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Aspects of Climate Around Narragansett Bay 59 pp

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Narragansett Bay Estuary Program

Current Report

The Narragansett Bay Project

ASPECTS OF CLIMATE AROUND NARRAGANSETT BAY

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Narragansett, RI

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The Narragansett Bay Project is sponsored by
the U.S. Environmental Protection Agency and
the R.I. Department of Environmental Management.



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FOREWORD

The United States Congress created the National Estuary Program in 1984, citing its concern for the "health and ecological integrity" of the nation's estuaries and estuarine resources. Narragansett Bay was selected for inclusion in the National Estuary Program in 1984, and the Narragansett Bay Project (NBP) was established in 1985. Narragansett Bay was designated an "estuary of national significance" in 1988. Under the joint sponsorship of the U.S. Environmental Protection Agency and the Rhode Island Department of Environmental Management, the NBP's mandate is to direct a program of research and planning focussed on managing Narragansett Bay and its resources for future generations.

The NBP will develop a draft Comprehensive Conservation and Management Plan (CCMP) by December, 1991, which will recommend actions to improve and protect the Bay and its natural resources.

The NBP has established the following seven priority issues for Narragansett Bay:

- management of fisheries
- nutrients and potential for eutrophication
- impacts of toxic contaminants
- health and abundance of living resources
- health risk to consumers of contaminated seafood
- land-based impacts on water quality
- recreational uses

The NBP is taking an ecosystem/watershed approach to address these problems and has funded research that will help to improve our understanding of various aspects of these priority problems. The Project is also working to expand and coordinate existing programs among federal, state and local agencies, as well as with academic researchers, in order to apply research findings to the practical needs of managing the Bay and improving the environmental quality of its watershed.

This draft represents the technical results of an investigation submitted to the Narragansett Bay Project in partial fulfillment of a professional services contract funded by the United States Environmental Protection Agency through Cooperative Agreement #CX812768 to the Rhode Island Department of Environmental Management. The results and conclusions contained herein are those of the author(s), and do not necessarily represent the views or recommendations of the NBP.

This study is an interim report; and, as such, has not undergone the Agency's and the Narragansett Bay Project's peer and administrative review. Therefore, the interested reader is encouraged to investigate additional sources of information and should not necessarily consider this report a comprehensive synthesis of the existing data on the subject.

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1. INTRODUCTION

When attempting to examine various features of the ecology of Narragansett Bay it is often tedious to acquire from various diverse sources the necessary basic and elementary data with respect to temperature, rainfall, water flow and other such aspects of the local environment that seem germane. In this report I present tabulations and graphs of some data that may be useful in this regard, along with a number of additional evaluations, comments, and such relationships as are easily seen in the data.

Many of the original sources of the data contain extremely detailed records. For example, there are hourly records of the temperature at weather stations, going back many decades, and daily records of the water flow at each of six or seven gauging stations. In order to keep this report to a manageable size, most of the data were cumulated or averaged by month, or monthly totals extracted from the original records. When appropriate, the varying lengths of the months were taken into account in making the averages. One disadvantage of using monthly totals or averages is that the response time of the bay to various perturbations must often or usually be on a shorter time scale than a month. Those who would investigate such phenomena may have to acquire the necessary detailed records, with perhaps this report as a beginning. The monthly averages are, however, convenient in most cases for examination of the seasonality of processes in the bay. In any case, our other data are often sparse enough that we cannot usefully use a more detailed record.

In a report of this size it is quite impossible to present a thorough description of the procedures used to acquire the data. Where possible, brief descriptions or citations are noted in the various sections. For some purposes it may be necessary to go to the sources for detailed evaluations. A few cautionary comments are noted in the various sections below.

The author will be much indebted to those readers who report errors or omissions in this report.

II. THE SETTING

Narragansett Bay occupies an irregular series of depressions carved by glaciers into the Pennsylvanian (about 300 million years old) sedimentary rocks that are found underlying this part of Rhode Island. The elevations and depressions are lightly and irregularly mantled by glacial outwash and other debris left behind during the last retreat. When glacial ice left this region the level of the sea was at first too low to enter the bay, and the area was occupied by fresh water streams and lakes. The evaluation by McMaster (1984) shows that the sea began to flood into the bay about 9000 years ago and that the present shape was more or less established by 2000 years ago. According to Hicks *et al.* (1983), however, sea level continues to rise, at a rate of perhaps 18 to 26 cm per 100 years in this region, based on a little more than 50 years of data.

As the post-glacial marine shoreline migrated into the bay, those deposits and soils that could be eroded by the waves were attacked, as they still are today. In the deeper regions, marine sediments began to accumulate, from sources on the shelf, from the eroding shoreline, and from the rivers. McMaster (1960) has plotted the apparent depth of sediment thickness in the bay. It ranges from negligible up to about 15 m. The sediment is complex, as expected in such a region, with areas of gravel, sand, silt, and clay, often poorly sorted. McMaster's maps show that in most of the bay the uppermost sediments consist of clayey silt. In the more nutrient-rich and polluted areas of the upper bay the sediments have high concentrations of organic matter, nutrients and pollutants.

There are about a dozen islands completely in the bay, with a total land area of 41 km², and Aquidneck I. at the southern end, with an area of about 99 km², of which about 76 km² drains to the bay. The total land drainage area is about 4450 km², including the drainage to the Sakonnet.

The area of water in the bay is 379.1 km², including all identified salt water or tidally influenced areas, if the southern boundaries are drawn as in Fig. II-1 (Pilson 1985). In Fig. II-1 the boundaries are set in the same way Kremer and Nixon (1976) did, to be most useful in treating the bay as a hydrologic and ecologic system, but the Sakonnet Passage (or "River") and Mount Hope Bay are included. For modeling the bay as a whole, Mount Hope Bay should be included, because the major exchange of Mount Hope Bay is with the rest of Narragansett Bay, with a lesser exchange to the Sakonnet Passage. On the other hand, the Sakonnet Passage may be left out of simple bay models, because it has only a narrow connection to the rest of the bay and it can be considered an arm of Rhode Island Sound. The map also shows a useful division into segments that has been used in several studies to help evaluate bay processes. The segments derive from Kremer and Nixon (1976) and Pilson (1985). The areas, mean depths, and volumes of the segments of the bay and estimates of the total areas of the islands in the bay are given in Table II-1. A useful source of detailed information is the report by Chinman and Nixon (1985), in which detailed cross sections and estimations of volumes are given at a series of depth intervals and at intervals along the axis of the bay.

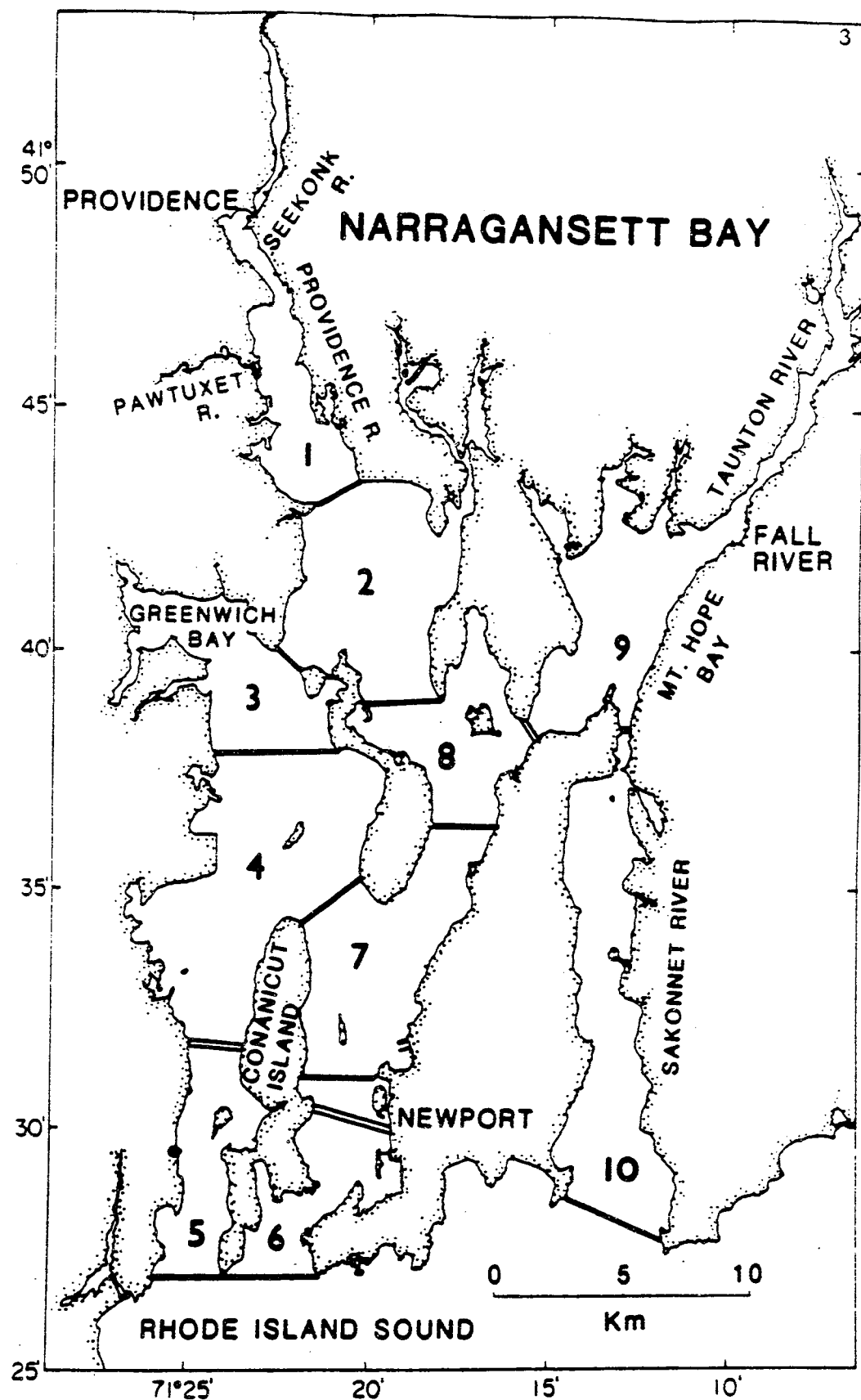


Fig. II-1. Map of Narragansett Bay, showing the lower the boundries used in measuring the areas of the bay as a whole and the various segments into which it is conveniently divided. Modified from Kremer and Nixon (1978) and Pilson (1985). See text and Table II-1.

Table II-1. Distribution of areas within the Narragansett Bay drainage basin. Gauge descriptions from USGS (1975-1985), land areas from K. Riese of the USGS (personal communication), and water areas from Pilson (1985).

<u>Region</u>	<u>Gauged Areas*</u>	<u>Area, km²</u>	
Taunton River at State Farm, MA		668.2	
Segregansett River near Dighton, MA		27.5	
Three-Mile River at N. Dighton, MA		218.3	
Blackstone River at Woonsocket, RI		1077.4	
Pawtuxet River at Cranston, RI		520.6	
Woonasquatucket River at Centerdale, RI		98.9	
Ten-Mile River at East Providence, RI		138.6	
Moshassuck River at Providence, RI		60.4	
Hunt River at East Greenwich, RI		59.3	
	Total	2869.2	
	<u>Drainage Areas</u>		
Taunton River*		1445.7	
Blackstone River		1222.5	
Pawtuxet River		600.9	
Ten-Mile River		143.5	
Woonasquatucket River		134.4	
Palmer River		122.8	
Moshassuck River		61.4	
Hunt River		59.3	
Smaller rivers and coastal drainage		542.8	
Area of islands with drainage to bay		116.9	
Total land area draining to bay		4450.1	
Total land area draining to bay (excluding Sakonnet) ^o		4362.8	
	<u>Salt Water Areas</u>		
Segment 1	24.7	Segment 6	24.5
Segment 2	49.5	Segment 7	39.4
Segment 3	30.6	Segment 8	26.2
Segment 4	63.0	Segment 9	49.2
Segment 5	20.6	Segment 10	51.4
Surface area of tidal water	(including Sakonnet Passage)		379.1
	(excluding Sakonnet Passage) ^o		327.8

* The length of the gauged record varies from less than one year to more than 50 years, depending on the station.

* The estimate of Riese for the Taunton drainage basin (1455.6 km²) includes the area down to the I-195 bridge. I have subtracted 9.9 km², the estimated area of tidal water above the bridge.

^o The Sakonnet Passage (Sakonnet "River") is an arm of Rhode Island Sound, and has only a small connection with the rest of Narragansett Bay through Mount Hope Bay. Its land drainage area has been roughly estimated to be 87.3 km².

The major rivers which enter the bay are also noted in Table II-1, along with their gauged areas and their total drainage areas. The areas differ in some cases from those given in Pilson (1985), because these estimates are derived from measurements made by K. Riese of the U.S. Geological Survey (personal communication), whereas the earlier estimates were derived from those published by the U.S. Army Corps of Engineers.

A summary of the land and salt water areas in the drainage basin is presented in Table II-2.

Table II-2. Summary of the areas in the Narragansett Bay drainage basin, giving total land (including fresh water) areas and tidally influenced or salt water areas.

Region	Area, km ²	Percentage
-----	-----	-----
Including the Sakonnet Passage:		
Total land drainage area	4450	92.2
Total salt water area	379	7.8
Total area	4829	100.0
Excluding the Sakonnet Passage		
Total land drainage area	4363	93.0
Total salt water area	328	7.0
Total area	4691	100.0

III. LIGHT

The main source of data on the light energy received from the sun in this region is the Eppley Laboratories, Inc., of Newport, RI. That company makes standard pyranometers which sense the total flux of incoming solar energy in ultra-violet, visible and infrared wavelengths. A sensor has been maintained since 1937 on the roof of one of the company buildings, although the instrumentation has changed from time to time. The data are reported in Langleys (gram calories per square centimeter), tabulated as hourly and daily totals, and kept in loose-leaf note books at Eppley Lab. Copies of the daily data from 1972 on are available in Pell Library at GSO.

Monthly means of the daily totals for the entire 50-year record are presented in Appendix Tables Ala and Alb. In the latter table the values are reported in $\text{MJ m}^{-2} \text{d}^{-1}$ (million Joules per square meter per day), as the Joule is now the standard unit in international usage. The averages of the monthly means of the daily totals are shown below in Table III-1, and in Fig. III-1

Table III-1. Monthly means of the light energy received each day at Newport, RI, from 1937 to 1987 inclusive, corrected where possible for changes in calibration. The units are $\text{MJ m}^{-2} \text{d}^{-1}$.

Jan	6.58	Jul	21.24
Feb	9.80	Aug	18.65
Mar	13.50	Sep	15.38
Apr	16.79	Oct	11.16
May	19.93	Nov	7.06
Jun	21.68	Dec	5.56

There is a long-term downward trend in the annual averages (Fig. III-2), which raises a number of questions. What is the standard of reference? Has the energy output of the sun decreased? Have the sensors remained in calibration? Has there been an increase in haziness, cloudiness or fogginess at Newport?

Over the years there have been a number of changes in the assigned values of the irradiance measured by the instruments used as absolute standards of reference (Iqbal 1983). Inquiry to Eppley Laboratory, Inc., prompted the following response from Mr. George Kirk, President:

"Effective 1957, the Eppley Laboratory shifted from the old Smithsonian Scale to the IPS 1956 scale. This would have the effect of having the older data approximately 2% higher. Subsequently, in 1977, Eppley shifted to the World Radiation Reference as determined in the National Pyrheliometer Comparison IV. This again changed the scale by 2%. This might explain some of your apparent trend. Over the years there have been a number of instrument changes, the last being in 1980.

Our data certainly suggest a downward trend as your [graph] indicates, but it is hard to quantify without further analysis which may not be possible from our records."

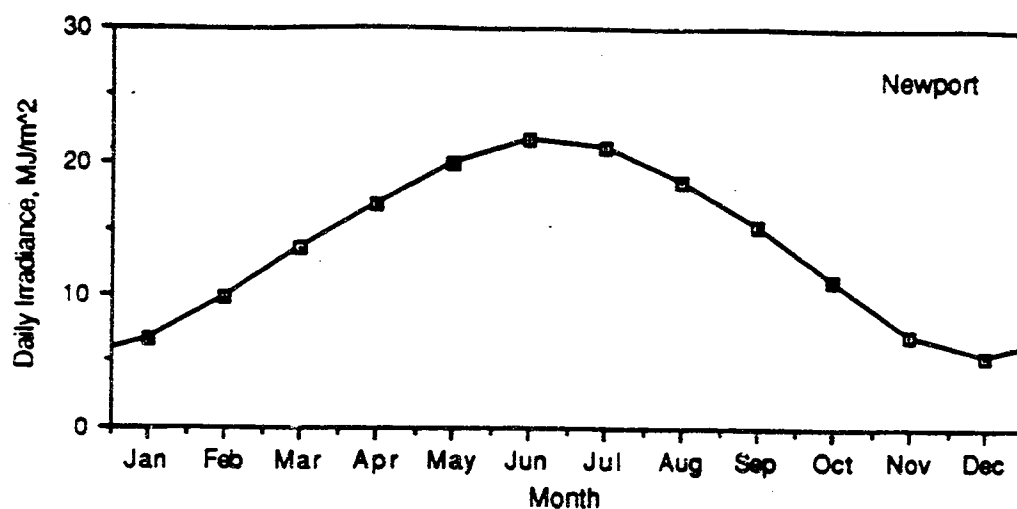


Fig. III-1. Monthly mean daily light energy received at Newport R.I., from 1937 to 1987 inclusive. Corrected values.

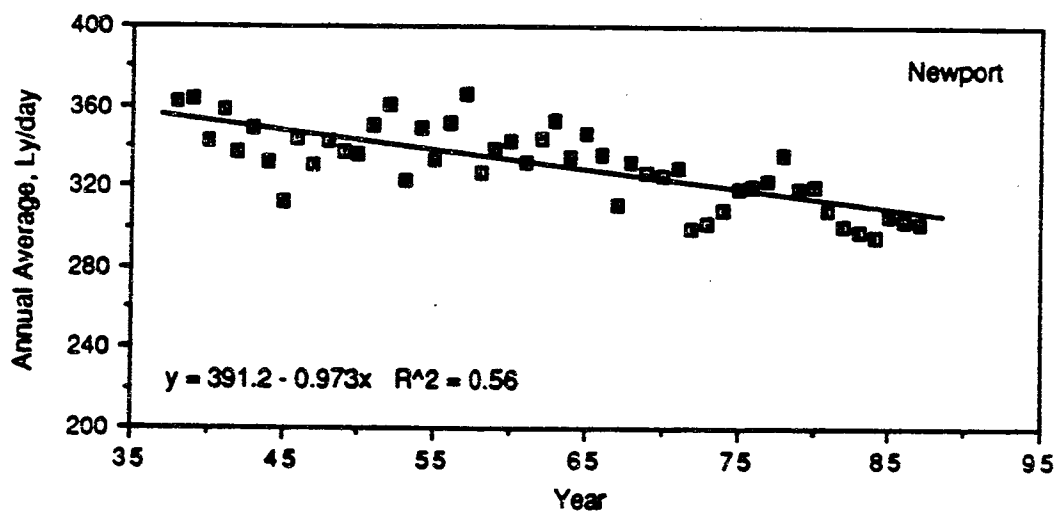


Fig. III-2. Annual averages of the monthly means of the daily light energy input at Newport, R.I. Uncorrected values as reported in Langley (cal./cm²) per day.

Calibration sheets currently supplied with the Eppley pyranometers suggest that the readings are good to $\pm 0.5\%$. Procedures which are used to integrate the records, with their extreme variability from minute to minute on cloudy days, might possibly have changed through time, however.

In 1956 the World Meteorological Organization adopted the IPS-1956 standard, effective 1 Jan. 1957, whereby:

"Measurements made according to the Smithsonian Scale 1913 are to be decreased by 2.0 per cent" (Iqbal 1983, p 378).

According to the calibration sheets provided by Eppley lab., a subsequent change occurred in 1977, as follows:

"As of April 1, 1977, the calibration traceability of Eppley solar radiation measuring instruments has been changed from the International Pyrheliometric Scale of 1956 (IPS 1956) to the Absolute Scale (SI). This change based on the results of IPC IV is such that instruments calibrated in SI units yield irradiance values which are 2.1% higher than values which would be obtained using Eppley instruments calibrated previously and referenced to IPS."

In order to take account of these somewhat confusing changes the original Eppley data given in Appendix Table A1a have been adjusted as follows: (a) Values from April 1977 until the present time have been left unchanged. (b) Values from 1957 to March 1977 inclusive have been adjusted upwards by 2.1%. (c) Values from 1937 until 1956 have been adjusted upwards by 0.1%. The adjusted values were also converted from calorie units to Joule units, as noted before, and are tabulated in Appendix Table A1b. These adjusted values are plotted on Fig. III-3. Clearly the recent downward trend is still, or even more, evident.

From Fig. III-3 it appears that the drop in received light energy is largely a phenomenon of the last 30 years. The data for the years 1955 to 1987 only are plotted in Fig. III-4. The negative slope is almost twice that for the whole data set. The decrease has been about 15% in the last 30 years. This change is not due to a decrease in the light output of the sun. The irradiance of the sun does vary on several time scales (there is a five-minute oscillation of several parts per million, and changes of up to 0.25 % lasting several days due to sunspot activity) and the trend from 1980 to 1985 appears to be downward, but the change was only about 0.019 % each year (Wilson et al. 1986), whereas the apparent slope at Newport has been about 30 times greater.

The problem of maintaining calibration of the sensors appears to need additional attention. Pyranometer data collected in several regions of the country were at one time routinely reported by the National Weather Service, but, because of the poor quality of the data, this reporting was discontinued in 1972; apparent changes in calibration of Eppley pyranometer instrumentation ranged from -16.7 % to + 15.6 % (Durrenberger and Brazel 1976).

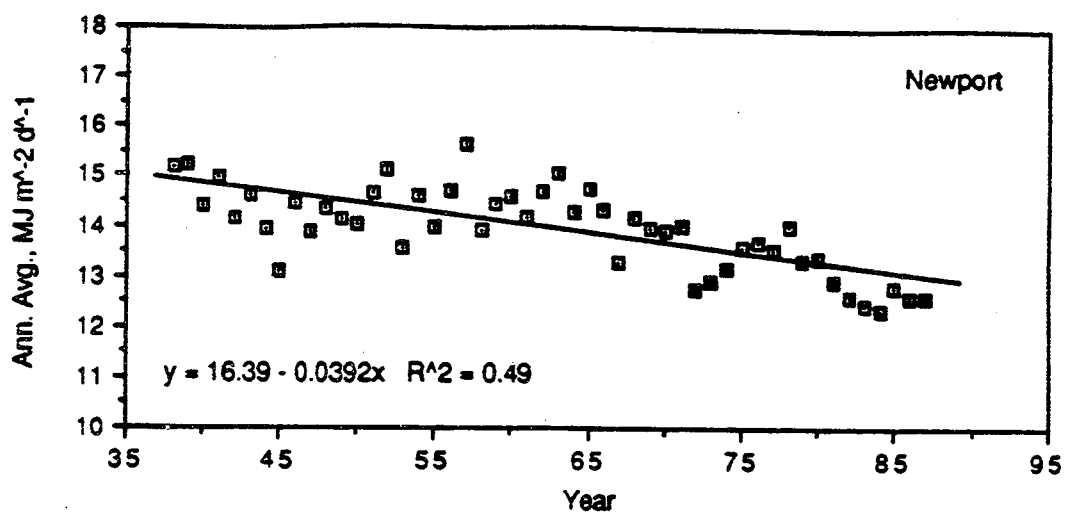


Fig. III-3. Annual averages of the monthly means of the daily input of light energy at Newport, RI, from 1938 to 1987. Values are in MJ m⁻² d⁻¹ (mega-Joules per square meter per day), and are corrected for changes in calibration.

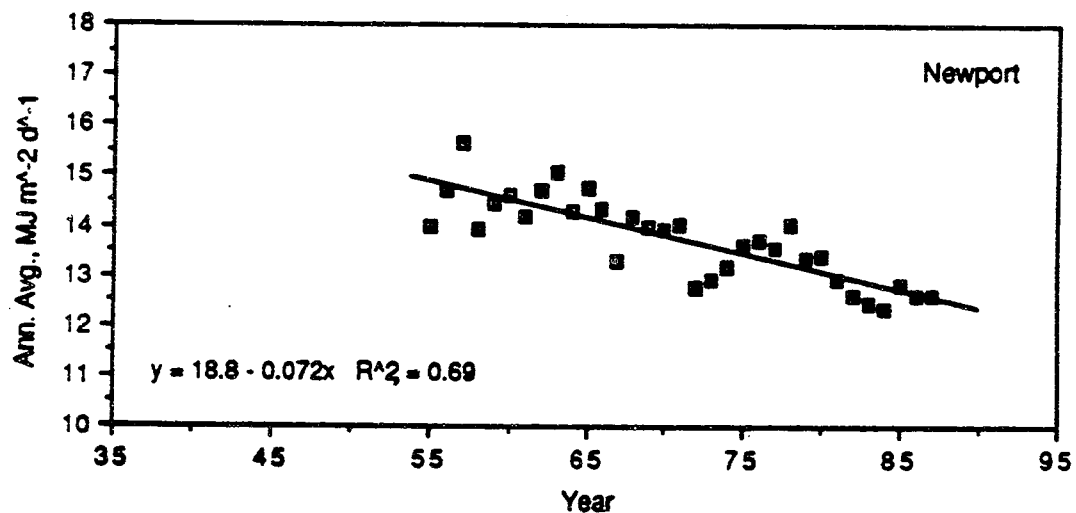


Fig. III-4. Annual averages of the monthly means of the daily input of light energy at Newport, RI, as above except that data are shown from 1955 to 1987 only.

Another line of evidence concerning the amount of light energy received in the local region comes from the Weather Bureau, which reports the amount of sunlight received each day as a percent of the maximum that could be received. The monthly averages of these values from 1964 to 1987 are included in Appendix Tables A3a to A3m, while additional data back to 1955 are plotted as annual averages in Fig. III-5. Overall, there appears to have been an increase in the amount of sunlight received at Warwick during these years. Again, calibration of procedures for collection of data such as these would have to be examined for a full evaluation. However, these data provide no support for the suggestion that there has been a general increase in cloudiness in the region; if anything, there seems to have been a small increase in the amount of sunlight received. These data do not address, however, the possibility that Newport itself might have become more foggy or hazy. Direct comparison of the individual yearly averages for % Sunlight and total energy received (Fig. III-6) shows essentially no relationship between them, which is somewhat surprising, but does suggest at least the possibility that, once the seasonal signal is removed, the amount of sunlight received at the two regions may not be strongly correlated. An additional point of interest is that the values of % Sunlight received at Warwick show rather less seasonality than might be expected. (Fig. III-7), although it is evident that November and December are the most cloudy months, and July the least cloudy.

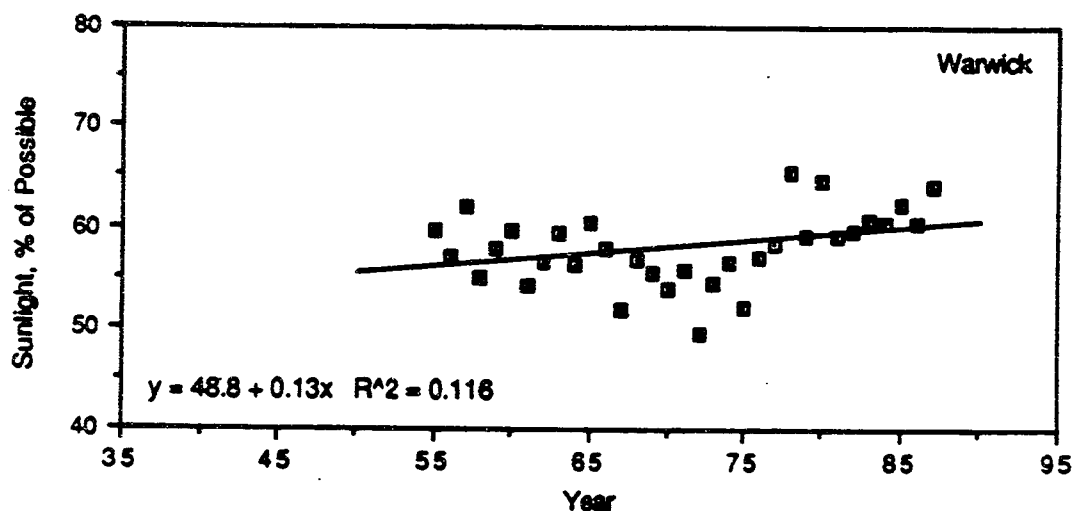


Fig. III-5. Annual averages of the monthly means of the Weather Bureau estimates of the daily amount of sunlight received at Warwick, RI, as a percent of the maximum amount of sunlight that could have been received.

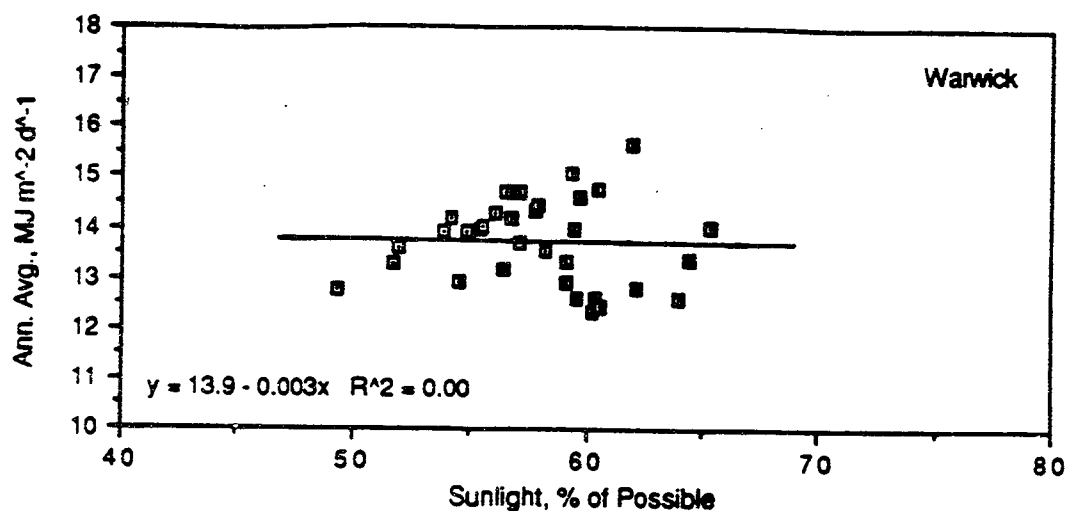


Fig. III-6. Relationship of the annual mean total light energy received at Newport, RI, and the annual mean percentage of possible sunlight received at the T.F. Green State Airport, Warwick, RI (data from Eppler Laboratories, Inc. and from NOAA, 1955-87).

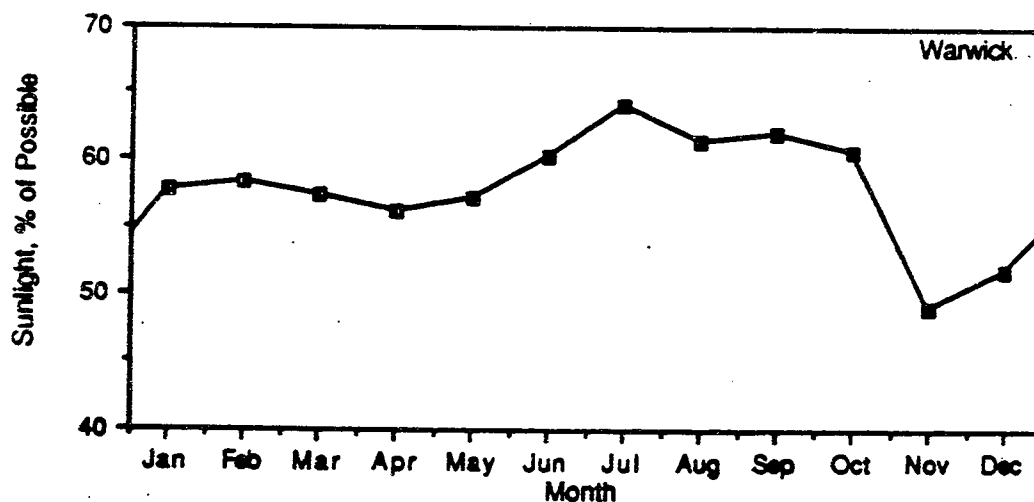


Fig. III-7. Seasonal distribution of the amount of sunlight received at T.F. Green State Airport, in Warwick, RI, expressed as a percent of the maximum possible amount of sunlight, averaged by month over the years 1964 to 1987 inclusive. Data from NOAA 1964-87.

IV. WIND

The monthly averages of the wind speed measured at the T. F. Green State Airport in Warwick, RI, are given in Appendix Tables A3a to A3m for the years 1964 to 1987, inclusive. Monthly averages for the 24-year data set are given in Table IV-1 below, and in Fig. IV-1.

Table IV-1. Averages of the monthly mean wind speed measured at T.F. Green State Airport in Warwick, RI, over the years 1964 to 1987, inclusive, and the overall mean value.

<u>Month</u>	<u>Mean</u>	<u>Std.dev.</u>	<u>Month</u>	<u>Mean</u>	<u>Std.dev.</u>
Jan	17.78	1.98	Jul	14.92	0.90
Feb	18.50	1.88	Aug	14.36	0.96
Mar	19.19	1.48	Sep	14.51	1.32
Apr	18.85	1.37	Oct	14.94	1.15
May	17.04	1.30	Nov	16.30	1.04
Jun	15.70	1.35	Dec	17.25	1.46
			Mean	16.61	0.51

As can be seen (Fig. IV-1), there is a relatively small but clearly defined seasonality to the average wind speed in the region, with a maximum of over 19 km/hr in March, and a minimum below 15 km/hr in August.

The wind may blow from any direction, but at any time there is a much preferred direction, which varies with the season (Fig. IV-2). For example, during 23 years of observations at T. F. Green Airport, there was no January or February when the vector-averaged resultant wind direction fell outside a sector from 10° E of North to 10° S of West, and the most common wind direction was a little W of NW. In the summer months of May to August the wind typically blows from the Southwest.

For evaluating the wind over the bay as a whole, however, it should be recognized that the coastline has a considerable influence on local wind conditions. Strong offshore winds are weakened as they pass over land, and there can be a significant effect over a distance such as the length of the bay. In the summertime the phenomenon of the sea breeze is particularly important. It is commonly observed that the wind may blow from the north or northwest in the morning, but, some time after midday, the sea breeze (which here is a southerly) sets in and blows up the bay. It is sometimes remarkable to see sailboats with spinnakers flying sailing south in the upper part of the bay, while similar sailboats are similarly sailing before the wind heading north in the lower part of the bay. Sometimes they are only a couple of miles apart. The southerly may blow at 15 km per hour in the lower bay, while the northerly is still blowing strongly at the weather station in Warwick. Thus, there are at least some occasions when the records collected at the airport weather station may not represent the winds that are having the most effect on the water movements within the bay and the exchange with offshore waters.

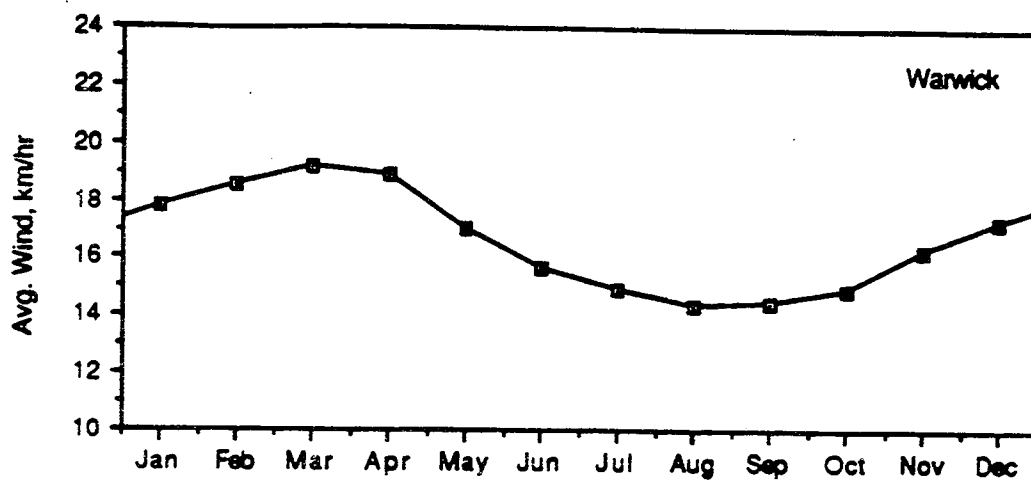


Fig. IV-1. Monthly mean wind speed at T. F. Green State Airport in Warwick, RI, averaged over the years 1964 to 1987, inclusive.

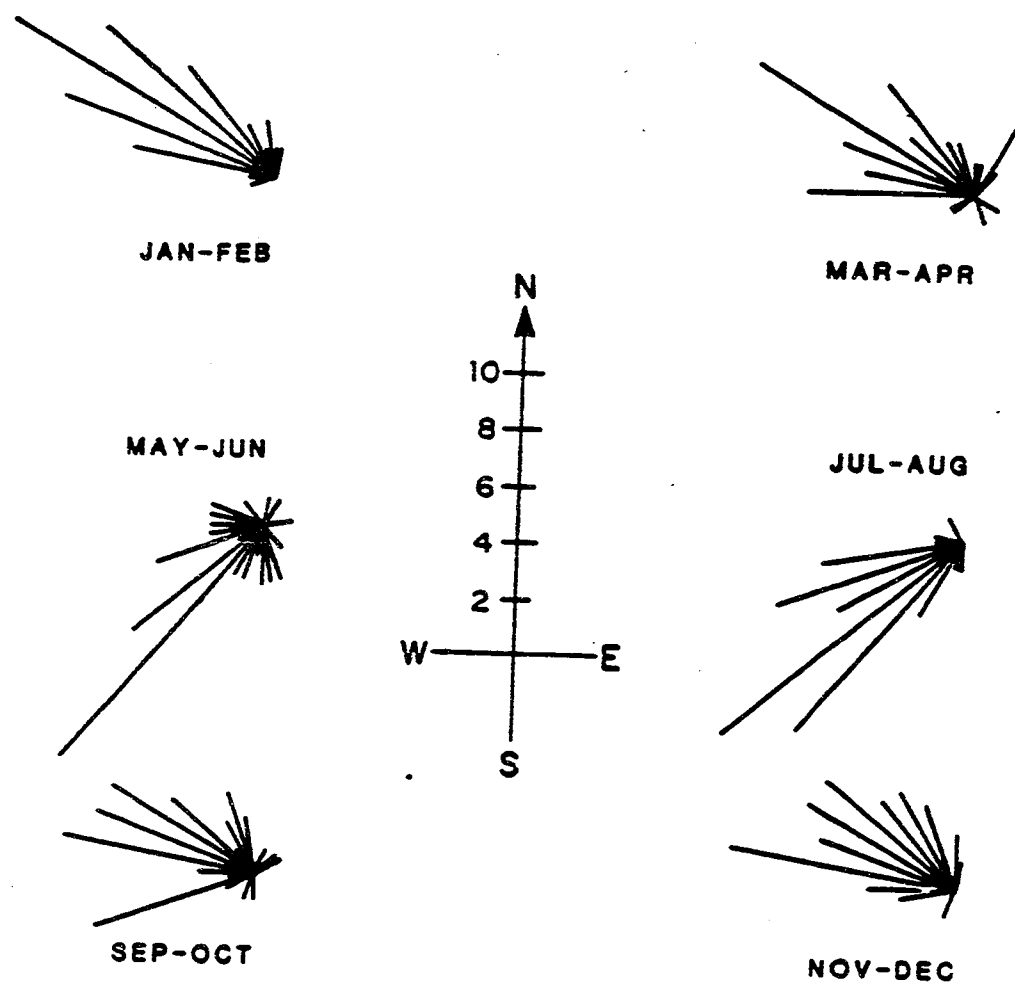


Fig. IV-2. Circular frequency histograms, in intervals each 10° wide, of the occurrence of vector averaged resultant wind direction for the 46 averages of two-month intervals from 1965 to 1986 inclusive, at T.F. Green State Airport in Warwick, RI. Data from NOAA (1964-1986). The scale indicates directions and the lengths corresponding to 0 to 10 occurrences of two-month intervals when the average wind blew from the direction indicated.

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V. TEMPERATURE

The records of the U.S. Weather Bureau from Providence, RI, began on Oct. 22, 1904, with the establishment of a Weather Bureau office in University Hall, Brown University, on Prospect Street. On Jan. 1, 1909, the recording location was moved to the Banigan Bldg., 10 Weybosset St. From Jan. 1, 1913 on the readings were affected by a higher building to west, so, on June 22, 1913, the instruments were moved to the Turks Head Bldg., 11 Weybosset St., where they could be located 74 to 86 feet higher (wind gauge at 251 feet above ground level, thermometers at 215 feet). On June 10, 1940 the recording station was moved to the Post Office Annex Bldg., except for the wind gauge that moved on June 16, 1941. The instrument exposure there was quite poor, so on Nov. 10, 1941 the official Providence observation program was transferred to the State Airport in Warwick, where there had been a subsidiary weather station since June 16, 1932. However, the official recording station for Providence temperature was transferred back to the Post Office Annex Bldg. on Jan 1, 1942, and the precipitation station on March 1, 1942; they both remained there until May 20, 1953, when they were again moved to the T. F. Green State Airport in Warwick. There have also been a number of moves within the grounds of the airport itself (NOAA 1984).

Earlier data for temperature (and precipitation) have been extracted by Scott Nixon from the archived records of the Providence City Engineer. Temperature was measured at Hope Reservoir from 1881 to 1884 inclusive, as well as for 10 months in 1886, and the remainder of the time until 1924, inclusive, it was measured at the City Engineer's office in Providence. The measurements were made at 7 am, 1 pm, and 9 pm.

The temperature data from Hope Reservoir and the City Engineer's office are listed in Appendix Table A2b. The data from the Weather Bureau for Providence (which since 1953 means Warwick) are in Appendix Table A2c for the years from 1905 to 1986. Temperature data collected from 1881 to 1924 under the authority of the City Engineer are plotted in Fig. V-1, along with data from the Weather Bureau for 1905 to 1924. In the years where overlap occurs, there is a systematic difference between the data sets, with the Weather Bureau temperatures being always lower. The locations of the instruments were of course different, and also the Weather Bureau daily averages included readings made at night so the averages are for this reason likely to be lower. The general trends are similar, however.

Inspection of the Weather Bureau data from 1905 to 1987 (Fig. V-2) does not suggest the existence of any long term trend in these annually averaged temperatures, in this region. The suggestion that there was a temperature increase during the period from 1930 to 1954 must be weighed against the record of instrument locations, with due regard to the local meteorological effects of cities.

Monthly temperature data from 1964 through 1987 are presented for Kingston, Newport, and Warwick, in Appendix Tables A3a to A3m.

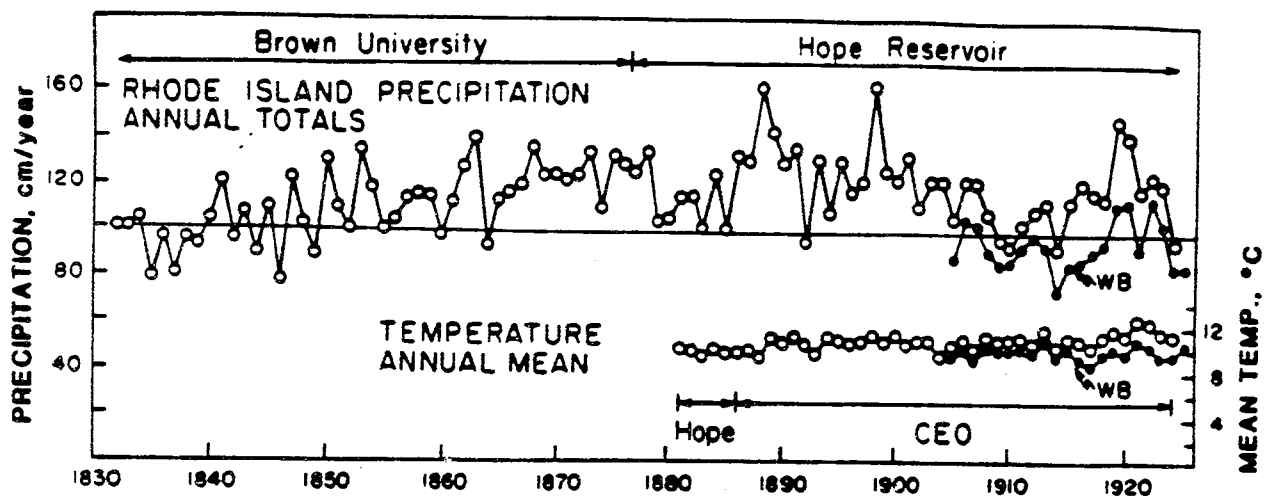


Fig. V-1. Early records of the annual total precipitation and the mean temperature in Rhode Island, extracted by Scott Nixon from the archives of the Providence City Engineer. Precipitation records were maintained from 1832 until 1876 by President Caswell of Brown University and by the City Engineer from 1877 until 1924 at Hope Reservoir. Temperature data were collected by the City Engineer at Hope reservoir beginning in 1881 and later at the City Engineer's Office (CEO) in Providence. Data from the official records of the Weather Bureau (WB) are also plotted for the period of overlap.

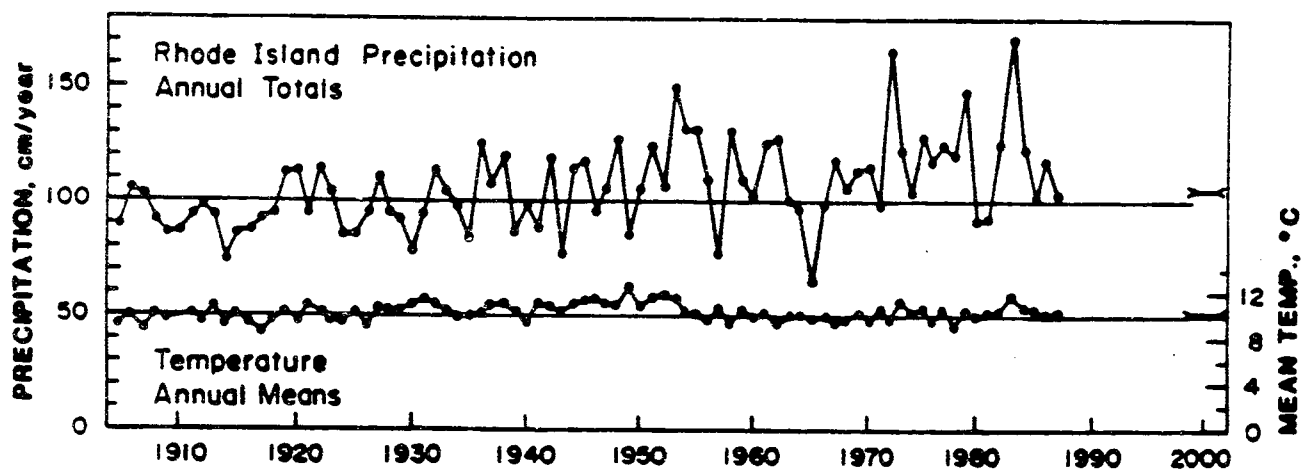


Fig. V-2. Long term trends of annual total precipitation and mean temperature in Rhode Island. These measurements by the U.S. Weather Bureau (now the National Weather Service) were made mostly in Providence from 1905 until 1953, when the recording station was moved to the T.F. Green State Airport in Warwick. Total precipitation is the sum of rain and snow. The light horizontal lines at 100 cm/yr and 10 °C are for visual effect. The mean values (small bars on the right) are 106.2 cm/yr and 10.3 °C.

Seasonal changes in temperature are shown by the plot of the long-term averages of the monthly mean air temperatures at Warwick, in Fig. V-3. As expected, July is the hottest month, with a mean temperature of 23.0°C , and January the coldest, with a mean temperature of -2.85°C . For a detailed evaluation of the variability of temperature, the original records of the Weather Bureau should be consulted.

There is a marked gradient in mean temperature between the ocean and the inland regions; the existence of this phenomenon makes it unlikely for the data from any single weather station to be a precise representation of the average conditions to which the bay is exposed. The two weather stations closest to the bay are those in Newport and at the airport in Warwick, R.I. The two stations are approximately 28 km apart. The difference in temperature between these two stations can be quite considerable at any one time. Even the monthly mean temperatures can differ by several degrees. The long-term, 24-year, averages of the monthly mean temperatures differ by up to 1.6°C , with the Warwick station being about 1.6°C warmer in July and about 1.6°C colder in January (Fig. V-4).

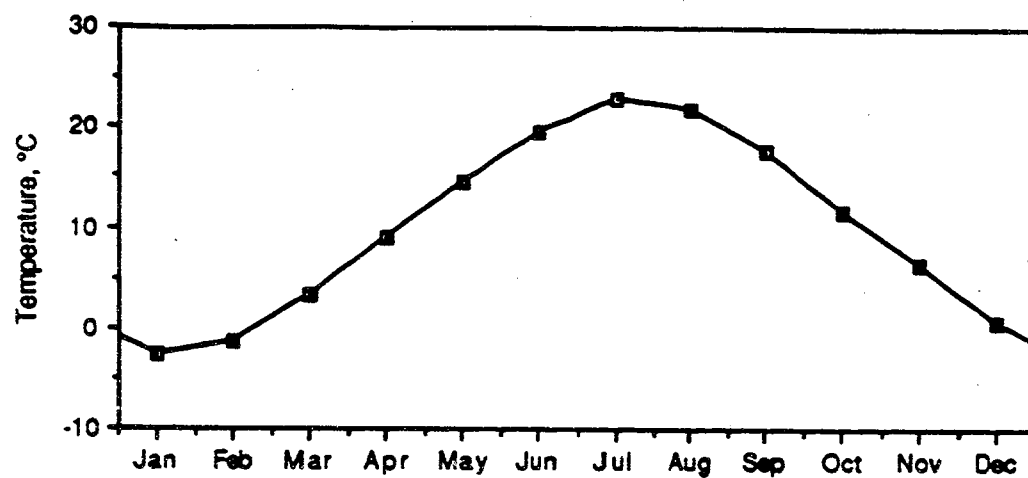


Fig. V-3. Monthly mean temperature (°C) at Theodore Francis Green State Airport in Warwick, RI, averaged over the years 1964 to 1987 inclusive.

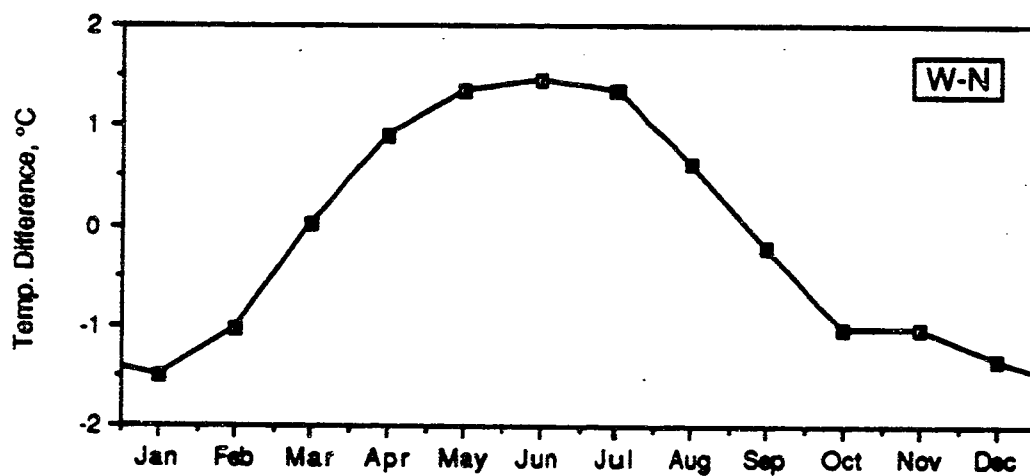


Fig. V-4. Difference between the monthly mean temperature measured at the airport in Warwick and that measured in Newport, RI, averaged over the years 1964 to 1987 inclusive.

VI. PRECIPITATION

Early records of rainfall in Providence were maintained under the direction of President Caswell of Brown University from 1832 until 1876. After that they were collected at Hope Reservoir from 1877 to 1924 under the authority of the Providence City Engineer. Extracts obtained from these early data by Scott Nixon are tabulated in Appendix Tables A2a and A2b, and graphed in Fig. V-1.

The official Weather Bureau station for Providence was established at Brown University in Providence in 1904, and then was moved several times, as noted in the chapter on temperature. It finally was moved, in 1953, to the grounds of T.F. Green State Airport in Warwick, RI. The data for annual total precipitation at the official Providence weather station, first in Providence itself, and then at the weather station in the airport at Warwick, RI, are given in Appendix table A2c, and are shown in Fig. V-2 for the years 1905 to 1987 inclusive; the monthly totals for the years 1964 to 1987 inclusive are tabulated in Appendix Tables A3a to A3m.

The annual totals from the official weather station in Providence are plotted also in Fig. V-1, along with the earlier data set. The two sets of data disagree, sometimes by as much as 35 cm/yr, or up to one third of the annual average. This shows how difficult it is to compare data from different sources or to know for sure the most representative or true values for the region, even for such an apparently easy and straightforward measurement.

The long term (1905-1987) average precipitation at the official R.I. weather station is 106.1 cm/yr (Fig. V-2), but the annual totals have increased over the last several decades (averaging 115.3 cm/year between 1964 and 1987), and they have also become more variable from year to year. The information published by the Weather Bureau does not address the question of whether the changes could have been influenced by the various changes in the location of the weather stations or by changes in techniques of measurement.

The seasonal distribution of precipitation at the Warwick station is shown in Fig. VI-1 and in Table VI-1. Not much seasonality is evident. The driest month is July, with a mean daily precipitation of 2.49 mm and the wettest is December, with 3.94 mm/day. There is, of course, a great range in the precipitation experienced in any month (Fig VI-2), so that little prediction is possible.

Geographic variations in precipitation around Narragansett Bay may exist and the differences may be seasonally dependent (Fig. VI-3), although not nearly so clearly as is the case for temperature. Reported values for precipitation at Kingston are usually greater than those for precipitation at Warwick, while precipitation at Newport is usually less. Precipitation at Kingston is consistently greater than at Newport, and the annual average is 12% greater. Again, questions of accuracy and intercalibration have not been satisfactorily addressed.

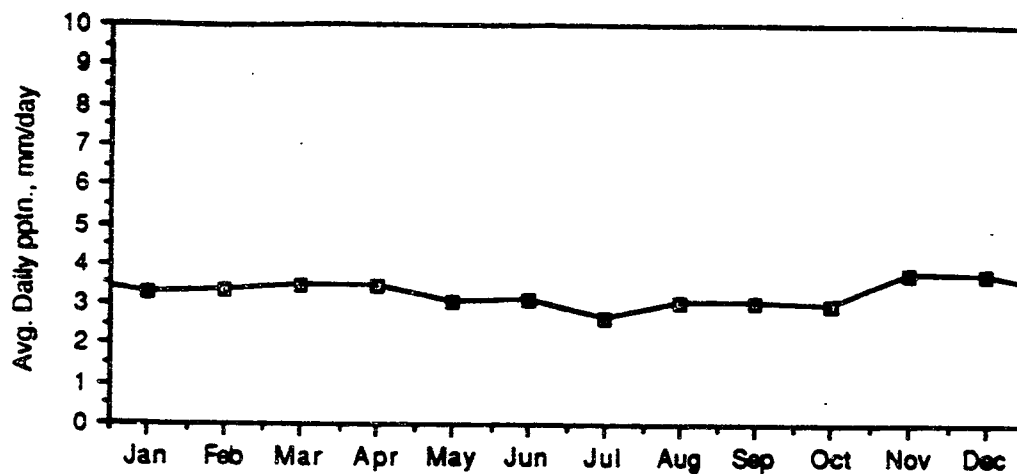


Fig. VI-1. Monthly means of the daily precipitation in the Narragansett Bay drainage basin, averaged over the years 1964 to 1987, inclusive. Data from Table A4b

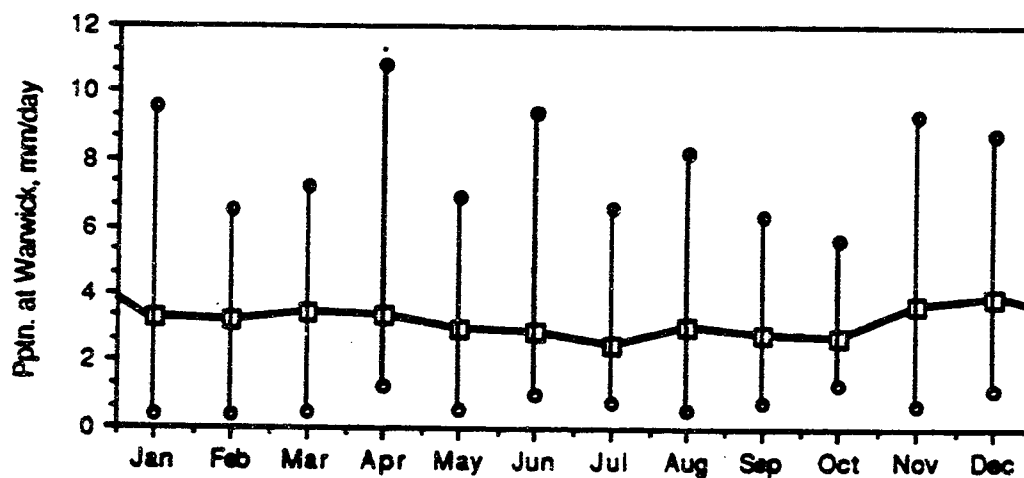


Fig. VI-2. Monthly mean values of the daily precipitation at Green State Airport in Warwick, RI, during the years 1964 through 1987, together with the minimum and maximum monthly values experienced during the same interval.

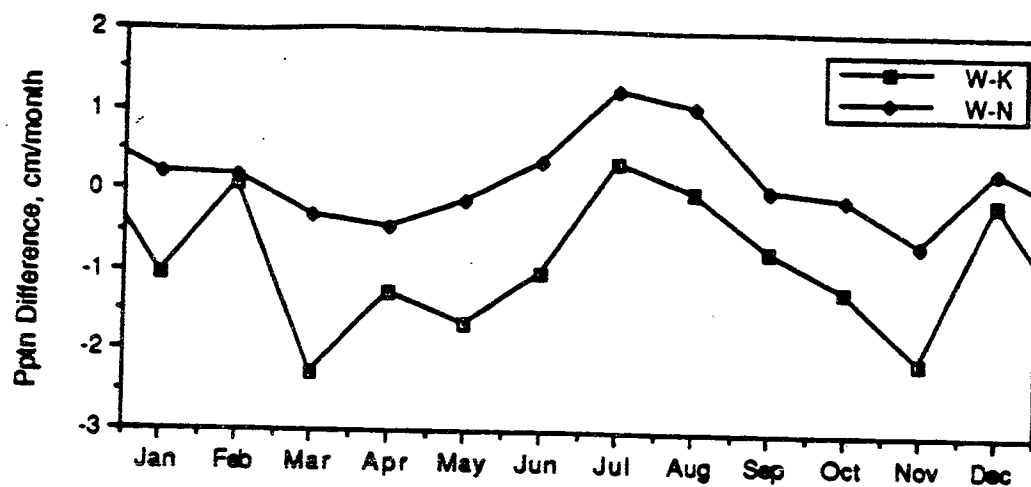


Fig. VI-3. Differences between the precipitation measured at Warwick, RI. (W) and precipitation measured at Kingston (K) and Newport (N), averaged over the years 1964 to 1967, inclusive. In each case, the values reported for K or N were subtracted from those at Warwick.

In order to obtain a representative estimate of the precipitation on the whole of the Narragansett Bay drainage basin, monthly totals for the years 1964 to 1987 from several stations located in various parts of the basin were tabulated and averaged (Appendix tables A4a and A4b). Overall, the estimate of basin precipitation obtained in this way was only about 4.0% greater than the precipitation recorded at Warwick.

The total amount of precipitation falling onto the drainage basin may be estimated by multiplying the rate of precipitation by the land and/or salt water areas of the basin (from Table II-1). For example, from 1964 through 1987 the average precipitation on the drainage basin was about 120 cm/year (Table A4b) and the total land drainage basin of Narragansett Bay excluding the Sakonnet is 4363 km², so the total input of water to the land surface was 5.23 billion cubic meters per year, or an average of 166 m³/s (Table VI-2).

Table VI-1. Averages of the monthly total precipitation reported by the weather stations at Kingston, Newport and Warwick, RI, during the years 1964 to 1987 inclusive. Values given in cm/month. Annual totals given in cm/year.

Month	Kingston	Newport	Warwick
Jan	11.18	9.94	10.14
Feb	8.91	8.80	8.98
Mar	13.01	11.04	10.73
Apr	11.48	10.66	10.21
May	10.80	9.27	9.13
Jun	9.65	8.26	8.64
Jul	7.23	6.47	7.72
Aug	9.50	8.48	9.52
Sep	9.12	8.35	8.40
Oct	9.77	8.64	8.59
Nov	13.16	11.67	11.06
Dec	12.28	11.89	12.20
Totals	126.12	113.48	115.32

Table VI-2. Total fresh water input to the Narragansett Bay drainage basin, based on an average precipitation of 119.88 cm/year.

Region	Surface area km ²	Annual input 10 ⁹ m ³ /year	Input rate m ³ /s
Land	4363	5.23	166
Water (salt)	328	0.39	12
Total	4691	5.62	178

VII. RIVER FLOW

While precipitation in this region differs only a little from season to season, the flow of river water is markedly seasonal, largely because of the high rate of evapotranspiration in the summer and to a lesser extent because of the hold-back as snow in the winter and later melting in the spring.

Each of the several river basins which drain to the bay might be expected to show individually characteristic discharge patterns, because of their varying size and topography, and the varying extent to which the rivers are dammed and the discharge manipulated by different authorities. For the purposes of this report the river data are lumped, to provide estimates of the total flow of fresh water into the bay, as was done in Pilson (1985). The monthly totals of the flows at each of the gauging stations reported by the USGS are tabulated in Appendix Tables A5a to A5i, for the years 1962-1985 inclusive. The monthly totals are given in Table VII-1, and averages of the monthly values are shown in Fig. VII-1. The same data are shown in Fig. VII-2, where some of the statistics of the variability are also presented.

While it appears that very high or very low flows may occur at any time during the cold months, high flows do not occur during the months of July, August and September, and the very lowest flows are found during these summer months. This is because much of the water that falls on the watershed during the summer time is transpired by plants and evaporated again before it can run off.

Over the 21-year interval from 1964 to 1984 the average runoff was 57.4% of the total precipitation, so the remaining 42.6% was lost back to the atmosphere. This fraction varies considerably from year to year, according to how wet or dry the year is (Fig. VII-3). In a dry year about 61% may be lost to evaporation while in a wet year only about 38% will be lost (calculated from data in Tables A4b and A5a-i according to procedure given with Fig VII-3). Most of this loss occurs during the warm months of the summer. In Fig. VII-4 the freshwater input to the bay is expressed as a percentage of the total water falling on the watershed. The only month when the runoff equals or exceeds the input is March, when there is a considerable contribution from snowmelt.

The seasonality of fresh water flow implies a corresponding seasonality of the residence time of water in Narragansett Bay, because the flow of fresh water strongly influences the exchange of bay water with the adjacent Rhode Island Sound water (Pilson 1985). The low flows during the summer months lead to long residence times of the water in the bay during these months (Fig. VII-5). The occurrence of the longest residence times in the warmest months, also characteristically a time of low wind energy input (Fig. IV-1) suggests that the the summer months are the times when planktonic organisms, nutrients and pollutants stay in the bay the longest. This is also the time when pollutants are subjected to the most chemical and biological processing in the bay.

Table VII-1. Estimated total river flow from the Narragansett bay drainage basin into Narragansett Bay, based on the total gauged flow and the ratio of the total area of the drainage basin to the gauged area. The flow of sewage ($\sim 5 \text{ m}^3/\text{s}$) is not included. Values are monthly and yearly averages, given in m^3/s .

Month	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Jan	169.5	100.6	143.3	54.1	24.1	56.5	109.1	71.5	118.6	58.1	80.2	180.0	184.3	160.0
Feb	83.2	106.0	137.4	100.5	65.1	62.0	119.1	79.3	265.8	130.2	102.3	191.5	166.4	125.7
Mar	199.9	182.6	162.8	105.6	106.8	112.0	297.4	200.4	122.1	187.6	316.0	126.6	155.7	144.9
Apr	179.8	94.7	181.8	75.7	46.5	141.9	107.8	234.5	122.4	109.4	149.5	171.7	171.4	127.1
May	80.0	81.0	59.2	42.6	55.8	202.8	76.7	100.3	76.4	115.1	191.2	132.1	92.5	56.6
Jun	52.0	46.5	25.9	28.0	37.0	144.6	109.9	38.5	52.6	39.9	178.2	63.4	48.0	51.1
Jul	25.9	28.0	24.0	16.5	16.7	82.6	52.8	25.7	14.5	20.1	72.9	87.9	25.8	24.7
Aug	24.5	21.6	17.7	16.4	13.8	52.8	23.1	27.7	22.6	20.1	36.9	48.5	20.4	22.2
Sep	27.6	24.0	18.8	15.3	19.5	34.5	19.8	30.8	18.8	20.4	62.3	55.0	43.3	48.3
Oct	122.3	24.1	22.1	17.5	24.7	34.9	19.5	27.1	23.9	21.6	66.4	36.6	55.8	100.3
Nov	140.6	64.7	25.7	17.1	52.0	44.9	53.9	95.0	54.5	34.6	210.8	50.6	48.9	159.3
Dec	121.9	78.2	68.5	20.6	42.2	74.6	95.0	176.6	63.4	67.9	284.6	207.3	101.2	166.3
Means	102.5	70.8	73.7	42.1	41.9	87.2	90.4	92.3	78.3	68.4	146.1	112.3	92.4	98.7

Month	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Means
Jan	250.8	56.7	243.2	349.8	55.7	21.9	171.9	96.9	94.6	45.2	120.7
Feb	223.5	67.9	134.3	160.7	35.1	111.8	175.5	165.2	200.0	66.1	128.1
Mar	136.0	234.8	191.1	188.7	155.6	89.7	127.9	334.9	227.5	78.3	174.4
Apr	91.2	166.4	186.2	128.4	172.2	78.0	138.0	371.8	269.3	51.0	148.6
May	78.2	116.8	138.0	155.5	95.7	68.3	67.3	148.3	131.5	58.3	100.8
Jun	30.6	50.5	59.6	80.4	44.7	34.1	305.2	87.5	212.0	37.6	77.4
Jul	44.2	25.7	27.7	35.7	33.2	32.9	57.4	30.1	77.1	23.8	37.7
Aug	66.4	22.7	60.4	71.0	30.6	17.9	39.3	28.1	32.0	37.5	32.3
Sep	31.2	40.9	27.6	52.7	18.2	25.0	39.0	22.2	27.4	48.3	32.1
Oct	49.5	113.8	31.3	81.5	28.5	39.2	45.8	33.8	37.3	---	46.0
Nov	37.7	121.3	29.3	116.2	36.3	64.2	63.3	98.4	46.8	---	72.4
Dec	45.4	187.5	65.6	71.9	34.5	131.9	58.6	202.1	60.0	---	105.5
Means	90.1	100.8	99.5	124.4	61.8	59.3	106.6	134.6	116.7	---	90.9

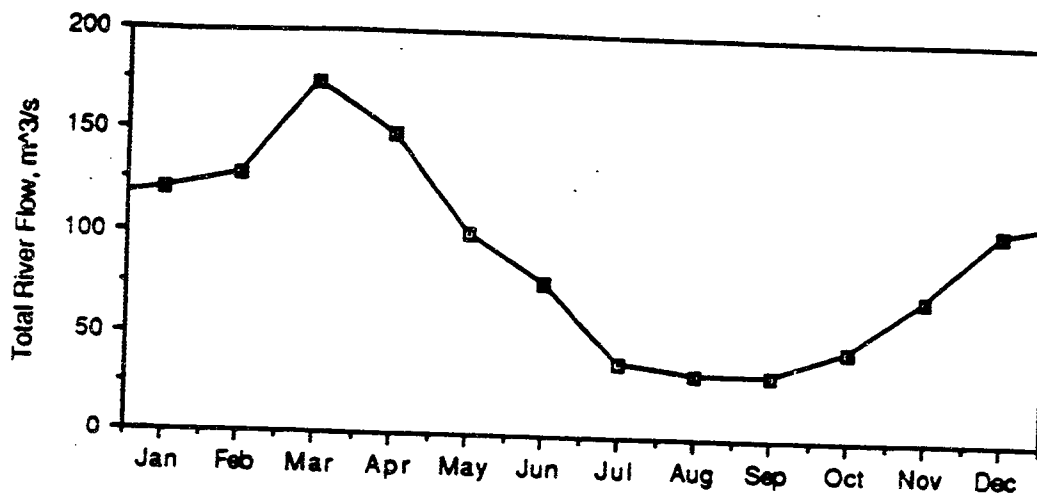


Fig. VII-1. Average monthly values for the estimated total flow of river water into Narragansett Bay from the watershed, not including the flow of sewage. Data from Table VII-1.

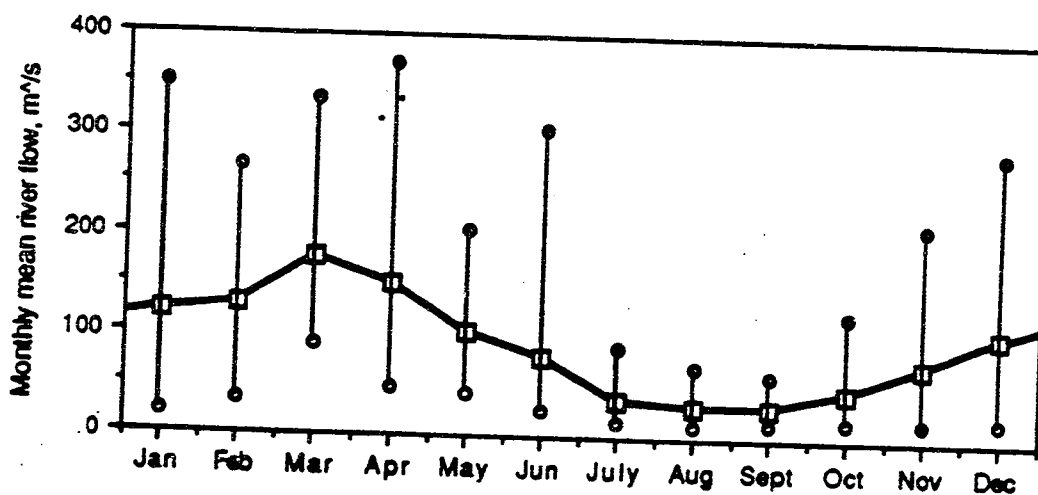


Fig. VII-2. Data as in Fig. VII-1, but the minimum and maximum monthly flows recorded during the interval 1962 to 1984 are also shown. Note that the vertical scales are different.

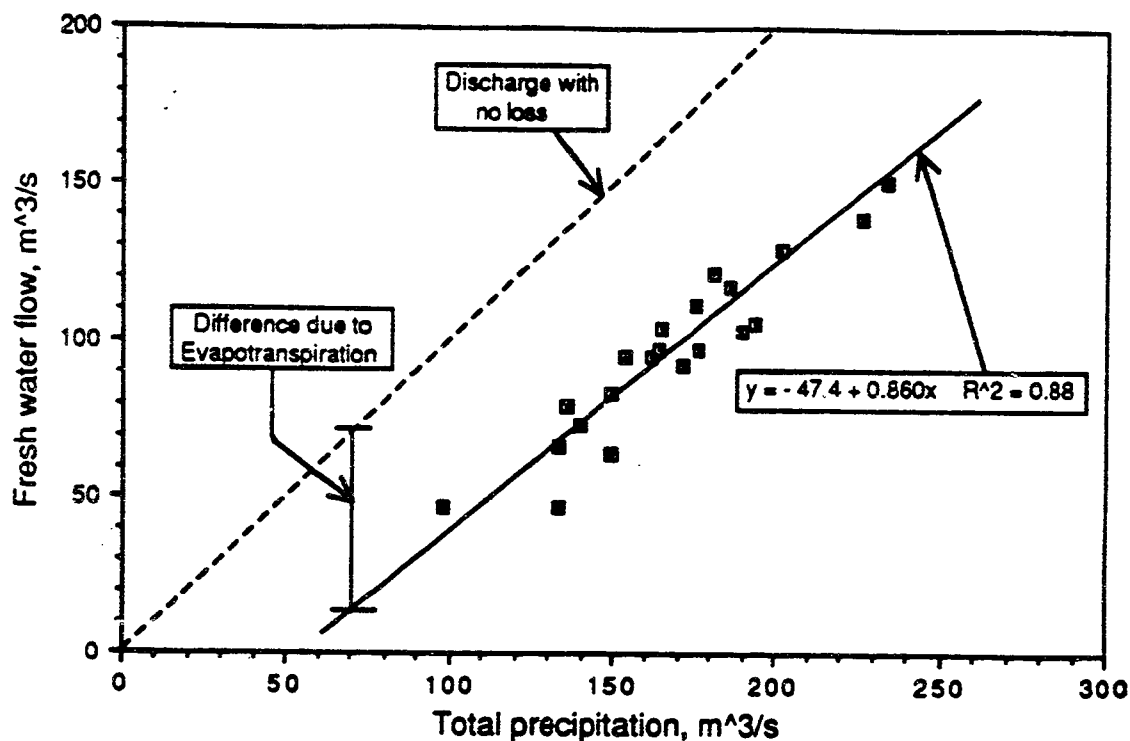


Fig. VII-3. Relationship of the annual total fresh water flow into Narragansett bay to the annual total precipitation on the watershed. The dashed line shows the expected relationship if all the water that falls on the watershed runs off to the bay. The solid line is the functional regression (Ricker 1973) calculated from 21 years of data (1964-1984). The total fresh water flow includes the flow of sewage, estimated at $5 m^3/s$. The intercept on the X-axis, $55 m^3/s$, is the extrapolated value for precipitation at which evapotranspiration from the watershed would just balance incoming precipitation.

The rate of total precipitation in the watershed, as plotted above, is calculated as follows:

$$TP = \frac{P \times A}{Y}$$

Where:

TP	=	Total precipitation on the watershed, in $m^3 s^{-1}$
P	=	Average precipitation on watershed, in m/year
A	=	Area of watershed, $4363 \times 10^6 m^2$
Y	=	Number of seconds in a year, 3.1557×10^7 .

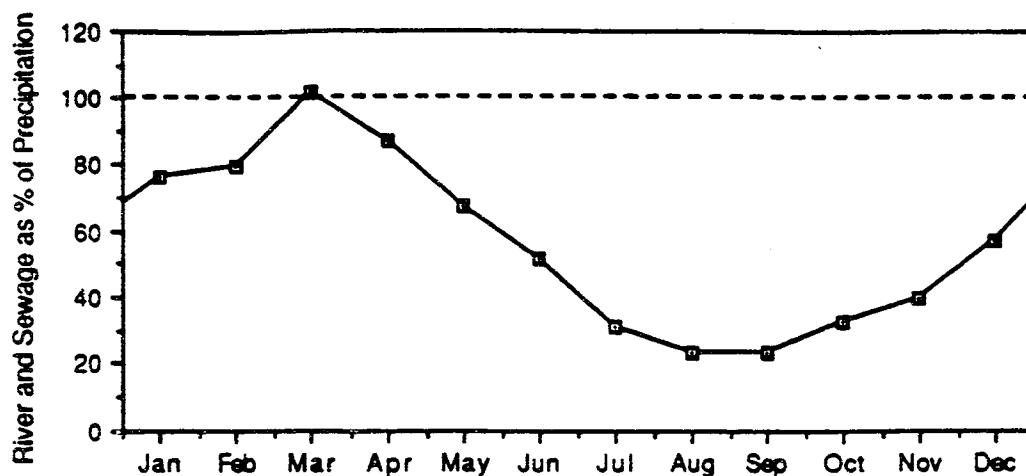


Fig. VII-4. Total fresh water flow to Narragansett Bay (rivers plus sewage), as a percent of the total precipitation on the drainage basin, averaged by month for the years 1964 through 1984. No lag is taken into account.

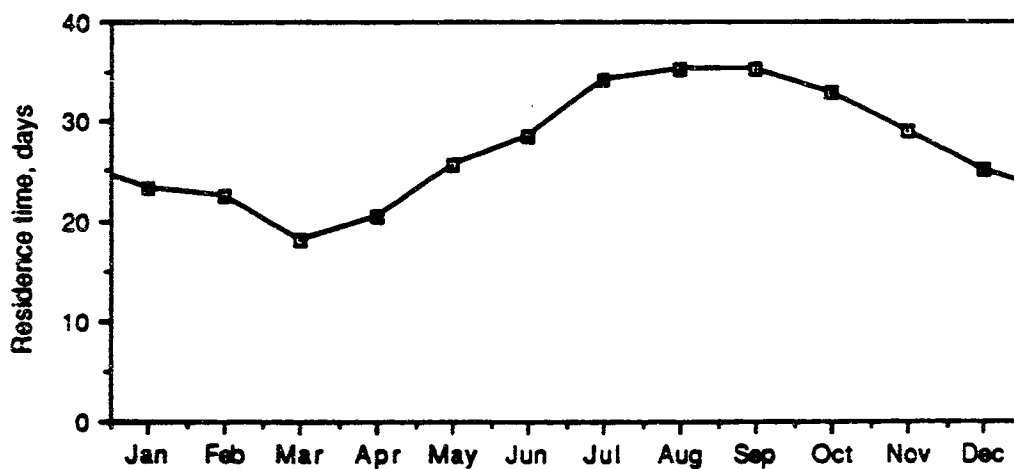


Fig. VII-5. Mean residence time of the water in Narragansett Bay, calculated from the average total fresh water input and the relationship between fresh water input and the residence time derived by Pilson (1985).

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ASPECTS OF CLIMATE AROUND NARRAGANSETT BAY

Appendix Tables

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Table A1a. Light energy received at Newport, R.I. Monthly averages of data from Eppley Laboratories, Inc.
Units are Langley's (cal/cm²) per day.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1937	---	---	---	---	---	470.5	540.1	420.6	378.2	247.6	187.9	132.6	---
1938	165.5	236.5	342.1	480.6	543.7	501.3	494.7	519.9	392.5	320.1	211.8	137.9	362.2
1939	172.7	219.2	339.9	382.3	553.3	572.9	596.3	484.2	402.9	282.0	223.5	137.7	363.9
1940	189.8	224.1	365.0	381.8	443.4	536.3	494.8	485.3	399.6	298.3	165.2	133.6	343.1
1941	162.8	252.1	354.3	462.9	501.7	529.2	471.4	500.4	437.5	283.7	190.4	145.2	357.6
1942	161.1	250.1	308.3	447.3	468.1	531.9	508.7	454.8	339.8	265.3	173.1	144.9	337.8
1943	151.6	239.2	308.1	466.7	453.2	608.5	504.1	491.2	356.4	260.5	184.6	158.1	348.5
1944	151.3	250.3	311.1	362.2	567.8	484.5	525.9	453.5	326.9	247.6	171.0	134.9	332.3
1945	151.3	214.3	304.3	422.0	430.1	474.7	475.6	432.2	319.9	242.5	155.3	128.8	312.6
1946	151.9	232.5	378.4	423.5	443.7	579.6	502.8	484.2	328.6	303.8	177.9	123.7	344.2
1947	144.8	175.4	352.5	369.5	401.0	534.6	489.3	459.6	375.2	337.5	168.6	160.7	330.7
1948	136.1	259.1	308.5	445.9	426.1	440.8	589.8	496.4	439.1	270.7	167.9	130.4	342.6
1949	115.6	239.1	340.3	165.5	517.8	668.2	541.6	461.3	391.8	297.6	161.6	150.0	337.5
1950	156.6	174.3	368.2	361.9	450.6	592.6	528.3	448.7	363.8	287.2	169.7	124.0	335.5
1951	142.5	200.9	296.7	461.3	545.6	483.3	566.1	463.1	446.5	268.8	186.8	139.5	350.1
1952	127.2	250.8	319.1	389.7	521.2	595.4	612.4	465.4	453.8	298.5	162.3	130.5	360.5
1953	141.8	254.2	281.5	308.8	448.8	564.3	473.0	445.1	391.1	243.4	170.6	158.0	323.4
1954	152.2	257.1	375.4	432.7	476.1	551.5	537.2	481.9	318.8	270.6	192.4	140.9	348.9
1955	195.6	240.6	367.1	337.1	410.9	521.4	546.1	399.3	411.2	243.3	174.9	159.5	333.9
1956	145.0	240.0	330.2	457.3	492.7	573.1	520.9	447.9	378.2	312.1	201.0	119.6	351.5
1957	172.7	279.4	380.5	479.6	548.1	624.5	521.2	451.5	365.4	249.3	193.5	131.5	366.4
1958	153.2	246.8	282.4	397.7	463.5	536.6	471.5	420.6	359.3	259.3	171.8	152.2	326.2
1959	177.4	240.5	374.9	444.1	518.5	450.5	470.3	434.0	427.5	253.5	138.9	126.8	338.1
1960	178.8	253.0	354.3	410.0	455.2	508.5	502.7	436.7	363.9	273.9	196.7	168.9	341.9
1961	202.6	260.4	332.4	392.7	453.3	508.5	463.0	436.4	380.1	243.7	167.3	137.3	331.5
1962	170.3	242.5	359.1	416.6	557.8	508.5	511.9	410.8	386.6	246.5	177.3	141.5	344.1
1963	163.9	254.1	328.2	457.9	532.8	542.7	523.3	463.8	342.7	323.9	146.9	155.0	352.9
1964	164.7	251.8	336.7	406.2	562.5	526.4	434.3	422.0	345.0	263.9	186.6	111.9	334.3
1965	157.3	243.9	311.7	400.1	521.3	555.7	532.6	453.0	353.4	301.2	183.4	136.7	345.9
1966	166.0	253.2	337.8	387.2	443.3	507.0	558.8	434.5	351.3	280.4	174.4	140.0	336.2
1967	154.9	226.7	295.9	402.1	459.5	519.1	395.8	319.7	401.9	276.9	160.6	124.4	311.5
1968	156.9	254.2	297.4	454.4	473.5	469.4	527.5	456.1	382.4	270.6	118.2	128.4	332.4
1969	148.1	177.2	328.3	448.4	489.8	500.0	424.9	482.9	356.7	291.0	150.3	121.7	326.6
1970	173.7	236.6	320.5	446.1	464.0	463.0	481.8	476.1	323.9	245.9	141.9	132.9	325.5
1971	166.6	205.2	328.6	369.3	401.7	575.6	514.3	507.8	354.7	259.5	152.0	111.7	328.9
1972	135.2	208.2	258.4	386.7	456.5	423.0	460.2	462.9	303.2	261.8	137.8	91.5	298.8
1973	171.3	225.9	243.8	373.6	407.2	441.1	453.0	432.6	360.9	252.5	155.9	107.8	302.1
1974	130.6	219.6	291.3	358.0	406.6	430.2	527.2	458.7	326.9	277.1	149.2	127.9	308.6
1975	164.4	244.3	296.8	405.2	529.2	468.1	486.6	405.2	304.4	234.3	168.6	114.6	318.5
1976	143.1	233.2	289.4	402.3	456.8	474.9	488.1	452.6	373.2	219.4	185.1	131.7	320.8
1977	175.1	206.7	295.3	445.7	529.3	478.2	543.1	415.5	311.9	218.6	133.6	120.3	322.8
1978	144.6	274.4	322.3	416.1	453.5	549.7	541.3	388.0	378.8	283.0	153.2	121.9	335.6
1979	129.8	230.5	276.9	397.6	426.6	585.4	506.7	395.3	365.8	210.9	158.4	144.1	318.8
1980	149.0	262.8	295.2	351.6	477.8	489.3	512.3	398.7	381.2	214.6	170.6	141.6	320.4
1981	167.8	185.1	309.9	374.6	454.1	478.7	508.8	427.0	317.4	218.9	159.1	106.3	309.0
1982	143.3	206.8	307.5	402.2	421.8	415.1	498.1	412.0	309.5	259.4	143.9	92.8	301.0
1983	139.1	205.7	237.0	321.2	370.0	483.4	507.1	387.0	392.5	234.7	169.9	127.2	297.9
1984	138.3	181.7	295.0	355.3	412.4	475.2	448.4	407.5	342.0	208.9	161.6	115.7	295.2
1985	137.2	211.8	321.3	380.1	451.3	437.2	498.1	348.4	355.2	266.1	130.3	134.8	306.0
1986	159.7	200.3	328.2	347.2	461.3	488.7	406.4	407.9	322.6	243.6	163.7	115.1	303.7
1987	134.6	275.4	299.4	296.2	446.4	470.4	432.2	435.5	293.4	262.8	161.7	117.3	302.1
Mean	155.7	232.2	319.7	397.7	472	513.7	503.3	441.9	364.4	264.5	167.8	131.8	330.4

Table A1b: Light energy received at Newport, R.I. Data from Eppley Laboratories, Inc., but converted to units of MJ m⁻² d⁻¹ (10⁶ Joules per square meter per day). Corrected for known changes of calibration.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1937	--	--	--	--	--	19.71	22.62	17.62	15.84	10.37	7.87	5.55	--
1938	6.93	9.91	14.33	20.13	22.77	21.00	20.72	21.77	16.44	13.41	8.87	5.78	15.17
1939	7.23	9.18	14.24	16.01	23.17	23.99	24.97	20.28	16.87	11.81	9.36	5.77	15.24
1940	7.95	9.39	15.29	15.99	18.57	22.46	20.72	20.33	16.74	12.49	6.92	5.60	14.37
1941	6.82	10.56	14.84	19.39	21.01	22.16	19.74	20.96	18.32	11.88	7.97	6.08	14.98
1942	6.75	10.47	12.91	18.73	19.60	22.28	21.31	19.05	14.23	11.11	7.25	6.07	14.15
1943	6.35	10.02	12.90	19.55	18.98	25.49	21.11	20.57	14.93	10.91	7.73	6.62	14.60
1944	6.34	10.48	13.03	15.17	23.78	20.29	22.03	18.99	13.69	10.37	7.16	5.65	13.92
1945	6.34	8.98	12.74	17.67	18.01	19.88	19.92	18.10	13.40	10.16	6.50	5.39	13.09
1946	6.36	9.74	15.85	17.74	18.58	24.27	21.06	20.28	13.76	12.72	7.45	5.18	14.42
1947	6.06	7.35	14.76	15.48	16.79	22.39	20.49	19.25	15.71	14.14	7.06	6.73	13.85
1948	5.70	10.85	12.92	18.68	17.85	18.46	24.70	20.79	18.39	11.34	7.03	5.46	14.35
1949	4.84	10.01	14.25	6.93	21.69	27.99	22.68	19.32	16.41	12.46	6.77	6.28	14.14
1950	6.56	7.30	15.42	15.16	18.87	24.82	22.13	18.79	15.24	12.03	7.11	5.19	14.05
1951	5.97	8.41	12.43	19.32	22.85	20.24	23.71	19.40	18.70	11.26	7.82	5.84	14.66
1952	5.33	10.50	13.36	16.32	21.83	24.94	25.65	19.49	19.01	12.50	6.80	5.47	15.10
1953	5.94	10.65	11.79	12.93	18.80	23.63	19.81	18.64	16.38	10.19	7.15	6.62	13.54
1954	6.37	10.77	15.72	18.12	19.94	23.10	22.50	20.18	13.35	11.33	8.06	5.90	14.61
1955	8.19	10.08	15.37	14.12	17.21	21.84	22.87	16.72	17.22	10.19	7.33	6.68	13.99
1956	6.07	10.05	13.83	19.15	20.64	24.00	21.82	18.76	15.84	13.07	8.42	5.01	14.72
1957	7.38	11.94	16.25	20.49	23.41	26.68	22.26	19.29	15.61	10.65	8.27	5.62	15.65
1958	6.54	10.54	12.06	16.99	19.80	22.92	20.14	17.97	15.35	11.08	7.34	6.50	13.94
1959	7.58	10.27	16.02	18.97	22.15	19.24	20.09	18.54	18.26	10.83	5.93	5.42	14.44
1960	7.64	10.81	15.14	17.51	19.45	21.72	21.47	18.66	15.55	11.70	8.40	7.22	14.60
1961	8.65	11.12	14.20	16.78	19.36	21.72	19.78	18.64	16.24	10.41	7.15	5.87	14.16
1962	7.27	10.36	15.34	17.80	23.83	21.72	21.87	17.55	16.52	10.53	7.57	6.04	14.70
1963	7.00	10.85	14.02	19.56	22.76	23.18	22.35	19.81	14.64	13.84	6.28	6.62	15.08
1964	7.04	10.76	14.38	17.35	24.03	22.49	18.55	18.03	14.74	11.27	7.97	4.78	14.28
1965	6.72	10.42	13.32	17.09	22.27	23.74	22.75	19.35	15.10	12.87	7.83	5.84	14.77
1966	7.09	10.82	14.43	16.54	18.94	21.66	23.87	18.56	15.01	11.98	7.45	5.98	14.36
1967	6.62	9.68	12.64	17.18	19.63	22.18	16.91	13.66	17.17	11.83	6.86	5.31	13.31
1968	6.70	10.86	12.70	19.41	20.23	20.05	22.53	19.48	16.34	11.56	5.05	5.49	14.20
1969	6.33	7.57	14.02	19.16	20.92	21.36	18.15	20.63	15.24	12.43	6.42	5.20	13.95
1970	7.42	10.11	13.69	19.06	19.82	19.78	20.58	20.34	13.84	10.50	6.06	5.68	13.91
1971	7.12	8.77	14.04	15.78	17.16	24.59	21.97	21.69	15.15	11.09	6.49	4.77	14.05
1972	5.78	8.89	11.04	16.52	19.50	18.07	19.66	19.77	12.95	11.18	5.89	3.91	12.76
1973	7.32	9.65	10.41	15.96	17.40	18.84	19.35	18.48	15.42	10.79	6.66	4.61	12.91
1974	5.58	9.38	12.44	15.29	17.37	18.38	22.52	19.60	13.96	11.84	6.37	5.46	13.18
1975	7.02	10.44	12.68	17.31	22.61	20.00	20.79	17.31	13.00	10.01	7.20	4.90	13.60
1976	6.11	9.96	12.36	17.19	19.51	20.29	20.85	19.33	15.94	9.37	7.91	5.63	13.70
1977	7.48	8.83	12.61	18.65	22.15	20.01	22.72	17.38	13.05	9.15	5.59	5.03	13.55
1978	6.05	11.48	13.49	17.41	18.97	23.00	22.65	16.23	15.85	11.84	6.41	5.10	14.04
1979	5.43	9.64	11.59	16.64	17.85	24.49	21.20	16.54	15.31	8.82	6.54	6.03	13.34
1980	6.23	11.00	12.35	14.71	19.99	20.47	21.43	16.68	15.95	8.98	7.14	5.92	13.41
1981	7.02	7.74	12.97	15.67	19.00	20.03	21.28	17.87	13.28	9.16	6.66	4.45	12.93
1982	6.00	8.65	12.87	16.83	17.65	17.37	20.84	17.24	12.95	10.85	6.02	3.88	12.60
1983	5.82	8.61	9.92	13.44	15.48	20.23	21.22	16.19	16.42	9.82	7.11	5.32	12.46
1984	5.79	7.60	12.34	14.87	17.25	19.88	18.76	17.05	14.31	8.74	6.76	4.84	12.35
1985	5.74	8.86	13.44	15.90	18.88	18.29	20.84	14.58	14.86	11.13	5.45	5.64	12.80
1986	6.68	8.38	13.73	14.54	19.31	20.46	17.02	17.07	13.51	10.20	5.63	4.82	12.61
1987	5.63	11.53	12.53	12.40	18.68	19.69	18.09	18.23	12.28	11.00	6.77	4.91	12.64
Mean	6.58	9.80	13.50	16.79	19.93	21.68	21.24	18.65	15.38	11.16	7.06	5.56	13.94

Table A2a. Precipitation on College Hill, Providence, R.I., observed and recorded under the direction of President Alexis Caswell of Brown University, from 1832 to 1876, inclusive. These data were extracted by Scott Nixon from the records of the Providence City Engineer. The data are given here in cm of water equivalent for the months listed, and in cm/year.

<u>Year</u>	<u>July</u>	<u>Dec.</u>	<u>Annual</u>
1832	4.62	14.30	100.23
1833	2.82	11.86	100.18
1834	19.25	7.54	104.19
1835	7.21	8.26	78.64
1836	3.89	12.32	96.19
1837	3.51	9.02	80.31
1838	1.68	2.74	96.29
1839	13.36	13.00	93.35
1840	8.59	7.87	104.67
1841	13.03	14.88	121.56
1842	3.76	9.98	95.78
1843	4.65	7.70	107.95
1844	11.25	6.99	88.93
1845	7.87	8.84	109.88
1846	3.66	8.00	77.75
1847	5.79	15.16	123.19
1848	4.70	9.73	102.82
1849	5.08	8.94	88.11
1850	5.97	14.86	130.78
1851	13.18	6.65	110.19
1852	4.27	9.40	100.99
1853	16.18	9.91	135.31
1854	6.22	8.51	118.24
1855	9.02	15.49	100.20
1856	10.67	14.73	104.19
1857	8.76	13.21	113.84
1858	12.45	8.76	115.60
1859	2.90	8.78	114.71
1860	7.85	11.84	97.64
1861	5.61	3.58	112.40
1862	8.94	5.33	127.86
1863	23.93	14.38	140.13
1864	3.71	12.57	93.60
1865	9.93	10.36	113.54
1866	5.16	10.06	116.97
1867	8.00	7.11	119.48
1868	5.31	6.10	135.94
1869	2.24	11.94	123.70
1870	6.30	7.54	124.51
1871	9.22	7.47	121.69
1872	13.49	7.01	123.72
1873	7.34	12.67	133.76
1874	6.55	6.38	110.21
1875	9.04	2.46	132.64
1876	10.52	13.34	127.91

Table A2b. Precipitation measured at Hope Reservoir from 1877 to 1924, and temperature measured at Hope Reservoir from 1881 to 1884 inclusive and during 10 months of 1886, and the remainder of the time at the City Engineer's Office in Providence. The measurements at the City Engineer's Office were made at 7 am, 1 pm, and 9 pm. Extracted by Scott Nixon from annual reports of Providence City Engineer.

Year	Precipitation, cm.			Temperature, °C		
	July	Dec	Annual	Jan	July	Annual
1877	9.14	3.56	124.0	--	--	--
1878	5.87	16.66	133.3	--	--	--
1879	10.41	9.27	103.1	--	--	--
1880	15.42	9.17	104.9	--	--	--
1881	10.39	8.61	113.8	-5.5	21.6	9.8
1882	4.90	8.26	114.2	-2.6	23.4	9.6
1883	8.08	11.51	100.4	-4.6	23.1	9.0
1884	7.80	17.07	123.9	-4.3	20.9	9.7
1885	5.59	6.88	100.8	-2.1	23.4	9.3
1886	5.05	15.04	132.1	-3.1	22.4	9.3
1887	15.47	10.67	129.5	-2.9	24.8	9.7
1888	6.48	11.10	161.1	-6.1	20.8	9.0
1889	24.10	6.65	142.0	2.1	21.8	10.8
1890	4.60	13.41	128.5	1.7	22.4	10.2
1891	8.41	10.80	135.1	0.1	21.6	10.9
1892	4.72	3.81	95.0	-0.9	23.4	10.2
1893	2.79	13.77	130.3	-5.9	21.9	9.2
1894	4.50	14.27	107.4	-0.5	24.4	10.8
1895	11.79	7.06	129.1	-1.2	21.8	10.6
1896	3.40	7.29	116.6	-3.7	23.5	10.2
1897	14.12	12.67	121.0	-1.8	23.3	10.4
1898	26.06	6.45	161.3	-1.1	23.3	11.0
1899	11.91	4.78	125.1	-1.0	23.0	10.5
1900	5.18	7.09	121.4	-0.3	24.7	11.1
1901	7.44	23.88	132.2	-1.7	24.5	10.2
1902	8.66	16.26	110.0	-2.3	21.2	10.6
1903	12.07	9.04	121.7	-0.6	23.1	10.6
1904	2.69	10.95	121.7	-4.9	23.0	9.2
1905	6.91	13.67	105.0	-3.2	24.2	10.2
1906	13.89	12.32	122.2	1.8	22.4	10.7
1907	2.49	16.15	121.5	-1.7	23.6	9.8
1908	10.34	9.96	108.1	-0.3	24.3	11.0
1909	1.57	8.26	96.8	-0.4	22.4	10.5
1910	7.54	7.26	93.9	-0.1	24.3	10.7
1911	9.50	8.59	103.2	0.7	25.4	10.8
1912	5.08	17.25	108.8	-5.8	23.9	10.4
1913	8.71	10.26	112.8	4.4	23.9	11.7
1914	9.37	10.44	93.2	-1.2	20.4	10.1
1915	20.12	15.04	113.3	0.9	22.1	11.0
1916	20.19	9.98	121.6	2.0	23.3	10.7
1917	3.12	6.93	116.9	0.7	24.3	10.2
1918	14.17	10.11	114.6	-4.6	23.1	11.1
1919	12.12	7.11	148.4	2.3	23.9	11.7
1920	8.59	12.67	141.0	-4.2	23.3	11.3
1921	16.69	7.75	118.1	1.5	24.2	12.7
1922	18.92	7.11	124.5	-0.5	23.1	12.4
1923	8.71	15.06	121.1	-0.7	22.4	11.6
1924	3.33	5.23	96.0	1.0	24.0	11.3

Table A2c. Annual mean temperature and annual total precipitation at Providence, R.I. (measured at the location of the official weather station, whether at Providence or Warwick), from 1905 to 1987.

Year	T, °C	cm/yr	Year	T, °C	cm/yr
1905	9.22	88.04	1951	11.61	124.51
1906	9.94	105.00	1952	11.72	106.25
1907	8.89	103.00	1953	11.50	148.77
1908	10.17	91.67	1954	10.22	130.89
1909	9.72	85.73	1955	10.11	131.34
1910	9.89	86.89	1956	9.67	108.38
1911	10.06	93.47	1957	10.72	76.40
1912	9.61	98.17	1958	9.33	130.91
1913	10.78	93.83	1959	10.50	109.58
1914	9.33	74.93	1960	10.00	101.80
1915	10.06	86.26	1961	10.17	125.88
1916	9.22	87.48	1962	9.28	127.84
1917	8.56	91.85	1963	9.89	100.33
1918	9.61	94.92	1964	10.00	97.56
1919	10.28	111.99	1965	9.89	64.62
1920	9.61	113.18	1966	9.89	98.25
1921	10.89	93.42	1967	9.50	118.11
1922	10.33	114.05	1968	9.78	105.05
1923	9.56	103.73	1969	10.22	113.26
1924	9.56	85.04	1970	9.72	115.37
1925	10.58	85.39	1971	10.67	97.59
1926	9.00	94.23	1972	9.78	165.25
1927	10.56	110.13	1973	11.39	122.53
1928	10.39	94.59	1974	10.28	103.28
1929	10.44	91.90	1975	10.67	129.11
1930	10.94	78.66	1976	9.67	117.65
1931	11.44	94.13	1977	10.67	124.05
1932	10.94	113.39	1978	9.22	119.41
1933	10.33	104.57	1979	10.39	147.80
1934	9.89	97.43	1980	10.00	91.72
1935	9.94	82.75	1981	10.33	92.38
1936	10.17	125.20	1982	10.39	125.12
1937	10.89	107.01	1983	11.67	174.04
1938	11.00	119.46	1984	10.78	123.80
1939	10.33	87.22	1985	10.60	102.67
1940	9.44	99.16	1986	10.10	117.17
1941	10.94	87.58	1987	10.44	103.30
1942	10.83	119.43			
1943	10.44	76.94			
1944	11.11	114.94	Means	10.28	106.05
1945	11.28	117.93			
1946	11.50	95.71			
1947	11.06	105.94			
1948	11.00	128.19			
1949	12.44	85.37			
1950	10.83	105.31			

Table A3a. Weather factors near Narragansett Bay, 1964. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1964										
Jan	-1.2	14.05	0.4	9.22	-0.8	14.35	19.6	—	29	60
Feb	-2.4	8.81	-0.7	8.64	-2.3	8.00	21.6	—	29	57
Mar	2.9	6.78	3.6	6.73	3.2	5.74	20.0	—	30	57
Apr	7.2	20.19	7.3	19.18	7.8	13.56	18.7	—	16	54
May	14.4	1.70	14.0	2.21	15.7	1.80	19.0	—	22	75
Jun	17.7	2.18	17.8	3.02	19.1	5.94	16.1	—	18	62
Jul	20.9	11.33	20.6	8.18	22.1	6.68	15.0	—	22	52
Aug	18.1	2.24	18.6	3.18	19.2	6.05	13.7	—	18	53
Sep	16.4	10.62	17.1	8.69	16.9	10.03	16.3	—	02	50
Oct	10.2	6.32	11.7	7.42	11.4	5.36	15.3	—	34	51
Nov	6.2	7.72	7.9	6.05	7.0	6.17	15.8	—	27	62
Dec	0.8	11.30	1.9	15.01	0.7	13.87	17.1	—	36	40
Means	9.3		10.0		10.0		17.3	—	29	57
Totals		103.3		97.51		97.56				

Table A3b. Weather factors near Narragansett Bay, 1965-66. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1965										
Jan	-4.3	8.56	-2.4	10.26	-3.9	8.79	19.3	10.6	31	53
Feb	-2.7	9.27	-0.7	6.45	-2.0	9.58	18.5	8.9	28	59
Mar	1.7	4.39	2.7	4.90	2.3	4.37	17.9	9.2	32	51
Apr	6.6	9.37	6.9	8.03	7.4	6.17	17.2	3.2	28	56
May	14.6	4.93	13.9	4.62	15.6	2.74	17.2	4.2	20	67
Jun	17.6	3.94	17.2	3.30	19.4	4.85	16.1	6.0	26	74
Jul	20.3	5.84	20.9	2.54	22.0	3.25	15.5	7.7	23	69
Aug	20.4	7.19	20.9	9.80	22.0	4.83	16.1	8.4	22	62
Sep	17.0	7.59	17.4	5.97	17.8	4.17	14.7	1.5	18	54
Oct	10.2	7.98	11.9	5.99	11.2	6.99	18.5	9.8	25	65
Nov	4.7	4.27	6.3	4.78	5.1	5.28	17.4	7.9	28	56
Dec	0.7	4.62	2.7	3.58	1.9	3.61	15.3	7.4	28	60
Means	8.9		9.8		9.9		17.0	5.8	27	61
Totals		78.0		70.2		64.6				
1966										
Jan	-1.8	6.91	-0.8	10.03	-1.8	8.64	22.4	14.2	31	60
Feb	-1.1	9.42	0.0	7.32	-1.2	10.92	17.4	8.2	30	56
Mar	4.3	7.24	3.8	5.77	3.8	6.10	18.7	7.1	27	59
Apr	7.6	3.56	6.9	3.05	6.6	3.76	17.4	2.1	24	44
May	12.7	16.79	11.7	12.65	12.4	9.78	17.2	5.1	23	50
Jun	19.3	5.79	17.7	4.88	19.7	5.87	14.8	3.9	22	56
Jul	21.2	5.41	21.6	3.94	22.6	7.04	15.6	7.1	23	73
Aug	20.4	3.73	21.2	2.95	21.5	8.56	14.6	6.6	23	58
Sep	15.0	12.50	17.2	11.48	16.3	13.28	15.6	3.1	29	59
Oct	10.0	6.88	12.0	7.04	10.8	6.60	15.1	7.6	26	66
Nov	7.1	12.24	8.2	10.57	7.5	9.98	15.3	1.9	26	55
Dec	0.0	7.42	1.9	6.60	0.4	7.72	18.7	8.7	30	58
Means	9.6		10.1		9.9		16.9	5.3	27	58
Totals		97.9		86.3		98.3				

Table A3c. Weather factors near Narragansett Bay, 1967-68. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1967										
Jan	1.0	4.17	2.2	4.37	0.9	4.06	15.8	8.4	28	53
Feb	-1.7	6.38	-1.7	7.01	-3.5	6.38	20.1	10.3	29	49
Mar	0.5	18.34	1.2	13.89	0.7	13.94	17.7	7.4	34	48
Apr	6.7	11.25	6.6	13.13	7.1	10.64	22.0	7.2	33	54
May	9.6	20.88	9.7	21.16	10.7	18.47	19.5	4.3	29	52
Jun	18.1	8.18	16.6	6.35	19.3	6.91	16.9	4.0	17	54
Jul	21.4	8.74	20.8	13.64	22.7	10.03	13.8	8.4	19	35
Aug	20.7	7.29	20.2	7.95	21.4	8.23	15.6	5.8	21	43
Sep	15.9	8.23	16.6	9.19	17.1	8.05	16.9	2.7	28	70
Oct	10.9	7.62	12.8	3.84	12.1	5.72	14.2	3.5	25	57
Nov	3.7	8.53	5.4	8.56	4.2	6.99	16.9	9.3	28	50
Dec	0.9	18.95	2.1	20.40	1.4	18.69	16.9	7.2	31	55
Means	9.0		9.4		9.5		17.2	4.5	28	51
Totals		128.55		129.49		118.11				
1968										
Jan	-3.9	11.20	-2.5	8.84	-4.2	8.89	17.1	9.7	30	60
Feb	-4.2	5.00	-2.2	2.18	-4.1	3.33	19.0	10.6	28	71
Mar	3.2	25.58	3.6	27.00	3.4	19.89	20.1	6.4	30	52
Apr	9.4	3.18	9.4	3.23	9.9	3.78	20.0	4.0	27	69
May	12.3	8.74	13.0	9.19	13.2	8.99	16.9	14.5	29	51
Jun	17.6	11.94	17.6	11.91	18.3	12.04	15.1	1.1	28	46
Jul	21.5	4.85	21.9	3.53	22.8	3.78	14.2	7.2	24	62
Aug	20.1	2.67	21.2	1.12	21.4	4.09	14.3	5.5	27	58
Sep	16.6	2.95	18.9	2.21	18.2	2.90	12.4	1.3	31	66
Oct	12.4	7.16	14.3	6.22	13.3	4.55	14.8	7.4	29	62
Nov	5.4	17.98	7.3	18.21	5.8	15.80	17.1	7.9	33	29
Dec	-0.6	19.00	0.6	14.66	-1.0	17.02	20.0	12.9	29	56
Means	9.2		10.3		9.8		16.7	5.8	29	57
Totals		120.24		108.31		105.05				

Table A3d. Weather factors near Narragansett Bay, 1969-70. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1969										
Jan	-2.3	5.87	-0.6	5.21	-1.8	5.66	17.5	10.8	31	59
Feb	-2.0	10.41	-0.4	14.66	-1.8	10.92	23.5	15.8	36	40
Mar	0.8	8.41	2.4	8.23	1.7	7.87	20.9	11.3	32	58
Apr	7.8	9.88	8.9	9.65	9.8	10.03	20.3	6.4	23	66
May	12.1	7.75	13.4	4.55	14.3	6.12	18.5	8.4	25	62
Jun	18.2	4.06	18.9	3.51	20.1	3.12	15.3	6.1	21	57
Jul	20.6	10.29		3.28	21.9	7.57	14.5	2.6	23	42
Aug	21.5	9.63		11.15	23.5	6.55	15.9	9.3	25	68
Sep	17.1	11.13	18.2	12.60	17.8	7.85	14.6	3.7	30	63
Oct	10.9	7.19	13.1	8.38	11.8	4.11	15.6	6.3	30	66
Nov	5.3	18.11	7.4	21.39	5.8	16.13	16.7	4.0	32	41
Dec	-1.3	26.11	1.1	22.81	-0.8	27.31	19.5	12.2	33	43
Means	9.1				10.2		17.7	5.6	30	56
Totals		128.8		125.4		113.3				
1970										
Jan	-6.0	4.62	-4.5	2.29	-6.9	1.27	18.2	12.9	32	58
Feb	-0.9	14.20	-0.1	14.22	-1.5	13.56	19.3	8.5	29	54
Mar	1.3	15.16	2.3	12.47	1.7	12.07	18.8	9.2	31	57
Apr	8.1	11.89	8.3	10.26	8.8	9.93	19.2	4.8	29	62
May	13.9	9.25		7.11	14.6	7.67	16.3	3.5	22	54
Jun	17.8	9.83	17.7	10.41	18.7	10.80	15.1	5.6	23	51
Jul	21.6	4.90	21.6	3.76	23.4	2.54	16.1	9.5	21	52
Aug	21.3	10.59	22.2	10.97	22.4	16.74	15.1	4.2	25	69
Sep	17.2	13.87	17.9	11.20	18.0	4.55	14.5	4.5	28	56
Oct	12.3	11.38	13.4	9.09	12.3	11.20	14.3	2.1	33	46
Nov	6.9	18.52	8.4	12.78	7.1	13.49	16.1	4.7	1	34
Dec	-1.1	8.86	0.2	5.69	-1.9	11.53	20.4	14.0	33	54
Means	9.4				9.7		16.9	5.0	29	54
Totals		133.1		110.3		115.4				

Table A3e. Weather factors near Narragansett Bay, 1971-72. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1971										
Jan	-4.6	5.82	-2.4	5.79	-5.1	5.11	19.6	13.0	30	62
Feb	-0.9	16.36	0.1	14.66	-0.6	13.61	18.2	6.6	29	52
Mar	2.2	11.35	2.8	8.51	2.6	9.68	21.6	11.4	30	57
Apr	6.1	7.92	6.9	5.44	7.7	5.87	19.6	7.2	32	52
May	12.2	12.95	12.7	12.07	14.5	9.73	16.3	2.1	26	43
Jun	18.6	2.21	18.6	1.63	20.6	4.17	15.0	5.1	23	68
Jul	20.9	9.60	22.0	3.84	23.5	8.84	14.6	6.9	23	68
Aug	20.7	8.33	21.4	6.96	22.8	7.70	15.0	6.0	26	74
Sep	18.9	2.82	19.8	4.06	20.4	6.45	12.6	12.9	20	49
Oct	14.0	11.81	15.1	8.05	15.1	7.32	12.7	0.6	06	56
Nov	4.7	17.30	6.3	14.83	4.7	13.11	16.1	8.0	32	39
Dec	2.1	7.92	3.4	6.55	1.7	6.02	16.7	7.6	32	47
Means	9.6		10.6		10.7		16.6	5.3	29	56
Totals		114.4		92.4		97.6				
1972										
Jan	-0.4	7.47	1.6	6.71	-0.7	4.70	16.9	8.5	30	51
Feb	-2.9	16.54	-1.2	16.03	-2.2	13.18	20.4	9.2	32	57
Mar	1.9	16.38		15.32	2.4	17.02	20.9	4.3	34	43
Apr	5.6	12.47	6.3	10.97	6.8	9.42	17.7	5.8	33	52
May	13.3	17.55		7.37	14.3	14.55	17.4	2.4	14	50
Jun	17.3	25.32	16.7	13.08	18.3	17.35	15.0	5.6	19	38
Jul	21.6	4.67	21.2	3.43	22.6	10.80	14.2	4.7	22	60
Aug	19.9	6.93	20.8	7.04	21.4	7.57	14.3	5.0	23	67
Sep	17.7	15.47	18.4	16.18	18.4	18.57	15.4	2.6	34	53
Oct	9.4	13.06	11.4	10.46	9.8	11.07	15.0	4.2	31	57
Nov	4.7	21.39	6.4	19.94	4.9	21.46	17.4	6.1	36	37
Dec	1.8	16.69	2.7	19.38	1.3	19.56	18.2	9.5	34	27
Means	9.2				9.8		16.9	3.4	31	50
Totals		173.9		145.9		165.3				

Table A3f. Weather factors near Narragansett Bay, 1973-74. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1973										
Jan	-0.5	10.19	0.9	9.19	-0.5	7.77	18.2	10.8	30	69
Feb	-1.2	10.03	-0.1	9.30	-1.3	9.02	18.4	9.7	35	57
Mar	6.3	10.54	6.4	9.75	6.5	7.06	17.7	5.0	03	39
Apr	9.2	19.74	9.1	18.06	10.0	18.19	17.9	5.0	29	53
May	12.9	12.42	12.7	9.07	13.7	10.13	15.5	4.0	22	45
Jun	20.1	9.32	19.0	7.24	21.3	8.84	14.8	4.7	22	48
Jul	22.1	12.60	21.8	16.43	23.1	7.42	13.2	4.7	24	54
Aug	22.2	10.44	22.6	7.37	23.9	13.13	12.2	2.3	26	60
Sep	16.8	11.13	18.3	9.63	17.4	7.72	14.2	3.9	29	68
Oct	11.3	8.56	13.4	7.62	12.3	8.5	14.5	4.4	32	63
Nov	6.4	7.29	7.2	6.96	6.6	5.82	17.2	10.1	28	52
Dec	3.4	20.42	4.6	20.32	3.5	19.38	17.2	4.5	29	46
Means	10.8		11.3		11.4		15.9	4.2	29	54
Totals		142.67		130.94		122.53				
1974										
Jan	-0.6	12.04	0.7	11.84	-0.2	11.30	15.3	7.1	30	50
Feb	-1.8	6.10	-0.7	5.66	-1.7	7.72	19.0	8.4	32	57
Mar	4.1	12.27	--	9.55	3.7	11.46	20.9	8.9	30	56
Apr	9.7	7.59	--	7.98	10.3	7.26	19.2	5.8	28	52
May	12.3	8.00	12.6	8.43	13.1	6.96	17.2	1.1	25	54
Jun	17.8	9.17	17.6	5.00	18.5	8.33	15.1	3.9	16	58
Jul	21.1	3.73	21.7	3.73	22.6	4.17	15.0	4.7	26	69
Aug	20.9	5.33	22.0	5.00	22.6	7.87	14.3	3.5	22	59
Sep	17.1	17.93	17.9	12.14	17.3	15.62	14.5	2.7	29	55
Oct	9.1	6.10	10.8	6.35	9.0	7.09	13.8	6.0	29	70
Nov	6.6	5.61	7.8	4.04	6.5	3.96	16.4	6.0	31	50
Dec	1.9	12.95	3.1	8.43	2.1	11.53	15.1	6.3	31	48
Means	9.8				10.3		16.1	4.3	29	57
Totals		106.83		88.16		103.28				

Table A3g. Weather factors near Narragansett Bay, 1975-76. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1975										
Jan	1.3	19.23	2.1	17.35	1.2	17.22	16.9	7.6	31	50
Feb	-1.0	10.34	0.5	8.81	-0.9	8.36	16.3	8.1	30	55
Mar	2.3	8.08	3.2	7.65	1.9	7.80	18.4	8.1	32	47
Apr	6.2	9.27	6.5	8.94	6.9	7.59	20.4	8.4	31	51
May	15.7	8.48	14.3	6.20	16.3	5.23	14.8	5.0	17	55
Jun	18.3	12.98	18.6	13.36	18.9	12.01	14.8	2.4	23	50
Jul	22.2	9.09	22.3	8.71	23.5	8.92	14.5	8.4	22	59
Aug	21.3	8.03	22.3	6.58	21.9	5.56	13.0	4.5	33	50
Sep	15.4	16.00	17.2	13.51	16.1	15.62	13.0	3.1	28	50
Oct	13.2	13.44	13.9	11.99	12.9	11.84	13.7	4.4	33	61
Nov	8.4	18.26	10.4	18.52	8.9	15.98	14.5	6.3	27	57
Dec	0.6	12.55	2.0	10.31	0.1	12.98	16.4	8.2	33	39
Means	10.3		11.1		10.7		15.6	4.5	30	52
Totals		145.8		131.9		129.1				
1976										
Jan	-3.3	17.15	-2.3	13.77	-4.7	16.21	17.7	9.0	31	48
Feb	2.0	8.03	3.2	6.25	1.9	7.39	18.5	10.0	27	64
Mar	4.1	9.30	4.5	9.37	3.9	8.74	18.5	5.6	29	56
Apr	10.2	4.29	10.4	4.57	11.4	5.08	16.7	7.7	30	54
May	13.1	8.00	13.7	5.54	14.4	6.43	16.1	6.9	23	57
Jun	19.4	1.98	19.1	2.59	21.1	4.06	15.1	8.2	22	57
Jul	20.8	5.79	21.5	5.87	21.1	20.52	14.2	6.0	26	60
Aug	20.3	19.02	21.0	17.12	21.1	17.81	13.4	3.2	25	60
Sep	16.0	6.30	17.7	4.90	16.4	3.99	11.3	5.5	25	56
Oct	9.8	15.57	11.8	11.15	9.3	16.56	16.3	6.1	30	49
Nov	3.0	1.93	5.4	2.26	3.3	2.06	15.8	11.1	28	64
Dec	-2.6	9.55	-0.8	8.10	-3.7	8.81	17.7	11.4	29	60
Means	9.4		10.4		9.7		16.1	6.8	27	57
Totals		106.9		91.5		117.7				

Table A3h. Weather factors near Narragansett Bay, 1977-78. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1977										
Jan	-6.4	8.97	-4.3	9.12	-6.2	9.91	18.2	11.8	29	66
Feb	-2.3	7.39	-0.4	6.73	-1.2	7.29	16.3	8.9	29	60
Mar	5.2	15.04	5.9	12.93	6.4	14.27	18.7	7.6	30	64
Apr	9.1	11.18	9.4	11.20	10.3	8.51	18.7	5.6	29	65
May	14.6	7.75	14.6	6.76	16.2	8.71	17.2	5.2	28	70
Jun	17.6	13.74	18.0	14.58	19.3	9.96	16.1	4.8	26	58
Jul	21.6	3.71	21.8	4.72	23.5	5.18	15.3	6.4	24	73
Aug	21.3	12.14	21.3	13.67	22.8	5.38	13.7	7.2	23	61
Sep	17.4	13.36	18.3	10.44	17.8	14.22	15.0	2.7	28	51
Oct	11.1	20.37	13.0	16.41	11.6	17.53	16.3	4.3	29	53
Nov	7.7	9.17	8.8	6.32	7.7	8.23	14.3	4.3	20	27
Dec	-0.1	19.79	1.0	19.00	-0.2	14.88	18.5	8.2	30	51
Means	9.7		10.6		10.7		16.7	6.0	28	60
Totals		142.60		131.88		124.05				
1978										
Jan	-3.7	24.08	-1.8	17.42	-3.8	22.89	19.0	7.6	28	57
Feb	-6.3	4.52	-3.1	4.67	-5.5	8.13	14.5	9.6	31	73
Mar	0.5	8.23	2.1	8.28	1.0	7.87	17.7	7.6	29	71
Apr	7.3	5.51	8.1	5.03	8.2	8.43	19.2	7.4	30	60
May	13.1	24.38	13.0	16.74	14.3	13.39	17.1	1.3	16	54
Jun	18.2	3.66	18.7	3.43	20.0	5.00	16.6	7.4	24	78
Jul	20.2	7.98	19.9	9.91	22.1	6.68	16.1	5.2	22	66
Aug	21.6	12.24	21.7	6.86	21.8	16.41	13.2	3.1	25	50
Sep	15.2	6.85	16.6	6.30	15.3	4.62	14.8	2.7	28	74
Oct	10.7	9.68	12.2	8.89	10.8	8.18	14.8	5.3	27	76
Nov	5.7	10.21	6.9	9.12	5.7	6.63	15.1	5.6	34	59
Dec	1.2	14.25	2.7	12.67	0.8	13.18	17.2	10.9	28	67
Means	8.7		9.8		9.2		16.3	5.1	28	65
Totals		131.39		109.32		119.41				

Table A3i. Weather factors near Narragansett Bay, 1979-80. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1979										
Jan	-0.5	31.52	0.1	30.00	-1.1	29.62	19.6	9.3	30	51
Feb	-5.7	11.91	-4.9	13.54	-6.8	10.36	20.8	14.8	32	71
Mar	4.8	7.39	4.7	5.44	4.7	5.61	17.9	2.7	28	59
Apr	8.2	13.69	7.7	12.83	8.2	13.00	17.7	2.9	32	55
May	15.8	18.01	14.2	15.72	15.7	19.35	16.1	2.1	22	49
Jun	17.6	4.95	17.3	3.20	18.4	3.66	16.1	5.6	22	71
Jul	22.1	5.56	21.7	5.44	23.1	4.19	13.8	6.8	20	81
Aug	21.0	21.74	21.0	12.19	21.2	25.63	15.1	4.8	22	49
Sep	17.4	13.31	18.1	8.41	17.8	10.36	14.8	3.5	24	64
Oct	11.4	11.76	12.3	9.65	11.7	10.01	14.3	5.8	25	47
Nov	8.4	13.59	9.0	9.65	9.1	11.40	15.5	5.6	26	44
Dec	2.6	3.91	2.9	7.21	2.9	4.60	18.0	9.3	29	68
Means	10.3		10.3		10.4		16.6	4.7	27	60
Totals		157.5		133.3		147.8				
1980										
Jan	-1.2	4.29	-0.3	3.33	-1.3	3.56	19.2	11.1	31	60
Feb	-2.8	3.61	-1.9	2.72	-2.9	2.95	17.2	11.4	31	76
Mar	2.7	26.92	2.0	24.16	2.8	20.60	20.8	5.6	31	59
Apr	8.9	14.25	8.6	15.95	9.7	15.70	17.4	0.6	27	51
May	14.6	4.17	14.2	4.27	15.7	4.52	15.8	2.9	32	64
Jun	17.4	7.11	17.3	7.01	18.1	9.78	15.1	5.6	25	65
Jul	21.9	4.78	22.1	3.35	23.8	5.16	14.2	7.4	23	71
Aug	22.3	4.50	22.7	3.43	23.0	5.05	14.6	3.2	25	55
Sep	18.2	2.34	18.9	1.63	18.3	2.29	15.1	4.8	25	81
Oct	10.2	10.72	11.9	11.18	9.9	8.66	14.6	6.8	27	68
Nov	4.7	10.44	5.4	9.55	5.0	9.47	16.9	10.0	30	61
Dec	-1.7	5.31	-1.1	5.59	-1.9	3.99	15.6	10.5	31	63
Means	9.6		10.0		10.0		16.4	5.8	29	64
Totals		97.1		92.2		91.7				

Table A3j. Weather factors near Narragansett Bay, 1981-82. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1981										
Jan	-7.6	2.29	-5.7	2.54	-7.3	1.96	13.5	10.0	30	65
Feb	2.1	12.42	1.9	10.49	3.4	12.17	17.7	2.7	25	54
Mar	3.3	2.34	2.4	2.97	4.2	1.42	16.4	8.8	30	66
Apr	10.9	13.28	10.1	11.71	12.1	10.41	19.6	9.0	27	64
May	15.9	4.45	15.0	3.78	16.6	4.88	17.5	0.5	21	55
Jun	21.5	12.90	21.6	11.05	23.4	5.87	16.1	6.9	23	60
Jul	25.3	6.45	25.3	4.95	27.3	9.53	16.1	4.2	24	78
Aug	22.7	2.31	23.4	2.64	23.8	6.73	14.2	3.9	25	68
Sep	18.4	7.01	19.3	6.05	19.0	6.55	16.6	5.0	31	56
Oct	10.9	10.64	12.4	7.52	10.7	8.59	15.3	4.0	31	55
Nov	6.6	10.13	8.1	8.59	7.2	8.13	17.5	10.1	32	50
Dec	-0.4	18.59	1.1	20.37	-0.6	16.15	16.4	10.3	31	38
Means	10.8		11.3		11.6		16.4	5.5	29	60
Totals		102.8		92.7		92.4				
1982										
Jan	-5.4	15.06	-4.6	14.02	-5.8	15.47	19.5	10.6	29	47
Feb	0.2	7.70	0.3	7.59	-0.3	7.82	18.3	9.3	32	45
Mar	2.8	8.28	2.8	7.62	3.8	9.55	17.4	6.6	28	67
Apr	7.2	12.60	5.9	10.87	8.8	9.25	21.2	10.5	27	71
May	14.2	5.21	13.4	6.50	14.9	4.09	14.2	2.3	8	66
Jun	16.9	36.45	16.4	23.52	17.7	28.14	16.9	2.9	3	56
Jul	21.8	3.91	21.2	2.79	23.1	8.92	14.2	6.3	23	77
Aug	19.6	8.51	19.2	6.76	20.7	9.32	14.2	5.6	25	70
Sep	17.1	10.46	17.0	10.11	17.8	9.17	13.2	1.8	5	63
Oct	11.1	7.09	12.2	6.32	11.8	7.82	13.7	3.5	34	70
Nov	7.9	11.10	8.8	10.72	8.8	10.97	16.4	2.9	27	46
Dec	3.4	6.27	4.0	6.63	3.7	4.60	16.6	2.9	31	37
Means	9.7		9.7		10.4		16.3	3.9	29	61
Totals		132.6		113.5		125.1				

Table A3k. Weather factors near Narragansett Bay, 1983-84. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1983										
Jan	-1.0	12.22	-0.3	12.04	-0.3	10.97	16.3	7.4	35	57
Feb	-0.2	11.79	0.5	13.26	-0.5	12.22	18.3	10.3	1	51
Mar	4.8	20.19	4.4	23.24	4.7	22.45	21.4	12.1	1	40
Apr	8.2	32.92	6.9	26.77	9.9	32.36	18.8	3.4	12	40
May	12.4	12.34	11.7	11.33	13.8	11.86	18.7	4.8	18	50
Jun	19.7	8.46	19.1	8.56	21.2	4.85	14.3	2.3	22	74
Jul	22.3	4.42	22.1	3.71	24.8	5.44	16.3	4.3	28	79
Aug	21.3	9.37	21.4	8.61	23.5	6.88	15.0	1.1	21	68
Sep	18.6	3.99	19.5	4.14	20.9	5.49	15.1	2.6	28	82
Oct	11.3	12.42	12.9	11.40	12.9	11.43	16.3	3.1	35	72
Nov	6.9	33.02	8.7	25.02	7.8	27.97	16.3	4.5	29	59
Dec	0.2	17.20	1.4	13.11	0.3	19.58	17.9	6.0	30	55
Means	10.4		10.7		11.7		17.1	2.7	34	61
Totals		178.3		161.2		171.5				
1984										
Jan	-3.2	7.47	-1.0	5.82	-3.1	5.08	14.0	6.9	34	54
Feb	3.1	17.20	3.3	16.23	2.8	18.29	17.4	5.3	33	47
Mar	0.3	13.97	0.9	13.08	1.0	14.66	20.1	10.0	36	60
Apr	7.9	10.97	8.1	12.47	8.7	10.92	17.1	4.8	4	56
May	13.2	21.39	12.8	22.83	14.1	21.29	17.4	4.0	22	65
Jun	19.9	16.56	19.1	16.21	20.6	10.39	16.1	4.0	20	70
Jul	21.4	17.86	21.3	14.99	21.9	13.11	16.1	9.7	23	69
Aug	22.2	2.77	22.7	1.65	23.1	1.80	13.7	2.1	26	74
Sep	15.6	5.13	16.5	5.64	16.7	4.50	14.5	4.0	30	79
Oct	13.1	9.58	13.7	11.96	13.5	10.80	14.3	3.5	35	49
Nov	7.1	5.13	7.4	3.43	6.4	4.95	17.1	6.9	28	55
Dec	3.7	10.01	4.9	9.40	3.3	8.03	15.0	6.6	30	45
Means	10.4		10.8		10.8		16.1	3.2	30	62
Totals		138.0		133.7		123.8				

Table A31. Weather factors near Narragansett Bay, 1985-86. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

Date	Kingston		Newport		Warwick					
	Temp	Pptn	Temp	Pptn	Temp	Pptn	W,k/h	RW	RD	Sun
1985										
Jan	-4.6	2.59	-2.9	3.02	-5.3	3.00	16.6	12.1	30	58
Feb	-0.3	4.19	0.0	4.06	0.1	3.99	17.5	7.6	29	60
Mar	4.7	9.96	4.3	9.02	4.9	7.82	19.6	8.0	30	71
Apr	9.5	3.07	8.9	3.02	10.6	4.19	19.0	6.4	27	73
May	14.3	14.88	13.4	14.58	15.7	12.09	18.0	3.4	23	59
Jun	16.6	11.96	17.0	10.52	18.2	11.94	17.1	5.1	27	56
Jul	21.3	7.39	21.6	6.30	22.8	7.32	16.1	8.0	22	78
Aug	20.7	32.28	21.4	32.79	21.7	21.77	14.5	2.7	22	66
Sep	17.3	6.99	18.6	4.50	18.4	4.29	14.8	2.7	30	64
Oct	11.8	6.27	13.1	4.19	12.6	4.52	15.4	5.8	28	62
Nov	7.2	23.29	8.1	18.82	7.5	18.14	18	6.8	34	37
Dec	-0.8	2.54	0.7	2.31	-0.9	3.61	15.8	9.3	28	62
Means	9.8		10.4		10.6		16.9	5.5	28	63
Totals		125.4		113.1		102.7				
1986										
Jan	-0.5	14.91	0.3	14.43	-0.5	14.94	18.7	9.3	28	73
Feb	-2.1	8.68	-0.7	8.56	-1.7	8.08	17.4	11.4	33	52
Mar	3.6	8.56	3.6	7.77	4.4	7.26	19.3	7.1	27	72
Apr	8.7	5.51	8.8	4.75	9.7	5.33	18.7	5.8	03	52
May	13.8	4.95	13.8	4.42	15.2	5.82	18.2	1.9	01	65
Jun	18.0	10.92	17.7	10.97	19.1	8.31	17.5	6.9	27	70
Jul	20.6	16.79	20.8	15.60	21.7	15.11	14.8	2.6	23	49
Aug	19.4	10.62	20.3	10.77	20.7	8.36	14.5	4.8	24	56
Sep	16.1	2.34	16.8	2.92	16.8	2.46	14.0	5.5	25	56
Oct	11.4	6.88	12.6	6.93	11.7	6.3	14.8	5.8	30	65
Nov	5.0	20.60	6.4	18.34	5.3	14.56	15.1	6.1	30	50
Dec	1.6	24.84	2.8	18.39	1.9	20.47	16.3	6.9	31	65
Means	9.6		10.3		10.4		16.6	6.2	30	60
Totals		135.6		123.9		117.1				

Table A3m. Weather factors near Narragansett Bay, 1987-88. Average monthly temperature in °C at Kingston, Newport, and Green State Airport in Warwick. Total monthly precipitation in cm of water equivalent. Average monthly total wind (W) speed in km/hr. Average monthly resultant wind vector (RW) in km/hr, with the resultant direction (RD) expressed in 10-degree units east of north. Sunshine expressed as a percentage of the maximum possible for each day, averaged by month.

[illegible]

Table A4a. Precipitation in the Narragansett Bay drainage basin, 1964 to 1987, inclusive. Annual total values from Providence (Warwick), Greenville, and Woonsocket in RI, and Fall River, Taunton, Mansfield, Milford and Worcester in MA. Collections at Greenville stopped in 1973, and N. Situate was picked to replace it; in 1974 N. Situate was replaced by N. Foster; this column is labelled "G/S/F". Collections at Fall River terminated in 1976, and at Mansfield at the end of 1986. Values in cm per year.

Year	Prov.	G/S/F	Woons.	Fall R.	Taun.	Mans.	Milf.	Worc.	Mean
1964	97.56	107.57	93.90	101.78	101.04	96.01	90.25	95.63	98.0
1965	64.62	76.40	69.47	64.72	69.37	69.11	71.22	81.23	70.8
1966	98.25	105.64	92.28	91.72	90.12	95.10	91.59	103.99	96.1
1967	118.11	134.37	134.09	119.23	122.43	114.48	115.52	128.85	123.4
1968	105.05	122.33	126.06	110.16	118.01	124.94	108.08	118.92	116.7
1969	113.26	138.81	148.44	122.63	121.64	--	120.45	117.09	126.0
1970	115.37	114.17	111.28	100.05	105.44	111.86	99.31	103.61	107.6
1971	97.59	106.55	96.82	102.69	98.81	97.23	98.27	111.33	101.2
1972	165.25	189.48	164.64	161.93	163.02	166.45	159.41	182.09	169.0
1973	122.53	143.03	126.19	132.64	140.97	141.96	117.86	145.42	133.8
1974	103.28	127.13	123.06	99.06	113.51	120.85	117.04	143.46	118.4
1975	129.11	145.14	137.01	144.63	132.77	143.94	132.46	131.98	137.1
1976	117.65	121.52	115.34	--	107.42	107.87	99.77	102.72	110.7
1977	124.05	149.89	138.48	--	152.45	147.29	144.12	124.41	140.1
1978	119.41	129.64	119.15	--	113.74	124.05	118.54	106.10	118.7
1979	147.80	151.94	142.57	--	145.34	158.75	136.45	136.37	145.6
1980	91.72	115.49	97.71	--	85.12	89.26	95.38	99.70	96.3
1981	92.38	121.34	114.48	--	102.11	95.63	106.63	124.38	108.1
1982	125.12	142.44	--	--	117.32	--	--	126.16	126.3
1983	171.50	169.24	--	--	159.36	157.76	156.49	163.40	163.5
1984	123.80	137.16	--	--	132.41	130.43	132.26	123.93	130.7
1985	102.67	--	--	--	103.68	90.14	100.79	111.89	102.6
1986	117.10	126.16	--	--	124.05	--	--	121.64	121.6
1987	103.30	118.52	--	--	126.29	--	--	121.29	115.8
Avg.	115.3	(129)	--	--	118.6	--	--	121.9	119.9

Table A4b. Precipitation in the Narragansett Bay drainage basin: averages of selected stations. Monthly total values from Providence (Warwick), Greenville, and Woonsocket in RI, and Fall River, Taunton, Mansfield, Milford and Worcester in MA. Collections at Greenville stopped in 1973, and N. Situate replaced it; in 1974 N. Situate was replaced by N. Foster; collections at Fall River ended in 1976, and at Mansfield at the end of 1986. Values in cm.

Month	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Jan	13.47	6.34	9.93	4.56	8.77	4.76	1.97	5.28	5.69	8.84	11.06	15.41	16.35
Feb	8.92	9.13	9.29	7.22	3.12	15.54	14.01	13.56	14.50	8.28	7.42	8.32	7.23
Mar	6.55	4.72	5.42	12.08	20.84	8.49	11.01	7.91	18.64	7.19	12.50	8.91	8.33
Apr	13.55	6.87	3.56	11.09	4.51	12.30	9.32	7.01	9.46	16.85	9.42	8.13	6.04
May	1.58	3.47	9.66	19.14	11.28	8.62	8.23	11.05	15.59	10.23	9.47	6.28	7.23
Jun	4.18	6.09	5.27	8.32	16.74	3.49	9.37	3.73	19.88	13.13	7.69	9.53	4.23
Jul	8.33	3.85	7.74	10.96	3.64	8.86	3.34	8.57	10.13	9.68	5.91	8.37	12.99
Aug	6.06	6.91	6.49	10.66	4.93	7.44	12.60	7.14	7.34	10.41	8.66	10.39	18.31
Sep	8.18	5.94	12.45	9.90	5.09	11.13	4.84	6.25	15.51	11.68	20.48	16.99	5.93
Oct	5.65	7.26	8.05	4.80	5.29	5.02	9.19	9.19	11.09	8.81	8.21	15.09	13.74
Nov	7.99	5.74	11.54	7.88	16.48	17.20	12.34	14.63	22.61	5.94	5.52	16.32	1.89
Dec	13.51	4.44	6.68	16.76	16.01	24.31	11.43	6.85	16.60	22.79	12.08	13.41	8.44
Totals	97.97	70.77	96.08	123.38	116.69	127.16	107.63	101.17	169.03	133.82	118.42	137.13	110.71
Month	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Means
Jan	9.99	24.43	29.89	3.23	2.17	13.49	12.56	6.04	3.06	12.20	14.88		10.18
Feb	7.38	8.28	10.08	2.70	17.38	8.64	12.84	17.51	5.40	7.80	1.33		9.41
Mar	15.47	8.43	8.12	17.99	1.80	7.88	22.14	16.91	6.56	8.13	13.27		10.80
Apr	9.72	5.86	13.38	14.14	10.33	10.55	25.23	12.18	4.30	4.09	23.18		10.46
May	8.24	13.41	15.93	4.21	6.81	5.72	12.08	19.79	11.67	6.09	4.66		9.60
Jun	11.14	4.79	2.70	10.73	6.83	28.92	5.33	12.83	12.29	14.39	6.38		9.50
Jul	7.93	6.66	7.51	11.80	10.08	10.29	4.96	12.55	9.78	13.12	3.54		8.36
Aug	8.21	16.11	21.34	5.70	3.05	8.22	13.24	2.71	14.42	11.20	8.58		9.59
Sep	17.01	4.78	10.68	2.33	10.33	8.03	4.37	5.08	6.77	2.30	16.93		9.29
Oct	18.48	9.05	10.37	11.38	12.46	8.82	12.03	11.23	5.86	6.30	8.30		9.40
Nov	10.52	5.93	11.27	9.27	9.03	11.04	22.80	6.26	19.00	14.94	8.84		11.46
Dec	16.01	10.93	4.32	2.86	17.86	4.67	15.89	7.63	3.52	18.87	5.95		11.83
Totals	140.10	118.66	145.60	96.34	108.14	126.28	163.46	130.72	102.63	119.44	115.84		119.88

Table A5a. Gauged river flows and estimated total flow towards Narragansett Bay, 1962. All values are given in m^3/s . These are the monthly mean values obtained from the reports of the U.S Geological Survey (USGS 1962-1985).

	<u>Tau.</u>	<u>Wad.</u>	<u>Bla.</u>	<u>Mos.</u>	<u>Woo.</u>	<u>Paw.</u>	<u>Pot.</u>	<u>Ann.</u>	<u>Total*</u>
1962									
Jan	31.44	4.16	38.35	-	4.36	17.56	2.60	0.72	169.5
Feb	13.14	1.54	19.65	-	1.79	10.65	1.33	0.59	83.2
Mar	33.53	5.04	52.08	-	5.21	17.62	2.77	0.78	199.9
Apr	26.65	4.56	49.22	-	3.65	18.01	2.39	0.73	179.8
May	11.64	1.61	23.48	-	1.78	6.68	1.15	0.52	80.0
Jun	6.74	0.97	14.56	-	1.26	5.44	0.89	0.56	52.0
Jul	3.26	0.33	6.15	-	0.92	3.74	0.36	0.42	25.9
Aug	3.43	0.11	5.72	-	0.56	3.99	0.17	0.36	24.5
Sep	4.36	0.16	6.46	-	0.54	4.11	0.2	0.34	27.6
Oct	26.28	3.00	27.75	-	1.68	10.68	1.61	0.61	122.3
Nov	26.73	3.85	33.08	-	3.34	12.29	2.22	0.76	140.6
Dec	21.24	2.83	29.62	-	2.51	12.91	1.61	0.62	121.9
Mean									102.5

* The estimated total is calculated by adding the flows for the individual rivers and multiplying the sum by the ratio of the area (4363 km^2) of the drainage basin to the area that is gauged. This total does not include flow to the Sakonnet Passage, rainfall directly onto the bay itself, or the flow of sewage directly into the bay; the latter has been estimated at about $5 \text{ m}^3/\text{s}$ (Pilson 1985).

The gauging stations used in reporting the data in this and subsequent related tables are listed below. The areas given below are those recently remeasured by K. Riese of the USGS (see Table II-1), and in some cases differ slightly from the values originally listed in the publications from which the information on river flows was extracted. Note that the drainage area listed refers only to the area above the gauge, often much less than that of the whole river.

<u>Name of stream.</u>	<u>Drainage area</u> <u>km^2</u>	<u>Years of</u> <u>service</u>
Tau - Taunton River at State Farm	668.2	1929-1976, 1985-1987
Wad - Wading River near Norton	112.4	1953-1966
3-mi - Three-mile River at N. Dighton	218.3	1967-
Seg - Segregansett near Dighton	27.5	1966-
Bla - Blackstone River at Woonsocket	1077.4	1929-
Mos - Moshassuck River at Providence	60.4	1963-
Woo - Woonasquatucket at Centerdale	98.9	1941-
Paw - Pawtuxet River at Cranston	520.6	1939-
Pot - Hunt (Potowomut) near E. Greenwich	59.3	1940-
Ann - Annaquatucket River	16.9	1961-1964

References

[illegible]

Table A5c. Gauged flows and estimated total flow (m³/s) towards Narragansett Bay, 1966 to 1968. See Table A5a for details and definitions.

[illegible]

Table A5e. Gauged flows and estimated total flow (m³/s) towards Narragansett Bay, 1972 to 1974. See Table A5a for details and definitions.

[illegible]

Table A5g. Gauged flows and estimated total flow (m³/s) towards Narragansett Bay, 1978 to 1980. See Table A5a for details and definitions.

[illegible]

[illegible][illegible]