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Baseline Climatic and Hydrologic Relationships for the High Ridge Evaluation Area

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Conversion Factors for English Units from Metric Units

<u>To convert:</u>	<u>Into:</u>	<u>Multiply by:</u>
hectares	acres	2.471
kilometers	miles	0.6214
meters	feet	3.281
Celsius	Fahrenheit	$(9/5^{\circ}\text{C}) + 32$
grams per cubic centimeter	pounds per cubic foot	62.43
liters per second	cubic feet per second	0.03531
kilometers per hour	miles per hour	0.6214

Abstract

This report summarizes the climatic and hydrologic measurements taken in the High Ridge evaluation area, a four-watershed complex within the Umatilla barometer watershed of eastern Oregon. The information--measurements of water yield; air, soil, and water temperatures; snow depth and density; and wind--is presented to identify the pretreatment condition and is representative of environmental conditions in similar stands within the Blue Mountain area.

KEYWORDS: Climatography, water supply, temperature (water), temperature (soil), Oregon (Blue Mountains), watershed management.

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Introduction

During the middle 1960's, the Barometer Watershed Program was established by the USDA Forest Service "to meet the need and demand for water information to support Land Use and Program Planning on National Forest system lands."¹

According to Dortignac and Beattie:² The "barometer" watershed program provides the basis for determining the effect of management practices on hydrologic behavior. It is the proving ground for (1) developing and refining watershed prescriptions based on the most recent research findings, (2) making water yield predictions, and (3) comparing predictions with actual performance. The system provides a basis for appraising cost-benefit relationships and suitable demonstration and training areas.

Watersheds were selected to represent a variety of climatic, vegetative, and physiographic conditions. Among these was the Umatilla barometer watershed in the Blue Mountains of eastern Oregon. Included within this 34 000-ha watershed complex was the High Ridge evaluation area with four subwatersheds comprising a total area of approximately 200 ha.

Background and supplemental information for the watershed complex and some details of the evaluation area are available in documents prepared as interim reports by Region 6, USDA Forest Service, Portland, Oregon. These include:

¹Hydrometeorological data bank water year 1977. May 1978. Umatilla River barometer watershed and Mill Creek municipal watershed. Umatilla Natl. For., USDA For. Serv. Pac. Northwest Reg.

²E. J. Dortignac and B. Beattie. 1965. Using representative watersheds to manage forest and range lands for improved water yields. Paper presented at International Association of Scientific Hydrology, Budapest, Hungary, October 5, 1965.

1. Umatilla barometer watershed analysis, 1965.
2. Watershed analysis and prescription - High Ridge evaluation area, Umatilla barometer watershed, 1970.
3. Umatilla barometer watershed, survey-analysis-plan, 1971.
4. Hydrometeorological data bank water years 1965-1975, Umatilla River barometer watershed.
5. Hydrometeorological data bank water year 1976, Umatilla River barometer watershed.

Although the overall objective of this program is to document hydrologic behavior caused by treatments, the baseline data collected during the pretreatment phase are representative of conditions in a larger block of untreated stands within the Blue Mountain area. Any information describing climate or hydrology of these stands is extremely limited. The data presented, therefore, provide the basis for evaluating treatment effects and are an aid to understanding present conditions and the potentials for these stands. Evaluating treatment effects will require a number of years for collection of posttreatment data. The utility of the information presented in this report to present land managers outweighs any advantage of waiting to accomplish the primary objective of the study. Also, data presented here will assist others who are studying the plant and animal interrelationships in these watersheds. These are the only baseline data available on temperatures (air, water, soil), wind, and seasonal distribution of snow; they are not duplicated in interim reports.

The Study Area

The study area (fig. 1) is located in the Blue Mountains of northeastern Oregon, about 22 km northwest of Elgin and 8 km southwest of the Spout

Methods

Precipitation

Beginning October 1, 1967, precipitation was recorded by a gage located in a natural opening near the center of the four watersheds at 1 493-m elevation. Five other recording gages and 12 storage gages are distributed over the Umatilla barometer watershed between the 731- and 1 706-m elevation.

Density and depth of snow have been measured at each recording site since 1970. In 1972, two plots were located in watershed 1 and one plot each in watersheds 3 (the control) and 4 for intensive snow measurements. The plots are approximately circular in shape and 0.3 ha in area. A stem map, such as that shown in figure 2, was made for each plot.

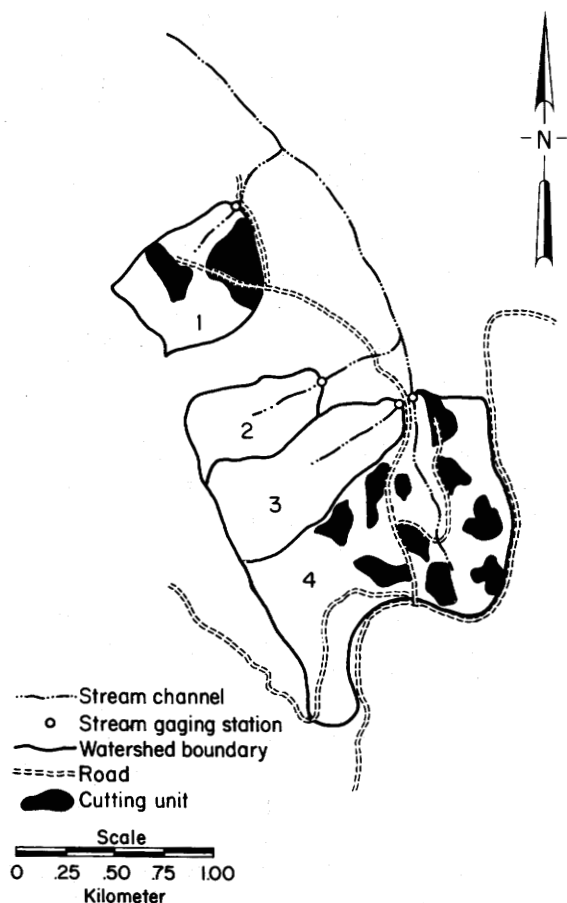


Figure 1.--The High Ridge evaluation area.

Springs Recreation Area. It consists of four individual watersheds containing 24.4, 29.6, 53.3, and 118.1 ha of drainage area. Elevation varies from 1 439 to 1 617 m; slopes vary from 2 to 25 percent; and aspect is generally northeast. The area is densely stocked with a mixture of grand fir (*Abies grandis*), Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), western larch (*Larix occidentalis*), Douglas-fir (*Pseudotsuga menziesii*), and lodgepole pine (*Pinus contorta*).

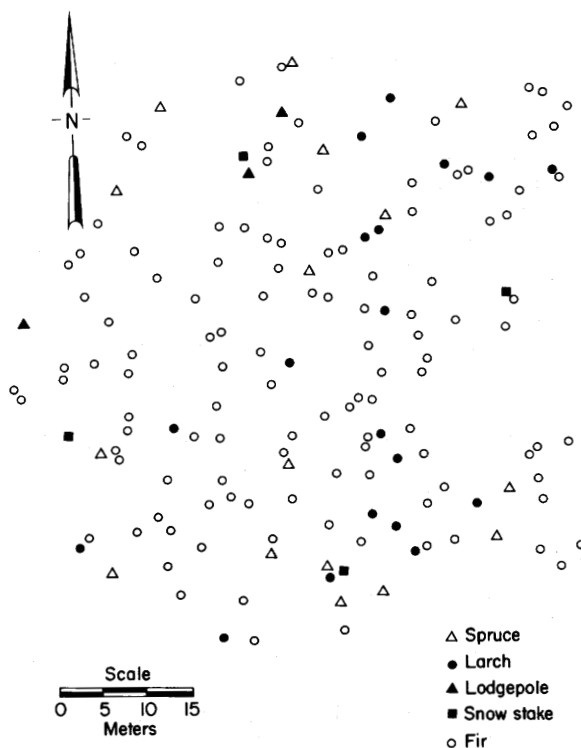


Figure 2.--Stem map for snow depth plot in control watershed 3.

Depth and density of snow on the plots were measured periodically with a snow tube. In addition, at the approximate time of maximum annual snow accumulations in 1972-76, each tree was marked with paint at the snow surface. After snowmelt, the height of each mark was measured and recorded by tree number.

Precipitation data were analyzed for:

1. Total annual amounts and the year-to-year variation.
2. Monthly average and the amounts recorded as rain and snow.
3. Maximum intensities per hour and per day during winter and summer months.
4. Changes in depth and density of snow over time.
5. Variance for selected dates to test the null hypothesis that snow accumulation did not differ significantly ($P=0.05$) between plots.
6. Maximum annual accumulations of snow to determine maximum depths of snow at frequencies of 5, 10, 25, and 50 years.

Streamflow

Stream flow is measured with modified V-notch weirs (fig. 3). A concrete cutoff wall forces the water through the control section. The control section consists of a V-notch cut in a steel plate that is attached to a fiberglass, trapezoidal flume. Notch sizes are 90° for watershed 2, 60° for watersheds 1 and 3, and 120° for watershed 4. Water level is measured with analog-to-digital recorders.

Summarized data were analyzed for:

1. Annual amounts and year-to-year variations.
2. Correlation of annual runoff with annual precipitation.



Figure 3.--Typical streamflow measuring section.

3. Runoff characteristics expressed as flow-duration curves.
4. Correlation of annual runoff between watershed 3 (the control) and each of the other watersheds.
5. Prediction of peak discharge for recurrence periods of 5, 10, 25, and 50 years.

Air, Soil, and Water Temperatures

Location of the High Ridge area precluded installation of equipment that would require continuing service. A new type of integrating temperature system with a digital printer was designed to satisfy data needs. Instruments print a degree-hour summary after each 3 hours, permitting calculation of average temperature for the period or accumulation of degree-hour summaries. A value of -10°C was selected as the base for the degree-hour summary; -10°C is thus the lower limit for any temperature measurement. In the several years of record, during only about 2 weeks a year was the temperature colder than -10°C .

Units are buried for temperature stability and to prevent vandalism. Tapes are collected twice a year. A simple calculator program summarizes the measurements. Soil temperatures were not evaluated before 1976.

Speed and Direction of Wind

A new "Adaptive Speed and Direction Analyzer" (Fowler 1977) was designed for the High Ridge study to provide an onsite summary of windspeed within several speed classes and a summary of wind direction corresponding to these classes. Memory storage is adequate for collecting data up to 2 months. More frequent readouts, usually at monthly intervals, were made to improve the overall resolution.

Units accumulate data based on a 134.08-m travel distance with direction resolved to quadrants. No wind direction data are accumulated if air movement is absent.

Results and Discussion

Precipitation

Average annual precipitation for the High Ridge area for 1967-76 is 142.47 cm. Annual amounts vary (fig. 4) between a high of 190.25 cm and a low of 73.15. Average regional precipitation for stations in the surrounding area--designated by National Oceanic and Atmospheric Administration as the "Northeastern Oregon Section"--is also shown in figure 4. Spatial averaging and inclusion of primarily lowland stations reduce the variability and lower average annual amounts to about a third (51 cm) of the High Ridge average.

Precipitation is primarily a cool season phenomenon throughout the Pacific Northwest States. Storm tracks for extra tropical cyclones

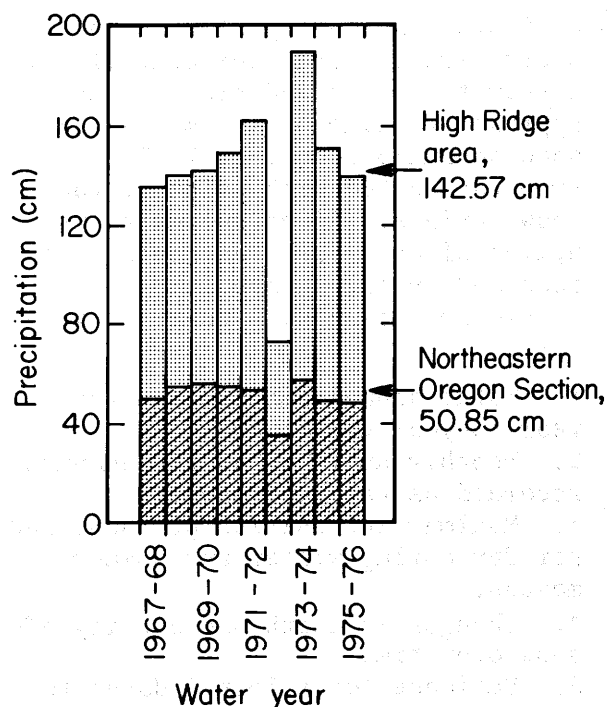


Figure 4.--Average annual precipitation for High Ridge area and Northeastern Oregon Section.

concentrate along the northern tier of States. Strong airmass contrasts, mild, moist Pacific air, and frigid continental polar air produce vigorous storms. Local amounts of precipitation are strongly influenced by topography. The seasonal distribution of precipitation by months is illustrated in figure 5. For the High Ridge area, 87 percent of the yearly total precipitation falls between October 1 and May 31; 13 percent in the summer months, June through September. For the Northeastern Oregon Section, corresponding figures are 79 percent and 21 percent. Topographic influences on precipitation in the cool season account for the major differences between lowland and mountain sites. Compared with lowland sites, the High Ridge location receives three times as much precipitation per month in

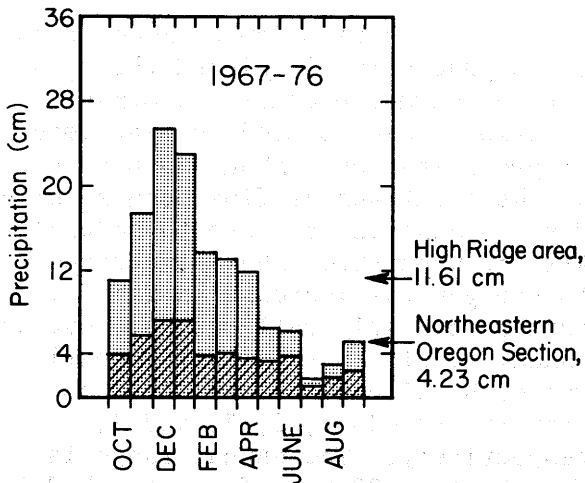


Figure 5.--Average monthly precipitation for High Ridge area and Northeastern Oregon Section.

the cool season but less than twice as much in the summer season.

Precipitation per day can amount to nearly 10 cm at these high elevation sites during winter storms (mixed rain and snow) or in intense, highly localized thunderstorms. Thunderstorm activity, based on a 7-year study (Morris 1934), is more prominent immediately to the east of the High Ridge location; however, the expectation is for between five and six lightning storms per 40 000 ha per year at this location. The individual cells of thunderstorms follow a southwest to northeast path over an 80- to 100-km traverse. Although intense thunderstorm paths may be up to 60 km wide (Morris 1934), precipitation values normally decline rapidly with distance from thunderstorm centers. Because stations in the High Ridge area are 7 to 10 km apart, situations occur where heavy rainfall (up to 10 cm) may be recorded at only one of the gages.

As air temperature decreases in the fall months, precipitation changes from rain to snow. The first few snowstorms may melt as temperatures

fluctuate above and below freezing. In most years, a snowpack usually begins to form by late November. It increases in depth and water content until late March or early April; then the snow gradually melts. Complete snowmelt varies from year to year, depending on maximum accumulation of snow and energy input in the early spring. The last snow usually is melted by early June.

Figure 6 illustrates the depth and density of the snowpack in 1973. The depth inside the watershed averaged 60 cm on January 12 when it was first measured. At that time, snow density was 0.22 g/cm³, and the total water content was 13 cm. Snow depth, density, and water content increased until April 3 when depth was 88 cm; density, 0.33 g/cm³; and water content, 29 cm. The date of maximum accumulation could not be determined from these measurements because of

Snowpack dynamics Winter 1973

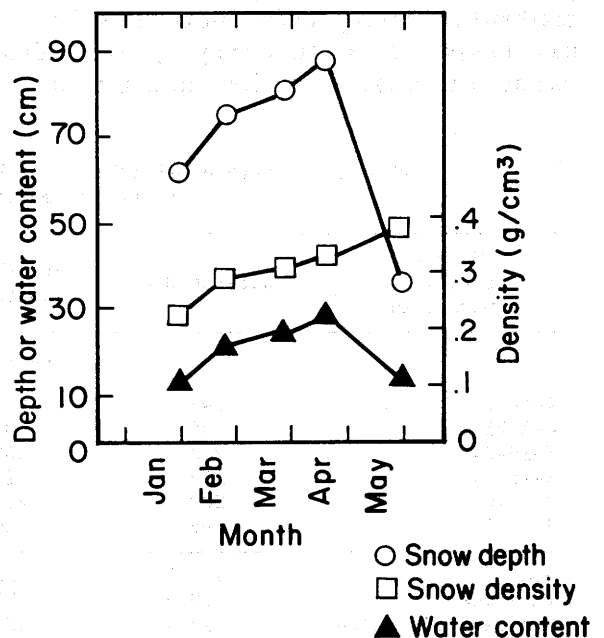


Figure 6.--Depth-density relationship for snowpack in 1973.

the infrequent sampling schedules, but the April 3 value is probably close to the maximum. On May 14, when the last measurement was made, snow depth had declined to 36 cm, but density had increased to 0.38 g/cm³. Water content was only 12 cm.

Table 1 lists the average depth of snow on the approximate date of annual maximum accumulation in 1972-77. A simple t test indicated no significant differences ($P=0.05$) in snow depth between plots. The within-plot variation was quite high because of uneven snow deposition under the dense tree canopy. For example, on April 4, 1972, snow depth on one plot varied from 127 to 257 cm.

Streamflow

Because flow rates are lowest in late summer, the water year is defined as extending from October 1 to September 30. Runoff rates are low in winter months as the snow-pack increases in depth and water content. Along with increases in air temperature in early spring, flow rates increase and the maximum an-

nual peak occurs in May or June. Flow rates gradually diminished throughout the summer because evapotranspiration losses exceed current amounts of precipitation. About 80 percent of the total annual flow occurs during May and June in response to snowmelt. All the watersheds show some response to the general increase in rainfall during the early fall months. Average annual runoff for the 1967-76 period was 43.9, 51.6, 51.8, and 47.2 cm from watersheds 1, 2, 3, and 4, respectively. The annual range is from 16.4 to 88.0 cm for watershed 1; 22.6 to 82.8 cm for watershed 2; 14.6 to 87.7 cm for watershed 3; and 21.1 to 72.0 for watershed 4.

If (1) precipitation is measured accurately, (2) there is little or no deep seepage, and (3) runoff is measured accurately, the difference between annual precipitation and annual runoff is the amount of water lost to evaporation and transpiration. Average annual precipitation minus average annual runoff for the High Ridge watersheds was 96.2, 88.5, 88.3, and 92.9 cm for watersheds 1, 2, 3, and 4, respectively. These values may be greater than actual evapo-

Table 1--Average depth of snow within four watersheds when depth was near the annual maximum, High Ridge area

Date or statistical parameter	Watershed 4	Watershed 3 (control)	Watershed 1		Mean
			Upper	Lower	
		<u>Centimeters</u>			
4-4-72	194	175	163	164	174.0
4-2-73	98	86	80	82	86.5
3-19-74	240	265	241	248	248.5
3-15-75	136	126	115	119	124.0
3-2-76	200	214	186	196	199.0
3-22-77	96	89	88	83	89.0
Mean	160.7	159.3	145.5	148.7	153.6
Variance	59.6	71.9	62.8	66.2	65.1
Standard deviation	12.4	13.5	12.6	13.0	12.9
Coefficient of variation	97.0	106.4	99.4	102.1	101.2
Standard error	5.1	5.5	5.1	5.3	5.27

transpiration because there appears to be a good possibility for some deep seepage into the fractured basalt bedrock.

Flow duration curves provide a useful way to study runoff patterns. These curves (fig. 7) show the percent of time that flow rate is above

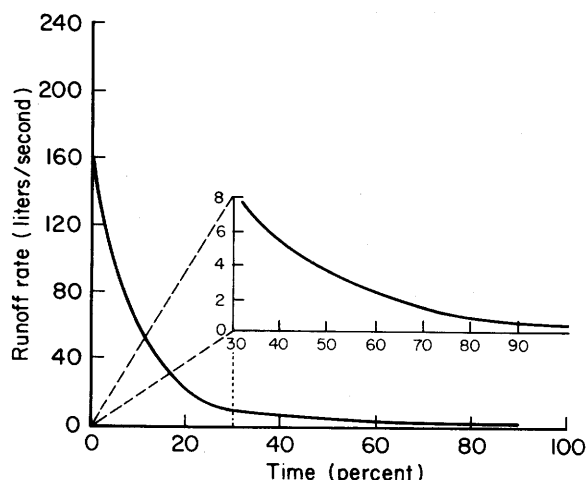


Figure 7.--Flow duration curves for watershed 4.

or below a given value. For example, figure 7 shows that runoff rate from watershed 4 was greater than 3.82 liters per second one-half of the time, and it was greater than 65.1 liters per second 10 percent of the time between October 1, 1967, and September 30, 1975. The maximum and minimum flow rates were 240.6 liters and 0.28 liter per second. Flow duration curves for the other watersheds have a similar shape, but the values are smaller because of smaller drainage areas. These curves are useful for detecting changes in the hydrograph after timber harvest. For example, an analysis after timber harvest may show that low flow rates increased significantly. Tests can also be made to determine whether peak flow rates increased after timber harvest.

When a new forest road is built, culverts or other structures must be installed at stream crossings to carry expected runoff under the road. What size culvert should be installed? This is an extremely important decision because an undersize culvert may be overtopped and a section of road destroyed. On the other hand, installing a culvert larger than needed wastes finances.

Experienced land managers can make an intelligent estimate of the size of culvert needed by observing the width and high water marks of the stream channel. When runoff records are available, a better estimate can be obtained by applying the laws of probability to measured runoff peaks. Although there are several methods available, the Log Pearson Type 3 method (United States Water Resources Council 1976) is recognized as the most accurate.

This method was applied to measured annual runoff peaks from the four streams at High Ridge. The ratio of maximum to minimum runoff peak during the 10 years of record varied from 11 on the smallest drainage to 4 on the largest. Peak discharge was computed for each drainage at recurrence intervals of 2, 5, 10, 25, and 50 years (table 2).

Figure 8 shows the expected peak discharge for each watershed as a function of the selected recurrence periods. The 10-year flood peak on watershed 4 is about 240.7 liters per second, and the 25-year flood peak is 283.2 liters per second. It is well recognized that peak discharge is a function of drainage area. Figure 9 illustrates a close relationship between drainage area and expected peak discharge at 5- and 25-year recurrence periods. This figure can be used to predict peak discharge in headwater streams of the Blue Mountains which have similar

Table 2--Computed peak discharge at selected recurrence intervals for 4 watersheds, High Ridge area

Recurrence interval	Watershed			
	1	2	3	4
Years	- - - Liters per second - - -			
2	42.8	49.7	102.6	176.3
5	76.4	65.1	135.8	237.7
10	90.6	70.8	158.5	263.2
25	107.5	76.4	186.8	285.8
50	116.0	79.2	206.6	300.0

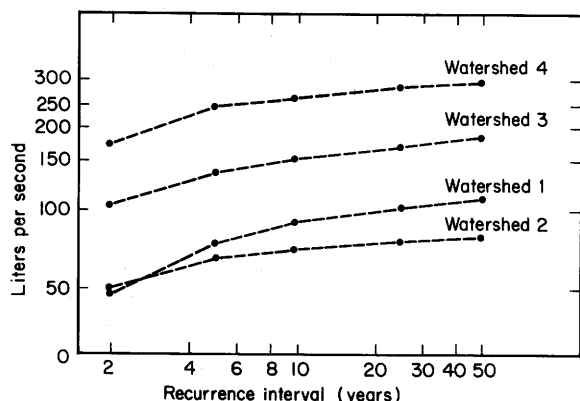


Figure 8.--Peak discharge for High Ridge watersheds as a function of recurrence period.

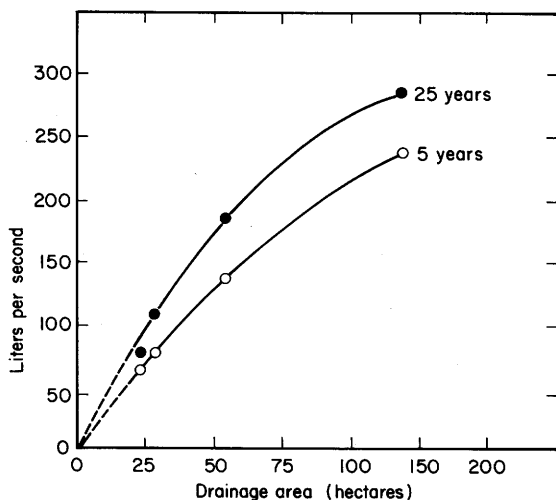


Figure 9.--Relationship between drainage area and peak discharge for 5- and 25-year periods.

exposure, vegetation, and annual precipitation to that of the High Ridge area.

The size of culvert needed for a given peak discharge rate depends on channel slope. Detailed methods for determining the relationship between channel slope, culvert size, and flow capacity were presented by Carter (1957) and Douglass (1974).

One of the original objectives of the High Ridge evaluation area was to determine the effects of timber harvest on water yield. This analysis requires linear regressions of annual runoff between watershed 3 (the control) and each of the other watersheds. The ability to detect changes in runoff after timber harvest depends on the degree of correlation between runoff from the control and each of the other watersheds. The data and regressions are plotted in figures 10,

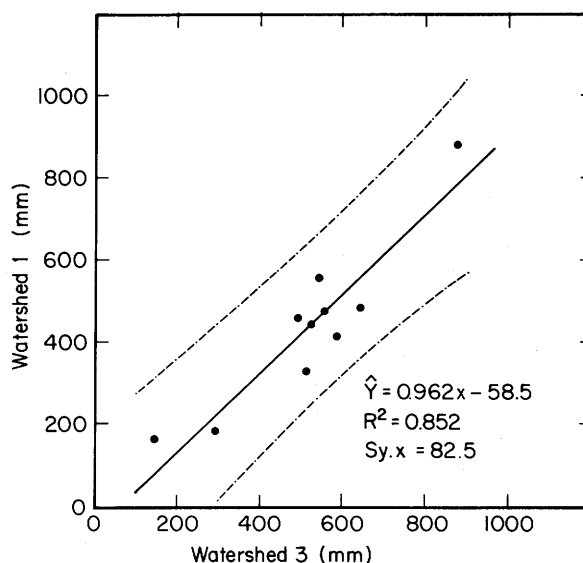


Figure 10.--Relationship between annual runoff, watershed 3 (control) and watershed 1. Solid line is plot of best fit regression equation. Dotted lines are 95-percent confidence limits for individual measurements.

11, and 12. Confidence bands (95-percent probability) apply to an individual measurement of runoff.

The correlation values for watersheds 2 and 4 indicate that most of the variation in runoff from these drainages is associated with runoff from watershed 3. The correlation of runoff between watershed 1 and 3 is lower. Increases in runoff after timber harvest from watershed 1 must exceed 19 cm during an average year to be statistically significant at the 95-percent probability level and 15 cm at the 90-percent level.

Soil Temperature

Canopy closure and limited air movement within the stand reduce energy input to the soil surface. Snow cover maintains isothermal

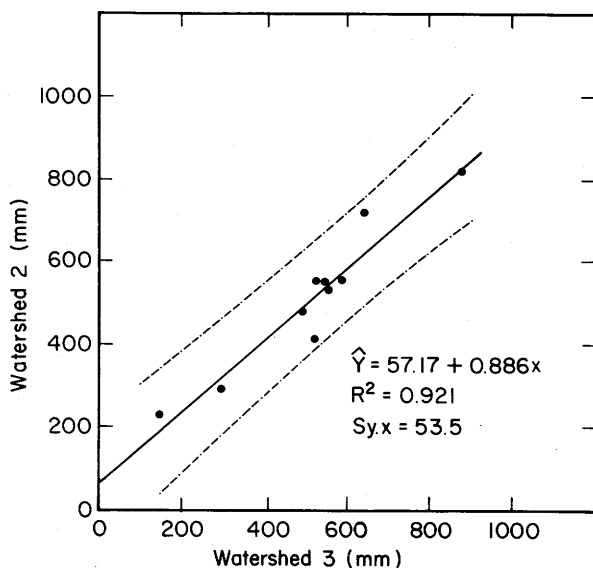


Figure 11.--Relationship between annual runoff, watershed 3 (control) and watershed 2. Solid line is plot of best fit regression equation. Dotted lines are 95-percent confidence limits for individual measurements.

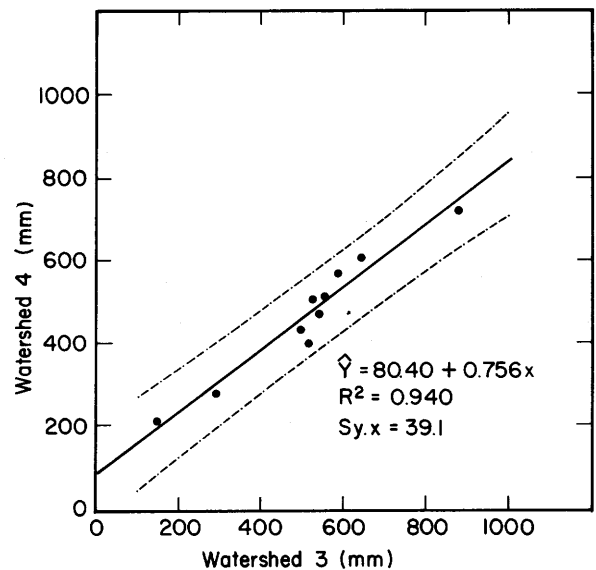


Figure 12.--Relationship between annual runoff, watershed 3 (control) and watershed 4. Solid line is plot of best fit regression equation. Dotted lines are 95-percent confidence limits for individual measurements.

conditions (near 0°C) from first snowfall to early June or mid-June. Maximum temperatures for watershed 4 in 1976, for example, at 2 cm did not exceed 20.6°C; at 10 cm, 15.5°C. Diurnal ranges of 8°-10°C were observed in the summer months.

Water Temperature

Stream temperatures follow an expected seasonal trend strongly influenced by duration of snow cover and flow regime. Figure 13 illustrates the temperature progression of maximum and minimum 3-hour averages for watershed 4 for the years 1973 through 1976. Temperatures of the snow-covered streams range between 1°C and 2°C; diurnal range is about 0.5°C. This condition persists through the peak runoff period; stream temperatures

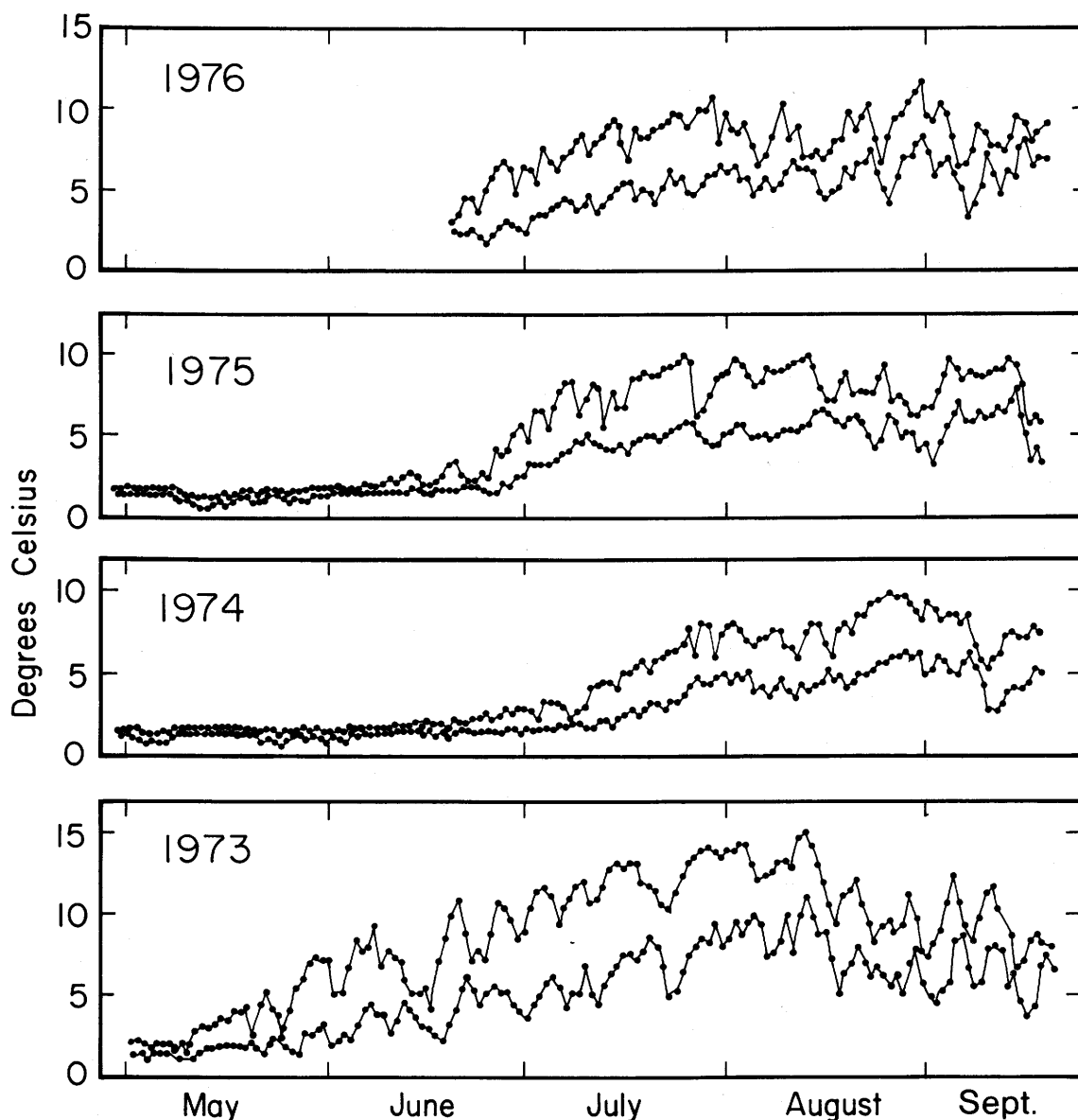


Figure 13.--Maximum and minimum 3-hour average stream temperatures for watershed 4 during spring and summer, 1973 through 1976.

start to rise during the recession part of the streamflow curve.

During average precipitation years 1974, 1975, and 1976, temperature maximums for all streams rarely exceeded 10°C; during the summer months minimums rose into the 6°C range. In the dry year of 1973, maximum water temperatures were closer to 12°C during the months of July and

August and minimum temperatures near 10°C, the expected maximum during wetter years.

A frequency distribution of water temperature from watershed 4 between September 21, 1972, and September 20, 1976, is illustrated in figure 14. The annual distribution indicates that stream temperature was between 0°C and 2°C for 59.5 percent of the

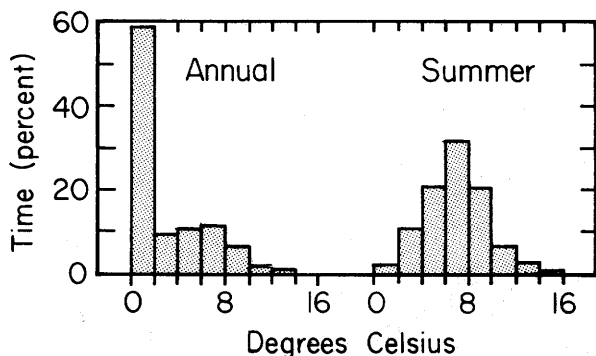


Figure 14.--Frequency distribution of 3-hour average stream temperature for watershed 4.

time. This distribution is heavily weighted toward the lower temperature because the streams are covered with snow about 6 months of the year. When summer temperatures alone are plotted, a normal distribution with a mean range of 6°C to 8°C results.

Watersheds 1, 2, and 3 (the control) show similar seasonal trends. Day-to-day variability in water temperature appears to be inversely related to amount of streamflow during the summer months, whereas

diurnal range is larger as flow increases. Watershed 1 has the highest day-to-day temperature fluctuation, the lowest diurnal range, and often the lowest annual runoff of the four watersheds.

The degree-hour summaries of water temperatures for the individual 3-hour periods of the day (fig. 15) illustrate the period of maximum daily heating and cooling. During this period in the summer of 1974, watershed 3, the control watershed, exhibits overall values similar to those of watershed 4, the adjacent watershed. Periods of minimum degree-hour accumulation are between 0600 and 0900 hours, as expected, for all watersheds. Maximum degree-hour accumulation in watershed 3 occurs between 1200 and 1500 hours; other watersheds show the maximum accumulation between 1500 and 1800 hours.

Figure 16 illustrates the relationship between daily maximum temperatures for stream and air for watershed 4 during 1974. Stream temperatures, as noted, are nearly isothermal for a large portion of the year, and

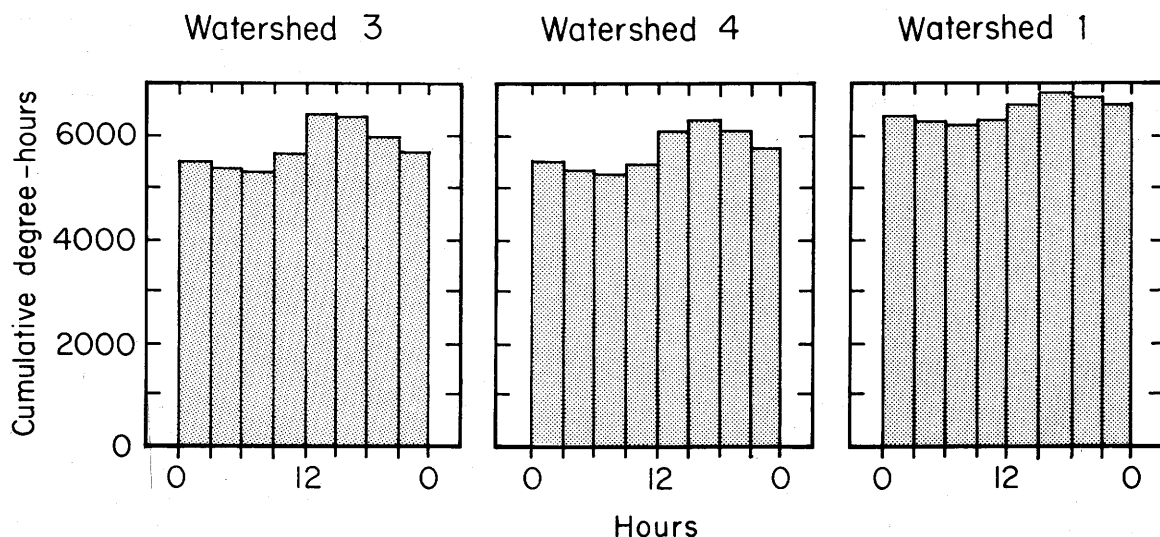


Figure 15.--Degree-hour summaries for 3-hour periods for watershed 1, 3 (control), and 4.

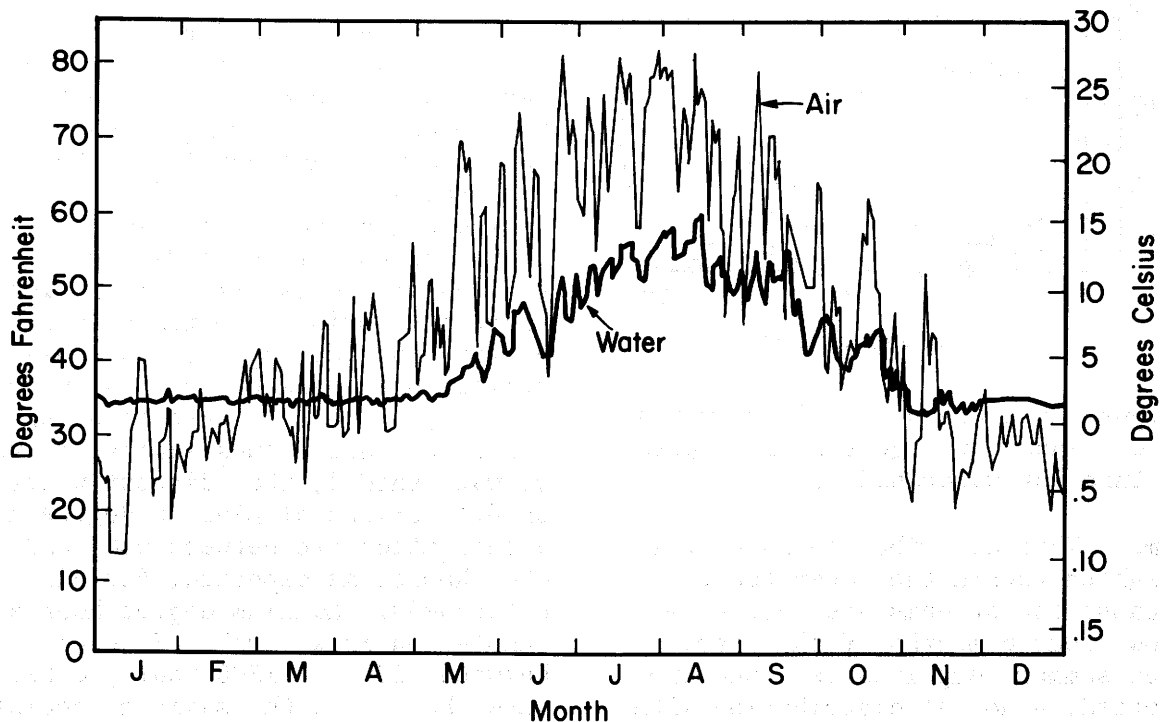


Figure 16.--Relationship between daily maximum air and water temperatures for watershed 4 (1974).

day-to-day fluctuations are small compared with the variation in air temperatures. The coefficient of determination, R^2 , between air and water temperatures in watershed 4 was 0.63.

During winter months, water temperatures are near 0°C under the several feet of snow cover. Correlation of water temperatures between watersheds would obviously be near unity. Table 3 lists the computed relationships for two periods-- March 21 to October 12, 1973, and June 8 to September 14, 1973. The strongest relationship is between watersheds 3 and 4; between watersheds 3 and 2, the weakest. Figures 17, 18, and 19 illustrate these relationships for both maximum and minimum daily temperatures during the summer of 1973.

Table 3--Relationships between water temperatures in watershed 3 (control) and treatment watersheds during calibration period

Watersheds and period	Regression equation	R^2 ^{1/}	n ^{2/}
March 21 to October 12, 1973:			
3-4 (min.)	$\hat{y}=1.038x-0.4241$	0.98	206
3-4 (max.)	$\hat{y}=1.098x-0.2502$	.98	206
3-2 (min.)	$\hat{y}=0.9517x+0.0581$	.90	206
3-2 (max.)	$\hat{y}=0.9447x+0.3759$	.90	206
June 8 to September 14, 1973:			
3-4 (min.)	$\hat{y}=1.0168x-0.2766$	0.97	99
3-4 (max.)	$\hat{y}=1.0826x-0.0924$	.97	99
3-2 (min.)	$\hat{y}=0.8738x+0.6887$	.80	99
3-2 (max.)	$\hat{y}=0.8514x+1.2098$	.60	99
3-1 (min.)	$\hat{y}=1.1877x+0.6925$	.83	99
3-1 (max.)	$\hat{y}=0.9893x+1.0001$	.83	99

^{1/} Coefficient of determination.

^{2/} Number of samples.

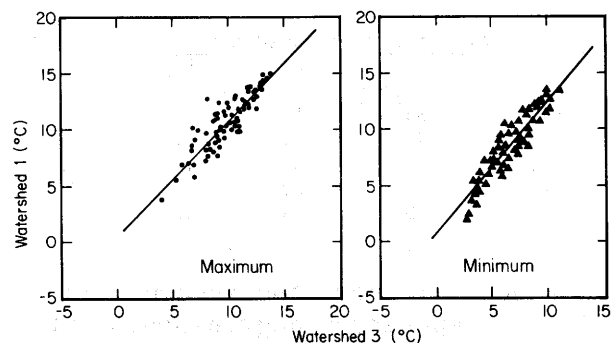


Figure 17.--Comparison of maximum and minimum water temperatures of watershed 3 with those of watershed 1.

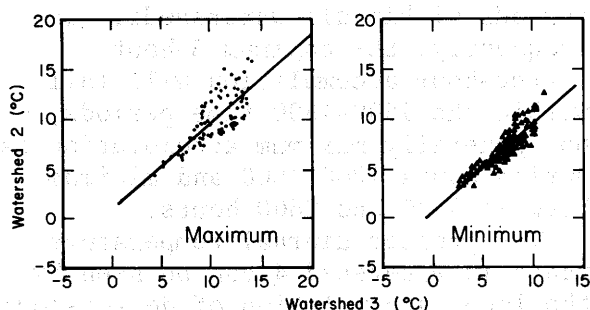


Figure 18.--Comparison of maximum and minimum water temperatures of watershed 3 (control) with those of watershed 2.

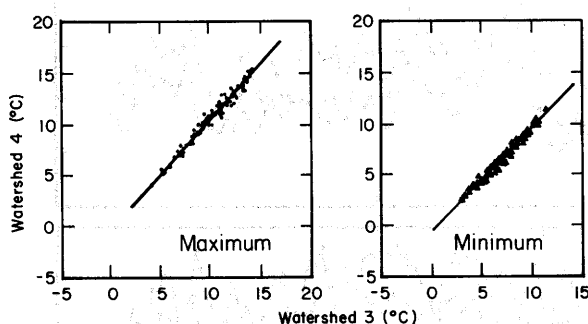


Figure 19.--Comparison of maximum and minimum water temperatures of watershed 3 (control) with those of watershed 4.

Wind

The dense canopy of the mature stand rapidly attenuates the penetration of wind into the depth of canopy and trunk space. Measurements were taken at 6 m in watersheds 1, 3, and 4 and at 20 m in watersheds 1 and 4.

Wind at 6 m in all watersheds rarely exceeded 9.6 km per hour. For instance, in watershed 1 from January 19, 1972, to July 9, 1976, when the recorder was removed prior to logging, only 3.08 km of wind travel were at speeds greater than 9.6 km per hour. Total wind travel for this period was 4 674 km; average speed was only 0.16 km per hour.

At 20 m in watershed 4 (at the main canopy level) between August 14, 1975, and July 9, 1976, total wind travel was 23 665 km, over four times that of watershed 1. This total was distributed among windspeed classes as follows:

Speed (km/h)	Total travel (km)
0-9.59	18 076
9.60-16.09	4 768
16.10-24.09	763
24.10-31.19	53
31.20-48.29	5
48.30+	0

Average windspeed for the period was 3.3 km/h.

Wind direction varied with location. Although the directional constancy of winds below 9.6 km/h, the speed class most commonly observed at the 6-m and 20-m levels beneath the canopy, is normally quite low, some preference is shown in the direction classes as follows:

Watershed	Height (Meters)	Period	Total travel by quadrants			
			N	S	E	W
			Percent			
1	6	8-14-75 to 7-9-76	27	54	18	1
3	6	10-14-72 to 3-7-73	7	41	51	2
4	6	10-15-75 to 7-9-76	23	25	37	15
1	20	8-14-75 to 7-9-76	24	33	30	12
4	20	8-14-75 to 7-9-76	17	59	9	16

Immediate and substantial changes in both speed and direction of wind are expected to occur with removal of canopy in these watersheds.

At 20 m in watershed 1 (beneath the live canopy which extended to 30 m or more), only 12.6 km of wind between August 14, 1975, and July 9, 1976, exceeded 9.6 km per hour. Total wind travel was 5 160 km, and average speed was 0.67 km per hour.

Air Temperature

Figure 20 illustrates the maximum and minimum air temperatures for watershed 3, the control, for a dry year (1973) and an "average" year (1975). Temperatures in the dry year are generally warmer, especially in the early spring and summer months.

Figure 21 shows the accumulation of air temperature degree-hours for the watersheds for several periods during summer and fall of 1974. Periods are of about 6 weeks. Data for watershed 2 for the initial period were not available. Periods of maximum and minimum temperatures fall generally within the same 3-hour periods within all watersheds. Infrequently, the maximum 3-hour degree-hour accumulation will fall within the 1500-1800 time periods, but generally maximum accumulation is during hours 1200-1500 and minimum between 0300 and 0600 hours.

The greater diurnal temperature range in watershed 4 can be seen by the lower accumulation of degree-hours during the three 3-hour periods from 0000 to 0900 in the graph for watershed 4 (lower right in fig. 21). The index line is at 4 000 degree-hours.

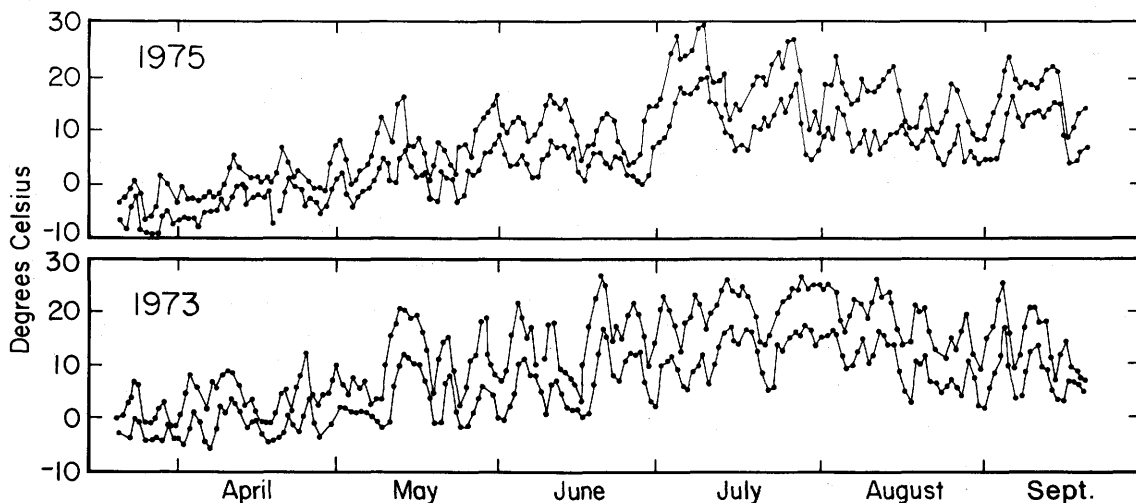


Figure 20.--Maximum and minimum air temperatures for watershed 3 (control) during spring and summer, 1973 and 1975.

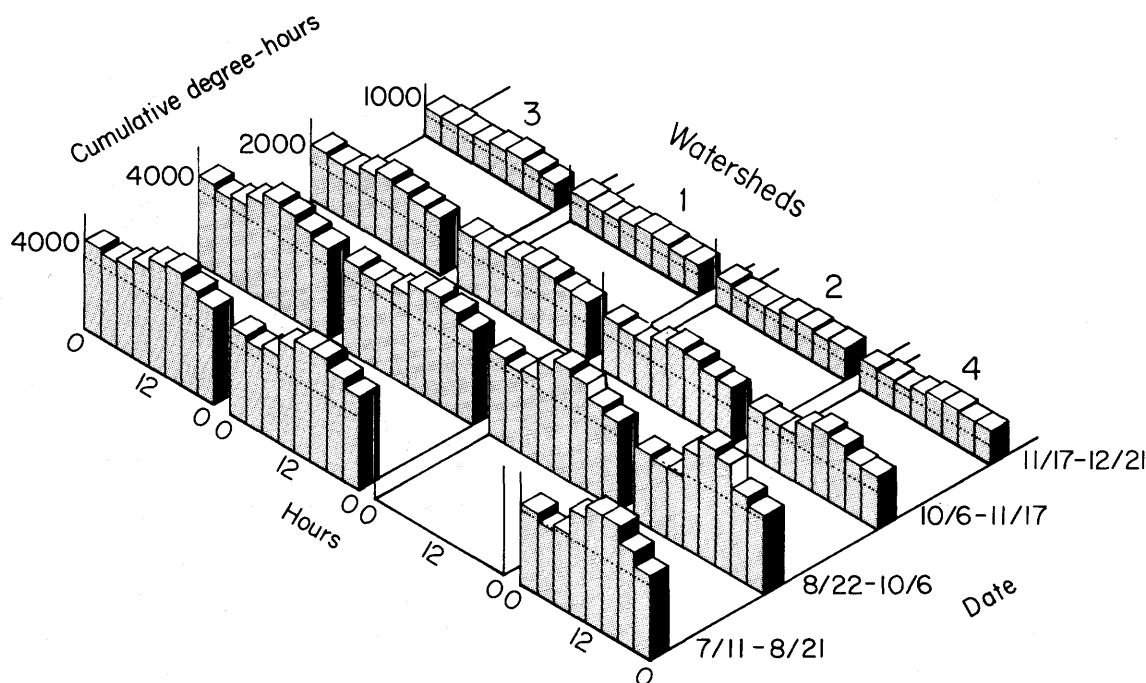


Figure 21.--Accumulation of air temperature degree-hours for selected periods during 1974.

Daytime maximum temperatures are similar within all watersheds.

Correlation coefficients and regression equations for the comparisons between air temperature in watershed 3 (control) and other watersheds are given in table 4. Figures 22, 23, and 24 are graphs of the maximum and minimum temperatures for the calibration period. Maximum temperatures are generally better correlated for all combinations than are minimum temperatures.

From the larger diurnal range exhibited in watershed 4, a location with a less dense overstory than other sites, the expected change in the temperature structure after timber harvest can be seen. We may anticipate further increases in the diurnal range in watershed 4 and at other sites with increased exposure.

The initial timber harvest was made in 1976. A cursory look at the post-harvest data indicates that some hydroclimatic variables were markedly

changed. Present plans are to continue measurements for about 3 years, then to analyze and publish the results.

Table 4--Relationships between air temperatures in watershed 3 (control) and treatment watersheds during calibration period

Watersheds and periods	Regression equation	R^2 ^{1/}	n ^{2/}
July 14 to December 20, 1974:			
3-4 (min.)	$\hat{y} = -0.4665 + 0.7138x$	0.94	132
(max.)	$\hat{y} = 0.4955 + 0.9978x$	.99	133
3-1 (min.)	$\hat{y} = 0.3262 + 0.9493x$	.99	142
(max.)	$\hat{y} = 0.2256 + 0.9783x$	.99	142
August 22 to December 20, 1974:			
3-2 (min.)	$\hat{y} = -0.0089 + 0.9081x$	.97	122
(max.)	$\hat{y} = 0.0402 + 1.0020x$	.99	122

^{1/}Coefficient of determination.

^{2/}Number of samples (varied because of missing data).

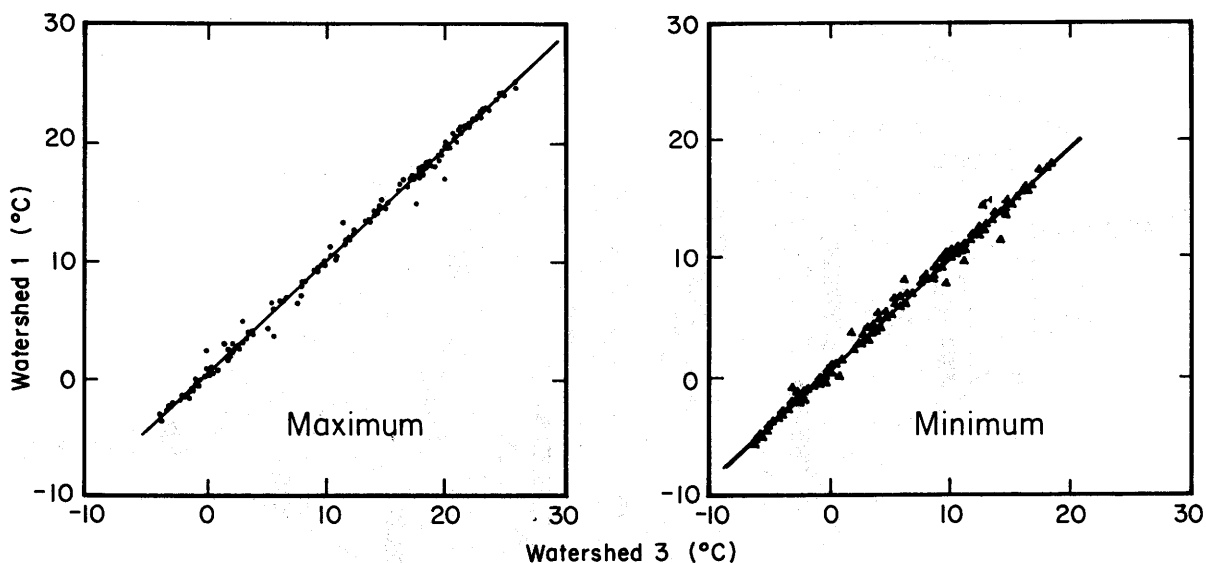


Figure 22.--Relationship between maximum and minimum air temperatures in watershed 3 (control) and watershed 1.

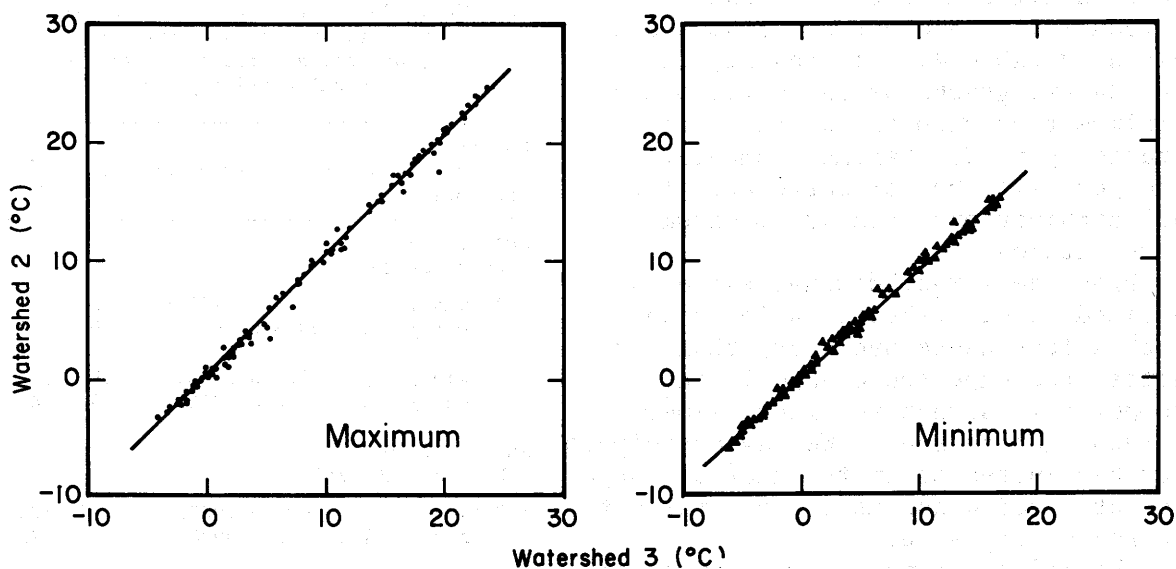


Figure 23.--Relationship between maximum and minimum air temperatures in watershed 3 (control) and watershed 2.

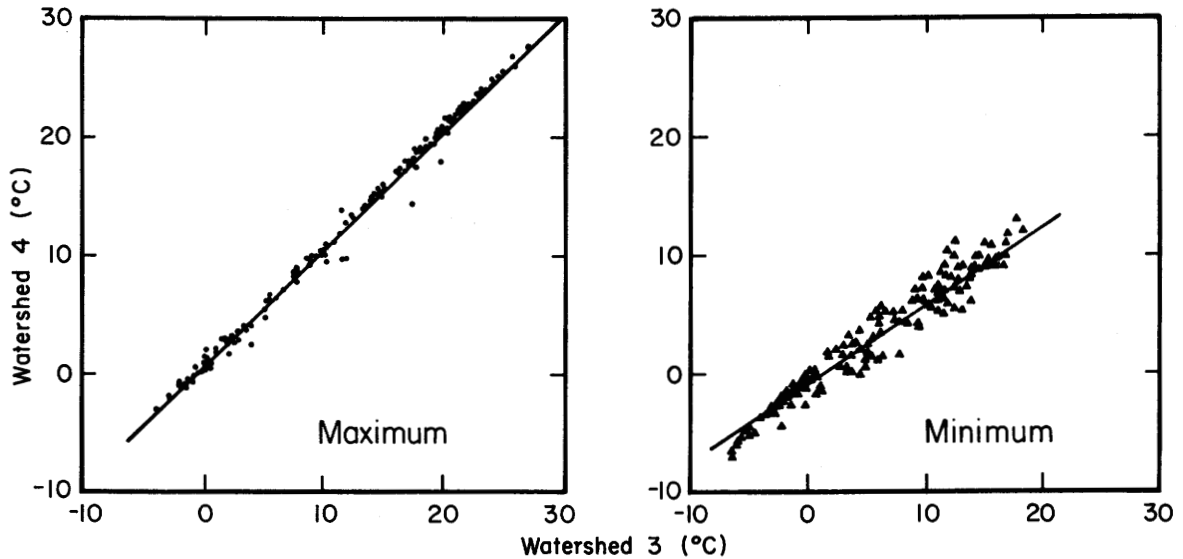


Figure 24.--Relationship between maximum and minimum air temperatures in watershed 3 (control) and watershed 4.

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