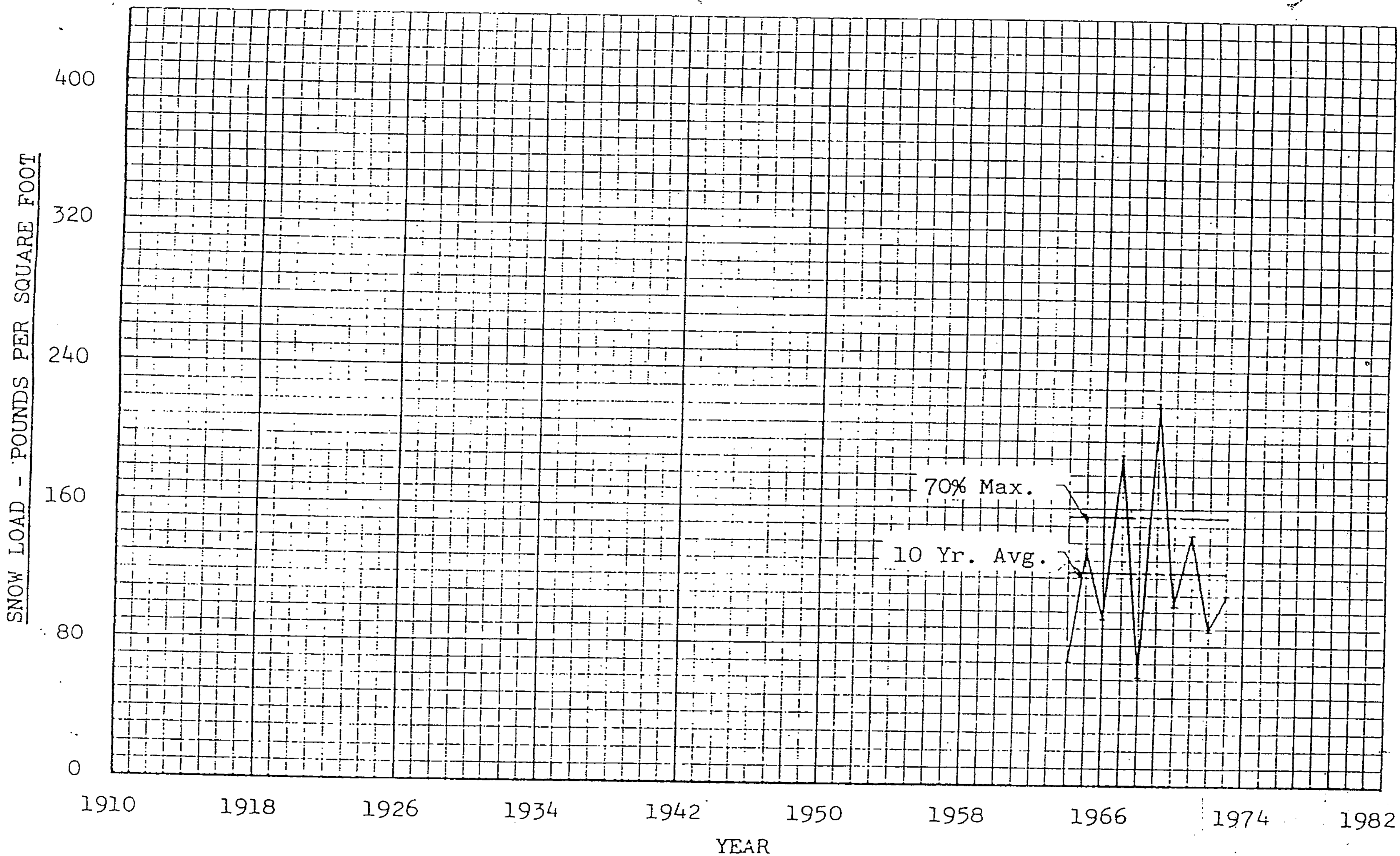
12A



Squaw Valley #2 Elev. 7500 SCS No. 20K19 1954-1973



Squaw Valley #1 Elev. 7500 SCS No. -- 1953-1960



Tahoe View Point   Elev. 7700   SCS No. --   1964-1973

9A