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TECHNICAL REPORT
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ENVIRONMENT OF THE NLABS ANNEX

by

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FOREWORD

The NLABS Annex, Sudbury, Massachusetts, is a primary testing area of the U. S. Army Natick Laboratories, and the Army Research Institute of Environmental Medicine (ARIEM). A number of different environments are in the nearly 3,000-acre reservation 12 miles northwest of the Natick Laboratories. The reservation is used mainly for airdrops of materiel and men, testing of military equipment, exposure studies of textiles, storage of supplies and equipment, and housing of military personnel. The reservation also serves as a convenient place where NLABS scientists can try out new instruments, equipment, field methods, and techniques. A 750-acre area was set aside for ARIEM to develop a military performance facility. The Air Force Cambridge Research Laboratories has 60 acres on lease for weather radar and other research purposes, and an electronic firm has 85 acres under permit on a special research project. In addition, the Office of Civil Defense has leased 262 acres in the eastern sector of the reservation adjacent to the area outside Gate 11, where one of its major facilities will be constructed.

NLABS scientists have requested that this Division furnish various kinds of environmental information pertaining to their curre[illegible] anticipated use of the NLABS Annex. To enhance the availabil[illegible] such knowledge, pertinent environmental information on the reservat[illegible] presented in a single report, with numerous illustrations. New multicolor maps contain up-to-date and more detailed information concerning the physical and man-made features.

Sincere appreciation is extended to personnel of the U. S. Army Electronics Command, Fort Huachuca, Arizona, for collecting climatic data on the reservation; to the U. S. Navy Photographic Laboratory, Quonset Point, Rhode Island, for taking vertical and low-altitude photographs for use in preparing new maps; to Miss Norine Mattimore, formerly of Earth Sciences Division, for tabulating a large part of the climatic data of the Base Station; to the Office of Post Engineer for furnishing information on the facilities and boundaries of the NLABS Annex; and to Miss Susan Woodward, formerly of Earth Sciences Division, for considerable assistance in preparing new maps, including field checks on many important details and necessary revisions of preliminary drafts to coincide with new map projection.

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ABSTRACT

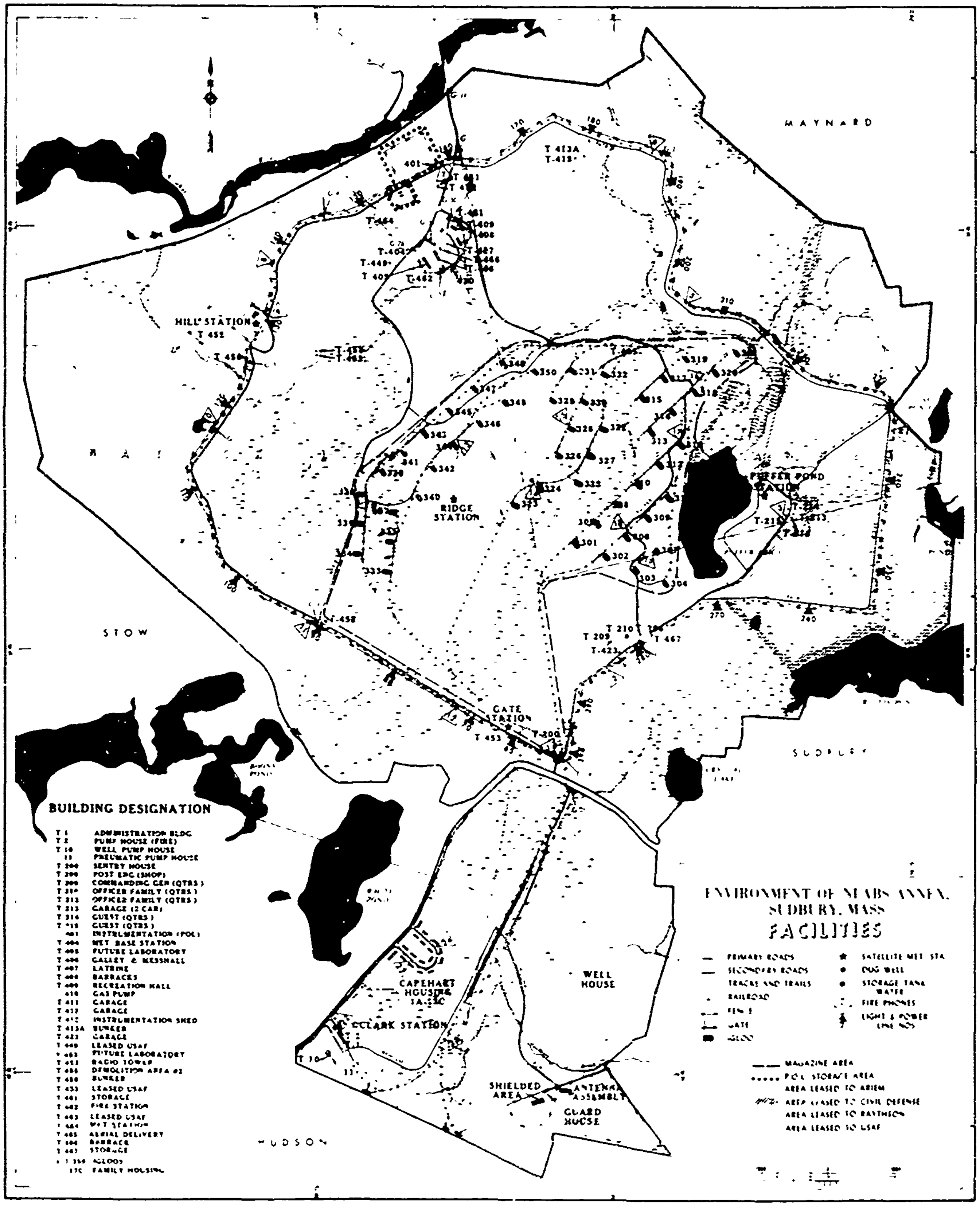
This report describes the environmental conditions at the U.S. Army Natick Laboratories Annex. This facility provides a nearby, adequately large area in an essentially rural locality for conducting field research and for developing and testing materiel. There are important environmental contrasts in slope, soil, drainage, vegetation, and in microclimate. Its climate is generally representative of intermediate climatic conditions specified in AR 705-15, Operation of Materiel under Extreme Conditions of Environment.

Characteristic landforms consist of level to slightly undulating lowlands and oval-shaped hills. The larger hills, rounded by glacial action, form conspicuous features that are over a hundred feet higher than the adjacent lowland. Swamps and marshes are numerous, vary greatly in size, and occur in lower parts of many lowlands. However, their extent in relatively level areas varies considerably with the amount of precipitation and season of the year.

Soils occurring in the reservation are closely related to elevation, texture of glacial materials, and drainage. Stony, loamy sand soil derived from granite and gneiss material occurs on well-drained hills. Most of the lowlands have a loamy sand soil, but muck and peat are found in poorly drained areas.

Temperatures at the Annex station are representative of conditions in the surrounding area. Daily maximum temperatures in summer average about 79°F; daily minima in winter are 32°F and below almost every day from December through March. Mean annual precipitation is 46.31 inches. Mean annual snowfall is about 57 inches. Severe flooding occurs infrequently.

The reservation is covered mostly with mixed deciduous hardwoods and conifers. The forests have been cut over many times but some dense stands of hardwood saplings occur in more recently abandoned fields.



MAYNARD
HILL STATION
STOW
RIDGE STATION
PUFFER POND STATION
GATE STATION
SUDBURY
BUILDING DESIGNATION
ADMINISTRATION BLDG
PUMP HOUSE (FIRE)
WELL PUMP HOUSE
SENTRY HOUSE
OFFICER FAMILY (QTRS)
GUEST (QTRS)
FUTURE LABORATORY
BARRACKS
GAS PUMP
GARAGE
INSTRUMENTATION SHED
LEASED USAF
STORAGE
FIRE STATION
AERIAL DELIVERY
FAMILY HOUSING
CAPEHART HOUSING
CLARK STATION
WELL HOUSE
SHIELDED AREA
ANTENNA ASSEMBLY
GUARD HOUSE
HUDSON
SUDBURY, MASS
FACILITIES
PRIMARY ROADS
SECONDARY ROADS
TRACKS AND TRAILS
RAILROAD
SATELLITE MET STA
STORAGE TANK WATER
FIRE PHONES
MAGAZINE AREA
AREA LEASED TO CIVIL DEFENSE
AREA LEASED TO RAYTHEON
AREA LEASED TO USAF

Figure 1

ENVIRONMENT OF NLABS ANNEX, SUDBURY, MASSACHUSETTS

1. Introduction

The U.S. Army Natick Laboratories Annex (NLABS Annex) is a $4\frac{1}{2}$-square-mile military reservation administered by the U.S. Army Natick Laboratories (NLABS), Natick, Massachusetts. The reservation is within the town of Maynard, Sudbury, Stow, and Hudson, Massachusetts (Fig. 1). The headquarters* area (Photo. 1) is in Stow; the closest business district is in Maynard; the mail is delivered through the post office at Hudson; and the main gate is in Sudbury. This entrance, the only one kept open, is about 25 miles west of Boston by highway and is about 12 miles northwest of the Natick Laboratories (Fig. 2 , Photo. 2). The NLABS Annex is 28 miles by highway from Logan International Airport, Boston, and 16 miles from L. G. Hanscom Field, Bedford, Massachusetts.

The NLABS Annex is readily accessible by several roads. The main gate is off Hudson Road about $2\frac{1}{2}$ miles west of its junction with route 27. This road in conjunction with either Sudbury Road or Main Street connects state routes 27 and 62 via the settlement of Pine Lake. Several state and federal routes crisscross the area near the reservation. Passenger transportation between NLABS and NLABS Annex can usually be provided in military vehicles. The trackage leading to the 50 bunkers (ammunition igloos) and other facilities in the reservation was recently sold (1966) and will be removed.

The NLABS Annex is a primary testing area of NLABS and the Army Research Institute of Environmental Medicine (ARIEM), a tenant at NLABS. A number of different environments are in the 2,947-acre reservation within a $\frac{1}{2}$-hour drive by automobile. The reservation is used mainly for airdrops of materiel and men, testing of military equipment, exposure of textiles, storage of supplies and equipment, and housing of military personnel. The reservation also serves as a convenient place where NLABS scientists can try out new instruments, equipment, field methods, and techniques.

A number of NLABS Divisions have used the Annex for a wide variety of projects. For instance, the Airdrop Engineering Division has laboratory, airdrop, and storage facilities at the Annex and conducts proficiency parachute jumps for its personnel needing such training. Their airdrop facility is used in the development of special-purpose parachutes and other airdrop equipment (Photo. 3). This Division also makes many tests at their drop-pad facility on Puffer Pond Road. The Mechanical

*Deactivated prior to 1 February 1966

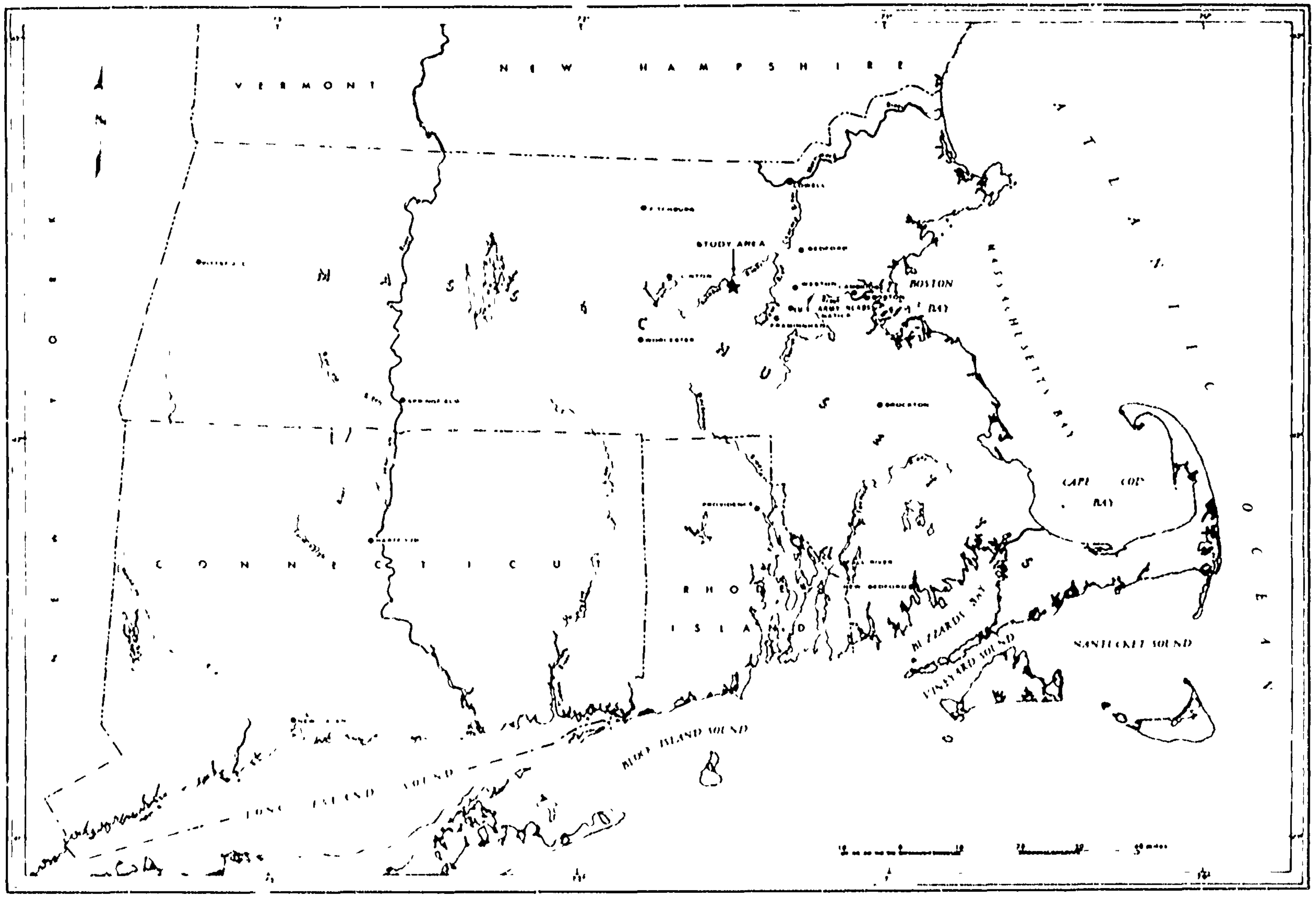


Figure 2. NLABS Annex location

Engineering Division runs field tests of equipment (vehicular, tentage, etc.) in the reservation, and the Clothing and Organic Materials Division performs exposure tests on fabrics in different environments (Photo. 4 , 5). The NLABS Annex is occasionally used for in-house evaluations of new concepts and proposals by representatives of private industry.

The Army Institute of Environmental Medicine (ARIEM) has about a 750-acre tract in the northeast part of the reservation on which tests can be made. This area will be used primarily for the measurement of military physical performance of volunteer test subjects. Attempts will be made to correlate these data with other variables, such as motivation, heat, cold, altitude, and fatigue.

Other government agencies have leased parts of the reservation mostly for research purposes. It is used by personnel of the Air Force Cambridge Research Laboratories (AFCRL) for weather radar and other experiments, by civilian contractors on special projects, and the Office of Civil Defense. The latter organization has leased 262 acres in the eastern part of the reservation near Gate 11 for construction of a major installation.

All buildings and bunkers designated by official numbers are shown on Figure 1. Both residential and nonresidential buildings include new as well as old. Six or more of the remaining buildings in the headquarters area, erected about 1952, are used for a variety of research purposes and for storage. One of the buildings, T-404, at the edge of White Pond Road became the weather station in the summer of 1966 and living quarters for the meteorological team at Base Station. Three of the former private homes provide residences for high ranking Army officers at NLABS. The Capehart housing area, in the south end off Concord Road, consists of 16 duplex and 1 triplex units (35 apts.), completed in October 1962 (Photo. 6). Officers live with their families in part of the development; enlisted personnel in the other part. There are a number of other buildings, as indicated on the location map (Fig. 1). Most of the buildings and bunkers are in constant use or used most of the time; others may only be used for various temporary projects. They provide mainly storage areas for various divisions at NLABS, ARIEM, and other government agencies; others provide important field facilities for various projects (Photo. 1 , 7).

The NLABS Annex averages over 200 feet in elevation and is near the inland (west) margin of the glaciated Atlantic coastal plain. Several rounded hills rise about 100 feet above the lowland, which is poorly drained in many places. Both the lower and higher areas are mostly covered with trees, varying greatly in size and composition.

The temperate climate of the reservation is modified by the nearby Atlantic Ocean. However, weather patterns result primarily from an easterly movement of high and low pressure areas. At times a shift in the wind brings cool, moist maritime air into the region. Occasionally, a "northeaster" can be hazardous to more exposed areas because of its characteristically high winds and heavy precipitation.

In eastern Massachusetts, cyclonic storms are common as many tracts cross the area. Cool, dry air masses from the subarctic mix with warm, moist air from the Gulf of Mexico and form cyclonic storms that are swept generally eastward by the westerlies. The Appalachians cause some modification in both types. Variable weather is characteristic, with changes about twice a week with no consistent pattern.

The climate at NLABS Annex is generally representative of intermediate climatic conditions specified in AR 705-15, Operation of Materiel under Extreme Conditions of Environment. Thus the reservation provides a suitable, much needed nearby area for developing and field testing materiel by NLABS and other government agencies.

2. Bedrock Geology

The bedrock beneath the NLABS Annex consists of igneous and metamorphic rocks. From oldest to youngest they are (Fig. 3): (a) Marlboro formation, Precambrian (?), a predominately fine grained thinly laminated medium-gray to dull-olive-gray amphibolite schist in the extreme southern part of the reservation; (b) Salem (?) gabbro-diorite, Devonian, a dark greenish-gray medium to coarse-grained rock of uneven texture along the southeast margin of the reservation; (c) Dedham granodiorite-quartz diorite facies, Devonian, massive, medium-grained, medium-light-gray rock; (d) Nashoba formation, Carboniferous, a predominately light-gray, medium-grained metamorphic rock underlying the extreme western part of the reservation; (e) Gospel Hill gneiss, Carboniferous, medium- to coarse-textured, moderately foliated granite gneiss; weathers to pearly gray to almost white; fresh surface pinkish or flesh colored. Gospel Hill gneiss underlies the northwest part of the reservation, about 1/2 its area (Hansen, 1956; Perlmutter, 1962).

The above units strike generally to the northeast and form the core of a closely folded asymmetrical anticline whose arc plunges to the northeast. Dips are generally steep. Thus the width of each bedrock area tends to vary in either of these directions. Joints are common in the outcrops of bedrock and presumably occur in the rocks beneath the glacial deposits. No significant faults have been noted.

The Marlboro formation and the Gospel Hill Gneiss crop out in five areas of ground moraine; the latter also crops out in an outwash plain south of Vose Hill. All ground moraine areas in the reservation are situated at higher elevations than are outwash plains, where glacial streams sorted and deposited additional materials over bedrock exposures. Hence outcrops are more frequent in these areas (Fig. 5).

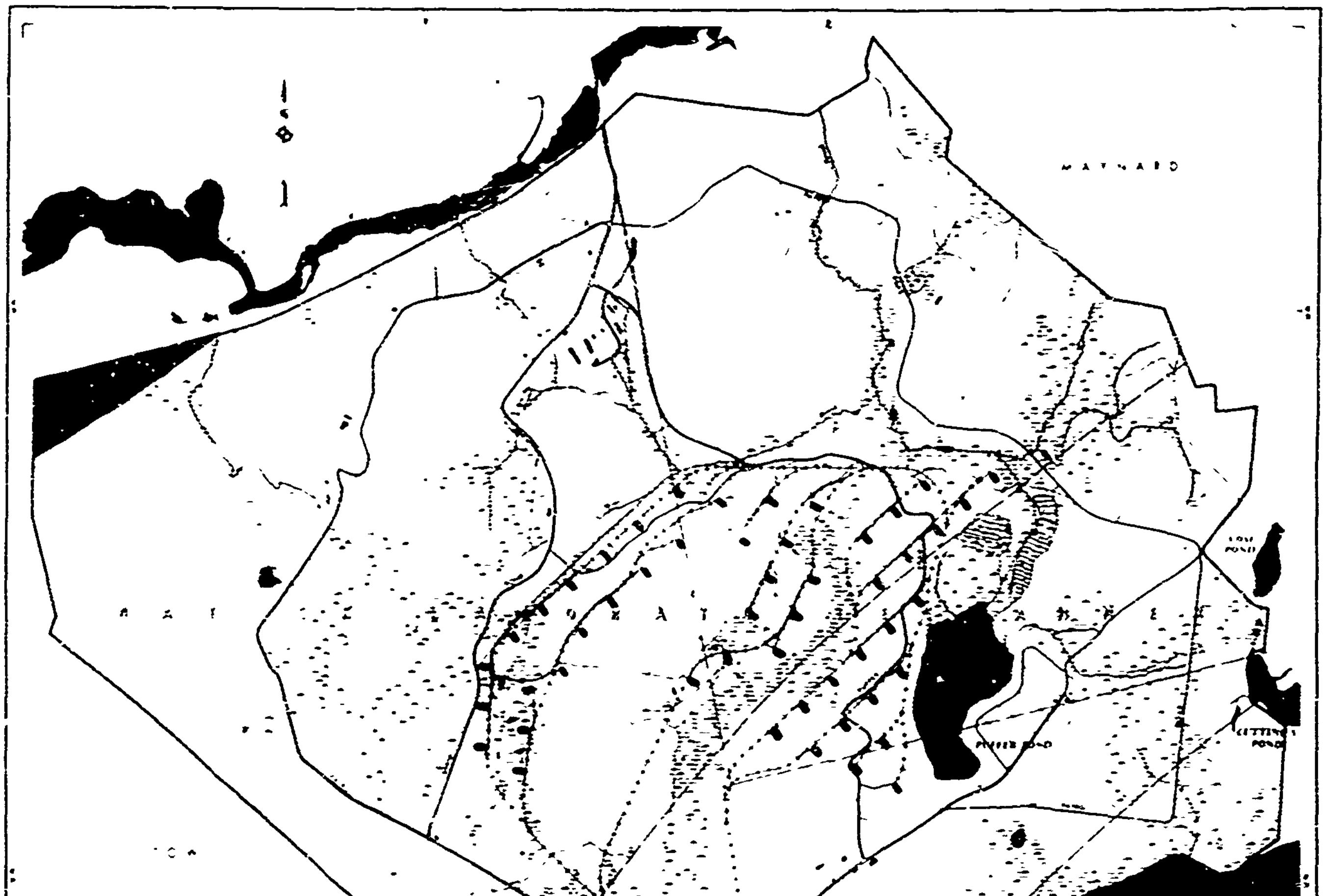

MAYNARD
BEDROCK GEOLOGY
GOSPEL HILL GNEISS
NASHOBA FORMATION
QUARTZ DIORITE FACIES OF THE DEDHAM GRANODIORITE
SALEM GABBRO DIORITE
MARLBORO FORMATION

Figure 3

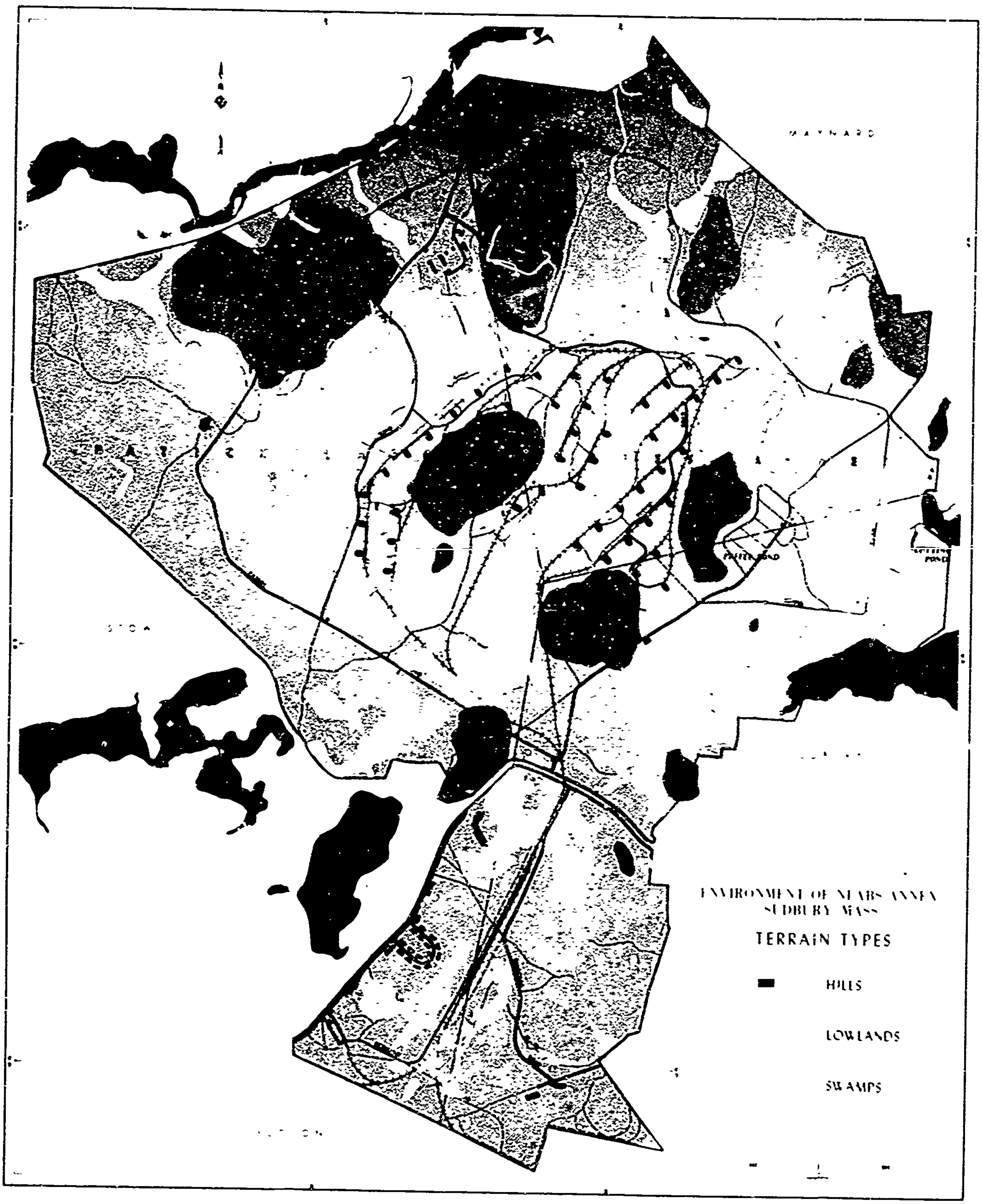


Figure 4

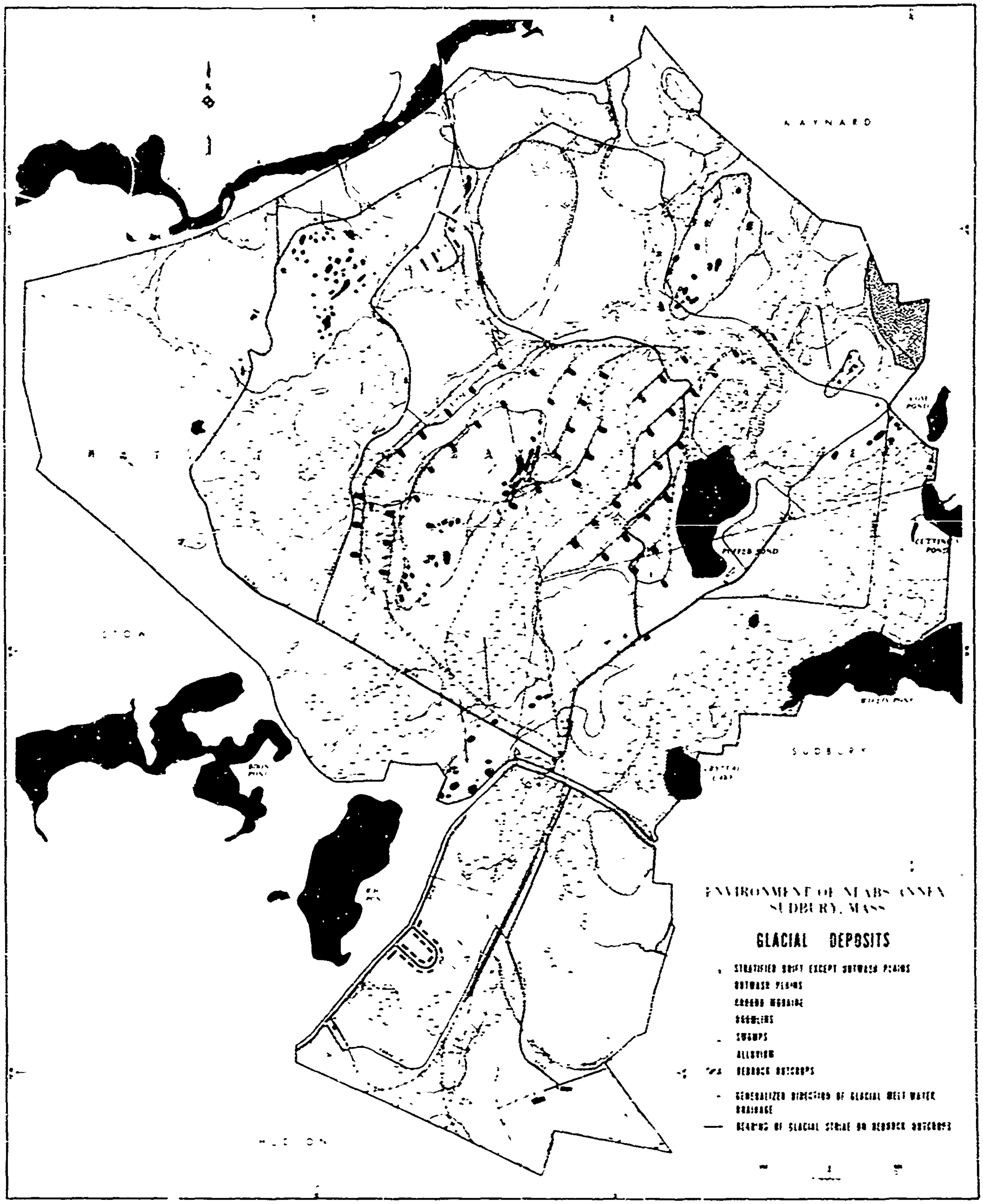


Figure 5

Glacial deposits include pitted outwash; fine-grained, slack-water deposits; and ground moraine. The degree of sorting and thickness of the outwash is locally quite variable, ranging from well sorted and stratified sand and silt to poorly sorted gravel and boulders which show little stratification. In outcrop areas, outwash deposits are thin or absent, however, in local depressions thicknesses of 20 feet or more may be encountered. In the southern portion of the reservation the average thickness ranges to 100 feet but averages approximately 50 feet (Perlmutter, 1962). Below the 200-foot contour outwash is the uppermost deposit. The underlying ground moraine deposits are compact and composed of a wide range of grain sizes and lithology.

3. Terrain and Drainage

The NLABS Annex lies mainly in the drainage area of the Assabet River (Fig. 1), which partially bounds it on the northwest; the southeast margin of the reservation drains into lakes or tributaries of the Sudbury River. Taylor Brook, flowing north to the Assabet River, is the largest stream draining the reservation. Puffer Pond* containing approximately 2531 acres, is the only large body of water within the area. Over 1/2 of Crystal Lake, 1/3 mile east of the main gate, lies inside the NLABS Annex. The northwest shore of Willis Pond forms part of the reservation boundary.

The two characteristic landforms in the reservation are level to slightly undulating lowlands and oval-shaped hills (Fig. 4). Lowlands make up about 80 percent of the land area, ranging in height from about 180 feet to slightly over 200 feet; the lower lowland areas and basins are poorly drained. The remaining 20 percent of the NLABS Annex is hill land.

Lowlands. A difference of only a few feet may separate marshes or swamps from adequately drained places; the transition from one to the other may be gradual or abrupt. Poorly drained sections of lowlands occur in most parts of the NLABS Annex and constitute about 1/4 of the total area. Numerous swamps, ponds, and undrained depressions are typical of poorly integrated drainage in recently glaciated regions. These areas range greatly in size. Although unsorted glacial materials of low permeability underlie some areas, sorted glacial materials, such as outwash, are likely to be highly permeable and afford good drainage. Surface runoff on lowlands is slow, streams are sluggish, and the water table is high. Since postglacial stream erosion of bed and banks is insignificant, valleys are broad, shallow, and poorly drained. Narrow, steep-sided gullies are common but only three are of significance, one west of the headquarters area near the Assabet River and two which cross the east boundary of the reservation south of Hudson Road (Fig. 1).

*Leased annually from the Commonwealth of Massachusetts. Puffer Pond is not included in the 2,947 acres of U.S. Government-owned land at the NLABS Annex.

Numerous bodies of water, including small man-made water holes, reflect the normally high water table in the area. The extent of swamp and marshland becomes significantly larger after periods of appreciable precipitation, but following prolonged drought they dwindle greatly in size. Little, if any, surface water could be found in many low areas field checked during late autumn and early winter of 1965 and spring of 1966. Although the flats along perennial streams remained precariously soft, the ground surface in many of the temporarily dried-up swamps provided good support for a man on foot, including some areas 4 or 5 feet below normally moist surfaces. In these usually swampy area, characteristic miniature hummocks ranged in height from a few inches up to about 3 feet. Aside from occasional dry cycles, the extent of swamp and marshland also varies seasonally, usually greatest in spring and least in summer.

There are two wells in the reservation south of Hudson Road. The well at T-11 (pump house) is 180 feet deep and has a 6-inch casing. The well north of Diagonal Road is only 30 feet deep and has a 10-inch casing. The larger output of the latter well is rated at 300 gallons per minute. The water from both wells is very high in iron bicarbonate and of poor quality. Through an arrangement with the Town of Maynard, good quality water is obtained from White Pond.

Hills. The larger topographic features consist of several rounded hills, including both drumlins and roches moutonnées. They are mainly in the northern and central areas, and rise from under 200 to over 300 feet above sea level. Four of the hills, on or near the northern border of the reservation, have an elevation of at least 300 feet. The highest hill, also in the northern area, is 323 feet above sea level; the lowest elevation, about 163 feet, is on the southern margin of the reservation, giving a range in relief of 160 feet.

Local relief varies from less than 10 feet in the vicinity of swampy areas to over 70 feet in areas of higher and more prominent hills, the latter are almost entirely in the northern and central parts of the reservation. A local relief of 10 to 20 feet is common in outwash (lowland) areas.

In the reservation there are four streamlined hills of unsorted glacial debris, called drumlins (Fig. 1, 5). The two larger drumlins in the north and northeast areas include the hill south of Tuttle Hill, the highest hill in the reservation (Photo. 12, 15), and part of Vose Hill, third highest hill (Hansen, 1956). The two drumlins are typically streamlined, oval-shaped, north-south oriented with steep slopes. South of Hudson Road, there are two less well formed, small drumlins with gentle slopes and a northwesterly alinement (Perlmutter, 1962). However, in this relatively flat area, they protrude conspicuously above mostly stream-laid materials. The orientation of the drumlins indicates the general direction that the latest ice sheet (Wisconsin) moved in each area (Hansen, 1956).

Most of the hill terrain has a moderate slope, ranging from 5 to 25 percent. However, slopes up to 25 or 35 percent are found on the western and southwestern sides of the higher hills, such as Tuttle Hill and the hill south of it. Hill tops are small but relatively level. Terrain over 300 feet in elevation is less than .5 percent of the area in the reservation.

4. Soils

At the NLABS Annex, the soils, classified as brown podzolic, are derived from glacial materials (Latimer and Lanphear, 1929). Their composition is similar in character to the underlying rock formation. The brown podzolic soils developed under a deciduous or mixed deciduous and coniferous forest in a humid, cool-temperate environment. They are acidic and infertile. The effect of humid climate is shown in the absence of soil carbonates and the effect of forest cover is evident in the low percent of organic matter in the well drained soils.

The depth of weathering seldom exceeds 2 feet and is determined to some extent by the character and depth of glacial materials, being deeper in areas of feldspars, ferro-magnesian minerals and shale (Latimer and Lanphear, 1929). There has not been sufficient time for any important accumulation of fine material within the weathered zone.

A striking feature of the soil profile is the characteristic vertical color variation or banding with no marked or consistent change in texture. The five soil series are shown in Figure 6. Pertinent facts concerning each type, including topographic location, geologic origin, and general description are outlined in Table 1.

The three most common soil series are: (1) Merrimac on outwash plains, (2) muck and peat on low, poorly-drained sections of the lowland and along stream beds, and (3) Gloucester on well-drained glacial till of uplands and hills. In areas undisturbed by human activities, the Merrimac and Gloucester soils are covered with a leaf litter and mold to a depth of 1 or more inches in most places. Below the litter a dark grayish-brown or rust-brown horizon 6 to 8 inches thick is underlain by a yellowish-brown subsoil which becomes paler with depth. At a depth of about 2 feet, the subsoil grades into usually gray, unweathered parent material. In some local areas, particularly on drumlins, thin Gloucester soil is underlain by a cementlike or compacted layer*.

Muck and peat are organic soils found only in areas where water stands at the surface most of the year. They are more or less spongy--never firm. These soils become lighter in color from surface to substratum, which is often underlain by gray or white sand. Muck consists of finely divided organic matter containing some mineral soil material. The upper 12 or 15 inches of organic matter is partially decomposed but

*Often called "hardpan". It is a compact layer in the original glacial drift (Latimer and Lanphear, 1929).

TABLE 1. SOILS AT NLABS ANNEX

Soil Series	%	Location	Origin	Description
Gloucester	15	Gentle slopes on hills, ridges, and uplands; excellent drainage	Loose, coarse unstratified glacial debris - mostly granite or granite-gneiss	Brown topsoils and yellowish-brown subsoils that become paler with depth and grade, at about 2 feet, into a substratum gray, unweathered, porous, and light-textured. Noticeable quantity of rounded and subangular stone; sandy loam best of series and less droughty than stony sandy loam.
Hinckley	1	Irregular hummocks (kames, eskers, and moraines)	Partially sorted glacial drift	Brown topsoils and yellowish-brown subsoils that become paler with depth and then grade, at about 2 feet, into a gray substratum of mixed sand and gravel. Light texture and excessively droughty.
Meadow	1	Frequently inundated lowlands	Lowlands subjected to flooding	Topsoils dark brown or black and often mucky; subsoil gray or dark gray mottled with brown, rust brown, or yellow. Substratum gray or light gray; variable texture ranges from sand to clay.
Merrimac	52	Terraces at various elevations	Stratified coarser sand and gravel of glacial outwash	Brown topsoils and yellowish-brown subsoil that become paler with depth. Sand and gravel substratum below a depth of 2 feet. More loamy at surface.
Muck and peat	31	Low, level areas	Poorly drained areas left by the ice sheet	Include all organic soils more than 18 inches thick. Muck consists of black, well-decomposed organic matter mixed with some soil material, underlain by brown or dark-brown, partly decomposed organic matter. Underlain, at depth of less than 4 feet, by a sandy substratum. Peat deposits commonly deeper and consist of a mass of brown fibrous, partly disintegrated plant remains.

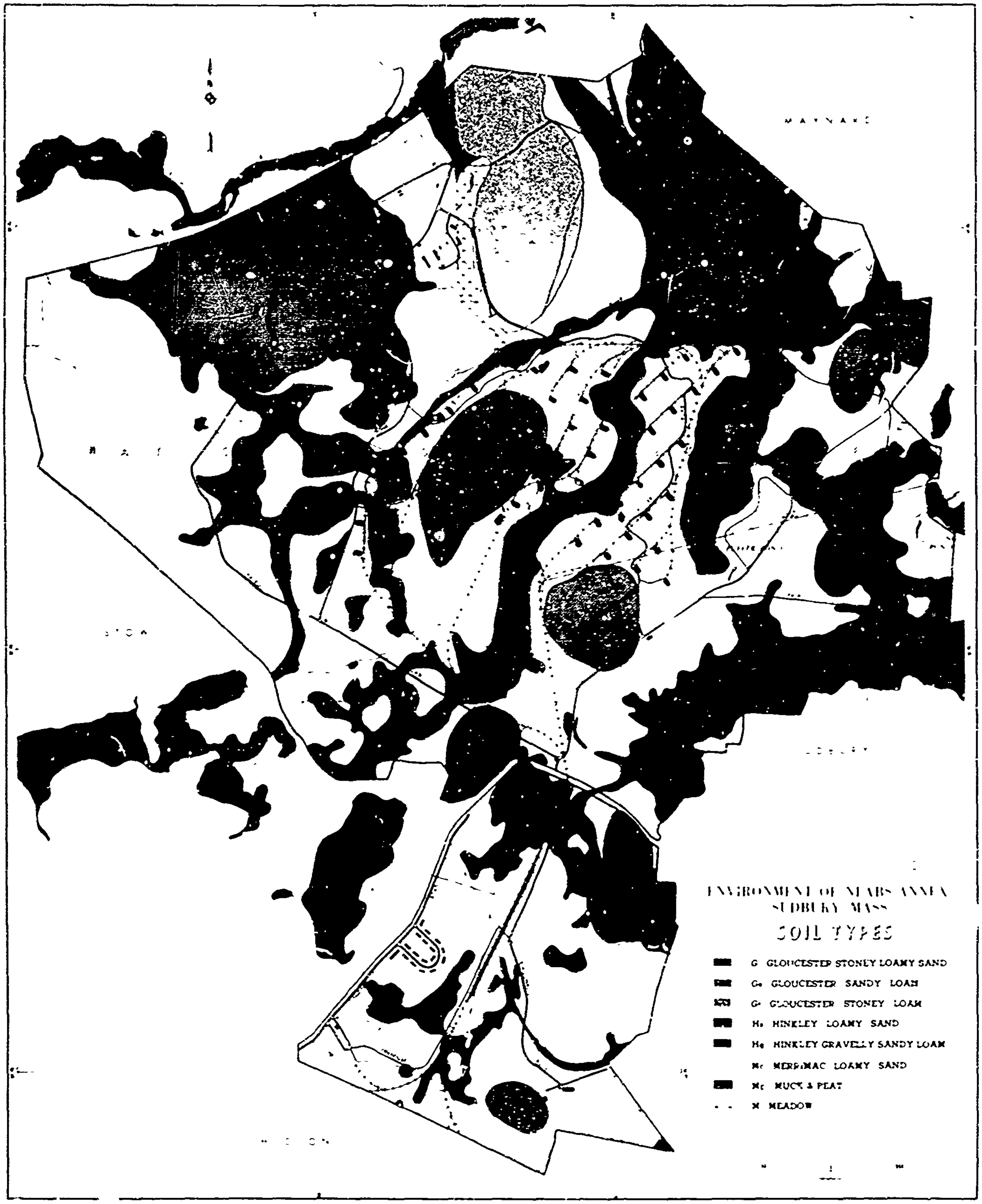

SOIL TYPES
G GLOUCESTER STONEY LOAMY SAND
GLOUCESTER SANDY LOAM
GLOUCESTER STONEY LOAM
HINKLEY LOAMY SAND
HINKLEY GRAVELLY SANDY LOAM
MERRIMAC LOAMY SAND
MUCK & PEAT
M MEADOW

Figure 6

becomes less so at greater depths. Deposits of muck usually range in thickness from 2 to 3 feet but occasionally reach 6 feet. Muck is found in stream bottoms and around the margins of swamps. When areas of muck are drained the land has a tendency to compact particularly if the vegetation is removed or destroyed. This produces a noticeably lower surface level.

Peat consists of brown, fibrous, partly disintegrated plant remains, including much woody material in deeper parts of such deposits. Peat is less compact, less decomposed, and contains much less mineral material than muck. Deposits range from 3 to 30 or more feet deep (Latimer and Lanphear, 1929). The depth depends largely on the original depth of a filled-in lake and the amount of accumulated plant remains.

Of the five soil series, loams and sandy loams of the Gloucester soils and the more clay rich Merrimac soils are the better drained and more fertile in the reservation, although they are low in humus.

5. Climate

Base weather station and data

Weather data used in this study unless otherwise indicated are based on observations taken at Base Station* in NLABS Annex by the U.S. Army Electronics Research & Development Activity, Fort Huachuca, Arizona. This station is at the headquarters in the northern part of the reservation. (Fig. 1). The weather station building T402A, until the summer of 1966** was about 300 yards southwest from the junction of White Pond and Puffer Roads (Photos. 3, 8).

The station, officially 205 feet above sea level, is in a small, open, lowland area. Forested hills, some of them steep, are about 100 feet above the lowland within a radius of 3,500 feet of the station on the west, east, and northeast sides. The closest and most conspicuous is a north-south oriented hill about 1,000 feet east of the station.

The nature and frequency of observations varied considerably in the 5- to 6-year period from June 1958 through August 1963, with a few minor exceptions. From June 1958 to July 1961, hourly observations were taken from 0800 to 1700 hours, except from April to May 1960 when hourly observations were taken from 0600 to 2000 hours. Since August 1961, hourly

*Although Maynard, Mass., is the station name used on Signal Corps Form 444, surface weather observations (WBAN 10A and 10B), and is near the business district of Maynard, the station is referred to in this report as Base Station or NLABS Annex. It is actually on the part of the reservation that is within the Town of Stow.

**Indoor weather instruments were moved into building T404 on opposite side of White Pond Road but location of outdoor instruments remains unchanged. Building T402A, the vacated building, was destroyed.

observations for the period of this study have been on a 24-hour basis. Hourly data for dry bulb temperatures and relative humidity are available from hygrothermograph charts for the entire period. Details concerning the Base Station data used are given in Table 2.

TABLE 2. CLIMATIC DATA FROM NLABS ANNEX

	No. Obs/Day	Date Began	Date Ended
Temperature	10-24*	Jun 1958	Aug 1963
Precipitation	3-4	Jun 1958	Aug 1963
State of ground	3-4	Jun 1958	Aug 1963
Peak wind gust	1	Jun 1958	Aug 1963
Wind speed	24	Aug 1961	Aug 1963
Wind direction	24	Aug 1961	Aug 1963
Relative humidity	24	Aug 1961	Aug 1963
Sky cover	24	Dec 1961	Aug 1963
Fog**	24	Jan 1962	Dec 1963
Haze**	24	Jan 1962	Dec 1963
Visibility	24	Jan 1962	Dec 1963

*Hourly observations starting with August 1961
**Also time beginning and ending

Temperature

Temperature at Base (NLABS Annex) Station: The reservation has warm summers and moderately cold winters. At this station, mean daily maximum and minimum temperatures for July*, the warmest month, are 80° and 57°F, respectively (Table 3). Mean temperatures during autumn (Sep, Oct, and Nov) average 5 F degrees warmer than spring (Mar, Apr, and May). Mean annual temperature for the 5- to 6-year period of 1958-1963 is 47°F.

*Mean temperature for July, 68.8°F, is only slightly higher than that for August, 67.3°F.

The absolute maximum temperature recorded at NLABS Annex is 96°F and the lowest recorded observation at this station is -21°F, occurring in July and February, respectively (Table 3). This gives an absolute range of 117 F degrees. However, it should be pointed out that greater extremes in temperature have occurred at some satellite stations in other parts of reservation where environments are also more extreme than at Base.

Diurnal ranges in temperature are large, but they can be even more pronounced in dry, cool weather in low areas. Monthly mean diurnal temperature ranges between 20 and 26 F degrees (Table 3, Fig. 7). These ranges are a few degrees greater in the warmer months. The maximum diurnal range for each month exceeds 40 F degrees; the greatest diurnal range, 55 F degrees, occurred in April. The effect of the station's proximity to the Atlantic coast (27 mi) is minimized by the prevailing westerly winds.

Compared to the interior parts of the United States, extremely high or extremely low temperatures occur infrequently, but the number of such temperatures may vary appreciably in one or more months of any particular year. In Table 4, the frequency of selected daily maximum and daily minimum temperatures are tabulated for each month and year of record. Maximum temperatures of 90°F and above normally occur 1 or more days each month from May through September. Days on which maximum temperatures remain 32°F or below occur on 44 percent of the days from December through February and are limited almost entirely to the 4-month period from December through March. On the other hand, minimum daily temperatures of 32°F and below occur almost daily from December through March and on about 1/2 the days in October, November, and April; they average less than 1/2 the days each year. Minimum daily temperatures of 0°F and below occur 10 days each winter (Dec - Feb).

Although the correlation of maximum and minimum frequency data for months of different years is moderately good, striking differences do occur (Table 4). For example, the number of days with maximum temperatures of 32°F and below was almost four times greater in December 1958 than in December 1959. Similarly, the number of days with minimum temperatures below zero was 9 times greater in January 1961 than they were in January 1962.

Temperatures at Base and Satellite Stations:

In addition to observations taken at Base Station, temperatures have been recorded on thermograph charts at five satellite stations during most of the period that Base has operated. Pertinent features of local environment at each station are outlined briefly in Table 5 (Fig. 1).

TABLE 3. DAILY MEANS, ABSOLUTE EXTREMES AND RANGES OF TEMPERATURE (F) AT NLABS ANNEX
2 June 1958 - 31 August 1963

	(yrs)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Absolute max	5-6	59	67	78	91	93	92	96	93	95	82	75	65	96
Mean daily max	5-6	34	36	44	58	69	76	80	79	74	62	50	36	58
Mean	5-6	24	25	34	46	56	64	69	68	62	50	40	26	47
Mean daily min	5-6	13	14	24	34	43	52	57	56	49	38	30	15	35
Absolute min	5-6	-15	-21	3	19	27	29	39	39	26	16	11	-7	-21
Average 24-hr range	5-6	21	22	20	24	26	25	23	24	25	23	21	20	23
Max 24-hr range	5-6	46	50	49	55	43	42	41	42	41	41	47	41	55

TABLE 4. NUMBER OF DAYS WITH SELECTED DAILY MAXIMUM AND MINIMUM TEMPERATURES AT NLABS ANNEX*

1 June 1958 - 31 August 1963

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Days with Maximum Temperatures of 90°F and above													
1958	-	-	-	-	-		1						-
1959					2	2	1	5					10
1960						1	2	1	1				5
1961						1			3				4
1962				1	1								2
1963						3	9		-	-	-	-	-
Avg				**	1	1	2	1	1				6
Days with Maximum Temperatures of 32°F and below													
1958	-	-	-	-	-						1	18	-
1959	14	11	4									5	34
1960	7	7	9									14	37
1961	19	7	2									10	38
1962	13	12	2									12	39
1963	12	14	2						-	-	-	-	-
Avg	13	10	4								**	12	39
Days with Minimum Temperatures of 32°F and below													
1958	-	-	-	-	-	1			1	13	18	31	-
1959	30	27	25	11	2				4	12	18	26	155
1960	31	26	28	10						7	17	30	149
1961	30	22	27	10	4				2	6	18	30	149
1962	30	28	26	14	4					13	26	29	170
1963	31	28	29	21	4				-	-	-	-	-
Avg	30	26	27	13	3	**			1	10	19	29	158
Days with Minimum Temperatures of 0°F and below													
1958	-	-	-	-	-							4	-
1959	2	3										1	6
1960	3											6	9
1961	9	5											14
1962	1	6										6	13
1963	2	7							-	-	-	-	-
Avg	3	4										3	10

-Months with no data or years with incomplete data.
*Months with no values indicates a frequency of "0".
**.5 day or less.

TABLE 5. ELEVATION AND LOCAL ENVIRONMENT AT BASE AND SATELLITE STATIONS

Station	Elev (ft)	Where Situated
Base Sta.	205	Lowland in small, open, or grassy area; partially surrounded by conspicuous hills in vicinity
Clark	180	Lowland between edge of small pitch pine grove and an open, flat, sandy area to west; no important hills or valleys in nearby area
Gate	190	Moderate north slope near foot of small hill; hardwood forest of moderate height, upper story not very dense with an understory of mixed hardwood and white pine saplings; asphalt patrol road nearby on SSW side
Hill	300	Was in grassy area near top of second highest hill in reservation but much of nearby area has since been paved with asphalt on one side; long, steep slopes to north, south, and west of station; except for clearing along patrol road and adjacent security fence, forested slopes range from pure white pine to hardwoods
Puffer Pond	180	Northeast of Puffer Pond on lowland about 50 feet from a large swamp; mixed hardwood-conifer forest, including large trees at station and some moderately dense underbrush in surrounding vicinity
Ridge	260	Top of large hill about 1/2 mile west of Puffer Pond in small clearing in a relatively open white pine grove mixed with some hardwoods

Mean and mean maximum temperatures at each satellite station for January and July 1961 varied not more than 3 F degrees from comparable temperatures at Base Station compared to mean minimum variation of not more than 5 F degrees for the same months and stations (Table 6). Other months of data for these stations showed similar trends.

Five-day, running-mean temperatures for Base Station and the satellite stations are shown in Figure 8 from 3 to 29 January 1961. The graph shows that Clark was coldest and Hill was warmest most of the time; Base temperature values were about average of the temperatures experienced at satellite stations. Although the illustrations show clearly the comparative trends of mean values for each station, it does not show the frequent, often significant day-to-day variations from normal trends among the stations.

During the cold period from 10 to 13 January 1961, daily minimum temperatures at each station were fairly uniform with respect to relative severity and to normal daily differences among the stations. Assuming reasonable accuracy of thermograph traces (to 2± degrees), the different environments of the satellite stations produced some important temperature variations. Aside from relative day-to-day differences among the stations for some periods, this period was generally consistent with longer period trends. For instance, Clark was the coldest station. It was on a flat, sandy area between a small grove of pitch pine and an open area (Fig. 9). By contrast, Hill was the warmest. This is to be expected of a site in an open area on top of a prominent hill, particularly regarding minimum temperatures at night. In this 4-day period, daily minimum temperatures at Hill ranged from 13° to 17°F compared to 3° to 6°F at Clark, averaging 14° and 4°F, respectively.

At about 0700 hours, 13 January 1961, a well-developed warm front passed over the reservation (Fig. 9). In the next six hours, temperatures rose from a minimum of 12°F to a maximum of 41°F at Hill and from 6° to 46°F at Clark. The effect of its passage also narrowed the range in temperature between these two extreme satellite sites. Thus the daily maximum on this day (13 Jan) was 46°F at Clark and 41°F at Hill. The following day (14 Jan), temperatures continued to climb more slowly, reaching a maximum of 49° at Clark and 48°F at Hill. Even though lower minimum temperatures were recorded each day at Clark than at Hill, maximum temperatures at Clark were the same or higher than at Hill on three out of five days, giving higher ranges in temperature at the lower station. Ranges in temperature at Clark were also the highest of any other station in the reservation during January and July 1961.

In the period from 20 to 22 January 1961, a well-developed storm was off the Mid-Atlantic coast on 20 January, producing strong winds over eastern Massachusetts (only up to about 13 knots at Base Sta.) and nearly an inch of snow fell at the main station in the reservation. At both Clark and Hill on 20 January daily minimum temperatures were 5°F; the minimum at Base Station was only 1 F degree lower (Fig.10). The next day (21 Jan) maximum temperatures increased moderately; minimum temperatures decreased moderately but more at Base Station and Clark than at Hill (Fig.10). On the third day (22 Jan), the minimum at Clark had dropped to a record low (-25°F) for any station operating in the reservation, compared to daily minima of -15°F at Base and only -3°F at Hill. On this last day, the absolute minimum at Clark was 10 F degrees lower than at Base Station and 22 F degrees lower than at Hill. Hill was again the warmest of the three stations on this occasion. In fact, the extreme range in daily maximum temperature for all six stations on the same day was within 2 F degrees.

Temperatures observed are representative of conditions prevailing in the general area of the reservation. Data compiled from NIABS Annex

TABLE 6. DAILY TEMPERATURES AND RANGES AT BASE AND SATELLITE STATIONS IN NLABS ANNEX FOR EXTREME MONTHS
January 1961

Day	Base				Clark				Gate				Hill				Puffer Pond				Ridge			
	Mean	Max	Min	Ra	Mean	Max	Min	Ra	Mean	Max	Min	Ra	Mean	Max	Min	Ra	Mean	Max	Min	Ra	Mean	Max	Min	Ra
1	28	39	17	22	29	42	16	26	26	39	14	25	22	34	10	24	28	40	16	24	30	38	22	16
2	24	34	13	21	20	33	6	27	24	35	13	22	28	36	19	17	24	32	15	17	26	34	19	14
3	20	30	10	20	16	31	1	30	21	32	10	22	-	33	-	-	20	30	11	19	23	31	15	16
4	18	29	8	21	9	23	-5	28	19	32	6	26	26	32	19	13	19	29	9	20	20	29	11	18
5	18	30	7	23	16	22	11	11	18	30	5	25	23	31	15	16	17	28	8	20	21	29	13	16
6	32	45	19	26	22	37	8	29	30	42	18	24	34	44	24	20	32	43	20	23	32	43	22	21
7	36	49	23	26	29	44	14	30	32	44	20	24	41	49	33	16	35	46	24	22	40	47	32	15
8	30	43	16	27	30	41	20	21	26	36	15	21	34	44	24	20	35	42	28	14	33	43	23	20
9	20	28	12	16	22	28	16	12	20	27	12	15	24	30	18	12	22	28	16	12	22	28	16	12
10	20	31	10	21	18	29	7	22	16	26	6	20	24	33	14	19	19	28	10	18	20	29	11	18
11	26	43	10	33	22	42	2	40	24	41	6	35	30	43	18	25	20	41	10	31	27	40	14	26
12	24	36	13	23	20	36	3	33	18	31	5	2	28	38	17	21	24	36	11	25	24	34	13	21
13	24	41	8	33	22	42	2	40	22	38	5	33	27	41	13	28	24	40	8	32	25	39	11	28
14	43	51	35	16	42	51	34	17	36	45	27	18	44	51	36	15	42	49	34	15	41	48	34	14
15	28	34	21	13	28	35	21	14	20	28	12	16	29	36	22	14	28	35	20	15	27	34	20	14
16	24	27	22	5	24	28	21	7	22	24	19	5	28	29	27	2	28	30	25	5	27	28	26	2
17	28	45	11	34	23	42	4	38	25	40	10	30	34	45	23	22	26	43	10	33	32	42	21	21
18	28	37	18	19	22	38	6	32	26	43	9	34	28	40	17	23	38	41	35	6	26	38	15	23
19	12	19	6	13	11	21	1	20	11	17	5	12	16	22	9	13	16	24	7	17	20	21	8	13
20	10	14	5	9	10	14	5	9	8	12	5	7	16	15	6	9	16	15	6	9	10	14	7	7
21	6	20	-8	28	-3	19	-25	44	8	19	5	14	20	40	0	40	2	19	-16	35	10	22	-1	23
22	4	23	-15	38	-1	23	-25	48	15	24	6	18	10	22	-3	25	4	23	-16	39	9	23	-5	28
23	2	18	-13	31	4	22	-14	8	-	18	-	-	2	12	-7	19	4	19	-11	30	6	17	-4	21
24	2	18	-15	33	2	25	-20	45	-	22	-	-	0	15	-14	29	1	20	-18	38	2	16	-11	27
25	8	18	-1	19	7	22	-8	30	-	20	-	-	4	14	-6	20	7	20	-6	26	4	14	-6	20
26	10	23	-3	26	9	26	-8	34	-	23	-	-	8	17	0	17	8	23	-8	31	8	18	-1	19
27	8	20	-5	25	6	24	-12	36	-	23	-	-	8	16	1	17	7	23	-9	32	10	22	-2	24
28	10	23	-4	27	6	27	-14	41	-	25	-	-	8	18	-1	19	8	25	-10	35	10	21	-2	23
29	16	27	6	21	17	31	3	28	-	28	-	-	12	23	1	22	14	29	-1	30	13	24	2	22
30	9	21	-3	24	16	21	10	11	-	20	-	-	14	21	7	14	13	20	6	14	16	22	10	12
31	10	26	6	20	14	24	4	20	-	23	-	-	16	24	7	17	13	24	1	23	20	30	10	20
Mean	19	30	7	23	17	30	3	27	-	29	-	-	21	31	12	19	19	30	8	23	20	30	11	18

TABLE 6. DAILY TEMPERATURES AND RANGES AT BASE AND SATELLITE STATIONS IN NLABS ANNEX FOR EXTREME MONTHS (cont'd)
July 1961

	Base				Clark				Gate				Hill				Puffer Pond				Ridge			
Day	Mean	Max	Min	Ra	Mean	Max	Min	Ra	Mean	Max	Min	Ra	Mean	Max	Min	Ra	Mean	Max	Min	Ra	Mean	Max	Min	Ra
1	64	79	49	30	64	84	44	40	67	79	55	24	66	78	54	24	65	77	53	24	69	81	57	24
2	66	87	46	41	68	93	43	50	71	88	54	34	68	86	50	36	68	86	50	36	72	91	53	38
3	72	81	64	17	72	84	61	23	74	80	67	13	74	83	64	19	72	79	64	15	74	82	65	17
4	62	72	52	20	62	73	50	23	66	72	60	12	62	71	53	18	62	70	54	16	66	75	58	17
5	60	74	46	28	57	74	40	34	64	73	55	18	64	77	51	26	60	72	49	23	67	79	55	24
6	62	76	47	29	62	75	39	46	62	72	52	20	60	73	46	27	58	70	47	23	66	77	54	23
7	66	77	55	22	63	76	50	26	66	72	60	12	65	74	56	18	64	73	55	18	66	74	59	15
8	64	71	58	13	62	72	52	20	66	68	62	6	62	69	55	14	63	68	58	10	64	70	59	11
9	63	71	55	16	60	69	50	19	64	68	59	9	60	68	53	15	63	69	57	12	62	67	56	11
10	66	76	56	20	64	80	52	28	66	71	60	11	70	80	60	20	70	79	62	17	72	83	61	22
11	65	80	50	30	64	82	47	35	64	74	53	21	70	86	55	31	66	78	53	25	70	82	58	24
12	72	86	59	27	72	87	57	30	70	78	61	17	76	88	64	24	72	84	61	23	77	88	66	22
13	76	87	64	23	74	88	60	28	72	79	64	15	77	88	66	22	74	83	65	18	76	87	66	21
14	64	66	62	4	64	67	62	5	63	65	61	4	66	68	63	5	64	66	62	4	64	67	62	5
15	62	65	60	5	64	67	60	7	62	63	60	3	63	66	60	6	62	65	60	5	65	67	63	4
16	64	67	60	7	63	67	59	8	61	62	60	2	64	68	60	8	63	66	60	6	65	67	63	4
17	70	81	60	21	73	82	64	18	68	74	62	12	70	79	60	19	67	75	59	16	68	75	62	13
18	74	87	61	26	75	89	61	28	75	83	67	16	76	87	64	23	76	85	66	19	75	84	65	19
19	74	85	63	22	76	89	64	25	70	77	64	13	72	83	62	21	72	81	63	18	72	81	64	17
20	-	-	62	-	71	80	62	18	72	75	69	[illegible]	72	77	66	11	69	74	64	10	70	74	67	7
21	74	88	60	28	76	92	60	32	74	84	63	21	76	89	63	26	72	83	61	22	74	86	63	23
22	73	85	61	24	76	89	62	27	73	81	65	16	74	84	63	21	73	82	64	18	74	83	64	19
23	74	88	59	29	76	93	59	34	73	83	63	20	76	89	63	26	74	85	62	23	76	87	64	23
24	78	86	69	17	81	88	74	14	84	89	79	10	81	87	75	12	83	87	79	8	82	86	77	9
25	78	86	69	17	78	88	67	21	84	89	78	11	78	87	69	18	77	84	69	15	77	85	69	16
26	75	86	64	22	74	87	60	27	78	85	71	14	77	88	66	22	75	83	66	17	74	82	66	16
27	68	80	57	23	68	84	53	31	70	77	64	13	70	81	59	22	69	77	61	16	71	79	63	16
28	68	84	53	31	68	88	48	40	72	85	60	25	70	85	56	29	70	84	56	28	68	81	54	27
29	68	76	60	16	69	79	59	20	68	76	60	16	69	76	62	14	70	77	64	13	70	76	63	13
30	74	86	61	25	70	86	53	33	78	87	69	18	76	88	63	25	76	86	65	21	74	85	62	23
31	74	84	64	20	76	86	65	21	72	78	67	11	74	86	62	24	73	81	65	16	74	83	66	17
Mean	69	80	58	22	69	82	56	26	70	77	63	14	70	80	60	20	69	78	60	17	71	79	62	17

***Same as main meteorological station (NLABS Annex) of reservation and the principal source of data for the climatic section**

-Missing or incomplete data

TABLE 7. TEMPERATURES (°F) AT NLABS ANNEX AND FOUR LOCAL STATIONS, 1960 - 1962

Daily Maximum		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YEAR
NLABS Annex	1960	35.8	40.0	38.4	60.0	70.9	78.2	80.7	80.1	72.2	61.3	54.5	35.3	59.0
	1961	30.4	38.4	44.1	53.1	65.1	78.6	79.9	79.3	78.0	64.2	49.4	36.0	58.0
	1962	34.3	33.3	45.5	59.5	66.8	77.8	78.1	77.5	69.6	60.6	47.6	35.4	57.2
	Mean (1960-1962)	33.5	37.2	42.7	57.5	67.6	78.2	79.6	79.0	73.3	62.0	50.5	35.6	58.1
Bedford	1960-1962	34.2	39.1	44.1	58.6	69.2	80.6*	82.8*	82.6*	74.7	63.5	47.2	35.7	59.4
Clinton	1960-1962	34.1	35.7	41.4	55.5	66.0	77.0	78.5	77.1	71.7	61.0	49.7	35.6	56.9
Framingham	1960-1962	34.6	38.3	43.3	58.8	69.3	80.4	83.2	81.7	75.8	64.3	49.4*	36.7	59.6
Weston	1960-1962	35.0	39.3	44.7	60.0	69.3	79.9	82.1	82.4	75.9	65.5	51.9	37.2	60.3

Daily Minimum		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YEAR
NLABS Annex	1960	15.1	22.9	20.2	35.2	47.1	55.8	56.9	58.2	48.9	37.6	32.4	11.9	36.8
	1961	7.4	15.0	25.2	34.7	44.1	55.2	58.2	56.2	54.3	41.6	31.0	19.9	36.9
	1962	12.8	8.5	25.6	32.6	41.1	52.0	51.3	54.7	44.6	36.7	26.7	12.5	33.3
	Mean	11.8	15.5	23.7	34.2	44.1	54.3	55.5	56.4	49.3	38.6	30.0	14.8	35.7
Bedford	1960-1962	14.3	17.5	24.7	35.7	45.1	56.2*	59.6*	59.2*	51.8	40.7	32.0	17.2	37.8
Clinton	1960-1962	13.1	15.4	22.7	36.5	46.3	57.1	59.8	60.0	53.4	42.3	33.3	18.5	38.2
Framingham	1960-1962	13.7	16.3	24.7	36.7	46.3	56.1	58.9	58.8	52.5	40.0	31.8*	16.5	37.7
Weston	1960-1962	15.2	18.4	20.7	35.4	43.8	53.6	55.8	57.5	50.5	39.9	31.4	16.5	36.6

TABLE 7. TEMPERATURES (°F) AT NLABS ANNEX AND FOUR LOCAL STATIONS, 1960 - 1962 (cont'd)

Absolute Maximum		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YEAR
NLABS Annex	1958	-	-	-	-	-	87	90	87	85	82	66	48	-
	1959	59	53	67	76	90	92	91	93	89	82	75	56	93
	1960	52	57	63	77	86	90	91	92	95	81	67	59	95
	1961	51	67	68	69	89	92	88	89	90	80	75	54	92
	1962	52	60	78	91	93	87	89	38	83	78	66	65	93
	1963	50	48	71	73	86	92	96	87	-	-	-	-	-
	Highest (1960-1962)	52	67	78	91	93	92	91	92	95	81	75	65	95
Bedford	1960-1962	54	66	77	91	95	93*	93*	93*	94	80	76	62	95
Clinton	1960-1962	55	61	71	84	97	91	88	86	88	78	70	68	97
Framingham	1960-1962	55	62	79	93	96	95	95	94	94	82	77*	66	96
Weston	1960-1962	54	65	76	92	94	92	91	92	93	80	76	64	94

Absolute Minimum		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YEAR
NLABS Annex	1958	-	-	-	-	-	29	42	43	31	16	14	-7	-
	1959	-3	-12	4	19	28	40	44	43	29	18	11	-1	-12
	1960	-1	-15	3	23	36	43	48	44	35	23	16	-4	-4
	1961	-15	-20	6	26	29	39	46	40	31	22	18	0	-20
	1962	-4	-21	4	19	28	41	39	42	26	19	16	-7	-21
	1963	-15	-13	9	20	27	41	44	39	-	-	-	-	-
	Lowest (1960-1962)	-15	-21	3	19	28	39	39	40	26	19	16	-7	-21
Bedford	1960-1962	-19	-11	0	20	29	40*	46*	43*	28	21	16	-6	-19
Clinton	1960-1962	-20	-15	3	26	31	43	47	45	32	26	22	-4	-20
Framingham	1960-1962	-16	-11	4	24	32	42	47	43	33	22	20*	-9	-16
Weston	1960-1962	-14	-14	1	20	29	37	40	40	26	17	14	-8	-14

*Data for 2 years for period 1960-1962
-No data

(including mean daily maximum, mean daily minimum, absolute maximum and minimum temperatures) are compared with similar data from Bedford, Clinton, Framingham, and Weston for the years from 1960 through 1962 (Table 7, 8, Fig. 11, 12). The locations of these weather stations are summarized in Table 8.

TABLE 8. LOCATION OF FOUR LOCAL STATIONS OUTSIDE THE NLABS ANNEX

Station	Latitude	Longitude	Elev (ft)
NLABS Annex	42° 25' N	71° 29' W	205
Bedford	42 28	71 17	135
Clinton	42 24	71 41	398
Framingham	42 17	71 25	172
Weston	42 23	71 19	220

For the most part, at the four selected stations in the area outside the reservation, maximum and minimum temperatures are slightly higher than those at NLABS Annex for the period from 1960 to 1962 (Fig. 11, 12). Temperatures at Weston correlate best with those at NLABS Annex. Mean daily maximum and mean daily minimum temperatures at Weston were 1 to 2 F degrees higher than comparable values at NLABS Annex; an average of the absolute maximum temperatures for all months as well as a similar average of absolute minimum temperatures reveals almost no annual differences between the two stations (±0.2 F°). Furthermore, with few exceptions, the graphs show good correlation between monthly temperature values for NLABS Annex and Weston. The most conspicuous exception is the 7 F degree lower absolute minimum in February at NLABS Annex.

The graphs reveal the temperature curves for Bedford, Framingham, and Clinton follow similar patterns but the curve for Clinton deviates most from that for NLABS Annex. At Clinton mean daily maximum and absolute maximum temperatures were the lowest of these stations; comparable minimum temperatures were the highest. Of the five stations, Clinton is the highest in elevation and is farthest from the coast.

Precipitation

Most precipitation in the area is of cyclonic origin. Thus in winter, precipitation is usually of low intensity and may persist for several days. Such precipitation is most commonly associated with the passing of slow-moving fronts. However, a fast-moving, well-developed, cold front can produce comparatively heavy precipitation for a limited period. But in summer, when cyclonic activity ebbs, convective showers, including those accompanied by thunder, tend to make up a deficiency in frontal rainfall. Though brief and often of small extent, summer showers are of relatively high intensity.

The amount of precipitation at NLABS Annex is normally moderate and evenly distributed throughout the year. Mean annual precipitation is 46.31 inches, averaging 3.86 inches per month. Mean precipitation for September and April, the wettest months, exceeds 5 inches; precipitation for June, the driest month, is less than 3 inches (Table 9).

Because several hills in the vicinity of Base Station are noticeably higher its mean precipitation was compared with similar data from four local stations outside the reservation for a comparable 3-year period (1960-1962). Mean annual precipitation was about 2 to 6 inches greater at NLABS Annex than it was at the other stations (Table 10, 11). The differences in precipitation between NLABS Annex and each of the other stations varied considerably for months of different years in the 3-year period.

Although mean precipitation at NLABS Annex is well distributed, it occasionally varies significantly from one month to another or for a given month of different years (Table 9). During 5- to 6-year period of record, monthly precipitation exceeding 7 inches has occurred during April, July, September, and October. The greatest precipitation for a single month is 9.48 inches; 5.85 inches of this fell when a tropical storm passed over the area from 7 to 9 October 1962, causing major flooding in southern New England. Except for this 3-day storm, precipitation for October was less than the mean for any other month. By contrast, a minimum precipitation of less than 1 inch was recorded during June 1958 and May 1959.

Prior to taking any weather observations at NLABS Annex, Hurricane "Diane" brought unprecedented torrential rains to New England on 19 August 1955. These rains, dwarfing previous records for intensity, and falling on already saturated soil and where streams remained high from Hurricane "Connie's" heavy rains of less than a week before, caused the most disastrous flooding in the history of New England. At Lake Cochituate station, nearest to NLABS Annex, a total of 15.35 inches was reported for August 1955 (11.17 inches above normal); the greatest precipitation for a day, 5.40 inches, was recorded on 19 August 1955.

The frequency of precipitation is relatively uniform throughout the year, occurring on about 4 days out of 10 (including all amounts too small to measure). A maximum frequency of 48 percent of the days occurs during April; no month has a minimum frequency of less than 33 percent (Table 12). Rain and drizzle, the most frequent types of precipitation,

TABLE 9. MONTHLY PRECIPITATION AND SNOWFALL (INCHES) AT NLABS ANNEX, June 1958 - August 1963

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Precipitation	1958	-	-	-	-	-	.55	2.75	1.70	5.35	2.55	2.80	1.35	-
	1959	3.55	2.10	5.30	5.50	.95	5.00	7.70	4.15	2.95	4.85	5.00	4.00	51.05
	1960	3.46	5.46	4.92	5.34	4.75	2.73	5.62	1.82	5.69	2.61	3.66	3.65	49.71
	1961	2.45	3.03	3.70	7.30	3.73	2.69	3.48	2.80	7.44	4.17	3.21	4.44	48.44
	1962	3.64	5.16	1.92	5.45	3.66	3.03	1.87	5.15	5.78	9.48	3.11	3.37	51.62
	1963	3.21	2.50	4.74	1.62	2.76	1.55	2.61	2.25	-	-	-	-	-
	Mean	3.26	3.65	4.12	5.04	3.17	2.59	4.28	3.12	5.42	4.73	3.56	3.36	46.31
Snowfall	1958	-	-	-	-	-						3.0	9.0	-
	1959	7.0	14.5	28.0								.4	5.6	55.5
	1960	15.7	3.0										22.0	40.7
	1961	14.0	14.5	18.8	3.6						1.7	5.0	17.8	75.4
	1962	1.1	40.7	1.4							2.0	1.5	12.0	58.7
	1963	8.6	12.3	22.7						-	-	-	-	-
	Mean	9.3	17.0	14.2	.7						.7	2.0	13.3	57.2

-Month during which no observations were made or an incomplete year of data. Blank spaces indicate no snowfall for those months.

TABLE 10. PRECIPITATION (INCHES) AT NLABS ANNEX COMPARED TO FOUR LOCAL STATIONS, 1960 - 1962

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
NLABS Annex	1960	3.46	5.46	4.92	5.34	4.75	2.73	5.62	1.82	5.69	2.61	3.66	3.65	49.71
	1961	2.45	3.03	3.70	7.30	3.73	2.69	3.48	2.80	7.44	4.17	3.21	4.44	48.44
	1962	3.64	5.16	1.92	5.45	3.66	3.03	1.87	5.15	5.78	9.48	3.11	3.37	51.62
	Mean	3.18	4.55	3.51	6.03	4.05	2.82	3.66	3.26	6.30	5.42	3.33	3.82	49.92
Bedford	1960-1962	3.36	4.55	3.03	5.12	3.36	2.06	4.18	2.37	5.85	6.25*	3.45	4.28	47.86
Clinton	1960-1962	3.28	4.54*	2.96	4.42	3.34	3.17	4.09	3.21	5.48	4.51	3.89	4.19	47.08
Framingham	1960-1962	2.96	4.01	3.03	4.26	3.08	2.56	4.48	2.78	5.90	5.54	3.73*	4.41	46.74
Weston	1960-1962	2.16	3.72	3.03	4.51	3.43	3.58	3.46	2.85	5.14	4.61	3.91*	3.21*	43.61

*Based on 2 years of data.

TABLE 11. SNOWFALL (INCHES) AT NLABS ANNEX COMPARED TO FOUR LOCAL STATIONS, 1961 - 1962*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
NLABS Annex	1.1	40.7	1.4							1.7	5.0	17.8	67.7
Bedford (A)	3.2	36.1	.3	.7						T	4.5	19.0	63.8
Clinton	2.8	39.7	1.7							T	7.5	22.5	74.2
Framingham	2.5	34.5	.3	.8						T	2.5	18.0	58.6
Weston	.6	28.5	T	.5						T	2.5	-	-

* July 1961 - 30 June 1962 (1 yr)
(A) Airport
\- Month with no data or year with incomplete data.

TABLE 12. FREQUENCY OF PRECIPITATION AND SNOWFALL* (% OF DAYS) AT NLABS ANNEX, June 1958 - August 1963

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Percent of days with:													
no precipitation	62	59	57	52	57	57	63	61	67	64	61	62	60
precipitation < 0.1 inch	15	17	21	20	18	18	15	19	16	15	17	18	18
precipitation ≥ 0.1 to 0.9 inch	20	21	18	23	24	24	19	17	12	17	19	17	19
precipitation ≥ 1.0 inch	3	3	4	5	1	1	3	3	5	5	3	3	3
precipitation (all amounts)	38	41	43	48	43	43	37	34	33	36	39	38	40
no snowfall	72	71	68	92	100	100	100	100	100	98	91	76	89
snowfall < 1 inch	16	17	18	6						1	6	12	7
snowfall ≥ 1 to 4.9 inches	10	7	9	2						1	3	10	3
snowfall ≥ 5 inches	2	5	5									2	1
snowfall (all amounts)	28	29	32	8						2	9	24	11

*Tabulations include amounts too small to measure (trace).

fall on 1 day out of 3 in a year (Table 13). Even from December through March rain and drizzle occur on 19 percent of the days, compared to 30 percent from snowfall*. No precipitation in frozen form has been recorded in the 5-month period from May through September, although hail may occur on rare occasions. Hail is normally associated with intense convectional activity of late spring and summer, the period of most frequent thunderstorms. In New England, thunderstorms occur on only 3 to 9 percent of days during their period of greater frequency (April - August) compared to rain and drizzle on 39 to 46 percent of days for these months.

At NLABS Annex, snow may fall any time from October to April, but significant amounts can be expected occasionally from December through March, averaging 13.4 inches for each of the four months. In five seasons, annual snowfall has averaged 57.2 inches, but the annual total has varied from 75.4 to 40.7 inches (Table 9). The greatest total snowfall for any one month was 40.7 inches in February 1962; February is also the month with the greatest mean snowfall. Thus far, maximum monthly snowfall has occurred most often in March but never in the same month of successive years. Variations in monthly totals are extreme for a 3-year period, ranging from .55 inch to 9.48 inches.

During the four coldest months (Dec - Mar), some snow is on the ground 68 percent of the time (Table 14). The percent of days with at least some snow cover is highest in January but snow cover is deepest in February. Only four months, December through March, have appreciable snow on the ground more than 1/2 the days; no other month has a snow cover on even 10 percent of the days.

Figure 13 describes the condition of the ground surface for each season, based on three or four observations per day on which the ground condition or its cover is classified according to one of nine categories. Thus from Figure 13 and Table 15 it can be determined that the ground is free of snow in winter about 20 percent of the time.

Wind

Wind data obtained from the main meteorological station (Base) vary significantly from that from other stations in eastern Massachusetts. The aerovane at NLABS Annex is only about 6 meters above the ground on a lowland (Photo. 4). The station is bordered by conspicuous hills to the west, east, and northeast. A forest cover on nearby hills and on much of the lowland exert an appreciable frictional effect on surface winds

*Mostly snow but includes some sleet and glaze. Any precipitation that freezes or melts and refreezes on the surface at observation site is measured to nearest 0.1 inch, as far as practicable, and recorded as snow (unmelted). Thus freezing rain is recorded as snow.

TABLE 13. TYPES OF PRECIPITATION (% OF DAYS) AT NLABS ANNEX, June 1958 - August 1963

Percent of days* with:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain and drizzle	18	21	23	46	43	43	40	39	33	35	33	15	33
Thunderstorms**			1	3	8	7	9	9	1	1			3
Snow and sleet	28	29	30	8						2	9	28	11
Hail	1										1		
Total***	38	41	43	48	43	43	40	39	33	36	39	37	40

*Less than .5 percent indicated by blank space
**Includes a few days with thunder without precipitation
***Based on total days with precipitation, not on total of days for each type of precipitation.

TABLE 14. FREQUENCY OF SNOW COVER AT SELECTED DEPTHS (% OF DAYS) AT NLABS ANNEX, June 1958-August 1963

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Trace	7	8	4	1						1	5	3	2
1-6 inches	51	28	35	3							3	39	14
7-12 inches	24	21	19								1	6	6
13-18 inches		11	6									4	2
19-24 inches		6	2										1
Total ≥ trace	82	74	66	4						1	9	52	25

TABLE 15. STATE OF GROUND AT NLABS ANNEX (% OF OBS.), JUNE 1958 - AUGUST 1963

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	Surface of ground dry	0	0	3	58	65	66	73	60	61	50	48	17
1	Surface of ground moist	0	0	9	28	24	26	21	30	31	39	30	11
2	Surface of ground wet	*	2	5	11	10	8	6	10	8	9	10	4
3	Surface of ground frozen	2	13	6	1	1	*	0	0	0	1	3	10
4	Glaze on ground but no snow or melting snow	*	0	*	*	0	0	0	0	0	*	0	1
5	Ice, snow or melting snow covering less than 1/2 of ground	19	12	11	*	0	0	0	0	0	*	3	6
6	Ice, snow or melting snow covering more than 1/2 of ground	13	5	14	*	0	0	0	0	0	*	2	5
7	Ice, snow or melting snow covering ground completely	53	65	47	1	0	0	0	0	0	1	4	37
8	Loose dry snow, dust or sand covering more than 1/2 of ground	3	0	0	0	0	0	0	0	0	0	*	2
9	Loose dry snow, dust or sand covering ground completely	10	3	6	0	0	0	0	0	0	0	*	7
	No Snow Cover	2	15	23	98	100	100	100	100	100	99	91	43

*0.5 percent or less

TABLE 16. FREQUENCY (%) OF HOURLY WIND SPEED AND DIRECTION AT NLABS ANNEX

1 August 1961 - 30 June 1963

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg (yr)	Wtr	Spr	Smr	Aut
Wind Speed																	
Calm	58	60	40	49	65	79	70	69	73	66	62	64	64	61	54	73	67
1-5 knots	30	28	32	33	29	20	23	25	21	25	23	24	26	27	31	22	23
6-10 knots	11	12	18	15	6	1	7	6	6	9	13	9	9	11	13	5	9
11-15 knots	1	*	1	2	*	0	*	*	*	*	2	2	1	1	1	*	1
16-20 knots	*	*	*	*	*	0	0	0	0	0	*	*	*	*	*	0	*
Direction																	
N	3	4	7	5	3	1	6	2	3	5	2	2	4	3	5	3	3
NNE	3	4	4	2	2	*	*	3	*	1	1	1	2	3	2	1	*
NE	4	3	1	1	2	2	2	1	2	2	*	1	2	3	2	2	2
ENE	1	*	5	*	*	*	0	0	*	*	*	*	1	*	2	*	*
E	0	2	1	2	1	*	*	*	1	*	*	1	1	1	1	*	*
ESE	*	*	2	*	1	*	1	*	1	0	*	1	*	*	1	*	*
SE	*	1	1	1	2	1	1	1	2	2	*	1	1	1	1	1	1
SSE	1	2	3	*	1	*	1	*	0	*	1	*	1	1	1	*	*
S	1	1	1	3	2	2	1	1	1	1	1	1	1	1	2	2	1
SSW	2	*	1	3	2	*	2	4	2	3	1	2	2	1	2	2	2
SW	5	1	2	2	4	3	1	6	1	2	*	3	2	3	2	3	1
WSW	3	2	1	4	1	1	*	2	1	1	2	2	2	2	2	1	1
W	5	6	6	6	4	5	2	2	2	3	6	5	4	5	6	3	4
WNW	3	2	2	7	2	2	2	3	2	2	5	4	3	3	4	2	3
NW	6	8	6	9	4	1	6	4	6	8	11	8	6	8	7	4	8
NNW	5	4	8	5	2	1	3	2	4	4	7	4	4	4	5	2	5

*.5 percent or less.

TABLE 17. FREQUENCY (%) OF HOURLY WIND DIRECTION AT L. G. HANSCOM FIELD
Bedford, Massachusetts

February 1943 - September 1953

Direction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
N	6	6	5	4	2	2	2	3	4	4	5	5	4
NNE	5	4	5	4	3	3	3	3	3	4	4	4	4
NE	4	4	4	3	4	3	2	3	4	5	4	3	4
ENE	2	2	4	4	5	3	2	3	3	4	3	1	3
E	1	2	3	3	5	3	2	3	2	2	2	1	2
ESE	1	1	2	4	5	3	3	3	2	2	2	1	2
SE	1	2	2	3	4	3	3	2	2	2	2	1	2
SSE	2	3	3	2	3	2	3	2	3	2	2	2	2
S	3	3	3	3	4	4	5	5	6	4	4	3	4
SSW	6	5	7	6	7	10	11	8	7	7	6	4	7
SW	7	7	8	8	8	12	12	10	9	11	7	7	9
WSW	8	9	7	9	8	12	10	9	6	9	7	11	8
W	11	9	7	9	7	8	8	7	7	8	10	13	9
WNW	9	11	8	9	6	6	6	4	5	5	8	10	7
NW	9	11	8	8	5	4	3	4	5	6	9	11	7
NNW	7	7	9	7	4	4	3	4	5	4	6	7	6
Calm	17	14	13	17	19	20	22	27	26	20	19	18	19

that is reflected in lower wind speeds at the station. The buildings, southeast of the station, also reduce the force and frequency from that direction.

At NLABS Annex, an unusually high percent of calm (< 1 knot) prevails most of the time, averaging annually 64 percent of hourly observations for a 23-month period (Table 16). Monthly frequency of calm varies from 79 percent in June to 49 percent in March and April; seasonal frequency is greatest in summer (73%) and least in spring (54%). The percent of days with 24 observations of calm averages annually 11 percent compared to 3 percent of days with no recorded observations with calm.

At L. G. Hanscom Field, Bedford, about 12 airline miles northeast of NLABS Annex in a more open area, a marked lower frequency of calm occurs (Fig. 14). The percent of calm at L. G. Hanscom Field averages only 19 percent annually, compared to 64 percent at NLABS Annex. At Bedford, calm prevails 27 percent of the time in August, the month with the greatest amount of calm, and 13 percent in March, the least calm month.

The high frequency of calm and at other times mostly low wind speeds are highly favorable to making air drops. Fortunately, the nearby air drop zone has an adequately large, flat, open area that is well drained.

Moderate wind speeds are unusual and high winds seldom occur in any season (Table 16). Wind speeds exceed 5 knots per hour only 10 percent of the time and rarely exceed 10 knots. Although the seasonal occurrence of winds is relatively uniform, Table 16 indicates that spring is the windiest season; summer is the least windy. Winds blow most often from the northwest quadrant and least often from the southeast quadrant as well as at L. G. Hanscom Field station (Table 16, 17).

TABLE 18. MEAN DAILY PEAK GUSTS* (KNOTS) AT NLABS ANNEX
10 June 1959 - 31 August 1963

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg (yr)
1959	-	-	-	-	-	(6.5)	11.3	(8.8)	10.2	13.0	15.3	12.9	-
1960	12.9	15.7	15.3	14.4	11.7	11.6	14.1	12.4	13.2	15.7	16.5	15.7	14.1
1961	15.7	16.8	17.4	15.2	14.4	13.5	11.8	10.1	8.0	10.3	13.7	12.3	13.3
1962	17.3	12.2	17.4	17.0	13.[illegible]	9.1	14.4	14.2	15.0	14.1	14.6	14.5	14.4
1963	12.9	15.8	15.8	18.8	14.8	11.2	8.8	8.8	-	-	-	-	-
Mean	14.7	15.1	16.5	16.4	13.5	11.5	12.1	10.9	11.6	13.3	15.0	13.8	13.7

*Based on hourly observations for the indicated periods below: 0800 - 1700 hours, 10 June 1959 to 31 July 1961, and including 0600 - 2000 hours for April and May 1960; 24 hourly observations from 1 August 1961 to 31 August 1963.

( )Parentheses indicate incomplete record based on 2 or 3 weeks' data for a 1-year period.

- Month with no data or year with incomplete data

Daily peak gusts are also less severe and less frequent than those reported at more representative places in eastern Massachusetts. These gusts average about 14 knots per year, varying from 8 to almost 19 knots for the months of record (Table 18). Daily peak gusts exceed 20 knots per hour only 14 percent of the time (Table 19). The highest absolute gust recorded was 55 knots per hour, which occurred at 1518 hours, 26 February 1961, from the west-northwest. Although daily peak gusts are most often from the northwest quadrant they are also relatively frequent from each of the other three quadrants (Table 19).

Relative humidity

Mean daily maximum and minimum and extreme maximum and minimum relative humidity are tabulated in Table 20 for each of the 25 months of hourly observations. On the basis of this record, mean daily maximum humidity exceeds 90 percent for all months and exceeds 95 percent from May through November. Mean daily minimum relative humidities are in the 40's and 50's for most months and show a monthly variation greater than daily maximum values, since variation of the latter is curtailed by reaching the limit of 100 percent. Seasonal frequency of daily maximum and minimum relative humidity is shown in Figures 15 and 16. These figures show a more varied range in occurrence of mean daily minimum humidities for the various indicated increments. A daily maximum relative humidity of 100 percent is most frequent in any season, especially in summer and autumn when a maximum humidity of 100 percent is recorded on about 2/3 of the days.

Lower extreme relative humidities occur generally in the cooler months, but extreme maximum relative humidities of 100 percent have occurred in all months of record (Table 20). The lowest extreme relative humdity is 11 percent.

Sky cover

Seasonal variation in sky cover is negligible at NLABS Annex, varying from only 50 to 52 percent (Table 21). Mean sky cover from sunrise to sunset exceeds mean 24-hour sky cover in all months and averages 5 percent higher annually, because of clouds produced by heating of the earth's surface by the sun and possibly also by observational difficulty at night.

Partly cloudy weather (31 - 70%) prevails more often than clear (0 - 30%) or cloudy weather (71 - 100%), based on 24 hourly observations for months of record (Table 22). Partly cloudy weather reaches a seasonal maximum of 51 percent in summer. The frequency of clear and cloudy weather are about equally divided.

TABLE 19. FREQUENCY (%) OF DAILY PEAK GUSTS AND DIRECTION AT NLABS ANNEX

10 June 1959 - 30 June 1963

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg (yr)	Wtr	Spr	Smr	Aut
Wind Speed (Knots)																	
Calm (< 1 knot)	0	1	0	0	0	0	0	1	1	2	1	2	*	1	0	*	1
1-5	5	4	0	1	2	6	9	6	9	4	4	10	5	6	1	7	6
6-10	27	23	18	8	23	37	31	23	33	26	21	24	25	25	17	30	27
11-15	21	22	29	34	41	39	37	37	21	25	28	26	31	23	34	36	28
16-20	28	32	23	32	24	14	15	16	13	23	25	15	22	25	27	16	20
21-25	7	12	23	11	9	2	6	3	6	13	12	14	10	11	14	4	10
26-30	9	4	4	9	1	1	0	0	1	1	5	5	3	6	5	1	2
31-35	3	0	1	2	1	0	0	0	1	1	1	0	1	1	1	0	1
36-40	0	1	1	1	0	0	0	0	0	0	2	2	*	1	*	0	1
41-45	0	0	0	0		0	0	0	0	0	0	2	*	1	0	0	0
46-50	0	1	0	0	0	0	0	0	0	0	0	0	*	*	0	0	0
Missing	0	2	0	2	0	1	2	14	5	5	1	0	3	1	1	6	4
Direction																	
N	13	9	6	9	8	9	10	12	8	8	9	13	10	12	8	11	8
NNE	2	7	7	4	2	3	1	3	4	2	3	2	3	4	4	2	3
NE	10	9	6	7	7	10	5	2	1	8	2	3	6	7	7	6	4
ENE	3	1	6	2	2	1	0	1	0	2	1	5	2	3	3	1	1
E	2	7	5	3	6	5	4	2	4	3	1	2	4	4	5	4	3
ESE	1	2	3	1	2	4	2	2	3	2	1	2	2	1	2	2	2
SE	0	2	4	9	14	9	13	7	3	10	10	2	7	1	9	10	8
SSE	1	4	3	0	3	3	2	0	1	2	5	2	2	2	2	2	3
S	3	2	5	3	7	9	3	6	9	2	5	5	5	3	5	6	6
SSW	4	2	2	5	3	4	4	8	12	3	1	4	4	3	4	6	5
SW	15	7	3	8	9	10	20	9	9	6	9	13	10	12	6	14	8
WSW	4	4	3	3	3	2	2	3	5	3	3	3	3	4	3	2	4
W	14	12	14	11	10	10	5	6	9	11	14	10	11	12	12	6	12
WNW	8	8	6	14	2	5	5	6	6	5	12	7	7	8	3	5	8
NW	12	12	12	15	14	10	10	14	12	21	13	22	14	15	14	11	15
NNW	6	9	13	3	6	5	10	5	7	4	8	3	7	6	7	7	6
Missing	2	4	0	2	0	2	2	14	6	5	1	1	3	2	1	7	4

*.5 percent or less

TABLE 20. DAILY MEANS AND MONTHLY EXTREMES OF RELATIVE HUMIDITY (%) AT NLABS ANNEX, August 1961 - August 1963

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Extreme Maximum	1961	-	-	-	-	-	-	-	100	100	100	100	100	100
	1962	100	100	100	100	100	100	100	100	100	100	100	100	100
	1963	100	100	100	100	100	100	100	100	-	-	-	-	100
	Highest	100	100	100	100	100	100	100	100	100	100	100	100	100
Mean daily maximum	1961	-	-	-	-	-	-	-	99	99	94	94	92	-
	1962	88	94	91	93	96	99	99	99	99	99	97	90	95
	1963	94	89	95	90	98	99	98	99	-	-	-	-	-
	Mean	91	92	93	92	97	99	98	99	99	96	96	91	95
Mean daily minimum	1961	-	-	-	-	-	-	-	54	57	55	54	55	-
	1962	41	52	44	37	45	49	47	54	52	50	48	48	47
	1963	56	46	44	30	35	46	46	46	-	-	-	-	-
	Mean	48	49	44	34	40	48	46	51	54	53	56	52	48
Extreme Minimum	1961	-	-	-	-	-	-	-	27	37	32	15	17	-
	1962	17	18	20	13	12	29	25	29	36	26	11	12	11
	1963	24	19	14	15	18	26	33	30	-	-	-	-	-
	Lowest	17	18	14	13	12	26	25	27	36	26	11	12	11

- Month with no data or year with incomplete data.

TABLE 21. SKY COVER AT NLABS ANNEX, December 1961 - August 1963

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YEAR
24-hour period	1961	-	-	-	-	-	-	-	-	-	-	-	57	-
Sunrise to sunset	1961	-	-	-	-	-	-	-	-	-	-	-	63	-
24-hour period	1962	50	59	49	55	51	59	46	53	51	52	54	44	50
Sunrise to sunset	1962	58	63	49	58	56	66	56	61	55	58	61	48	57
24-hour period	1963	59	43	52	48	46	49	53	53	-	-	-	-	-
Sunrise to sunset	1963	58	50	57	50	53	55	59	61	-	-	-	-	-
Mean 24-hour sky cover	1961-63	54	51	50	52	48	54	50	53	51	52	54	50	52
Mean sky cover from sunrise to sunset	1961-63	58	56	53	54	54	60	58	61	55	58	61	56	57

- Month with no data or year with incomplete data.

TABLE 22. PERCENT OF DAYS WITH SKY COVER AT NLABS ANNEX, December 1961 - August 1963

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YEAR
24-hour average													
Clear	27	34	32	30	34	24	27	21	37	29	33	31	30
Partly cloudy	37	34	37	35	38	48	49	56	27	36	27	39	39
Cloudy	36	32	31	35	28	29	24	23	37	36	40	31	31
Sunrise-to-sunset average													
Clear	31	32	31	28	26	25	19	16	33	30	30	36	28
Partly cloudy	26	32	30	32	36	37	49	43	20	30	20	19	32
Cloudy	44	36	39	40	38	39	32	41	47	40	50	45	40

Clear - 0 to 30 percent of the sky covered
Partly cloudy - 31 to 70 percent of the sky covered
Cloudy - 71 to 100 percent of the sky covered

From sunrise to sunset the percent of cloudy days is appreciably higher (9% annually) than values based on all hourly observations (Table 22, Fig. 17). This increase reduced mainly the percent of partly cloudy days and increased the percent of cloudy days. Clear days are least frequent in July and August; partly cloudy days are most common then. Seasonal differences in frequency of sky cover between daylight and 24-hour periods are fairly uniform in each of the three categories, although allowance must be made for the usual monthly variations in a short period of record.

Visibility

At NLABS Annex, visibility is good most of the time and is generally characteristic of eastern Massachusetts inland from the coast. In a 2-year period (1962-1963), a visibility of 7 miles or more occurred 74 percent of the time, based on hourly observations. Visibility at that distance tends to be somewhat more frequent in winter when the area is dominated more often by passage of drier air masses.

In the same period, visibility limited to 6 miles or less occurred 26 percent of the time compared to only 7 percent at 1 mile or less (Table 23). However, visibility for each of the two selected limits often varies greatly for a given month of one year compared with the other year. In both categories, visibility was significantly better in 1963 than it was in 1962, particularly from April 1963 through October and also for February and November of the same year (9 mos). In so short a period of record, no conclusive seasonal trends in conditions can be determined, but the tabulations serve to give an indication of visibility in the area.

Visibility is reduced to 6 miles or less mainly by fog and secondarily by precipitation (Table 23). Fog (including ground fog) restricts visibility almost twice as often as precipitation (both in liquid and frozen forms). In some instances, combinations of fog, precipitation, and haze were recorded as reasons for restricted visibility*. Fog (mostly ground fog) is more common in summer and early autumn. Precipitation reduces visibility to 6 miles or less mainly in the cooler half year, because of its more frequent occurrence and longer duration in those months. Snow also restricts visibility more than rain does. Haze, least important of the three factors reducing visibility, is most frequent in the warmer months.

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*When a combination of causes limiting visibility to 6 miles or less are noted on daily weather observation forms (WBAN 10A) each cause given was tabulated, although this procedure exaggerates slightly observed conditions. In such instances, it is impossible to determine accurately the relative importance of each cause when noted in combination with others.

TABLE 23. FREQUENCY AND CAUSES OF VISIBILITY LIMITED TO SELECTED DISTANCES AT NLABS ANNEX
1 January 1962 - 31 December 1963

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YEAR
Visibility at ≤6 miles (% of obs):													
1962	15	38	20	27	42	51	24	50	32	39	19	26	32
1963	27	15	26	11	10	19	23	29	23	18	28	15	20
1962-1963 avg.	21	27	23	19	26	35	24	40	28	28	23	21	26
Visibility at ≤1 mile (% of obs):													
1962	6	23	6	4	10	8	6	10	10	15	4	7	9
1963	6	5	13	2	1	1	3	4	5	3	8	3	5
1962-1963 avg.	6	14	10	3	5	5	4	7	7	9	6	5	7
Visibility limited to ≤6 miles by (% of obs):													
Fog	17	14	17	9	19	26	18	31	21	23	19	11	19
Precipitation	10	18	14	10	8	6	4	6	9	10	14	13	10
Haze	*	*	0	2	3	7	3	7	1	*	*	*	2

*Month with no data.

In Table 24 the frequency and duration of fog, ground fog, and haze are given for February and August for each year from 1962 to 1964, representing extreme months. In either month, ground fog is far more common than fog and haze combined; ground fog is also several times more frequent in August than it is in February. Fog and haze also occur more frequently in August than they do in February. For the 4-year period, there is good correlation between the number of days of occurrence and duration of fog, ground fog, and haze.

However, duration of fog, ground fog, and haze for months of different years sometimes varies greatly from mean monthly values (Table 24). For instance, in February, there is marked contrast in the frequency and duration of fog as well as ground fog for the years 1962 and 1964.

In a visibility study at the reservation by Anstey (1964), three sites were selected at random in its Transitional Hardwoods-White Pine-Hemlock Forest in connection with similar studies made in other world environments. In the report, techniques used in target identification are described and the results of over 300 measurements of visibility distances are summarized.

TABLE 24. FREQUENCY AND DURATION OF VISIBILITY REDUCED TO 6 MILES OR LESS BY FOG, GROUND FOG, AND HAZE AT NLABS ANNEX

		Fog		Ground Fog		Haze	
Mo	Yr	Freq. (da)	Dur. (hr)	Freq. (da)	Dur. (hr)	Freq. (da)	Dur. (hr)
February	1962	7	66	10	63	1	4
	1963	1	6	9	52	1	1
	1964	0	0	3	18	0	0
	1965	6	33	8	31	4	39
	Mean	4	26	8	41	2	11
August	1961	10	71	23	181	6	28
	1962	5	22	30	269	11	81
	1963	5	16	27	167	5	19
	1964	5	22	30	269	8	41
	Mean	6	33	28	222	8	42

6. Representative 7-day weather patterns

Climatic averages present a conventional picture of representative weather, but it is not averages that men must face in the field. They are subjected to an ever-changing combination of weather elements. Because of important and frequent variations of each weather element (precipitation, temperature, etc.), a typical weather pattern does not exist except for a characteristic changeability. Identical combinations of weather conditions for a 7-day period may never occur again; such conditions may differ significantly from the preceding or following weeks; but more or less typical weather can be expected to occur far more often than extreme deviations from the normal pattern in any season. It is believed that a discussion of a 7-day period of recorded weather observations considered reasonably representative of each of the four seasons introduces an added note of realism concerning weather conditions at NLABS Annex.

Week of 16 - 22 January 1961 (winter)

In winter, rapid and often drastic changes in weather are characteristic. Variability in weather elements for hours of observation from 16 to 22 January 1961 is illustrated in Figure 18; contrasts in daily averages and extremes of different elements is indicated in Table 25.

Hourly temperatures ranged from -15° to 45°F, giving an extreme range of 60 F degrees for the week. In the period, maximum temperatures exceeded 32°F on only 2 days; minimum temperatures never reached 32°F at any time but dropped below 0°F on 2 days (Table 25). Frequency of these selected temperatures correlates closely with the 5-year January averages. The lowest minimum temperature, -15°F, for the 7-day period is also the lowest temperature recorded for January in a 5-year period.

Daily range in temperature for the 7-day period varied from 5 to 38 F degrees. This range was lower on cloudy days and on days with precipitation.

Two cyclonic storms passed over the NLABS Annex during the week. A snowfall of [illegible] inches fell on an already snow-covered surface on 16 January and an additional 8.5 inches fell four days later. After the first snowstorm sunny to partly cloudy weather prevailed for the next two days. In the next two days all recorded sky cover observations show 100

TABLE 25. SEVEN-DAY WINTER WEATHER SUMMARY AT NLABS ANNEX, 16 - 22 JANUARY 1961

Weather Element*	16	17	18	19	20	21	22	Week
	Day of Week							
Highest relative humidity (%)	100	100	63	96	100	98	98	100
Lowest relative humidity (%)	86	29	29	28	77	30	43	28
Mean relative humidity (%)	97	68	43	45	91	61	73	68
Maximum temperature (°F)	27	45	37	19	14	20	23	45
Minimum temperature	22	11	18	6	5	-8	-15	-15
Mean temperature	25	28	28	13	10	6	4	16
Range (F°)	5	34	19	13	9	28	38	60
Wind speed (knots)								
0800 hours	15	0	12	0	15	3	0	
0900	12	0	9	0	15	4	0	
1000	14	3	12	3	15	4	0	
1100	10	4	13	4	15	5	0	
1200	18	4	13	4	15	7	6	
1300	10	6	12	4	14	8	9	
1400	8	7	9	3	14	8	8	
1500	4	7	9	3	14	7	9	
1600	7	5	10	3	12	7	7	
1700	5	0	9	3	9	5	5	
Mean wind speed (knots)	10.3	3.6	10.8	2.7	13.8	5.8	4.4	7.3
Peak gusts	20	14	25	18	26	14	10	25
Prevailing wind direction	NNE	WSW	WNW	N	NNW	W	SW	W
Mean sky cover (%)	100	39	3	100	100	0	11	53
Total snowfall (inches)	2.5	0	0	0	8.5	0	0	11.0

*Humidity and temperature based on 24 hourly observations each day; summaries of other weather elements based on 10 hourly observations (0800 - 1700 hrs) percent cloudiness, with a major snowstorm on the second day (20 Jan). The next day was a beautiful winter day and only limited cloudiness occurred on the following day (22 Jan). The two storms increased the snow depth from 0.5 inch to more than 10 inches.

During the week, hourly relative humidity varied from 28 to 100 percent. High relative humidity prevailed during each cyclonic disturbance. Humidity was relatively high during periods of greater cloudiness, precipitation, and tended to be high during normally cooler hours of day.

Wind speeds also varied appreciably from hour-to-hour and from day-to-day. The two higher wind speeds of the week occurred on days in which snow fell. An absolute maximum wind speed of 15 knots occurred on the day of the second storm, with gusts to 26 knots. Mean daily wind speeds for the hours of record for each of the two days were 10.3 and 13.8 knots, respectively. Mean wind speed for the week was 7.3 knots. Variable winds from westerly and northerly directions were most common.

Week of 24 - 30 April 1962 (spring)

The 7-day period from 24 to 30 April 1962 illustrates the variability of the weather during the transitional spring season at NLABS Annex. Rapid and drastic changes in weather constitute one of its most important features. Although no given period of different years has the same combination of weather conditions, the above period was generally typical of conditions that may be expected. During the week, mean daily minimum temperature was only 1 F degree lower than for the month of April for a 5-year period but mean daily maximum temperature was 12 F degrees higher than the 5-year period for April. Thus mean daily range was also significantly higher than the 5-year mean. Other weather elements discussed in this section show good correlation between this 7-day period and the 5-year period.

During the week, hourly temperatures ranged from 24° to 91°F -- a difference in extreme temperatures of 67 F degrees. Daily ranges in temperature varied from 3 to 55 F degrees (Table 26, Fig. 19). On 27 April the temperature rose from 36°F at 0500 hours to 91°F at 1500 hours (10 hrs later), giving an absolute maximum daily range for the week and month of April for a 5-year period. Mean daily range in temperature for the week averaged 35 F degrees, compared to 24 F degrees for 5-year period for April. During the 7 days, mean daily maximum and mean daily minimum temperatures were 70° to 35°F, respectively.

TABLE 26. SEVEN-DAY SPRING WEATHER SUMMARY AT NLABS ANNEX
24 - 30 April 1962

Weather Element	Day of Week							Week
	24	25	26	27	28	29	30	
Highest relative humidity (%)	86	88	100	100	97	99	100	100
Lowest relative humidity	24	26	38	18	26	59	93	18
Mean relative humidity	55	56	71	55	61	83	96	68
Maximum temperature (°F)	54	76	62	91	86	79	42	70
Minimum temperature (°F)	26	24	35	36	43	41	39	39
Mean temperature	40	45	48	63	64	60	40	52
Range (F°)	28	52	27	55	43	38	3	67
Mean wind speed (knots)	4.2	2.7	1.2	1.9	2.8	1.5	1.6	2.3
Peak gusts	28	23	11	17	21	16	6	28
Prevailing wind direction	N	WSW	SSE	WNW	SSW	NW	NNE	SSW
Calm (% of obs)	50	46	62	54	46	58	33	50
Mean sky cover (%)	15	51	50	12	32	75	100	48
Mean precipitation (in.)	0	0	0	0	0	.70	.78	1.48

Fluctuations in relative humidity vary inversely with that of temperature except for minor deviations. Relative humidity ranged from 100 percent at night down to 18 percent when the highest temperature of the week was recorded (1500 hrs, 27 Apr 1962). The highest minimum relative humidity was 93 percent, occurring on the last day of the week and also on a day on which it rained. Minimum relative humidity normally fluctuates much more from day to day than does maximum relative humidity.

Wind speed averaged about 2 knots at NLABS Annex during the 7-day period. Mean daily wind speeds varied from about 1 to 4 knots. They were usually higher in the midday hours but sometimes in the latter half of day. No observed hourly wind speeds exceeded 11 knots. The maximum peak gust was 28 knots. Calm ($<$ 1 knot) occurred on 52 percent of the hourly observations -- an unusually high frequency but is characteristic of conditions at this protected station (see section on winds). The prevailing wind direction was south-southwest 11 percent of the time. Winds from the southwest and northwest quadrants were about equally common (17 or 18% each). The high frequency of calm lowers mean wind speed and also frequency of winds from all directions.

A total of 1.48 inches of precipitation fell in the last $1\frac{1}{2}$ days of the 7-day period. It varied in intensity from very light drizzle to heavy rain (Table 27). Although light drizzle persisted almost three times longer than all other types of precipitation combined those types characterized by greater intensity produced nearly all the precipitation. Thunder accompanied by moderate rain occurred for 25 minutes in the midafternoon of 29 April. During the rainy period, hourly relative humidity remained at or close to 100 percent and sky cover was 100 percent. For the rest of the week, the percent of sky cover varied from clear to cloudy at irregular intervals and often within a few hours.

TABLE 27. TOTAL DURATION* OF DIFFERENT PRECIPITATION INTENSITIES AT NLABS ANNEX 24 - 30 April 1962

Day/ Precip	Very Light Drizzle	Light Drizzle	Rain Showers	Very Light Rain	Light Rain	Mod. Rain	Heavy Rain	Thunder	Total Precip (in)
29 Apr		3:01			3:37	0:49	0:29	0:25	.70
30 Apr	1:05	17:31	1:01	0:50		0:17			.78
Total	1:05	20:32	1:01	0:50	3:37	1:06	0:29	0:25	1.48

*Given in hours and minutes (hrs: min).

Week of 10 - 16 July 1960 (summer).

The weather data for the period from 10 to 16 July 1960 at NLABS Annex are for the most part representative of data for other 7-day periods in July (Fig. 20, Table 28). The same applies to a lesser extent for other summer months. However, some variation in one or more weather elements from the average condition is always present and occasionally this variation may be considerable. Although irregular variation in weather is much less frequent and less drastic in summer than it is in winter, this changeable characteristic is an important part of the basic weather pattern. It is unlikely that an almost infinite combination of weather elements would closely approach average conditions for any particular week.

During the week, temperatures occurring were typical of those recorded for a 6-year period. Mean daily maximum temperature for the week was 82°F, compared to 80°F for the 6-year period; mean daily minimum temperature was 57°F for both periods (Fig. 20, Table 28). Hourly temperatures ranged from 91° to 48°F. Daily maximum temperatures varied from 91° to 68°F, a difference of 33 F degrees between the highest and lowest maximum temperatures within the week. Daily minimum temperatures fluctuated only 17 F degrees in the same period. Daily maximum temperatures were 90°F and above on 2 days; daily minimum temperatures were below 50°F on 1 day and in the mid-and-high 50's on 4 days. Daily range in temperatures in the 7-day period averaged 25 F degrees, but varied from 10 to 34 F degrees. The absolute maximum range for the week was 43 F degrees, compared to 60 F degrees for the 7-day winter period (Table 25).

TABLE 28. SEVEN-DAY SUMMER WEATHER SUMMARY AT NLABS ANNEX
10 - 16 July 1960

Weather Element*	Day of Week 10	11	12	13	14	15	16	Week
Highest relative humidity (%)	100	100	100	100	100	100	100	100
Lowest relative humidity	40	50	37	44	93	37	36	36
Mean relative humidity	78	79	72	80	99	70	73	79
Maximum temperature (°F)	82	86	90	91	68	76	82	82
Minimum temperature	54	65	57	63	58	54	48	57
Mean temperature	68	76	74	77	63	65	65	70
Range (F°)	28	21	33	28	10	22	34	43
Wind speed (knots)								
0800 hours	0	4	4	0	-	10	0	
0900	0	5	4	3	-	11	4	
1000	4	5	4	5	-	11	4	
1100	4	8	3	4	-	10	4	
1200	4	7	0	4	0	11	0	
1300	4	9	7	4	6	7	4	
1400	5	6	7	8	0	0	4	
1500	6	0	6	4	7	0	10	
1600	9	4	0	0	8	0	0	
1700	4	7	0	-	3	0	4	
Mean wind speed (knots)	4.5	6.3	4.1	4.0	(4.5)	8.0	4.1	5.4
Prevailing wind direction	S	SW	SW	SW	N	N	N	SW & N
Peak gusts	-	9	13	13	16	18	12	18
Calm (% of obs)	20	10	30	22	33	30	30	25
Mean sky cover (%)	16	58	11	37	100	8	0	33
Total rainfall (inches)	0	0	0	.40	1.75	0	0	2.15

*All temperature and humidity values are based on hourly observations from 0800 to 1700 hours and from thermograph traces for the remaining hours. All wind and sky cover values are based on hourly observations from 0800 to 1700 hours. Because of an unusually high frequency of calm at other hours these data are not representative of 24-hour periods, particularly regarding mean wind speed and percent of calm each day.
- No data.

Although fluctuations in summer weather, particularly in its diurnal course, are caused mostly by cloudiness and showers resulting from heating of the earth's surface by the sun, cyclonic disturbances account for the less frequent but more irregular variations. During the week, one cyclone passed over the NLABS Annex. Atmospheric pressure started dropping slowly on 10 July. Three days later both sky cover and relative humidity had reached 100 percent and remained at 100 percent for about a day during which time 2.15 inches of rain fell. Its intensity varied from light to mostly moderate. No thunder was reported.

Relative humidity reached a maximum of 100 percent for at least a few hours each day between sunset and sunrise and during period of precipitation. Daily minimum relative humidity fluctuated greatly from day to day, varying from 93 percent on the most rainy day (14 July) to 36 percent on the only day when no cloud cover was reported (16 July).

During the week, hourly wind speeds in the 10-hour period from 0800 to 1700 hours varied appreciably from the 24-hourly average for July 1962 (Table 28). In the 7-day period, mean daily wind speeds at NLABS Annex ranged from 4.0 to 8.0 knots, based on 10 hourly observations each day. Maximum wind speeds up to 11 knots were recorded three times on the day following the rain, with gusts to 18 knots (Table 28). These winds were from the north and occurred during a period of rising atmospheric pressure and decreasing temperature. During the entire week, north and southwest winds each prevailed 22 percent of the time, and calm (<1 knot) prevailed 25 percent of the time.

By contrast, during July 1962 at NLABS Annex, the prevailing winds were north and northwest, each prevailing only 6 percent of the time. In that month, calm was almost three times more frequent than occurred during the sample week in July 1960. At the station, prevailing winds are normally from the northwest quadrant (not southwest) at any time of year.

Although the sample week selected appears at first unrealistic regarding ind velocity, a detailed examination of the hourly data for July 1962 and analysis of similar data for other months reveals that the hours from 1800 to 0700 have a high percent of calm. If the remaining 14 hourly observations had been taken the percent of calm would have been higher and mean wind speed lower, based on study of months in which 24 hourly observations are available. Thus the wind data tabulated from only the ten hourly observations and shown in Table 28 and illustrated in Figure 20 are reasonably representative of wind conditions occurring during those hours at the station--usually the warmer hours of each day.

Week of 15 - 21 October 1961 (autumn)

The 7-day sample of recorded weather data from 15 to 21 October 1961 exemplifies the rapidly changing weather conditions in a transition season at NLABS Annex (Table 29; Fig. 21). During this period, temperature conditions were particularly representative. Mean daily maximum temperature was only 2 F degrees cooler than the 5-year daily maximum for October; mean daily minimum temperature for the two periods was the same.

TABLE 29. SEVEN-DAY AUTUMN WEATHER SUMMARY AT NLABS ANNEX
15 - 21 October 1961

Weather Element	Day of Week							
	15	16	17	18	19	20	21	Week
Highest relative humidity (%)	100	100	100	95	100	100	92	100
Lowest relative humidity	75	34	37	37	45	67	56	34
Mean relative humidity	92	78	68	69	83	82	65	77
Maximum temperature (°F)	47	49	65	78	77	60	57	78
Minimum temperature	25	25	25	39	39	51	47	25
Mean temperature	36	37	45	58	58	56	52	49
Range (F°)	22	24	40	39	38	9	10	53
Mean wind speed (knots)	2.5	1.6	1.5	1.1	.1	3.9	2.3	1.9
Peak gusts	16	13	13	10	8	18	17	18
Prevailing wind direction	N	WSW	SSE	WNW	SSW	NW	NNE	N
Calm (% of obs)	29	67	50	62	96	25	42	53
Mean sky cover (%)	72	34	38	0	17	99	100	51
Precipitation (in.)								
Rain	.50	0	0	0	0	T	0	.50
Snow	1.7	0	0	0	0	0	0	1.7
Duration of ground fog (hrs)								22
Duration of fog (hrs)								18
Duration of haze (hrs)								9

T - an amount (trace) too small to measure.

In the 7-day period, daily range in temperature varied from 9 to 40 F degrees and averaged 26 F degrees. In the 3-day, midweek period (17 - 19 Oct), temperature fluctuated greatly each day, averaging 39 F degrees. During the first and last two days of the week hourly temperatures were relatively uniform. During the midweek warming trend, temperature rose from a minimum of 25°F to a maximum of 78°F in 33 hours. Daily maximum temperatures varied from 78° to 47°F compared to daily minima from 25°F for three successive days up to a peak of 51°F for the week. Thus it can be expected that the daily maximum and daily minimum temperatures are likely to vary appreciably from day to day.

Figure 21 illustrates the significant fluctuations and variations in relative humidity and temperature. Diurnal fluctuations were particularly evident from 16 to 19 October when the sunshine was the controlling influence in the daily weather pattern. However, cyclonic disturbances had a more important effect on the weather for the rest of the week. At night on most days relative humidity increased to or near 100 percent; during daylight hours daily minimum relative humidity varied greatly.

Observations with calm (<1 knot) are common at HLABS Annex. It occurred over 1/2 the time for the 7-day period compared to 2/3 of the time in October over a 2-year period. On an occasional day, all or almost all observations may be calm, such as occurred on 19 October (Fig. 21).

Variable winds averaged less than 2 knots for the 7-day period. Hourly observations never exceeded 8 knots, with peak gusts to 18 knots. The wind direction often varied from day-to-day and sometimes hourly. Winds from the northwesterly quadrant were most common, but the prevailing wind was from the north 15 percent of the time. In the absence of an important cyclonic disturbance, winds are higher during the day than they are at night.

Precipitation fell on two of the seven days. On the first day, this included .50 inch of very light to mostly light rain, including an estimated 1.7-inch snowfall of light intensity (melted as it fell). This was the first snowfall of the season. Four days later a 6½-hour rain of very light intensity fell without producing a measurable amount.

During the week, ground fog occurred on 3 days, fog on 2 days, and haze on 1 day. The total duration of each is tabulated in Table 29. Ground fog occurred mainly between sunset and sunrise.

7. Storms

Hurricanes

A hurricane is a severe tropical cyclone that sometimes inflicts heavy damage to the Atlantic seaboard, its adjacent interior, and the

West Indies. This storm has a vortex composed of air swirling 65 to over 130 knots (75 to over 150 mph) counterclockwise and upward around a low pressure center, called its eye. In the eye, 5 to 60 miles in diameter, calm or light winds and clear to partly cloudy skies prevail. Winds spiral around the eye and the highest wind speeds occur in the right forward quadrant in relation to the storm's movement. Destructive, gusty winds of a storm may extend out from the eye 10 miles in a small hurricane to 250 miles in a major hurricane (Tannehill, 1939). When the eye of a hurricane moves inland away from the coast or when cooler or drier air is drawn into the storm, wind speed diminishes rapidly. Friction of the wind against rough terrain, covered with trees or man-made structures, also reduces a hurricane's intensity.

The infrequent hurricanes that hit New England in some years originate over warm, moist water of the southeast portion of the North Atlantic south of Cape Verde Islands between latitudes 10° N and 15° N and less often in these latitudes farther west. They occur primarily in August and September.

Once a tropical cyclone shows potential of reaching hurricane force the storm is assigned a girl's name by the Weather Bureau for convenience in future identity. A storm designated a hurricane* usually lasts 8 to 12 days, but torrential rain and destructive winds affect southern New England only a day or two.

Although relatively few hurricanes affect at least a part of southern New England, a number of them were highly destructive storms. Many occurred prior to the period of meteorological observations at NLABS Annex. The famous 1938 hurricane caused extremely heavy losses, partially because of inadequate warning systems at the time (Table 30). This relatively intense September storm was clocked at 49 knots (56 mph) as it moved through New England. In Cambridge, Massachusetts, a velocity of more than 87 knots (100 mph) was recorded 5 times by a bridled anemometer during the storm. Gusts of 65 knots (75 mph) or more were recorded 76 times in 4 hours, and 48 of these came in a single hour (Brooks, 1940). At Blue Hill Observatory**, Milton, Massachusetts, a gust of 162 knots (186 mph) was recorded during the same storm, with an uncertainty, however, of 26 to 35 knots. Where the wind had to flow over, around or between obstructions the velocity was greatly increased locally, as indicated by greater damage to man-made structures and to trees in more exposed places.

*Once a tropical cyclone, or tropical storm, reaches hurricane force it is referred to as a hurricane even when the intensity drops appreciably below hurricane strength.

**Elevation of weather shelter was 635 feet; the anemometer was situated 30 feet higher. As expected, wind velocity was significantly higher at the observation station near the summit of this conspicuous hill.

TABLE 30. EIGHT MAJOR HURRICANES IN SOUTHERN NEW ENGLAND

Name	Period			Date; Path across or near New Eng	Remarks
	Year	Days	Mo		
	1938	16-22	Sep	21 Sep; N across W-cen Mass	Greatest property damage of any previous storm anywhere in world at the time
Carol	1954	-31	Aug	31 Aug; N across E-cen Mass	Intensity comparable to 1938 hurricane in New Eng; 2" - 5" precip but no serious flooding; E Mass swept by 43- to 61-knot winds, with 56- to 74-knot gusts; NLABS Annex in disaster area
Edna	1954		Sep	11 Sep; passed over Marthas Vineyard and Cape Cod	2nd hurricane within 11 days; less wind and wave damage than Carol but more water damage
Connie	1955	4-13	Aug	13 Aug; NW across Pa	4 - 6" of rain over most of S New Eng but only 2-4" over NLABS Annex area
Diane	1955	11-19	Aug	18-19 Aug; passed E-ward near S coast of New Eng	Rains less than a week earlier by Connie left ground saturated - thus high run-off rate and major flooding; Mass declared disaster area after 48 hrs of almost uninterrupted heavy rain
Gracie	1959	20-2	Sep-Oct	Eastward N of Mass. border	Erratic intensity and movements
Donna	1960	29-13	Aug-Sep	12 Sep; moved NE across E-cen Mass.	Full hurricane force winds in Fla., Mid-Atlantic States, and New Eng - first occurrence in all 3 areas in 75 yrs.
Esther	1961	11-26	Sep	25 Sep; passed over Cape Cod	Clockwise turn SE of Cape Cod, Mass. started 21 Sept, passing over Cape on 25 Sept

In August 1954 hurricane Carol smashed northward across east-central Massachusetts (Worcester area) with an intensity comparable to the 1938 storm, with water and wind damage of similar catastrophic proportions. Eleven days later the eye of hurricane Edna passed over Cape Cod, causing more water damage but less wind damage than did Carol.

Again in August of the following year (1955) hurricane Diane dealt a staggering blow to the three southern New England states as the eye of the storm moved east-northeast off their southern coast. Although winds were well under hurricane strength Diane's torrential rain produced record floodings, for hurricane Connie had deposited 2 to 4 inches of rainfall over the area in which the NLABS Annex is situated less than a week before and 4 to 6 inches in most parts of southern New England. Diane delivered an additional 9.00 inches of rainfall to Clinton and 9.22 inches to Framingham in a 37-hour period. These stations are about 11 airline miles west and 9 miles south of the reservation, respectively. Since the ground was already soaked, and reservoirs at high levels Diane's very heavy rain on the tristate area for nearly 2 days almost without interruption produced unprecedented rapid and widespread runoff and consequently resulted in major flooding.

In September 1960, hurricane Donna devastated Florida, the Middle Atlantic States, and New England. This was the first time in 75 years that a hurricane had hit all three areas with full hurricane-force winds (Moore, 1961). The unusually large hurricane passed northeastward through east-central Massachusetts. Although a maximum peak gust of 122 knots (140 mph) was recorded at Blue Hill Observatory the highest gust recorded at NLABS Annex was 37 knots (43 mph) from the northwest (See section on wind). A total of 4.40 inches of rain fell at NLABS Annex in about a 30-hour period. In this period, heavy rain occurred for a total of 9 hours and 26 minutes. Meteorological conditions that occurred before, during, and after hurricane Donna are shown graphically in Figure 22.

Although hurricane Daisy caused little wind damage in October 1962, it contributed appreciably to the 5- to 11-inch rainstorm in the eastern part of southern New England. Heavy rains accompanying and preceding Daisy resulted in serious flooding in the interior. However, rains from a weak extratropical system moving through New England just prior to Daisy's arrival were a heavy contributor to the large precipitation and to subsequent flooding. In this nearly 4 days of continual rain, 7.85 inches fell, including heavy rain for a total of 7 hours and 37 minutes. An additional 1.63 inches was recorded later in the month. The 9.48 inches of precipitation for October 1962 was the wettest of the 63 months of record. In the following three years (1963 - 1965), no hurricane came close enough to New England to cause widespread damage.

Although hurricanes tend to move along broad paths over water no two hurricanes ever take the same path. Once formed, a hurricane is carried along by large-scale (hemispheric) air streams extending up to heights of 40,000 feet in much the same way that an eddy in a brook is steered by a broad water current. In the lower latitudes (Florida and southward) a hurricane moves in a west-northwesterly direction in the trade wind belt. As a hurricane moves to the west of the subtropical high pressure area over the southern portion of North Atlantic the storm is usually caught in a meandering stream of the prevailing westerlies. From there on a hurricane generally moves in a more northerly direction and finally eastward. Thus when the westerlies and trades shift abnormally far north for an unknown reason, a hurricane may be swept sufficiently northward to affect New England before the storm moves out to sea or dissipates over land.

In a given area, amount of wind damage is mainly dependent on the intensity of a hurricane and proximity of a place to the most violent winds whirling around the eye of a storm as it passes. Location of an area with respect to a hurricane's path also determines the direction of the highest winds and the sequence of wind shifts.

Because of many complicated variables in hurricane behavior, such as forward speed and direction and intensity, the Weather Bureau seldom issues hurricane warnings more than 24 hours in advance and sometimes, in case of unusual or erratic hurricane movement, only a few hours in advance of the onset of hurricane conditions. For instance, a hurricane may remain almost stationary for a short time, but its forward speed can exceed 50 knots, usually increasing at higher latitudes. Thus it is of utmost importance that precautionary measures be taken immediately when a hurricane warning is announced.

Tropical storms

A tropical storm is a tropical cyclone having an intensity of 28 to less than 65 knots (32 to 75 mph), differing from a hurricane in that hurricane force is never reached. Those affecting New England originate over the southern portion of the North Atlantic, Caribbean Sea, or occasionally over the Gulf of Mexico. A tropical storm brings strong to violent wind conditions and usually abundant rain to the affected areas.

The number of tropical storm tracks (eye) passing through New England (including Long I.) by 5-year periods from 1901 to 1955 are shown in Figure 23. This graph shows that the occurrence of such storms averages less than 1 per year. A tropical storm may affect several or even all the New England States. It is less intense but is likely to affect a larger area than does a hurricane.

Glaze storms

As defined officially by the U.S. Weather Bureau, glaze consists of "... homogeneous, transparent ice layers which are built upon horizontal as well as vertical surfaces either from supercooled rain or drizzle, or from rain or drizzle, when the surfaces are at a temperature of 32°F or lower." Glaze should not be confused with such terms as "sleet", "ice storms", "glazed frost", "silver thaw", and "glare ice". (Bennett, 1959, according to Haynes, 1947)

Glaze develops only where exacting temperature and moisture conditions between two air masses are sharply drawn. Freezing rain or freezing drizzle seldom occurs by itself. This is because storms with which glaze is associated are usually dynamic moving systems from which several types of precipitation are falling simultaneously. Snow, sleet, or non-freezing rain or drizzle almost always precede, follow, or even accompany the formation of glaze. A typical sequence of precipitation consists of snow, sleet, freezing rain, and nonfreezing rain, in that order, as a storm passes over a point, but almost any possible combination or sequence of precipitation types can occur. When snow follows glaze extremely dangerous conditions are created, particularly for motor vehicles.

The earliest glaze storms in eastern Massachusetts occur almost entirely after 15 November and the latest in April. December, January, and February are about equal as months with maximum number of days of freezing precipitation, with a slightly greater frequency in January.

According to a map* by Bennett (1959), the NLABS Annex is near the east edge of the area having the highest frequency of occurrence in the 48 contiguous United States, based on data for a 9-year period and including storms causing no damage. In this general area, including northern Connecticut and most of Massachusetts, the total number of glaze storms, without regard to ice thickness, varied from 36 to 44 storms, averaging 4 to 5 storms per year. A substantial number of the storms produced glaze 0.25 inch or more in thickness. Findings mapped by the American Telephone and Telegraph Company engineers indicate that a heavy ice storm** occurs in eastern Massachusetts in at least one year out of three.

Most storms show wide variation in thickness of ice deposited - often within remarkably short distances. Only slight meteorological changes affecting intensity or duration of glaze storms produce conspicuous variations in ice thickness. Influence of purely local factors related to microclimate also may cause sharp contrasts in thickness of ice deposited on exposed surfaces.

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*Data from Association of American Railroads study for period from 1928-1929 to 1936-1937 (undated).

**Defined by the American Telephone and Telegraph Company as the diameter of the ice covering a cable 3/4 of an inch or more. When the diameter is less than 3/4 of an inch, but still sufficient to cause appreciable damage to exposed cable, the storm ranks as "medium" (Anonymous, Weather Res Bull, vol 3, no 1).

Brooks (1930) illustrates an unusually sharp demarcation in glaze formation produced by small but critical temperature differences. "In Worcester [Mass.], an altitude of 570 feet above sea level divided ice from bare areas. The line was so definite on trees that it could be described as at the level of the tops of first story windows in a certain house. While lower branches were bare, the tree tops bent under 1/4 inch of glaze."

In regard to the important influence of microclimate, Geiger (1950) states "Glaze is probably the most sensitive symptom of changing ground conditions. "... Every street, every curb-side, every kind of ground, every kind of stone has its own (different) glaze formation. Long-filled excavations at the side of the street are plainly visible. Surface roughness, the thickness and type of stone facings, the inclination of the ground - everything shows up." Thus the formation and duration of glaze are intricately affected by the heat-conducting and heat-storing ability of surface materials of various types.

Temperature of the air near the ground and exposure of surfaces to wind are also important factors in the microclimate affecting formation and duration of glaze, particularly when temperatures are both at or near the freezing and dew points. A greater flow of saturated air over frozen surfaces increases formation of glaze, but at other times a brisk wind is likely to remove glaze from such surfaces as tree limbs or utility lines.

Glaze storms are much less publicized than violent storms and last longer, but no storm can be more paralyzing to communication and transportation. Utility lines and poles are especially vulnerable during a heavy glaze storm, the breakage of wire being the most common type of damage suffered. Wires are broken mainly by unequal distribution of ice load, by wind multiplying many times this ice burden, and by trees and limbs falling across wires.

Although glaze storms never halt railroad operations, major effects of such storms are loss of communication and signal systems. Disrupting of these facilities causes delays of a few hours to two weeks in on-schedule operations, but restoration of normal communications takes somewhat longer.

In most situations, cross-country movement of any vehicle adapted for non-highway operation will usually not be hindered by glaze (Bennett, 1959). If the ground is unfrozen or only slightly frozen the weight of most vehicles will break through the ice; if the ground is frozen, vehicles may break through frost heaves and perhaps have better traction on the ground beneath the ice. Tracked vehicles, of course, perform better than those mounted on wheels and encounter difficulty mainly when climbing steep slopes where unusually thick glaze overlies solidly-frozen ground. Movement through wooded areas might be difficult after some storms, because of broken boughs and downed trees on the forest floor. Badly bent trees and sagging limbs entangled with ice-coated shrubs and grasses also tend to reduce visibility a few feet above the ground surface in forested areas.

The effect of glaze on vehicular and foot travel varies considerably with different surfaces. "Braking tests [by National Safety Council] indicate the average stopping distances for trucks and passenger cars traveling 20 miles per hour are 10 times longer on glaze than on dry concrete and from 2 to 3 times longer on glaze than on packed snow." (Bennett, 1959). Glaze forms at about the same rate on concrete as on macadam, but sometimes melts a little sooner on macadam. Trafficability over ice-coated gravel or rocky surfaces is extremely treacherous for vehicles and for pedestrians. During a glaze storm, trafficability is generally much better in places where low herbaceous vegetation grew in the previous season. However, it is dangerous for one to walk in a forest during or just after a major glaze storm owing to the crashing of boughs and lumps of ice.

The most economically effective remedies for improving the flow of traffic on icy paved areas are the application of cinders, sand, or one of the chloride salts. Fortunately, the remedies are most effective when the temperature is near 32°F, that is, when the ice is slipperiest. At extremely low temperatures abrasive materials do not sink into the ice so readily under pressure from traffic.

Northeasters

A northeaster is a cyclonic storm of the east coast of North America in which the winds are from a northeasterly quadrant. Although a northeaster may occur at any time of year such storms are most frequent and most violent between September and April.

Storms that develop into northeasters usually originate between latitudes 30° and 40° N within 100 miles east and west of the coastline. They move generally northward and northeastward and typically attain maximum intensity near New England and the Maritime Provinces. Northeasters nearly always bring precipitation--sometimes substantial precipitation over a period of two or three days in New England. Frequently winds of gale force occur on the affected coastal areas, but inland from the coast wind velocity diminishes.

The northeaster illustrated in Figure 24 exhibits characteristics of this type of storm. The January storm brought 2.31 inches of rain and freezing rain to NLABS Annex. Since the weather station is partially protected by a prominent ridge and the aerovane is mounted only 2 meters above ground, wind speeds never exceeded 5 knots during the period of precipitation. Elsewhere at the NLABS Annex, particularly on hill tops and at greater heights above ground, higher wind speeds presumably occur. In winter, northeasters account for some of the larger snowstorms in the area. This is especially true when a storm center remains relatively stationary for a few days near the coast in such a location that northeast winds prevail at the station.

Hailstorms

Hail is precipitation in the form of balls or irregular lumps of layered ice. Individual units are called hailstones. They are always produced by convective clouds, nearly always cumulo-nimbus. Conditions favoring its formation include thunderstorms characterized by strong updrafts, large liquid water contents, large cloud-drop sizes, and great vertical height.

Hailstorms are rare, averaging less than 1 per year in area of NLABS Annex in a 10-year period from 1944 to 1953 (Anonymous, Weather Res Bull, vol 1, no 1). Except at Hartford, Connecticut, total days with hail average less than 1 per year at each of the six stations in New England (Table 31). During a nearly comparable period (Feb 1943 - Sep 1953) at Bedford, Massachusetts, hail occurred three times (U.S.A.F., Air Weather Service - unpublished). Local terrain and nearness to the ocean affect somewhat the distribution of hailstorms that are characteristically small in areal extent. A hailstorm is most likely to form in the hours just after the warmest part of the day and during the warmer months, but have occurred in all months in New England and have also occurred at night.

Statistics on the likelihood of a hailstorm within eastern Massachusetts appear to be well documented, but are not in a form in which frequency of hail by size can be related to probability at any station. The most frequent size of the largest stones for each storm is 1/4 inch, based on 472 reports from cooperative residents well within 100 miles of Boston in a 5-year period. Sizes as large as 3/4 inch were mentioned in one-quarter of the reports. Frequency of very large sizes in these five years were:

Size	Frequency	Cumulative Probability
1.00 inch	11	4.45%
1.25 inches	4	2.12%
1.50 inches	5	1.27%
3.00 inches	1	0

"Assuming that this distribution of excessive sized hail stones is typical of the distribution in a representative sample of hailstorms that might be encountered at any one station in eastern Massachusetts over many years, the probability that a storm at a given point in the area will include hail equal to or greater than 1.0, 1.25, and 1.50 is the same as the cumulative probability shown in the tables above." (Sissenwine and Gringorten, 1966)

TABLE 31. TOTAL DAYS WITH HAIL* AT STATIONS IN NEW ENGLAND

Station	Yrs Obs	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Burlington, Vt.	37	0	0	1	1	5	4	7	3	4	1	0	0	26
Hartford, Conn.	39	0	0	2	5	11	12	15	7	1	1	2	1	57
Nantucket, Mass.	40	0	0	4	5	3	1	0	0	1	1	4	2	21
New Haven, Conn.	40	1	1	3	4	10	4	5	3	1	2	1	0	35
Portland, Maine	40	0	0	2	4	4	3	6	6	2	6	0	0	33
Boston, Mass.	40	0	0	1	3	5	5	8	3	1	0	2	0	28

Tornadoes

A tornado is a violent local storm with rapidly whirling winds estimated at over 400 knots (or 500 mph). A tornado can be easily identified by a spinning funnel-shaped cloud that extends toward the ground from the base of a thundercloud. This typically gray, black, or often greenish-black tornado cloud looks much like a huge spinning top. Most tornadoes move from a westerly direction at an average speed of 30 to 45 knots (25 to 40 mph). When one is nearby, it sounds like the roaring of hundreds of propeller-driven airplanes.

Tornadoes start to form several thousand feet above the earth's surface and some never reach the ground, or they may touch the ground and rise again. Tornado formation requires the presence of layers of air of contrasting temperature, moisture, density, and windflow characteristics. It seems probably that a tornado occurs only when there is a precise combination of several rather common but highly variable weather conditions. Tornadoes usually occur in connection with thunderstorms, particularly those producing hailstones that fall to the ground. A tornado is sometimes accompanied by a series of smaller tornadoes.

*After Hull, 1957

Severe tornado destruction is confined mainly to the path where its funnel swept the earth's surface. This path of destruction is usually 10 to 40 miles long but occasionally may be 300 miles long. Its average width is about 400 yards but swaths over a mile in width are sometimes experienced.

Although a tornado can occur at any time of day or year and can be the most dangerous of all storms, the probability of a tornado striking a given locality is slight because of infrequent occurrence and small areas of destruction. The NLABS Annex lies in an area where an average of 3 to 6 tornadoes are reported annually, but the odds that a given square mile of land in the reservation will be struck by a tornado run into five or six figures (Anonymous, Weather Res Bull, vol 1, no 1). In fact, tornadoes are infrequent in the heart of the nation's tornado area, where the probability of a tornado in a given square mile is 1,200 to 1 against in Iowa (where risk is greatest). In Massachusetts from 1956 to 1962, the number of tornadoes reported to the Weather Bureau each year ranged from none in 1960 to 10 in 1956 and in 1958. For various reasons, many additional tornadoes are not observed and, if so, are not reported.

Most tornadoes actually do relatively little damage to property and seldom result in many fatalities, but there are notable exceptions. One of the most disastrous tornadoes in the nation hit Worcester, Massachusetts, on 9 June 1953. As far as known, no tornado has ever devastated any part of the NLABS Annex. National records indicate that tornadoes occur most often in late spring and early summer. They are most likely to form in the hours closely following the warmest parts of the day but can occur at any hour of the day or night.

8. Vegetation

The vegetation of NLABS Annex, originally part of the Transition Hardwoods - White Pine - Hemlock Zone, reflects earlier uses of the area and recency of them (Westveld, 1956). These have resulted in sharp contrasts in species composition and size of species - even between small fields that were abandoned 25 or more years ago. The vegetation is conveniently classified into six major types, based on use of recent air photographs (13 and 21 May 1965) and field checks in almost all areas. The six vegetation types are: 1) conifers (70 to 100% canopy), 2) deciduous hardwoods (70 to 100% canopy), 3) mixed hardwoods and conifers (neither 70% canopy), 4) grass, abandoned orchards, and low shrubs (< 5 ft), 5) saplings and high shrubs (> 5 ft), and 6) sparse vegetation and barren ground.

Of the three forest types illustrated in Figure 25, hardwoods are most extensive; conifers least extensive (Photo 9). Each type has a canopy greater than 70 percent. Forests cover about 3/4 of the reservation, and contain 4,000,000 board feet of lumber.* The trees are mostly of medium height, averaging 30 to 80 feet. Over a large part of the reservation a tree trunk of 6 inches in diameter is fairly large, but trunks of 6 to about 15 inches are not uncommon in the more heavily forested areas.**

Mixed hardwoods and conifers grow on adequately drained lowlands and on hill tops as well as sandy terraces (Fig. 25). A variety of oaks (Quercus) and hickories (Carya), along with white pine (Pinus strobus), grey birch (Betula populifolia) and aspen (Populus tremuloides, P. grandidentata) are representative species in those areas. Other characteristic hardwoods include red maple (Acer rubrum), American elm (Ulmus americana), and pin cherry (Prunus pensylvanica). Red maple is frequently the dominant hardwood in swamps and in floodplains along streams (Photos. 10, 11). Thus the presence of red maple as a dominant hardwood species is a good indication of inadequate drainage and swampy conditions, although an occasional tree may be found on relatively high, dry soils. Of the conifers, white pine is by far the most common but density of trees often varies significantly within short distances (Photos. 10, 12). Species composition and size of trees in this mixed forest type also vary greatly, because of complex differences in soil, slope, exposure, drainage, microclimate, former land use, and in processes of natural reforestation. Underbrush consists mainly of deciduous saplings, a number of occasional pines, and infrequent patches of shrubs (Photos. 13, 14). Pitch pine (P. rigida), least common of the pines, grows in relatively open localities in which soils are very poor and dry; it rarely occurs in groves. A small grove mixed with some hardwoods does occur at the east margin of a former satellite weather station (Clark) at the south end of the NLABS Annex. Other conifers, such as white spruce (Picea glauca), hemlock (Tsuga canadensis), and tamarack (Larix laricina) are sometimes mixed with other species but are uncommon in the reservation.

Pure or nearly pure stands of conifers occur as mostly small groves, but larger groves are found in some places. Conifer groves are in many parts of the reservation. Although they may be found adjacent to any of the other vegetation types, small groves commonly occur alongside or within mixed hardwood and conifer forests. Only white pine groves occur in the reservation north of Hudson Road. Among the larger white pine groves, one occupies the southeast slope of the highest hill (323 ft), another grove is on the southeast side of the second highest hill (312 ft), and a third grove is on the lowland between the latter hill and Taylor

*Estimated by a forester, according to personal communication with Mr. William H. Brocklebank, Office of Post Engineer, NLABS, 16 June 1966.
**The largest tree, a white pine in the Puffer Pond picnic area, measured by the author, is 34 inches in diameter [106 inches in circumference] at about 3 feet above the ground (June 1966).

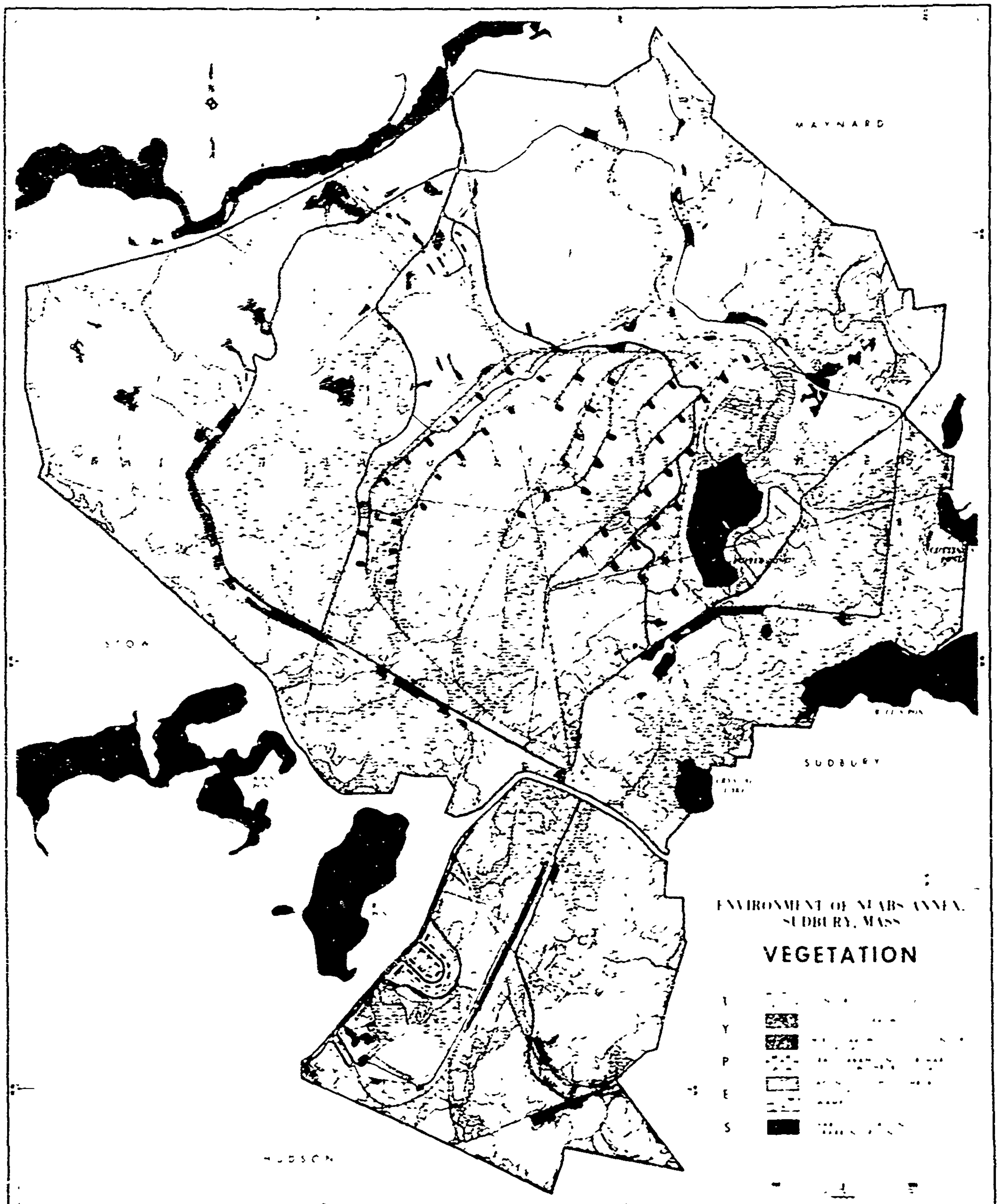

Figure 25

Brook (Photos. 12, 15). South of Hudson Road, several plantings of red pine (P. resinosa) occur in narrow strips along roads or trails (Photos. 6, 16). In dense pine groves in which trees are of at least medium height, underbrush is conspicuously absent; pine needles completely cover the ground. Except on large pine trees, all the lower limbs are dead and easily broken, but hamper visibility and mobility until they are removed. A typically dense canopy in pine groves reduces greatly the amount of light reaching the ground and thus prevents growth of underbrush. Numerous tree trunks in dense stands also restrict visibility and mobility. In older groves lower dead branches to well above head height are normally absent; foot travel is relatively good, although pine needles tend to be slippery in any area, particularly on slopes.

Hardwoods are most extensive of any vegetation type in the reservation (Photos. 9, 12). Representative stands occur on hill west of main gate, on a large hill (252 ft) outside the security fence in the north-northeast area (Photo. 14), on the hill slope west-southwest of the headquarters area (Photo. 16), and in large swamp west of Willis Pond (Photo. 10). Where appreciable light penetrates a hardwood canopy, many hardwoods and occasional white pine saplings to over 10 feet high grow in both hill and lowland areas. Although these saplings are moderately numerous they were disregarded in classification when larger hardwood trees formed a canopy greater than "0 percent (Photos. 7, 13). A hardwood forest consists of numerous species but one or a few species may dominate a given locality. For instance, red maple is usually the dominant species in poorly drained areas (Photo. 10), and gray birch often grows in relatively pure stands on small plots where soils are dry or sandy but occasionally on wet or swampy soils along margins of streams. Birch can propagate rapidly from roots but is not tolerant of shade. Hardwoods are particularly dominant on swampy flats. In wet areas underbrush varies considerably from place to place. Underbrush consists of shrubs or saplings and sometimes both. Shrubs are relatively more important than saplings compared to better drained areas.

Saplings and high shrubs (>5 ft) grow in many parts of the NLABS Annex. They form a canopy over at least 50 percent of each area shown in Figure 25. Saplings usually grow in open areas that are not exceedingly wet or exceedingly dry. They are found along abandoned roads and trails, outer margins and higher places in swamps, in more recently abandoned fields and former pastures, and in older orchards. Although high shrubs grow in some dry places on hills, high shrubs often form the dominant vegetation in swamps. Examples of high shrub swamps can be seen northwest of Pine Lake settlement (Photos. 10, 11) and south of Hudson Road immediately east of the railroad. High shrubs also grow in large patches in scantily forested areas on the hill west of headquarters; some of these shrubs bear spines. Because of the high density of stems in areas of saplings and high shrubs it is considerably more difficult to walk through these areas than it is in any of the forest types previously described.

Grass, old orchards, and low shrubs (<5 ft) constitute a fifth vegetation type. Grass occurs in usually small areas. However, the headquarters area and the adjacent airdrop zone are almost completely grass covered (Photo. 3). Grass also thrives in most abandoned orchards, including places where apple trees have all but disappeared. The largest of these small orchards is adjacent to the patrol road southwest of Vose Hill (near Gate 11). The old apple orchard, about average in size, is shown in Photo. 3 but is in far better condition than most. Where no roads or trails exist trafficability by vehicle or on foot is better in grass areas than in any other vegetation type in the reservation. Except for some remaining apple trees and an occasional small patch of saplings growing in periodically moist places there are no obstructions to visibility at eye-level height in many places.

All herbaceous vegetation is included in this same vegetation type, regardless of whether they grow in wet or other areas.

Although low shrubs form a dense cover about waist high in both poorly drained and well-drained areas they tend to be more continuous and extensive over swamps (Fig. 25, Photos. 11, 17). Low shrubs, such as sweet gale (Myrica gale), grow along borders of ponds and in swamps; by contrast, sweet fern (Myrica asplenifolia) is found in usually smaller patches on sterile, dry soil. Although the shrubs are low, walking through their thick, tough, gnarled stems and branches can be extremely difficult, but more widely spaced, tree-shaped shrubs may present little difficulty. For instance, in the swamp north of the Pine Lake settlement, the author found trafficability exceedingly poor on foot during the late dry autumn of 1965 (Photo. 11). In that area, a dense mass of sturdy low shrubs, mainly leather leaf (Chemaedaphyne caliculata), almost covered an exceedingly irregular ground surface. The ground was also covered with moss, where no evidence of standing water existed. Where slight changes in elevation and drainage occur gradually the boundary between low and high shrubs is not always clearly evident on either aerial photographs or in the field, particularly in larger transition belts such as those bordering Willis Pond (Photo. 11) or south of Hudson Road (Photo. 17).

Ferns are common in the low-lying, damp, wooded areas.

Abandoned cranberry bogs occur in a few places. Two of the larger areas are north of Puffer Pond (Photo. 14); a small one is shown in Photo. 7. They form part of the low-shrub vegetation type. The larger bogs are easily identified in the photograph by their parallel ditches between which low cranberry shrubs dominate most parts of both saturated areas. Because of the sluice gate beside the patrol road in the north part of the NLABS Annex the ground water level remains relatively constant.

Sparse vegetation and barren ground, the sixth category shown in Figure 25, includes those areas in which more than 50 percent of the ground is exposed or covered with buildings or paved roads. Such areas may be infertile or excessively sandy, places where top soil had been removed, or where surface had recently been distrubed by excavation, testing, or other activity. Except in excessively sandy or wet places, they provide adequate support for limited vehicular traffic.

Physical Changes

Human occupance of the area included in the present reservation has produced drastic changes in the original forest. The area was repeatedly deforested prior to about 1943 when the U.S. Government acquired the present reservation. Much of the land was altered significantly by cultivation and grazing, drainage ditches, excavations for various purposes (sand, gravel, construction, etc.), and field research and testing in recent years. Because of these effects on the natural vegetation its general pattern shows numerous and often small areas of contrast in species compostion, size, and density. This complex pattern is also basically one of different drainage and soil conditions.

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APPENDIX I

Graphs

MEAN AND MAXIMUM DAILY RANGES IN TEMPERATURE (F°) BY MONTHS AT NLABS ANNEX

2 June 1958 - 31 August 1963

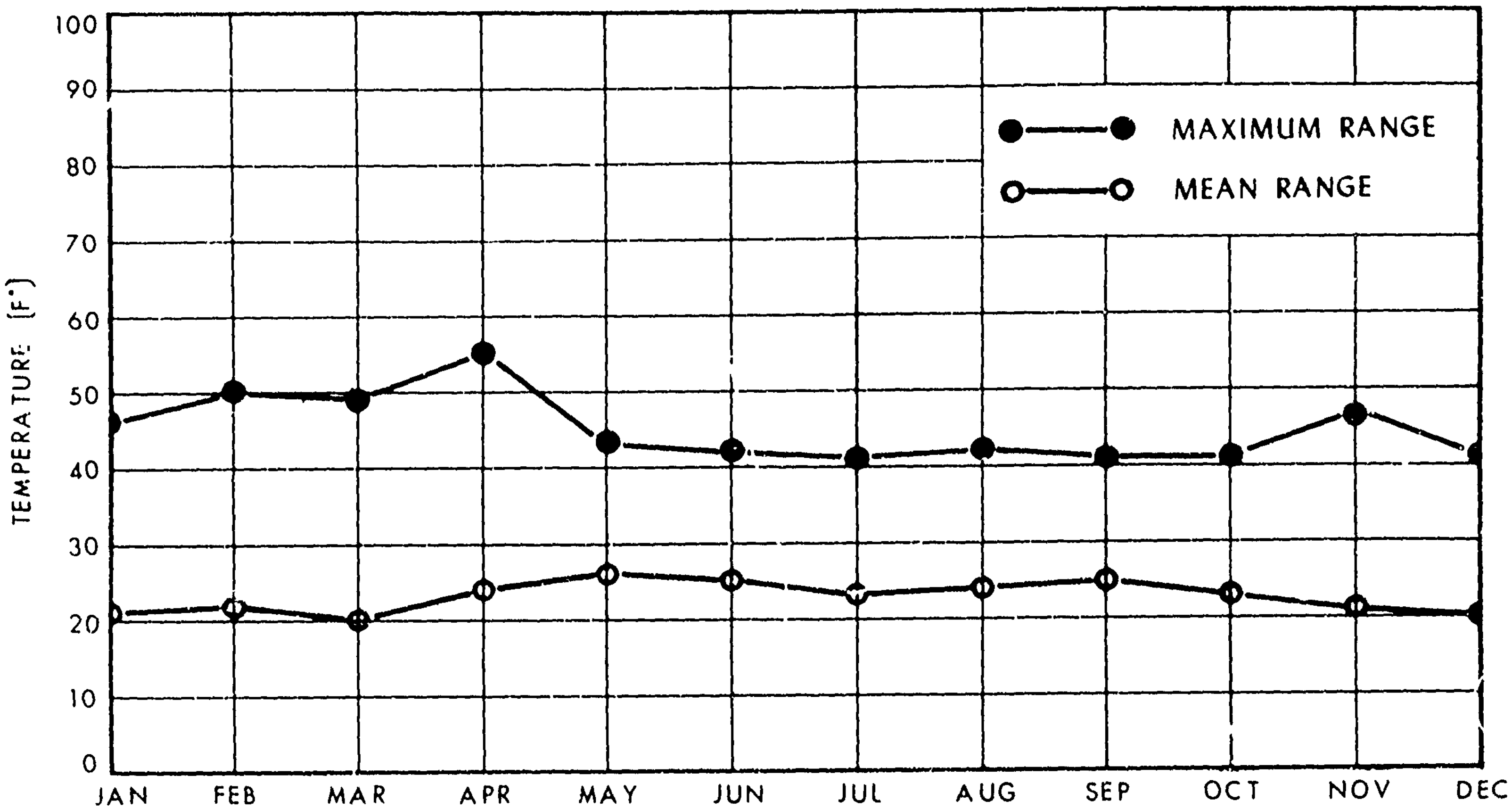


Figure 7

5-DAY, RUNNING-MEAN TEMPERATURES AT BASE AND FIVE SATELLITE STATIONS AT THE NLABS ANNEX

3 - 29 JANUARY 1961

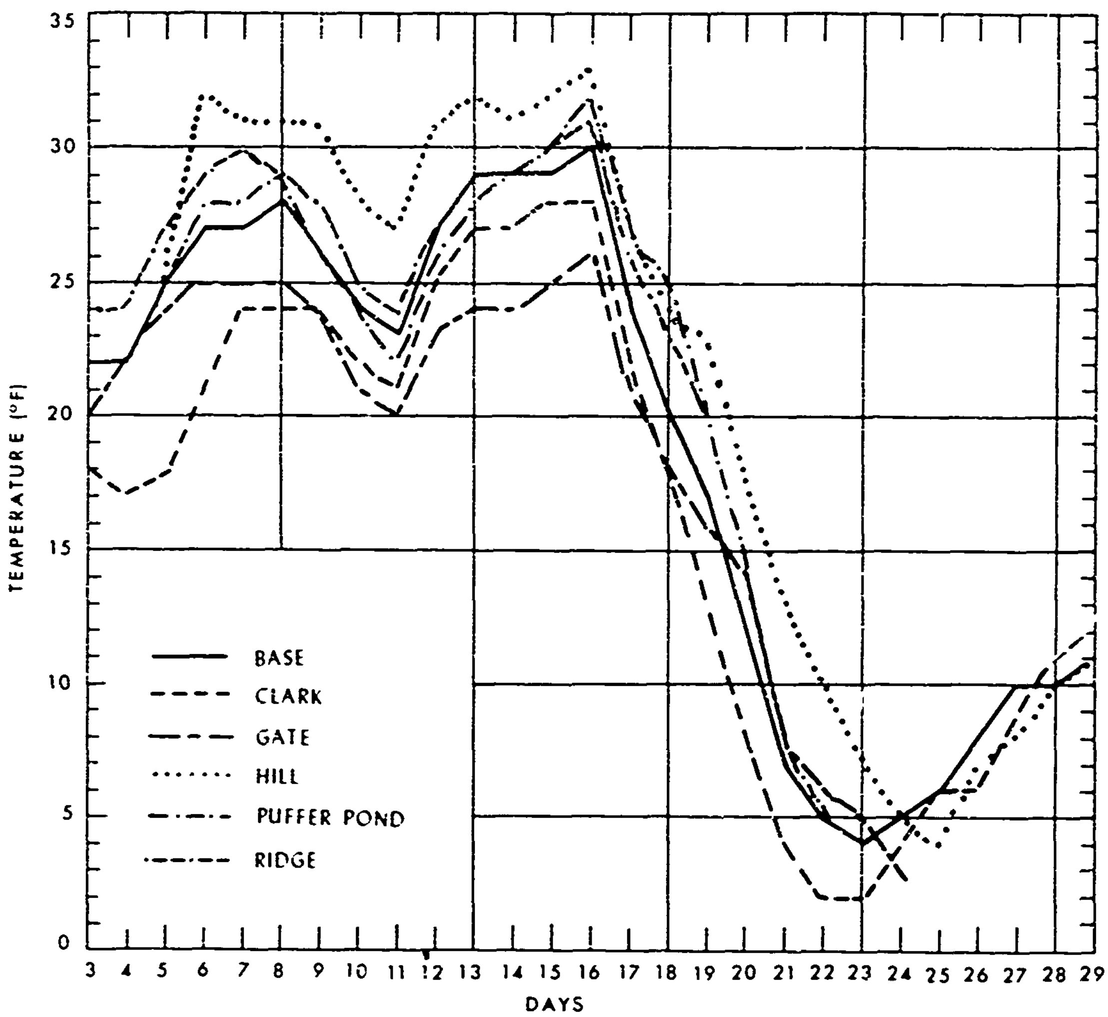
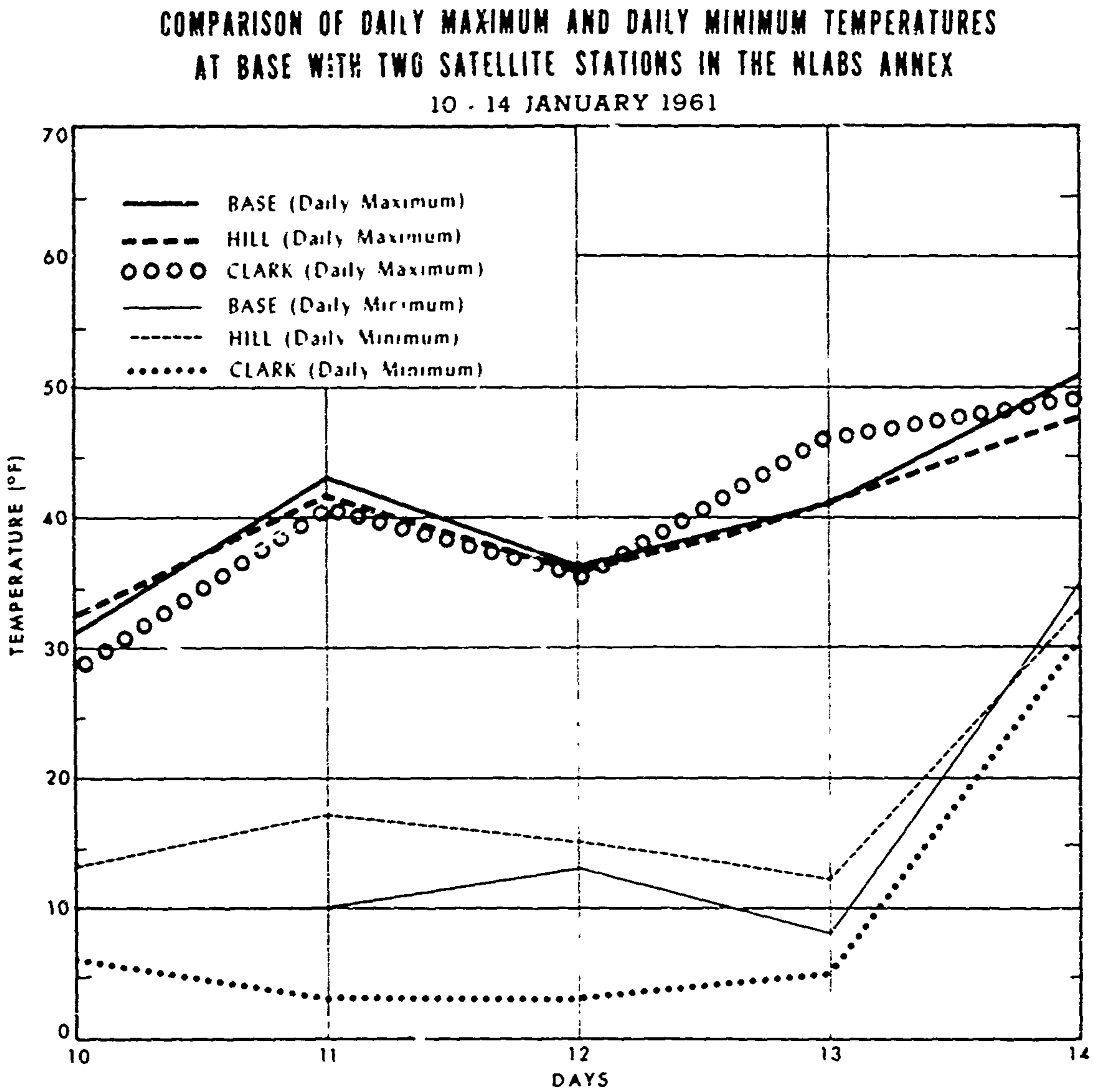


Figure 8



COMPARISON OF DAILY MAXIMUM AND DAILY MINIMUM TEMPERATURES
AT BASE WITH TWO SATELLITE STATIONS IN THE NLABS ANNEX
10 - 14 JANUARY 1961
BASE (Daily Maximum)
HILL (Daily Maximum)
CLARK (Daily Maximum)
BASE (Daily Minimum)
HILL (Daily Minimum)
CLARK (Daily Minimum)
TEMPERATURE (°F)
DAYS
0
10
20
30
40
50
60
70
10
11
12
13
14

Figure 9

COMPARISON OF DAILY MAXIMUM AND DAILY MINIMUM TEMPERATURES

AT BASE WITH TWO SATELLITE STATIONS IN THE NLABS ANNEX

20 - 22 JANUARY 1961

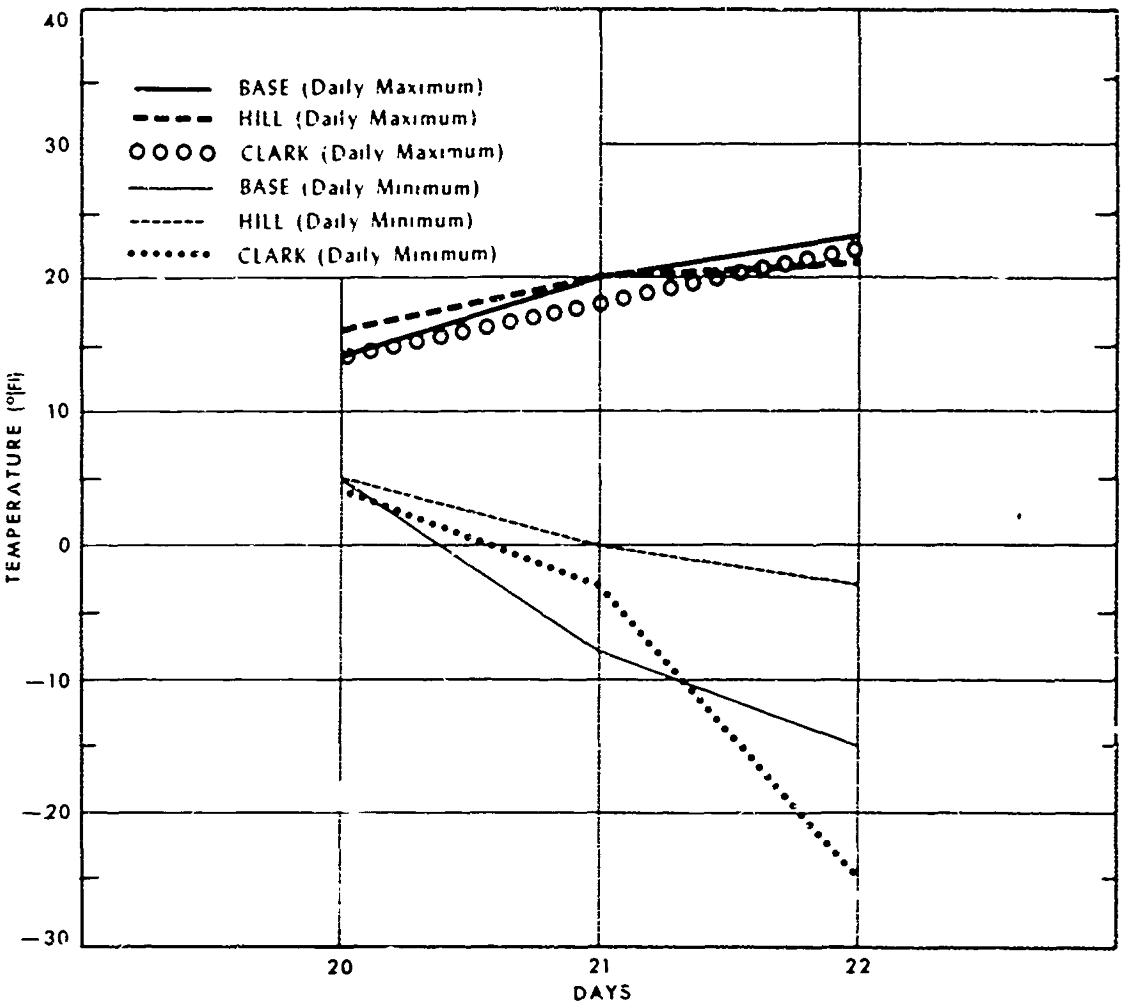


Figure 10

SELECTED MEAN DAILY MAXIMUM AND ABSOLUTE MAXIMUM TEMPERATURES IN EASTERN MASSACHUSETTS, 1960 - 1962

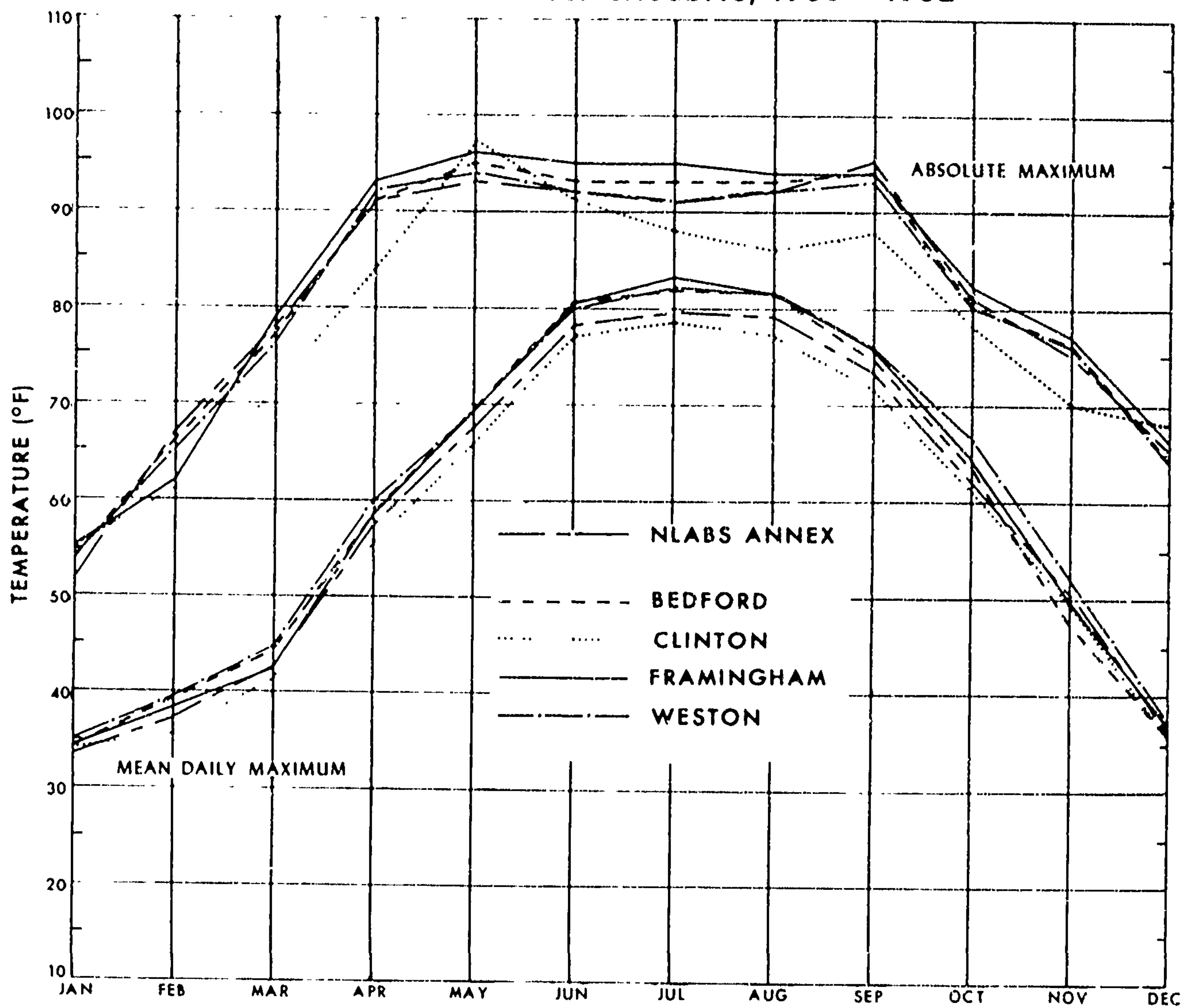


Figure 11

SELECTED MEAN DAILY MINIMUM AND ABSOLUTE MINIMUM TEMPERATURES IN EASTERN MASSACHUSETTS, 1960 - 1962

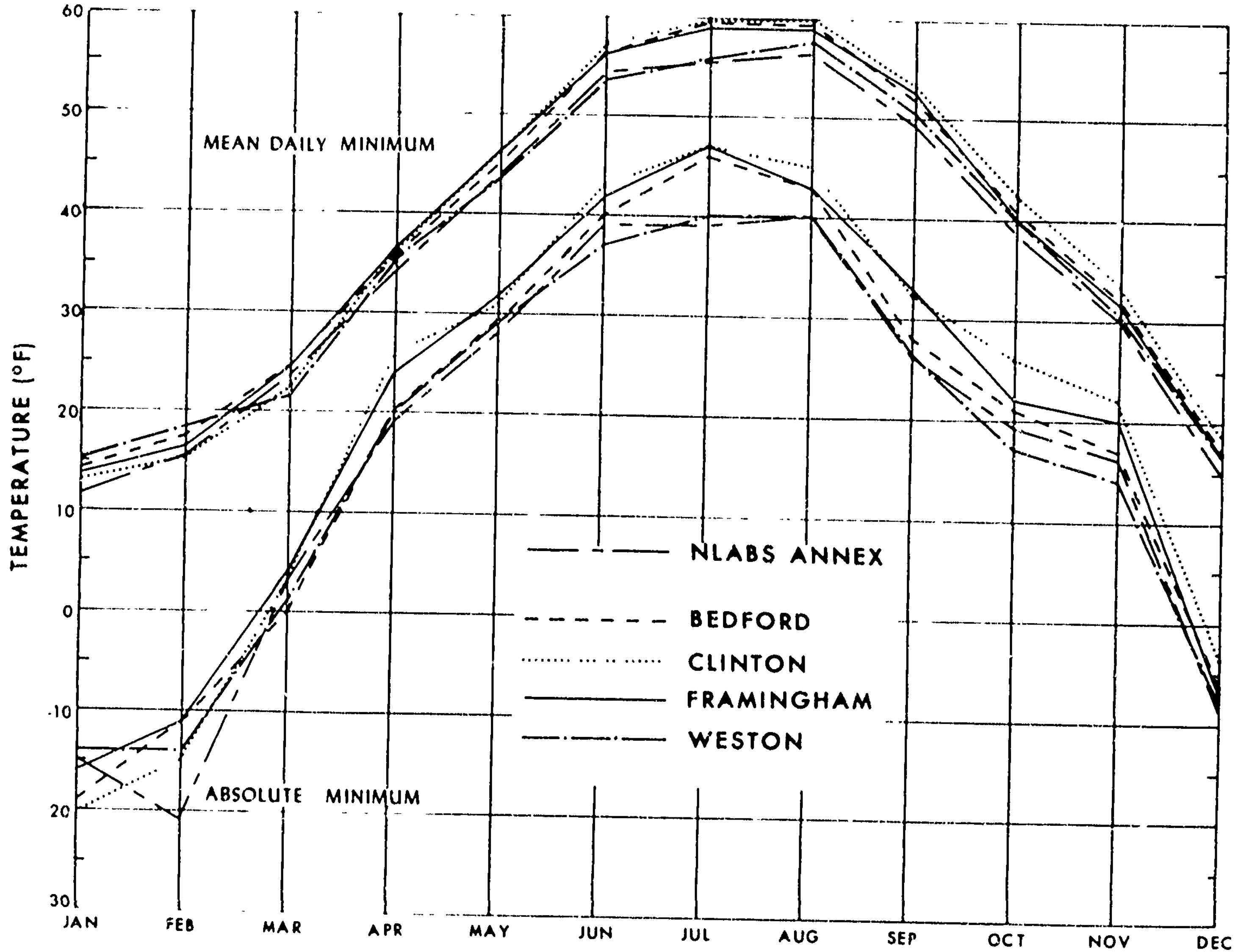


Figure 12

STATE OF GROUND AT NLABS ANNEX

JUNE 1958 - AUGUST 1963

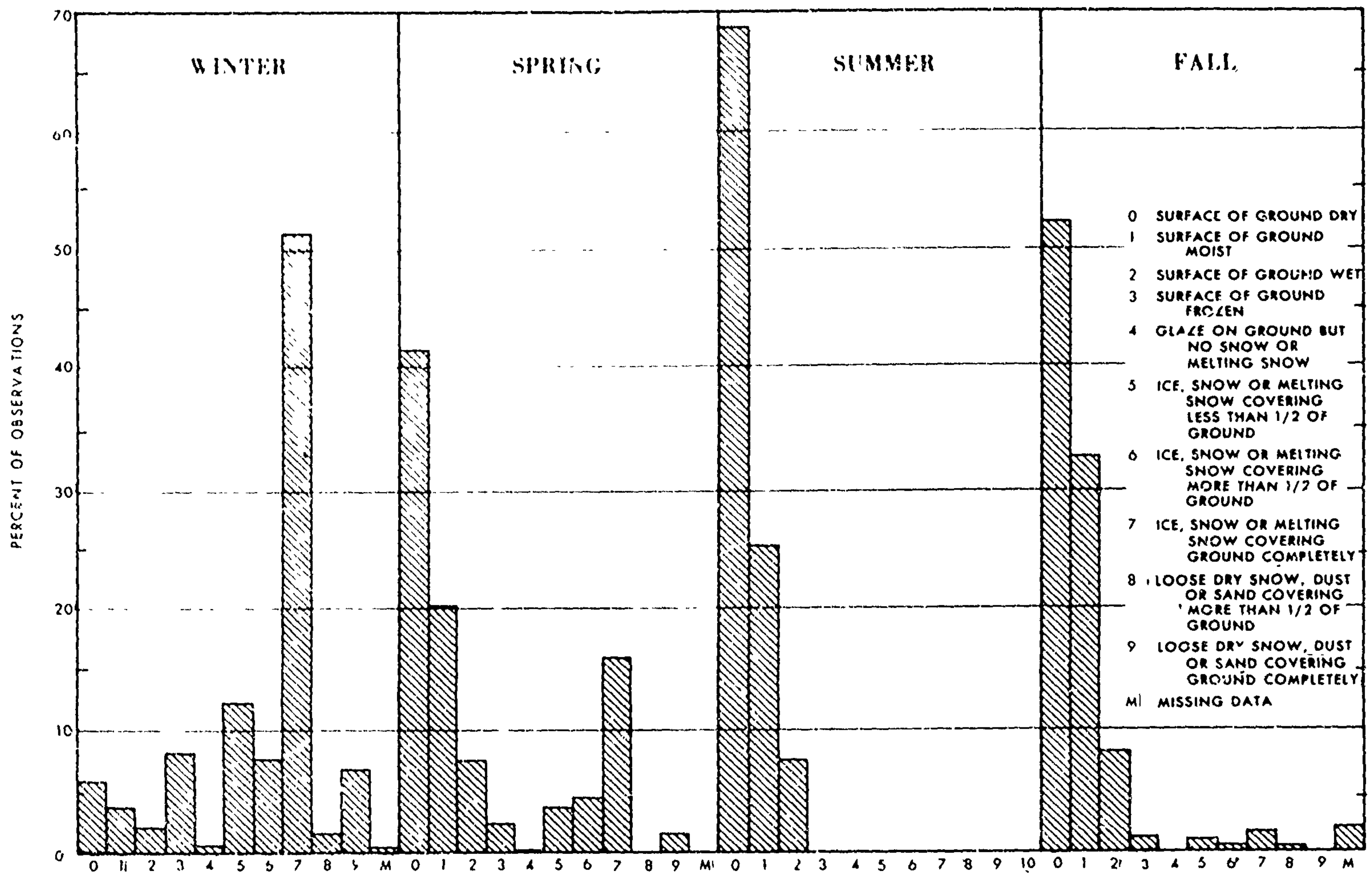


Figure 13

FREQUENCY OF CALM AT NLABS ANNEX AND L. G. HANSCOM FIELD

NLABS Annex: 1 August 1961 - 30 June 1963
Hanscom Field: 1 February 1943 - 30 September 1953

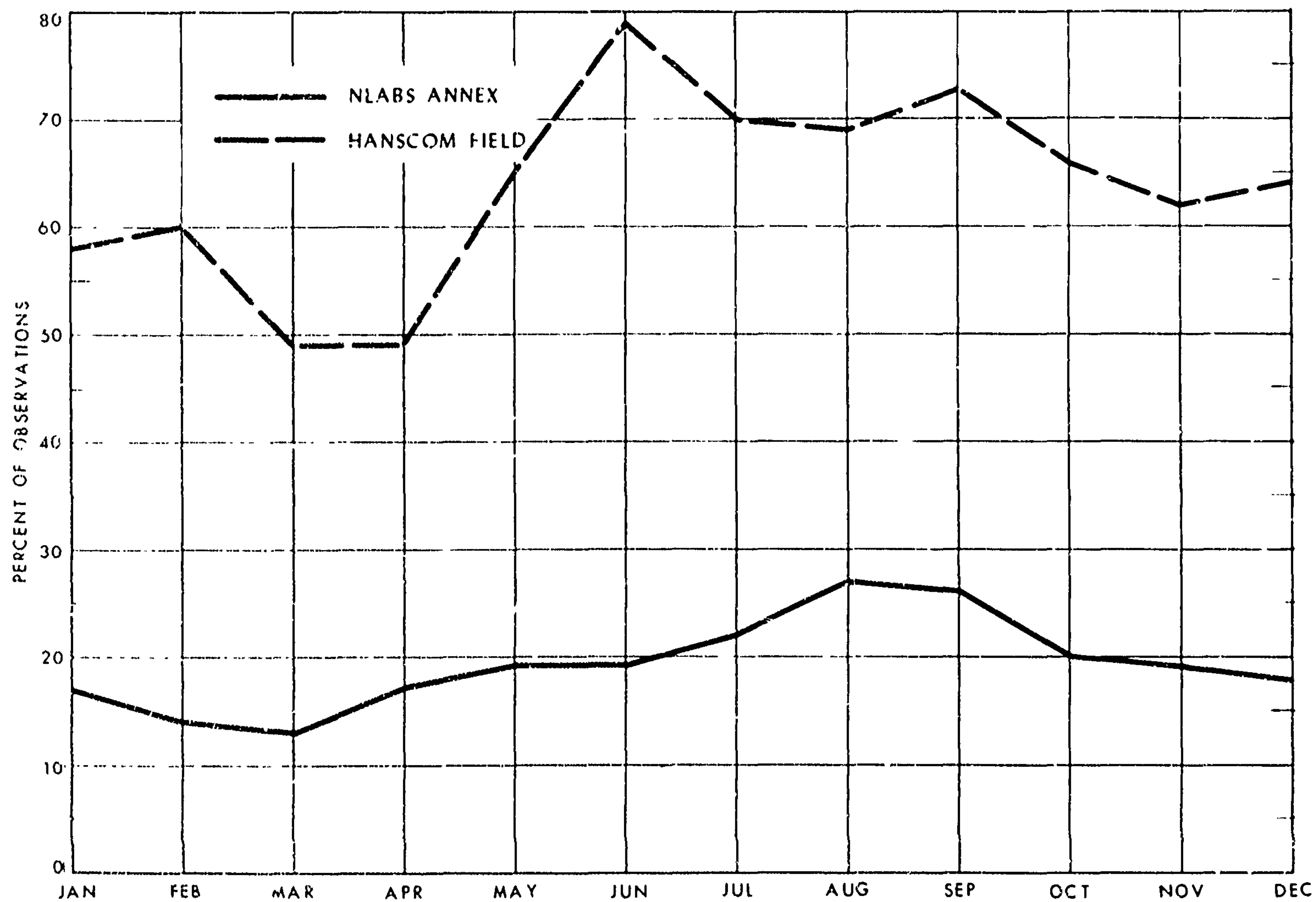


Figure 14

FREQUENCY OF DAILY MAXIMUM RELATIVE HUMIDITY (%) AT NLABS ANNEX

AUGUST 1961 - AUGUST 1963

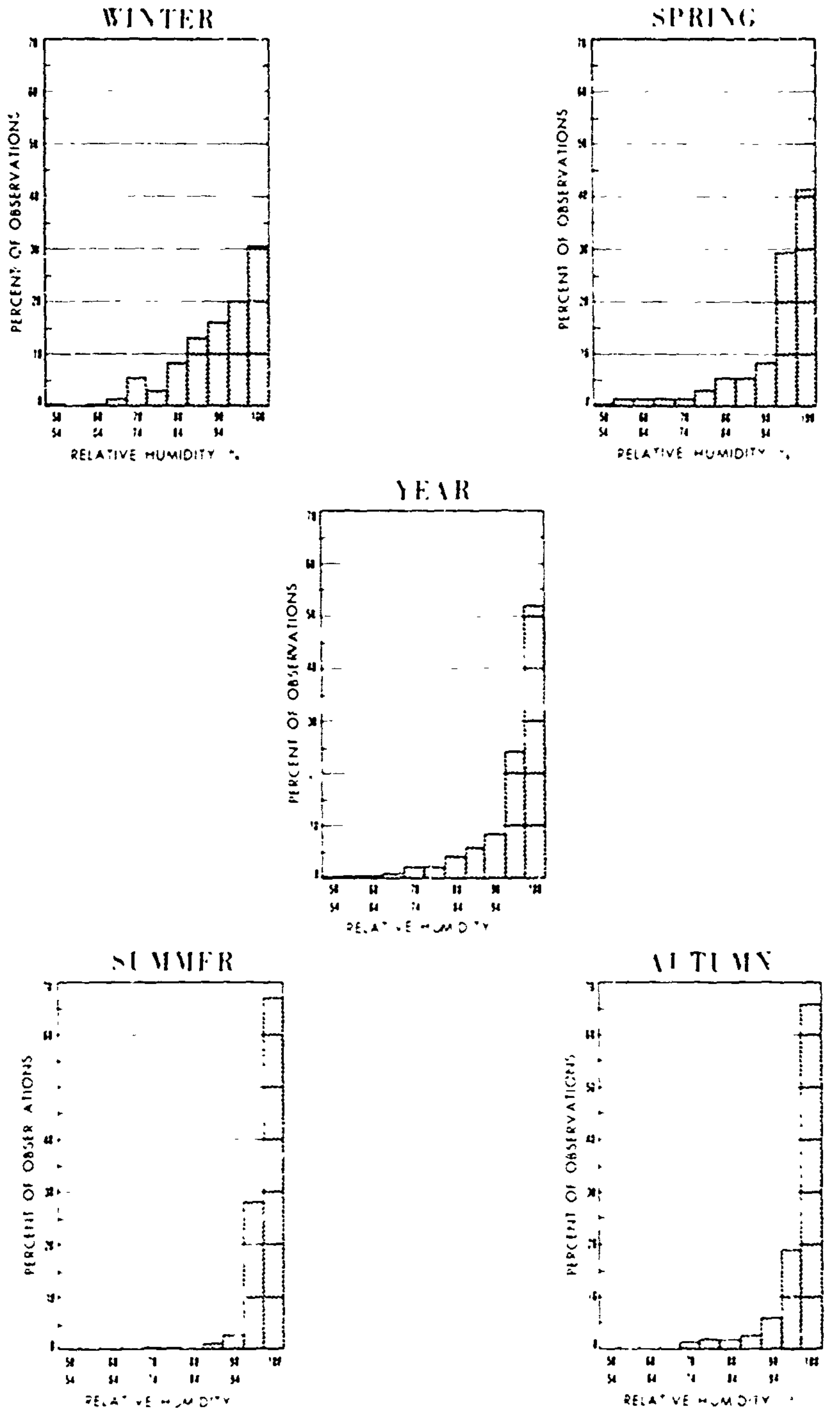


Figure 15

FREQUENCY OF DAILY MINIMUM RELATIVE HUMIDITY (%) AT NLABS ANNEX

AUGUST 1961 - JUNE 1963

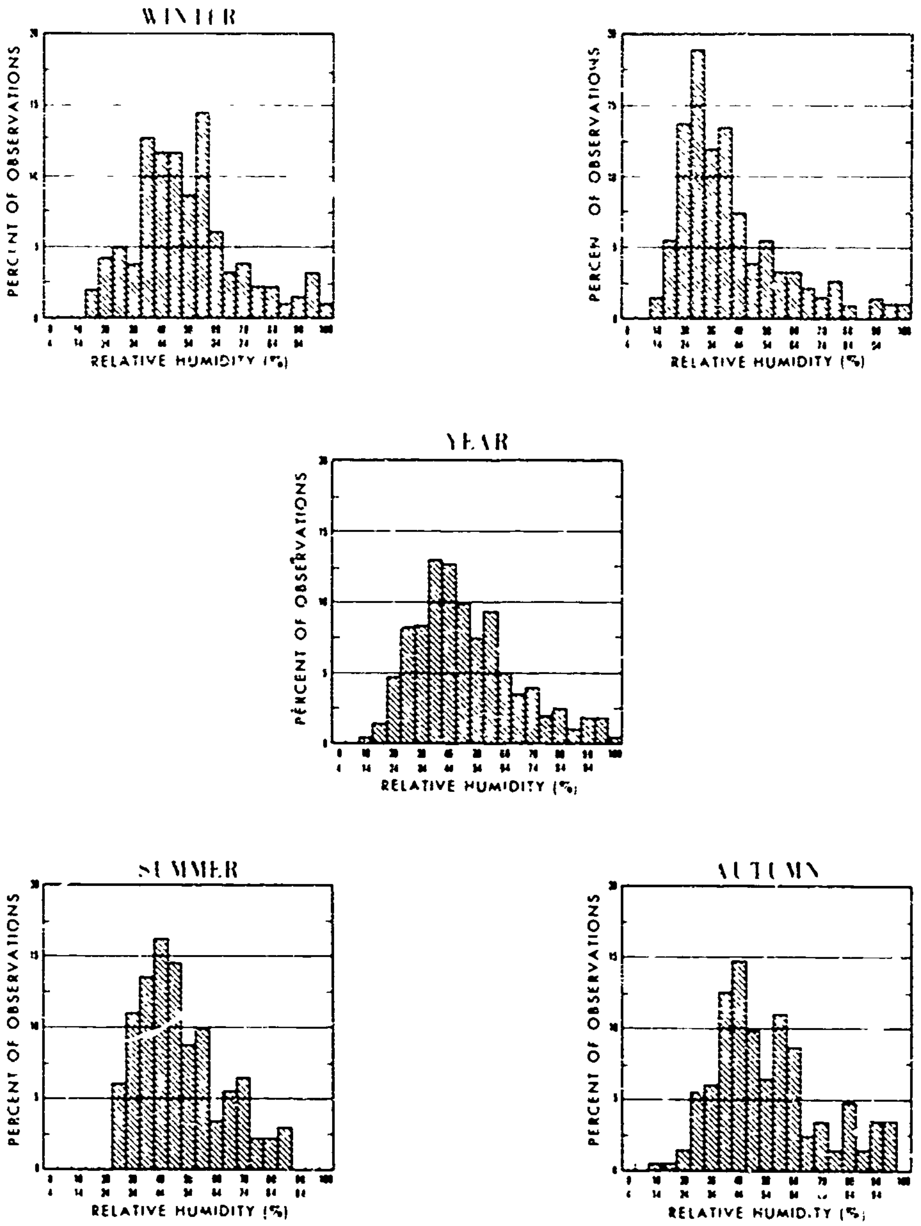


Figure 16

SKY COVER FROM SUNRISE TO SUNSET AT NLABS ANNEX

DECEMBER 1961 - AUGUST 1963

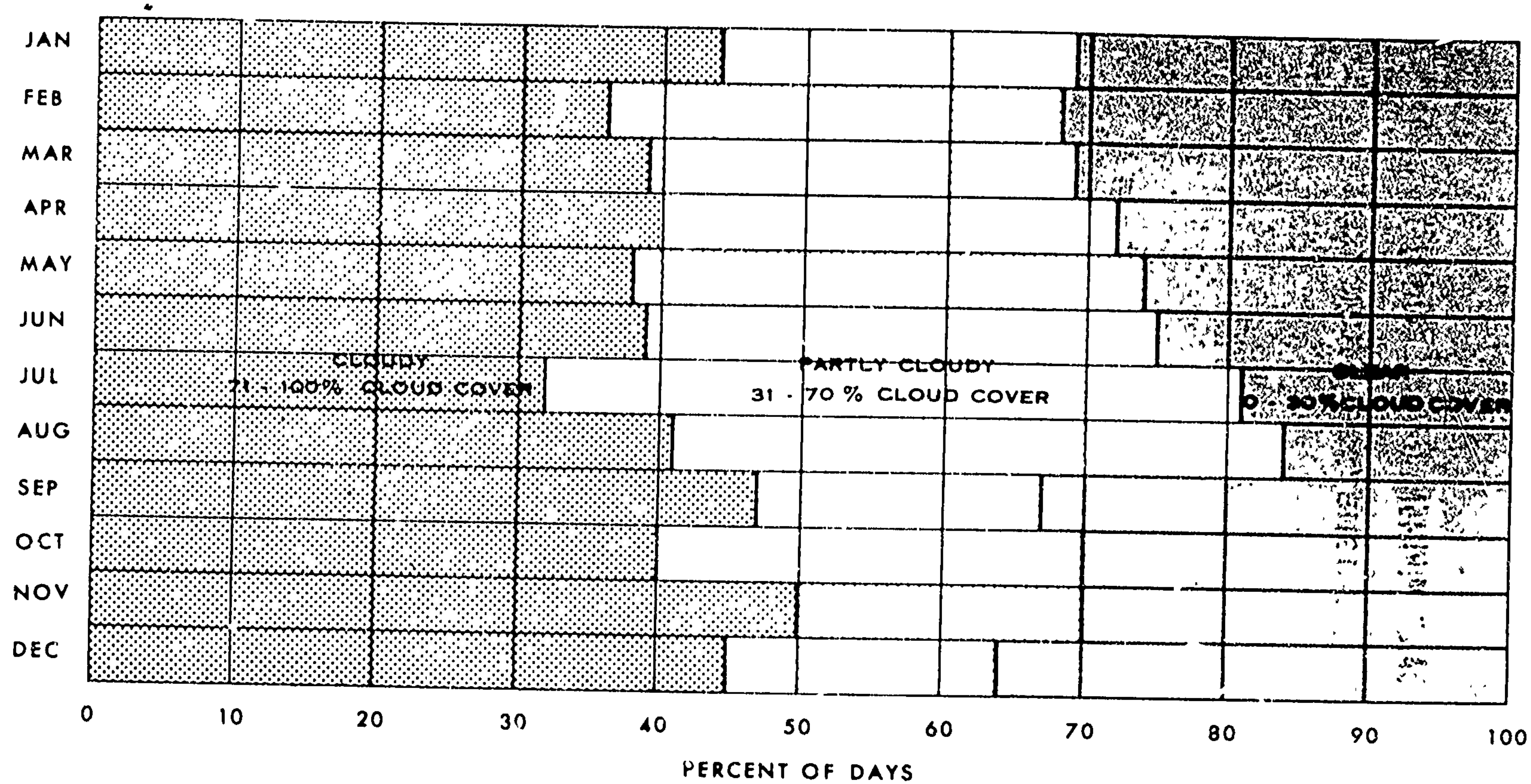


Figure 17

REPRESENTATIVE MID-WINTER WEEK WITH TYPICAL NORTHEAST STORM
16 - 22 JANUARY 1961

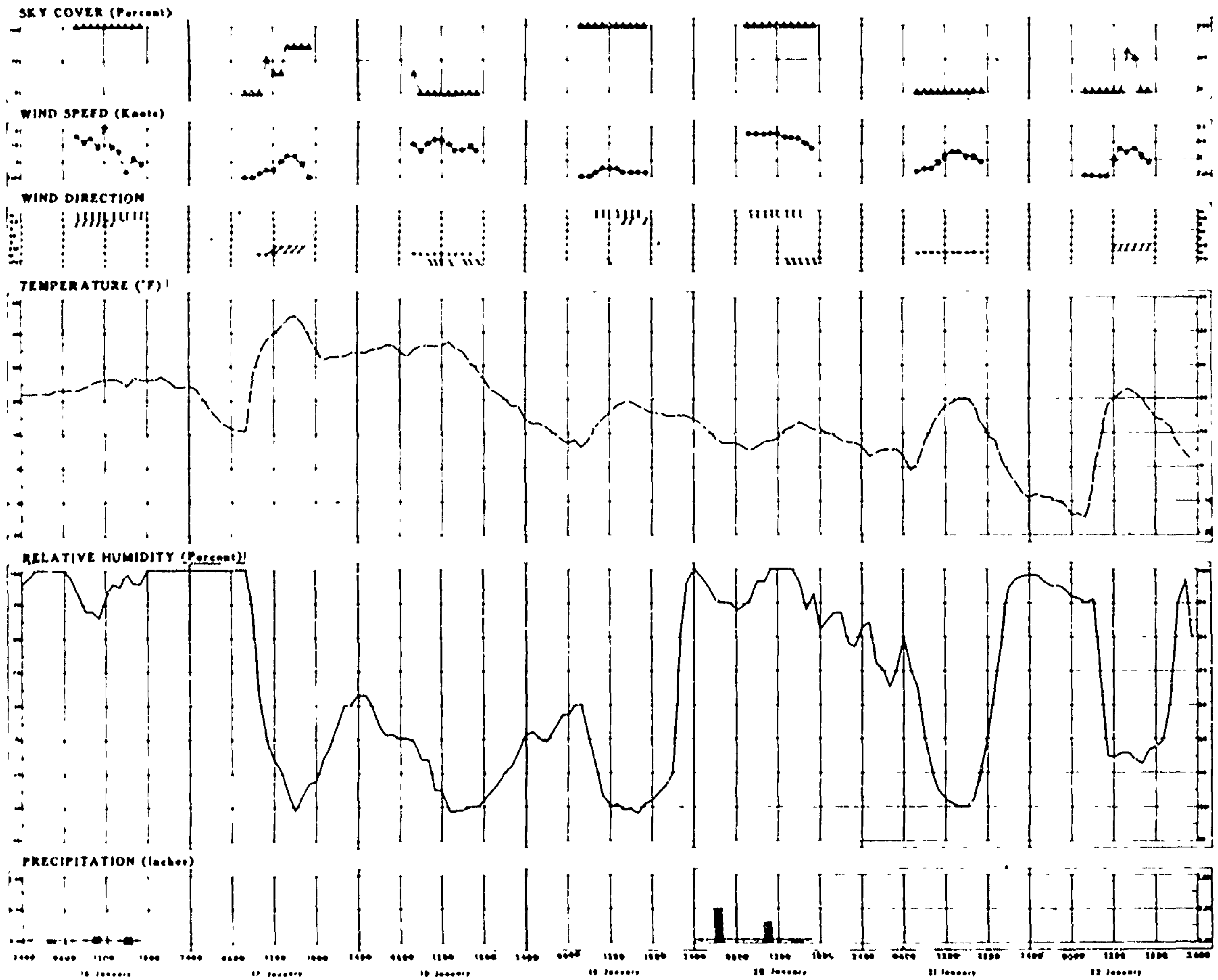


Figure 18

REPRESENTATIVE MID-SPRING WEEK SHOWING INTRA-WEEKLY VARIABILITIES
24-30 APRIL 1962

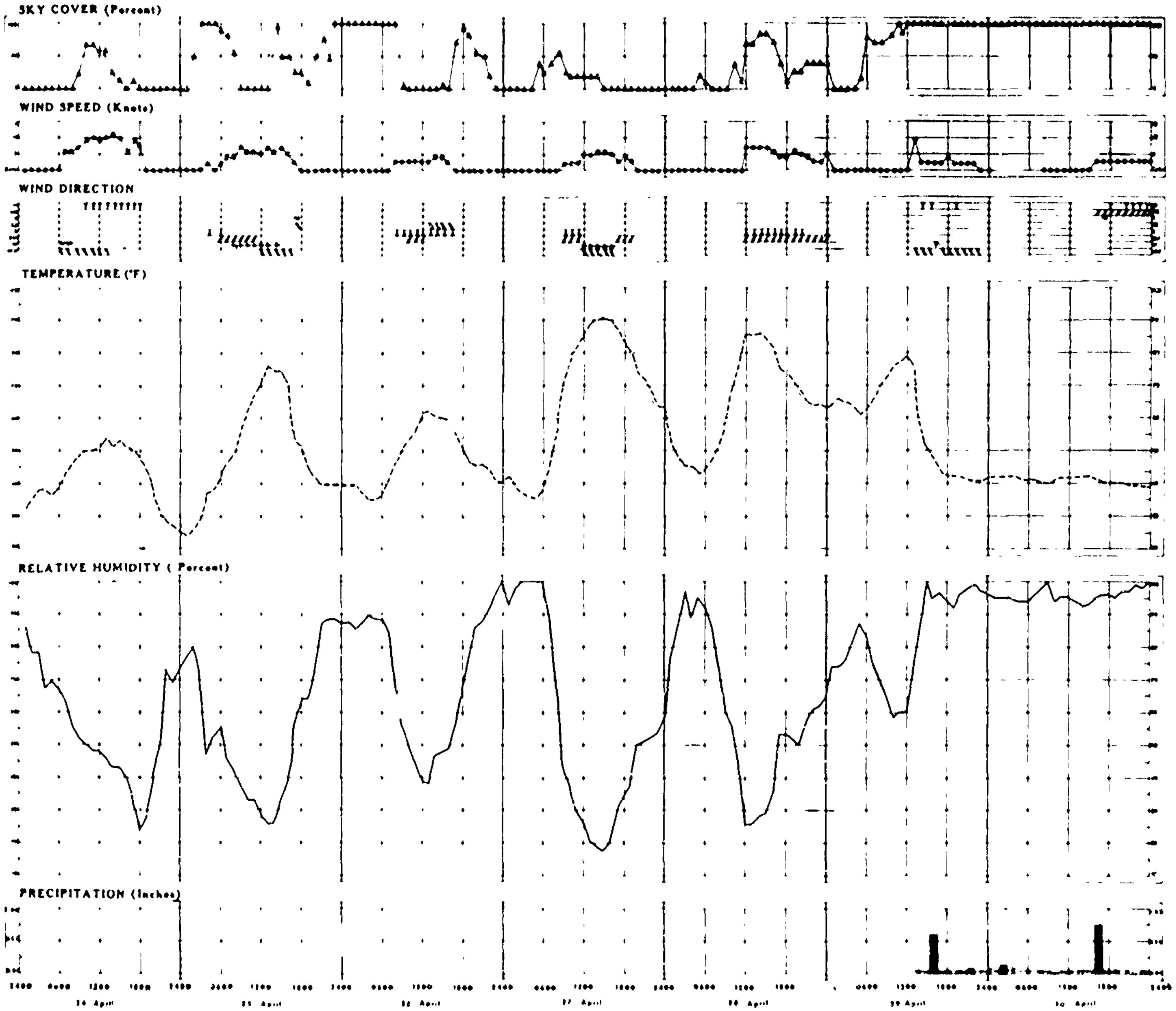


Figure 19

REPRESENTATIVE MID-SUMMER WEEK
10 - 16 JULY 1960

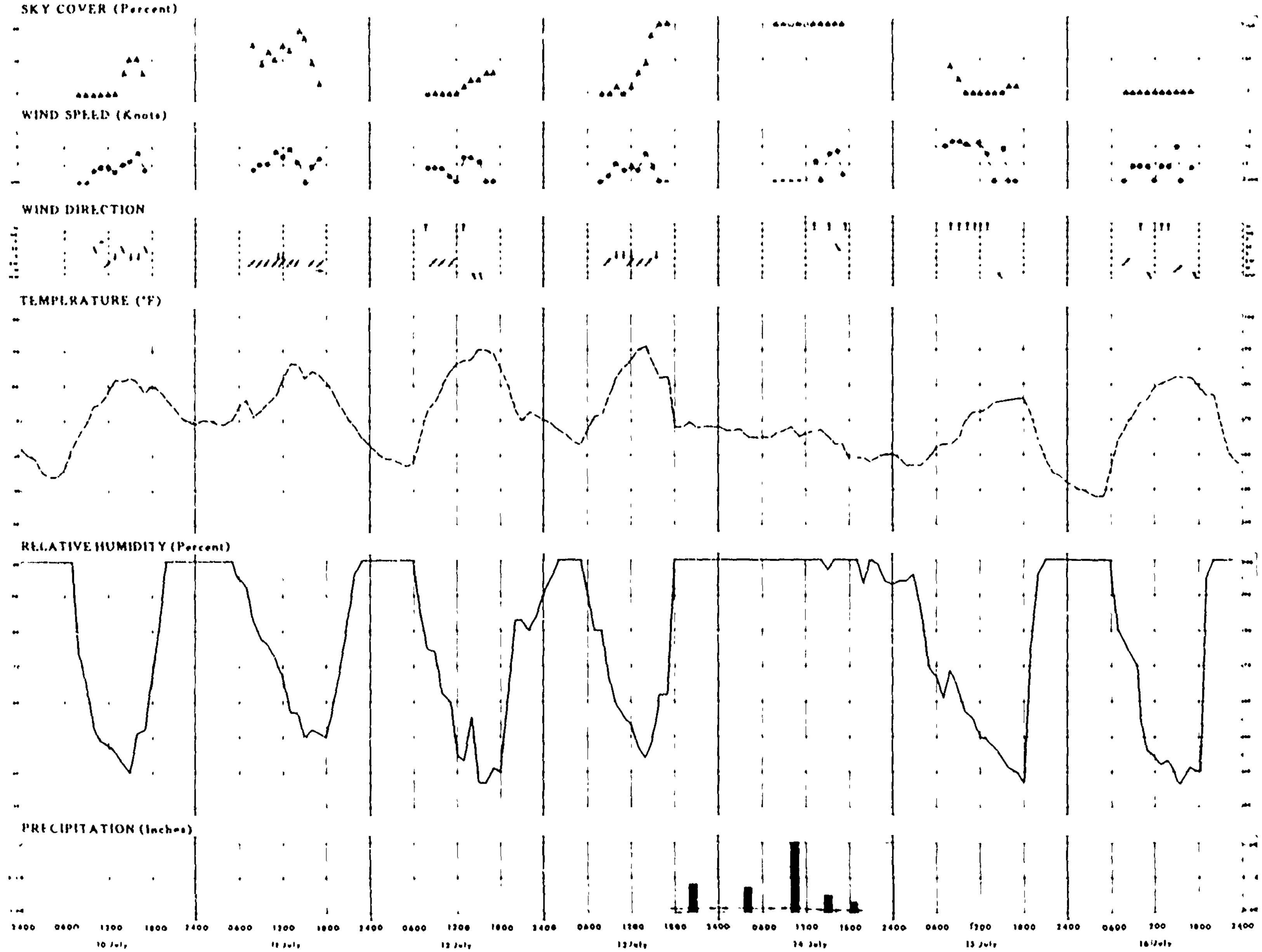


Figure 20

REPRESENTATIVE AUTUMN MID-WEEK WITH TWO INDIAN SUMMER DAYS
15-21 OCTOBER 1961

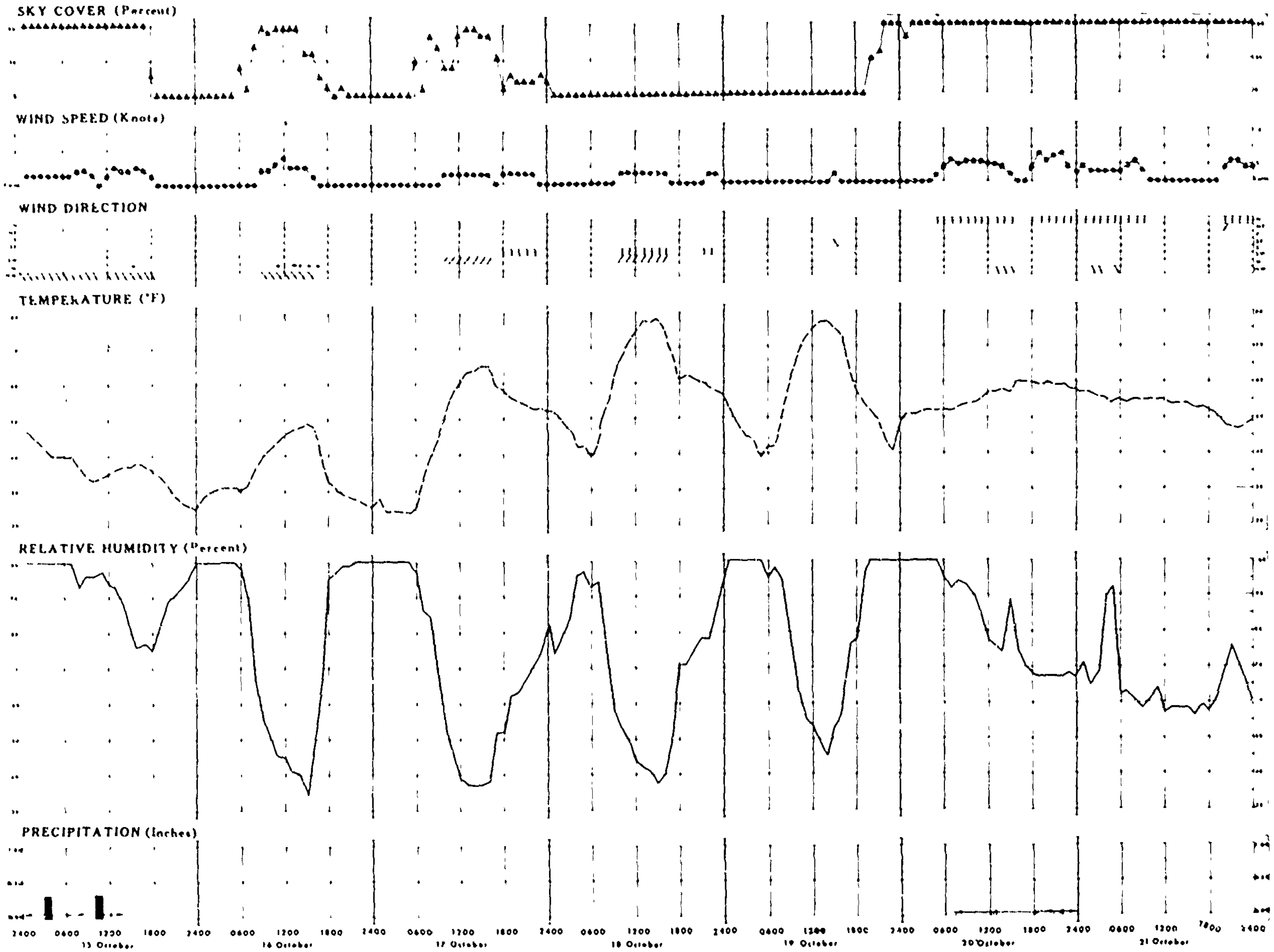


Figure 21

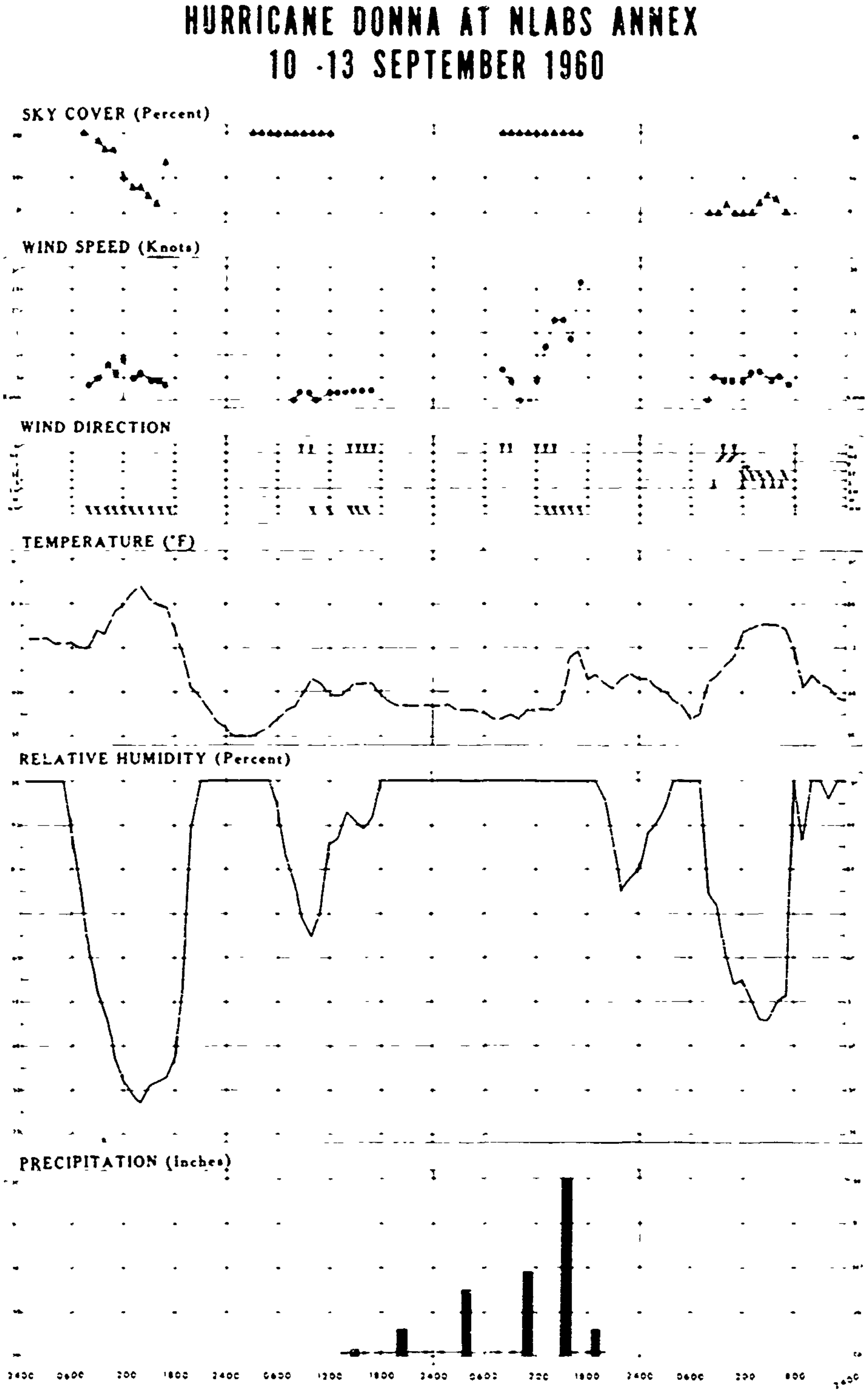
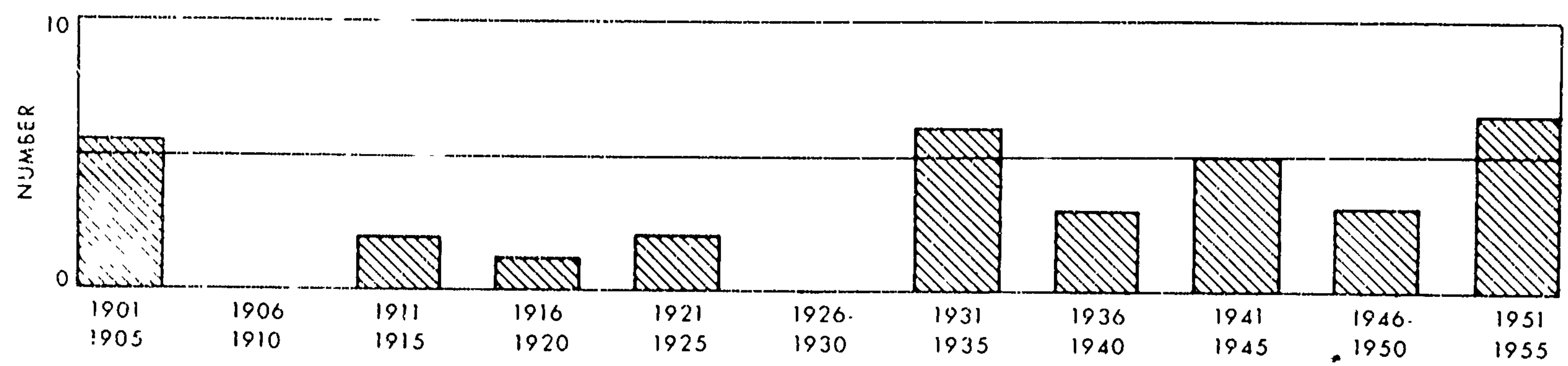

HURRICANE DONNA AT NLABS ANNEX
10 -13 SEPTEMBER 1960
SKY COVER (Percent)
WIND SPEED (Knots)
WIND DIRECTION
TEMPERATURE (°F)
RELATIVE HUMIDITY (Percent)
PRECIPITATION (Inches)

Figure 22

NUMBER OF TROPICAL STORM TRACKS (EYES) PASSING THROUGH NEW ENGLAND AND LONG ISLAND (N.Y.) BY 5-YEAR PERIODS, 1901 - 1955 *



* After Weather Bureau chart (L S 5610), April 10, 1956

Figure 23

NORTHEASTER AT NLABS ANNEX
5-7 JANUARY 1962

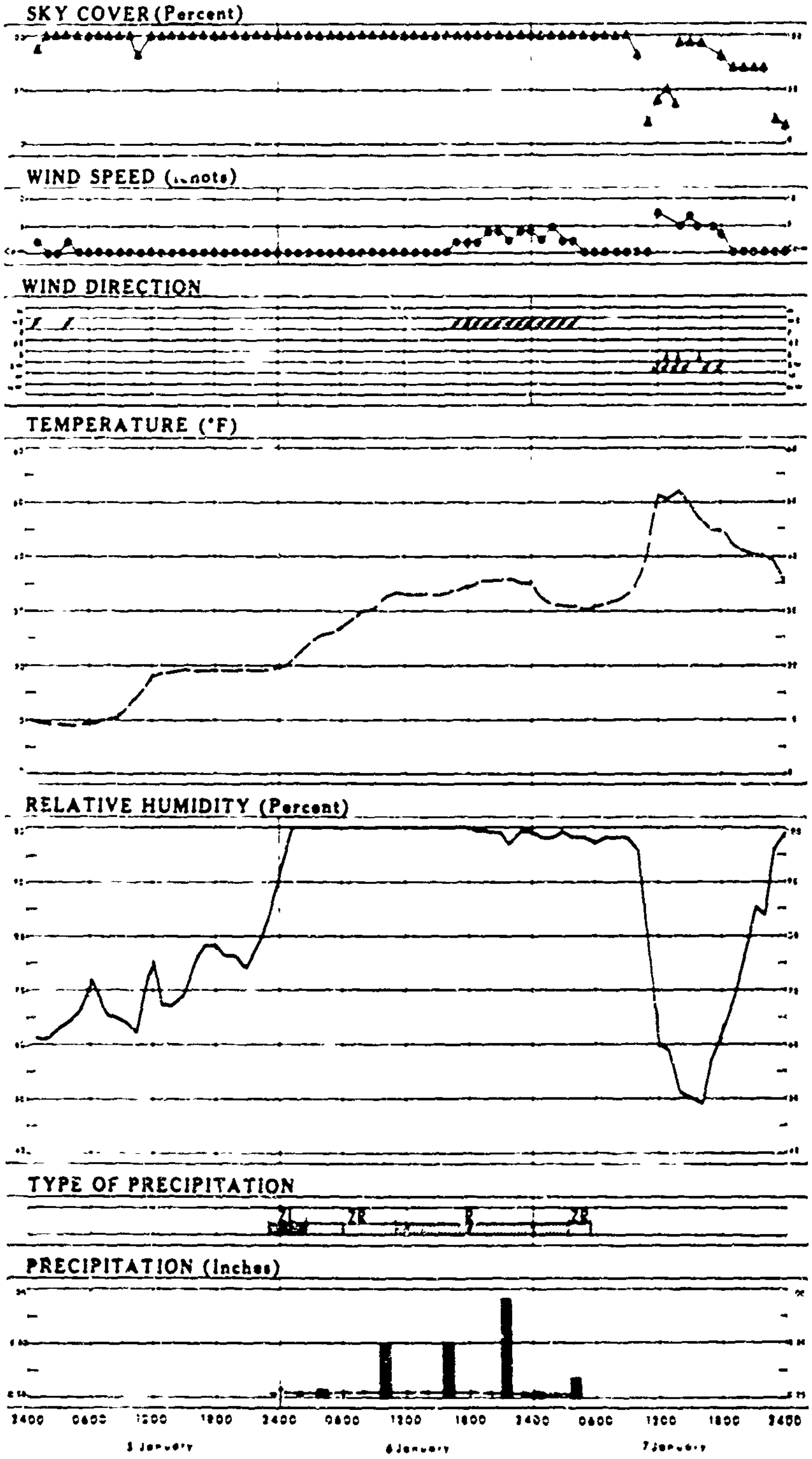


Figure 24

APPENDIX II

Photographs

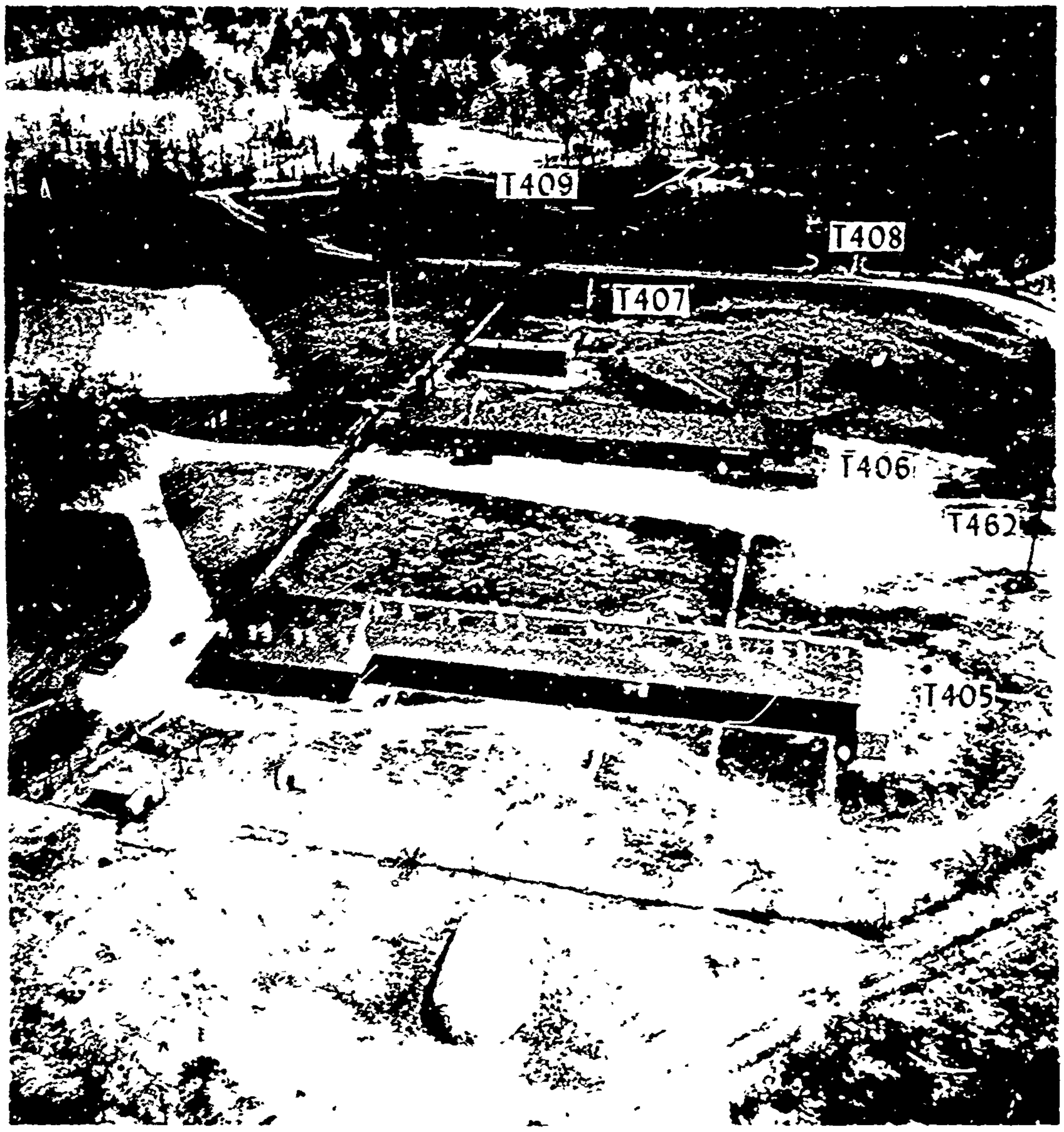


Photo 1. Headquarters area, NLABS Annex (looking NE). The two experimental foam shelters in foreground were constructed by spraying polyurethane over an air supported and slightly reinforced tent about 4 years ago. Both remain cool inside on a hot day. The larger foam shelter is 45 feet long, 20 feet wide, and 10 feet high. Puffer Pond Road crosses the area on far side of headquarters buildings. The small building behind flag pole (T-419) was recently destroyed. U.S. Navy photograph, 4 May 1966.

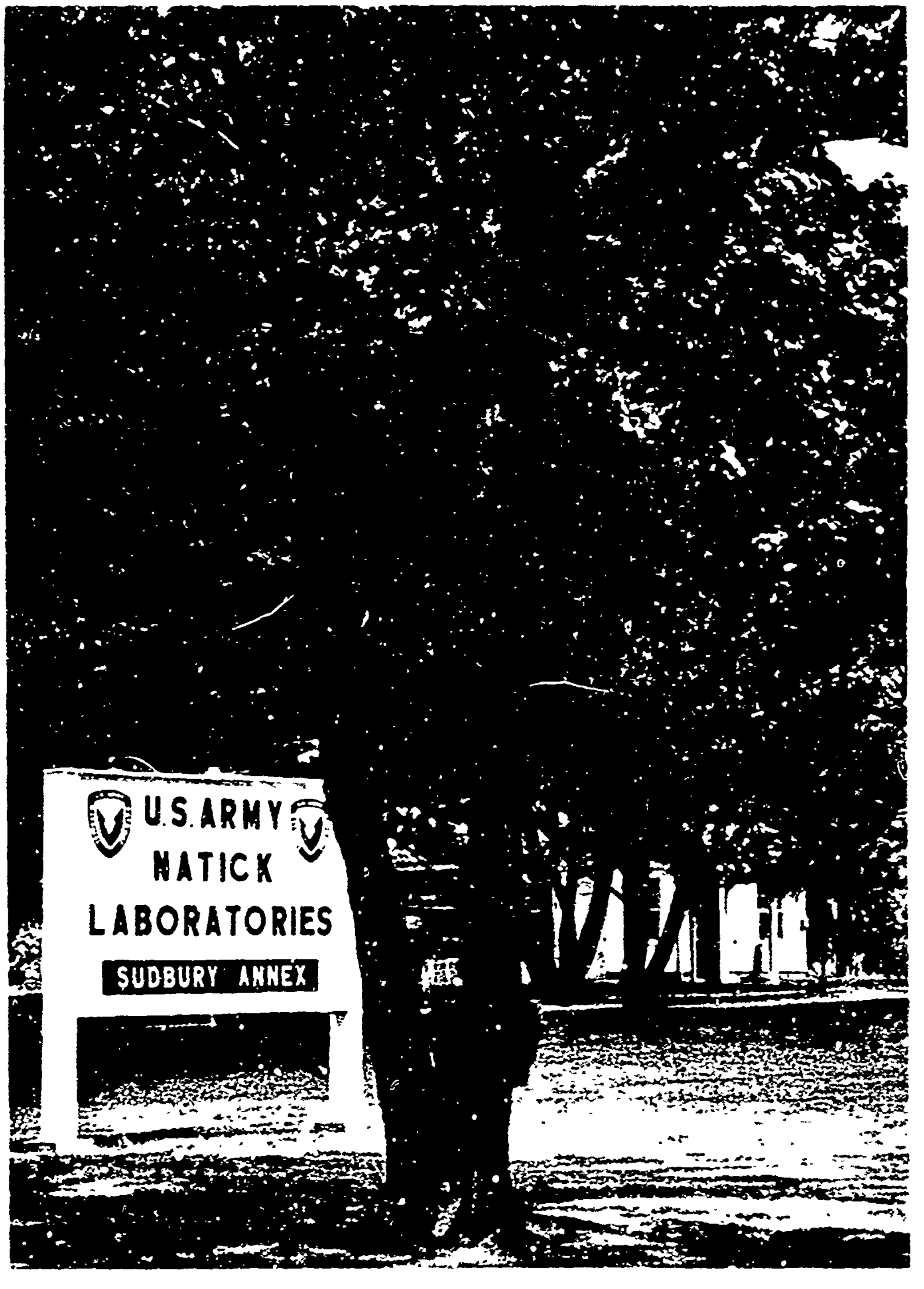


Photo 2. Main gate at NLABS Annex (looking northwest) in Town of Sudbury, Mass. This entrance is on Hudson Road 2½ miles west of route 27. June 1966.

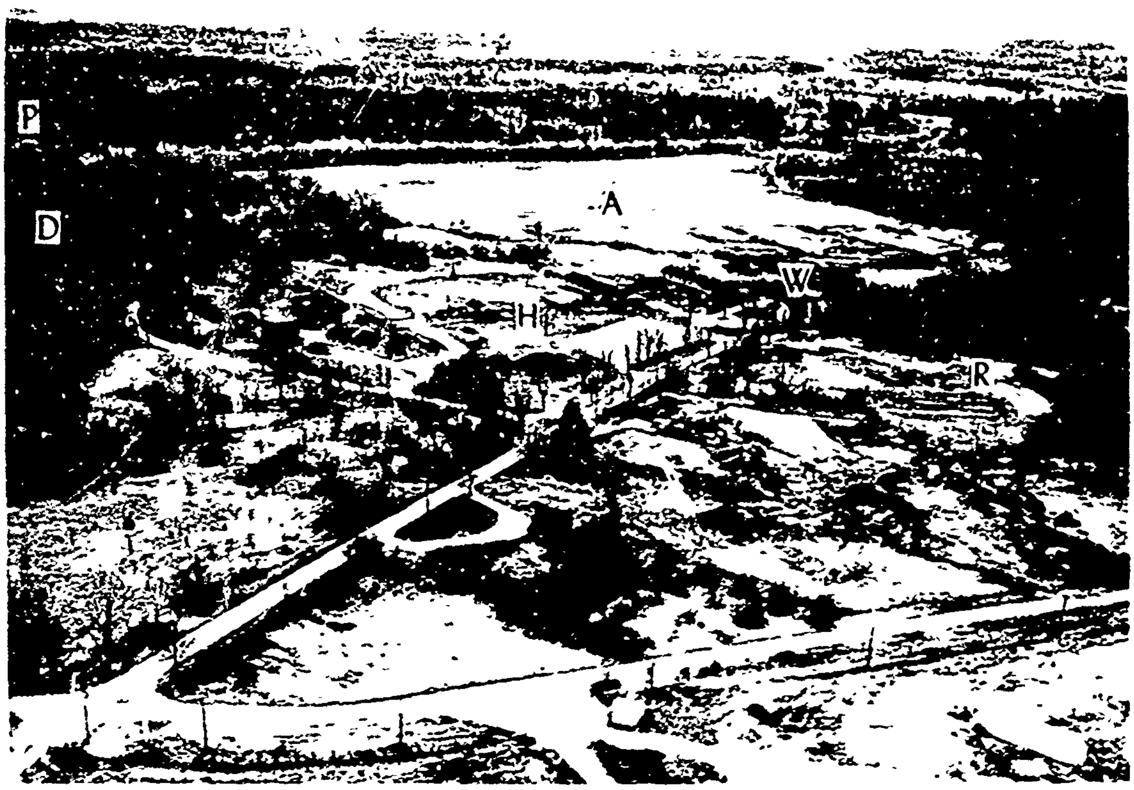


Photo 3. Air view of headquarters and adjacent areas (looking SSE). In foreground, one of numerous abandoned apple orchards. An air-supported tent and its anchor stakes are being tested by Mechanical Engineering Division against possible wind damage in a sandy, open area on this side of patrol road. White Pond Road leads from lower left corner to background at right. Puffer Pond Road curves around south end of drumlin (D) from headquarters area (H). The light-shaded area is ADED's airdrop zone (A); its drop pad is at left (P). The outdoor weather instruments are between white house and exposure racks (R) at right; the indoor weather instruments were moved from white house (recently destroyed) across White Pond Road into building T-404 (W). The distant forested areas are generally representative of other parts of the reservation. U.S. Navy photograph, 4 May 1966.

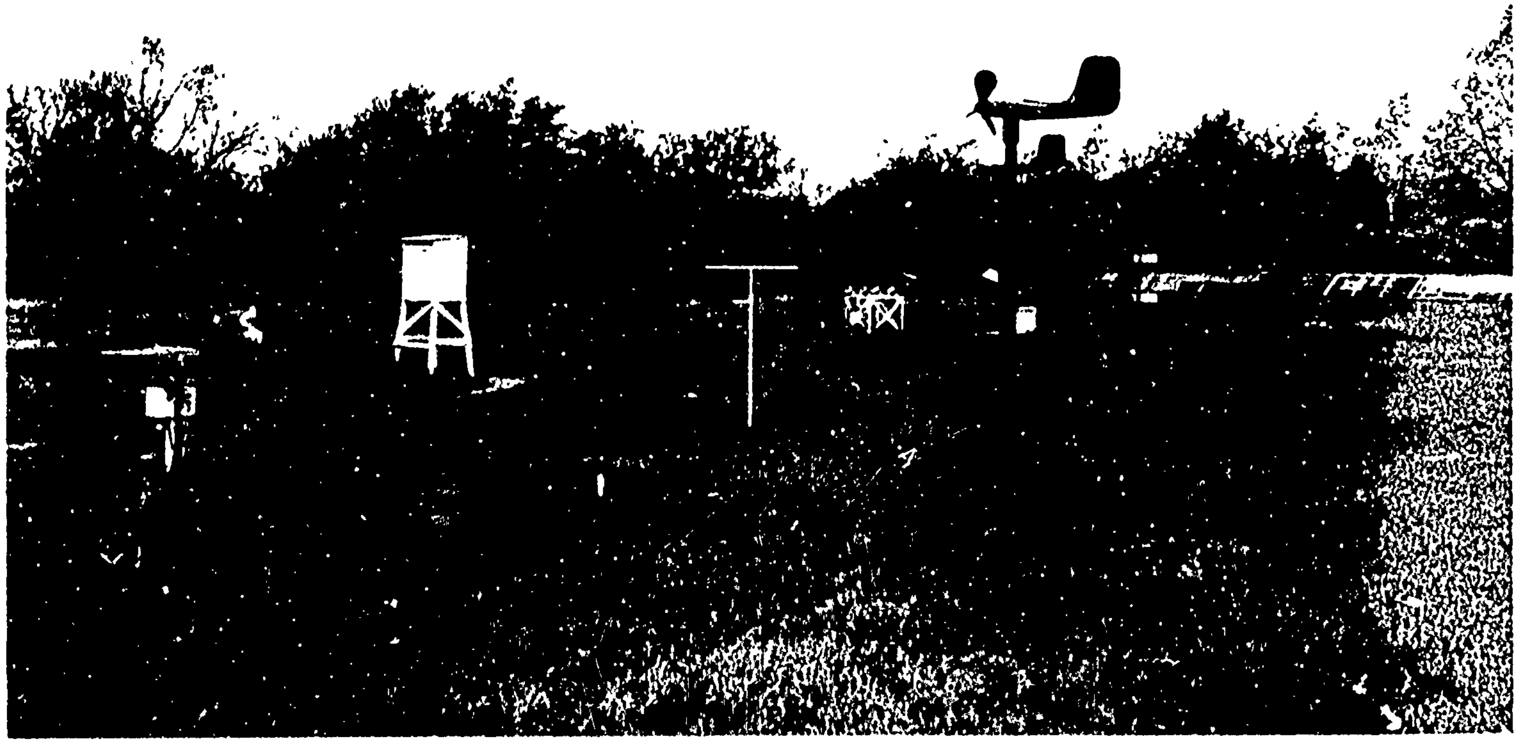


Photo 4. Outdoor weather instruments at NLABS Annex. In foreground, Beckman and Whitley net and total hemispheric radiometers (left) and a Friez aerovane (anemometer and wind vane, 2 meters above ground). In center, standard weather shelter (left), containing a hygrothermograph, a maximum and minimum thermometer, and a psychrometer; and a black globe thermometer to right of shelter. In backfround, Eppley pyranometers with filters mounted at 45° from the zenith to correspond to angle of exposure rack mountings; behind these instruments, three Eppley pyranometers with filters on an equatorial mount which track the sun and give direct radiation measurements in the various spectral bands. Two instruments (not shown) include a solar exposure analyzer by deHaart, Inc., and an 8-inch rain gauge (weighing gauge type). 25 May 1966.

Photo 5. Puffer Pond satellite stations (looking NE). The station is on a low but adequately drained site in a mixed hardwood-coniferous forest. The weather shelter (left), containing a hygrothermograph, is about 50 feet from edge of swamp northeast of Puffer Pond, where there is always standing water during frost-free period. Radiation is measured in the more deeply shaded locale (right) by an Eppley Pyrheliometer (pyranometer) and recorded by a Honeywell Brown - Electronik in connection with exposure of fabrics on rack, where undergrowth of vegetation is moderately dense. 25 May 1966.

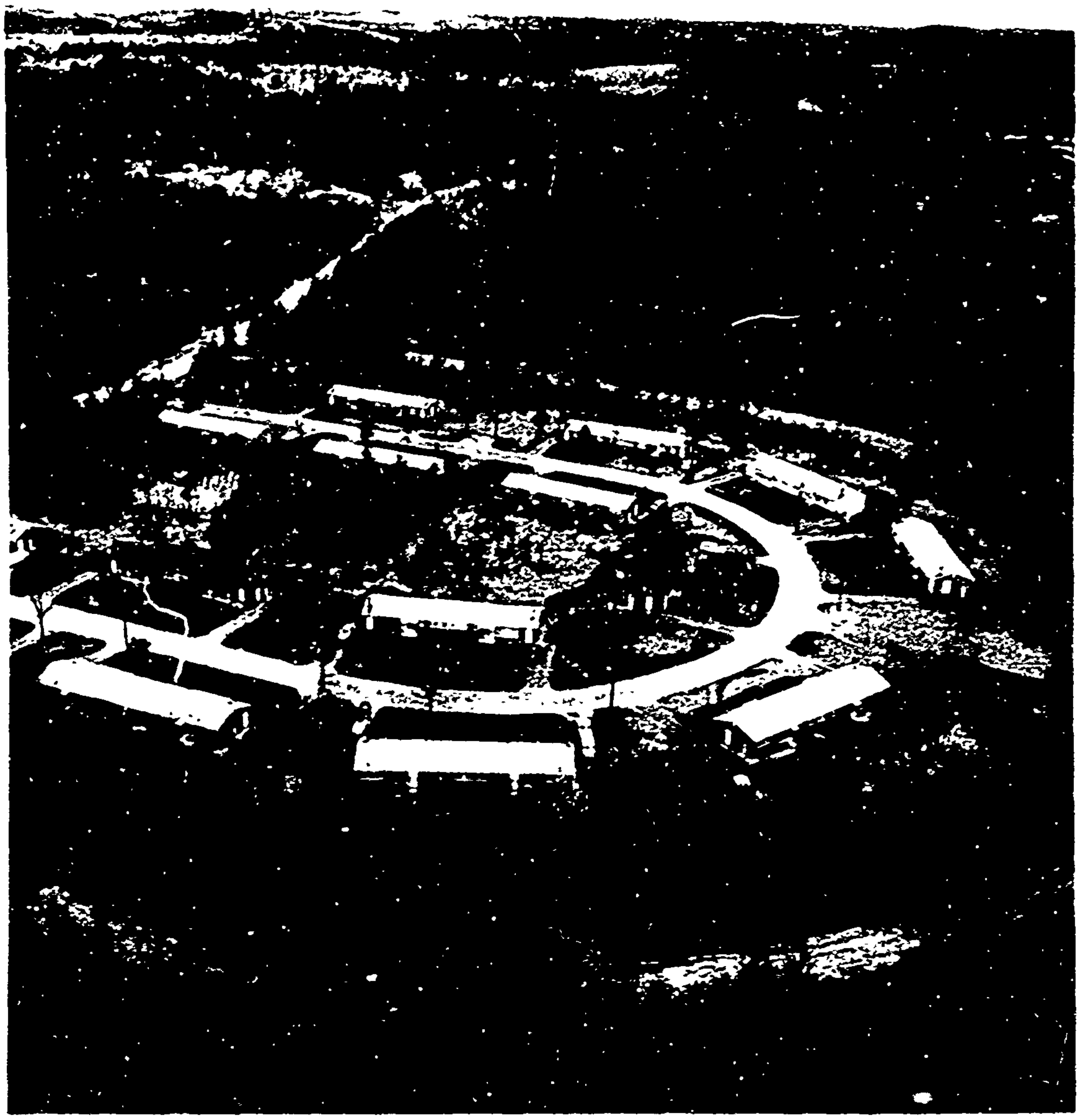


Photo 6. Capehart housing, on Concord Road at south end of NLABS Annex, consists of 35 units occupied by officer and enlisted personnel working at NLABS. The horseshoe-shaped barren strip outside the development is a firebreak. Along Concord Road and extending at almost a right angle from it along a trail beyond the housing area, dense red pine (*Pinus resinosa*) plantings occur in narrow strips. U.S. Navy photograph, 4 May 1966.

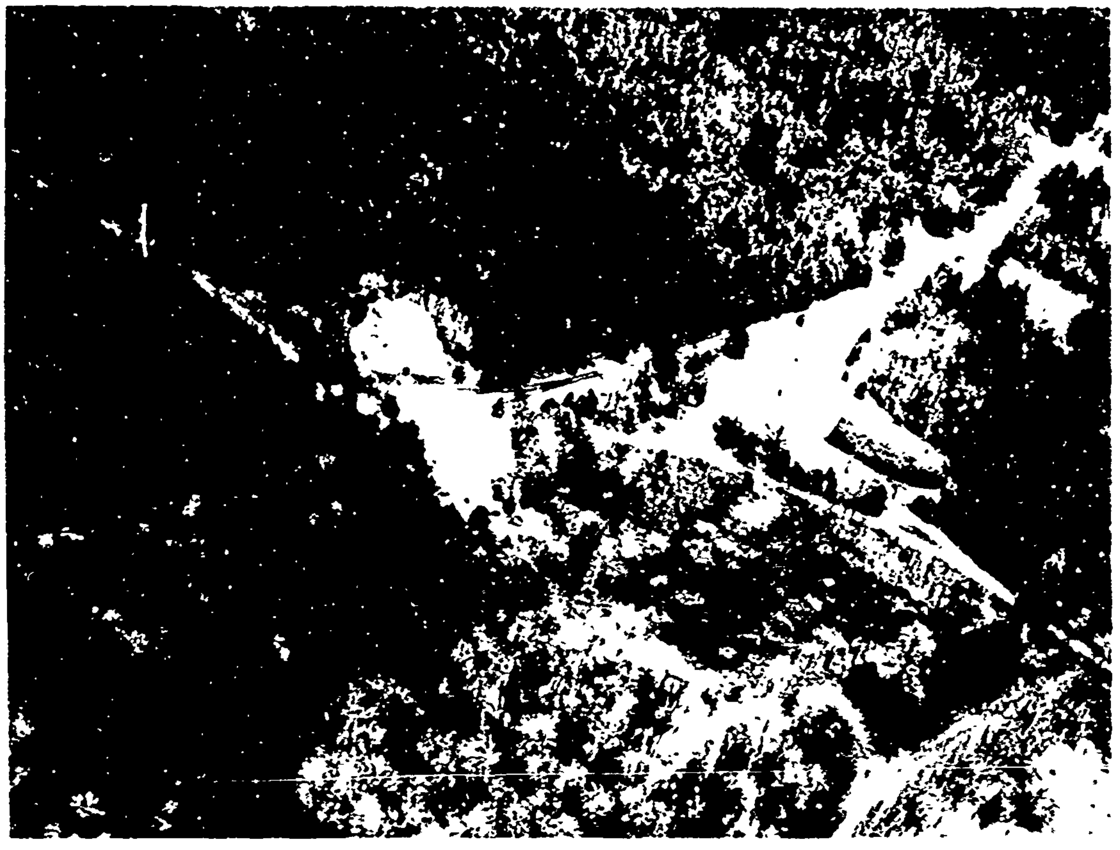


Photo 7. Variation in vegetation types on southwest margin of large hill east of White Pond Road (looking SE). In the partially forested swamp (foreground), low shrubs (mainly cranberry) occupy its far end but hardwoods (mostly red maple /Acer rubrum/) are dominant at this end of of the wet, spongy area. On its drier margin high shrubs (> 5 ft) and saplings thrive in relatively open places. The characteristic deciduous-coniferous forest often merges into pure hardwood stands and sometimes into conifer groves, transition belts varying sharply in width. In extensive hardwood forest (right background), a number of white spruces are conspicuous. The oval-shaped, grass-covered, earthen mounds lined with concrete are 3 of the 50 bunkers in the reservation. Although dark and damp inside and without electrical wiring they provide secure, accessible storage adjacent to vehicular trails or roads. The trackage will soon be removed. U.S. Navy photograph, 4 May 1966.

Photo 8. Weather station at NLABS Annex (looking W). All indoor instruments were kept in white house (T-402A) on opposite side of White Pond Road during period of observations used in this report. During 1966, these facilities were moved across the road into the larger and better building (T-404), after which T-402A was destroyed. The location of the outdoor instruments between the former weather station building and the exposure racks (right) remains the same. U.S. Navy photograph, 4 May 1966.

Photo 9. Distant air view of typical vegetation types (looking SE). Paved section of patrol road in foreground. Observed area lies between entrance to dump near northwest border of reservation and Puffer Pond area, beyond which Old Marlboro Road leads to horizon. The weather station, headquarters, and airdrop areas are situated on lowland (center). These are among the larger grass areas. Although conifers are conspicuous in places and patches of shrubs are common, most areas are covered with relatively small hardwoods and often by a combination of hardwoods and conifers. U.S. Navy photograph, 4 May 1966.

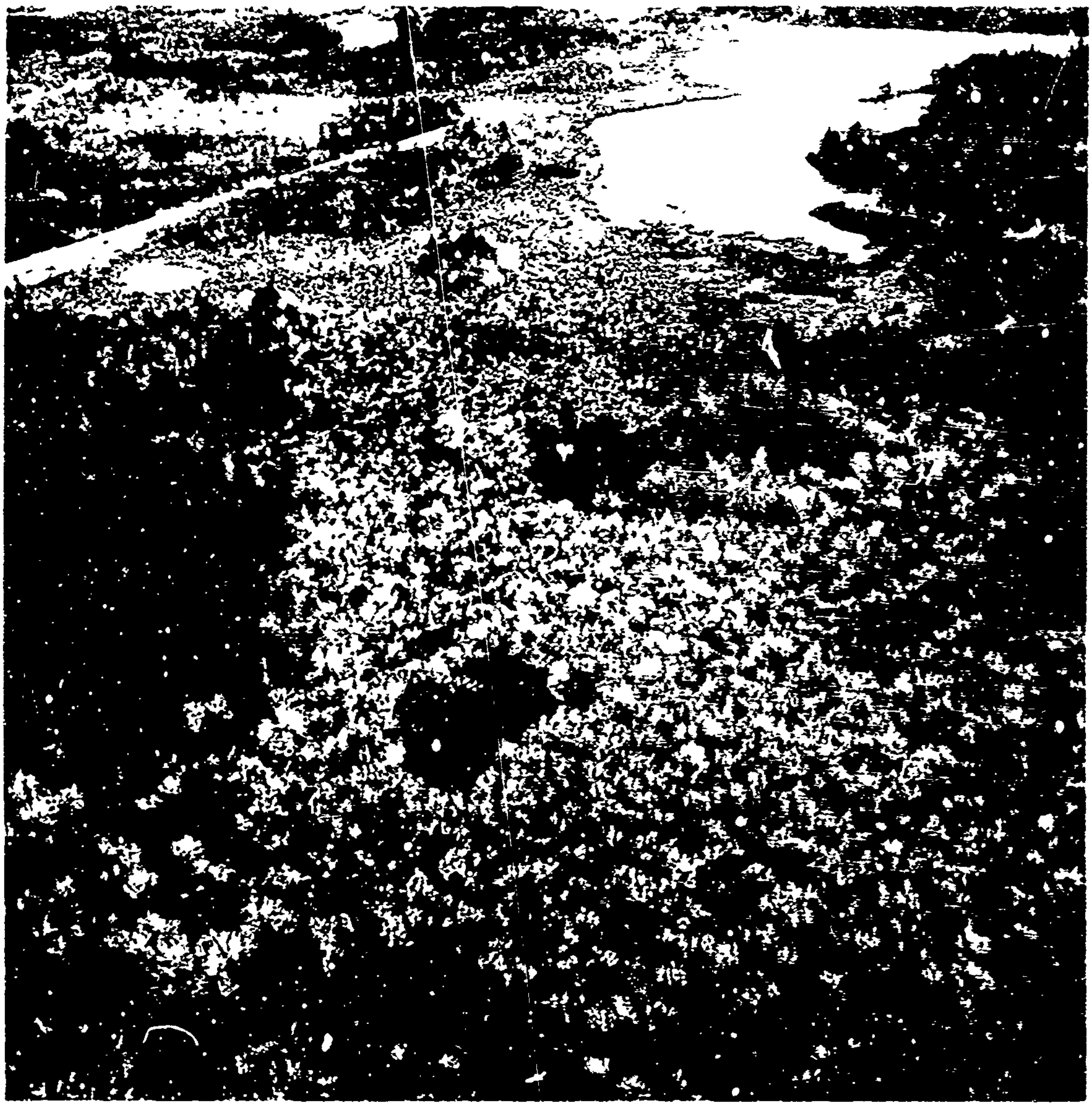


Photo 10. Extensive swamp bordering Willis Pond (looking NE). Red maple (Acer rubrum), identified by its light colored branches, forms the dominant swamp vegetation in foreground but low shrubs characterize most of lower parts of swamp near Willis Pond and small pond at left. Where red maple is a dominant species it is an indicator of swamps and wet lands bordering swamps and streams. The presence of white pine and other hardwoods mark the approximate boundary between the swamp and higher areas surrounded by it and its outer margin. In background, patrol road is at left; settlement of Pine Lake is at right. U.S. Navy photograph, 4 May 1966.

Photo 11. Shrubs in swamp west of Willis Pond (air view looking N from Pine Lake settlement). Low, tough, gnarled shrubs (S), such as leather leaf (Chemaedaphyne caliculata) and to a less extent sheep laurel (Kalmia angustifolia), cover much of area in center of photograph. Here the ground surface, partially covered with moss, is spongy and extremely irregular. During an extended drought (1966), water remained in lower areas and deeper holes away from outer margin of the swamp. Numerous tamaracks (Larix laricina), deciduous conifers (C) with narrow pyramidal crown, grow among the low shrubs. In foreground, a 25- to 50-foot belt of high shrubs (H), like Amalanchier, grow in outer margin of swamp where drainage is better. In background, many small red maples (Acer rubrum) /M/ are common but white pines (P) become increasingly common in adjacent areas outside the swamp. U.S. Navy photograph, 4 May 1966.

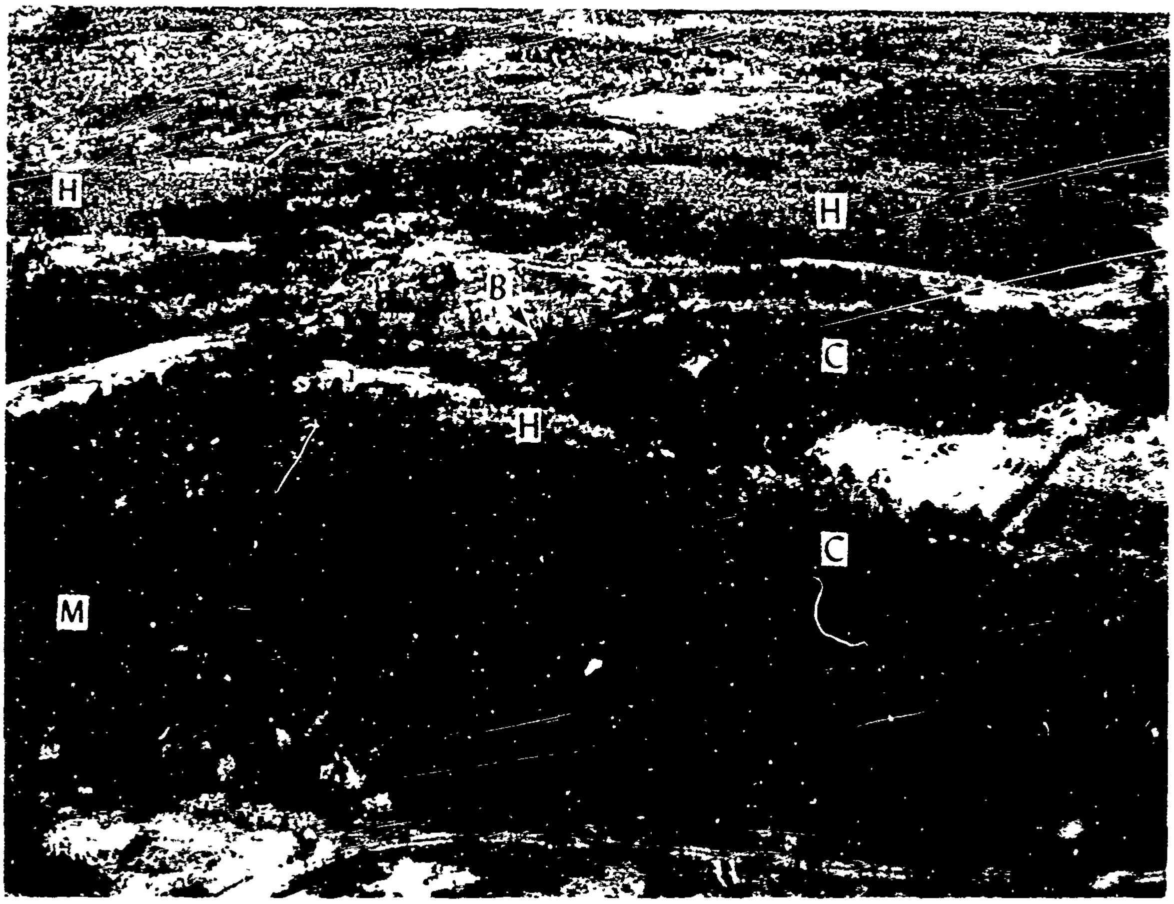


Photo 12. Forest types in north part of NLABS Annex east of headquarters (looking ENE). On the large drumlin (foreground), mixed hardwoods and conifers (M) predominate but forest types range locally from pure conifers (C) to small stands of hardwoods (H). Beyond the hill, a large conifer grove (C) covers most of the lowland on this side of Taylor Brook (B). On far side of patrol road, a representative hardwood forest (H) occupies a broad hill top (252 ft); the forest canopy is fairly open. A second area of hardwoods is also shown at left (H). U.S. Navy photograph, 4 May 1966.

Photo 13. Vegetation in and along Taylor Brook swamp (looking NE) downstream from its junction with Honey Brook. The swamp condition is accentuated by the sluice gate about 1500 feet farther downstream. Grass and low shrubs grow mostly in the areas of standing water and often in adjacent wet places. Higher shrubs and saplings, such as high bush blueberry (Vaccinium) and alder (Alnus incana) are found in poorly drained places and in bordering areas. At left many white pine saplings grow in hardwood forest on a moist lowland. The patrol road can be seen through mixed hardwood and conifer trees. U.S. Navy photograph, 4 May 1966.

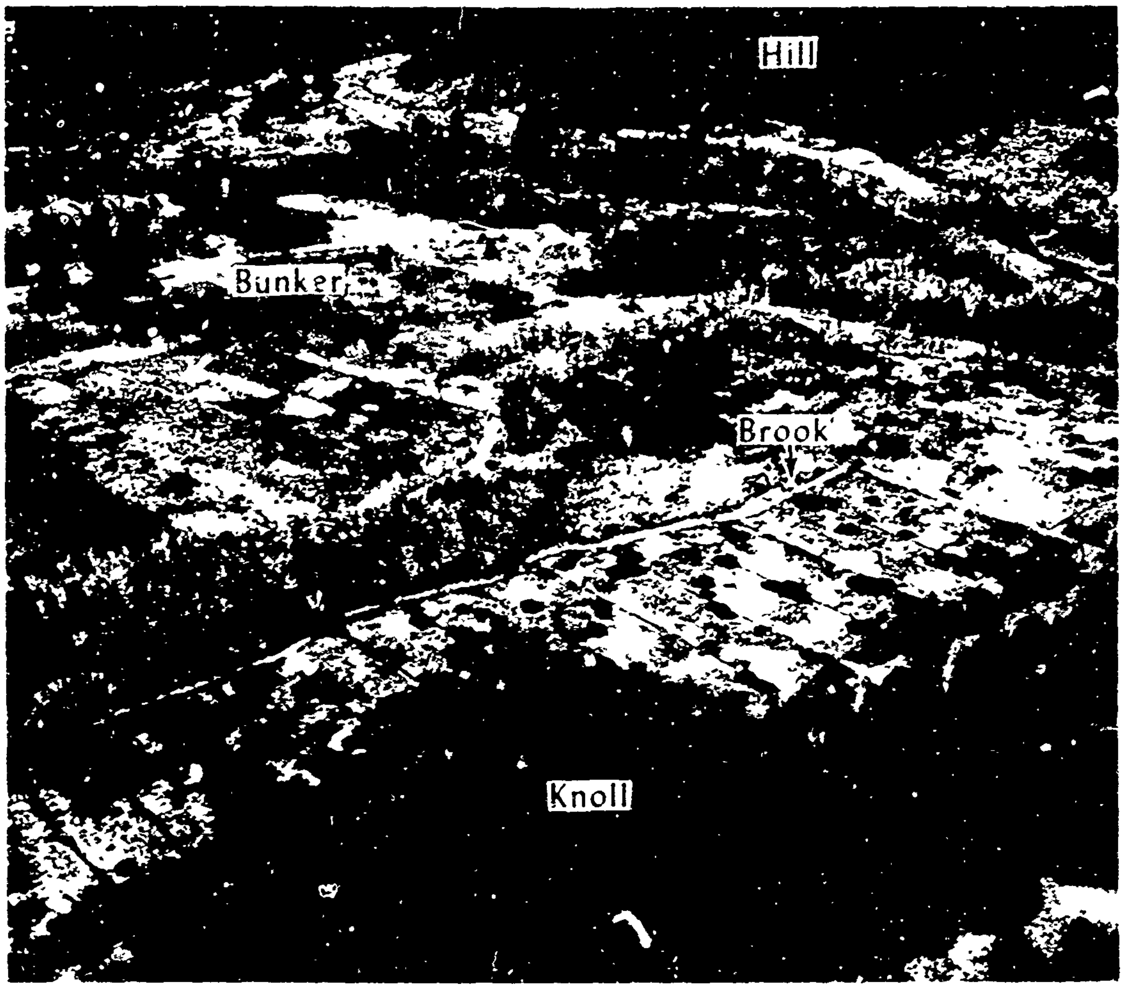


Photo 14. Cranberry bogs, Taylor Brook swamp, and other environments north of Puffer Pond (looking NNW). The two distinct areas with parallel drainage ditches are abandoned cranberry bogs; these low shrubs dominate most of both perennially saturated areas. The stagnant Taylor Brook flows north between the two bogs and to left of patrol road. The stream and its tributary (right) border much swamp area, where low and high shrubs are common. Saplings thrive in some less swamply but wet places. A white pine grove is well established on small knoll in foreground. On a broad, high hill (252 ft - see Fig. 1) in background, a characteristic stand of hardwoods is about average in size and only moderately dense; occasional white pine saplings are common in such forests. Three bunkers are near Taylor Brook swamp in left background. U.S. Navy photograph, 4 May 1966.

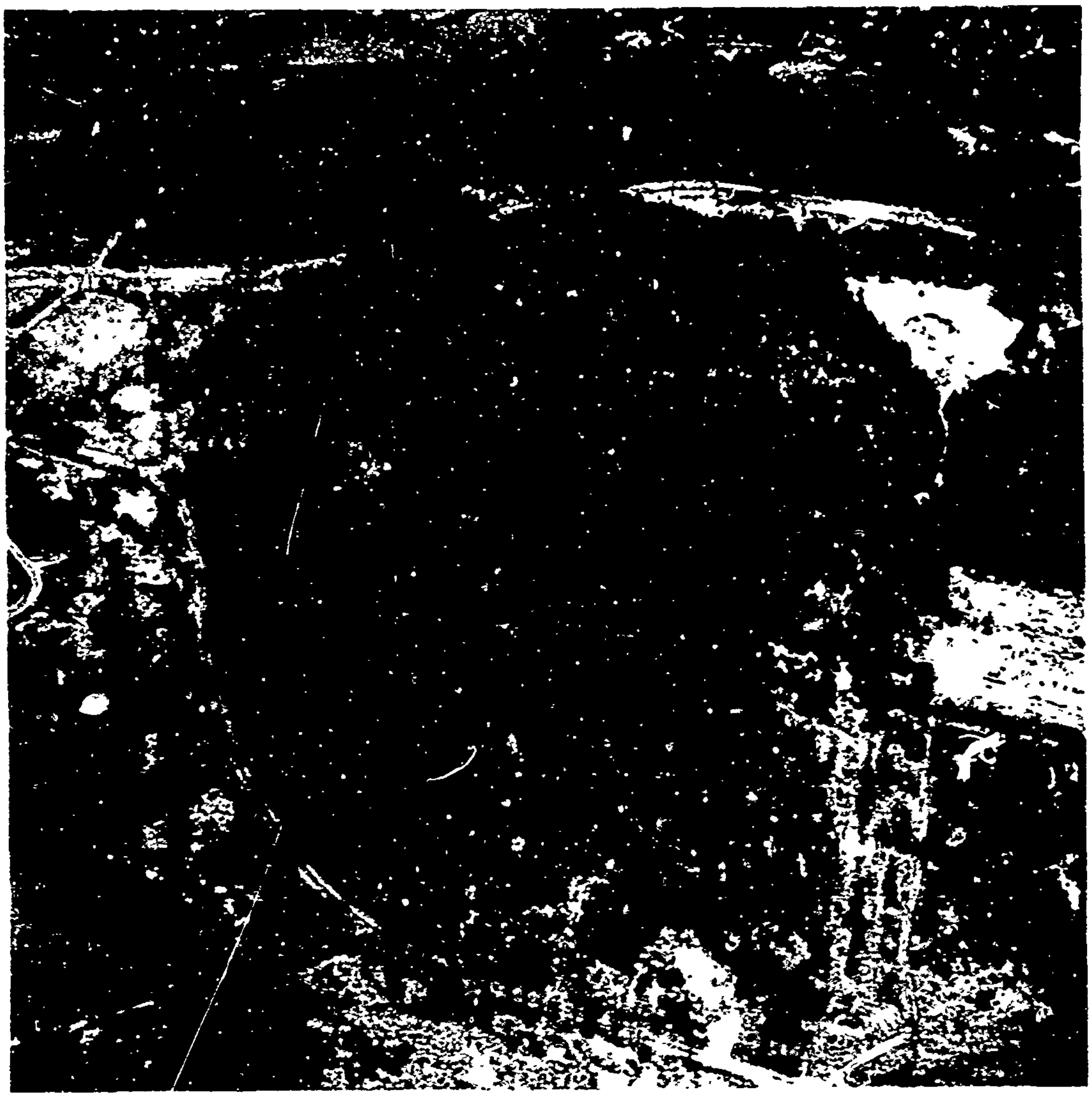


Photo 15. Vegetation contrasts on hill and lowland areas east of headquarters (looking N toward Assabet R.). Prior land use and environmental conditions account for many sharp contrasts in vegetation types on and around this drumlin (center). All vegetation types mapped in Figure 25 are shown. Tentative selection of a place for field work or testing may be made by studying the essential conditions provided on various maps and photographs. U.S. Navy photograph, 4 May 1966.

Photo 15. Representative hardwood forest during dormant period (look-NE toward weather station from helicopter over hill southwest of the station). Low-altitude photograph provides a close-up view of moderately dense hardwoods through a small, grassy opening. When deciduous canopy is at least fairly dense conifer saplings are scarce or absent and deciduous underbrush present little hindrance to movement on foot. The experimental building in foreground is leased to the U.S. Air Force. U.S. Navy photograph, 4 May 1966.

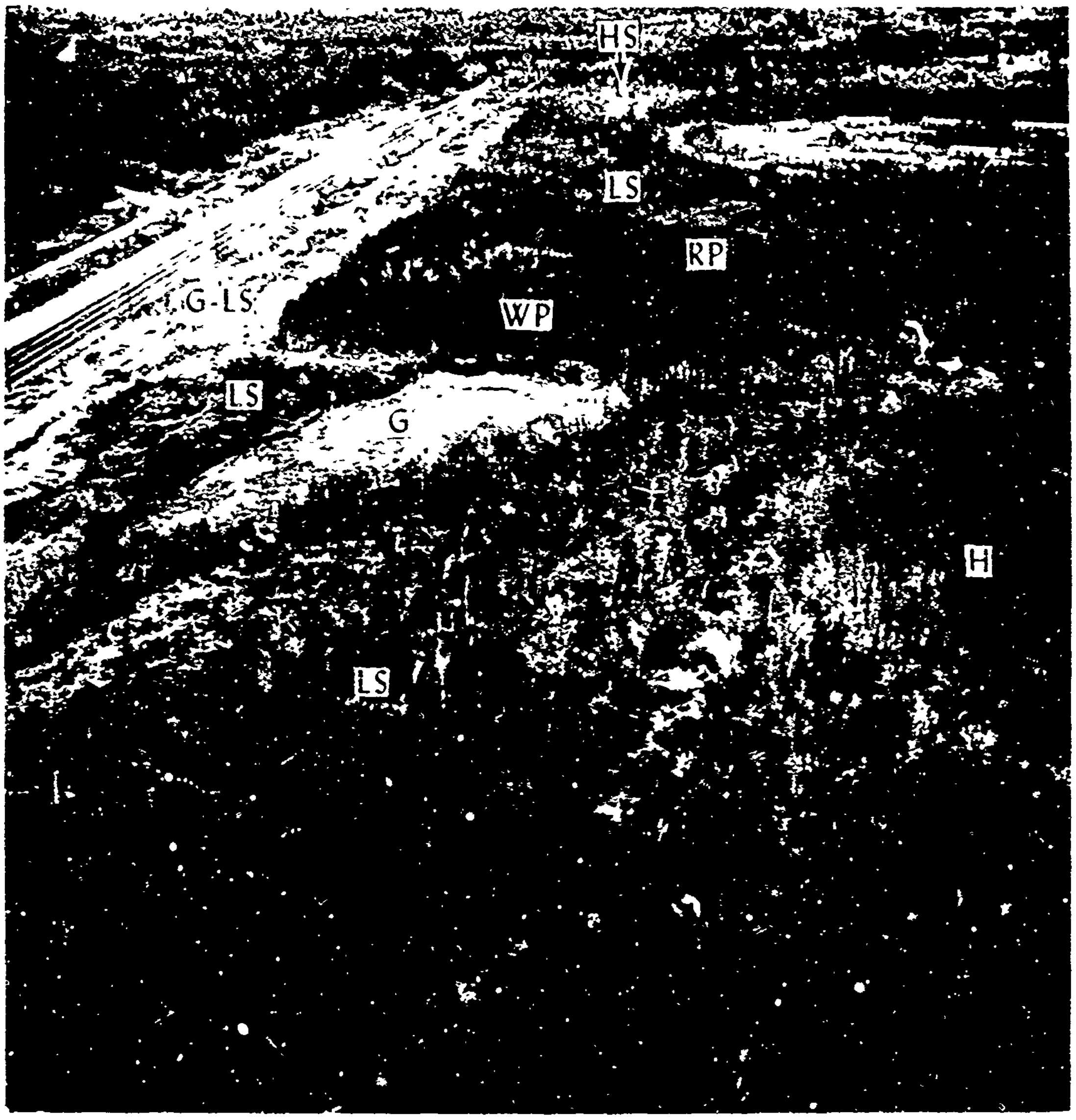


Photo 17. Vegetation types on glacial outwash plain south of Hudson Road (looking SSW). About half the area shown is swampland, including large area draining toward lower left. Vegetation types are identified and located as follows: low shrubs in swamp (LS); hardwoods (H); grass (G) where a mound was removed (center); to its left, gnarled patch of low shrubs [< 5 ft] (LS)--difficult to walk through; white pine grove (WP); narrow strip of red pine (Pinus resinosa) plantings (RP); low shrubs (LS) on infertile, well drained lowland (background); high shrubs (HS) and dead hardwoods in swamp (background); mostly grass (G) and scattered low shrubs (LS) along railroad tracks. The trackage will soon be removed. Diagonal Road (paved) is in left background. Part of Capehart Housing area is in right background. U.S. Navy photograph, 4 May 1966.

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13. ABSTRACT

This report describes the environmental conditions at the U. S. Army Natick Laboratories Annex. This facility provides a nearby, adequately large area in an essentially rural locality for conducting field research and for developing and testing materiel. There are important environmental contrasts in slope, soil, drainage, vegetation, and in microclimate. Its climate is generally representative of intermediate climatic conditions specified in AR 705-15, Operation of Materiel under Extreme Conditions of Environment.

Characteristic landforms consist of level to slightly undulating lowlands and oval-shaped hills. The larger hills, rounded by glacial action, form conspicuous features that are over a hundred feet higher than the adjacent lowland. Swamps and marshes are numerous, vary greatly in size, and occur in lower parts of many lowlands. However, their extent in relatively level areas varies considerably with the amount of precipitation and season of the year.

Soils occurring in the reservation are closely related to elevation, texture of glacial materials, and drainage. Stony, loamy sand soil derived from granite and gneiss material occurs on well-drained hills. Most of the lowlands have a loamy sand soil, but muck and peat are found in poorly drained areas.

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