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General Technical Report NE-305

Hydrometeorological Database for Hubbard Brook Experimental Forest: 1955 – 2000

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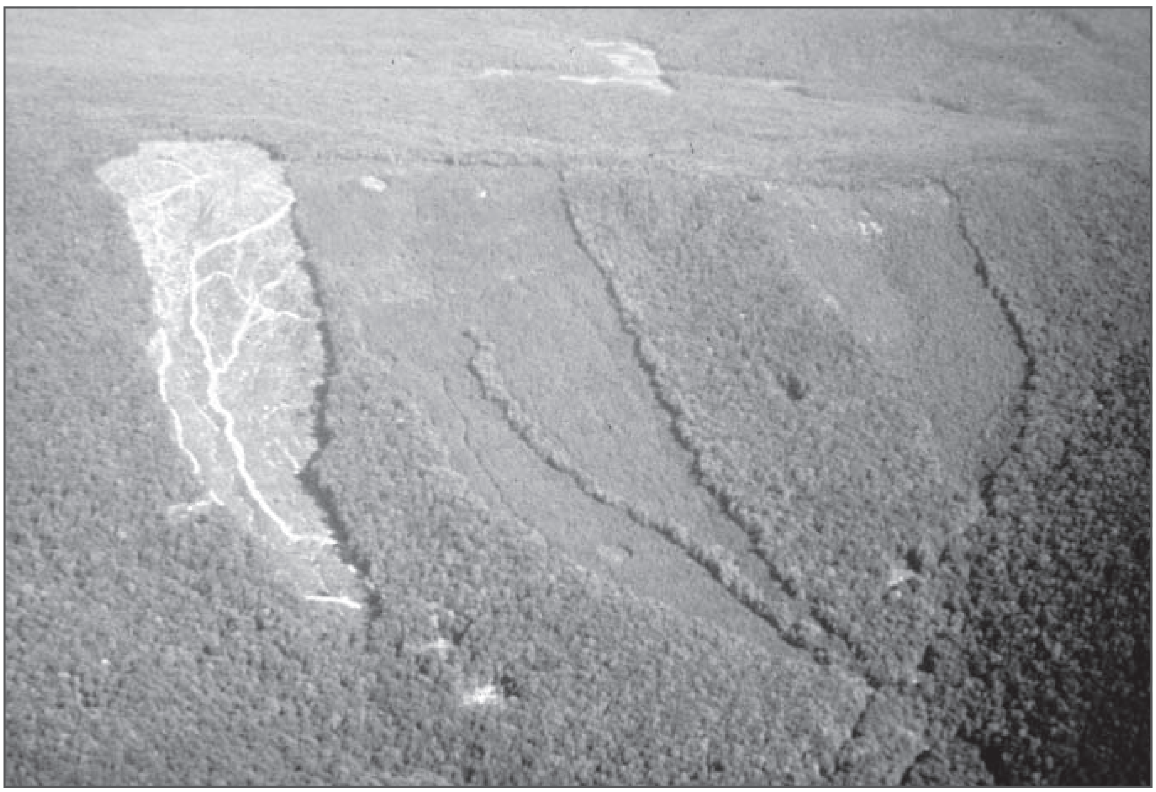

Abstract

The 3,160-ha Hubbard Brook Experimental Forest (HBEF) in New Hampshire has been a prime area of research on forest and stream ecosystems since its establishment by the USDA Forest Service in 1955. Streamflow and precipitation have been measured continuously on the HBEF, and there are long-term datasets for air and soil temperature, snow cover, soil frost, solar radiation, windspeed and direction, and humidity. This information has provided the basis for hundreds of publications by Forest Service and cooperating scientists on numerous aspects of forest hydrology research as part of the ongoing Hubbard Brook Ecosystem Study. This report updates the tables, methods, watershed descriptions, and other pertinent data in "Thirty Years of Hydrometeorological Data at the Hubbard Brook Experimental Forest, New Hampshire" (General Technical Report NE-141).

The Authors

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Foreword

C. Wayne Martin, retired research forester with the Northeastern Research Station, was site manager at the Hubbard Brook Experimental Forest from 1969 to 1999. One of his many responsibilities was overseeing the collection of data summarized in this report. Wayne supervised many people and participated in all aspects of data collection, including calibrating and maintaining instruments, processing and checking data, and ensuring high standards of quality control. That many individuals and groups use Hubbard Brook data with great confidence is a reflection of Wayne's personal commitment to excellence. Accordingly, this report is dedicated to C. Wayne Martin in recognition of his invaluable efforts in facilitating the important research conducted at Hubbard Brook.

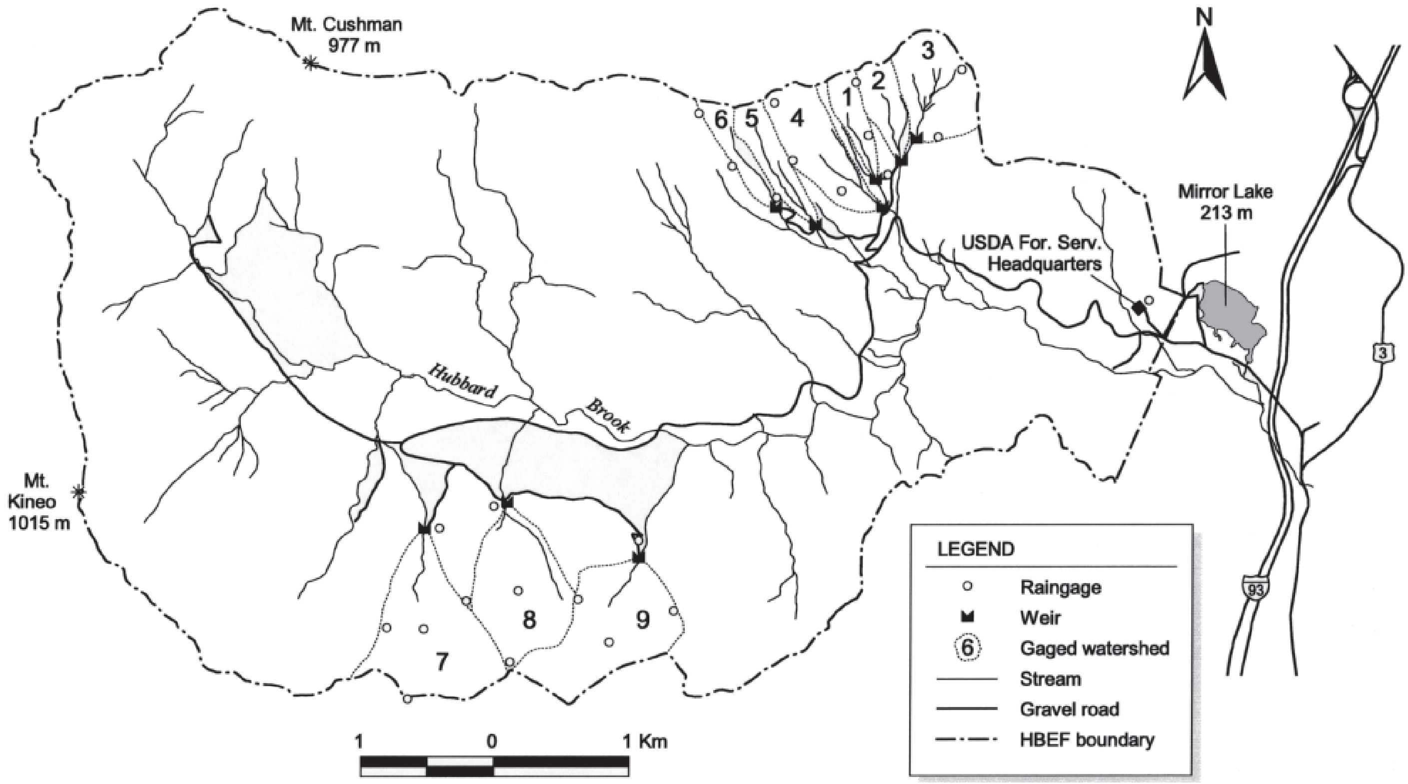

Figure 1.—Locations of watersheds and stations on the Hubbard Brook Experimental Forest.

Introduction

Scientists with the USDA Forest Service and cooperating researchers have been conducting studies on forest hydrology at the 3,160-ha Hubbard Brook Experimental Forest (HBEF) since its establishment in 1955 within the White Mountain National Forest near Thornton, New Hampshire. Since that time, streamflow and precipitation have been measured continuously on the HBEF, and data on air and soil temperature, snow cover, soil frost, solar radiation, windspeed and direction, and humidity have been collected on one or more of the HBEF's nine watersheds as part of the ongoing Hubbard Brook Ecosystem Study (HBES). These data serve as the foundation for world famous research on the cycling of water, nutrients, and energy in forests and related aquatic ecosystems, and are fundamental to research conducted by HBES scientists. In this report we describe and summarize the many long-term data sets maintained by Forest Service personnel at Hubbard Brook. Included are starting dates, equipment locations, methods, watershed descriptions and data summaries. This report updates the tables, trends and methods in "Thirty Years of Hydrometeorological Data at the Hubbard Brook Experimental Forest, New Hampshire" (Federer 1990).

Topography and Vegetation

The center of HBEF is at latitude 43°56'N and longitude 71°45'W in the southwestern corner of the White Mountain National Forest. Elevation ranges from 252 m near HBEF Headquarters (HQ) at the east end to 1,015 m at the summit of Mt. Kineo at the west end (Fig. 1). The HBEF is a bowl-shaped watershed basin with many subwatersheds that drain into Hubbard Brook, which flows easterly into the Pemigewasset River, a major tributary of the Merrimack River.

Approximately 14,000 years ago, HBEF was covered by continental glacial ice. The ice sheet removed the preglacial soil and smoothed the surface of the schist and granite bedrock. The bedrock surface has weathered little since glaciation. When the ice melted, debris in the glacier became the stony till in which today's soil has formed. The till thickness over bedrock ranges from zero to several meters. Four thousand years after glaciation, forests covered the landscape, which along with the humid, cool, continental climate, caused the development of a typical spodosol soil profile: a black organic forest floor over a highly leached, thin gray horizon, and then a red-orange horizon of accumulated

Table 1.—Description of watershed features with mean streamflow and precipitation for each watershed calculated from starting year to 2000

Watershed no.	Streamgage start year	Area	Slope	Aspect	Avg. annual streamflow	Avg. annual precipitation
		ha	*degrees*		------ *mm* ------	
1	1956	11.8	12.3	Southfacing	828	1322
2	1957	15.6	17.5	Southfacing	916	1315
3	1958	42.4	15.9	Southfacing	831	1324
4	1961	36.1	15.1	Southfacing	875	1358
5	1962	21.9	14.3	Southfacing	881	1389
6	1963	13.2	14.0	Southfacing	917	1423
7	1965	76.4	14.2	Northfacing	949	1450
8	1969	59.4	15.4	Northfacing	925	1471
9	1995	76.1	13.3	Northfacing	994	1493

iron and a yellowish-gray subsoil ranging from coarse and sandy to a dense hardpan.

From 1890 to 1920, the original mixed conifer-hardwood forest at HBEF was cut heavily for sawtimber and fuelwood. The resulting forest release and regeneration led to the current northern hardwood forest, which is dominated by sugar maple (*Acer saccharum* Marsh.), American beech (*Fagus grandifolia* Ehrh.), and yellow birch (*Betula alleghaniensis* Britt). Balsam fir (*Abies balsamea* (L.) Mill.) and red spruce (*Picea rubens* Sarg.) are found primarily at higher elevations, particularly on north-facing slopes. Although trees in the 80- to 100-year class dominate, the cutting left many residual trees that today are more than 200 years old. Apart from salvage logging following the hurricane of 1938, the forest has been undisturbed since 1920 except for recent research treatments.

Hydrometeorologic Network

Early construction of streamgages on small subwatersheds within HBEF occurred side by side on the south-facing slope, where watersheds are well defined, accessible, and of suitable size for weir construction and study. Weir construction on south-facing tributaries to Hubbard Brook (Watersheds 1 - 6) began in 1955 and continued through 1963. Gaging on the north-facing slopes was established on Watershed 7 in 1965, Watershed 8 in 1969, and Watershed 9 in 1995 (Fig. 1, Table 1). A watershed is the area upslope from the streamgage, defined by its ridgelines, that contributes water to the stream channel at the gage location. The gaged watersheds were numbered in the order constructed.

Openings were cut in the forest to about 2 tree heights or more in diameter in or near each gaged watershed. These openings have at least a standard precipitation gage and are numbered from 1 to 25 (Fig. 2). Station 18 was a temporary station in Watershed 2; its data are not reported here. All other stations are currently in operation. Stations 1, 6, 10, 14, 19, 22, and 23 have a weight-recording precipitation gage; Stations 1, 6, 14, 17, 23, 24, and HQ have a temperature and humidity recorder (hygrothermograph). A variety of sensors has been maintained at the HQ weather station (Station 22) over the years and it is the original site for electronically measured weather data at HBEF.

Four experimental watersheds on the south-facing slope have undergone treatment since the HBEF was established. Watershed 2 was clearfelled in 1965 by cutting all stems and leaving them in place. It was further devegetated by application of herbicide in 1966, 1967, and 1968. Watershed 4 was commercially cut in sequential parallel strips (25 m wide) in 1970, 1972, and 1974, resulting in complete cutting and log removal over the entire area except for a streamside buffer. Watershed 5 was whole-tree clearcut in late 1983. In the fall of 1999, Watershed 1 was manipulated chemically. Fifty tons of wollastonite ($CaSiO_3$) were applied to evaluate the role of calcium in regulating the structure and function of the forested watershed. All of the treated watersheds have been left undisturbed following manipulation.

Nearly all of the equipment at HBEF continues to be operated by mechanical transducers linked to pens on spring-wound strip-chart recorders. These instruments

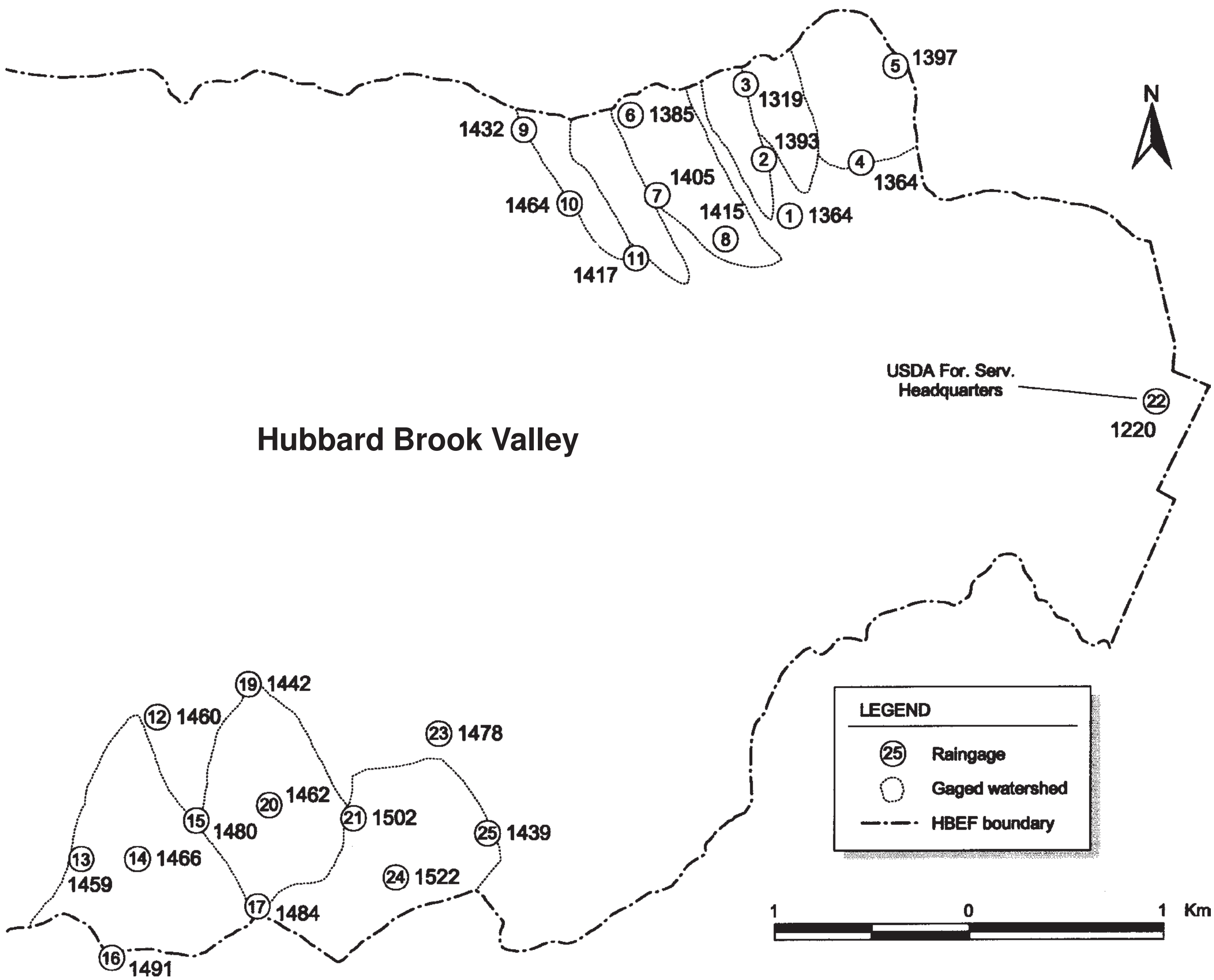

Figure 2.—Average annual precipitation (mm) for 1969-2000 (1997-2000 for raingages 23-25) for each standard gage (circled numbers indicate standard gages; precipitation is in boldface).

represented the state of the art in 1955 and remain highly reliable in adverse weather conditions. The instruments are monitored weekly and malfunctions are repaired immediately. Data from the charts are entered into computer programs and spreadsheets where they are analyzed and archived. The data presented here are available at the Hubbard Brook website (www.hubbardbrook.org) and updated annually.

Precipitation

Three types of raingages have been used to measure precipitation at Hubbard Brook: standard, weight recording, and tipping bucket. All gages are located in clearings that are maintained to uniform standards such that any tree beyond a 40-degree angle measured from the base of the raingage stand is cut down. Each gage has a shield to reduce wind effects. Raingages are mounted so that the tops are 2.5 m off the ground; this ensures that they are above the deepest snowpack.

Precipitation is measured weekly at standard gages located at 24 stations in or near gaged watersheds and at HQ (Fig. 2). Weight-recording gages are located at 7 of the 24 stations for a continuous chart record of how much rain fell each day. An automated tipping bucket was installed at the HQ meteorological station in 1981; a second one was installed at rain gage 23 in 2000. Tipping buckets provide hourly data, which are commonly sought after by forest modelers.

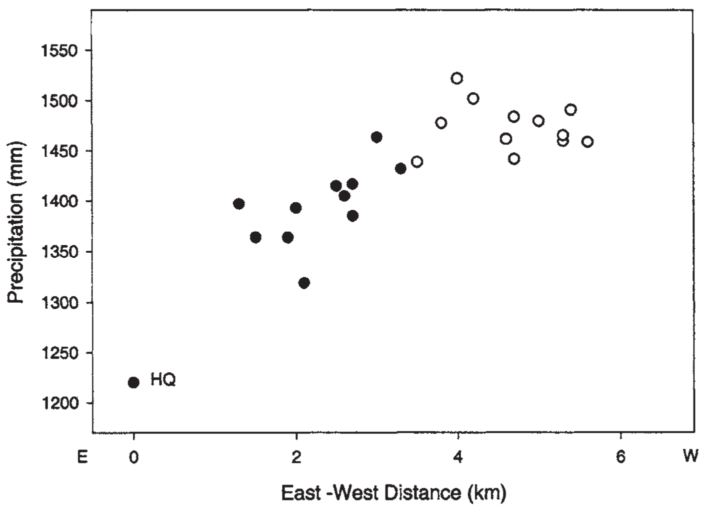

Figure 3.—Average annual precipitation from east to west (raingages 1-22 estimated from 1969-2000, gages 23-25 from 1997-2000). Solid dots are on the south-facing slopes, open circles are northfacing. The easternmost site, Headquarters was assigned a value of zero; all other gages are the distance (km) from headquarters determined by longitudinal UTM coordinates.

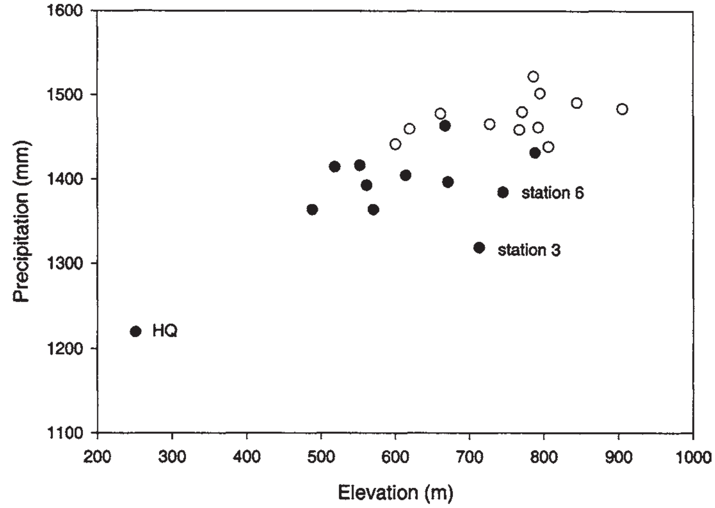

Figure 4.—Average annual precipitation by elevation for each standard gage (raingages 1-22 estimated from 1969-2000, gages 23-25 from 1997-2000). Solid dots are on the south-facing slopes, open circles are northfacing. Stations 3 and 6 receive less precipitation due to their topographic positions near the top of the watersheds.

The daily precipitation for a standard gage is obtained by prorating its weekly total using daily totals from the nearest recording gage. Precipitation for an entire watershed is estimated using the Thiessen weighting method (Linsley et al. 1958). The daily watershed precipitation reported is a weighted average of daily precipitation for several standard gages. The weighting factor for each gage is the fraction of the watershed area nearest that gage.

Standard Raingages

Raingage 1 often is used to report average annual rainfall from a single gage at Hubbard Brook. Using the record from 1969 to 2000, that value is 1,364 mm. However, mean annual rainfall at HBEF is characterized by high spatial variability ranging from 1,220 mm at raingage 22 to 1,522 mm at gage 24 (Fig. 2). These precipitation trends are related to topography and tend to increase from east to west, from south to north-facing slopes, and with elevation.

Total precipitation by gage is strongly controlled by longitude (Fig. 3). Raingage 10, at Watershed 6, the westernmost gaged watershed on the south-facing slope, has the highest average annual rainfall (1,464 mm). Gage 10 receives an average of 100 mm more precipitation annually than its easternmost counterparts, e.g., raingages 1 and 4, which receive average annual rainfall of 1,364 mm. The east/west trend is not as significant on the north-facing slope.

Elevation is important when describing precipitation trends at HBEF (Fig. 4). On both the south- and north-facing slopes there is a 300-m difference between the lowest and highest raingage. The highest gage receives 70 mm more precipitation annually than the lowest on the south-facing slope and 40 mm more than the lowest on the north-facing slope. Gages 3 and 6 receive about 100 mm less annual precipitation than expected for their elevation on the south-facing slope. Raingage 3 is near the top of Watershed 1 and has annual average rainfall of 1,319 mm. Gage 6 near the top of Watershed 4, has annual average rainfall of 1,385 mm. Each is less than 20 m in elevation below the ridgeline. The other high-elevation raingage on that ridge, gage 9, is 40 m below the ridge and does not have unusually low precipitation (1,432 mm annual average). Because winds at HBEF often are from the northwest, the south-facing slope is a lee slope. It may be that raingages 3 and 6 often are in the region of flow separation at the lee side of a ridgetop and thus are subject to abnormal wind conditions.

Experimental watersheds at HBEF are arranged on south- and north-facing slopes. Raingages on the north-facing slope receive up to 150 mm more precipitation

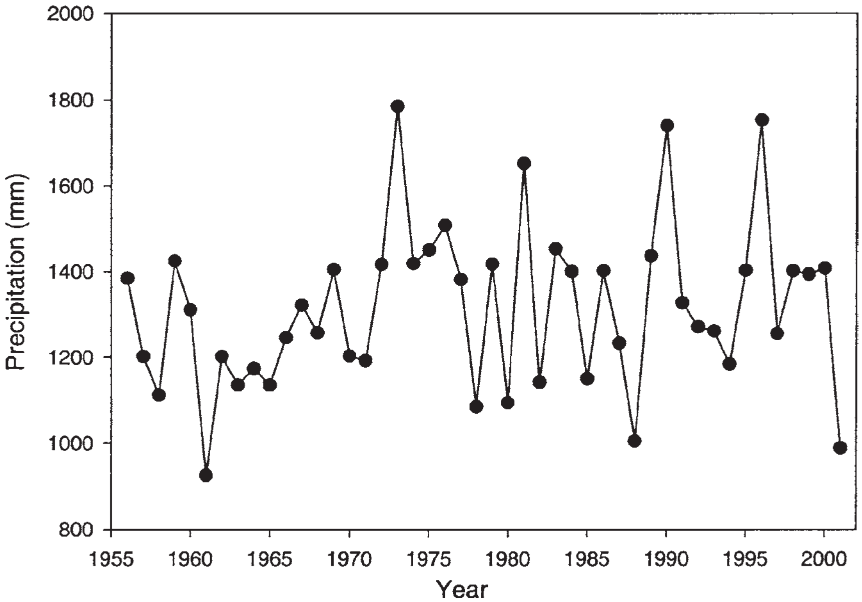

Figure 5.—Total annual precipitation at raingage 1 (1956-2001).

annually than gages on south-facing slopes. Much of that is in the form of snow. Raingage aspect within a watershed on both south- and north-facing slopes does not indicate a significant trend in rainfall.

Topography affects precipitation trends at HBEF, though seasonal variation and the composition of individual events, e.g. the direction they come from, can be important. At gage 1, the driest year on record is 1961 with 914 mm of rainfall; the wettest is 1973 with 1,778 mm. These totals indicate year-to-year variability (Fig. 5).

Watershed Precipitation

Annual watershed precipitation varies by year and watershed. Watershed 3, the easternmost watershed serves as the hydrologic control while Watershed 6 is the biogeochemical control. Precipitation increases from east to west across south-facing watersheds, reflecting the pattern recorded with individual raingages. Average annual precipitation is 1,325 mm at Watershed 3 and 1,423 mm at Watershed 6. These differences are not as apparent on the north-facing slope, possibly because north-facing gages are at higher elevations than south-facing gages. The resulting increase in rainfall might be masking the east/west effect.

Summaries of monthly precipitation are sought for many uses. At Watershed 3, the average monthly rainfall is 110 mm and has been as low as 24 mm in 1965 (May) and as high as 354 mm in 1973 (June). However, on average, watershed precipitation varies little from month to month (Fig. 6). Tables 2- 4 show monthly precipitation for Watersheds 3, 6, and 7. (Tables 2 through 20 are in the Appendix.)

Year-to-year variation is much larger than watershed-to-watershed variation (Table 5). The standard deviation of annual precipitation at all watersheds is about 185 mm (Table 5). The wettest year from 1956 to 2000 was 1973 as 1,793 mm of precipitation fell on Watershed 3. The driest year was 1961 with 979 mm recorded on the same watershed. This dry year included a series of dry months (Table 2). The record precipitation in 1973 is attributed to abnormally high rainfall in June and December. The 354 mm of precipitation in June 1973 is the highest monthly total on record.

Differences in monthly precipitation among watersheds are smallest in the summer months and largest in November through April, suggesting that snowfall varies spatially more than rainfall does. Using the criterion of >1 mm for a "rain day," slightly better than 1 day in 3 experiences precipitation in the winter months and rain falls less than 1 day in 3 during the summer months.

The largest storms at HBEF produce total rainfall of 100 to 200 mm over several days (Table 6). These storms can occur any time of year, usually causing local or regional flooding. The HBEF record began shortly after the severe New England hurricanes of 1954 and 1955. Only 1 of the largest 20 storms on record (October 5-10, 1962) was a tropical hurricane. The storm periods in

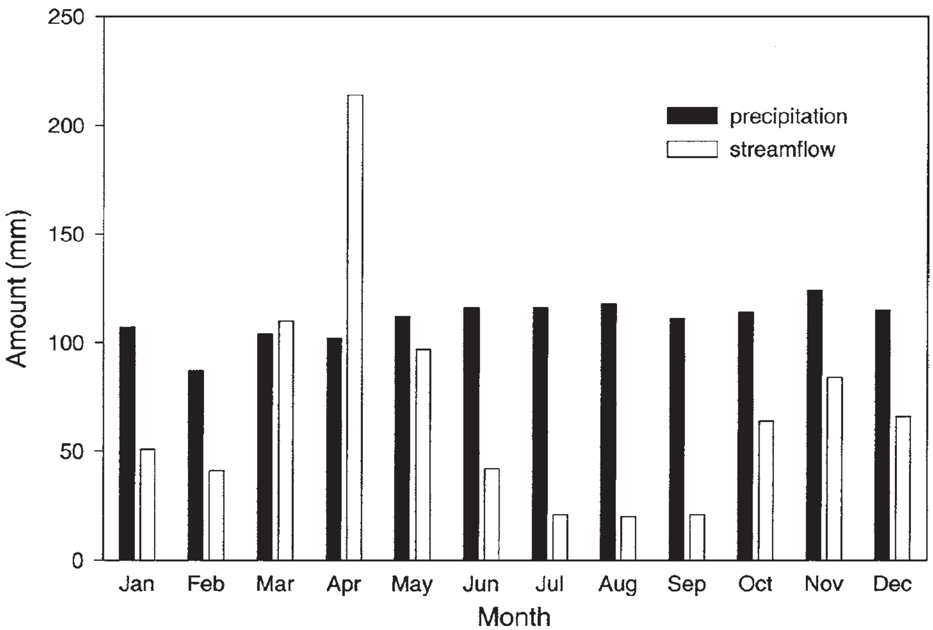

Figure 6.—Average monthly precipitation (solid bars) and streamflow (open bars) for Watershed 3 (1958-2000); data used to calculate averages are from Tables 2 and 7.

Table 6 include consecutive days with precipitation. Most of the precipitation fell in a shorter period than shown. The high precipitation events in winter occurred with temperatures at or above freezing, and were predominantly rain events.

Streamflow

Streamgages are located at the bottom of the 9 gaged watersheds at HBEF and have been running continuously from as early as 1955 (Fig. 1, Table 1). Small watersheds were surveyed and chosen for gaging by their accessibility, size, and proximity to other gaged watersheds. Construction of the streamgages at HBEF is described in Reinhart and Pierce (1964). To prevent leakage, each gage is anchored to bedrock. The streamflow is forced over a V-shaped dam, also called a V-notch weir. The height of water behind the dam increases as streamflow increases. This height is measured continuously by a float attached mechanically to a pen on a spring-wound strip-chart recorder. For each day, 2 to 130 points on the chart trace are digitized depending on the rate of change of flow. These "gage heights" are converted to streamflow rate by calibration factors and then integrated to give daily streamflow. The streamgages on Watersheds 5-8 have a rectangular (modified San Dimas) flume in series with the V-notch weir. When streamflow surpasses the height of the V-notch, the depth of the water in the flume is recorded as the measure of streamflow. Both V-notches and flumes are heated by propane burners to keep them free of ice. This allows continuous measurement of streamflow throughout the year.

Streamflow rate is measured as volume per unit time (L/s) and is proportional to the watershed area. To make streamflow comparable among watersheds of different areas, the streamflow rate is divided by watershed area to give units of depth per unit time (over the entire watershed area). After integrating over a given time, streamflow is expressed in millimeters, and is directly comparable to precipitation.

Streamflow varies considerably from day to day and season to season in response to precipitation, soil drying by evapotranspiration, and snow accumulation and melt. Hydrographs for a dry, normal, and wet year for Watershed 3 (the hydrologic control) are shown in Figure 7. The graphs illustrate how annual hydrologic activity varies by day and by season.

Streamflow also varies considerably from year to year in response to variation in annual precipitation. The highest annual streamflow on Watershed 3 (1,414 mm) occurred in 1996 and the lowest (436 mm) in 1961 (Table 7). These values correspond respectively to years of the second highest and lowest annual precipitation. Average annual streamflow at Watershed 3 is 831 mm. The standard deviation of annual streamflow is about 200 mm for all watersheds (Table 8), and is similar to that for precipitation (185 mm).

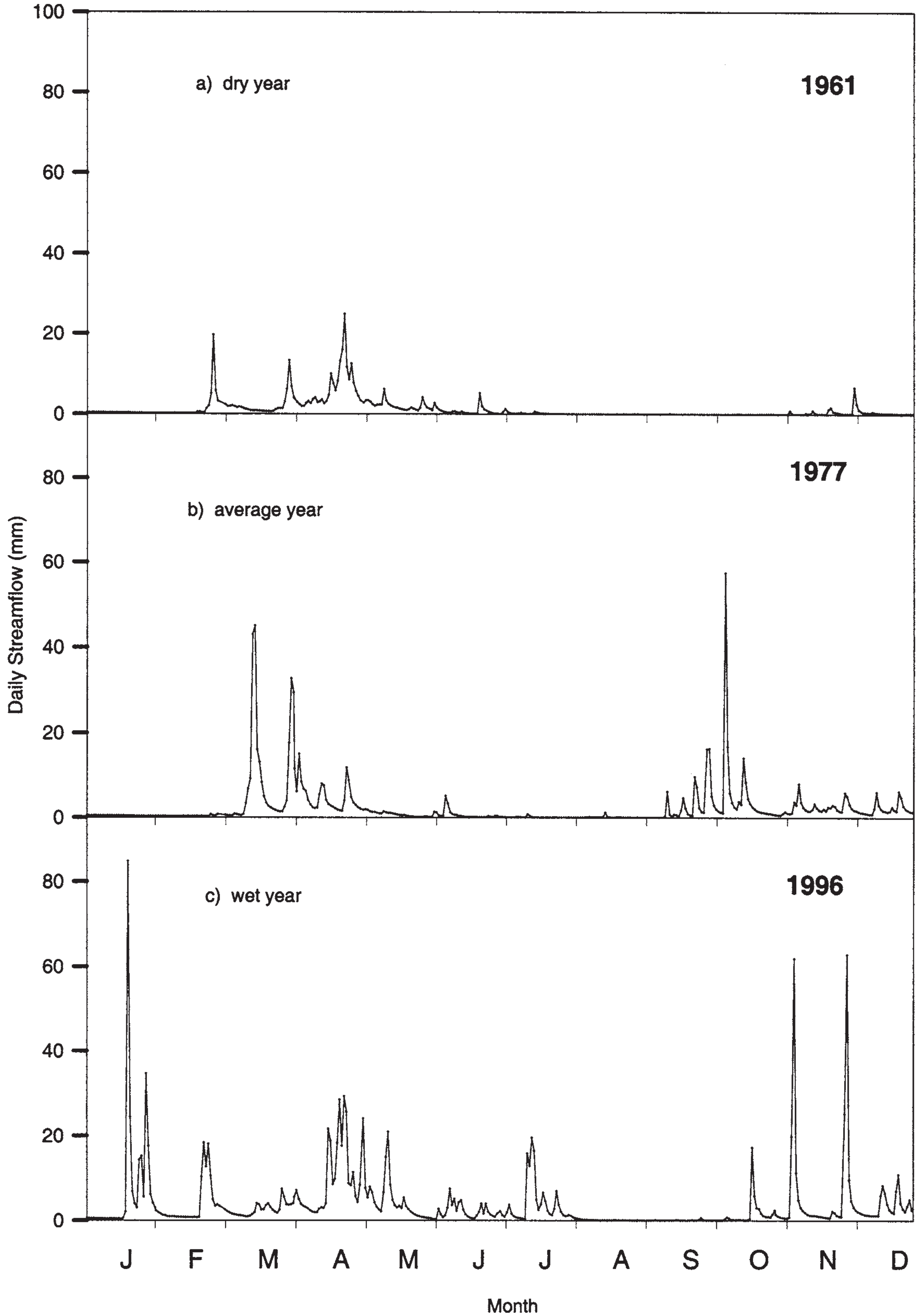

Figure 7.—Daily streamflow at Watershed3 for a) dry, b) average, and c) wet years; data used in calculations from from Table 7.

Monthly streamflow is highly seasonal (Fig. 6). April has the highest streamflow because the snowpack that has accumulated through the winter typically melts during this month. Streamflow is lowest in August when summer evapotranspiration rates are highest. Tables 7, 9 and 10 show monthly streamflow for Watersheds 3, 6, and 7.

During the snow-free period, streamflow generally increases from east to west across the gaged watersheds due to the precipitation pattern. Average annual streamflow from 1969 to 2000 was 882 mm for Watershed 3 (the easternmost watershed) and 975 mm for Watershed 7 (the westernmost). Snow melts later on north-facing watersheds (7, 8, and 9) than on the south-facing watersheds (1 to 6) due to the higher elevation and northern aspect. Consequently, March streamflow is lower and May streamflow is higher on Watersheds 7, 8, and 9. In April, peak flow occurs later in the month on these watersheds, though the average April total is similar at each site.

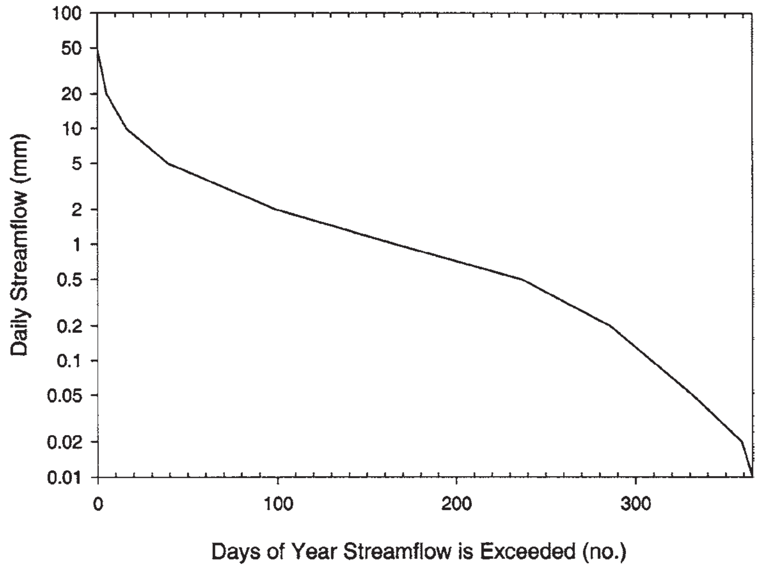

Figure 8.—Flow-duration curve shows average number of days in a year from 1958-2000 that streamflow is greater than previous amount for Watershed 3.

The highest monthly streamflow recorded for Watershed 3 is 435 mm in April 1969 (Table 7) vs. 409 mm for Watershed 7 in May 1971 (Table 10). Both of these months had normal precipitation (Tables 2 and 4), indicating that the high streamflows were caused solely by snowmelt runoff.

Monthly streamflows of only 1 or 2 mm are common during summer months (Tables 7, 9-10). In winter, streamflow is maintained for long periods at about 50 mm/day due to continuous melt from the bottom of the snowpack. At Watershed 3, the minimum flow in January and February is about 9 mm (Table 7). The lowest winter streamflow on record occurred in February 1980 due to a lack of snow. During that year, a deep soil frost delayed snowmelt runoff.

The 20 highest peak flows at HBEF (Table 11) are not well correlated with the 20 largest precipitation events. Melting snow along with rain occurred during 6 of the 8 highest streamflow peaks. Heavy rain in summer rarely causes high streamflow because the soil is somewhat dry from evapotranspiration. Only 2 of the top 20 streamflows occurred in the summer. From June 27 to July 1, 1973, the greatest rainfall recorded (212 mm) produced only the 13th highest streamflow event.

Flood return periods and frequency of streamflow are two measurements of particular interest to hydrologists and engineers. Calculating the flood return period requires knowledge of the highest streamflow rate recorded each year (see Table 12 for Watershed 3). Frequency of streamflow occurrence is shown by flow-duration curves (Fig. 8). Daily flow greater than 10 mm occurs about 5 percent of the time but contributes 37 percent of the annual total. Daily flow of less than 1 mm occurs on more than half the days but contributes only 10 percent of the annual total.

Flow recession after storm peaks is rapid at HBEF, particularly from June through September when the trees have fully developed leaves and evapotranspiration is high.

Streamflow Response to Treatments

The "paired watershed" method at HBEF is fundamental to research, i.e., one watershed is treated while another remains an untreated reference. Before treatment, the water budgets of the paired watersheds ideally would be identical so that any differences after treatment could be interpreted as treatment effects. Because no two watersheds are identical, regression comparisons of the two watersheds before treatment are used for calibration. At HBEF, experimental treatments entailing timber removal were carried out on three south-facing gaged watersheds (Hornbeck, et al. 1997). Responses in annual water yield varied among treatments but increased initially and then decreased as the forest regenerated (Fig. 9). Most of the increases in water yield occurred during the growing season and some peak flows increased. Snowmelt volume did not change but the snow melted earlier on treated watersheds.

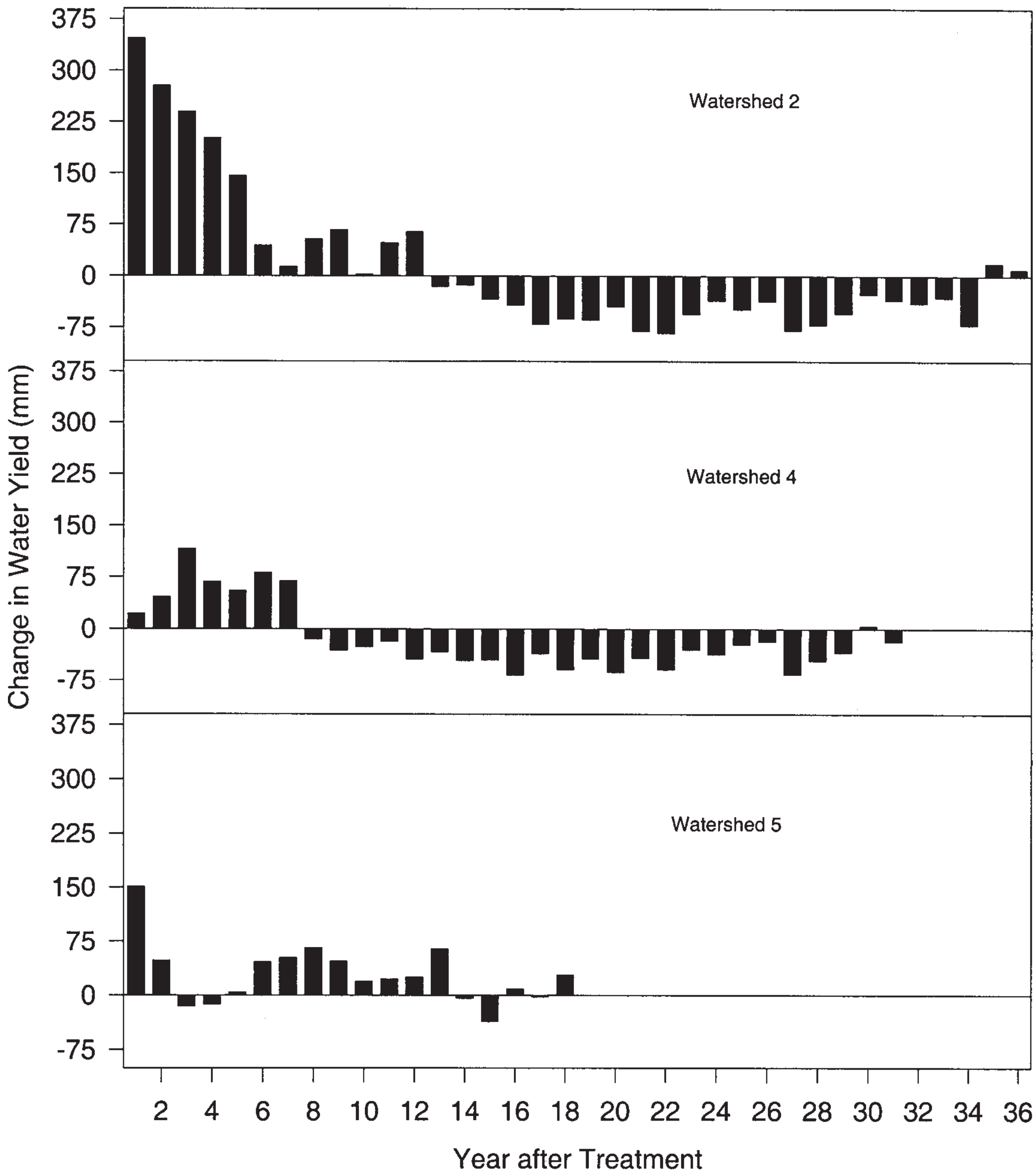

Figure 9.—Estimated change in water yield for watersheds 2, 4, and 5 after treatment. Change was calculated by subtracting treated streamflow yield from estimates of what yield would have been if watershed had not been treated.

Water Budget

The annual water balance at HBEF for Watershed 3 is:

Precipitation (1,326 mm) = Streamflow (833 mm) + Evapotranspiration (493 mm)

Thus, 63 percent of the precipitation that enters Watershed 3 leaves as streamflow while 37 percent is returned to the atmosphere by evapotranspiration.

The water budget is based on long-term measurements of precipitation and streamflow. Assuming that bedrock at HBEF is water tight, precipitation enters a watershed and, after short periods of storage in the soil or snowpack, leaves as streamflow or evapotranspiration (water evaporated directly from the leaves, soil, or snow). Seepage through fractures in the bedrock, by leaks under the streamgage, or laterally through the soil into adjacent watersheds may occur but are thought to be negligible,

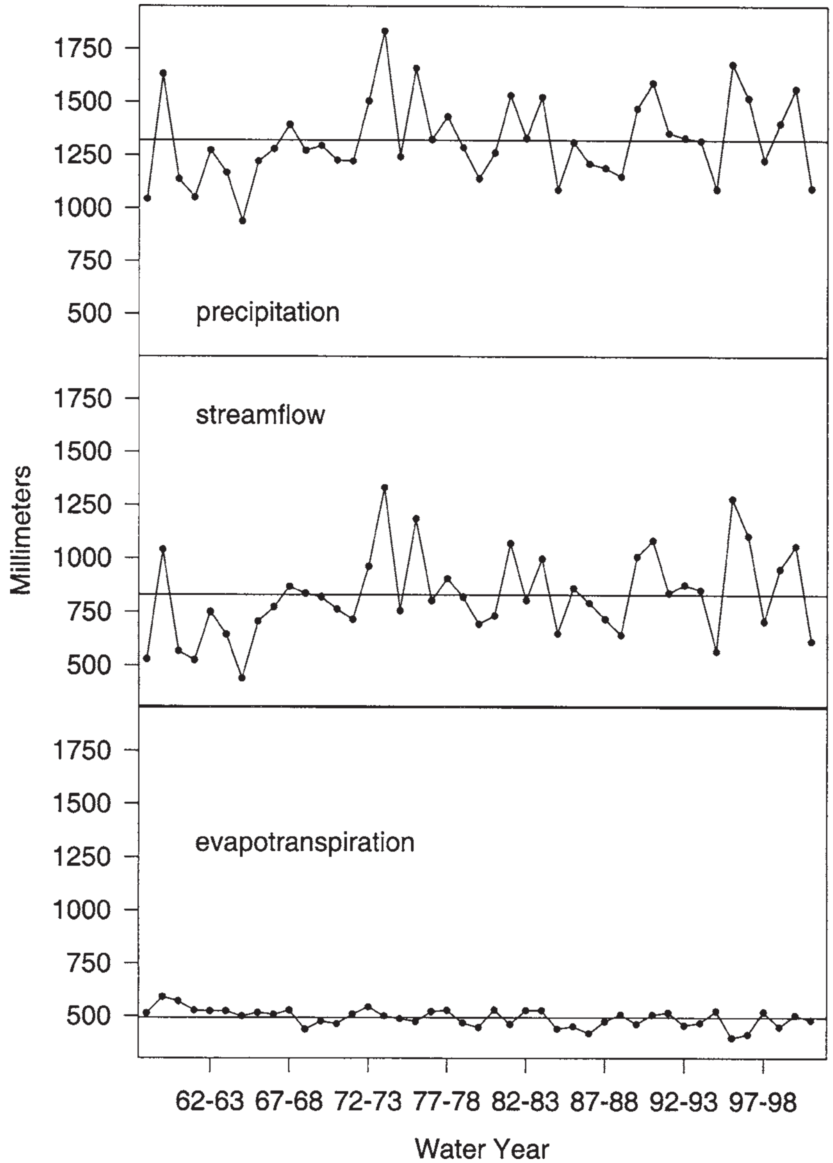

Figure 10.—Total annual precipitation, streamflow, and evapotranspiration at Watershed 3 for the water year beginning June 1 (1958-2000). Evapotranspiration is precipitation minus streamflow (Table 13). The mean on each graph is calculated with 43 years of data.

an important assumption in much of the research at HBEF. The streamgages are anchored to bedrock and maintained carefully to eliminate leaks. The watershed area surveyed using the topographic divide between the watersheds is assumed to be the same as the bedrock divide. Geologic surveys, behavior of bedrock wells near HQ, and annual precipitation minus streamflow suggest only a small amount of water is gained or lost by seepage. Soil water is fully recharged around May 31 of each year after snowmelt; little change in storage is thought to occur from one year to the next.

The period from June 1 to May 31 is a "water year." Analysis of hydrologic data by water year is useful when the effect of change in water storage should be minimized. Annual geochemical inputs and outputs that have been published for HBEF use the June 1 water year. Annual precipitation, streamflow, and evapotranspiration for Watershed 3 using a June 1 water year are shown in Table 13.

Variation in precipitation minus streamflow among water years is small compared to variation in precipitation or streamflow (Fig. 10). At HBEF, this estimate of evapotranspiration usually ranges from 450 to 600 mm. Differences in evapotranspiration among years occur because evaporation of intercepted water in

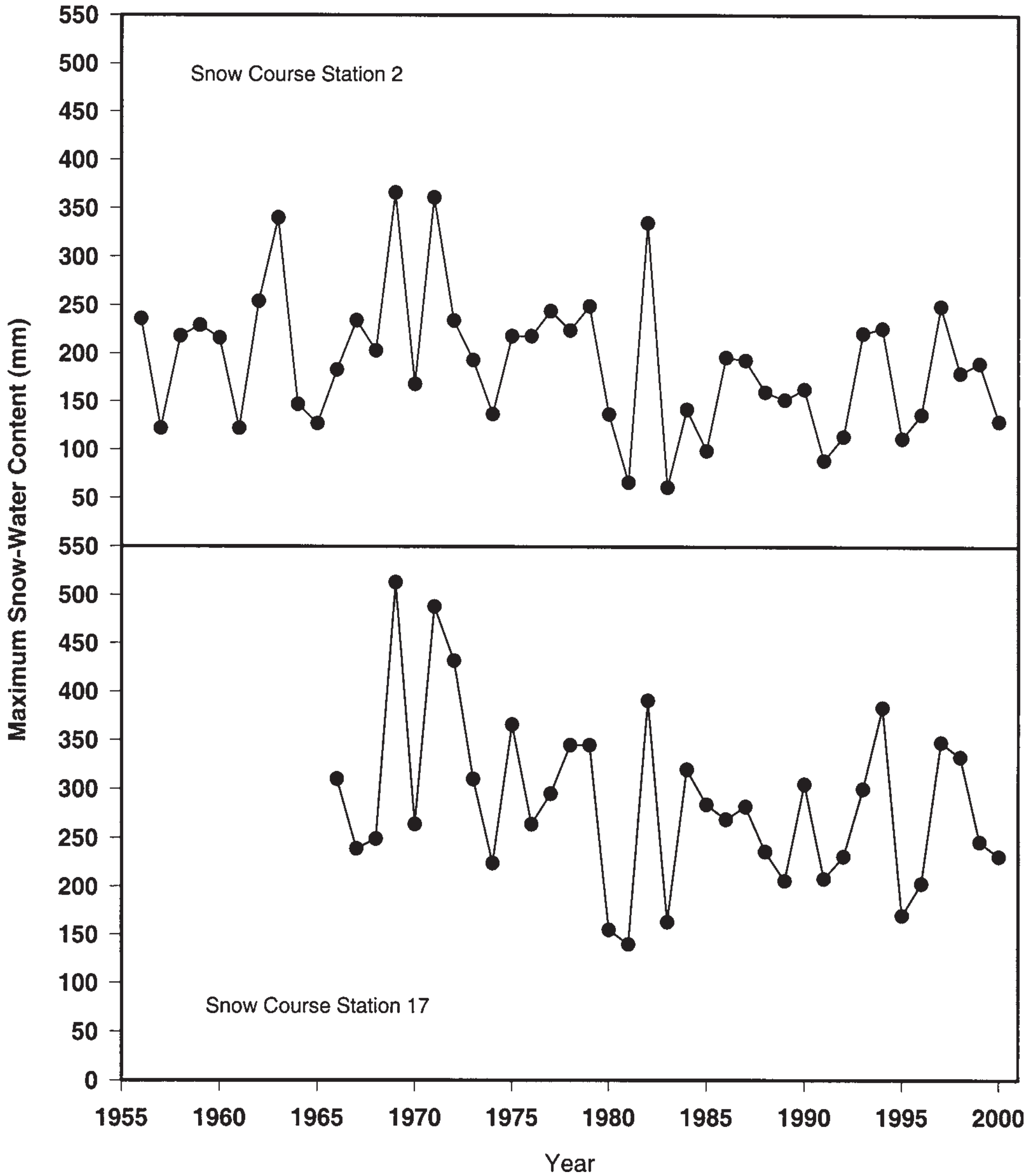

Figure 11.—Maximum water content of snowpack at snow course Stations 2 and 17.

the canopy is greater with higher precipitation, and because dry summers result in lower transpiration.

Following harvest treatments, evapotranspiration decreases for several years because the cover of regenerating vegetation is incomplete (see values marked with T in Table 14). However, only several years of regrowth are sufficient to restore the preharvest rate of evapotranspiration.

Snow and Frost

At HBEF, snow depth and water content has been measured continuously under the forest canopy near selected raingage stations. Each "snow course" consists of an area of approximately 0.25 ha and is designated by the nearby gage number. On each weekly measurement date, 10 points are sampled for depth and water content at intervals of 2 m along a line. On the next date, a parallel line, 2 m from the previous line, is used. Values for snow depth and water content from the 10 points are averaged. The number of snow courses used in any year has varied, first as new locations were added, then as the network was reduced to eliminate sites with similar values. On the south-facing side, only Station 2 has a continuous record, and on the north-facing side, only Station 17. Snow-water contents measured at these two locations are shown in Figure 11. Maximum snow water

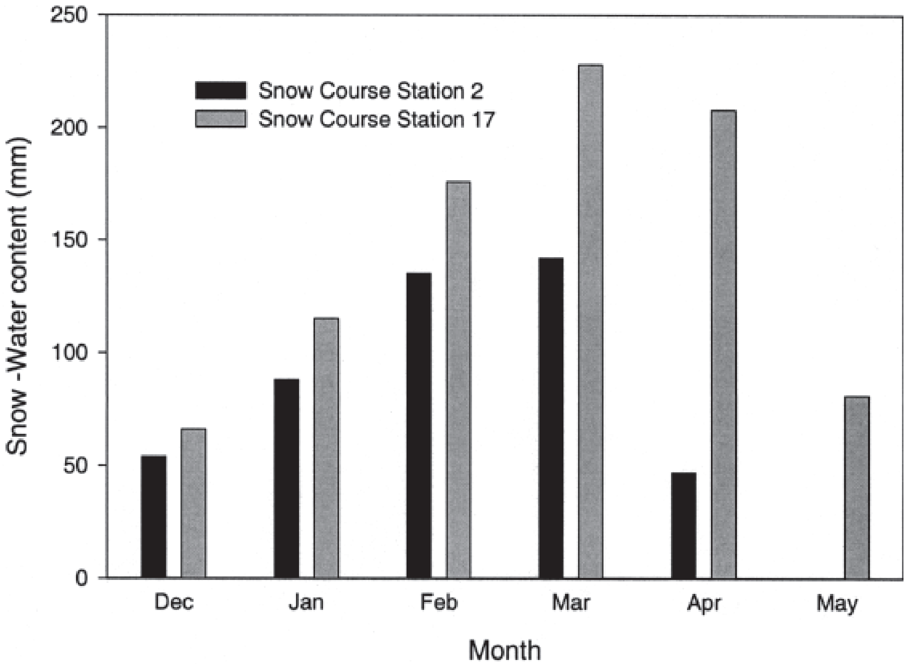

Figure 12.—Average snow-water content (1965-2000) by month for snow course Stations 2 and 17.

content varies from year to year but averages about 200 mm at snow course 2 and 300 mm at snow course 17. Station 2 has an elevation of 560 m and reflects low- to mid-elevation hardwood forests on south-facing slopes at HBEF. Station 17 has an elevation of 893 m and reflects a mixed hardwood-conifer forest at high elevation on the north-facing slope. The earliest HBEF publications summarize snow-course data and address snow conditions at HBEF (Sartz and Trimble 1956).

Snow generally accumulates more and lasts weeks longer at Station 17 than at Station 2 (Fig. 12) due to its aspect and topographic position. This causes the delay in snowmelt streamflow on the north-facing watersheds.

The five lowest snow years on the south-facing side and the corresponding maximum water content of the snowpack were 1983 (61 mm), 1981 (66 mm), 1991 (89 mm), 1985 (99 mm), and 1995 (112 mm). The five deepest snow years on the south-facing side and corresponding highest water contents were 1962 (254 mm), 1982 (335 mm), 1963 (340 mm), 1971 (361 mm), and 1969 (366 mm). At Station 17, peak water contents usually are 100 to 200 mm higher than at Station 2 (Fig. 11).

The density of "ripe" or melting snow at HBEF is about 0.35, so maximum depths are at least 3 times the maximum water content. Thus, depths reach 0.3 to 1 m on the south-facing side and approach 1.5 m at high elevation on the north-facing side.

Soil frost is measured at each snow course. The ground is probed with a ski pole to detect the presence or absence of frost at 2 points adjacent to each of the 10 snow sample points. At the first 2 points for which frost is detected, the soil is excavated and frost thickness is measured.

For many years during the late 1950's and early 1960's, frost was seldom detected (Table 15). It was not measured in the late 1960's. Since 1970, frost has been present in February at south-facing Station 2 about 1 year in 3 (Table 15). At Station 17, frost was detected at some points every February until the late 1990's. In heavy frost years, all points can have frost, with thickness exceeding 10 cm. The greatest frost depth usually occurs during winters of thin and late snow cover.

Frost develops in December in the absence of snow cover and can thicken if snow is thin in January. Once an insulating snow blanket is present, frost begins to melt from below because the soil is warmer at greater depths. A light, early frost may disappear in January or February as the snowpack thickens. Heavy frost persists until spring when melting occurs from above.

In 1994, a snow course was established near HQ at an elevation of 252 m. Early soil frost has been present there every year to date due to cold air inversions that occur at lower elevations. These inversions result in air temperatures that are well below freezing in the late fall and early winter before the onset of an insulating snowpack.

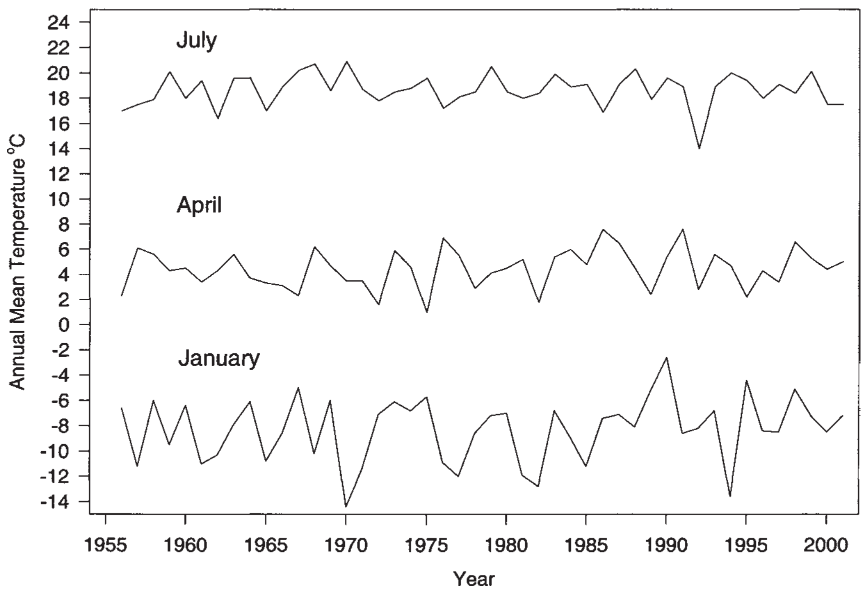

Figure 13.—Annual mean temperatures for Station 1 (1956-2000) for July, April, and January.

Air Temperature

Air temperature has been measured by hygrothermographs at seven locations at HBEF. The temperature sensor is a liquid-filled Bourdon tube that bends as the air temperature changes, mechanically driving a pen across a clock-driven chart. The maximum and minimum temperatures for each day (midnight to midnight) are read from the charts. The mean temperature for the day is calculated by averaging the maximum and minimum values. The hygrothermographs are housed in standard shelters (Stevenson screens) near the middle of openings at weather stations HQ, 1, 6, 14, 17, 23, and 24.

Maximum daily temperature at Station 1 averages –3.8°C in January and 23.8°C in July (Table 16). Minimum daily temperature averages –12.9°C in January and 13.5°C in July (Table 17). Mean daily temperature averages -8.3°C in January and 18.7°C in July (Table 18). The average annual temperature at Station 1 was 5.6°C from 1956 to 2000, 6.4°C at HQ from 1957 to 2000, and 4.1°C at Station 14 from 1958 to 2000. The record high temperature at HBEF, 37°C, was recorded at HQ on June 18, 1994. The record low, –37°C, occurred at Station 14 on January 15, 1965.

Daily variation of air temperature is considerable at HBEF. The range in maximum, minimum, and mean daily temperatures is approximately 35°C in winter and 15 to 20°C in summer. Variation among years in average monthly, maximum, minimum, or mean temperature is greater in the winter than in summer and exceeds 10°C (Tables 16-18). Monthly minimum temperatures vary more from year to year than monthly maximums (Tables 16, 17).

Long-term average monthly temperatures generally decrease with increasing elevation, from HQ at 252 m, to Station 17 at 905 m (Table 19). Only for minimum temperatures in summer does cooling with elevation fail to hold. Nighttime cooling causes the heavier, colder air to move downslope. This creates a valley temperature inversion that includes HQ. From May through September, the minimum temperature average at HQ is lower than at Station 1.

The growing season is defined as the period between the last frost in spring and the first frost in autumn. If we use a minimum temperature of 0°C at Station 1, the growing season on average begins May 11 and ends October 3 (146 days long). If –1°C is used as the criterion, the growing season increases by several days. Compared to Station 1, the average growing season is 9 days shorter at HQ and 7 days shorter at Stations 6 and 14. The shorter growing season at HQ compared to Station 1 is caused by the valley temperature inversion.

An increasing trend in air temperature at Station 1 from year to year is not apparent for the period 1956 to 2000 (Fig. 13). Annual mean air temperature for January, April, and July varies considerably from year to year but the averages do not show a trend upward or downward.

Solar Radiation

Solar radiation has been measured at HQ since 1958. Before 1981, several bimetal recording pyranographs

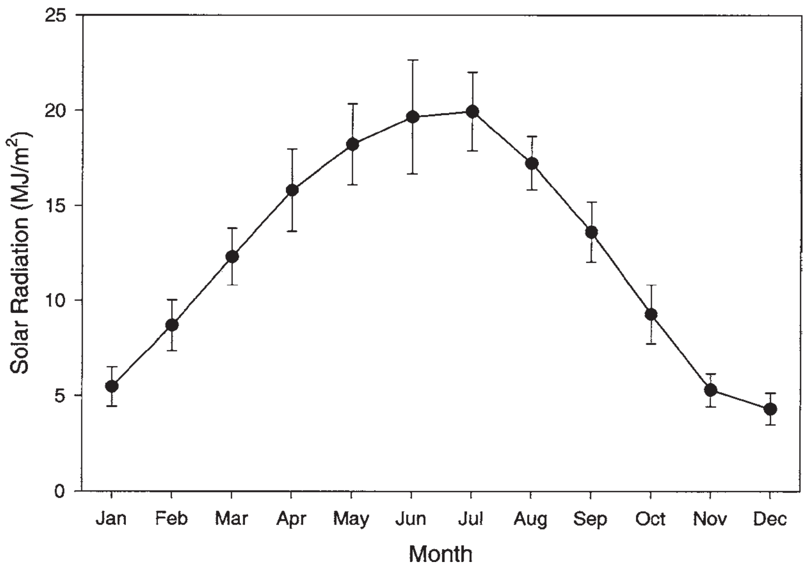

Figure 14.—Mean monthly solar radiation at Headquarters (1958-2000). Vertical bars show the standard error.

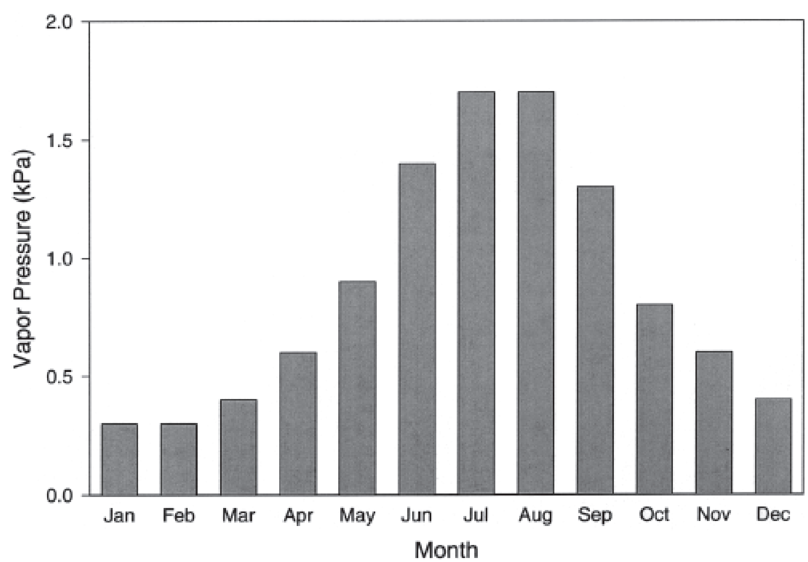

Figure 15.—Average vapor pressure by month at Headquarters (1966-2000).

(actinometers) were used. Since that time, a Li-Cor solar cell sensor has provided hourly data on solar radiation. A pyranograph operates as a backup and provides comparable data.

Solar radiation averages about 5 megajoules per square meter (MJ/m^2) in the early winter months and 20 MJ/m^2 in the early summer months (Fig. 14). On a clear day in June, solar radiation can exceed 30 MJ/m^2; it is typically about 10 MJ/m^2 in winter. On cloudy and overcast days, solar radiation is generally 1 to 2 MJ/m^2.

Solar radiation varies among years for a given month with most variability occurring during the summer (Table 20). The highest annual solar radiation (5,219 MJ/m^2) was recorded in 1997; the lowest on record (3,765 MJ/m^2) was recorded in 2000.

Humidity

The humidity of the air is an important meteorological variable but also one that is difficult to measure. It can be expressed in several meaningful ways. The amount of water vapor in the air is reported here as vapor pressure (kPa). Vapor pressure does not vary with temperature, so it changes little over one day and only as the amount of water vapor in the air changes.

Hygrothermographs at HBEF weather stations measure both humidity and air temperature. Since 1981, solid-state humidity sensors have been part of the automatic HQ weather station and have recorded humidity on an hourly basis. The average monthly vapor pressure at HBEF is obtained by combining data from hygrothermographs during the 1960's and 1970's with data from the sensor installed in 1981 (Figure 15).

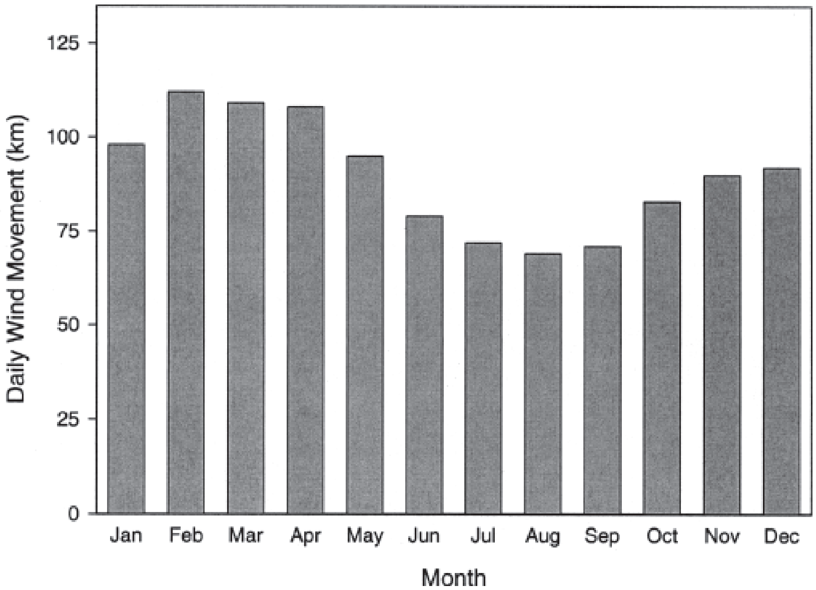

Figure 16.—Average daily wind movement at Headquarters by month (1966-2000 with some gaps).

Wind

Windspeed and direction have been measured at HQ since 1965 by an anemometer mounted 3 m above the ground. The HQ anemometer is in a sheltered location with surrounding trees, a nearby building, and moderate topographic relief. Until 1981, every mile of wind movement caused a tick mark on a strip-chart recorder, and wind direction, as N, S, E, W, or a combination, was recorded continuously. Only a portion of these data have been analyzed. Since 1981 windspeed and direction have been measured at the automatic weather station at HQ. This record has both short and long gaps due to equipment failures and related poblems.

Monthly average daily wind movement calculated from a patchy database from 1966 to 1981 and a continuous database from 1982 to 2000 is shown in Figure 16. Dividing these values by 24 gives the average speed in km/hr. This value is somewhat misleading because windspeeds usually are considerably greater during the day than at night. A more accurate daytime speed is obtained by dividing by 12.

February is the windiest month, averaging 112 km/d, or about 3m/s during the daytime. August is the calmest month, averaging 69 km/d. At HBEF, windspeed 3 m above the ground at HQ probably is lower than that at 3 m above the forest canopy.

The data on wind direction at HBEF are continuous from 1982 to the present. Data from earlier years are available on strip charts but have been analyzed only for short periods. November through April is the windiest period of the year as winds from the north and northwest winds are dominant. From May through October, west winds become somewhat more prevalent than north winds. South winds occur fairly frequently but usually are light. East winds are infrequent.

Soil Temperature

Soil temperature has been measured at several locations at HBEF. Weekly values from a location 300 m southwest of the streamgage for Watershed 4 are available from 1959 to 1998. The soil at this location is Berkshire fine sandy loam, which is a coarse loamy, mixed, frigid Typic Haplorthod. Soil temperature is measured at depths of 3, 8, 15, 30, 61, and 91 cm below the litter layer (Oi horizon) using thermistor Colman fiberglass soil-moisture sensors. These sensors are stable and accurate to +/-1^{o}C.

Variation in soil temperature by day of the year is shown for depths of 8 cm (Fig. 17) and 61 cm (Fig. 18). Near the soil surface in winter, soil temperatures are below freezing only when the soil freezes. Soil frost generally occurs during winters when snow cover is thin or late in developing. Warming at 8 cm is rapid in April after snowmelt because the sun is high and leaves are not fully developed. Soil temperatures reach a maximum in late July and August. Average maximum soil temperatures, about 16^{o}C at a depth of 8 cm, are slightly lower than the average daily mean air temperature (about 18 ^{o}C). Soil temperature varies much less at a depth 61 cm. At

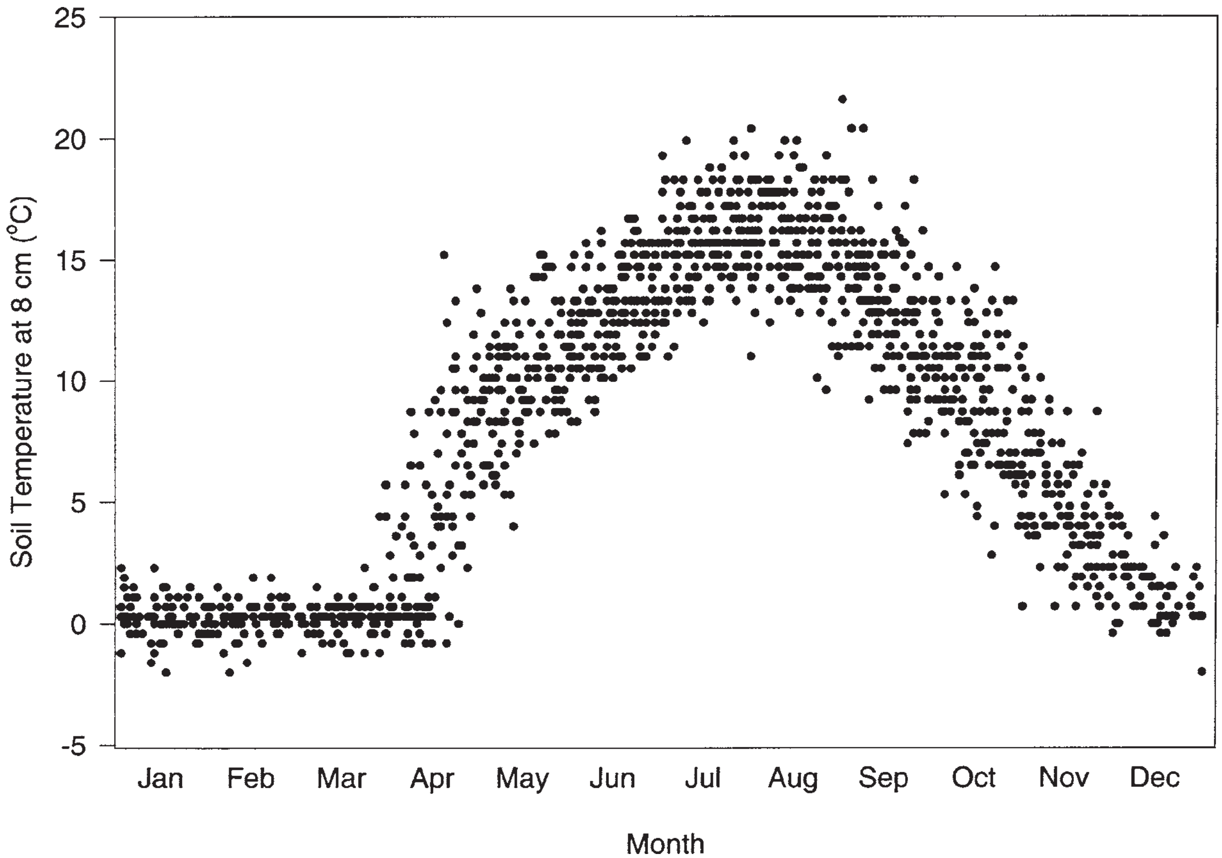

Figure 17.—Soil Temperature at depth of 8 cm by day of year (1959-98).

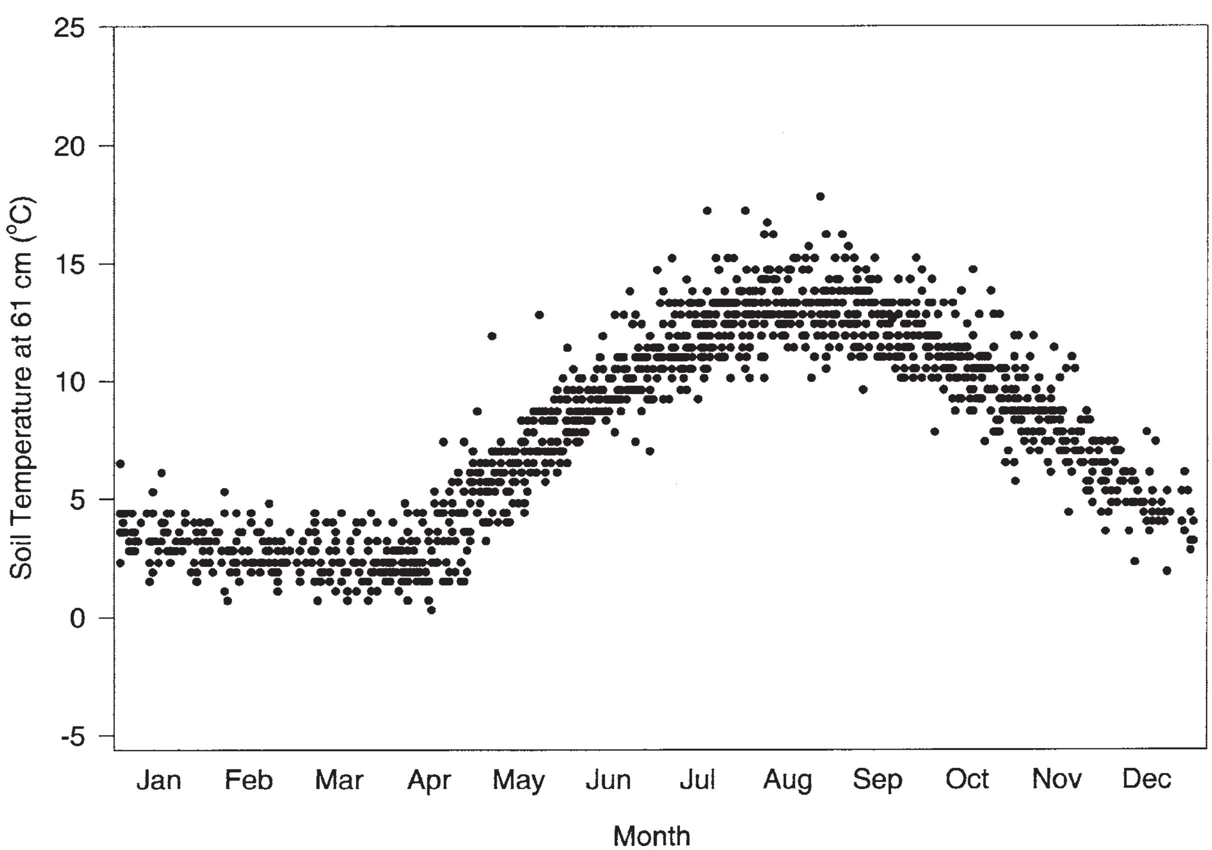

Figure 18.—Soil Temperature at depth of 61 cm by day of year (1959-98).

greater depths, the soil warms more slowly and reaches a summer maximum of 13°C at 61 cm. Around mid-April and in early October, the soil is isothermal, that is, the temperature is the same at all depths. In autumn, cooling is slower at greater depths.

Conclusion

Commitment to long-term hydrometeorlogic data collection at the HBEF by the Northeastern Research Station has resulted in a unique resource. These long-term data are used by scientists, resource managers, and students interested in understanding and explaining changes in the environment. Significant effort is expended in maintaining the integrity of ongoing data collection and accommodating new technology. It is this outstanding effort that has made Hubbard Brook a valued and dependable contributor to the knowledge base required to explain ecosystem processes.

Acknowledgment

Ian Halm, Ralph Perron, Don Buso, Vinnie Levasseur, and Don Mower assisted tirelessly in data collection in all weather conditions. The ideas and commitment they bring to the job improve data collection techniques and make gathering data in mountainous conditions at all times of the year more manageable. Bob Smith reworked antiquated computer programs to accommodate the new millennium and changes in methods and technology. Without his programming, the processing and organization of 45 years of hydrometeorological data would be an insurmountable task.

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Appendix

Table 2.—Monthly precipitation (mm) for Watershed 3 reported as total weighted average of daily precipitation for several standard gages each month; the weighting factor for each gage is the fraction of watershed area nearest that gage; the average and standard deviation are estimated from 45 years of data; annual total is monthly sum

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
56	71	98	145	107	142	94	228	112	173	62	94	127	1453
57	71	64	48	61	87	143	137	19	78	110	179	221	1218
58	202	82	56	115	104	60	125	57	113	98	96	54	1161
59	137	91	80	80	52	113	71	142	64	304	220	125	1479
60	114	125	97	121	133	93	180	28	142	130	89	73	1325
61	32	99	63	124	85	99	86	54	49	56	113	119	979
62	89	108	65	112	100	53	86	98	93	253	79	95	1230
63	99	79	117	144	77	65	74	150	39	31	205	71	1151
64	121	43	144	114	110	60	118	150	37	50	114	115	1175
65	61	100	28	82	24	108	91	89	195	124	147	72	1121
66	63	60	115	66	91	106	97	194	116	83	134	100	1224
67	57	99	53	132	108	79	112	137	135	121	113	150	1297
68	73	62	97	113	202	162	62	57	67	75	128	188	1285
69	72	179	83	88	110	90	187	152	45	63	139	194	1403
70	26	99	106	99	93	96	62	155	139	100	91	135	1201
71	73	119	95	50	110	68	143	114	77	103	101	120	1173
72	69	81	169	88	88	120	158	159	49	95	165	182	1424
73	128	88	93	102	164	354	85	115	149	94	133	287	1793
74	115	88	123	129	162	123	102	130	167	47	118	108	1410
75	117	81	143	69	38	167	181	95	167	143	134	114	1449
76	146	123	110	91	187	113	107	136	133	204	61	105	1516
77	77	74	166	109	39	123	70	99	198	195	99	140	1388
78	230	27	71	76	104	142	52	88	35	93	63	105	1086
79	226	56	142	129	155	52	72	131	124	147	118	80	1433
80	54	38	136	129	58	77	88	85	132	112	126	67	1101
81	24	259	43	120	128	167	234	139	150	197	65	139	1665
82	119	74	112	106	29	157	70	70	110	51	146	71	1114
83	123	84	139	118	190	33	75	150	46	97	204	195	1452
84	53	118	121	130	302	176	139	31	38	79	118	98	1404
85	60	88	92	64	104	118	54	84	146	114	131	83	1137
86	207	75	125	61	114	85	140	168	98	63	133	105	1373
87	90	11	164	72	81	194	77	109	154	106	115	61	1235
88	62	81	48	99	85	70	110	133	71	55	131	65	1010
89	72	69	87	93	192	148	76	136	131	188	161	65	1419
90	147	87	72	98	160	205	77	311	114	191	100	168	1729
91	83	49	114	90	89	49	108	265	112	159	89	112	1319
92	89	99	119	90	61	76	159	161	128	76	162	58	1280
93	98	82	140	119	71	86	116	114	127	99	146	90	1288
94	140	46	143	111	100	109	129	95	131	31	85	77	1195
95	115	87	77	62	94	48	167	144	92	236	154	100	1374
96	212	109	53	245	120	169	226	22	80	159	122	209	1724
97	129	86	146	63	109	78	169	110	71	42	165	74	1242
98	170	74	118	62	93	309	110	93	83	121	108	61	1401
99	178	50	130	21	135	83	105	109	321	79	105	57	1373
00	109	112	112	224	146	92	94	106	92	80	102	143	1411
Avg.	107	87	104	102	112	116	116	118	111	114	124	115	1325
SD	53	40	36	40	53	64	45	55	55	62	36	50	185

Table 3.—Monthly precipitation (mm) for Watershed 6 reported as total weighted average of daily precipitation for several standard gages each month; the weighting factor for each gage is the fraction of watershed area nearest that gage; average and standard deviation are estimated from 37 years of data; annual total is monthly sum

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
64	117	50	147	110	115	59	126	154	39	54	120	117	1207
65	66	103	29	83	26	115	99	84	193	127	153	78	1157
66	72	67	129	70	94	118	100	200	118	87	154	108	1314
67	63	111	57	149	117	82	116	134	142	125	118	160	1374
68	77	69	103	126	219	160	55	53	77	80	138	212	1369
69	84	182	102	104	103	93	203	147	48	64	156	206	1491
70	27	102	119	103	93	100	66	162	140	106	97	149	1263
71	89	136	107	57	120	70	151	123	75	109	114	119	1270
72	77	83	180	93	87	129	158	167	48	94	176	201	1493
73	121	75	97	118	181	373	87	115	142	99	129	287	1824
74	115	94	136	145	166	121	111	138	172	48	118	111	1475
75	121	93	168	68	39	171	182	96	174	143	158	126	1540
76	161	145	124	93	196	113	110	145	138	206	77	114	1622
77	91	86	168	117	37	133	73	96	198	193	124	153	1470
78	250	32	83	85	113	148	53	96	36	95	70	115	1176
79	232	61	140	153	162	47	82	132	128	163	128	79	1506
80	53	41	147	135	58	81	92	92	136	124	130	77	1166
81	26	298	44	122	135	150	234	151	160	197	72	149	1736
82	135	78	118	112	32	163	77	72	114	52	150	72	1174
83	134	95	153	128	199	34	77	155	47	98	217	221	1558
84	60	130	135	149	314	179	143	37	39	88	120	122	1515
85	74	93	125	74	106	129	57	90	156	116	145	93	1258
86	224	83	135	64	133	89	151	176	97	65	142	119	1479
87	108	14	178	81	92	204	75	114	166	113	123	72	1338
88	68	94	53	108	101	68	115	147	75	58	153	67	1107
89	75	71	90	107	209	161	72	137	130	198	167	75	1492
90	159	98	86	106	164	202	79	329	117	198	107	174	1819
91	95	54	122	100	92	52	110	285	117	160	90	122	1399
92	95	107	126	98	62	75	162	149	138	75	167	61	1313
93	107	95	143	133	68	94	121	127	134	101	151	104	1377
94	149	51	156	118	99	107	128	101	139	30	94	91	1263
95	126	91	85	66	97	46	171	151	94	268	179	110	1484
96	223	121	59	264	122	174	242	21	80	163	136	220	1824
97	137	92	160	71	114	80	174	121	74	46	178	83	1328
98	178	73	122	67	95	325	108	103	88	123	132	62	1475
99	193	59	149	23	143	79	121	114	357	83	116	59	1495
00	115	114	114	239	157	92	103	115	102	79	111	159	1500
Avg.	116	93	119	109	121	125	118	130	120	114	133	126	1423
SD	56	47	38	45	59	71	48	57	60	54	32	54	187

Table 4.—Monthly precipitation (mm) for Watershed 7 reported as total weighted average of daily precipitation for several standard gages each month; the weighting factor for each gage is the fraction of watershed area nearest that gage; average and standard deviation are estimated from 36 years of data; annual total is monthly sum

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
65	70	108	33	82	23	122	94	79	178	136	145	72	1142
66	89	68	127	68	105	107	89	170	122	86	159	107	1294
67	52	96	56	136	124	104	117	136	141	121	116	147	1347
68	69	65	107	117	172	170	33	44	99	77	148	200	1298
69	86	192	100	103	110	100	201	154	43	63	190	226	1568
70	28	114	118	108	93	98	66	141	137	108	92	147	1250
71	90	142	115	56	119	55	155	120	81	112	113	125	1284
72	67	97	179	95	98	127	152	154	46	98	191	197	1501
73	113	73	100	139	202	347	80	111	139	102	117	290	1815
74	116	98	138	145	174	124	135	145	175	48	125	114	1535
75	123	96	158	74	55	159	192	95	176	143	146	123	1541
76	156	130	120	96	202	109	118	168	133	217	73	103	1625
77	98	85	165	115	36	140	63	96	206	200	128	156	1488
78	249	29	84	93	122	154	69	85	34	99	69	106	1194
79	232	58	136	153	173	39	76	134	124	165	124	76	1490
80	52	37	161	158	64	94	81	108	147	133	128	74	1235
81	23	314	41	127	148	169	230	149	172	190	74	124	1763
82	147	78	119	102	36	165	71	83	112	52	139	71	1176
83	130	98	167	147	196	40	71	185	51	93	236	207	1620
84	64	125	129	165	316	185	146	34	42	80	136	132	1554
85	60	87	135	74	104	115	62	87	177	120	161	93	1275
86	232	78	139	63	108	94	155	213	94	62	160	136	1533
87	114	13	165	85	97	218	83	98	170	124	127	82	1375
88	70	104	55	137	113	59	113	164	69	60	177	62	1182
89	77	80	91	98	210	188	66	141	134	206	178	64	1532
90	165	96	82	119	176	210	56	322	120	191	101	195	1831
91	95	52	122	113	97	51	110	269	122	152	86	111	1381
92	94	99	123	94	65	72	194	140	145	67	156	65	1312
93	107	110	138	144	71	88	121	147	124	110	150	103	1412
94	160	50	164	110	109	121	143	97	154	31	99	111	1349
95	135	92	86	66	99	47	147	170	91	281	188	113	1514
96	208	113	65	267	140	167	262	17	74	204	138	220	1873
97	148	81	159	69	119	80	204	149	79	51	190	89	1418
98	168	72	139	59	102	319	155	110	85	126	139	72	1545
99	202	73	165	22	138	72	130	84	312	85	126	69	1478
00	118	97	116	244	138	87	117	109	93	81	113	150	1463
Avg.	117	94	119	112	124	128	121	131	122	119	137	126	1450
SD	57	52	36	41	58	63	56	60	45	59	39	55	188

Table 5.—Annual precipitation (mm) by watershed. Data are from annual total column in Tables 2, 3, and 4 and are similarly calculated for other watersheds

	Watershed								
Year	1	2	3	4	5	6	7	8	9
1956	1453	-	-	-	-	-	-	-	-
1957	1218	1220	-	-	-	-	-	-	-
1958	1155	1167	1161	-	-	-	-	-	-
1959	1472	1483	1479	-	-	-	-	-	-
1960	1316	1321	1325	1327	-	-	-	-	-
1961	968	979	979	975	-	-	-	-	-
1962	1221	1232	1230	1234	-	-	-	-	-
1963	1134	1139	1151	1153	-	-	-	-	-
1964	1178	1175	1175	1180	1187	1207	-	-	-
1965	1123	1115	1121	1137	1147	1157	1142	-	-
1966	1229	1222	1224	1261	1284	1314	1294	-	-
1967	1320	1315	1297	1351	1357	1374	1347	-	-
1968	1270	1269	1285	1302	1334	1369	1298	-	-
1969	1374	1368	1403	1412	1443	1491	1568	1549	-
1970	1193	1185	1201	1216	1231	1263	1250	1255	-
1971	1172	1164	1173	1208	1228	1270	1284	1275	-
1972	1436	1431	1424	1412	1439	1493	1501	1495	-
1973	1806	1804	1793	1780	1785	1824	1815	1824	-
1974	1413	1407	1410	1428	1437	1475	1535	1546	-
1975	1433	1422	1449	1411	1432	1540	1541	1549	-
1976	1518	1512	1516	1528	1534	1622	1625	1626	-
1977	1389	1382	1388	1394	1404	1470	1488	1495	-
1978	1093	1088	1086	1114	1124	1176	1194	1181	-
1979	1425	1417	1433	1460	1462	1506	1490	1497	-
1980	1094	1088	1101	1118	1123	1166	1235	1218	-
1981	1641	1632	1665	1703	1702	1736	1763	1766	-
1982	1100	1089	1114	1151	1149	1174	1176	1185	-
1983	1447	1437	1452	1513	1522	1558	1620	1621	-
1984	1405	1397	1404	1467	1480	1516	1554	1558	-
1985	1137	1128	1137	1203	1217	1258	1275	1283	-
1986	1375	1364	1373	1446	1450	1479	1533	1516	-
1987	1228	1223	1235	1284	1298	1338	1375	1378	-
1988	1008	1004	1010	1060	1073	1107	1182	1158	-
1989	1421	1411	1419	1464	1464	1492	1532	1528	-
1990	1728	1719	1729	1787	1796	1819	1831	1853	-
1991	1329	1324	1319	1375	1383	1399	1381	1388	-
1992	1260	1255	1280	1308	1310	1313	1312	1325	-
1993	1292	1290	1288	1348	1365	1377	1412	1402	-
1994	1188	1184	1195	1239	1246	1263	1350	1339	-
1995	1376	1364	1374	1453	1469	1484	1514	1505	1527
1996	1721	1705	1724	1810	1814	1824	1873	1857	1884
1997	1238	1227	1242	1305	1313	1328	1418	1414	1409
1998	1402	1398	1401	1448	1459	1475	1545	1551	1584
1999	1382	1375	1373	1447	1467	1496	1478	1487	1511
2000	1415	1411	1411	1464	1475	1500	1463	1452	1466
Avg.	1322	1315	1324	1358	1389	1423	1450	1471	1564
SD	184	183	186	192	185	187	183	189	168
n	45	44	43	41	37	37	36	35	6

Table 6.—The 20 largest precipitation events for Watershed 3, 1958-2000; storm periods are consecutive days with precipitation; total precipitation during a storm period is recorded for each event

Event	Millimeters
Jun 27 - Jul 1, 1973	211.6
Oct 23 - Oct 26, 1959	184.9
Oct 5 - Oct 10, 1962	182.9
Jan 16 - Jan 20, 1996	174.3
Aug 6 - Aug 8, 1990	171.2
May 28 - Jun 2, 1984	162.1
Jul 26 - Aug 2, 1969	151.1
Jul 9 - Jul 15, 1975	140.4
Jan 25 - Jan 28, 1986	132.2
Jul 12 - Jul 16, 1996	125.4
Mar 30 - Apr 6, 1960	125.0
Sep 8 - Sep 13, 1987	116.8
Mar 30 - Apr 1, 1987	111.9
Nov 5 - Nov 17, 1985	110.4
May 23 - May 30, 1979	110.2
Aug 19 - Aug 22, 1991	105.3
Feb 24 - Feb 26, 1969	102.6
Oct 20 - Oct 24, 1996	100.4
Jul 3 - Jul 15, 1992	99.0

Table 7.—Monthly streamflow (mm) for Watershed 3; streamflow reported in mm to make it comparable among watersheds of different areas; streamflow rate is divided by watershed area to give units of depth per unit time over entire watershed area; average and standard deviation are estimated from 43 years of data; annual total is monthly sum

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1958	38	18	40	291	89	25	7	1	3	13	28	15	567
1959	48	19	44	295	30	15	4	3	7	176	198	78	918
1960	48	48	64	310	88	18	19	3	5	64	61	24	752
1961	9	42	66	188	66	24	7	1	1	1	10	20	436
1962	32	10	64	268	85	4	1	2	2	110	85	36	699
1963	12	9	65	321	103	6	1	3	1	1	82	58	663
1964	56	19	92	253	71	3	6	10	1	4	43	71	630
1965	24	28	37	178	33	13	2	1	35	80	88	27	547
1966	39	22	117	180	101	34	4	20	19	47	120	54	757
1967	23	15	45	272	119	19	8	11	27	96	71	75	781
1968	17	36	184	199	124	103	18	1	2	3	24	53	763
1969	23	18	33	435	121	17	51	50	6	15	116	114	999
1970	23	71	25	256	75	6	7	10	33	83	70	39	698
1971	20	31	33	271	159	10	6	11	14	48	20	52	676
1972	32	22	93	200	206	43	56	40	6	26	99	62	886
1973	101	84	209	112	122	245	72	8	34	41	103	266	1396
1974	46	37	100	239	140	49	17	10	51	38	82	79	890
1975	25	21	118	201	62	94	53	4	56	138	118	49	940
1976	62	83	184	186	159	13	11	35	29	151	64	45	1022
1977	12	9	258	149	24	20	3	3	42	187	63	73	844
1978	149	20	24	219	100	77	1	1	1	3	6	11	614
1979	76	20	305	201	116	18	4	4	20	98	111	64	1036
1980	30	4	64	217	60	11	2	2	5	33	70	51	548
1981	8	277	57	113	103	69	94	80	43	164	56	30	1094
1982	37	32	60	363	43	38	7	2	4	10	84	77	756
1983	82	67	121	151	162	35	1	3	1	6	102	160	889
1984	16	115	64	259	235	95	65	1	1	3	38	78	971
1985	23	68	98	112	67	21	3	1	17	75	100	44	628
1986	175	24	180	145	75	19	19	77	37	52	90	66	961
1987	20	11	248	102	49	95	21	7	46	64	79	54	797
1988	19	29	78	161	63	7	7	7	11	11	87	23	502
1989	12	17	94	201	166	79	6	13	19	146	137	19	909
1990	69	66	190	132	129	93	30	183	14	156	89	149	1302
1991	32	26	129	130	52	6	4	71	19	137	64	74	743
1992	73	16	118	196	60	19	25	45	64	53	160	41	870
1993	42	15	121	259	31	26	5	9	19	47	144	82	801
1994	23	27	52	334	82	17	9	11	20	16	35	87	714
1995	111	16	118	61	64	16	14	61	4	152	159	21	797
1996	234	106	82	277	155	65	126	6	2	42	129	191	1414
1997	31	39	70	283	122	16	43	4	5	9	70	21	713
1998	95	48	232	104	58	204	40	8	13	55	77	48	981
1999	96	38	169	120	82	12	8	7	154	75	100	47	910
2000	39	35	200	257	123	22	6	16	16	27	66	127	932
Avg.	51	41	110	214	97	42	21	20	21	64	84	66	831
SD	46	45	70	79	47	50	27	33	27	56	41	49	213

Table 8.—Annual streamflow (mm) by watershed; average and standard deviation calculated using number of years available for each watershed; T = treated watersheds

	Watershed								
Year	1	2	3	4	5	6	7	8	9
1956	942	-	-	-	-	-	-	-	-
1957	732	-	-	-	-	-	-	-	-
1958	590	645	567	-	-	-	-	-	-
1959	947	1012	918	-	-	-	-	-	-
1960	761	825	752	195	-	-	-	-	-
1961	458	470	436	495	-	-	-	-	-
1962	697	777	699	710	740	-	-	-	-
1963	652	774	663	713	686	775	-	-	-
1964	653	712	630	713	683	704	-	-	-
1965	520	599T	547	583	624	581	504	-	-
1966	746	1189T	757	826	826	845	851	-	-
1967	758	1132T	781	839	815	834	816	-	-
1968	771	1057T	763	823	832	835	790	-	-
1969	1046	1348T	999	1099	975	1070	1174	1106	-
1970	661	905T	698	727T	669	735	741	704	-
1971	641	801T	676	765T	659	718	780	737	-
1972	877	1006T	886	990T	903	948	995	936	-
1973	1403	1586T	1396	1589T	1428	1470	1408	1419	-
1974	887	998T	890	1021T	928	951	1004	993	-
1975	934	1086T	940	1085T	944	963	991	983	-
1976	1067	1143T	1022	1158T	1069	1074	1116	1110	-
1977	895	966T	844	971T	863	878	957	895	-
1978	650	722T	614	717T	635	683	757	701	-
1979	1052	1136T	1036	1085T	1035	1070	1088	1075	-
1980	560	585T	548	575T	554	578	693	655	-
1981	1098	1129T	1094	1117T	1059	1078	1208	1164	-
1982	756	803T	756	792T	718	743	785	774	-
1983	908	917T	889	916T	843T	894	980	962	-
1984	974	1001T	971	1003T	1129T	977	1063	1036	-
1985	640	635T	628	643T	704T	688	777	732	-
1986	958	988T	961	976T	957T	998	1024	988	-
1987	769	790T	797	804T	789T	839	919	902	-
1988	497	491T	502	520T	544T	574	673	644	-
1989	882	948T	909	918T	950T	949	994	965	-
1990	1245	1396T	1302	1333T	1349T	1357	1387	1360	-
1991	737	784T	743	759T	821T	776	812	798	-
1992	786	876T	870	860T	871T	863	893	858	-
1993	775	834T	801	841T	872T	873	921	872	-
1994	677	713T	714	749T	751T	763	881	835	-
1995	833	859T	797	847T	897T	910	916	899	859
1996	1429	1517T	1414	1455T	1483T	1479	1409	1394	1405
1997	713	734T	713	751T	801T	1288	853	809	798
1998	994	1054T	981	986T	989T	1055	1086	1057	1059
1999	896	962T	910	949T	961T	1017	947	933	933
2000	811T	998T	932	985T	985T	998	959	887	912
Avg.	828	928	831	875	881	917	949	943	994
SD	210	247	213	252	211	218	199	196	200
n	45	44	43	41	37	37	36	35	6

Table 9.—Monthly streamflow (mm) for Watershed 6; streamflow reported in mm to make it comparable among watersheds of different areas; streamflow rate is divided by watershed area to give units of depth per unit time over entire watershed area; average and standard deviation are estimated from 38 years of data; annual total is monthly sum

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1963	14	11	68	383	124	9	2	5	1	2	100	57	775
1964	57	19	98	266	82	4	7	20	2	7	61	80	704
1965	27	31	38	179	40	15	5	1	46	77	92	31	581
1966	34	22	115	199	120	41	9	32	27	52	138	58	845
1967	26	16	43	270	136	24	13	14	36	101	77	79	834
1968	18	39	189	210	149	113	16	2	4	8	33	54	835
1969	26	19	32	449	143	21	68	54	7	17	119	116	1070
1970	25	67	28	267	82	9	10	15	35	77	80	41	735
1971	23	36	33	267	202	11	8	15	10	41	22	49	718
1972	33	22	99	213	219	56	60	48	8	28	101	61	948
1973	97	84	205	138	143	277	74	11	29	42	98	272	1470
1974	47	40	98	265	147	52	23	15	59	38	86	81	951
1975	28	22	124	208	73	94	60	7	60	120	112	55	963
1976	62	85	185	191	157	16	14	48	41	157	72	46	1074
1977	13	11	253	155	24	28	5	5	50	175	81	79	878
1978	163	24	28	220	125	84	2	2	1	8	11	15	683
1979	77	20	310	199	122	20	5	6	25	110	112	64	1070
1980	28	4	54	219	61	13	3	3	10	57	73	53	578
1981	9	285	63	107	104	58	85	80	49	158	53	29	1078
1982	36	29	55	351	46	44	8	3	7	14	76	72	743
1983	84	67	111	168	158	35	1	5	1	9	101	154	894
1984	16	110	60	285	227	99	63	1	1	5	44	68	977
1985	21	66	104	135	65	31	5	2	31	79	104	46	688
1986	174	26	177	146	92	20	28	87	39	54	86	69	998
1987	23	13	252	107	56	104	22	9	54	69	78	52	839
1988	19	30	79	175	78	8	9	12	17	14	109	24	574
1989	13	17	85	217	180	89	7	15	20	144	142	20	949
1990	68	67	208	141	133	93	25	199	16	166	94	148	1357
1991	33	24	123	148	55	8	5	86	23	135	63	73	776
1992	73	18	121	201	57	22	24	43	61	53	147	43	863
1993	45	15	119	286	32	33	7	19	31	57	143	86	873
1994	23	28	51	343	88	20	12	13	31	21	43	91	763
1995	112	18	128	67	70	17	18	64	7	196	189	24	910
1996	234	104	75	302	165	74	137	8	4	51	133	192	1479
1997	35	42	68	299	148	21	43	7	8	19	92	22	1288
1998	94	51	229	123	62	225	41	11	13	64	81	60	1055
1999	104	39	177	134	91	16	13	9	199	79	107	48	1017
2000	38	38	201	268	136	23	9	26	28	33	66	133	998
Avg.	54	44	118	218	110	51	25	26	29	67	90	72	917
SD	49	47	72	82	51	57	29	37	34	54	36	50	218

Table 10.—Monthly streamflow (mm) for Watershed 6; streamflow reported in mm to make it comparable among watersheds of different areas; streamflow rate is divided by watershed area to give units of depth per unit time over entire watershed area; average and standard deviation are estimated from 36 years of data; annual total is monthly sum

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1965	35	25	17	147	30	6	2	48	97	74	22	504	
1966	33	15	74	130	248	50	6	14	34	64	127	57	851
1967	15	12	15	175	247	41	16	17	39	110	60	68	816
1968	13	27	128	272	112	104	17	1	4	8	41	62	790
1969	18	13	15	377	296	26	78	58	4	11	159	120	1174
1970	20	59	16	266	138	9	11	9	29	90	65	29	741
1971	13	23	25	129	409	13	7	17	20	65	25	35	780
1972	26	18	71	89	404	64	67	39	6	34	115	62	995
1973	79	66	150	259	165	228	61	7	29	47	94	223	1408
1974	31	30	72	291	182	50	47	23	84	46	85	63	1004
1975	18	14	85	111	233	117	61	4	80	121	108	40	991
1976	47	61	126	284	171	16	11	98	36	170	58	36	1116
1977	9	6	194	263	29	36	5	11	73	202	67	62	957
1978	142	21	15	136	302	97	2	2	1	7	14	18	757
1979	77	16	200	280	168	20	2	4	29	129	115	47	1088
1980	16	1	30	256	98	31	5	5	37	95	74	45	693
1981	6	271	54	174	123	83	97	95	71	163	49	22	1208
1982	26	27	28	301	135	63	14	3	8	24	93	62	785
1983	63	51	97	211	207	39	2	6	2	13	149	139	980
1984	13	69	38	347	283	110	69	2	1	3	55	74	1063
1985	21	49	52	203	88	28	8	2	61	105	123	37	777
1986	151	20	122	226	82	19	32	133	43	46	90	61	1024
1987	18	8	181	206	69	139	21	5	55	90	80	49	919
1988	14	25	41	240	118	10	6	19	23	16	143	18	673
1989	8	10	60	159	264	109	9	20	29	176	136	15	994
1990	48	54	168	220	160	112	20	197	10	166	84	147	1387
1991	24	11	82	212	63	9	4	103	38	138	62	65	812
1992	62	13	86	173	108	40	54	54	75	52	143	35	893
1993	33	11	64	339	62	39	6	40	40	79	143	65	921
1994	17	20	28	309	184	29	21	25	63	30	47	108	881
1995	119	14	88	100	90	22	8	86	5	207	162	15	916
1996	167	80	30	281	270	65	166	8	2	87	95	159	1409
1997	28	28	52	185	283	29	72	16	15	23	108	16	853
1998	79	37	181	193	73	210	60	11	16	82	65	81	1086
1999	90	27	103	192	133	10	9	3	159	83	101	37	947
2000	28	22	116	338	144	23	10	36	30	41	62	108	959
Avg.	45	35	81	226	175	59	30	33	36	81	91	64	949
SD	42	44	55	73	93	53	35	44	32	58	38	46	199

Table 11.—Twenty hightest instantaneous streamflows, cubic square meters (csm) and liters per second per ha ($Ls^{-1}ha^{-1}$) for Watershed 3, 1957-2000, and associated storm precipitation, in mm

	Peak discharge			
Date	csm	$Ls^{-1}ha^{-1}$	Storm precipitation	
Oct 24, 1959	394.3	43.1	Oct 23 - 26, 1959	184.9
Mar 31,1987	337.2	36.9	Mar 30 - Apr 1, 1987	111.9
Jan 19,1996	308.1	33.7	Jan 19, 1996	63.1
Oct 9,1977	256.3	28.0	Oct 8 - 9, 1977	92.8
Feb 11,1981	227.2	24.8	Feb 11 - 12, 1981	65.2
Jan 27,1986	203.4	22.2	Jan 25 - 28, 1986	132.2
Dec 21,1973	178.5	19.5	Dec 20 - 21, 1973	88.9
Apr 5,1984	159.2	17.4	Apr 5 - 8, 1984	70.8
Jan 9,1978	154.3	16.9	Jan 6 - 11, 1978	98.9
Oct 20,1975	147.6	16.1	Oct 15 - 20, 1975	87.5
Mar 13,1977	147.4	16.1	Mar 13 - 14, 1977	62.3
Jun 16,1998	146.7	16.0	Jun 12 - 18, 1998	201.3
Jun 29,1973	145.2	16.0	Jun 27 - Jul 1, 1973	211.6
Oct 20,1989	141.3	15.4	Oct 16 - 22, 1989	113.6
Aug 11,1990	131.4	14.4	Aug 6 - 11, 1990	253.3
Nov 26,1979	130.5	15.9	Nov 24 - 28, 1979	69.7
Apr 1,1976	128.1	14.0	Apr 1 - 3, 1958	45.8
Oct 21,1995	126.5	13.8	Oct 21 - 22, 1995	80.2
Apr 10,1980	115.9	12.7	Apr 9 - 16, 1980	79.5
Nov 3, 1966	115.7	12.6	Nov 2 - 3, 1966	79.8

Table 12.—Highest instantaneous streamflow in each year for Watershed 3, in cubic square meters (csm) and liters per second per ha ($Ls^{-1}ha^{-1}$)

Date	Peak discharge	
	csm	$Ls^{-1}ha^{-1}$
Jul 14, 1956	109.6	12.0
Dec 21, 1957	129.1	14.1
Apr 17, 1958	55.3	6.0
Oct 24, 1959	394.3	43.1
Mar 31, 1960	72.6	7.9
Apr 23, 1961	46.0	5.0
Apr 7, 1962	86.1	9.4
Apr 30, 1963	54.1	5.9
Apr 14, 1964	95.3	10.4
Apr 16, 1965	38.1	4.2
Nov 3, 1966	115.7	12.6
Apr 3, 1967	85.6	9.4
Apr 25, 1968	89.7	9.8
Jul 29, 1969	106.4	11.6
Apr 24, 1970	71.5	7.8
Oct 10, 1971	42.7	4.7
Aug 27, 1972	115.2	12.6
Dec 21, 1973	178.5	19.5
Dec 8, 1974	72.0	7.9
Oct 20, 1975	147.6	16.1
Apr 1, 1976	128.1	14.0
Oct 9, 1977	256.4	28.0
Jan 9, 1978	154.3	16.9
Nov 26, 1979	130.5	14.3
Apr 10, 1980	115.9	12.7
Feb 11, 1981	227.2	24.8
Apr 27, 1982	100.8	11.0
Feb 3, 1983	77.9	8.5
Apr 5, 1984	159.2	17.4
Sep 27, 1985	50.8	5.6
Jan 27, 1986	203.4	22.2
Mar 31, 1987	337.2	36.9
Mar 27, 1988	31.6	3.5
Oct 20, 1989	141.3	15.4
Aug 11, 1990	131.4	14.4
Aug 8, 1991	75.8	8.3
Mar 3, 1992	85.6	9.4
Nov 28, 1993	107.0	11.7
Apr 16, 1994	62.4	6.8
Oct 21, 1995	126.5	13.8
Jan 19, 1996	308.1	33.7
Nov 2, 1997	37.3	4.1
Jun 16, 1998	146.7	16.0
Sep 16, 1999	65.4	7.1
Dec 17, 2000	217.0	23.7
Apr 22, 2001	64.9	7.1
Apr 13, 2002	170.0	18.6

Table 13.—Annual precipitation (mm), streamflow (mm) and evapotranspiration (precipitation minus streamflow) for Watershed 3 by water year (beginning June 1); average and standard deviation are calculated from 43 years of data

Water year	Precipitation	Streamflow	Evapotranspiration
1958-59	1042	529	513
1959-60	1630	1039	590
1960-61	1137	567	571
1961-62	1050	524	526
1962-63	1274	750	524
1963-64	1167	644	523
1964-65	939	439	500
1965-66	1221	705	516
1966-67	1278	772	506
1967-68	1394	866	528
1968-69	1271	834	437
1969-70	1294	819	475
1970-71	1226	762	464
1971-72	1222	714	508
1972-73	1505	961	543
1973-74	1832	1332	500
1974-75	1242	755	487
1975-76	1658	1185	473
1976-77	1324	802	522
1977-78	1432	904	528
1978-79	1286	819	467
1979-80	1138	693	445
1980-81	1261	732	528
1981-82	1531	1070	461
1982-83	1328	803	525
1983-84	1522	997	525
1984-85	1087	648	439
1985-86	1311	860	451
1986-87	1210	792	418
1987-88	1190	717	474
1988-89	1150	642	508
1989-90	1469	1007	462
1990-91	1590	1084	506
1991-92	1354	837	517
1992-93	1331	875	456
1993-94	1317	851	466
1994-95	1090	566	524
1995-96	1678	1281	397
1996-97	1518	1105	413
1997-98	1225	705	520
1998-99	1399	950	449
1999-00	1562	1058	504
2000-01	1095	614	481
Avg.	1320	828	493
SD	195	202	41

Table 14.—Evaporation (annual precipitation minus streamflow) by watershed for years beginning June 1, in mm; T = treated watersheds

	Watershed								
Year	1	2	3	4	5	6	7	8	9
1956-57	522	-	-	-	-	-	-	-	-
1957-58	513	-	-	-	-	-	-	-	-
1958-59	490	456	513	-	-	-	-	-	-
1959-60	565	482	590	-	-	-	-	-	-
1960-61	541	525	571	-	-	-	-	-	-
1961-62	518	497	526	506	-	-	-	-	-
1962-63	505	370	524	483	-	-	-	-	-
1963-64	513	447	523	455	-	-	-	-	-
1964-65	501	443	500	456	413	481	-	-	-
1965-66	543	419T	516	498	524	524	501	-	-
1966-67	545	102T	506	499	533	534	488	-	-
1967-68	521	154T	528	488	503	521	507	-	-
1968-69	392	79T	437	356	474	453	403	-	-
1969-70	441	163T	475	425T	517	490	484	531	-
1970-71	496	231T	464	453T	533	501	471	508	-
1971-72	533	383T	508	420T	544	539	507	548	-
1972-73	561	443T	543	400T	523	535	488	509	-
1973-74	521	327T	500	328T	484	488	562	554	-
1974-75	459	311T	487	330T	445	500	513	543	-
1975-76	464	334T	473	333T	486	581	519	519	-
1976-77	461	394T	522	386T	497	552	494	539	-
1977-78	493	377T	528	409T	528	550	493	573	-
1978-79	455	375T	467	436T	504	511	487	487	-
1979-80	423	380T	445	432T	454	486	460	479	-
1980-81	502	473T	528	528T	566	576	496	525	-
1981-82	429	351T	461	440T	548	556	496	539	-
1982-83	510	492T	525	553T	612	597	532	567	-
1983-84	521	483T	525	549T	642	635	583	603	-
1984-85	431	418T	439	485T	361T	529	487	530	-
1985-86	437	406T	451	509T	466T	512	471	506	-
1986-87	454	409T	418	479T	488T	477	481	489	-
1987-88	473	465T	474	493T	518T	522	505	527	-
1988-89	527	495T	508	548T	514T	530	523	523	-
1989-90	502	382T	462	488T	461T	499	470	526	-
1990-91	536	437T	506	543T	512T	546	543	564	-
1991-92	559	460T	517	544T	506T	558	517	552	-
1992-93	496	432T	456	484T	466T	482	446	492	-
1993-94	526	446T	466	483T	487T	496	466	495	-
1994-95	508	512T	524	548T	518T	531	500	543	-
1995-96	366	273T	397	429T	410T	411	496	496	558
1996-97	406	317T	413	447T	393T	418	501	525	530
1997-98	517	479T	520	558T	528T	519	542	556	591
1998-99	452	375T	449	495T	514T	467	536	569	579
1999-00	595	475T	504	522T	519T	517	539	581	587

Table 15.—Average February soil-frost incidence and thickness by year for snow course Stations 2 and 17; incidence is percentage of frost occurrence at the 10 measurement sites at each station; thickness is average depth of frost at the 10 sites within a station (cm) for February

Year	Station 2		Station 17	
	Incidence	Depth	Incidence	Depth
	Percent	*cm*	*Percent*	*cm*
1956	20	5		
1957	0	0		
1958	0	0		
1959	0	0		
1960	7	3		
1961	0	0		
1962	0	0		
1963	0	0		
1964	0	0		
1970	56	6	95	12
1971	0	0	43	1
1972	0	0	22	2
1973	0	0	0	0
1974	76	10	100	15
1975	0	0	50	1
1976	26	2	100	2
1977	0	0	91	1
1978	0	0	33	3
1979	0	0	30	1
1980	100	17	100	22
1981	0	0	93	7
1982	0	0	29	2
1983	100	8	100	12
1984	0	0	25	1
1985	0	0	60	2
1986	16	0	70	2
1987	0	0	13	1
1988	0	0	83	3
1989	84	2	100	10
1990	0	0	35	2
1991	55	7	100	9
1992	98	15	100	10
1993	81	17	100	14
1994	12	1	92	6
1995	50	3	87	3
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	83	3	91	3

Table 16.—Average daily maximum air temperature (°C) by month for Station 1 (1956-2000)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1956	-3.0	-1.7	-0.6	6.2	14.3	21.7	21.6	22.4	15.4	13.9	6.2	-0.4
1957	-6.1	1.0	3.3	12.0	17.6	24.0	23.0	21.7	18.9	13.5	6.7	2.1
1958	-2.2	-4.4	4.3	10.4	15.1	18.0	22.4	23.3	17.4	11.0	5.1	-5.4
1959	-5.2	-3.8	1.7	9.1	19.8	19.4	25.6	23.7	19.6	10.9	4.1	-0.2
1960	-2.6	0.2	-0.6	9.0	18.4	21.1	23.2	23.3	18.6	10.6	6.5	-2.8
1961	-6.1	0.1	2.6	7.0	15.5	23.0	24.5	22.8	23.5	13.5	4.1	-2.3
1962	-4.9	-4.7	3.7	9.9	17.2	23.2	21.9	22.5	16.1	10.2	3.9	-1.8
1963	-3.7	-4.3	3.5	10.3	18.3	24.0	25.2	20.3	17.1	17.9	6.1	-6.6
1964	-1.8	-2.4	3.0	8.9	19.6	22.3	24.9	20.3	16.7	11.7	4.9	-1.8
1965	-6.2	-3.4	1.3	8.1	19.6	22.0	23.0	22.5	17.7	9.9	1.3	-1.4
1966	-3.8	-1.6	2.8	7.7	16.9	23.4	24.6	22.9	16.9	12.3	7.4	-0.5
1967	-0.8	-3.9	0.8	7.5	11.9	24.7	25.0	23.4	19.9	11.5	1.8	-0.6
1968	-4.9	-5.5	3.5	11.9	16.1	19.7	26.2	22.4	20.8	14.0	3.1	-3.1
1969	-1.6	-0.3	1.7	9.7	16.0	22.6	23.1	25.1	19.5	11.7	4.0	-3.4
1970	-9.2	-2.8	0.1	8.5	18.4	22.9	26.1	25.0	18.8	13.5	6.7	-3.6
1971	-5.8	-0.8	2.5	8.0	16.2	22.4	23.4	22.3	19.4	15.6	3.8	-1.0
1972	-2.6	-2.9	0.4	5.0	17.2	17.4	21.6	20.0	17.4	9.5	1.7	-2.0
1973	-2.0	-3.1	5.1	9.7	14.0	19.5	22.4	23.2	15.5	13.3	3.3	0.3
1974	-2.7	-2.7	0.6	8.8	12.6	21.2	23.1	22.7	16.7	8.8	5.6	0.4
1975	-1.8	-1.8	0.6	4.6	20.3	21.0	24.5	21.5	15.4	12.7	8.3	-2.6
1976	-5.8	0.7	3.1	12.1	16.1	23.5	22.5	21.5	17.5	9.9	1.4	-5.2
1977	-7.6	-3.2	6.0	11.1	20.4	19.4	23.7	22.6	15.9	11.8	6.2	-2.7
1978	-4.0	-4.0	1.6	6.5	18.7	20.6	23.9	22.6	17.5	11.3	5.8	-1.5
1979	-3.7	-6.6	4.2	8.0	16.8	22.5	25.6	21.5	18.9	10.7	7.5	-0.3
1980	-2.5	-4.2	2.3	8.8	18.0	19.6	23.4	22.8	17.7	9.4	2.1	-4.4
1981	-6.2	2.1	3.8	10.3	17.9	21.3	23.1	21.5	16.3	10.2	4.4	-1.9
1982	-8.0	-3.0	1.5	6.8	18.8	18.2	24.0	20.5	18.6	13.4	6.4	1.4
1983	-2.4	0.5	3.5	9.4	14.6	24.0	25.4	23.9	21.0	12.8	5.3	-3.1
1984	-4.2	3.1	-0.2	10.9	15.1	22.5	23.9	24.4	18.1	15.1	5.5	1.4
1985	-6.7	-0.9	4.4	10.1	17.4	18.6	24.8	22.3	19.2	12.8	4.2	-3.7
1986	-2.6	-3.0	3.8	13.1	18.0	19.2	21.0	20.9	17.1	12.0	3.4	-0.6
1987	-3.1	-3.5	4.6	11.4	17.5	20.8	24.1	21.5	17.4	12.3	4.8	-0.5
1988	-3.4	-1.2	2.8	8.4	17.8	20.8	25.0	24.0	18.2	9.6	5.6	-1.9
1989	-0.4	-2.2	2.2	7.0	17.3	20.0	23.1	19.8	19.6	14.4	4.3	-6.9
1990	1.4	1.0	5.3	10.2	15.5	21.2	25.1	24.4	17.6	13.5	6.2	1.5
1991	-3.8	0.5	3.1	12.9	19.3	22.6	23.8	23.6	17.3	13.4	5.9	-1.3
1992	-3.6	-1.9	2.2	7.5	19.2	21.0	18.8	20.2	17.1	8.7	4.0	0.5
1993	-2.8	-4.6	3.8	11.1	16.9	21.6	24.2	24.1	16.5	10.0	4.8	-0.8
1994	-7.9	-4.6	1.6	9.5	16.8	22.9	24.9	21.7	16.1	13.5	7.3	2.3
1995	-1.0	-3.3	3.7	7.0	16.0	24.3	24.9	23.5	17.0	14.1	1.7	-3.4
1996	-3.3	-2.7	3.2	9.0	16.0	21.1	22.6	24.3	18.5	11.2	2.1	1.0
1997	-3.5	0.8	0.2	8.3	12.9	22.6	24.5	23.1	18.1	12.2	2.7	-0.3
1998	-1.2	3.0	4.3	12.2	21.0	19.6	23.4	23.5	18.7	10.7	3.6	1.2
1999	-2.4	1.1	2.9	10.6	19.2	24.4	25.4	22.7	20.6	11.3	7.6	0.3
2000	-3.8	-0.1	6.9	8.7	17.3	21.1	22.8	21.6	17.6	12.9	4.5	-3.1
Avg.	-3.8	-1.9	2.7	9.2	17.1	21.5	23.8	22.5	18.0	12.1	4.7	-1.5
SD	2.2	2.3	1.7	2.0	2.1	1.8	1.4	1.3	1.6	1.9	1.8	2.2

Table 17.—Average daily minimum air temperature (°C) by month for Station 1 (1956-2000)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1956	-10.1	-10.4	-9.5	-1.7	2.3	10.6	12.3	11.9	6.4	3.5	-2.5	-8.4
1957	-16.2	-10.1	-5.5	0.2	5.1	12.1	12.0	10.0	8.8	3.6	-1.1	-5.8
1958	-9.8	-14.2	-3.2	0.7	3.1	7.5	13.4	11.7	7.6	1.3	-2.8	-15.3
1959	-13.8	-16.9	-8.3	-0.6	6.7	10.3	14.6	13.6	10.0	3.5	-3.7	-6.5
1960	-10.2	-8.0	-9.5	0.0	8.2	10.2	12.8	12.5	8.8	1.5	-1.1	-12.7
1961	-15.8	-10.2	-6.8	-0.2	3.8	11.3	14.2	13.4	12.8	3.5	-2.2	-9.1
1962	-15.6	-14.6	-6.6	-1.4	5.2	11.6	10.9	12.2	7.0	1.2	-3.3	-11.8
1963	-12.1	-16.0	-6.7	0.8	4.8	11.7	14.0	11.0	5.3	4.2	-0.5	-14.6
1964	-10.4	-12.7	-5.7	-1.5	5.8	9.3	14.3	9.6	6.4	1.0	-3.1	-9.4
1965	-15.3	-14.3	-7.3	-1.5	5.0	9.1	10.9	12.0	7.6	0.8	-5.9	-8.3
1966	-13.4	-11.6	-6.2	-1.6	4.8	11.5	13.1	13.1	6.8	1.1	-0.4	-9.1
1967	-9.2	-15.7	-9.6	-2.9	1.6	13.3	15.3	13.4	8.5	1.9	-5.8	-8.8
1968	-15.4	-16.3	-6.0	0.5	4.3	11.4	15.2	11.9	11.1	5.3	-3.3	-10.9
1969	-10.4	-9.0	-6.7	-0.3	4.7	12.1	14.1	14.6	10.1	2.4	-2.6	-10.6
1970	-19.6	-14.6	-9.1	-1.6	6.4	11.0	15.6	13.8	9.7	4.4	0.1	-12.4
1971	-16.9	-10.2	-7.5	-1.0	6.9	12.3	14.0	13.8	11.9	7.5	-3.3	-8.9
1972	-11.6	-11.6	-7.1	-1.9	7.6	10.9	13.9	13.0	8.8	1.6	-3.2	-8.5
1973	-10.1	-11.8	-1.3	2.1	6.7	12.2	14.5	15.4	8.7	4.7	-2.8	-7.1
1974	-10.8	-12.5	-7.8	0.3	4.6	12.3	14.5	14.2	9.8	0.5	-1.8	-5.1
1975	-9.5	-10.0	-7.7	-2.6	9.8	12.1	14.7	12.2	7.3	2.8	0.2	-11.7
1976	-16.0	-10.2	-7.0	1.6	4.7	12.7	11.9	12.5	7.8	1.2	-5.1	-15.5
1977	-16.3	-11.2	-2.3	-0.2	6.2	10.2	12.4	12.7	6.6	1.5	-1.2	-10.3
1978	-13.2	-14.0	-7.8	-0.8	7.2	10.9	13.0	12.8	5.8	2.4	-3.0	-9.8
1979	-10.6	-14.5	-3.4	0.1	7.9	10.6	15.3	12.6	7.0	2.7	0.4	-8.3
1980	-11.5	-13.5	-7.0	0.1	5.7	9.0	13.6	13.3	6.9	1.0	-4.8	-16.3
1981	-17.5	-7.1	-5.2	0.1	5.8	9.9	12.9	11.6	7.9	1.0	-2.9	-7.7
1982	-17.5	-12.9	-7.7	-3.3	5.9	9.6	12.8	10.2	9.1	2.1	-1.2	-7.2
1983	-11.2	-8.7	-3.9	1.3	5.4	11.7	14.3	13.2	9.1	2.1	-1.1	-12.2
1984	-13.5	-5.8	-9.9	1.0	4.2	11.0	13.8	14.7	5.8	2.8	-3.2	-7.5
1985	-15.6	-10.5	-6.3	-0.6	5.4	9.6	13.3	12.9	9.9	3.3	-1.5	-11.7
1986	-12.2	-11.8	-5.9	2.0	6.9	8.7	12.7	12.1	7.5	1.9	-4.9	-8.0
1987	-11.1	-13.3	-4.7	1.5	5.6	11.8	14.0	10.6	9.1	1.8	-3.5	-6.9
1988	-12.8	-11.3	-6.9	0.6	7.8	9.3	15.5	14.5	7.9	2.1	-1.4	-10.6
1989	-10.0	-12.1	-8.1	-2.3	7.4	10.8	12.6	10.6	9.6	5.0	-3.7	-15.9
1990	-6.6	-9.4	-4.9	0.6	4.9	11.3	14.0	14.1	8.7	4.7	-1.6	-7.0
1991	-13.3	-9.6	-4.3	2.2	7.3	11.2	14.0	14.2	7.2	3.6	-0.9	-10.3
1992	-12.8	-11.4	-7.6	-2.0	5.6	9.4	9.2	11.0	7.5	0.9	-2.3	-6.8
1993	-10.7	-15.4	-7.1	0.1	5.3	10.0	13.5	13.4	7.6	-0.5	-4.0	-9.3
1994	-19.2	-14.8	-6.6	-0.1	4.8	12.0	15.1	11.3	8.0	3.2	-1.5	-6.7
1995	-7.8	-12.6	-4.4	-2.7	4.6	11.2	13.9	12.5	5.6	4.3	-5.8	-11.3
1996	-13.4	-12.1	-7.2	-0.5	4.5	11.6	13.3	13.4	9.7	1.0	-5.1	-5.1
1997	-13.5	-9.6	-9.0	-1.6	4.0	10.1	13.6	13.4	8.9	2.5	-4.5	-8.9
1998	-9.0	-6.4	-4.7	1.0	9.1	11.3	13.5	13.8	9.5	3.3	-1.1	-6.9
1999	-11.9	-7.9	-5.0	-0.1	7.4	12.1	14.7	12.4	11.5	1.0	-0.5	-6.5
2000	-13.2	-10.0	-2.8	0.1	6.1	11.3	12.1	12.1	7.0	3.0	-1.9	-12.0
Avg.	-12.9	-12.0	-6.6	-0.4	5.6	10.8	13.5	12.6	8.3	2.5	-2.7	-9.7
SD	3.1	2.6	2.0	1.4	1.6	1.2	1.3	1.4	1.7	1.6	1.7	2.9

Table 18.—Average daily mean air temperature (°C) by month for Station 1 (1956-2000)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1956	-6.5	-6.0	-5.0	2.3	8.3	16.1	16.9	17.2	10.9	8.7	1.9	-4.4
1957	-11.2	-4.5	-1.1	6.1	11.4	18.1	17.5	15.9	13.9	8.6	2.8	-1.9
1958	-6.0	-9.3	0.6	5.5	9.1	12.8	17.9	17.5	12.5	6.2	1.2	-10.4
1959	-9.5	-10.4	-3.3	4.3	13.3	14.9	20.1	18.7	14.8	7.2	0.2	-3.4
1960	-6.4	-3.9	-5.0	4.5	13.3	15.7	18.0	17.9	13.7	6.0	2.7	-7.8
1961	-11.0	-5.0	-2.1	3.4	9.7	17.2	19.4	18.1	18.2	8.5	1.0	-5.7
1962	-10.3	-9.7	-1.5	4.3	11.2	17.4	16.4	17.4	11.6	5.7	0.3	-6.8
1963	-7.9	-10.2	-1.6	5.5	11.6	17.9	19.6	15.7	11.2	11.1	2.8	-10.6
1964	-6.1	-7.5	-1.4	3.7	12.7	15.8	19.6	15.0	11.6	6.4	0.9	-5.6
1965	-10.8	-8.8	-3.0	3.3	12.3	15.6	16.9	17.3	12.7	5.4	-2.3	-4.9
1966	-8.6	-6.6	-1.7	3.1	10.9	17.4	18.9	18.0	11.9	6.7	3.5	-4.8
1967	-5.0	-9.8	-4.4	2.3	6.8	19.0	20.2	18.4	14.2	6.7	-2.0	-4.7
1968	-10.2	-10.9	-1.3	6.2	10.2	15.6	20.7	17.2	16.0	9.7	-0.1	-7.0
1969	-6.0	-4.7	-2.5	4.7	10.4	17.4	18.6	19.9	14.8	7.0	0.7	-7.0
1970	-14.4	-8.7	-4.5	3.5	12.4	16.9	20.9	19.4	14.3	9.0	3.4	-8.0
1971	-11.4	-5.5	-2.5	3.5	11.6	17.4	18.7	18.1	15.7	11.6	0.3	-5.0
1972	-7.1	-7.3	-3.4	1.6	12.4	14.2	17.8	16.5	13.1	5.5	-0.8	-5.3
1973	-6.0	-7.5	1.9	5.9	10.4	15.9	18.4	19.3	12.1	9.0	0.3	-3.4
1974	-6.8	-7.6	-3.6	4.5	8.6	16.8	18.8	18.4	13.3	4.7	1.9	-2.4
1975	-5.7	-5.9	-3.6	1.0	15.1	16.6	19.6	16.9	11.4	7.8	4.3	-7.2
1976	-10.9	-4.8	-2.0	6.9	10.4	18.1	17.2	17.0	12.7	5.5	-1.9	-10.4
1977	-12.0	-7.2	1.9	5.5	13.3	14.8	18.1	17.7	11.3	6.7	2.5	-6.5
1978	-8.6	-9.0	-3.1	2.9	13.0	15.8	18.4	17.7	11.7	6.9	1.4	-5.7
1979	-7.2	-10.6	0.4	4.0	12.4	16.6	20.4	17.1	13.0	6.7	4.0	-4.3
1980	-7.0	-8.8	-2.4	4.5	11.9	14.3	18.5	18.1	12.3	5.2	-1.4	-10.4
1981	-11.9	-2.5	-0.7	5.2	11.9	15.6	18.0	16.6	12.1	5.6	0.8	-4.8
1982	-12.8	-8.0	-3.1	1.8	12.4	13.9	18.4	15.4	13.9	7.8	2.6	-2.9
1983	-6.8	-4.1	-0.2	5.4	10.0	17.9	19.9	18.6	15.1	7.5	2.1	-7.7
1984	-8.8	-1.4	-5.0	6.0	9.7	16.8	18.9	19.6	12.0	9.0	1.2	-3.1
1985	-11.2	-5.7	-1.0	4.8	11.4	14.1	19.1	17.6	14.6	8.1	1.4	-7.7
1986	-7.4	-7.4	-1.1	7.5	12.5	14.0	16.9	16.5	12.3	7.0	-0.8	-4.3
1987	-7.1	-8.4	-0.1	6.5	11.6	16.3	19.1	16.1	13.3	7.0	0.7	-3.7
1988	-8.1	-6.3	-2.0	4.5	12.8	15.1	20.3	19.3	13.1	5.9	2.1	-6.3
1989	-5.2	-7.2	-3.0	2.4	12.4	15.4	17.9	15.2	14.6	9.7	0.3	-11.4
1990	-2.6	-4.2	0.2	5.4	10.2	16.3	19.6	19.3	13.2	9.1	2.3	-2.8
1991	-8.6	-4.5	-0.6	7.5	13.3	16.9	18.9	18.9	12.3	8.5	2.5	-5.8
1992	-8.2	-6.7	-2.7	2.8	12.4	15.2	14.0	15.6	12.3	4.8	0.8	-3.1
1993	-6.8	-10.0	-1.7	5.6	11.1	15.8	18.9	18.8	12.1	4.8	0.4	-5.0
1994	-13.6	-9.7	-2.5	4.7	10.8	17.4	20.0	16.5	12.1	8.3	2.9	-2.2
1995	-4.4	-8.0	-0.4	2.1	10.3	17.8	19.4	18.0	11.3	9.2	-2.0	-7.4
1996	-8.3	-7.4	-2.0	4.3	10.3	16.4	17.9	18.9	14.1	6.1	-1.5	-2.0
1997	-8.5	-4.4	-4.4	3.4	8.4	16.4	19.1	18.3	13.5	7.4	-0.9	-4.6
1998	-5.1	-1.7	-0.2	6.6	15.1	15.4	18.4	18.6	14.1	7.0	1.3	-2.9
1999	-7.2	-3.4	-1.1	5.3	13.3	18.2	20.1	17.6	16.0	6.1	3.5	-3.1
2000	-8.5	-5.1	2.0	4.4	11.7	16.2	17.5	16.9	12.3	8.0	1.3	-7.5
Avg.	-8.3	-6.8	-1.9	4.4	11.4	16.2	18.7	17.6	13.2	7.3	1.1	-5.6
SD	2.6	2.4	1.8	1.6	1.7	1.3	1.3	1.2	1.5	1.6	1.7	2.5

Table 19.—Average daily maximum, minimum and mean temperature (°C) by station and month, and number of years used to calculate average for each station

Station	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual avg.
							Daily Maximum							
HQ	1957-1997	-2.5	-0.6	4.3	11.0	18.6	23.1	25.5	24.4	19.8	13.7	6.2	-0.4	11.9
1	1956-2000	-3.8	-1.9	2.7	9.2	17.1	21.5	23.8	22.5	18.0	12.1	4.7	-1.5	10.4
6	1961-1997	-5.3	-3.9	0.7	7.0	15.1	19.8	22.0	20.9	16.5	10.8	3.2	-2.7	8.7
14	1965-1997	-6.2	-4.3	0.9	7.4	15.4	20.3	22.5	21.2	16.3	9.5	2.3	-3.5	8.5
17	1999-2000	-6.7	-4.1	1.2	5.4	13.5	19.3	21.1	19.4	16.4	7.5	1.6	-5.6	7.4
23	1996-1997	-5.0	-2.3	1.3	7.0	15.1	20.4	22.1	21.4	17.1	9.2	1.7	-2.8	8.8
24	1999-2000	-5.9	-1.3	3.5	7.0	14.8	20.3	22.0	19.6	16.2	8.0	2.6	-4.4	8.5
							Daily Minimum							
HQ	1957-1997	-12.8	-11.6	-5.7	-0.2	5.5	10.4	13.1	12.2	7.9	2.4	-2.0	-9.2	0.8
1	1956-2000	-12.8	-11.7	-6.4	-0.4	5.7	10.9	13.5	12.6	8.3	2.5	-2.6	-9.6	0.8
6	1961-1997	-14.0	-12.9	-7.9	-1.8	4.8	10.1	12.6	11.7	7.5	2.0	-3.7	-10.6	-0.2
14	1965-1997	-14.2	-13.1	-8.1	-2.0	4.4	10.0	12.7	11.8	7.4	1.5	-4.0	-10.7	-0.3
17	1999-2000	-15.1	-11.6	-7.3	-3.0	3.4	8.9	10.9	10.5	7.7	0.2	-4.0	-12.2	-1.0
23	1996-1997	-13.4	-10.9	-7.9	-2.0	4.7	10.6	12.6	12.1	8.4	0.8	-4.2	-9.7	0.1
24	1999-2000	-15.3	-11.8	-7.1	-2.9	3.3	8.7	11.2	9.9	6.8	-0.9	-3.9	-11.7	-1.1
							Daily Mean							
HQ	1957-1997	-7.6	-6.1	-0.7	5.4	12.0	16.8	19.3	18.3	13.8	8.0	2.1	-4.8	6.4
1	1956-2000	-8.3	-6.8	-1.9	4.4	11.4	16.2	18.7	17.6	13.2	7.3	1.1	-5.6	5.6
6	1961-1997	-9.6	-8.4	-3.6	2.6	9.9	14.9	17.3	16.3	12.0	6.4	-0.3	-6.8	4.2
14	1965-1997	-10.2	-8.7	-3.6	2.7	9.9	15.2	17.6	16.5	11.8	5.5	-0.9	-7.1	4.1
17	1999-2000	-10.9	-7.8	-3.0	1.3	8.4	14.1	16.1	15.0	12.0	3.8	-1.2	-8.8	3.2
23	1996-1997	-10.2	-6.6	-3.3	2.5	9.9	15.6	17.4	16.7	12.7	5.0	-1.2	-6.2	4.4
24	1999-2000	-10.7	-6.5	-1.8	2.1	9.0	14.5	16.7	14.8	11.5	3.5	-0.7	-8.1	3.7

Table 20.—Average daily solar radiation (MJ/m²) by month at HQ (1959-2000); estimated annual total calculated by adding the 12 monthly averages and multiplying by 30.5

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
1959	3.8	7.6	13.1	14.8	17.6	11.6	19.3	17.4	16.2	5.6	4.3	3.8	4118
1960	7.2	8.3	13.2	16.1	17.6	20.3	19.8	18.6	14.1	10.7	6.1	5.4	4803
1961	6.7	8.7	13.4	13.7	17.5	19.7	18.8	16.5	15.2	9.9	5.2	4.1	4550
1962	6.2	7.6	14.7	16.2	18.9	21.3	20.0	17.2	14.0	8.2	6.5	5.5	4761
1963	5.0	9.8	12.5	16.6	18.1	21.1	19.8	15.2	15.5	12.8	4.1	5.7	4766
1964	5.0	9.6	11.9	15.6	20.8	22.7	19.3	17.0	14.4	10.6	6.3	3.6	4779
1966	4.9	9.6	11.8	15.5	17.8	21.0	21.7	18.0	14.8	10.5	5.2	4.6	4739
1967	5.0	8.6	13.2	14.9	16.3	16.3	16.3	14.9	14.2	8.0	4.3	4.1	4151
1968	6.4	9.2	11.2	17.2	17.5	11.7	19.9	16.5	11.5	5.5	3.1	1.6	4004
1969	4.5	7.3	10.7	15.1	17.0	18.2	14.8	16.4	11.4	10.0	4.5	4.9	4111
1970	7.5	8.7	13.2	17.3	19.9	20.4	20.6	19.1	11.4	8.5	5.2	4.3	4761
1971	6.2	7.9	14.4	17.3	18.0	24.7	22.7	18.9	13.2	10.1	5.9	5.1	5015
1972	6.4	9.6	10.9	18.2	19.7	16.5	20.5	17.7	13.9	10.6	4.4	3.4	4628
1973	6.7	10.7	11.7	16.0	15.0	18.4	20.4	16.9	12.8	11.0	6.8	4.2	4596
1974	5.6	10.5	12.4	17.0	17.2	21.0	19.6	19.3	12.5	10.5	6.0	3.9	4739
1975	5.5	8.2	11.9	17.7	20.7	19.9	21.0	17.6	13.0	10.6	6.5	4.2	4783
1976	6.1	9.1	14.0	19.2	18.8	22.3	21.2	18.2	14.7	9.3	6.4	5.5	5026
1977	7.1	8.2	12.8	18.1	23.1	16.6	21.3	15.9	11.3	9.2	5.4	5.1	4701
1978	5.5	12.2	13.5	17.0	20.5	19.4	21.9	17.8	16.3	9.3	7.1	4.8	5039
1979	4.2	11.1	10.5	15.8	16.1	23.1	21.3	15.4	16.3	7.3	5.7	5.4	4648
1980	6.9	10.5	13.5	14.7	21.4	20.5	20.7	17.1	15.8	9.0	5.6	6.0	4932
1981	7.5	7.9	13.5	16.2	20.3	21.3	21.0	17.0	12.0	9.2	6.6	4.2	4784
1982	6.6	10.1	13.9	19.1	21.8	18.5	23.9	18.0	13.9	11.1	4.7	4.1	5059
1983	5.9	9.6	10.9	13.7	14.4	24.4	22.3	18.9	16.7	10.8	5.0	4.3	4787
1984	6.0	7.8	14.3	16.2	16.8	22.5	20.5	18.3	15.4	10.2	6.5	4.3	4846
1985	6.3	9.6	16.1	17.7	19.8	18.7	23.6	19.3	15.5	10.6	4.8	4.1	5070
1986	5.2	8.6	11.6	16.8	18.5	21.0	16.6	15.7	11.9	9.0	5.3	4.0	4394
1987	4.9	10.3	11.4	13.5	18.2	18.3	19.4	18.4	11.5	9.6	5.1	3.9	4411
1988	5.4	7.8	12.3	12.9	17.0	21.2	18.6	17.2	13.7	7.2	4.9	4.8	4362
1989	5.0	7.6	12.3	15.2	14.1	17.0	19.5	16.7	13.7	8.4	4.9	5.3	4263
1990	4.6	8.1	12.7	12.7	16.4	17.4	21.1	18.1	12.0	8.0	5.8	3.4	4279
1991	4.9	7.6	10.2	14.0	18.7	20.5	18.2	14.7	12.8	7.6	4.6	3.8	4205
1992	4.7	6.3	10.0	12.6	18.8	19.5	17.1	15.1	12.9	7.9	4.8	3.5	4063
1993	4.4	7.9	10.8	12.5	17.2	19.8	17.9	16.7	11.7	8.4	5.0	3.9	4150
1994	4.5	8.2	10.0	14.2	17.5	19.8	18.9	16.1	12.0	10.4	5.4	4.5	4314
1995	4.3	7.2	10.5	14.2	15.3	21.1	18.6	17.8	14.1	8.9	4.6	4.1	4288
1996	5.3	7.2	14.3	14.4	19.7	18.2	18.6	19.5	12.6	10.9	5.5	3.1	4558
1997	4.7	8.8	10.3	20.9	18.2	26.9	24.7	19.8	15.1	11.4	5.3	5.0	5219
1998	4.8	10.1	11.9	19.2	21.8	16.8	20.3	17.6	13.6	7.9	4.2	3.9	4640
1999	3.8	8.3	11.3	17.2	19.2	21.9	19.9	15.6	11.9	8.1	4.8	3.9	4454
2000	4.3	6.1	11.0	10.6	14.4	16.4	16.9	14.5	12.6	8.1	4.8	3.6	3765

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The 3,160-ha Hubbard Brook Experimental Forest (HBEF) in New Hampshire has been a prime area of research on forest and stream ecosystems since its establishment by the USDA Forest Service in 1955. Streamflow and precipitation have been measured continuously on the HBEF, and long-term datasets exist for air and soil temperature, snow cover, soil frost, solar radiation, windspeed and direction, and humidity. This information has provided the basis for hundreds of publications by Forest Service and cooperating scientists on numerous aspects of forest hydrology research as part of the ongoing Hubbard Brook Ecosystem Study. This report updates the tables, methods, watershed descriptions, and other pertinent data in "Thirty Years of Hydrometeorological Data at the Hubbard Brook Experimental Forest, New Hampshire" (General Technical Report NE-141).

Keywords: Streamflow, precipitation, watershed studies, air temperature, continuous measurements.

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