HYDROLOGIC CONSIDERATION FOR THE PROPOSED FINDING OF WATER RIGHTS IN THE LEMHI RIVER BASIN, IDAHO

A study prepared for the

water users

by

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Introduction

The Idaho Department of Water Administration has proposed to make a finding of water rights in the Lemhi River Drainage System which is a tributary to the Salmon River in Central Idaho. Certain elements in the proposed determination appear to place unnecessary and costly restrictions on the present agricultural use of water in the area. This has been a cause of concern to the water users who subsequently requested that a study be made to determine the physical facts pertinent to the issue and to have interpreted for them the implications of enforcing some of the questionable facets of the proposed determination. This report is the product of that concern and the investigation completed by Mr. Frank W. Haws, Mr. Eugene Israelsen, and Mr. Joel E. Fletcher.

This study was initiated in November, 1975 and consisted of an on-site visit at that time, the collection of soil samples to determine texture and permeability, the assembly of all available hydrological and meteorological data, the acquisition of geographic and agricultural land use data, and the analysis and interpretation of the data. Since the initial approach by the water users of the upper reaches of the river, the investigators were contacted by users from the lower part of the Lemhi River and asked to supplement the data already analyzed with additional on-site measurements. Since the request came too late to adequately instrument the area for the 1976 season, the investigators had to be content with gaining what information could be acquired through specific dye-tracer studies and with temperature-radiation measurements in hopes of determining return flow

characteristics and to extend temperature data by correlations with existing official weather station data.

The Problem

Authorization by the district court to prepare a proposed finding of water rights was signed on April 13, 1970. Since that time the Department of Water Administration has diligently pursued the task of identifying and quantifying the existing rights in the Lemhi River Basin. The validity of each claim and of the individual quantities of use are not to be considered in this study. Some of the other findings of facts that pertain to the specific hydrology and meteorology of the area will be discussed and additional facts will be presented.

The problems which are of concern to the water users are centered principally in paragraphs 4, 5, and 7 of the findings of fact and in paragraphs 7 and 8 of the conclusion of law. These paragraphs describe the "water requirement" or "duty of water for irrigation purposes." The general feeling of the water users is that the proposed duty or "requirement" of 3 acre feet per acre is unnecessarily restrictive, does not represent present practice, and if inforced would present an economic hardship to the users. There is also some question as to the length of the growing season although some beneficial use of water before and after the dates between April 1 and November 1 is admitted.

In attempting to answer some of these problems it is necessary to examine the hydrological and meteorological measurements which are available and to examine the spatial and temporal differences which exist over the basin area. Since the amount of data needed is not available, it is necessary to reconstruct the most probable values by

using standard statistical methods. The type of agriculture practiced in the area is also important as is the type of soil and geologic structure of the basin.

One of the problems with the proposed determination is the ambiguity in the language of the determination and the difficulty a reader has in discovering the intent of the Department of Water Administration. For example, paragraph 7 of the conclusions of law states, the "duty of water for irrigation purposes is 3.0 acre feet per acre at the field headgate . . . " The last sentence of that paragraph reads, "Regulation by the water master should be on the basis of the rate of diversion herein specified rather than by the acre foot allotment." Is it the intent of the Department to enforce the 3.0 acre feet allotment which leaves the conveyance loss unquantified or to ignore the allotment and use the diversion rate method which quantifies total diversion--field use plus conveyance loss.

To place present practice more in perspective, consider for example what has been allotted to some of the rights by the diversion rate method. Claim No. 74-0243A, which has the first priority on Agency Creek, may divert 0.90 cfs to irrigate 72.0 acres. With a diversion period of 214 days (April 1 to November 1) the total diversion equals 5.3 acre feet per acre (measured at the point of diversion). Uses by other claims can be similarly computed and it will be observed that the allotment varies considerably (Table 1). Observe also that the allotment in the first instant gives 80 acres per cfs and that the claims also vary considerably about this number (Table 1, column 5). It is interesting to observe also what happens

Table 1. Amount of water allocated by diversion rate method

1 Claim No.	2 Rate of Diversion cfs	3 Land Irrigated acres	4 Use/acre ac.ft/ac.	5 Acre/cfs
74-0243A	0.90	72.0	5.3	80
74-0243B	0.90	75.9	5.0	84
74-0247	1.20	64.5	7.9	54
74-1570	0.10	4.6	9.2	46
74-1571	0.34	16.6	8.7	49
74-0248	0.8	64.5	5.3	80
74-0244) 74-0245A)	0.8	75.9	4.5	95
74-0245B	1.0	72.0		72.0
74-0236 74-0246A	2.4) 0.2)	90.7	12.0	34
74-0250	0.3	15.5	8.2	51.7
74-0246B	0.2	72.0		
Statuatory Limit	1.0	50.0	8.5	50

when the statuatory limits are applied to this area. The statuatory limit of 50 acres per cfs over a growing season of 214 days gives 8.5 acre feet per acre.

The foregoing figures do not tell a true story, however. The water actually diverted and applied will conform to the availability of the supply and the demand or need for water. These two parts, availability and demand, are dependent upon the whims of nature: precipitation, including snow pack during the winter months, and the temperature during the growing season. The temporal distribution of these two factors result in the maximum streamflow occurring in the

spring, often associated with floods, and decreasing to a minimum while the demand is increasing to a maximum. It is this natural phenomenon which makes water rights, priorities, and allocation by legal means a necessary social function. A specified rate of flow for each user is a convenient way of proportioning the available supply among the various users, but the actual quantity of water used will usually be different than as calculated in Table 1. If the total allotment is used to irrigate only part of the farm while the other part remains idle, the use per acre could far exceed the tabulated amount.

Why Are Water Rights Necessary?

Before getting into the physical characteristics of the Basin and the demand for water it is well to analyze why allocation by the courts became necessary and to view the process hopefully from an objective point of view.

Since water is the resource we are concerned with we should first establish in our minds what water is, what it is not, and what function it performs in irrigated agriculture. First, what is water? It is a liquid, a solid, and a vapor. We should not confine our thinking to water only as a liquid. Water is constantly being converted from a liquid to a vapor and back into a liquid, or into a solid and back to a liquid again, or from a solid to a vapor to a liquid. This process is continuous; the state and direction of change being highly temperature dependent. In the liquid form, water is manageable. We can carry it in a bucket, run it down a ditch, or pump it up a hill. As a vapor, water can be transported many miles through the air by the winds and redistributed upon the land in the form of rain and snow. As a solid, water can accumulate and be stored in the mountains to provide

the source of spring floods and late summer streams. Water, therefore, is the all-purpose, all-pervading resource. It exists everywhere, cannot be used up or destroyed, and is an essential ingredient to all life processes.

What water is not? Water is not a scarce economic resource. Confusion over this point has led to many questionable and perhaps unwise practices and development decisions. It is probably natural for people living in the western arid states to look upon water as a scarce resource. Farmers who experience drought conditions or crop loss because of lack of water may find it difficult to believe that water is not scarce. Actually there is an abundant supply and that supply is constant, being the same amount in 1976 as it was 4000 or more years ago. The total world supply of water does not change. The problem is that the water is not uniformly distributed over the surface of the globe. This occurs because water phase (solid, liquid, or vapor) is temperature dependent, and temperature on the surface of the globe is dependent upon the amount of solar radiation received, the absorption characteristics of the surface material and the reradiation and convective heat transfers which take place. Because the earth spins on its axis and orbits about the sun the radiation received at a point changes continually which means temperature changes continually, water is continually in motion (changing phase) and the rainfall which produces the manageable supply comes in cyclic periods and in variable amounts.

The water which occurs, however, comes as a product of nature, without cost or effort by man. There is always enough water <u>at some place</u> and <u>at some time</u> to satisfy the needs of man and of civilization. Transporting the water from the place of supply and making it available at the times of need requires energy and direction and it is this

element of the system that is economically scarce. Water by itself is free and abundant. Management (diversion, storage, conveyance, and distribution) is costly and will only be accomplished when an economic return justifies the economic input. Separating the free resources (water) from the scarce resources (water control facilities) in an economic system is a concept which needs to be learned if proper decisions are to be made.

Consider now what this concept does to our thinking about efficiency in a water resource system. Since water is not the economic scarcity, it follows that there is no such thing as wasted water. Regardless of what use we make of the water or whether it is even used at all the water eventually ends up downstream and gets back into the atmosphere to begin a new cycle. The part of the system which can be wasted is that part which costs and requires an expenditure of energy and/or material: the control works. If the control works have been overdesigned or are operated only at half capacity, the efficiency is measured by comparing the useful capacity against the total capacity. The part unused or surplus becomes the wasted part of the resource. Suppose, for example, that nature provides a water supply sufficient to irrigate 100 acres, but instead that water is all used on 50 acres. Does that represent a waste of the resource? Obviously not, because the water will move downstream as it has always done whether used or not. The water has not been wasted. On the other hand, if energy and material had been expended to build a conveyance and distribution system adequately to serve 100 acres and if the system is used only to irrigate 50 acres, there has been a waste of a resource, the energy and material expended for the unused capacity. Costs have been expended which could have been less. Also, if applying all the water on

50 acres depresses the crop yield, the wasted resource would have been the productive capacity of the field, not the water, since the costs involved apply only to the production.

Now let's extend this thinking to water rights. If there were two fields of 50 acres each which could benefit from the water and each owner had invested in a conveyance and distribution system, the value system is measured by the legal right to a share in the supply. Non-use constitutes a waste in energy, material, and the value invested in the right. The water is still not the wasted element. Water rights, therefore, have value depending upon the time, location, and amount of flow guaranteed.

In allocating water rights, this concept should be kept in mind. A water right should be evaluated on the basis of its worth in the production of wealth and the potential misuse of the resources of energy and material--not on the amount of water used or required.

Let's turn now to what function water has in irrigated agriculture. The objective of the farmer is to secure for himself and his family an economic return on his investment. To do this he relies on the energy of the sun, the seedbed and nutrients of the soil, and an environment which will be conducive to the growth and maturation of his crop. Water is essential both as a part of the plant structure and as an environment conditioner. The growth process is dependent upon water to transport nutrients from the soil to the cells and to assist in the elongation of the plant tissue. The energy needed to transfer water from the soil to the plant is limited and since the force needed increases as the soil moisture decreases a certain minimum water content (wilting point) must be maintained in the soil. Soils also have a maximum amount which can be held without drainage (field

capacity). Thus the usable water in a soil is that between field capacity and wilting point. This usable capacity is inherant in the soil type and therefore determines the period of replenishment.

When insufficient water is maintained in the soil the plant may wilt, giving an indication that the temperature regulation provided by the water system in the plant has ceased to function. Thus water can be said to perform two general functions in a plant. First, the complex process of nutrient transfer which we shall call growth or elongation, and second that of cooling the plant during periods when the intense radiation of the sun would otherwise heat the plant to destructive limits.

In the soil or in the atmosphere water is an environmental conditioner, softening the soil, regulating the temperature (to retard or stimulate growth), diluting toxicants, dissolving nutrients, and regulating "piping" or tunnel erosion. In some instances the effect may be adverse to the plant as when too much water ponds around the roots preventing air and gases from performing their vital function or flushing soluable nutrients away from the plant root system.

One other important aspect of water use is external to the individual farm, but probably the best reason we have for inviting the State to administer water rights. This is the effect one user has upon the potential or actual use by another. This effect begins at the diversion point and reverberates downstream to the "end" of the system. Water diverted from the surface supply reduces the amount available for another divertor. Hence, to ensure equity, a system of water "rights" has been developed. The State's role as an administrator of water rights has been to protect the economic investment of the divertor by preventing unauthorized headgate regulation and by enforcing the

decisions of the local courts. It is also the responsibility of the State to advise the courts as to the effects each right might have on the quantity, quality, and timing of the remaining resource. The State should not attempt to dictate farm management practices which may affect the economic return of the farm unit.

The question of how much water can beneficially be diverted for agricultural purposes has often been asked. The term "duty of water" was an early phrase used to represent the amount of water diverted for each acre irrigated and of course varied with type of soil, conveyance system, and method of distribution. In an attempt to be a little more scientific about it, researchers began to measure the amount of water applied to get the best crop response and later to determine the amount of water evaporated from the soil and from the plant during the growth season and to correlate this "consumed" water with climatological conditions. This led to predictive tools such as the Blaney-Criddle Method of estimating evapotranspiration and has erroneously been applied to water right allocation as being the measure of beneficial use in irrigated agriculture. The methods have value for agriculturalists who must design effective and adequate distribution systems and it has value in estimating the amount of water "depleted" from the hydrologic system. It does not, however, measure the total benefits to be derived from a diverted water supply.

A common practice which has evolved from the knowledge that plants transpire a given amount of water under certain temperature conditions is to determine an "efficiency" of irrigation. This is a ratio of the amount of water "consumed" to the amount of water diverted or applied. This may have value to a researcher or to an agriculturalist who desires to extend an existing supply, but the term is misleading

to farm managers who must make a profit from farming, and to water rights allocators who fail to grasp the larger perspective. The word "efficiency" usually implies that someone is doing something right. (He may not be doing the right thing, but what he is doing, he is doing with the least amount of waste.) A high efficiency should mean a greater return on investment, but irrigation efficiency may be completely unrelated to economic return on the individual farm and a detriment to the economic production of the whole system. We have indicated earlier that water cannot be wasted. Productive capacity of farmland may be greater than realized or conveyance and distribution systems may be larger than needed and either or both may reduce the total economic efficiency of the farm, but the economic efficiency of the farm cannot be expressed validly in terms of the amount of water diverted. A classic example of this exists in the Lemhi River Basin. It can be shown, on the basis of water consumed and water diverted, that farmers in the basin have low efficiencies, perhaps as low as ten percent. Nowhere in the basin can it be demonstrated that increasing the efficiency, except perhaps in the high water table pastures next to the river, will also increase the yield of the farm. Increasing the efficiency will, however, add additional costs to the conveyancy and distribution system, thus effectively reducing the efficiency of the farm operation. This increase in irrigation efficiency will also have an adverse impact on the total system. Under present practices the surface flow of the river is effectively delayed in time so that late summer water is available for use to the lower users. Increasing irrigation efficiency would decrease late summer flow in the river forcing farmers to use the underground supply. This means an added cost to the operation without increasing the return.

In summary, then, water is a natural resource, provided by nature without cost. Water can be managed to render an economic return if energy and/or material is expended at a cost to construct the necessary works. And every use of the natural supply has an impact throughout the whole hydrologic system by altering either quantity (reducing the amount available for others), quality (making water unfit for certain uses), and the timing of occurrence (such as delayed stream flow). The State's role in this process is to know what effects are produced by man-made diversions and to protect the economic investment of the users of the natural supply. It should not dictate what uses are "best" or suggest farm management practices to "conserve" water unless those practices actually increase the economic utility of the whole system.

Physical Description of Lemhi Basin

The Lemhi River drainage basin is a part of the Salmon River drainage and is located on the eastern side of the Salmon River basin (Figure 1). The elongated Lemhi River basin trends northwest-southeast and is bounded on the east by the Beaverhead Mountains whose crest forms the Continental Divide and on the west by the Lemhi Range which forms the divide between the Lemhi and the Pahsimeroi valleys. The Lemhi River empties into the Salmon River at the city of Salmon, Idaho, and is noted for its high quality water and excellent fishing habitat. The basin is nearly 65 miles long and about 25 miles wide. The lower part of the valley from Salmon to Lemhi is relatively narrow with the river entrenched in a trough about two miles wide. Above Lemhi the valley widens as the stream bed ascends to a width of about ten miles. The upper portion of the valley starts above 7000 feet elevation and descends to the confluence with the Salmon River at about 4000 feet. The total area of the drainage basin above Salmon is 1270 square miles. The basin is effectively separated into two separate sub-basins by the gaging station at Lemhi with a smaller sub-basin at Texas Creek. The basin and sub-basin are shown in Figure 2.

Geology

This is not to be a detailed description of the geology, but only a brief outline of those features of geology which assist in understanding the movement of water through the basin. To aid in understanding the structure reference is made to Figure 3 which is a portion of a structural cross section taken at right angles to the river at a

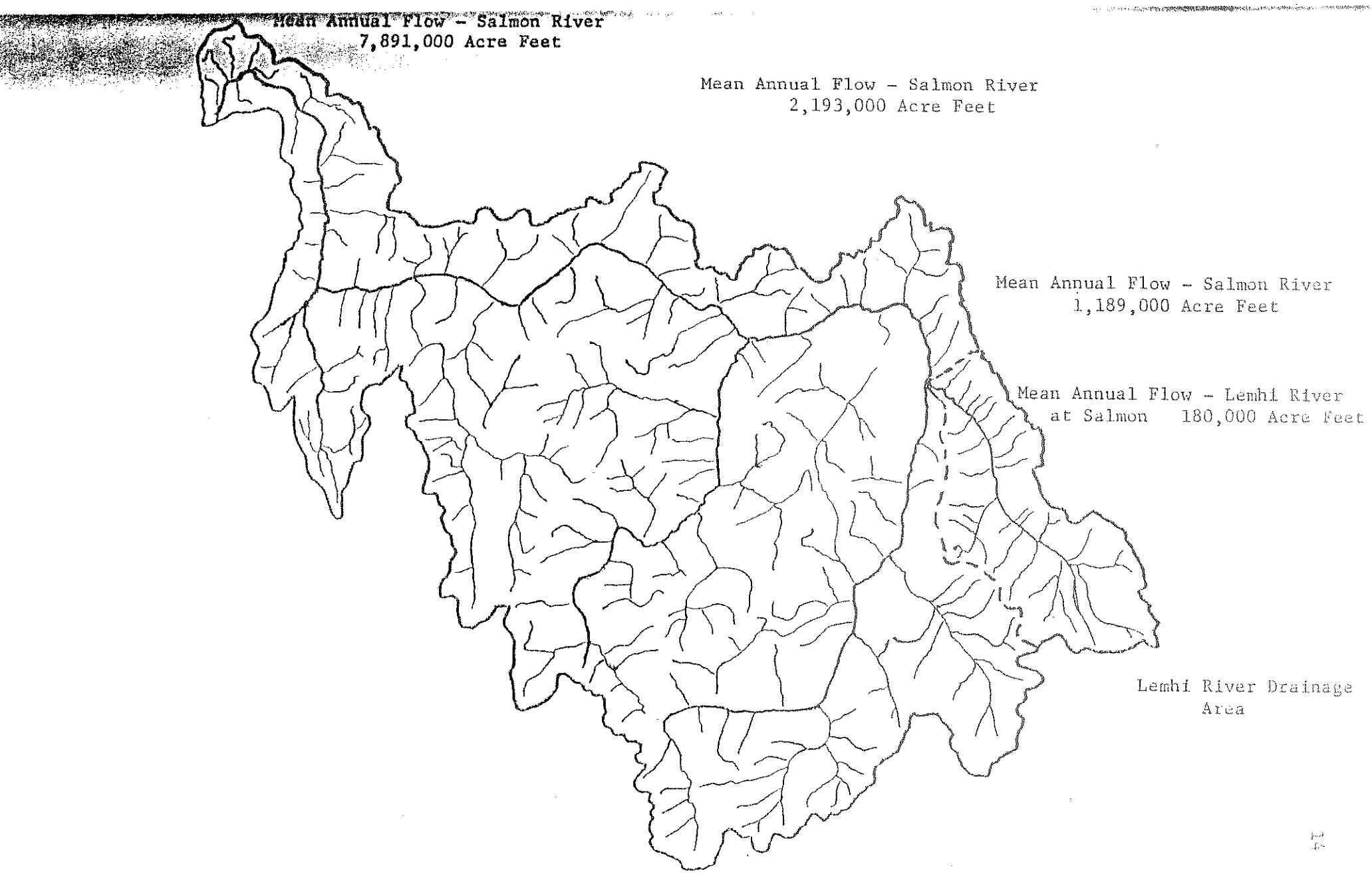


Figure 1. Salmon River Drainage Area

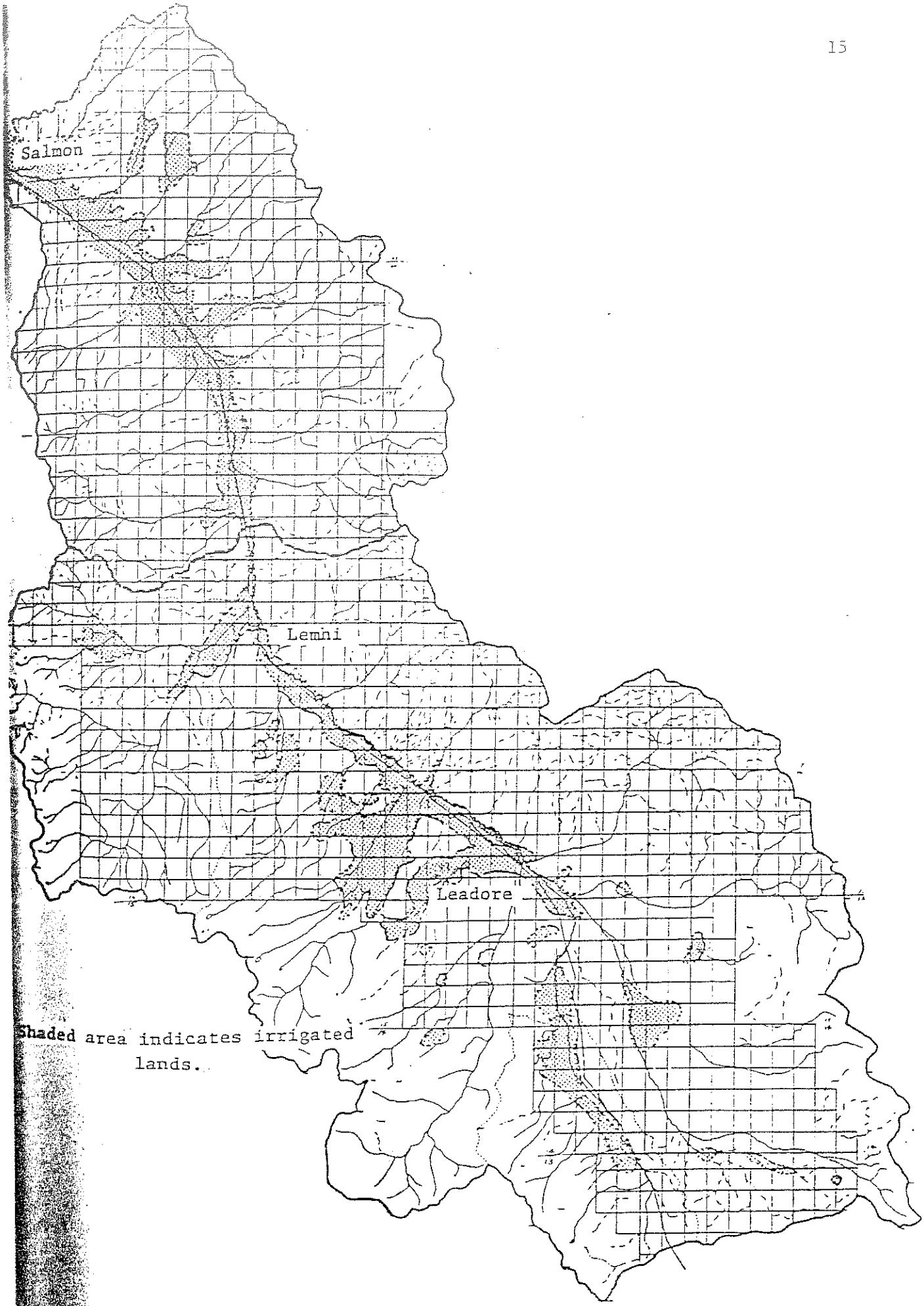
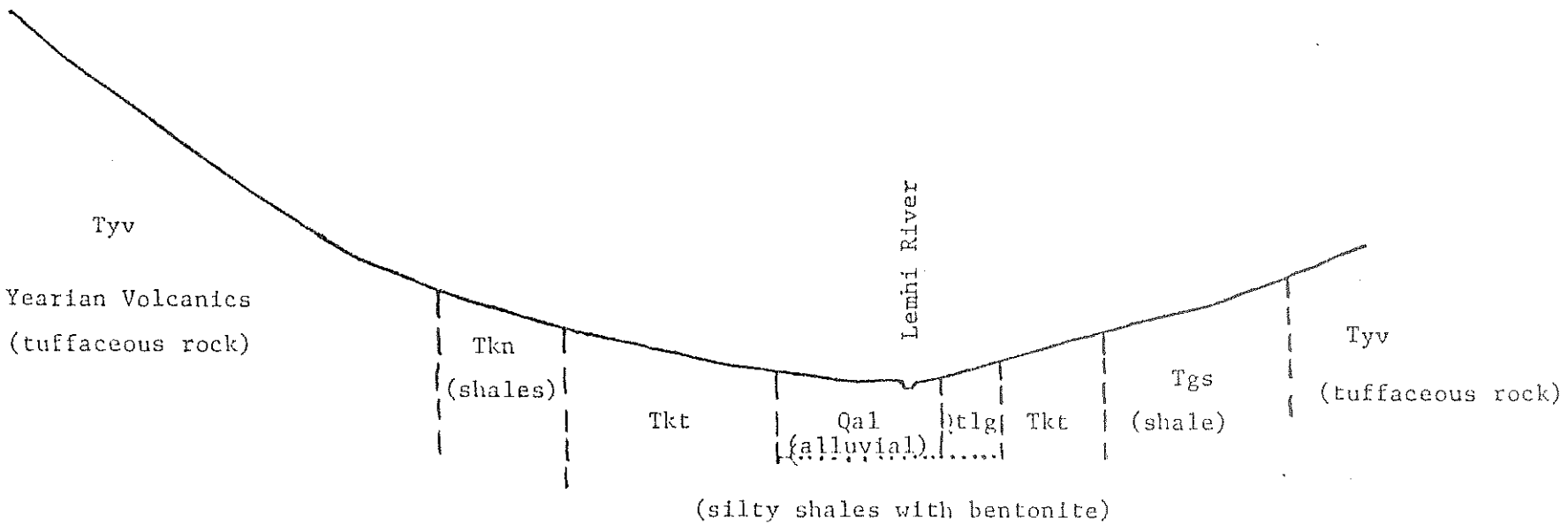


Figure 2. Lemhi River Drainage Area.



Qtlg = terraced gravels

Figure 3. Geologic Cross Section of Lemhi Drainage Area.

point about 10 miles north of Lemhi, Idaho. The information is taken from a published report of the Idaho Bureau of Mines and Geology.[1] The vertical scale has been exaggerated for convenience in describing the hydrologic relationships to the geology. Although this section is at a specific location, the pattern of deposition demonstrated here is repeated in other parts of the valley including the upper reaches around Leadore.

In examining a geologic map, it is to be noted that the cultural activities of man, such as agriculture pursuits and the rural and urban activities which support towns and cities, are nearly all located on the surficial deposits of nature known geologically as the quaternary deposits. These are the sediments derived from other older formations which have been re-deposited in more recent periods through the action of streams, lakes, winds, and glaciers. The non-quaternary deposits of sedimentary origin generally provide too harsh an environment for agriculture and are not suitable for community habitation, but are used for grazing, timber harvest, and mining.

The quaternary deposits in the Lemhi Valley are generally flood plain deposits which straddle the stream bed in a long narrow belt from one half to one mile in width. In addition there are alluvial fan deposits where tributary streams enter the river and older water-formed terraces. In the higher elevations, glacial morraines exist. Along the Lemhi River these deposits are clean sands and gravels (with the silty soils on top) which have high permeabilities and good water transmission capacities.

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[1] Anderson, Alfred L., "Geology and Mineral Resources of the Lemhi Quadrangle, Lemhi County." Pamphlet No. 124. Idaho Bureau of Mines and Geology, Moscow, Idaho. August 1961.

The quaternary deposits in the Lemhi Valley lie on top of tertiary deposits which are soft sedimentary rocks consisting mostly of silty or sandy shales with some sandstones, conglomerates, or tuffaceous materials. The younger members of the tertiary group in the Lemhi Valley also contain bentonitic clays and some lignite. The water permeability of these rocks is low, particularly where bentonite is present.

Since the Lemhi River flows over the surface of the permeable quaternary gravels, and since flow is impeded by the tertiary layers, there is a natural tendency for the quaternary material to fill with water and for this formation to then act as a conduit for water moving parallel with but underneath the stream bed. That this is so in the Lemhi Valley is evidenced by the shallow depth to water noted in the pastures next to the river and the shallow wells (10-12 feet) used for domestic purposes in the homes not far from the river. As you proceed further from the river to higher elevation the depth to water increases.

The total depth of the quaternary layer in the Lemhi Valley is unknown, but Chapman[2] estimates it to be 200-300 feet. One well log for a well drilled on the Ellsworth Ranch in Sec 2 T15N R26E was available. It showed the well penetrated to a depth of 200 feet without reaching the tertiary material. The static water level was only 17½ feet below the surface. One other deep well exists in the area (Truman Chapman) but the well log was not available.

The point of this discussion is that because the surface material (which may be 200-300 feet deep) over which the surface drainage occurs

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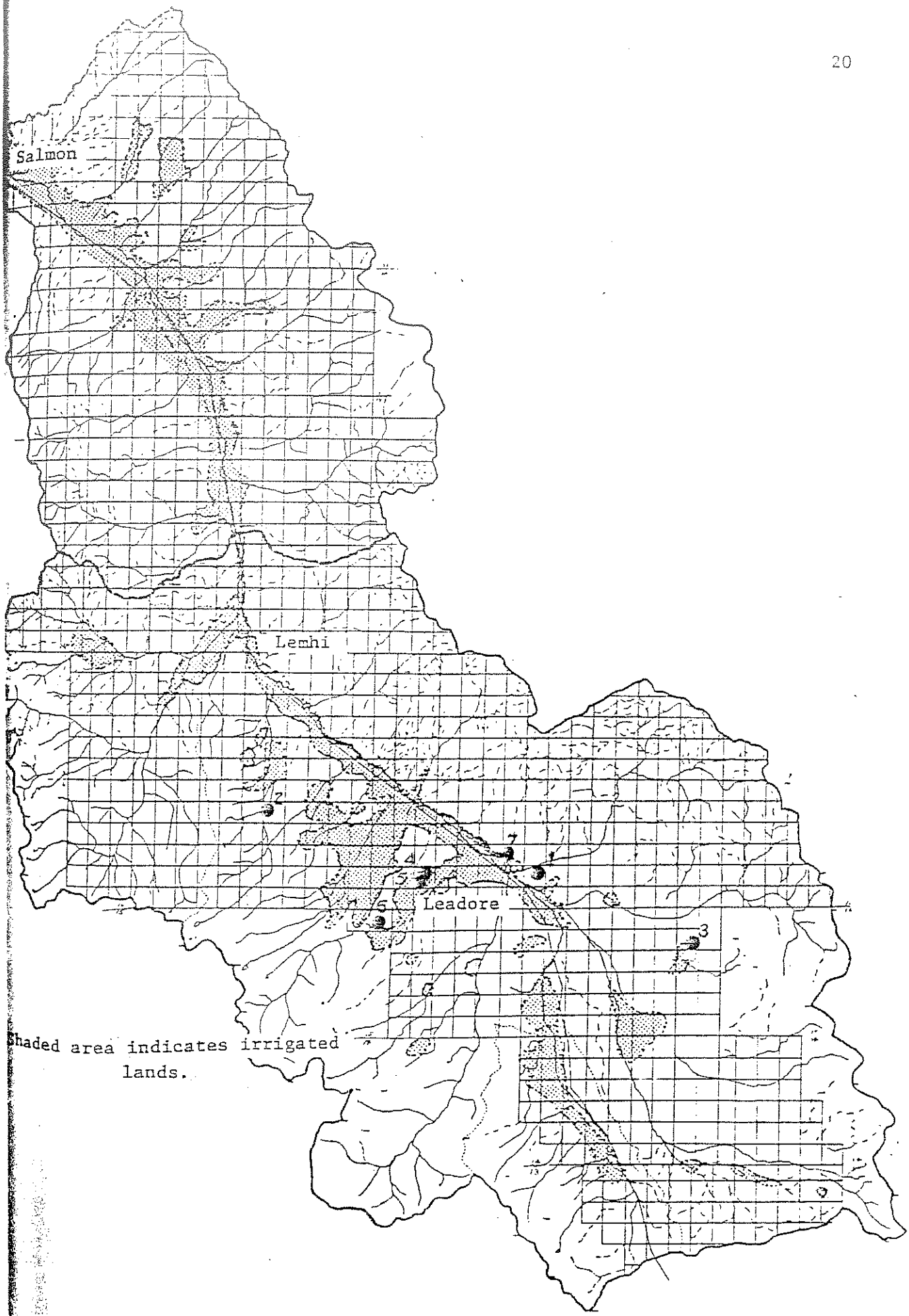
[2]Chapman, Sherl L., "Lemhi River Basin Geology, Hydrology, and Irrigation Efficiency." Consultant's report to Mr. James Herndon, Attorney at Law. Salmon, Idaho. January 1976.

is highly permeable and because the impermeable tertiary material beneath the quaternary prevents further downward percolation, the quaternary material is filled with water. The only direction this water can go is downstream in the same direction as the Lemhi River. Water from the tributary streams which is diverted for irrigation and not consumed must eventually enter this underground water reservoir and, because the reservoir is filled, overflow back to the surface at some point further downstream. The peak flow of the natural stream is thus delayed in time but not diminished in quantity.

Soils

The word "soils" is an agricultural term and most often refers to the upper five feet of granular earth in which agricultural crops are grown. It is important to our study because it is this material which must be moistened through the irrigation process to provide the environment for crops to grow. If the soil is fine textured and deep (five feet or greater), sufficient water can be stored in the soil to permit the growth process to occur without frequent re-wetting or without excessive percolation beyond the root zone. Thin layers (less than two feet) of coarse soils do not store sufficient water for growth and therefore require frequent re-wetting and in the process much deep percolation beyond the root zone. The Lemhi River Valley contains essentially the latter soil type.

Soil samples collected from various farms in the upper Lemhi Valley near and around Leadore were analyzed in the soils laboratory for texture and permeability. The location of these samples is shown in Figure 4. It was also observed in the field that soil depths were generally very shallow, in some areas being less than one foot. In



Shaded area indicates irrigated lands.

general the soils have silt textures and are very permeable. The permeability increases beneath the soil as the size of particles increases and the fines decrease. Laboratory results are shown in Table 2.

Table 2. Results of soil analysis

Sample No.	% 1/3 Atmosphere	Hydrometer % Sand	% Silt	% Clay	Texture
1	15.3	41	43	16	Loam
2	9.4	61	26	13	Sandy Loam
3	18.7	43	36	21	Loam
4	14.8	51	33	16	Loam
5	10.6	53	35	12	Sandy Loam
6	11.8	59	31	10	Sandy Loam
7	15.7	45	29	16	Loam
	13.76 ± 3.28				

Hydrologic Description of the Basin

Precipitation

All the water in the Lemhi Basin must trace its origin at some point in time to precipitation. Determining the amount of precipitation and following its movement through the basin is difficult and complex and at best can only be approximated. There are only three points in the valley where precipitation has been measured and, except for the Salmon station, no long term record exists. Some measurements were taken at Leadore, Idaho, during the period from 1948 to 1954, but the record is far from complete. A new station was established at Leadore in 1965 and a good record exists from that time on. At Lemhi, Idaho, intermittent measurements were kept from 1914 to 1976, but only three complete years of record exist during that period. At Salmon, Idaho, the record is longer, beginning in 1906, but with many missing data points until about 1928. The record from that point until 1970 is fair. A new station was begun in 1970 and has good records to the present time.

The precipitation records available from the National Weather Service are duplicated in Tables 3 to 6 for the stations of Salmon, Lemhi, and Leadore. The monthly and annual average values are shown as computed from this data. To reduce the variability due to the missing sampling dates and for the length of the record, a graphical method was used to also calculate the mean values and these are also shown in the tables.

e 3. Monthly Precipitation for Salmon, Idaho. (inches)

r	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
05	–	–	–	–	–	–	–	–	–	–	–	–	–
06	1.20	.79	.84	.70	1.26	1.07	.36	1.57	1.20	.77	1.01	.85	11.62
06	.58	.65	.92	–	.52	3.12	2.38	1.02	.21	.80	.77	.44	11.41
07	.10	.06	.43	.17	2.48	2.84	.48	.35	1.33	.54	.13	.33	9.24
08	.84	.43	.19	.26	.93	.44	–	–	–	–	–	–	–
09													
10													
11													
12													
13													
14	.81	.56	.19	.86	1.87	1.83	.60	.27	.47	.62	.13	.23	8.44
15	.65	.25	.72	.80	1.75	2.15	1.62	.57	.89	.50	.53	.81	11.30
16	.75	1.04	.50	.87	.82	1.68	1.08	.61	.20	.89	.23	.62	9.29
17	.55	.77	.91	.48	1.48	.43	.15	.05	1.00	.04	.81	.92	7.59
18	1.22	.54	.84	.30	.43	1.06	.38	1.35	–	–	–	–	–
19	–	–	–	–	–	T	.08	.21	.81	–	.35	.60	–
20	.54	.20	.40	.16	.15	–	–	.14	–	–	–	–	–
21	–	–	–	–	2.27	1.78	0.12	0.3	.94	.24	.70	–	–
22	–	–	–	–	.83	.51	1.00	2.70	.03	.03	.21	.61	–
23	–	.08	.22	–	1.18	1.90	.70	1.14	.43	.88	–	.79	–
24	.40	.10	–	.18	–	.53	.74	.38	.10	–	.35	1.37	–
25	–	–	.60	.34	.28	2.38	.88	1.09	1.76	.25	.01	.89	–
26	.41	.59	.43	.72	.87	.28	.46	.91	.66	.10	1.37	.60	7.40
27	.53	.37	.30	.27	2.23	.67	.71	.98	2.27	.96	–	.83	–
28	1.01	0.12	.65	.33	.13	.57	.78	.56	.46	.76	.09	.72	6.13
29	.82	.02	.53	.75	.66	.73	.84	.40	1.04	.16	.05	1.48	7.53
30	.72	.70	.27	.99	.31	.44	.67	1.38	1.18	.58	.14	.20	7.58
31	.30	.22	.62	.48	1.51	.47	.46	.07	1.13	.01	2.21	.72	8.20
32	.38	.08	0.81	.45	1.46	1.67	.42	–	3.19	–	–	.25	–
33	.26	.50	.03	.83	1.35	.27	.39	.17	.36	1.36	.19	.84	6.55
34	.42	.14	.77	.88	.10	1.33	.61	.43	.46	1.44	.27	.54	7.39
35	.10	.08	.41	1.18	.38	.13	.31	.19	T	.36	.24	.25	3.63
36	1.11	.78	.08	2.07	.66	2.50	.71	.39	1.12	.05	.15	.17	9.79
37	.45	.13	.61	.52	.82	1.46	1.44	.05	.86	.40	.41	.63	7.78
38	.79	.28	.66	.14	1.30	1.60	1.18	.23	.16	1.88	.37	.25	8.84
39	.61	.62	1.22	.49	1.34	1.09	.89	.43	.79	.41	T	.26	8.15
40	1.01	.70	1.39	.77	.48	.14	.79	.08	3.12	.77	.89	.34	10.48
41	.27	.10	.07	.42	2.27	1.17	2.55	.94	.77	1.05	.50	.82	10.93
42	1.05	.47	.26	.65	3.88	1.26	.08	.35	.22	.48	1.18	–	–
43	1.18	.63	.21	.77	.66	.73	1.23	1.39	.49	.79	.42	.31	8.81
44	.58	.39	.29	.70	1.88	2.29	–	.34	.62	.12	.74	.28	–
45	.23	.62	.33	.06	.63	1.74	1.10	.56	.77	.56	.47	.95	9.02
46	.80	.15	.60	.33	1.94	.71	1.15	1.57	2.24	1.54	2.19	1.14	14.36
47	.23	.44	.34	.01	1.13	2.07	.33	.71	1.16	.73	.59	.37	8.11
48	.24	.55	.54	.89	2.86	2.30	1.58	.49	1.09	.49	1.17	1.63	13.83
49	.08	.27	.34	.27	2.11	.06	.12	.35	.74	.44	.70	.15	5.63
50	.51	.14	.56	.39	.19	1.35	.25	1.05	1.39	.29	1.01	.64	7.77
51	.55	1.32	.56	.40	1.23	–	.84	1.09	–	.73	.63	.68	–
52	.33	1.21	1.16	–	1.63	2.10	.91	.35	.07	T	.08	.42	–
53	1.04	.79	.29	1.13	1.36	2.24	.05	.33	.18	.07	.72	.21	8.41

ble 3. (continued)

ar	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
54	.27	-	.53	.43	.61	3.15	.93	1.03	.22	.12	.13	.26	-
55	.25	.47	.32	.84	1.19	1.33	1.62	.01	.35	.55	1.53	1.63	10.09
56	1.72	.23	.39	.77	1.50	.61	.47	.91	.56	1.01	1.01	1.31	10.49
57	.69	.52	.99	.30	2.51	1.32	.19	.10	.13	.93	.21	.49	9.28
58	.46	.57	.46	1.00	.64	2.78	.67	.31	.24	.01	1.02	.90	9.06
59	.28	.59	.16	.57	1.10	1.92	.42	.68	1.73	1.51	.28	.28	9.52
60	.53	1.11	.99	.98	1.40	.15	.23	1.57	.63	-	.68	.19	-
61	.17	.42	.09	.68	1.11	.63	.74	.33	1.22	.39	.34	.33	6.45
62	.61	.75	.28	.14	1.99	2.06	.48	.57	.20	.58	1.46	.21	9.33
63	.72	.87	.17	1.25	.67	3.03	.09	.78	1.08	1.03	.90	.41	11.0
64	.54	.31	.27	1.19	1.60	4.32	.23	1.08	.03	.07	.58	2.26	12.48
65	1.22	.22	.39	1.07	.70	1.23	.83	2.02	1.04	.38	.65	.37	10.12
66	.33	.28	.04	.17	.49	1.62	.03	.48	1.84	.17	1.10	1.02	7.57
67	1.08	.32	.95	2.57	1.63	2.16	1.09	.23	.73	2.40	.58	.67	14.41
68	.43	.84	T	.70	1.09	.75	.01	2.13	.32	.34	1.50	.59	8.70
69	.90	.22	.16	.35	1.03	1.82	1.61	.12	.67	.17	.31	.61	7.97
70	1.10	T	1.00	.25	2.06	1.75	.54	.21	1.19	.47	2.48	.76	11.31
N	56	55	56	55	59	58	58	59	56	53	54	56	
$\bar{x}$	.62	.47	.51	.64	1.25	1.44	.72	.68	.86	.61	.681	.65	
σ	.355	.312	.323	.463	.757	.922	.546	.575	.698	.504	.564	.433	

Table 4. Monthly Precipitation for Salmon II, Idaho. (inches)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1966	–	–	–	–	–	–	–	–	–	–	–	–	–
1967	–	–	–	–	–	–	–	–	–	–	–	.12	–
1968	–	–	–	–	–	–	–	–	–	–	–	–	–
1969	–	–	–	–	–	–	–	–	–	–	–	–	–
1970	–	–	–	–	–	–	–	–	–	–	–	–	–
1971	1.52	.64	.83	2.54	1.14	1.49	.40	.78	.40	.42	1.11	1.43	12.70
1972	.82	.75	1.25	.14	1.44	1.86	.75	1.27	.46	.92	.34	.42	10.42
1973	.36	.06	.18	.42	.45	1.97	.67	.50	.84	.30	1.00	1.13	7.88
1974	.86	.23	1.41	.10	.66	.29	.33	.91	.02	1.02	.45	1.07	7.35
1975	1.48	.63	.76	1.83	.62	1.21	2.46	1.40	.09	1.84	.60	1.39	4.70
1976													
$\bar{x}$	1.01	.46	.89	1.01	.86	1.36	.92	.97	.36	.90	.70	.93	8.01
σ	.490	.299	.481	1.112	.412	.672	.878	.366	.328	.610	.339	.536	3.058

Table 5. Monthly Precipitation for Lemhi, Idaho. (inches)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1905	–	–	–	1.05	1.98	3.23	.20	1.52	.83	.55	–	–	–
1906	–	–	–	–	–	–	–	–	–	–	–	–	–
1907	–	–	–	–	–	–	–	–	–	–	–	–	–
1908	–	–	–	–	–	–	–	–	–	–	–	–	–
1909	–	–	–	–	–	–	–	–	–	–	–	–	–
1910	–	–	–	–	–	–	–	–	–	–	–	–	–
1911	–	–	–	–	–	–	–	–	–	–	–	–	–
1912	–	–	–	–	–	–	–	–	–	–	–	–	–
1913	–	–	–	–	–	–	–	–	–	–	–	–	–
1914	–	–	–	–	–	–	–	.70	.85	.62	.06	.61	–
1915	.62	.19	.65	1.21	4.20	2.10	2.18	.36	–	–	–	–	–
1916	1.03	.65	.79	1.33	1.91	1.73	1.12	.52	.48	1.07	.08	.30	11.01
1917	.44	.54	1.06	1.66	1.31	–	–	–	–	–	.52	.40	–
1918	1.25	.62	.39	.98	.60	.45	.99	1.64	1.53	1.08	.50	.16	10.19
1919	.14	.94	–	1.25	–	.00	.03	.10	.25	.91	.19	1.87	–
1920	.19	.50	1.52	.65	.55	–	–	–	–	–	–	–	–
1921	–	–	–	–	–	–	–	–	–	–	–	–	–
1922	–	–	–	–	–	1.17	1.19	2.41	.13	.20	–	.69	–
1923	–	.35	.35	1.63	2.18	2.01	.90	.50	.15	.70	.29	–	–
1924	.30	.20	.95	.54	.44	.12	.78	.10	.74	.83	.36	1.05	6.41
1925	–	.10	.60	–	–	2.93	1.09	.58	2.26	.46	.30	1.59	–
1926	–	–	.11	–	–	.06	–	.73	–	–	–	–	–
1927	–	–	–	–	–	–	–	–	–	–	–	–	–
1928	–	–	–	–	–	–	–	–	–	–	–	–	–
1929	–	–	–	–	–	–	–	–	–	–	–	–	–
1930	–	–	–	–	–	–	–	–	–	–	–	–	–
1931	1.11	–	–	–	–	–	–	–	–	–	–	–	–
1932	–	–	–	–	–	–	–	–	–	–	–	–	–
1933													–
1934													–
1935													–
1936													
1937													
1938													
1939													
1940													
Until 1975		No Data											
$\bar{x}$	.635	.454	.71	1.16	1.60	1.32	1.04	.76	.81	.73	.29	.83	
σ	.440	.270	.426	.412	1.337	1.046	.590	.722	.811	.304	.173	.620	

Table 6. Monthly Precipitation for Leadore, Idaho. (inches)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1941	–	–	–	–	–	–	–	–	–	–	–	–	–
1942	–	–	–	–	–	–	–	–	–	–	–	–	–
1943	–	–	–	–	–	–	–	–	–	–	–	–	–
1944	–	–	–	–	–	–	–	–	–	–	–	–	–
1945	–	–	–	–	–	–	–	–	–	–	–	–	–
1946	–	–	–	–	–	–	–	–	–	–	–	–	–
1947	–	–	–	–	–	–	–	–	–	–	–	–	–
1948	.44	.43	.54	.61	1.80	2.07	.63	.49	1.38	.62	.83	1.18	11.02
1949	.60	.32	.40	–	2.47	.29	.82	.11	1.00	.24	.34	.56	–
1950	–	–	–	–	–	–	–	–	–	–	–	–	–
1951	.57	.62	–	.51	1.54	.47	.99	1.60	.08	–	–	–	–
1952	–	–	–	–	–	–	–	–	–	–	–	–	–
1953	.54	.46	.47	.56	1.94	.94	.81	.73	.82	.43	.59	.87	–
1954	.085	.152	.099	.070	.480	.980	.180	.774	.668	.269	.346	.438	–

Monthly Precipitation Inches

Leadore No. 2, Idaho

1965	–	–	–	–	–	–	–	–	–	T	.35	.07	–
1966	.12	.10	T	T	.30	1.21	.08	.15	.89	.32	.44	.06	3.67
1967	.42	.33	.93	1.34	.91	2.66	.61	.13	.50	1.28	.59	.44	10.14
1968	1.20	.54	.40	.28	1.46	1.50	.30	2.17	2.11	.17	1.49	.80	12.42
1969	.50	.20	.07	.17	.80	1.18	1.17	.25	.67	.47	.48	.20	6.16
1970	.40	T	.50	.82	1.24	1.04	1.09	1.03	.71	.31	1.37	.20	–
1971	.42	.10	.10	1.04	1.49	1.51	.08	1.00	.89	.66	.73	.95	8.97
1972	.80	T	.32	.23	1.42	1.06	.58	1.14	.63	1.01	.25	.19	7.63
1973	.30	T	.40	.92	.34	2.05	.87	.62	.95	.17	.67	.61	7.90
1974	T	.19	.75	.20	1.52	.20	.40	1.21	T	1.19	T	.55	6.21
1975	.34	.03	.28	1.31	1.57	.56	1.12	T	.03	1.24	.20	2.13	8.81
$\bar{x}$	.5	.21	.42	.70	1.11	1.30	.63	.86	.82	.68	.66	.56	7.99
σ	.319	.173	.281	.486	.488	.699	.418	.655	.558	.456	.442	.598	2.529
[illegible]	.68	.52	.64	.52	1.37	1.33	.72	.69	1.00	.44	.77	.90	

The frequency distribution of the graphical values are plotted in Figures 5 to 16 for each month. Indicated by arrows on the graph are the values of the mean, the mode (maximum frequency), and the 20 percent probability (chance of happening once every five years). These values will be used later on to estimate consumptive use but one should use caution in using these figures, particularly in the Lemhi and Leadore areas because the record is not of sufficient length or completeness to estimate long term averages with great confidence. For this reason additional measurements were taken during July-November 1976 by the investigators, hoping to establish a correlation which would provide greater confidence in the estimated monthly temperature.

Plotted in Figure 17 is an accumulated monthly precipitation curve sometimes referred to as a mass curve. Each of the three frequencies noted above are shown. It is to be noted that the mean values give maximum precipitation occurring during May, June, and September. These peak precipitation periods are also reflected in the peak runoff curves as will be noted later.

The precipitation measuring stations are all located on the valley floor and therefore do not provide an estimate of the total precipitation available in the basin. To obtain this estimate, the rainfall map prepared by the Weather Bureau in 1965 for the State of Idaho was used. This has been reproduced for the Lemhi basin in Figure 18. The area between iso-lines was measured and the precipitation determined by multiplying that area by the average rainfall in that area. Summing these values over the entire basin gives the following results:

Total average annual precipitation = 15.53 in. (1,055,000 ac.ft.)

Precipitation above gage at Lemhi = 15.76 in. (751,300 ac.ft.)

Precipitation below gage at Lemhi = 14.98 in. (303,600 ac.ft.)

Precipitation above gage on Texas Creek = 14.58 in. (56,100 ac.ft.)

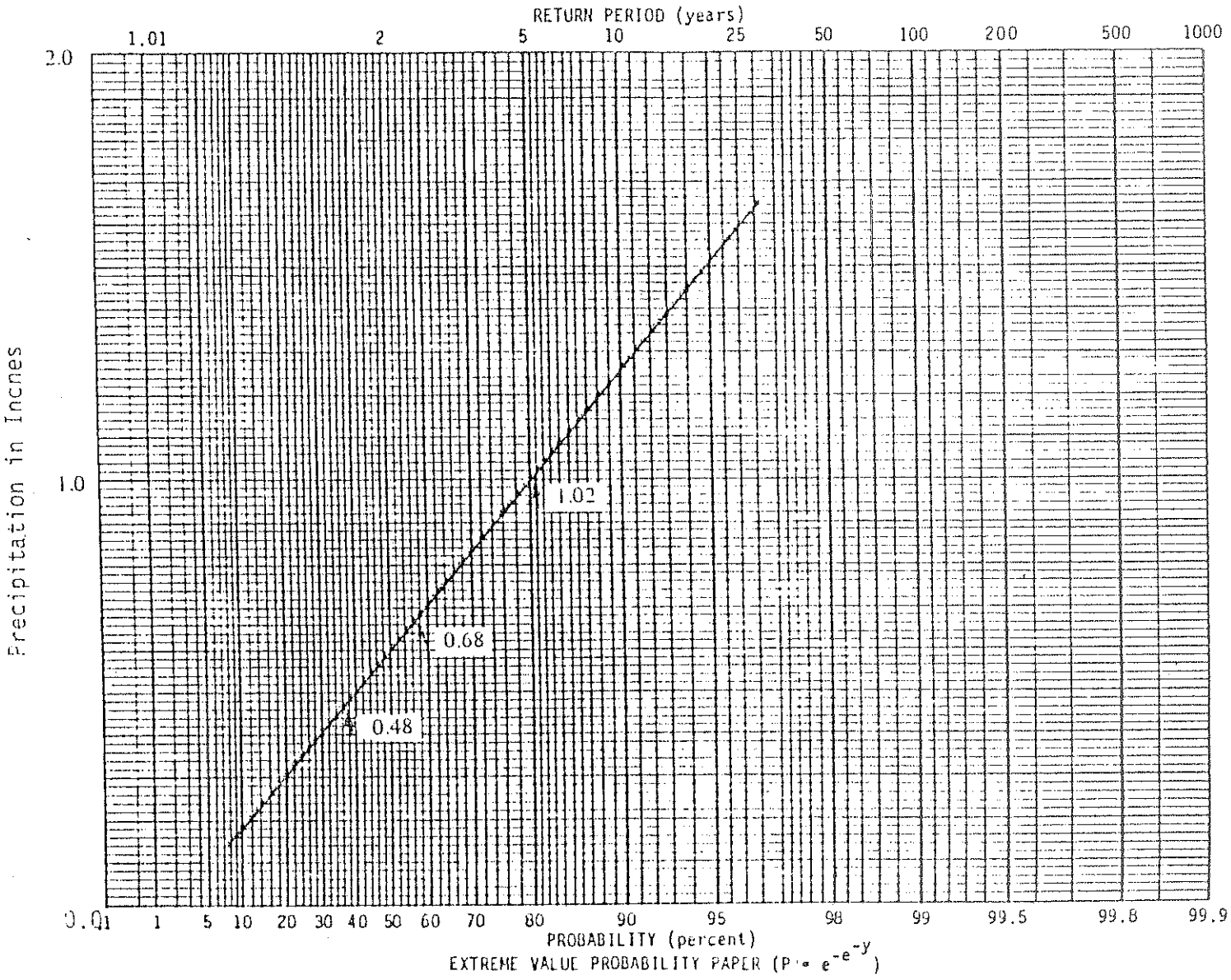


Figure 5. Frequency Distribution of Precipitation at Leadore, Idaho. January

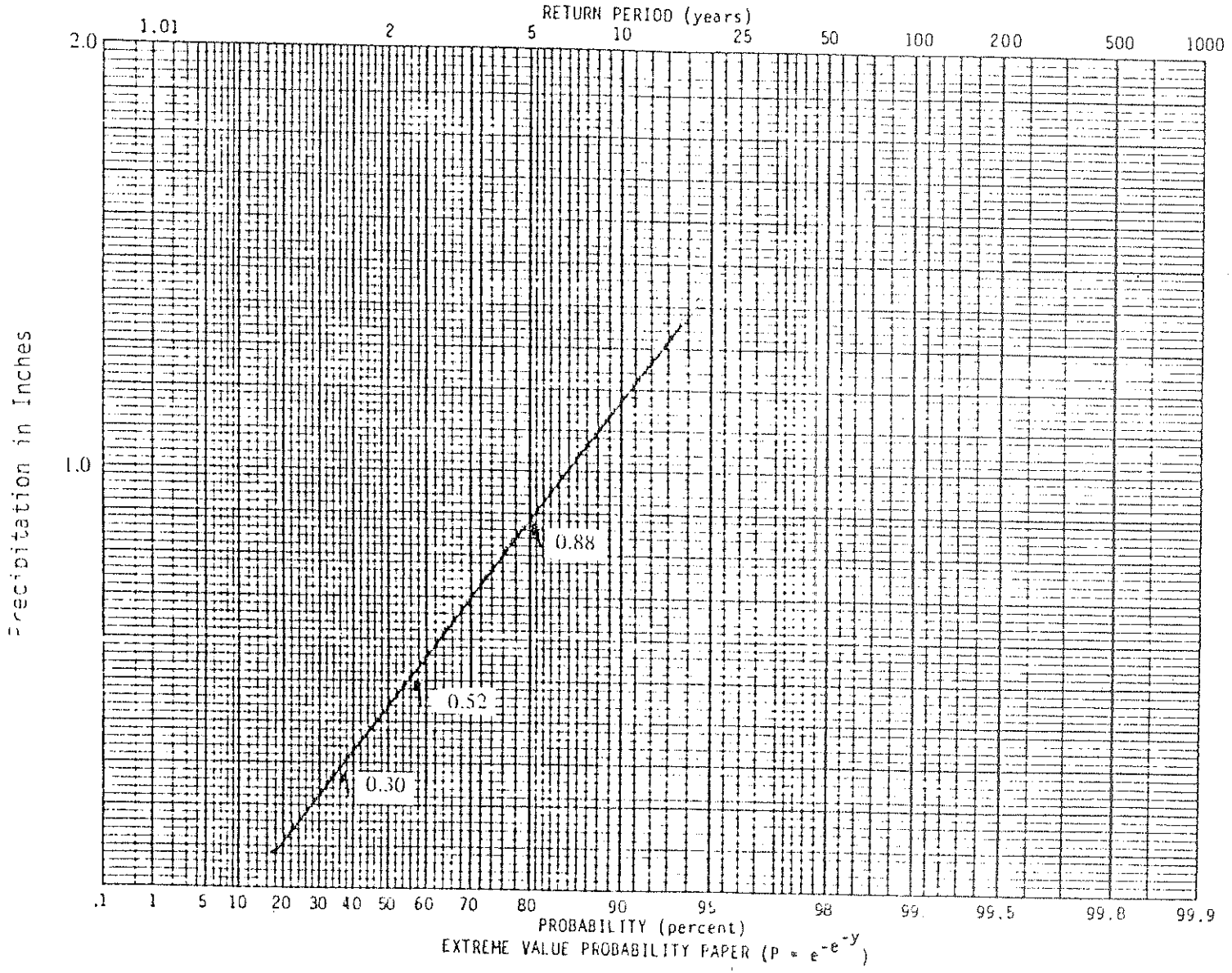


Figure 6. Frequency Distribution of Precipitation at Leadore, Idaho. February

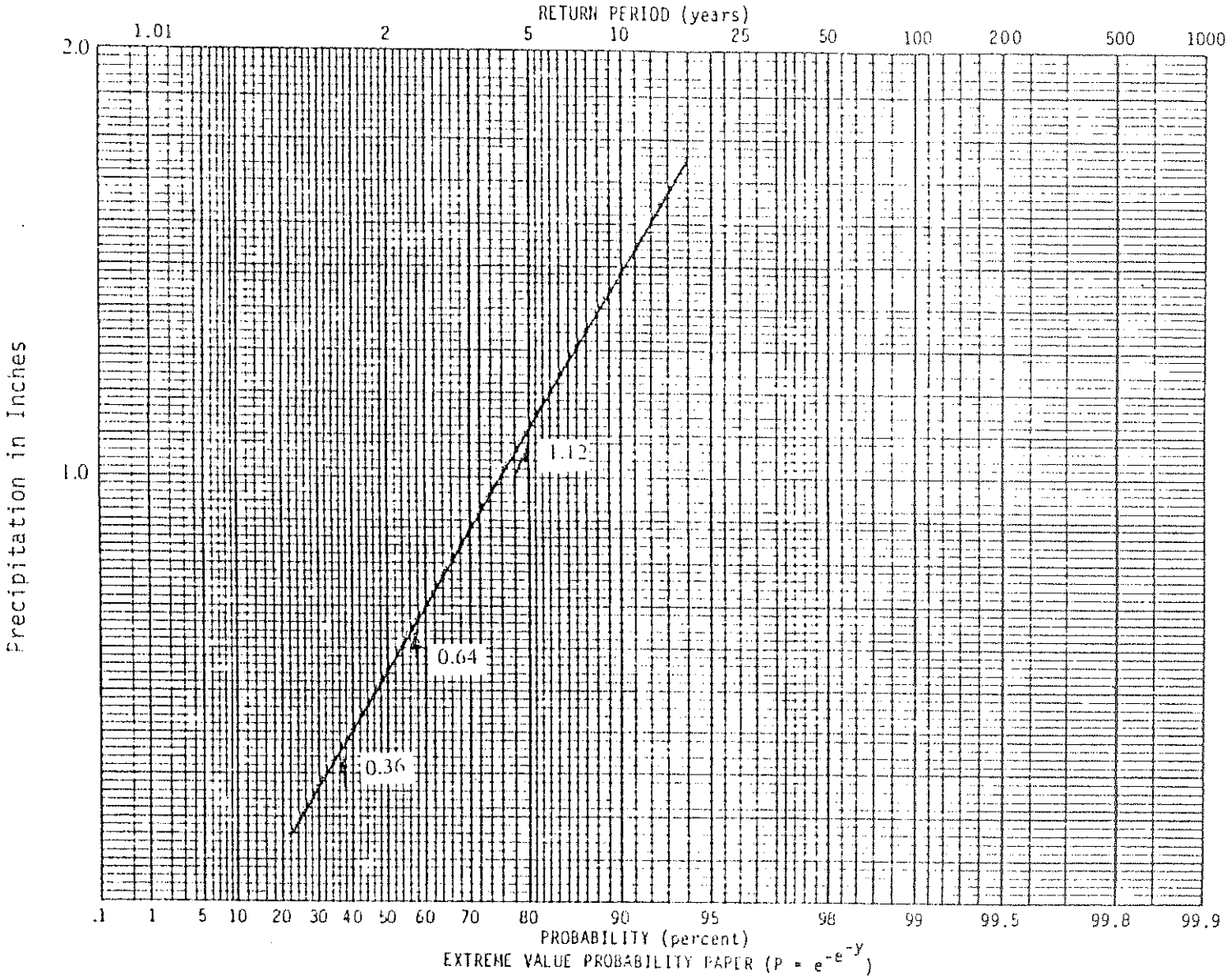


Figure 7. Frequency Distribution of Precipitation at Leadore, Idaho. March

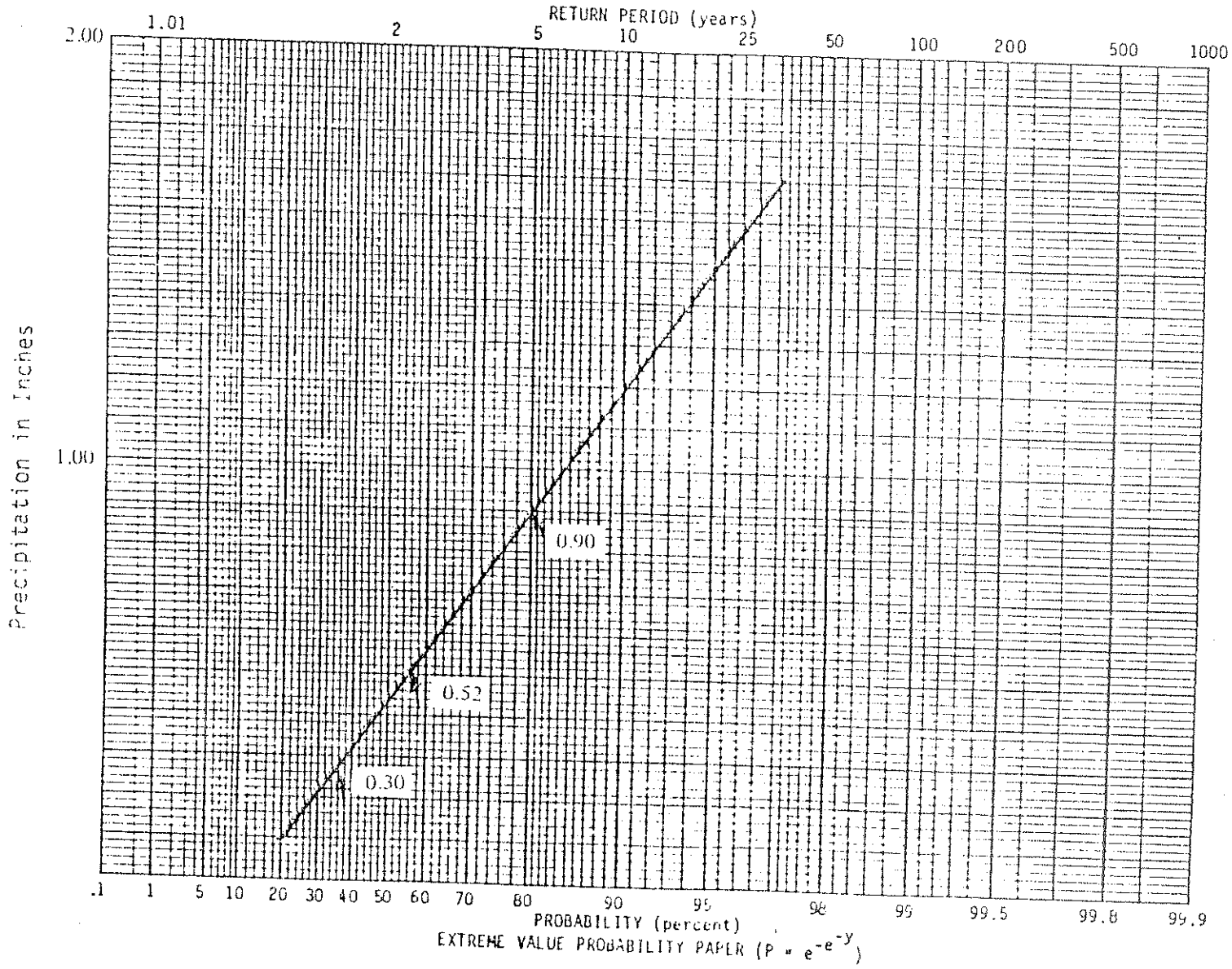


Figure 8. Frequency Distribution of Precipitation at Leadore, Idaho. April

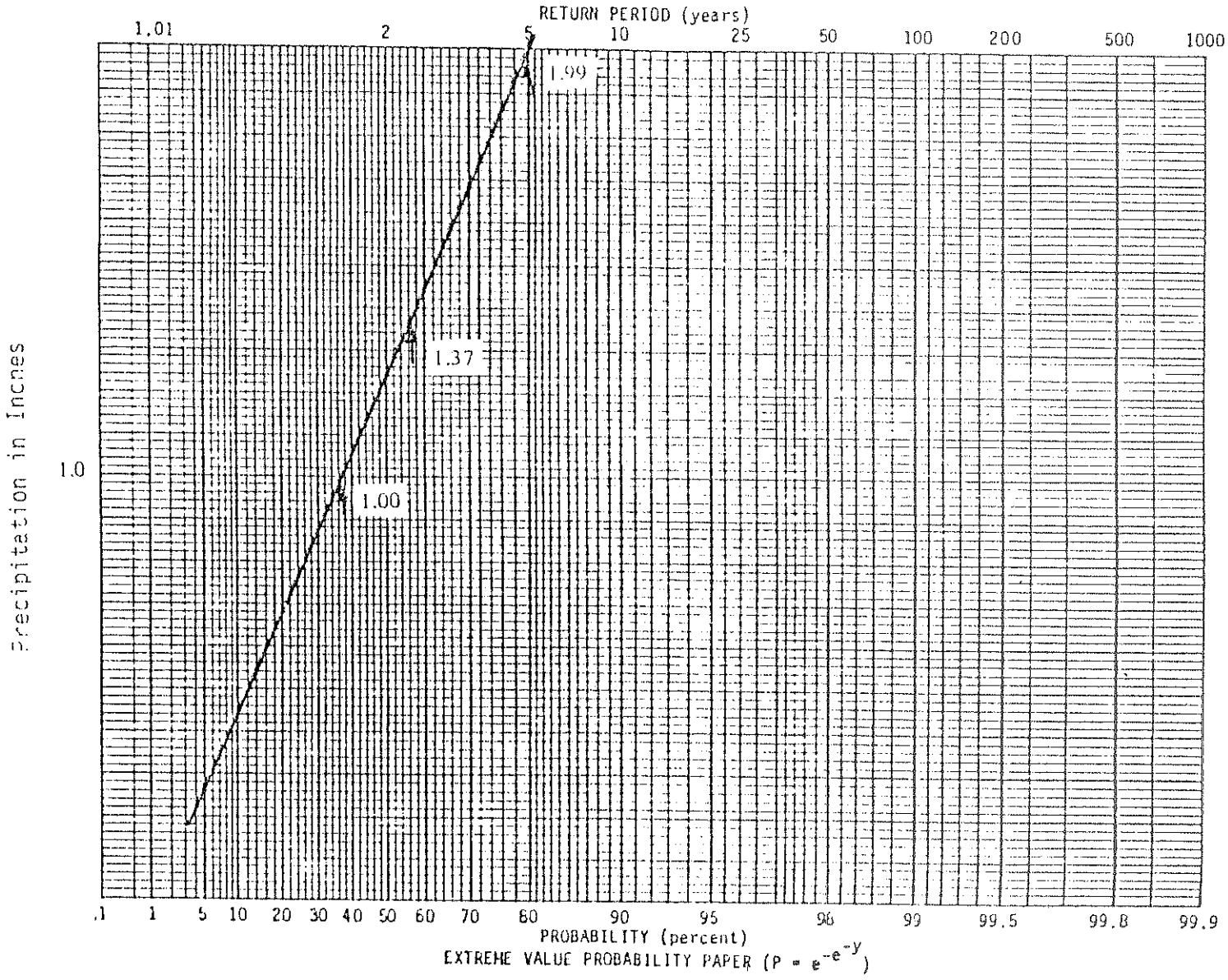


Figure 9. Frequency Distribution of Precipitation at Leadore, Idaho. May

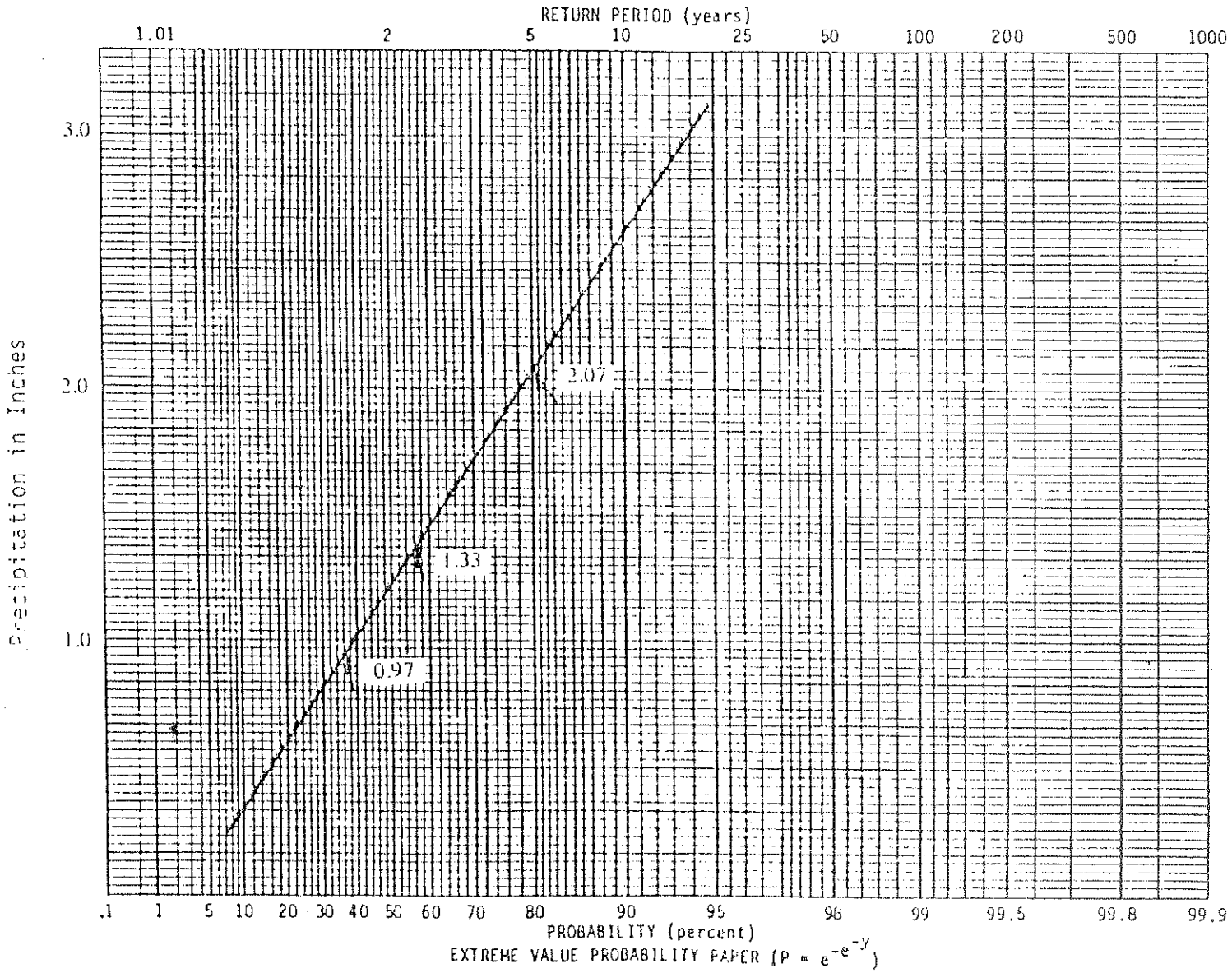


Figure 10. Frequency Distribution of Precipitation at Leadore, Idaho. June

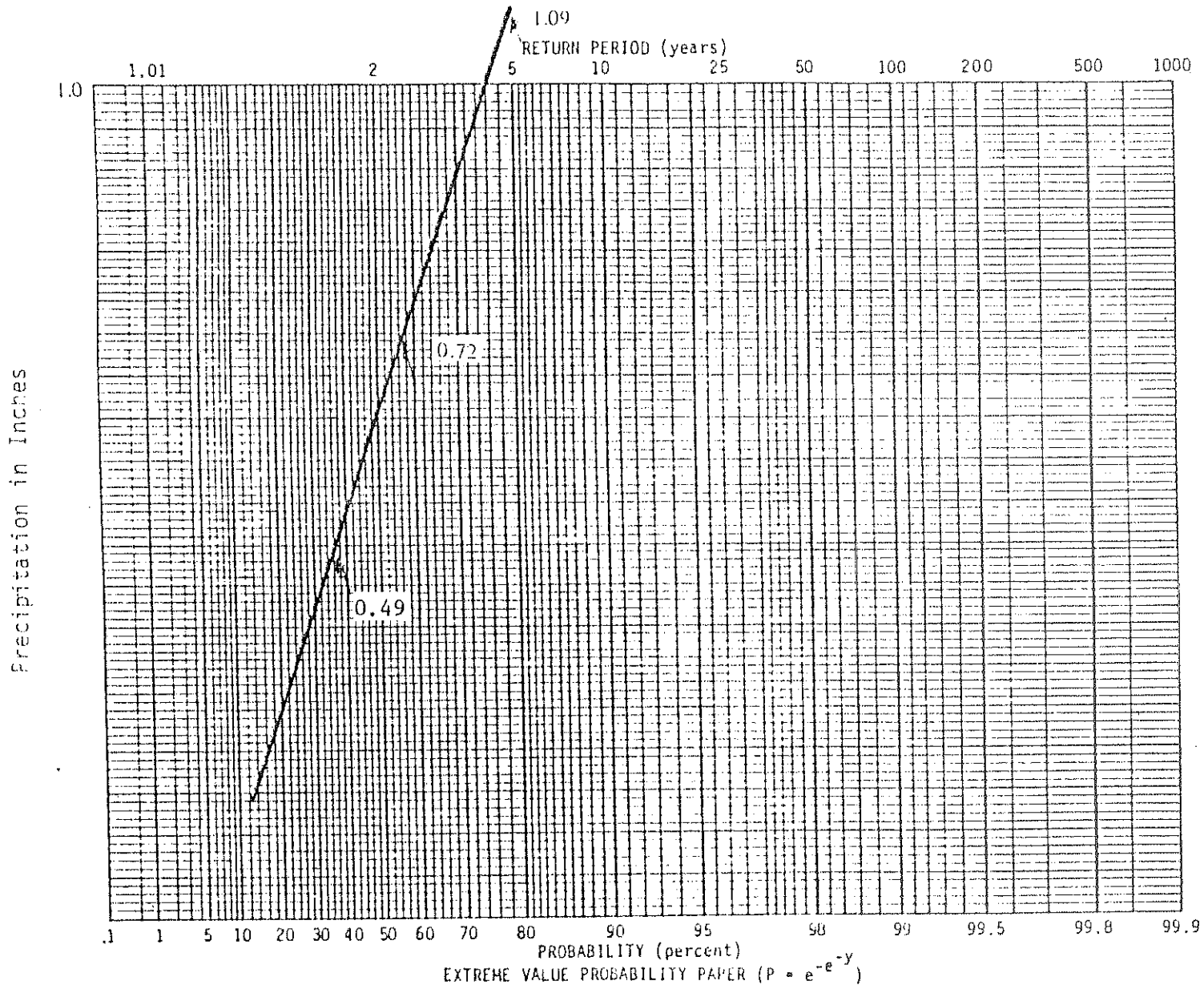


Figure 11. Frequency Distribution of Precipitation at Leadore, Idaho. July

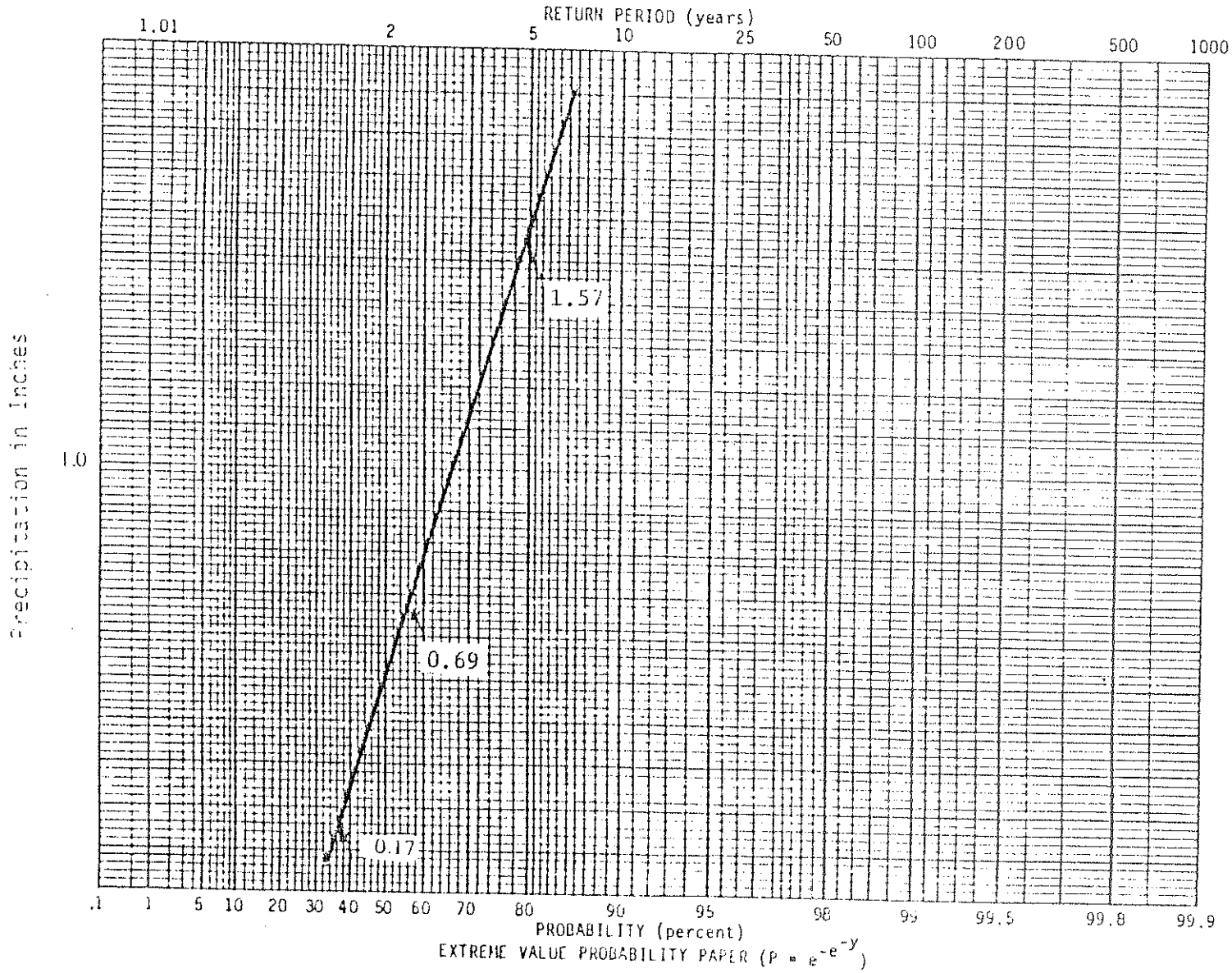


Figure12. Frequency Distribution of Precipitation at Leadore, Idaho. August.

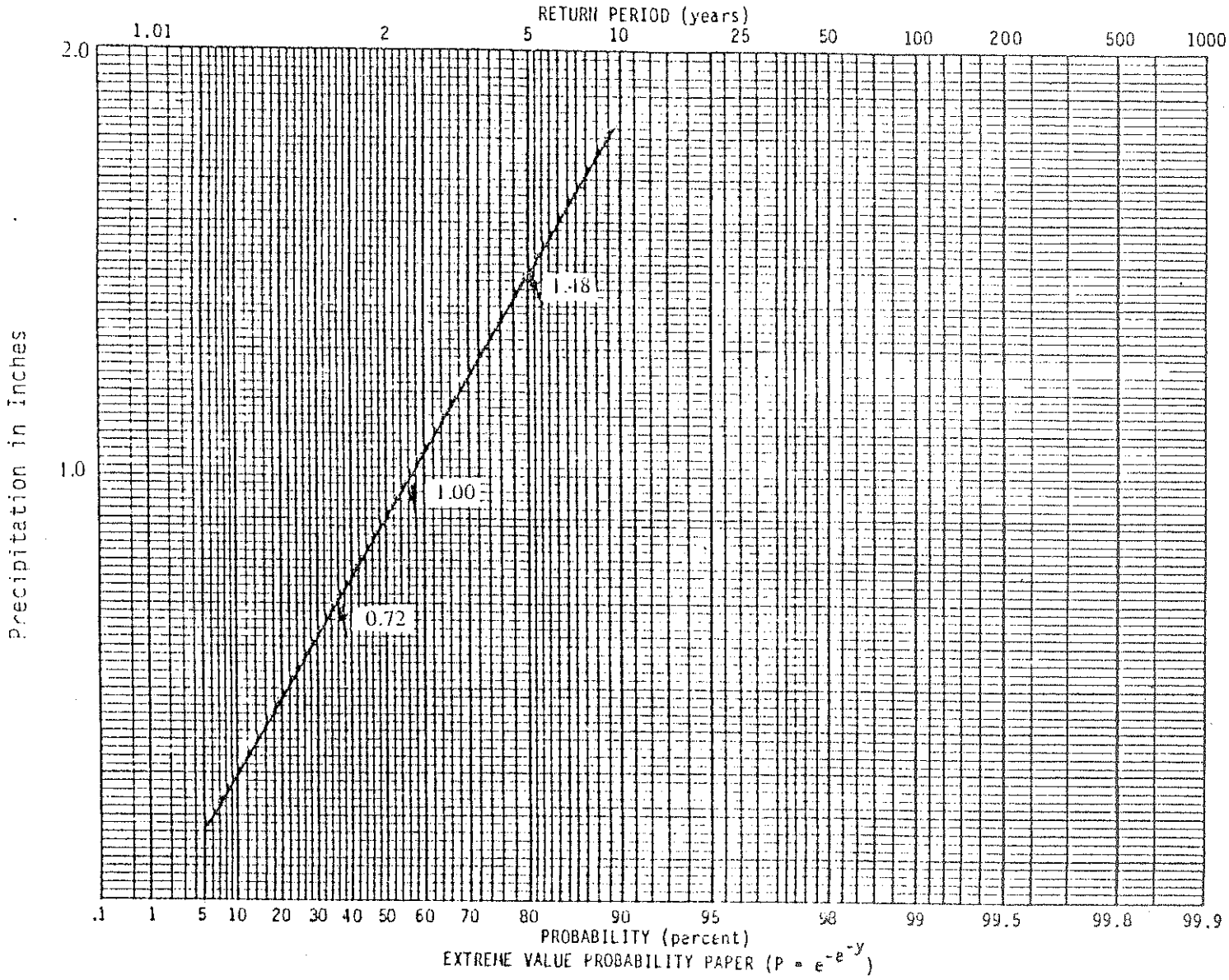


Figure 13. Frequency Distribution of Precipitation at Leadore, Idaho. September

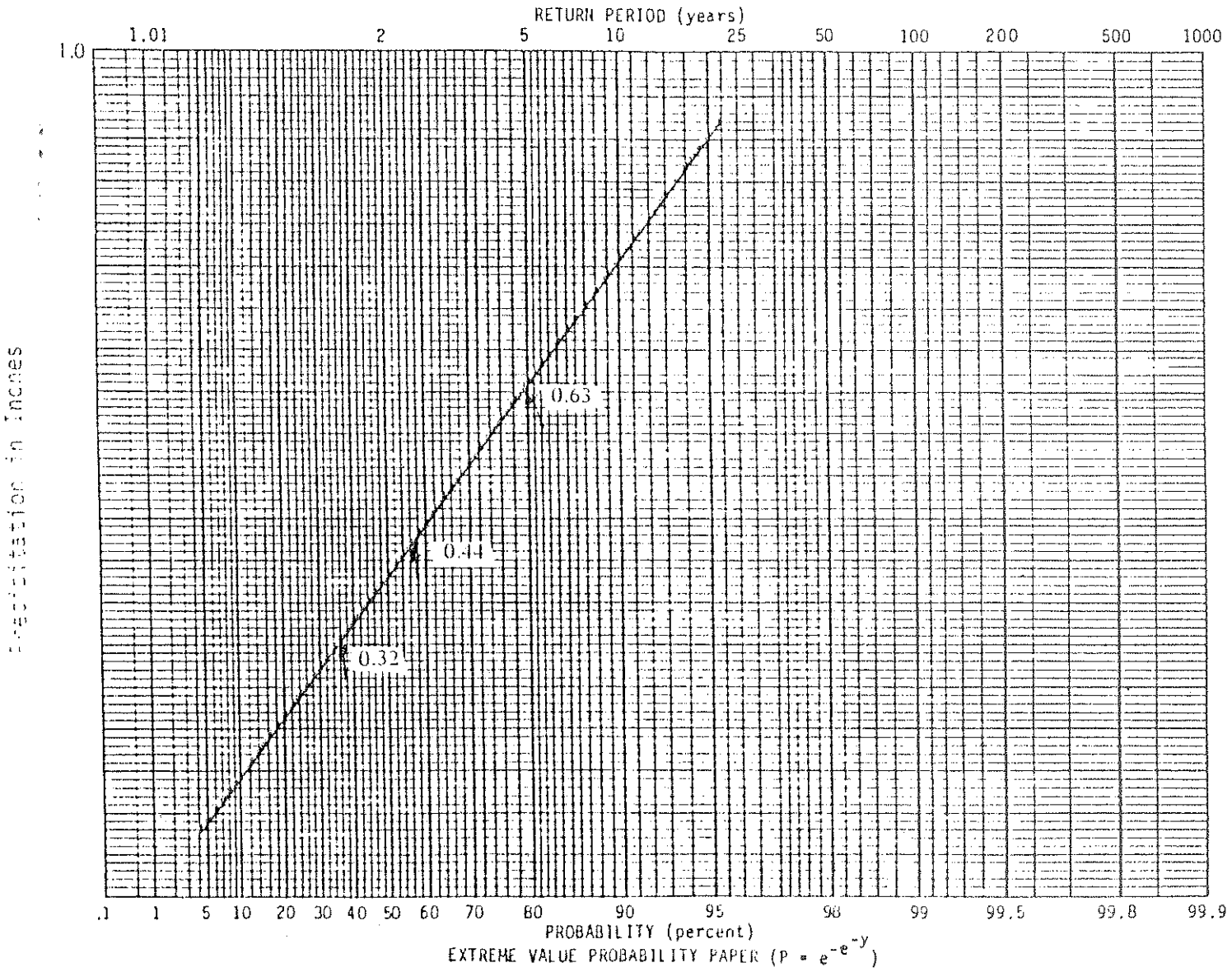


Figure 14. Frequency Distribution of Precipitation at Leadore, Idaho. October

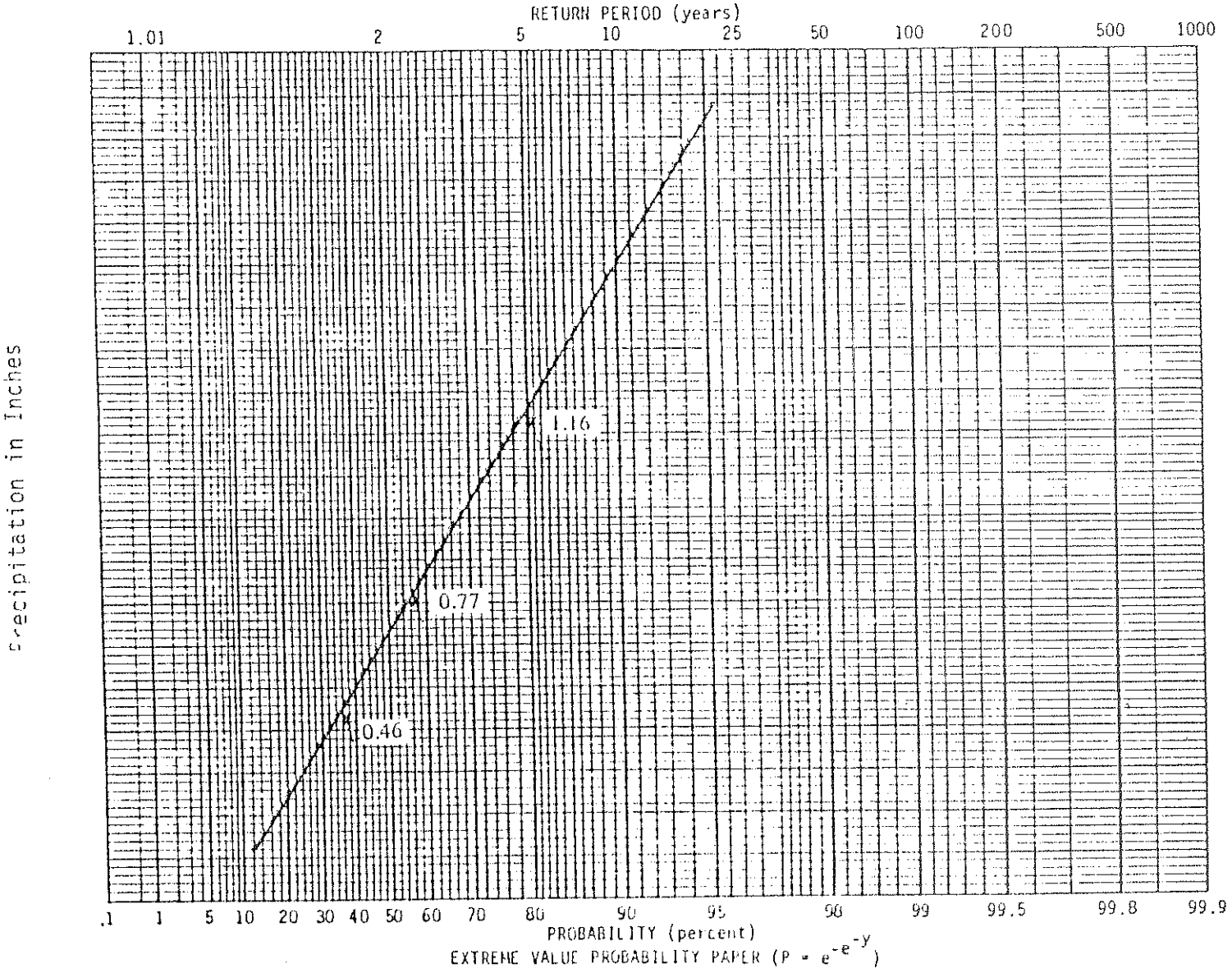


Figure 15. Frequency Distribution of Precipitation at Leadore, Idaho. November

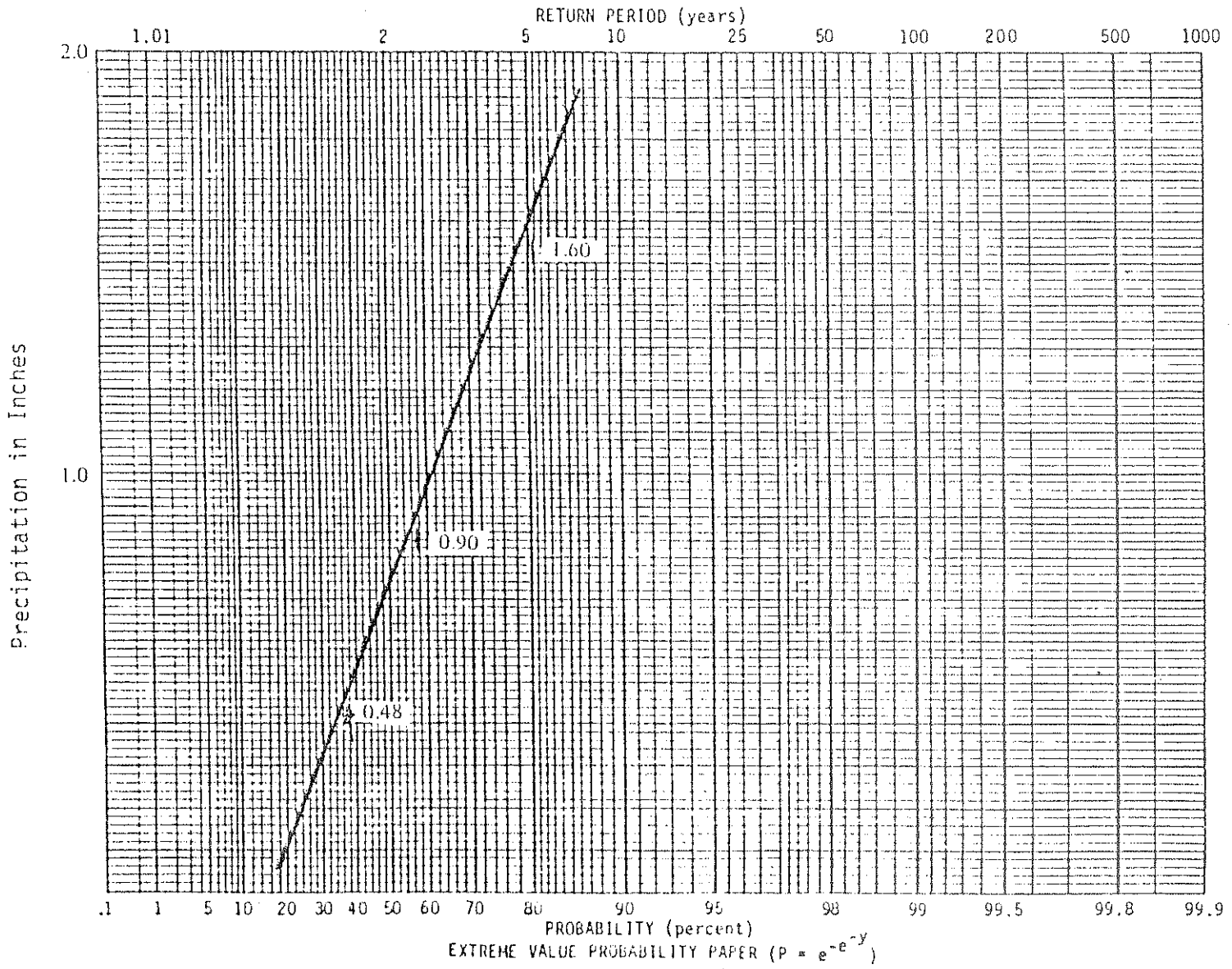


Figure 16. Frequency Distribution of Precipitation at Leadore, Idaho. December

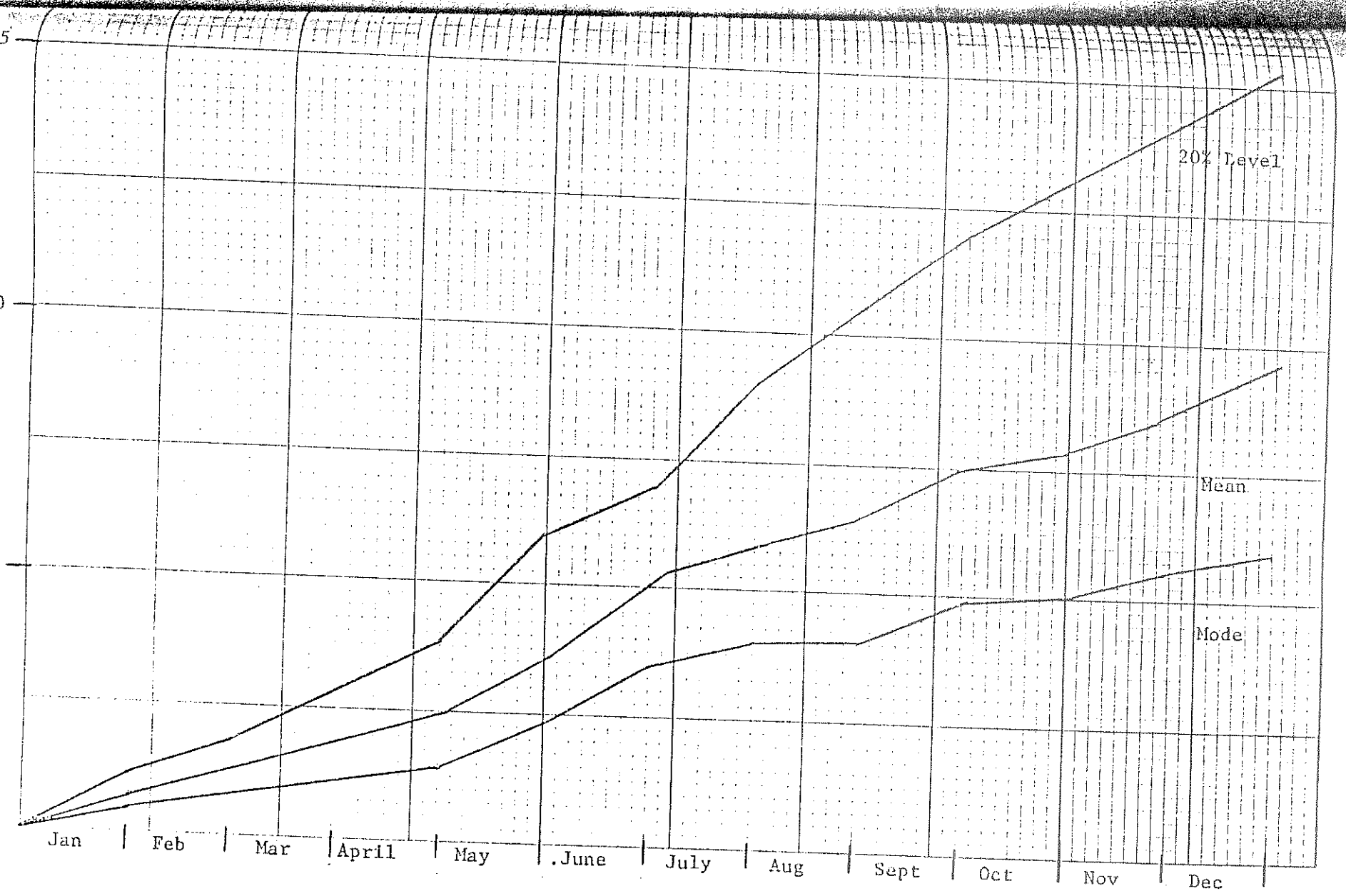


Figure 17. Accumulated Monthly Precipitation.

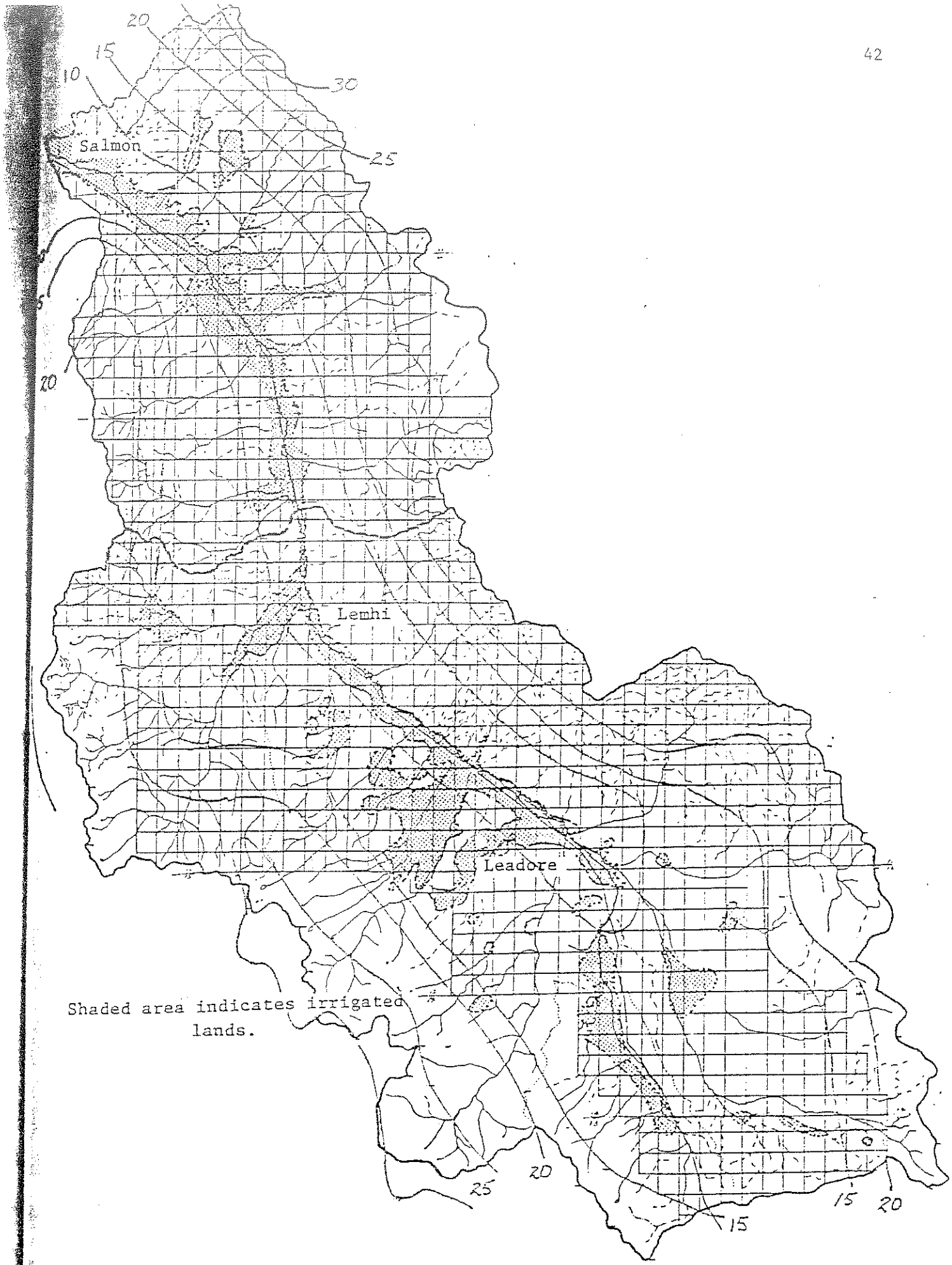


Figure 18. Annual Rainfall Map for Lemhi River Drainage Area.

Runoff

The precipitation which falls upon the land is disposed of in a variety of ways. Part of the water stays on the land surface until it is evaporated back into the atmosphere; part penetrates the soil into the root zone of the vegetation and is transpired back into the atmosphere or stored in the tissues of the plants; part percolates deeply into the soil and forms the ground water which may then move to the surface streams, be pumped out and transpired by vegetation or exit the basin underground. The water which is left over after all these other processes have taken their toll flows in the streams and is either diverted as irrigation, domestic, or industrial water, or exits the basin as river flow.

River flow in the Lemhi Basin is measured at gaging stations at Lemhi, Idaho, and at Salmon, Idaho. One upper tributary stream is measured at Texas Creek and some sporadic measurements have been made at Big Springs Creek. As with the meteorological measurements so with the river measurements, the records are not complete. The station at Salmon was discontinued in 1943 and the Lemhi and Texas Creek stations did not begin until 1955 and were discontinued in 1963. Because all measuring stations are within the same basin, one would expect a consistency between records. This is demonstrated by the plot of frequency distribution for the three stations as shown in Figure 19. The fact that the points all fall on a straight line indicates that the meteorological conditions in the basin affect all streams in a similar manner.

The gaging station records at Salmon and at Lemhi do not cover the same time period so cannot be directly compared, but the average flow during the period of record is of interest. The average flow of Lemhi River at Salmon, Idaho, is 178,000 acre feet. This is all that

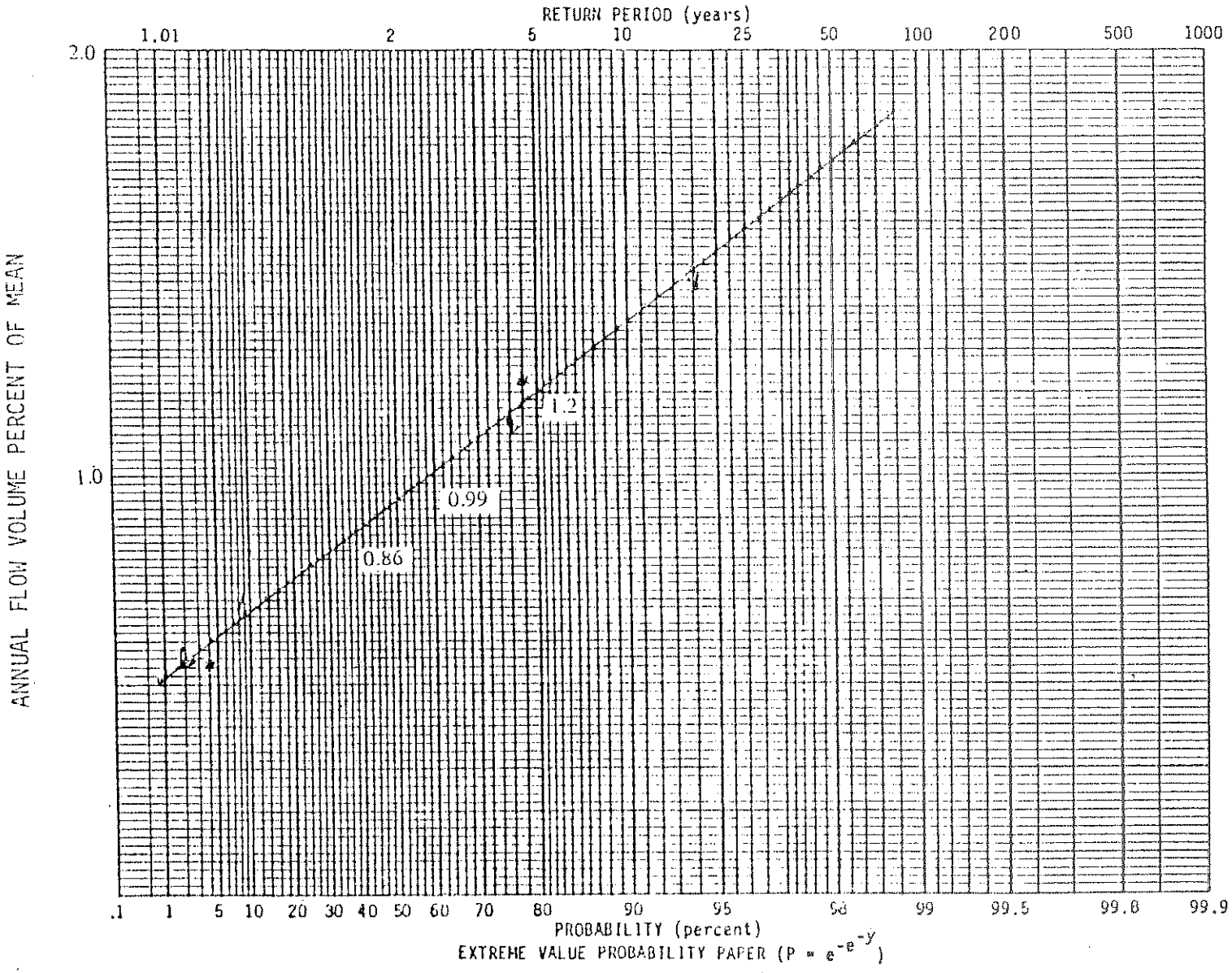


Figure 19. Frequency Distribution of Annual Stream Flow for Three Stations of the Lemhi River, Idaho.

remains of the 1,055,000 acre feet which fell as precipitation. The difference of 877,000 acre feet has been disposed of through the processes of transpiration, evaporation, and underground outflow.

One of the important things pertaining to this study is to ascertain if the existing records, as imcomplete as they might be, can be used to make judgments about the effect of high irrigation rates upon river flow. It is postulated, and perhaps even observed by those who have been acquainted for a long time with the area, that heavy irrigation rates in the early part of the season create river flows in the late season which are beneficial to downstream users. If this is true it should be reflected in the records of stream flow. Since the gage at Lemhi and the gage at Texas Creek are in the same hydrologic province, the ratio of these two flows should be nearly constant except as modified by snow melt or irrigation diversions and return flow. The plot of this ratio is shown in Figure 20. The high value of the ratio in the months of May and June means that snow melt is affecting the flow at Lemhi much more than it is at Texas Creek. This is to be expected due to the larger drainage area and more numerous tributaries contributing to the flow at Lemhi. The values for July and August reflect the normal recession as the ground water, increased by the snow melt, returns to normal. The interesting thing in this plot is the departure from the recession curve occurring in the month of September. In this month diversions are expected to be down, crop transpiration down, and thus return flow if any to be up. This return flow would apply more to the area below the Texas Creek gage and thus the ratio would increase. That this occurs, as shown on the plot, is confirming evidence that heavy irrigation application rates are beneficial to the flow in Lemhi River. If return flow were not present, the heavy irrigation diversion

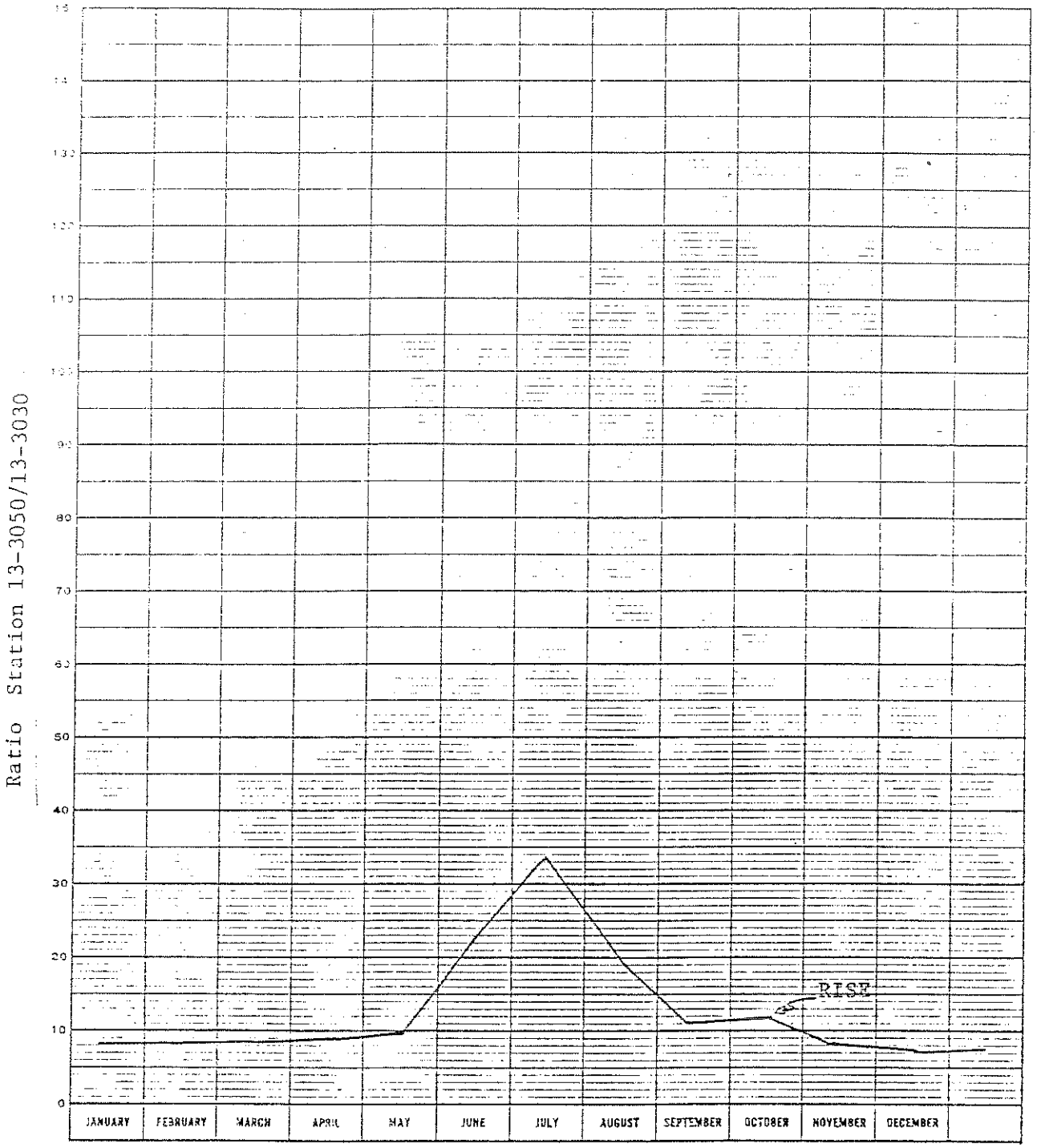


Figure 20. The Ratio of the Monthly Flow Volume of the Lemhi River at Lemhi (13-3050) to that of Texas Creek (13-3030).

rates would reduce the flow at Lemhi proportionately greater than it would the natural flow at Texas Creek and the ratio would be smaller.

The flow hydrograph for the three gaging stations are shown in Figures 21, 22, and 23. The peak runoff period occurs during May and June and regresses during July and August. It will be remembered that May and June are also high precipitation months and that snow melt usually occurs during this period. The regression during July and August is due to the drainage of the ground water after the snow melt period has ended. The small peak occurring in September may be a reflection of the increased precipitation during that month, but could also be associated with a reduction in irrigation diversions if such occurs. The fact that the peak occurs both in the Lemhi gage and the Texas Creek gage would imply that precipitation is the strongest cause and our previous analysis using the ratio of flows is still valid. The increase in the ratio during September is caused by some increase in flow to the river below Texas Creek which is linked in some manner to return flow and reduced consumptive use in the area.

Temperature

Plant growth rates and water evaporation rates are both dependent upon temperature and therefore water requirements are similarly dependent. Temperature records, again, are not good except at Salmon, and to extrapolate the Salmon temperatures to the upper reaches of the valley would induce large errors. The few years of record available at Leadore indicate a mean annual difference of about 7° F. when compared with Salmon. The temperature records available are shown in Tables 7 to 10.

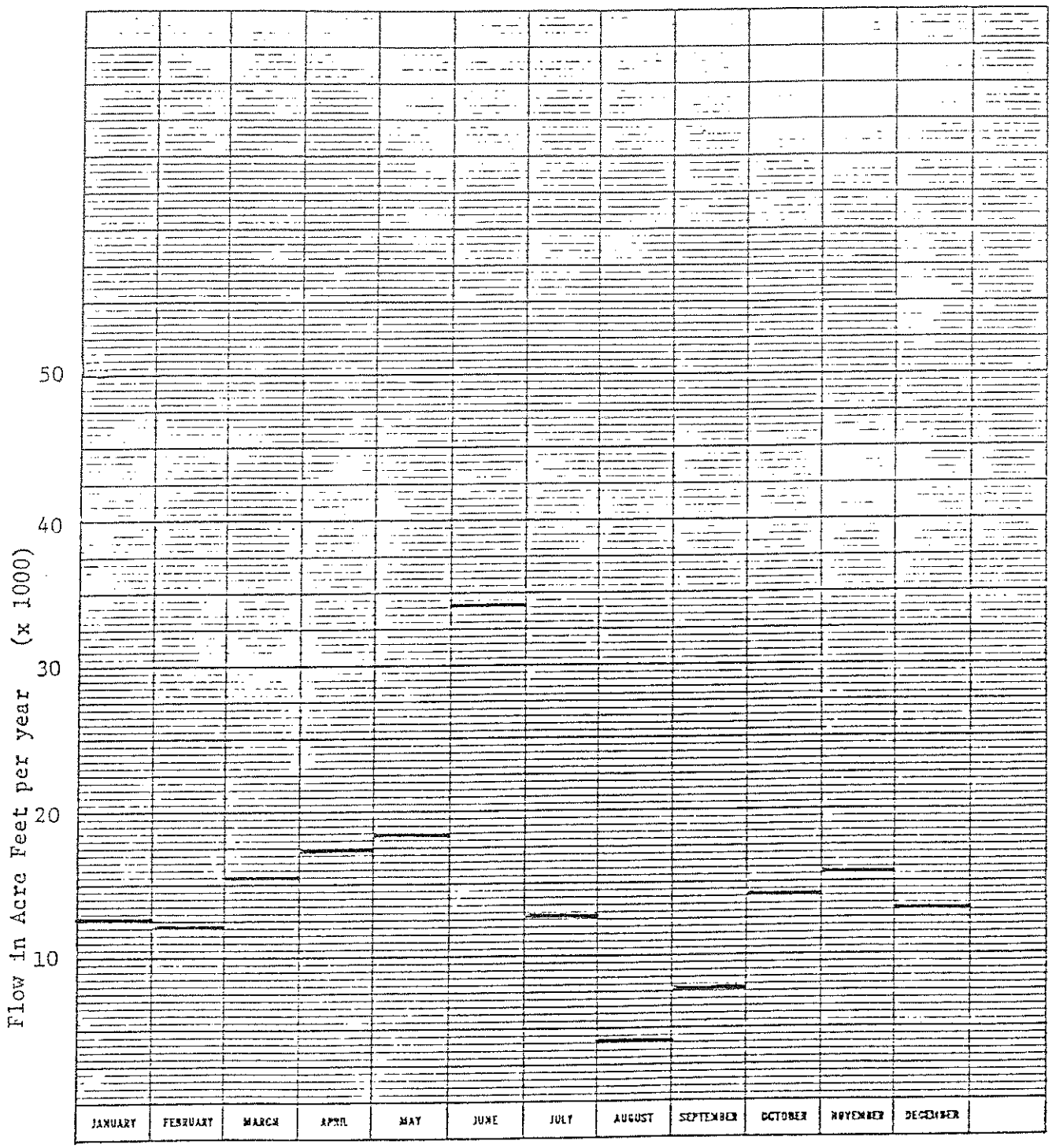


Figure 21. Flow Hydrograph of Lemhi River at Salmon

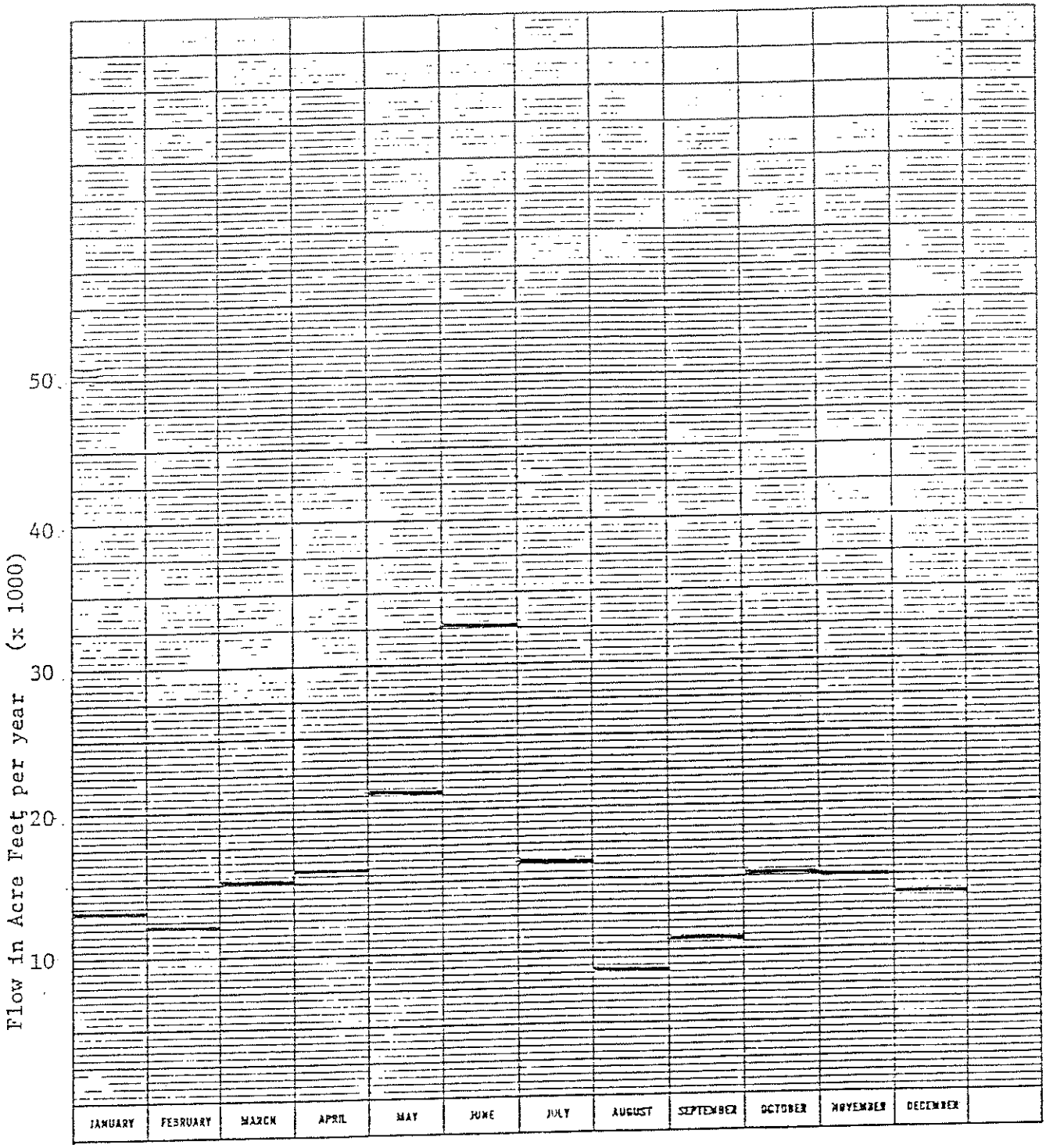


Figure 22. Flow Hydrograph of Lemhi River at Lemhi

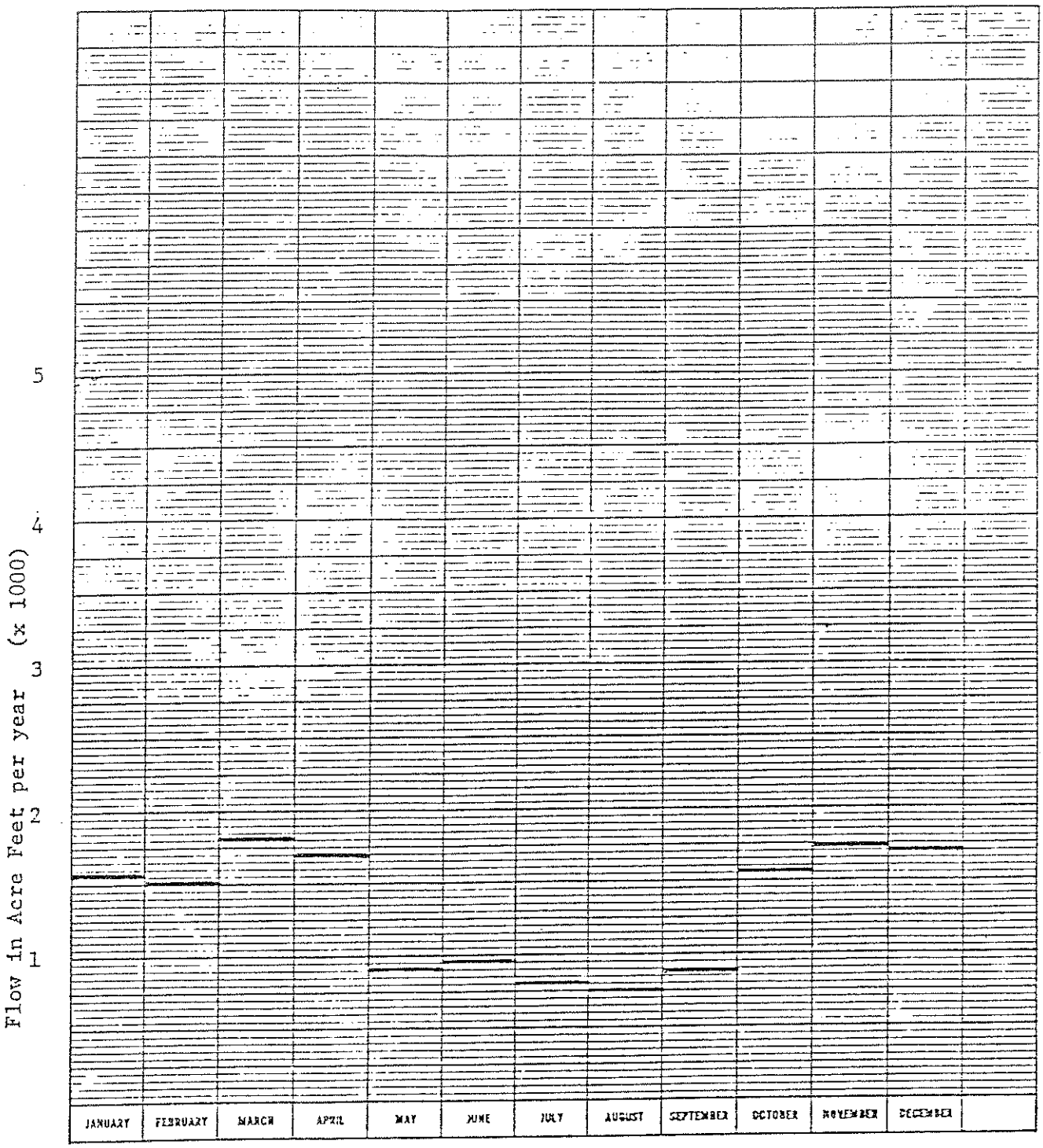


Figure 23. Flow Hydrograph of Texas Creek

Table 7. Monthly Temperature for Salmon, Idaho (F^{o})

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1914	26.8	25.5	40.2	47.4	57.2	61.4	66.9	64.7	56.0	46.6	34.0	15.0	45.1
1915	17.7	31.8	39.8	52.4	52.1	57.0	63.1	67.4	55.6	48.2	33.84	22.7	45.1
1916	9.2	26.8	40.8	47.0	48.4	57.6	67.6	64.2	57.0	42.4	28.0	17.4	42.2
1917	16.0	22.4	27.0	43.3	50.8	58.2	70.9	65.9	60.2	46.0	36.0	36.5	44.4
1918	24.2	23.2	37.6	44.6	52.4	67.2	67.8	62.8	-	-	-	-	-
1919	-	-	-	-	-	-	71.6	67.4	59.4	41.2	30.2	6.2	-
1920	15.6	27.8	33.6	41.4	51.4	56.6	-	65.5	-	44.2	-	24.8	-
1921	22.6	26.1	41.6	45.2	56.1	64.3	70.2	66.8	55.0	50.1	35.4	23.2	46.4
1922	9.4	15.2	29.0	43.5	53.2	63.9	68.6	68.8	59.7	50.8	32.8	22.2	43.1
1923	26.9	20.4	35.2	45.4	55.6	58.6	70.2	66.8	59.0	44.4	-	19.5	-
1924	11.4	31.4	33.8	44.5	56.9	60.6	66.4	65.4	55.4	48.5	32.4	10.0	43.1
1925	23.2	31.3	37.6	48.6	56.5	63.8	70.0	63.5	55.8	42.7	31.7	26.6	-
1926	12.5	28.8	37.0	49.4	53.8	63.1	68.8	65.0	49.6	46.6	34.8	23.4	44.4
1927	20.9	29.6	38.7	44.7	51.7	62.5	67.6	63.5	55.6	46.1	-	15.3	-
1928	18.6	18.9	34.6	43.9	59.2	58.0	68.6	64.0	53.6	44.7	32.0	18.2	42.9
1929	12.6	15.6	37.6	43.4	52.2	63.2	70.8	70.2	55.7	45.7	26.8	30.6	43.7
1930	6.4	30.8	37.2	51.4	54.7	62.6	70.6	69.4	58.1	44.2	29.6	15.6	44.2
1931	18.6	21.1	34.9	45.6	-	63.0	70.4	68.2	57.9	45.8	26.6	16.0	-
1932	-	-	-	-	-	-	-	65.2	56.0	43.4	34.2	16.0	-
1933	20.8	12.8	35.8	43.4	49.5	65.2	70.4	64.9	54.4	49.3	35.3	32.6	44.5
1934	30.0	36.0	43.7	52.2	59.3	61.3	69.0	68.8	54.0	47.6	39.4	24.0	48.8
1935	24.0	27.8	34.5	43.0	50.4	61.1	66.8	65.3	58.4	42.2	27.5	17.9	43.2
1936	14.8	16.2	33.7	46.2	58.2	62.9	71.4	68.6	-	45.4	25.6	21.7	-
1937	3.2	22.4	36.5	43.1	54.9	59.3	70.1	65.0	58.3	46.1	34.7	24.5	43.2
1938	19.3	27.5	35.9	-	52.0	60.8	-	-	61.4	45.0	29.2	24.3	-
1939	-	19.3	35.9	47.3	55.1	57.0	-	64.3	56.1	45.5	31.8	30.3	-
1940	17.2	27.1	40.1	46.7	56.4	64.6	68.3	67.2	57.8	47.2	26.6	24.2	45.3
1941	18.1	25.6	39.9	44.7	54.8	60.3	66.9	64.4	49.8	43.4	34.3	25.2	44.0
1942	8.95	14.6	30.2	46.1	48.4	55.9	67.7	-	56.5	45.5	-	21.5	-
1943	14.8	20.8	26.7	48.7	49.0	56.5	66.2	63.2	57.8	47.3	33.2	19.9	42.0
1944	11.2	27.6	-	47.1	54.5	58.2	-	64.6	57.8	49.5	31.7	-	-
1945	-	33.3	-	43.0	53.9	-	-	67.4	54.2	48.2	31.6	21.6	-
1946	-	-	-	-	-	61.7	69.1	66.1	54.1	-	63.5	25.8	-
1947	14.5	30.5	39.7	42.8	57.4	56.3	68.0	64.6	56.1	49.6	31.9	23.6	44.6
1948	22.3	27.9	34.1	44.3	54.0	63.3	63.8	63.8	56.5	44.7	31.4	8.6	42.9
1949	-2.4	23.2	37.2	47.7	56.0	60.2	66.7	66.9	57.3	40.2	36.4	23.1	42.7
1950	19.4	31.0	36.7	44.1	50.8	59.8	67.1	65.7	56.2	50.1	33.6	22.5	44.8
1951	27.2	39.0	43.9	64.8	71.7	-	89.9	82.5	-	58.8	-	32.0	-
1952	29.9	18.9	26.0	-	56.1	61.5	66.5	66.6	60.0	47.8	26.2	23.9	-
1953	34.3	30.7	38.9	43.2	49.5	58.1	69.6	65.8	59.7	47.3	36.7	25.9	46.6
1954	28.6	-	39.1	47.3	55.0	56.3	68.5	63.3	56.8	44.5	38.3	19.9	-

Table 7. (continued)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1955	17.2	18.9	29.6	41.7	52.2	59.6	66.1	68.2	56.6	47.1	28.5	25.6	42.6
1956	20.3	16.5	34.9	47.3	56.4	61.8	67.5	63.0	56.2	44.6	28.3	23.0	43.3
1957	9.0	26.5	37.0	44.8	56.5	60.9	68.2	66.4	57.4	45.8	29.7	26.8	44.1
1958	17.7	31.3	35.7	43.8	59.7	61.7	66.4	68.3	56.6	47.0	32.1	27.1	45.7
1959	24.0	30.5	37.1	46.0	50.0	63.3	66.7	63.5	54.5	43.6	29.1	22.7	44.3
1960	13.2	19.5	30.2	45.5	50.7	61.6	70.7	62.8	57.9	44.7	33.8	20.9	42.6
1961	20.5	35.6	37.9	44.1	53.2	66.0	69.7	69.8	52.0	44.2	31.8	21.8	45.5
1962	11.0	25.1	34.6	47.8	53.4	60.6	66.0	64.3	58.1	47.5	34.5	29.8	44.4
1963	13.1	35.7	39.0	43.0	55.0	58.5	67.7	67.2	60.4	50.2	35.2	17.9	45.2
1964	18.7	21.6	30.1	42.4	52.9	58.2	69.7	63.5	54.9	45.6	32.3	24.8	42.9
1965	26.4	29.1	31.7	47.0	50.2	60.2	66.8	64.6	50.0	46.7	37.0	24.3	44.5
1966	26.9	28.2	37.1	43.9	56.9	60.0	69.6	66.4	60.3	43.4	35.1	23.6	46.0
1967	30.2	31.2	37.5	42.0	54.0	61.9	69.4	69.4	60.6	45.1	33.4	21.4	46.3
1968	18.6	29.7	42.1	43.1	52.2	62.8	71.9	64.3	55.7	44.9	32.0	21.9	45.0
1969	24.7	26.0	32.8	49.5	58.1	60.8	68.5	70.2	58.2	40.3	32.5	25.7	45.6
1970	26.3	34.5	35.4	40.3	53.1	63.8	69.6	70.3	52.4	41.5	34.1	20.1	45.1
	–	–	–	–	–	–	–	–	–	–	–	–	–
N	51	53	52	52	53	53	51	55	53	55	51	55	–
$\bar{X}$	18.45	26.02	35.91	45.82	53.84	60.82	68.34	66.28	56.56	46.14	32.98	22.36	–
σ	7.480	6.213	4.116	3.841	4.764	2.712	3.559	3.084	2.662	3.268	5.413	5.829	–
	–	–	–	–	–	–	–	–	–	–	–	–	–
	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 8. Monthly Temperature for Salmon II, Idaho. (F^{o})

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1966													
1967												19.9	
1968													
1969													
1970													
1971	22.4	29.8	34.7	43.8	53.9	59.4	68.3	70.8	53.8	44.0	33.8	16.8	44.3
1972	19.5	24.8	40.3	43.6	54.1	63.9	67.6	69.3	54.4	45.7	32.4	17.6	44.4
1973	18.1	28.9	37.9	44.8	56.1	63.2	72.0	69.0	57.5	48.0	35.1	29.5	46.7
1974	19.6	33.7	37.6	47.4	51.5	67.4	71.2	65.7	59.5	47.0	36.1	24.5	46.8
1975	19.7	22.8	34.0	40.7	51.4	59.1	72.1	64.9	58.2	46.7	30.9	28.3	44.1
$\bar{x}$	19.90	28.0	36.90	44.06	53.4	62.6	70.24	67.94	56.68	46.28	33.66	22.77	45.26
σ	1.802	4.296	2.564	2.412	1.977	3.449	2.134	2.52	2.471	1.516	2.077	5.468	1.365

Table 9. Monthly Temperature for Lemhi, Idaho. (F^{o})

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1914	-	-	-	-	-	-	-	60.2	52.4	44.6	34.5	13.0	-
1915	19.5	31.9	37.2	48.6	48.4	52.2	58.4	64.2	-	-	-	-	-
1916	10.0	26.8	38.8	43.1	44.4	53.0	62.6	59.6	52.0	38.6	26.0	16.1	39.2
1917	14.0	23.4	24.0	38.6	47.0	53.6	64.0	62.6	56.4	41.0	36.0	34.1	41.2
1918	21.3	19.3	34.2	39.2	47.3	60.7	62.6	60.5	53.4	45.7	-	22.6	-
1919	21.1	22.2	-	43.9	-	59.8	65.6	-	56.6	36.3	26.0	10.0	-
1920	18.4	23.0	28.6	36.0	47.2	-	-	-	-	-	-	-	-
1921	-	-	-	-	-	-	-	-	-	-	-	-	-
1922	-	-	-	-	-	-	-	-	-	-	-	-	-
1923	23.9	20.2	29.6	41.6	48.8	54.6	65.4	60.6	56.2	42.0	31.2	17.9	41.0
1924	13.4	30.0	26.7	40.8	51.2	56.5	62.8	61.0	53.0	43.6	29.0	12.2	40.0
1925	21.9	30.2	36.9	-	-	57.0	65.6	59.8	53.1	38.9	33.4	24.8	-
1926	14.6	27.5	37.8	46.1	-	-	69.2	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
$\bar{x}$	17.81	25.45	32.64	41.99	47.76	55.93	64.02	61.06	54.14	41.24	30.87	18.84	-
σ	4.537	4.435	5.494	3.908	2.070	3.137	2.976	1.568	1.925	3.255	4.019	7.993	-

Table 10. Monthly Temperature for Leadore No. 2, Idaho. (F°)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1965	-	-	-	-	-	-	-	-	-	44.2	34.7	22.5	-
1966	18.5	20.4	30.1	36.6	49.9	54.5	63.7	61.1	55.5	40.3	29.7	16.8	39.8
1967	20.0	21.4	26.7	32.5	45.1	53.9	63.4	62.9	55.7	41.5	27.8	13.2	38.7
1968	13.6	25.0	33.0	33.9	43.3	54.7	62.0	56.4	49.1	40.5	25.1	15.7	37.7
1969	19.4	18.2	22.9	40.5	49.2	53.2	60.3	62.9	53.7	34.2	28.7	20.6	38.7
1970	19.2	26.6	26.7	32.4	46.9	55.9	63.1	62.7	47.4	35.3	29.8	14.8	-
1971	17.7	20.5	22.6	37.5	47.4	53.7	61.3	64.4	48.7	37.3	28.0	12.2	37.6
1972	15.4	20.8	34.9	36.5	45.8	57.1	60.5	60.9	48.2	39.8	-	8.1	-
1973	11.1	20.3	-	M	47.8	56.3	62.9	60.7	51.3	43.7	29.8	22.2	-
1974	15.0	24.5	30.0	41.1	46.5	59.9	62.4	57.9	51.4	43.0	30.7	18.8	40.1
1975	15.0	19.4	27.5	32.5	44.3	52.7	64.5	58.1	51.6	42.2	29.2	25.0	38.5
1976	-	-	-	-	-	-	-	-	-	-	-	-	-
$\bar{x}$	16.49	21.71	28.27	35.94	46.62	55.19	62.41	60.8	51.26	40.182	29.35	17.26	38.73
σ	2.92	2.713	4.171	3.372	2.079	2.169	1.384	2.594	2.968	3.324	2.443	5.099	.950

One use of temperature records is to determine the length of the growing season. Normally this is thought to be that period between killing frosts--the last in the spring and the first in the fall. What constitutes a killing frost depends upon the sensitivity of the particular crop being considered. Some plants fail to recover after a 32° F. frost while others survive 26° F. frosts. Some plants continue to grow despite nighttime frosts if daytime temperatures exceed certain minimum temperatures above freezing.

The principle crops in the Lemhi Valley generally support a livestock industry and are therefore limited to hay (alfalfa and grasses) and pastures (grasses). Some grain is also grown, but the crop is not usually a late season user of water and not usually terminated by frosts. Since mountain meadow pastures predominate in the Lemhi Valley, it is this crop we will consider in determining length of growing season. Meteorologists contend that grasses will exhibit some growth whenever daytime temperatures exceed 40° F. A task force from the USDA Agricultural Research Service and certain Rocky Mountain universities suggested that where mountain meadow pastures are involved that any day whose maximum temperature reaches 50° F. or above be considered a growing day. Using the record for Leadore, Idaho (Leadore No. 2 which began in 1965), the frequency distribution of those days having temperatures 50° F. or above were plotted for each month, Figures 24 to 35. Again the arrows point to the mean value, the mode or most likely value, and the 20 percent probability value. These values are then summarized in the graph of Figure 36 when the growing days above 50° F. are accumulated by months. It can thus be seen that the growing season begins in March and ends in November with the most likely length, that is the length that will recur most often, is 196 days; the average

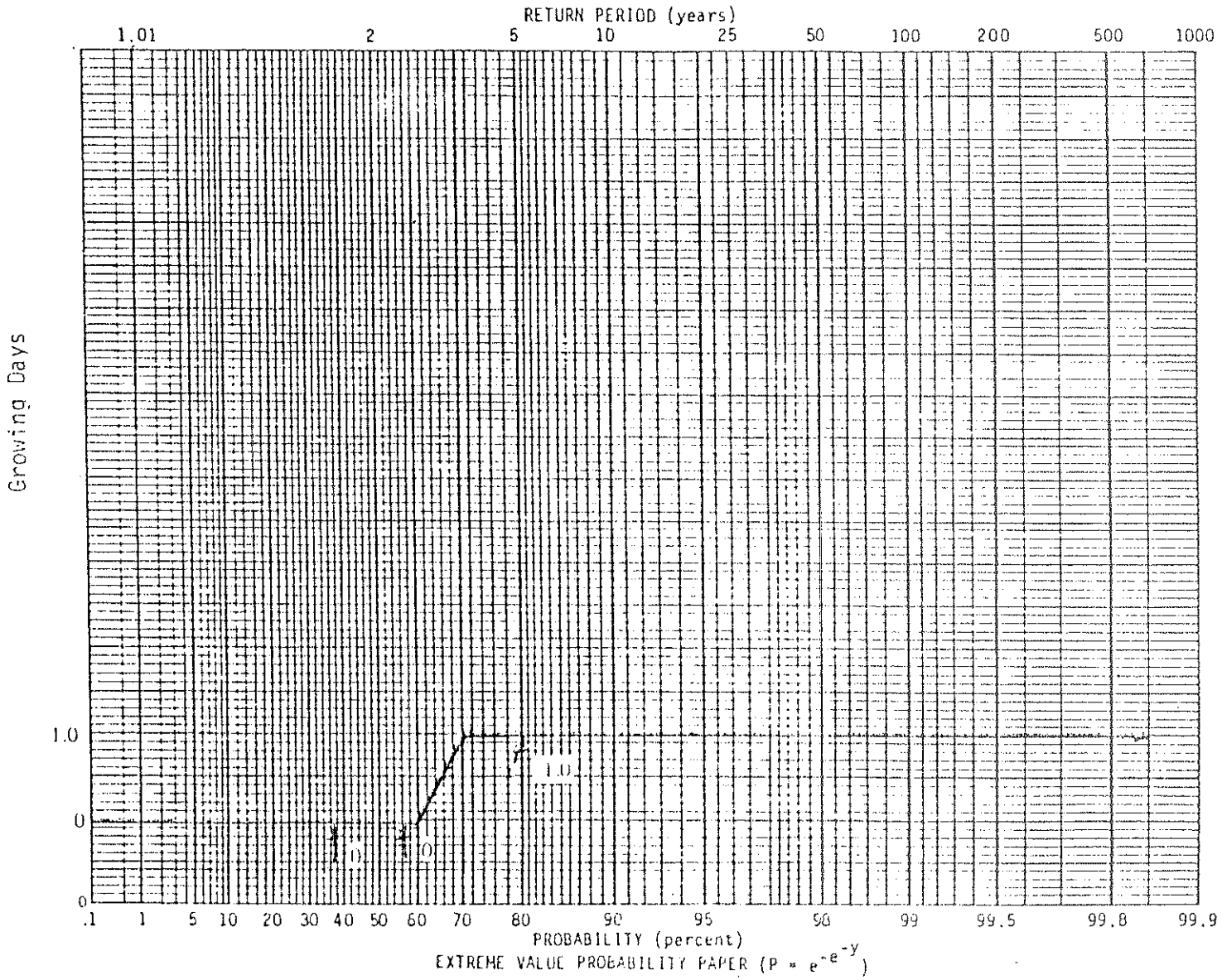


Figure 24. Frequency Distribution of Days With Temperature Above 50 Degrees F. January

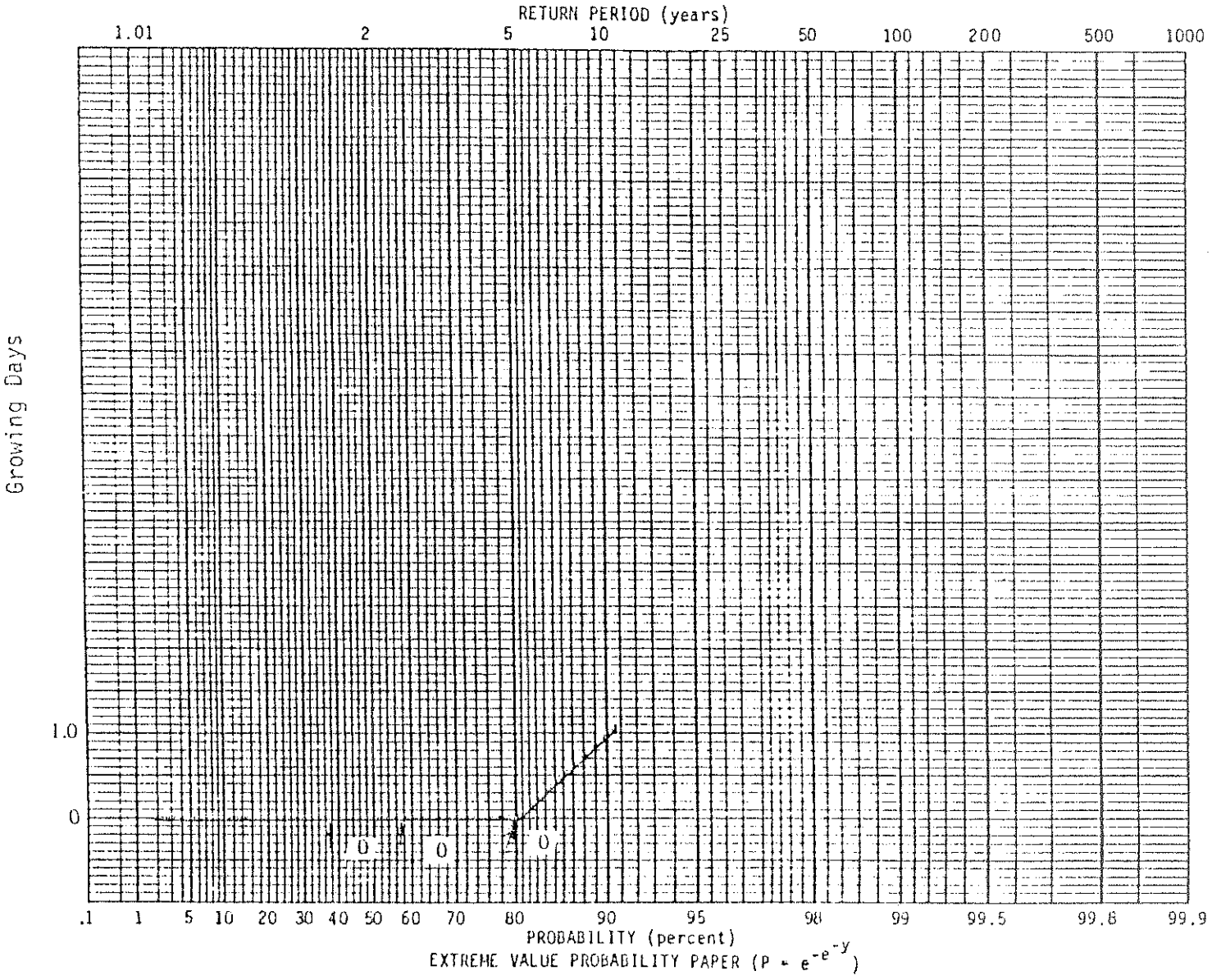


Figure 25. Frequency Distribution of Days With Temperature Above 50 Degrees F. February

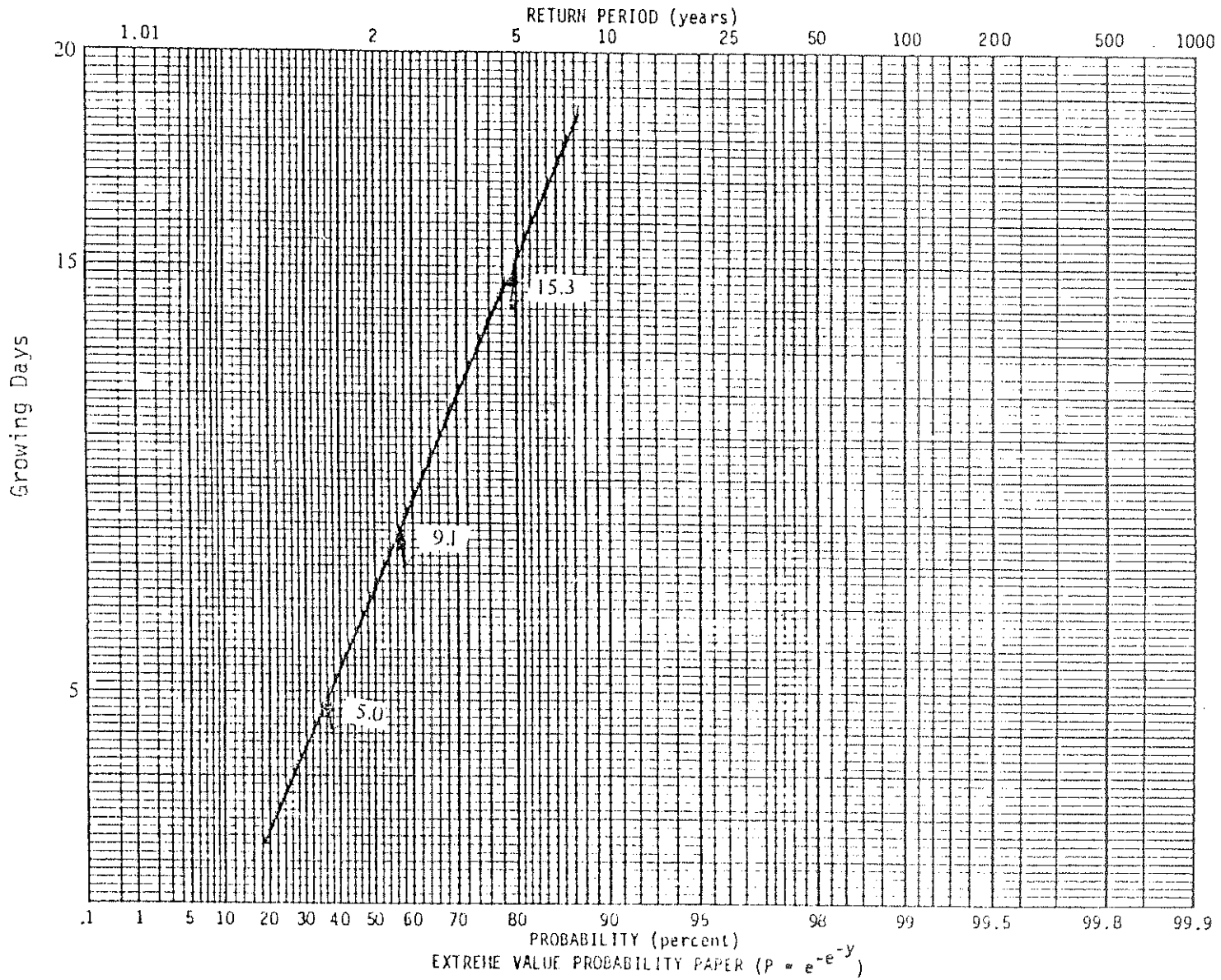


Figure 26. Frequency Distribution of Days With Temperature Above 50 Degrees F. March

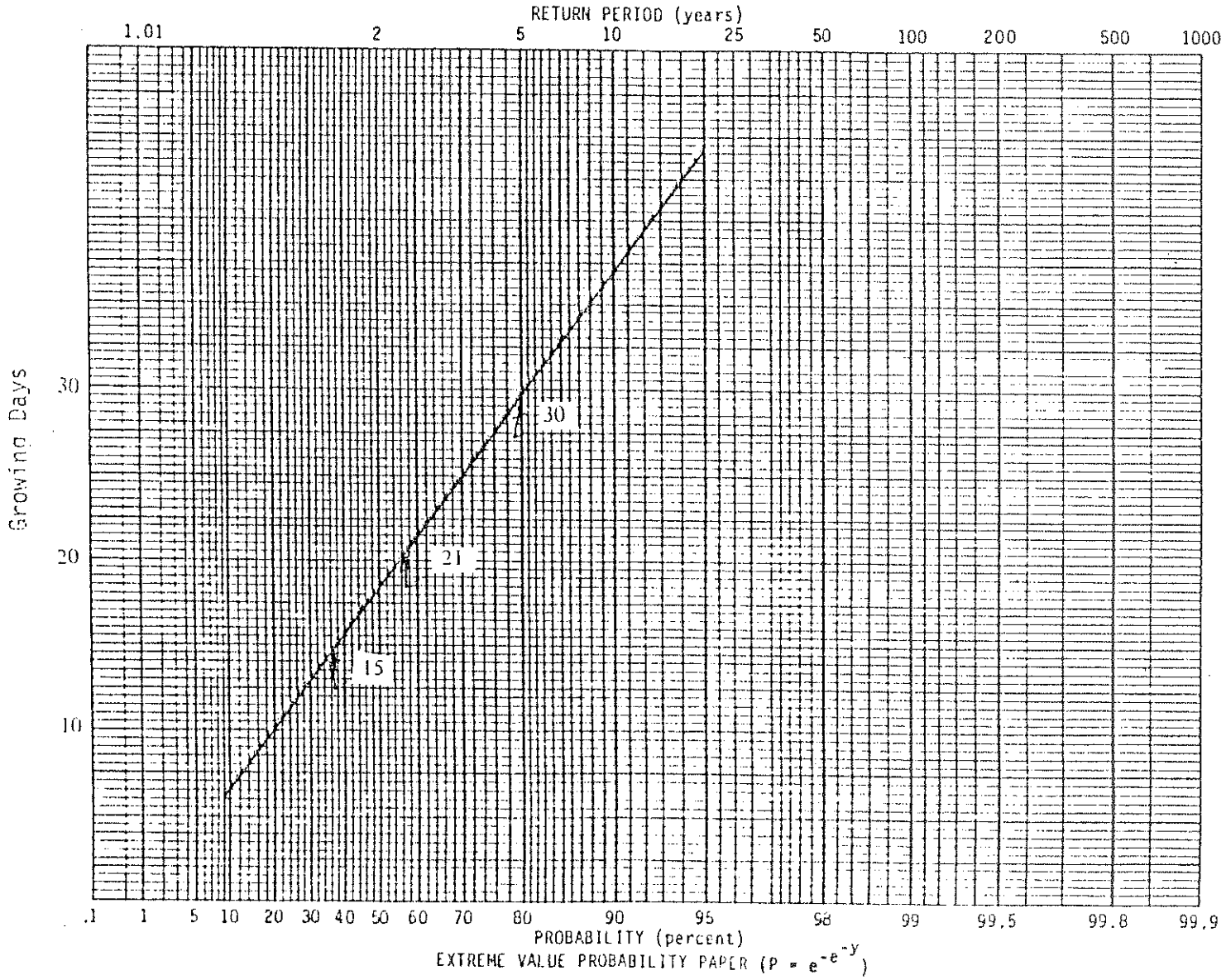


Figure 27. Frequency Distribution of Days With Temperature Above 50 Degrees F. April

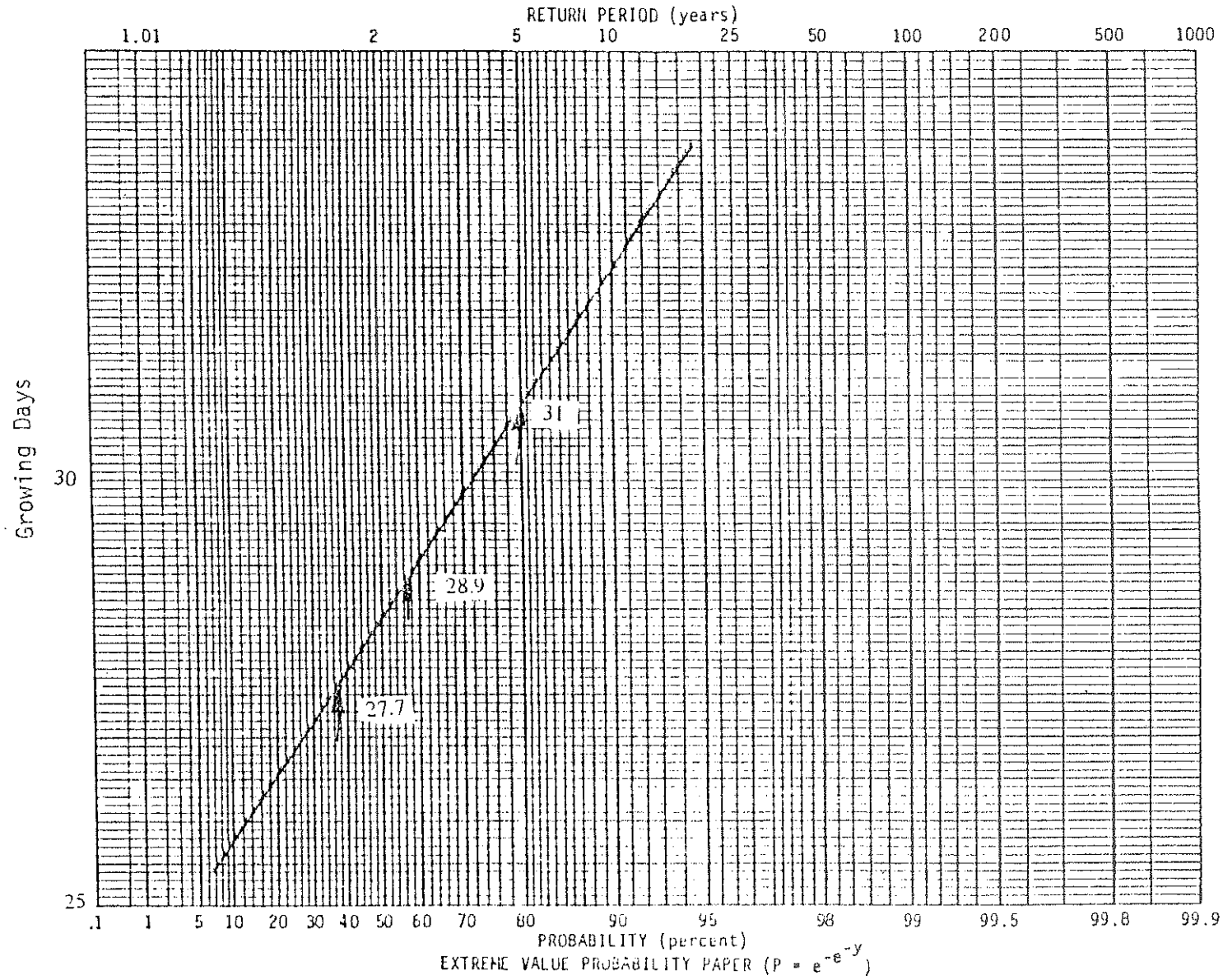


Figure 28. Frequency Distribution of Days With Temperature Above 50 Degrees F. May

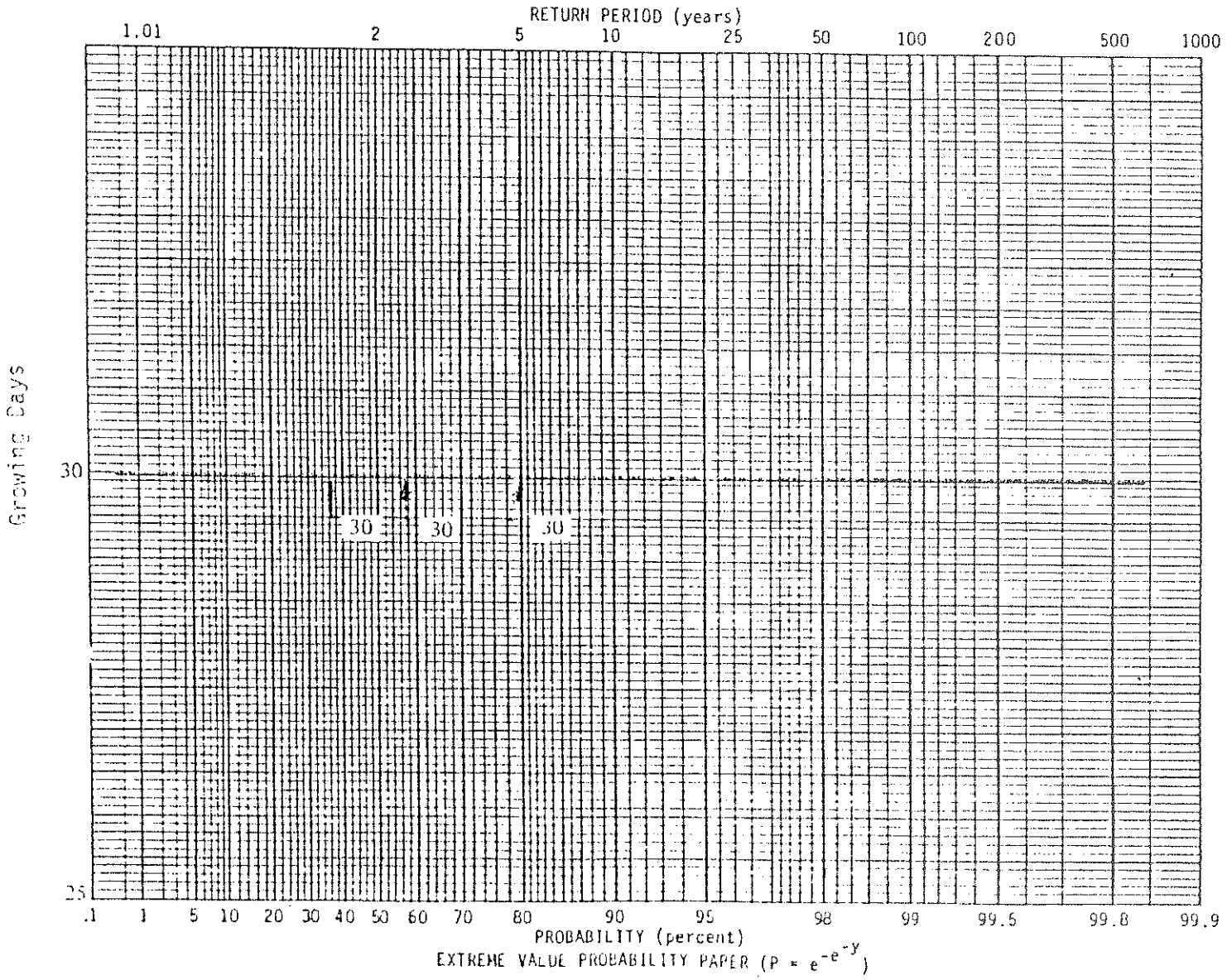


Figure 29. Frequency Distribution of Days With Temperature Above 50 Degrees F. June

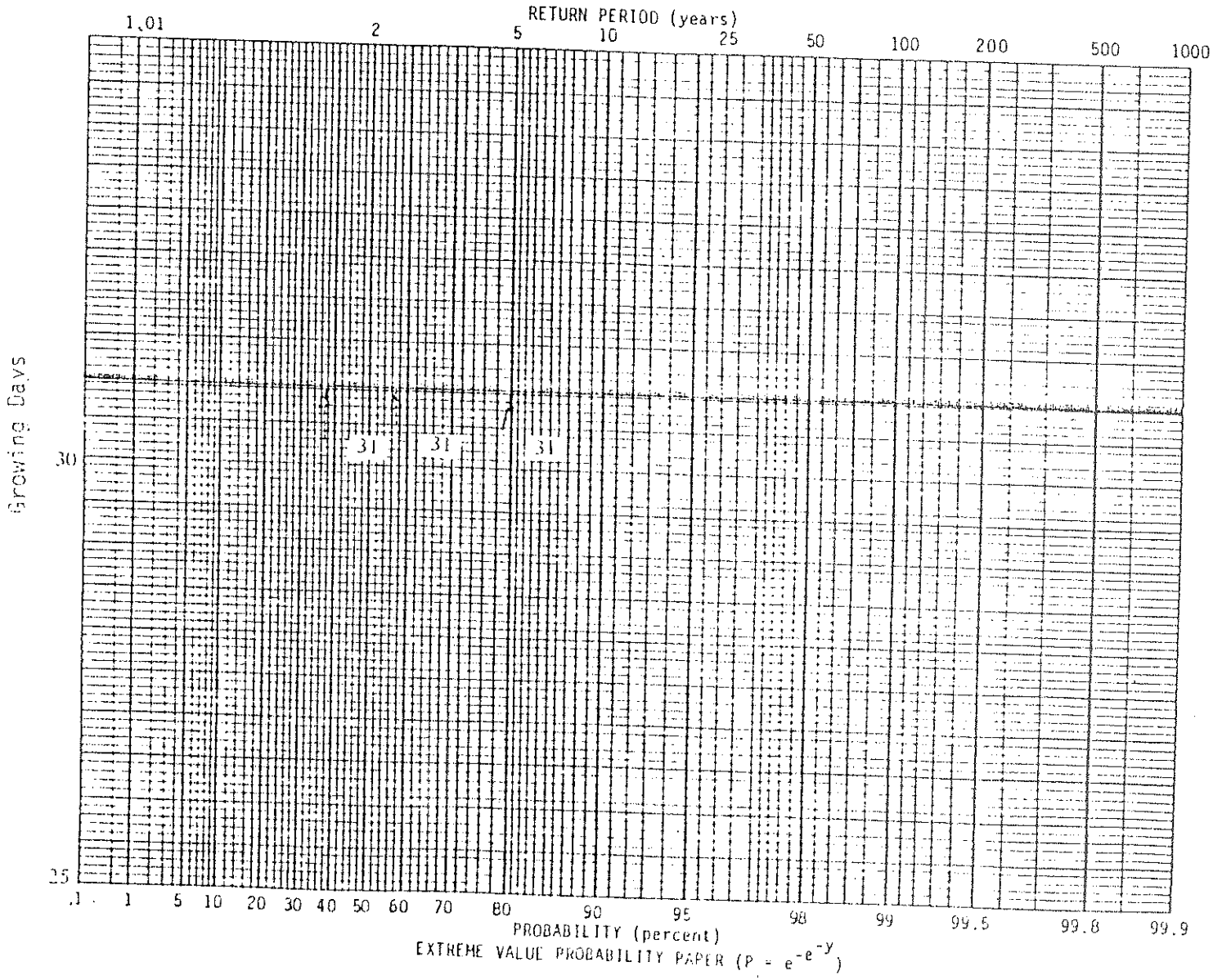


Figure 30. Frequency Distribution of Days With Temperature Above 50 Degrees F. July

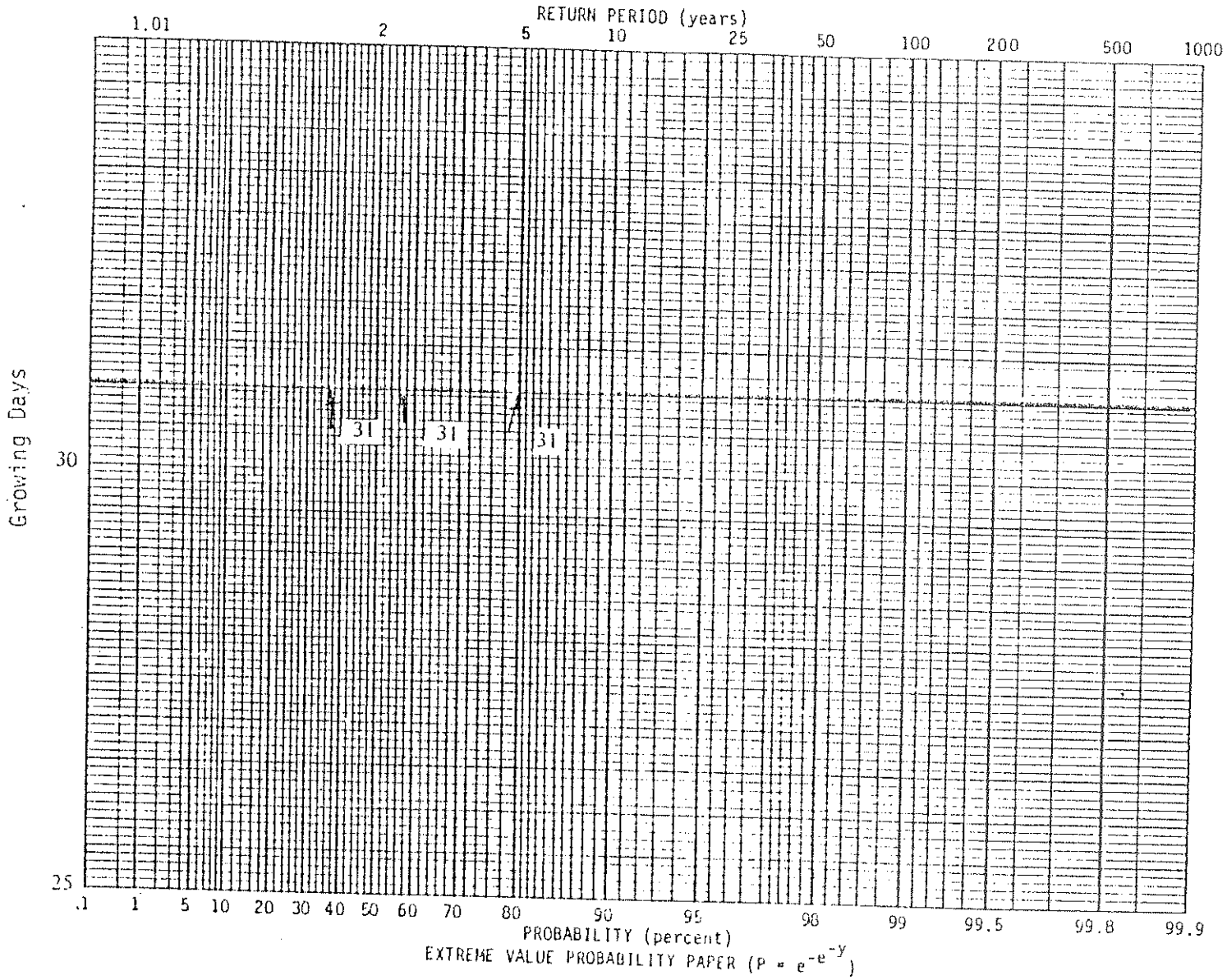


Figure 31. Frequency Distribution of Days With Temperature Above 50 Degrees F. August

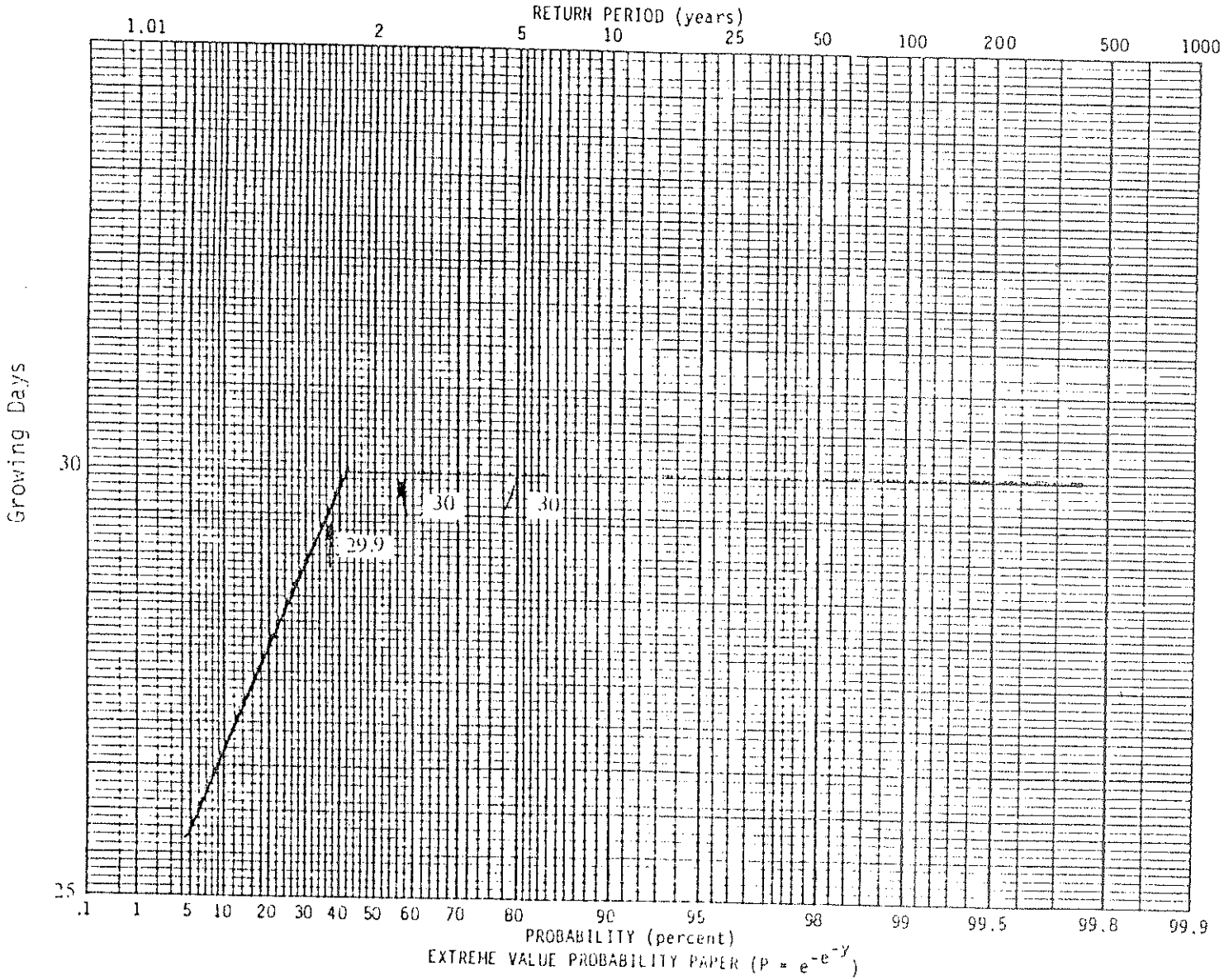


Figure 32. Frequency Distribution of Days With Temperature Above 60 Degrees F. September

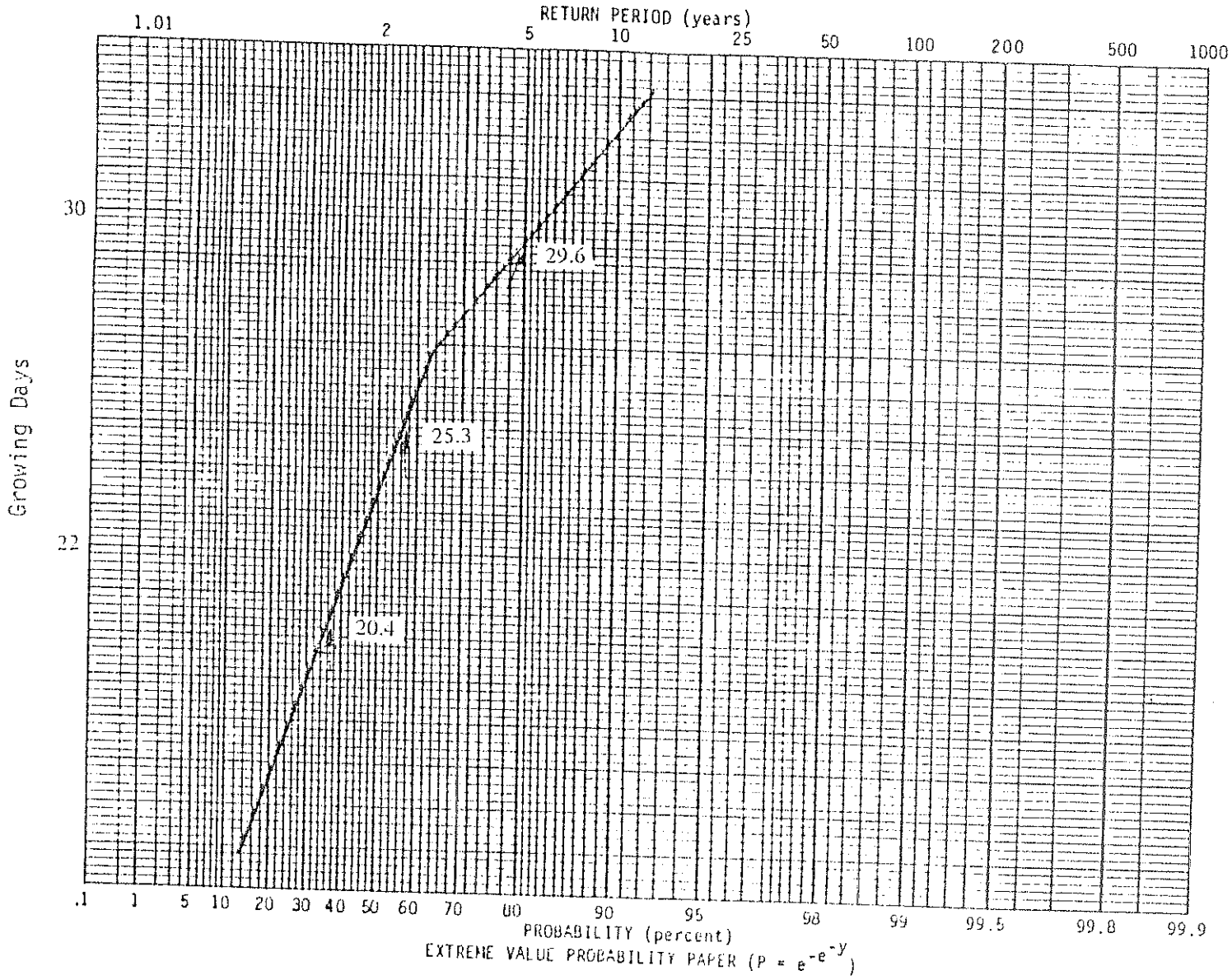


Figure 33. Frequency Distribution of Days With Temperature Above 50 Degrees F. October

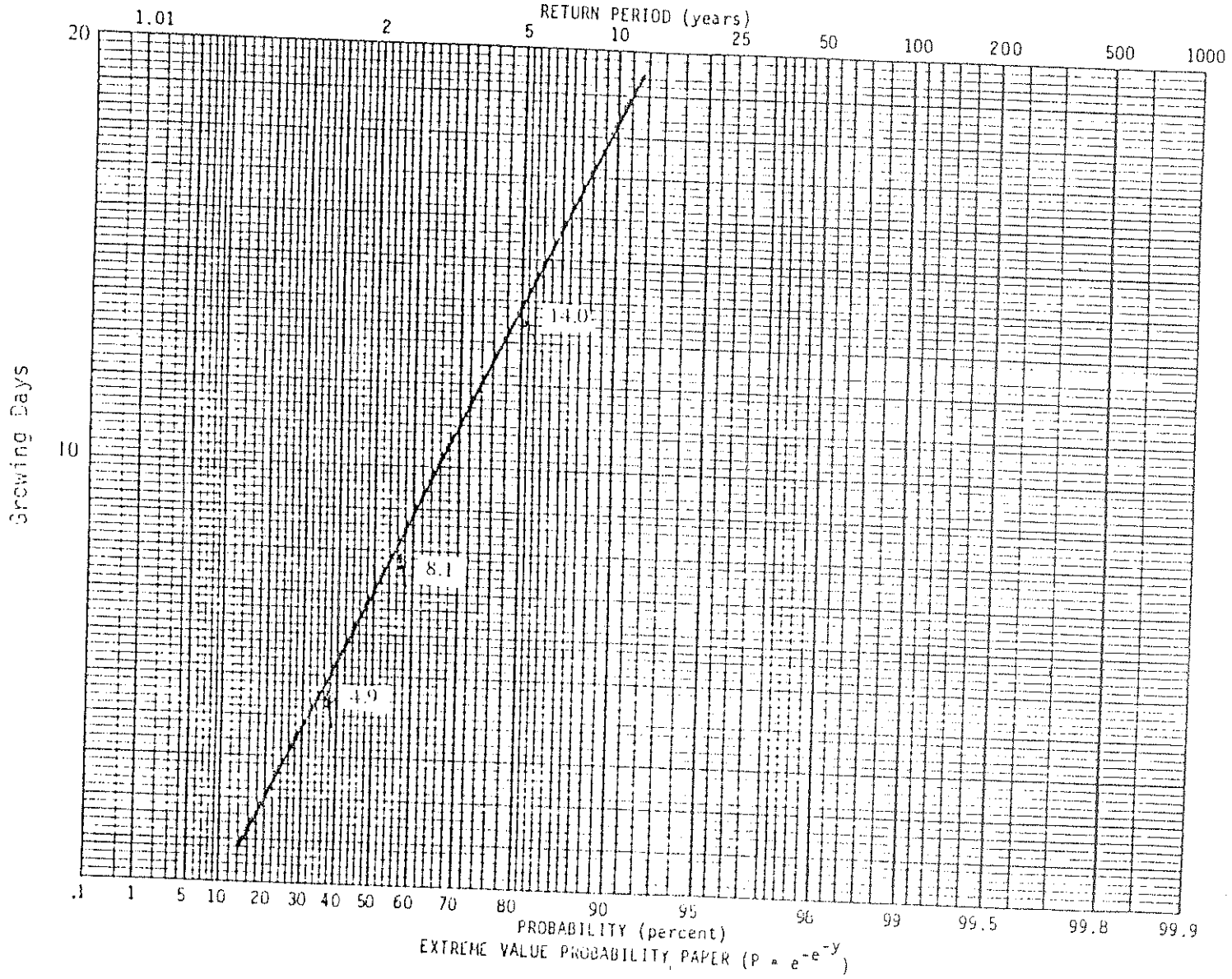


Figure 34. Frequency Distribution of Days With Temperature Above 50 Degrees F. November

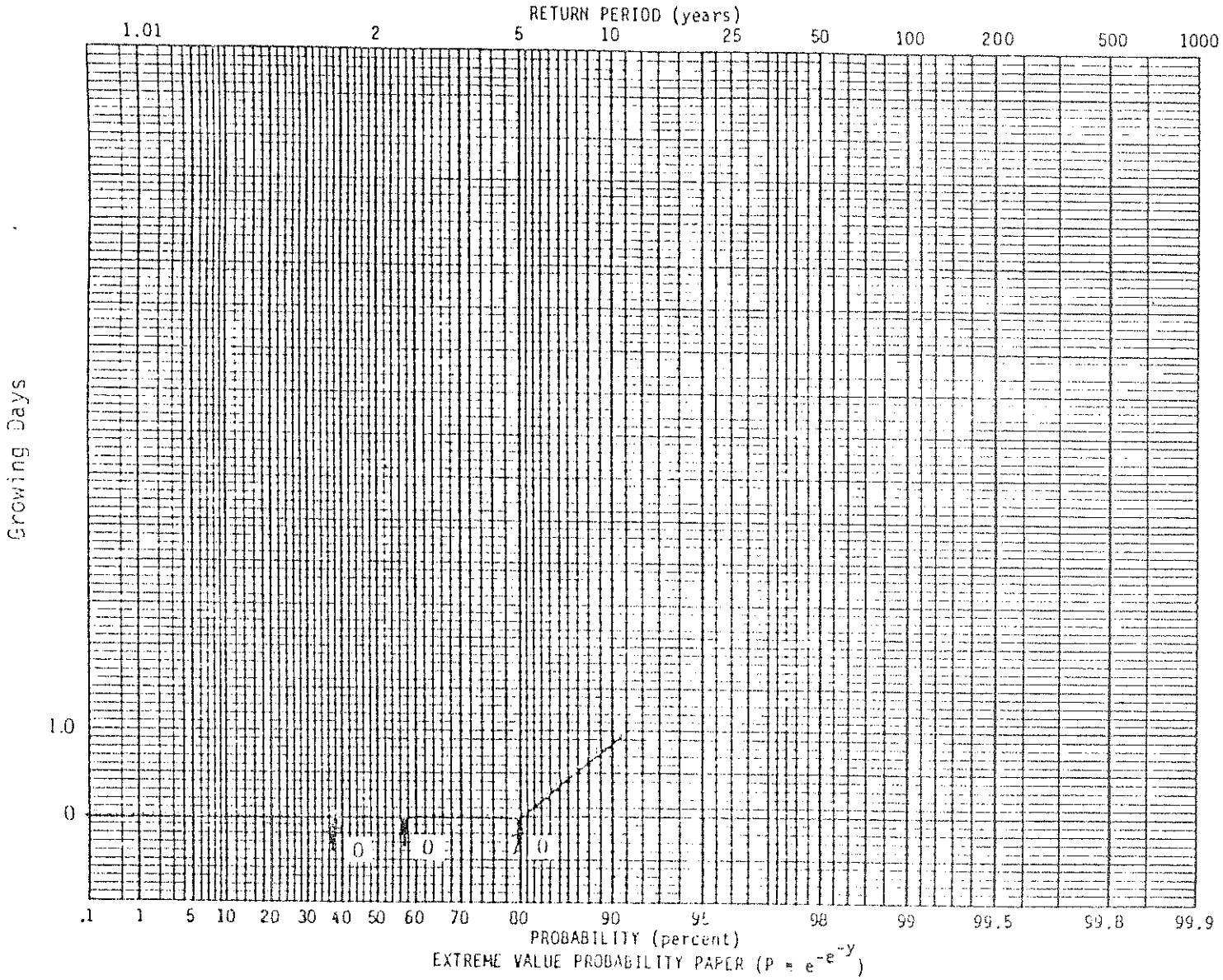


Figure 35. Frequency Distribution of Days With Temperature Above 60 Degrees F. December

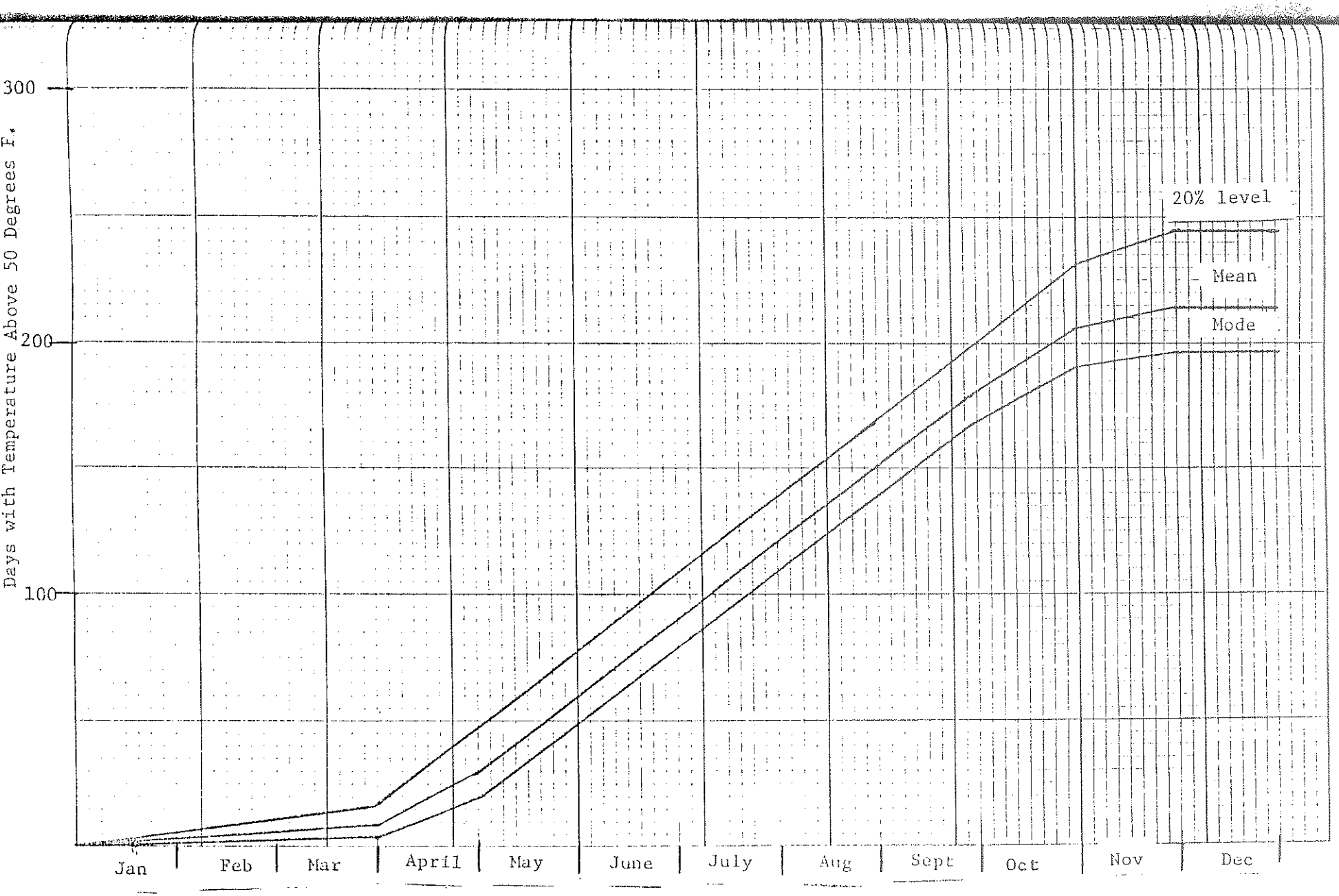


Figure 36. Cumulative Growing Days with Temperatures above 50° F.

length 215 days, and the 20 percent probability (or recurring one out of 5 years) length is 245 days. Since the record is for Leadore the growing season length would be longer for the warmer areas of Lemhi and Salmon.

Consumptive Use

Using the records for temperature, precipitation and growing season, we are now ready to analyze the potential consumptive use in the basin. The potential evaporation can be approximated by the Blaney-Criddle formula:

$$U = \frac{k\,pT}{100} \quad \text{where}$$

U = evaporation or transpiration in inches of water

p = percent daylight hours

T = average monthly temperatures

k = a constant dependent upon crop

Using the graphical values of mean temperature mentioned previously, and assuming $k = 1.0$, graphs of monthly U values have been plotted for the three stations and are shown in Figures 37 and 38. Plotted on the same graphs are the graphical mean values for precipitation determined at the same locations. Summing these values for each location gives the potential annual evaporation rates: Salmon--47.0 inches, Lemhi--44.35 inches, and Leadore--42.15 inches. Subtracting the precipitation for the same period gives annual net use factors of: Salmon--38.18 inches, Lemhi--35.13 inches, and Leadore--33.51 inches. Using these same graphs and calculating the use during the growing season for the mountain meadow pastures at Leadore gives 36.2 inches. Subtracting the precipitation gives 28.74 inches and multiplying by a k factor of 0.85 gives 24.43 inches which compares with the value of

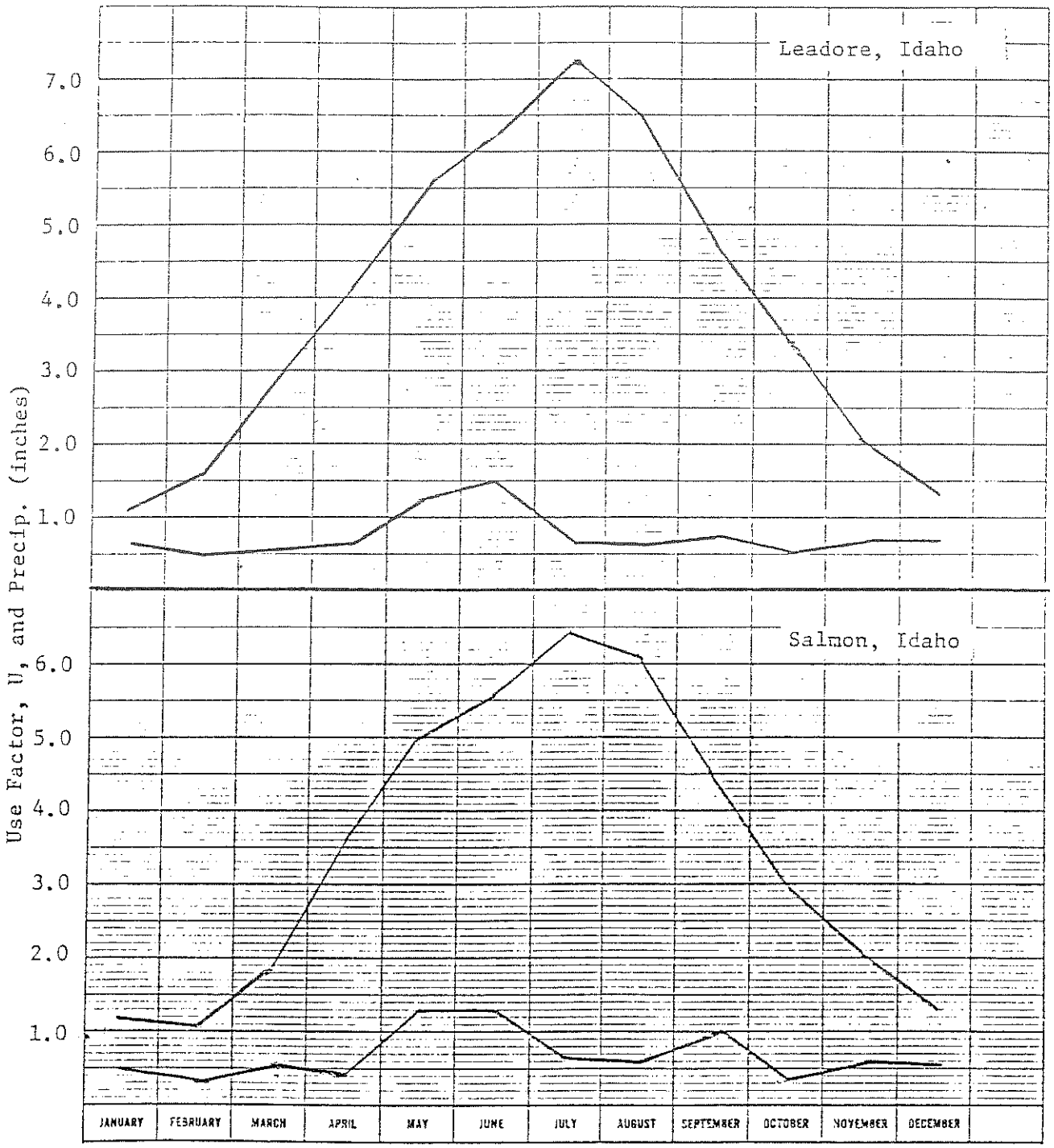
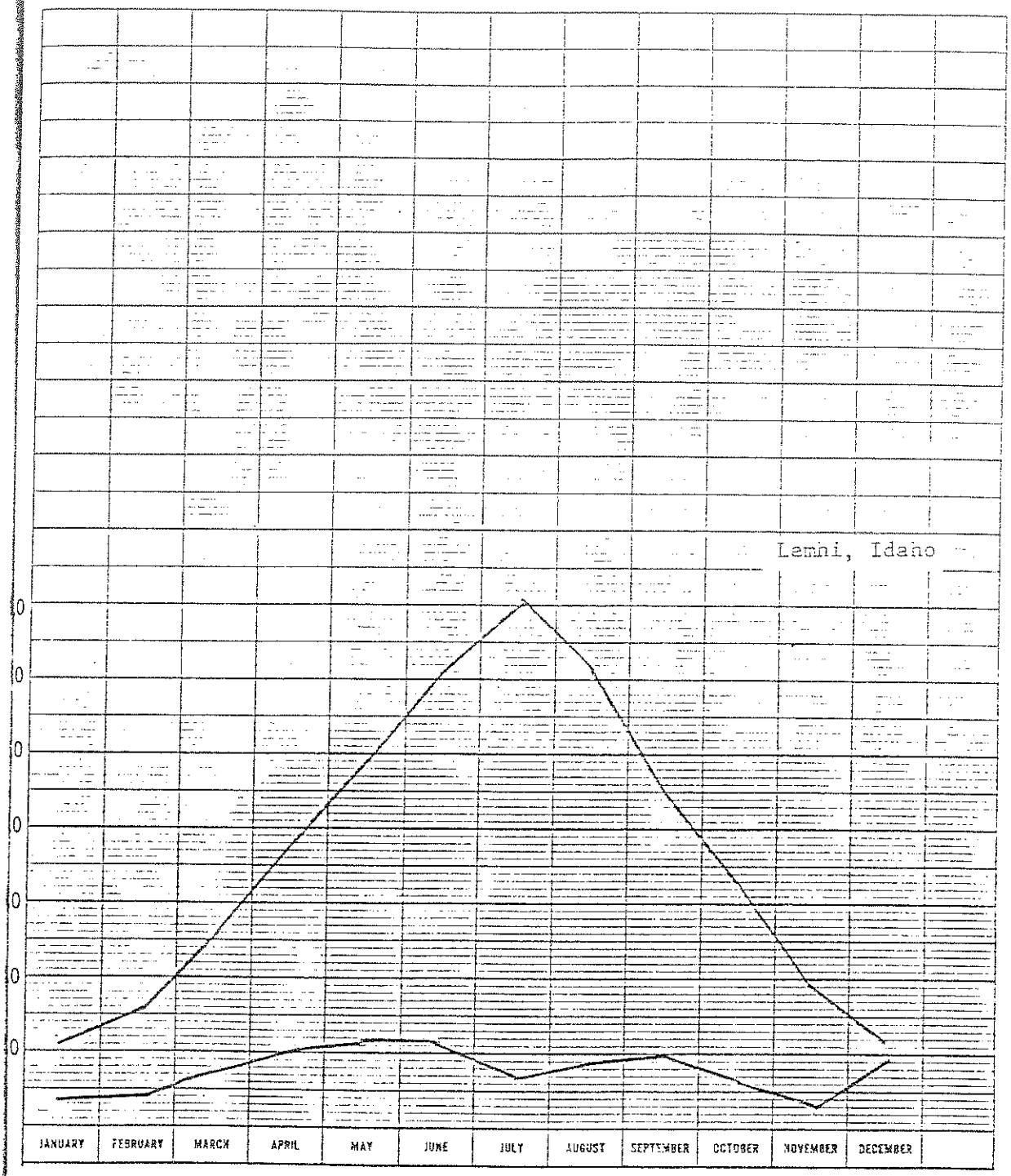


Figure 37. The Monthly Consumptive Use Factor, U, and Monthly Precipitation for Leadore and Salmon, Idaho



gure 38. The Monthly Consumptive Use Factor, U, and Monthly Precipitation for Lemhi, Idaho

21.6 inches given by the Idaho Department of Water Resources. Using these figures and and assuming 60 percent of the water applied to be used consumptively gives a headgate use of 3.31 ac.ft. per acre at Leadore. Using present irrigation methods probably only 20 percent of the water is consumed which brings the headgate requirement to 12.21 ac.ft. per acre.

We have been assuming that all the precipitation during the growing season is effective and does not need to be replaced by diversion requirements. There is a difference of opinion in this regard, but it is most certain that rainfall during July and August and quite likely during May, June and September is not effective in increasing elongation in the plant tissue. It may reduce cooling requirement if clouds persist during the storm. On the assumption that the summer (June-September) rain is not effective, the following use requirements are calculated:

Consumptive use	- 33.34 inches	
Effective precipitation	- 2.84 inches	
Net use	30.50 inches	
Headgate requirement @ 60 percent use	- 50.83 in.	- 4.24 ac.ft./ac.
@ 20 percent use	-152.50 in.	-12.71 ac.ft./ac.

These calculations are for conditions as they exist on the average at Leadore, Idaho. Uses at Lemhi and at Salmon would be 10 to 15 percent higher than values shown for Leadore.

Groundwater

The other means of disposing of precipitation not discussed as yet is the groundwater. This is mentioned primarily because it

represents a resource undeveloped in Lemhi basin and an alternate source of water if surface use should be curtailed. The groundwater is not only supplied by precipitation that enters directly into the ground but also by the residual in the surface stream which is diverted in the process of irrigation. Abundant groundwater is evidenced by the shallow water tables and permanent pastures which border each side of Lemhi River as it meanders through the valley. A good portion of the groundwater probably exits the basin and contributes to the flow of Salmon River below the gage at Salmon. The magnitude of this outflow cannot be approximated with the limited data available.

Depletion

The water transpired by the agricultural crops is often referred to as depletion, it being assumed that such water does not condense within the same basin, but is transported by winds to other basins. Because the agricultural plants transpire at rates determined by the temperatures, a maximum depletion exists within the basin which is limited by the total area of cropland. Irrigation practices can reduce this depletion by failing to provide sufficient water to match the transpiration potential, but irrigation practices cannot increase this potential depletion. Thus increasing the so-called irrigation "efficiency" by just meeting the transpiration potential (100 percent efficient!) would deplete the water system in exactly the same amount as with an irrigation "efficiency" of 10 percent. Whether the extra water diverted at 10 percent remains in the basin depends on the underground flow characteristics. Based on an irrigated acreage of 55,000 acres, the annual depletion from the Lemhi River Basin is about 161,000 acre feet.

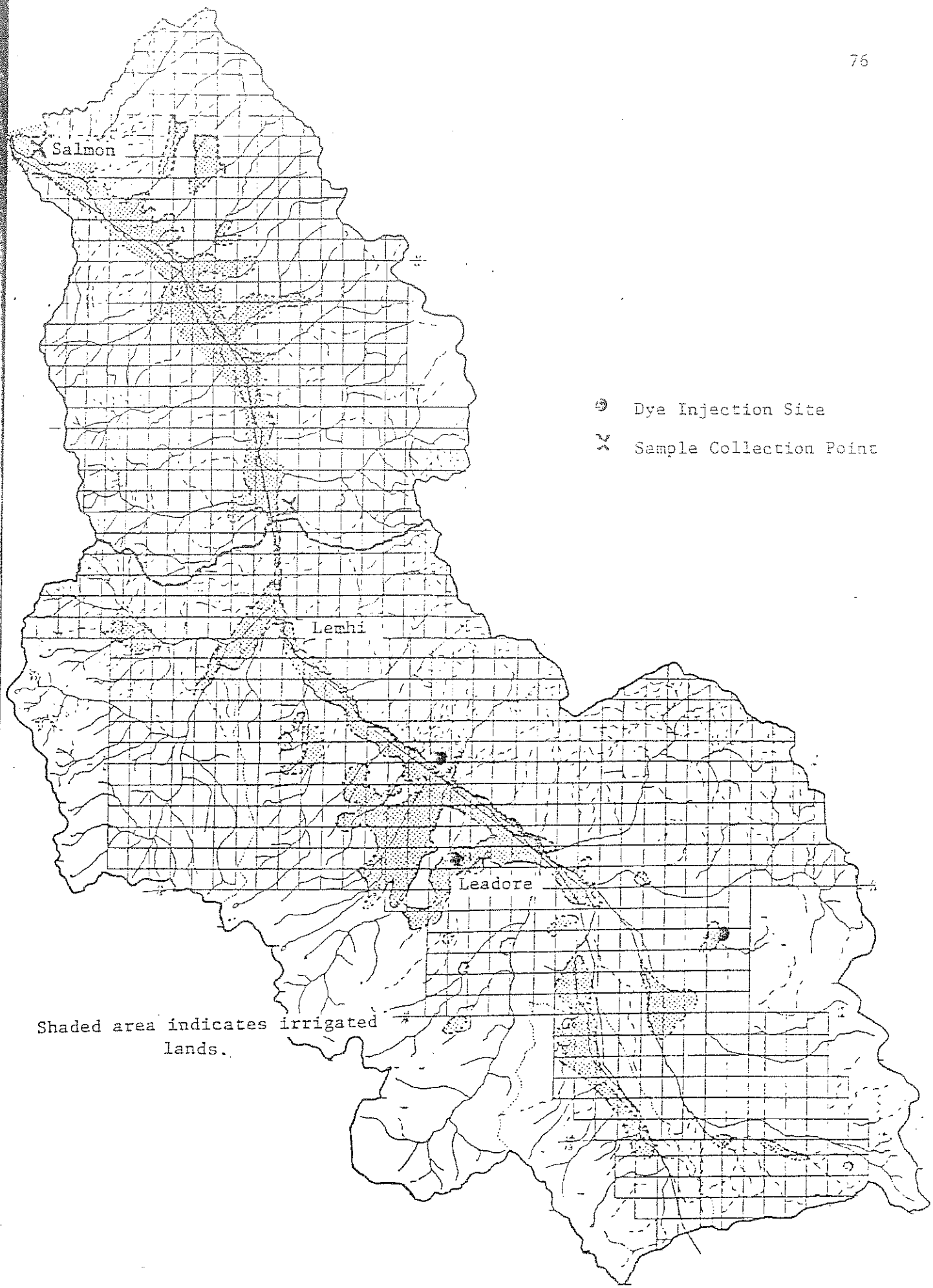
Results of Additional Measurements

Dye Test

In order to confirm the suspicion that the excess water which was applied on irrigated lands near the headwaters of the Lemhi River would reappear as streamflow, rhodamine dye was applied at three locations. One was on the Jack Powers farm, one on the Don Petersen farm, and one on the Ellsworth farm (Figure 39). At the sites where the dye was added no direct surface route for the water to the river was known. Sufficient dye was added over a period of time, 24 hours or longer, at concentrations in the ditch or canal between 100 and 200 parts per billion. Samples were taken at all sites prior to adding dye to assess the natural fluorescence. Two sites were sampled daily on the Lemhi River. The first site was at Lemhi and the second site was at Salmon for a period of time between two and three months, 23 July 1976 to 25 October 1976.

The first traces of dye appeared in the Lemhi River at Lemhi 2 days following application (July 25, 1976) and continued to appear intermittently through October (see Figure 40). The amounts of dye appearing are very high percentages of those added indicating the return has a very high efficiency.

Although some dye appeared very rapidly after initial application the peak dye flow occurred about six weeks after and receded slowly for another six weeks and had not entirely left the system when sampling was discontinued. Return flow would be expected to follow a similar



Shaded area indicates irrigated lands.

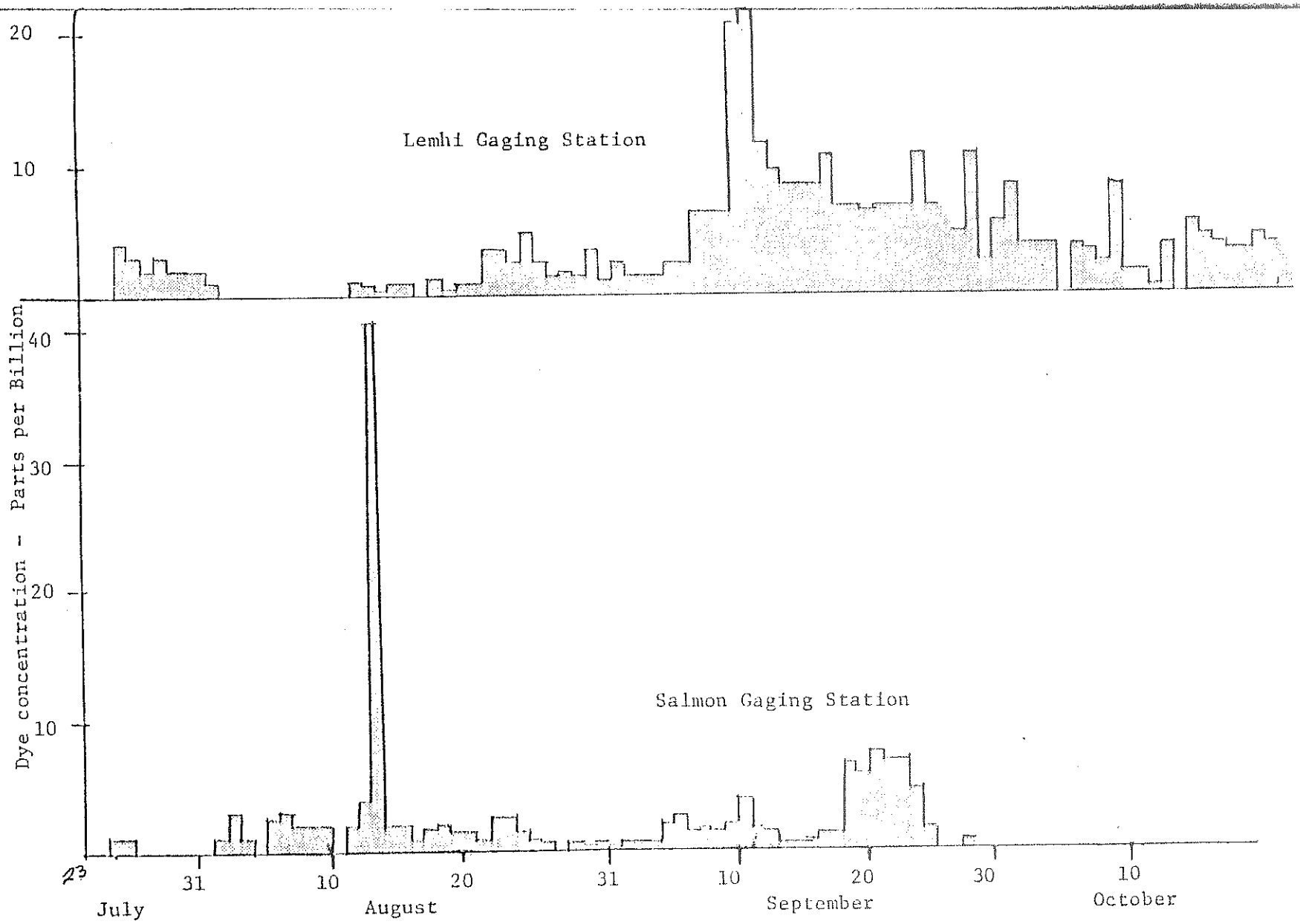


Figure 40. Results of Dye Test. Concentration of Dye Detected in Samples of Lemhi River Water Taken at Lemhi and Salmon, Idaho

pattern, augmenting the natural flow some six weeks after irrigation begins and continuing to affect flow throughout the irrigation season.

Radiation and Temperature Measurements

(This section to be submitted later when data is fully analyzed.)

Summary and Conclusions

The following points are established as a result of this investigation:

1. Because of the geographical and hydrological setting of the Lemhi River, regulation of water rights on a consumptive use or potential crop transpiration basis would benefit no one.

2. Salmon River below the confluence with the Lemhi River is many times larger than the small potential agricultural use which might become dependent upon its flow, therefore any change in the flow of Lemhi River, greater or smaller, could in no way adversely affect any Salmon users.

3. Users of the lower Lemhi River are dependent upon late season flow to mature their crops.

4. Return flow from irrigation practices in the upper Lemhi River system contributes substantially to the late season flow needed by lower valley users.

5. Soils in the upper Lemhi Valley have such a small water holding capacity that frequent applications of water are needed to prevent plant stress.

6. The only way irrigators in the valley could increase the ratio of water applied to water used ("efficiency") to a value approaching 60 percent would be to install sprinkling systems.

7. The productive capacity of the soil would not be increased by reducing the total water applied, therefore sprinkling systems are an added expense with no additional economic return.

8. In the event the court should decide to impose a consumptive use requirement, the value suggested by the Department of Water Administration is arbitrary, unrealistic, and not based on adequate hydrologic data.

9. Consumptive use requirements should be based on mountain grasses which have a growing season of 245 days or longer and require water over and above that supplied by precipitation in all months from March through November.

10. The estimated consumptive use requirement for grasses at Leadore with use ratios of 20 percent and utilizing only effective precipitation is 12.2 acre feet per acre. Lower valley requirements are 10 to 15 percent higher.

11. Consumptive use of water is only one of many reasons for irrigating crops for economic returns. Others such as diluting toxic materials, softening hard layers, changing soil temperature, and preventing piping, may give equal or greater returns per unit of water diverted than consumptive use, and should be so considered in any water rights adjudication procedure.

Recommendations

It would be to the advantage of the Department of Water Administration and to the benefit of all Lemhi River water users if paragraphs 4 and 5 of the findings of fact and paragraph 7 of the conclusions of law were deleted completely from the proposed findings of water rights. It is recommended that such be done.