Overview of a Changing Climate in Rhode Island

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Rhode Island has experienced a significant trend over the past 80 years toward a warmer and wetter climate regime. Trends are evident in annual temperatures, annual precipitation, and the frequency of intense rainfall events. Inland, these trends have combined to produce an increase in river flooding; some locations are experiencing more floods while other locations are seeing an increase in the severity of floods.

Temperature Trends

Temperatures have been steadily climbing in the ocean state since the early 1930s (Figure 1a). The average annual temperature for the state is currently increasing at a rate of 1 degree Fahrenheit every 33 years. What is most interesting is the inability of the state to sustain cold years. Notice the frequency of years with an annual temperature at or below 48 degrees prior to 1970 vs. after 1970. Only one year has produced an average annual temperature at or below 48 degrees since 1970. Similarly, notice the absence of years producing average annual temperatures warmer than 51 degrees compared to how frequently they have occurred over the past decade.

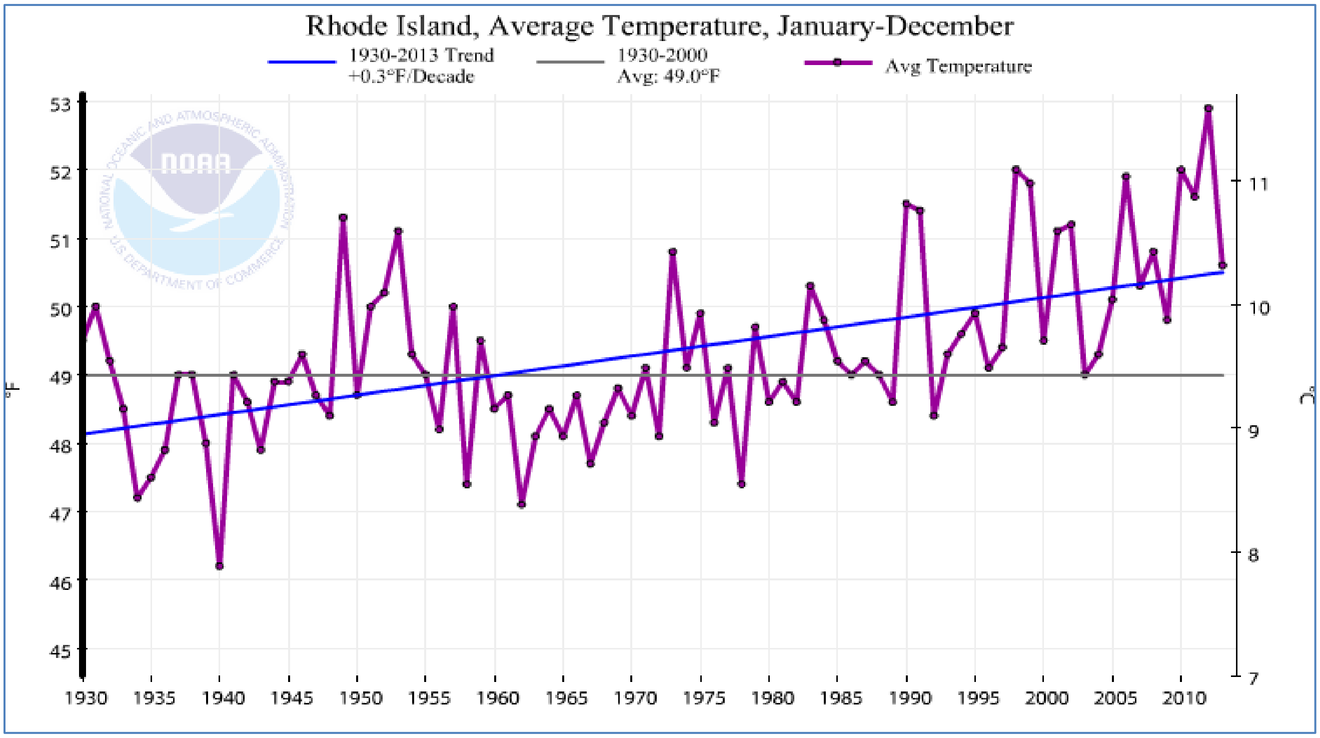

Figure 1a. Average annual temperature for Rhode Island for the period 1930 to 2013.
Data provided by the National Climatic Data Center at ***http://www.ncdc.noaa.gov/cag*.**

Further examination of the warming trend yields other significant indicators as to how the warming is playing out across the region. The frequency of days with high temperatures at or above 90 degree has increased while the frequency of days with minimum temperatures at or below freezing has decreased. Figure 1b provides an analysis of the number of days per year since 1949 in which maximum temperatures equaled or exceeded 90 degrees. Notice the upward trend in the frequency of 90 degree days since 1970; the average number of days expected in 1950 was about 7 while the new normal is 12. Similarly, Figure 1c provides an analysis of the number of days per year since 1949 in which minimum temperatures were equal to or colder than 32 degrees. Prior to 1980 experiencing minimum temperatures at or below freezing typically exceeded 120 days in the year. Notice how infrequent this has become since 1949, and that since 2000 not one year has experienced 120 or more days below 32 degrees.

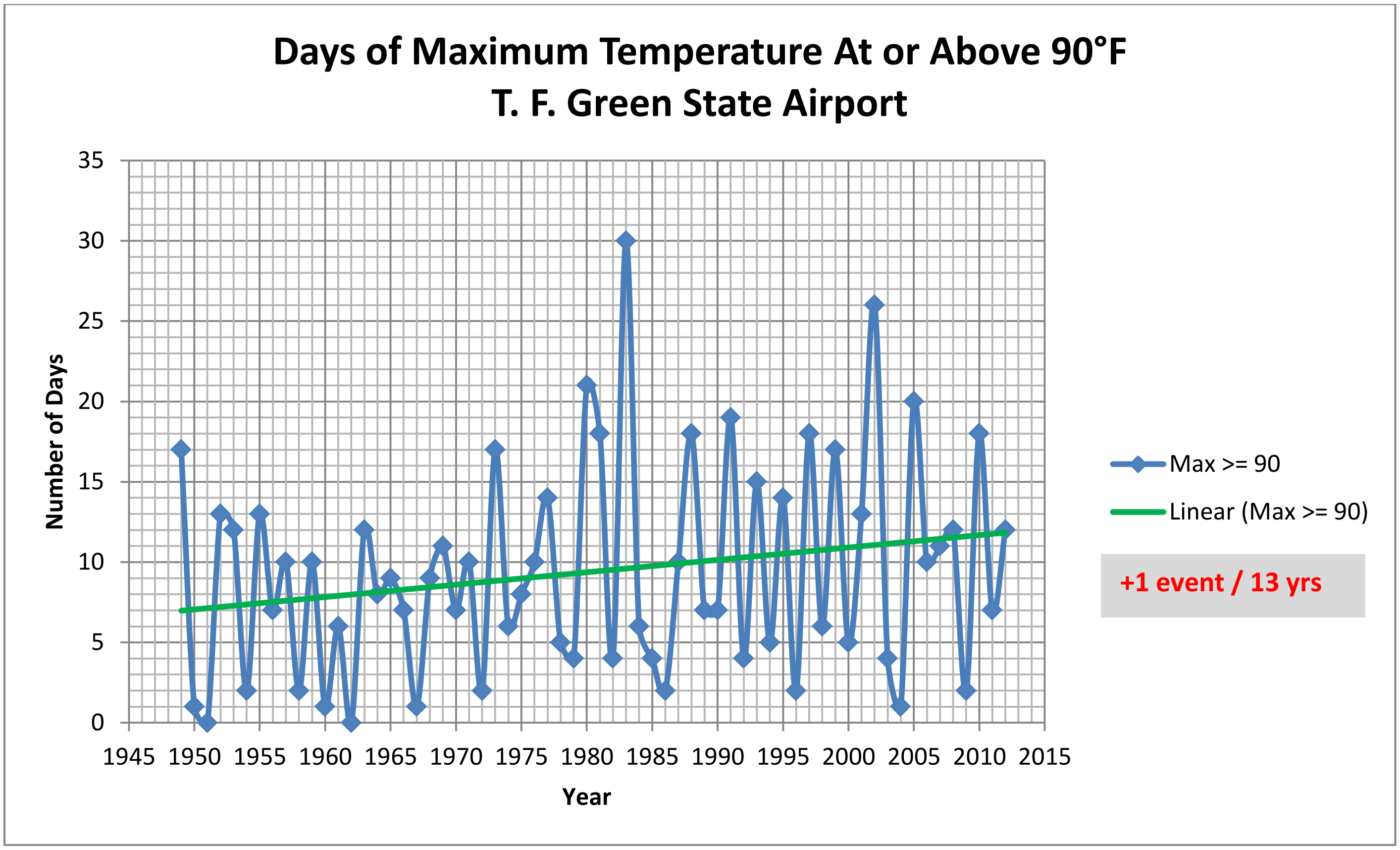

Figure 1b. Days experiencing maximum temperatures of 90 degrees or greater for the period 1949-2012 as recorded at the National Weather Service office T. F. Green State Airport. Analysis provided by the Northeast River Forecast Center.

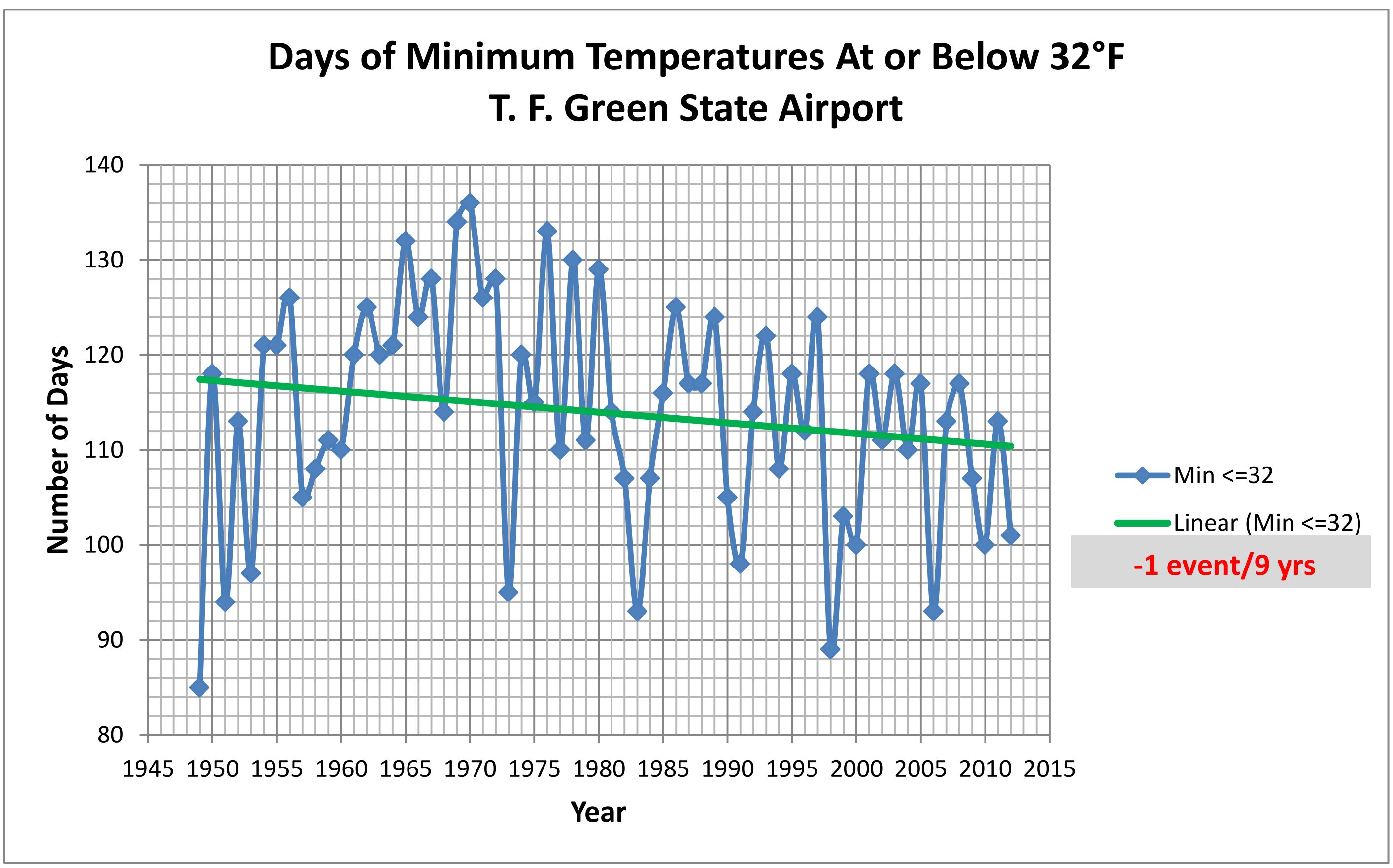

Figure 1c. Days experiencing minimum temperatures of 32 degrees or less for the period 1949-2012 as recorded at the National Weather Service office T. F. Green State Airport. Analysis provided by the Northeast River Forecast Center.

Precipitation

Equally striking is the pronounced increase in precipitation from 1930 to 2013 (Figure 2). Increased precipitation has occurred as a result of large, slow moving storm systems, multiple events in the span of a few weeks (such as the 2010 spring floods), as well as an increase in the frequency of intense rain events. The average annual precipitation for Rhode Island is increasing at a rate of more than 1 inch every 10 years. The frequency of days having one inch of rainfall has nearly doubled. Notice the striking absence of dry years with precipitation less than 40 inches and the increased frequency of years producing more than 55 inches of precipitation.

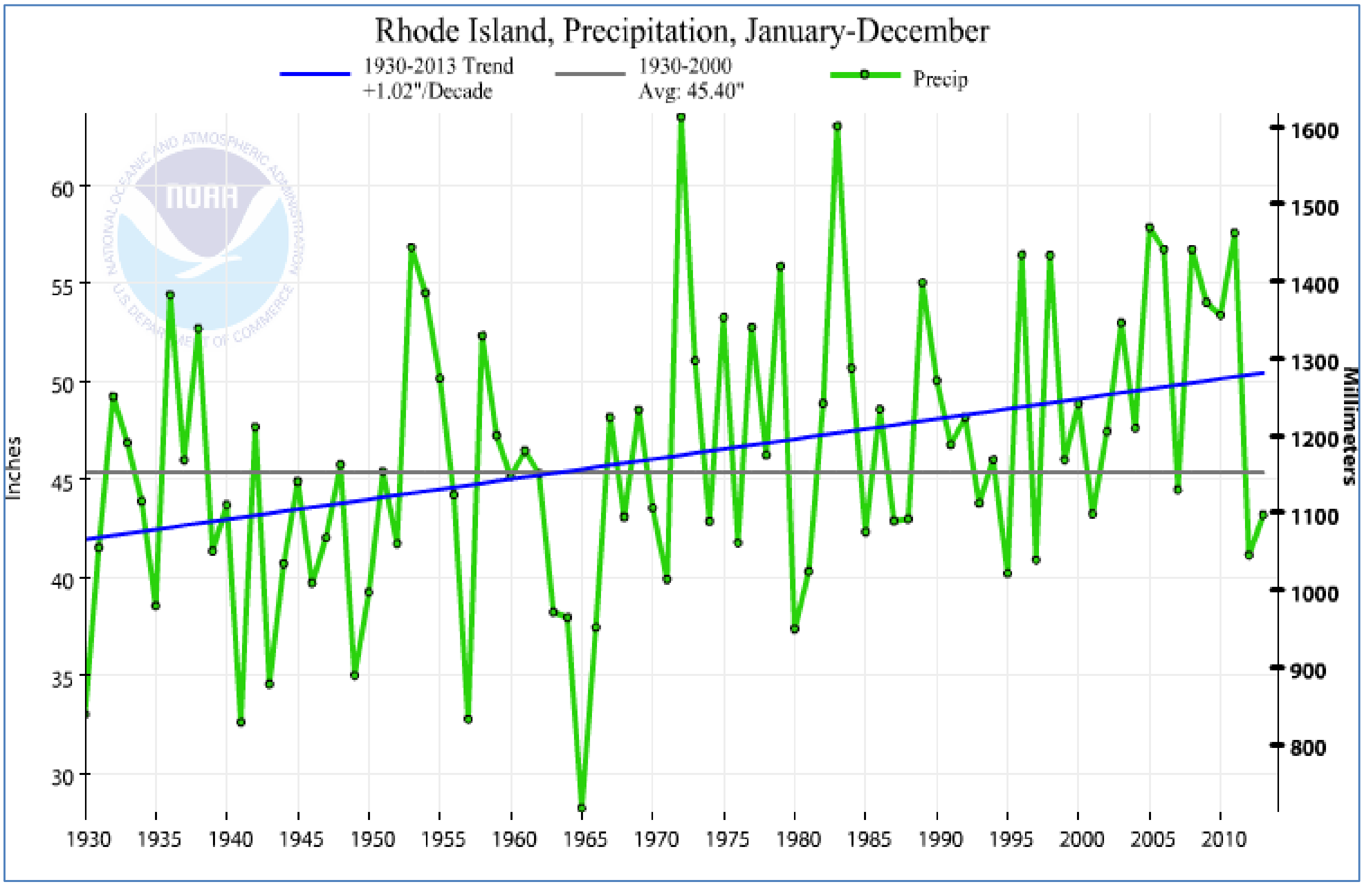

Figure 2. Average annual precipitation for Rhode Island for the period 1930 to 2013. Data provided by the National Climatic Data Center at ***http://www.ncdc.noaa.gov/cag***.

Relationship to increased flooding

The increased amounts of precipitation since 1970 has resulted in a much wetter state in terms of soil moisture and the ground's ability to absorb rainfall. One way of examining this is through the Palmer Drought Severity Index (Figure 3). The Palmer index tracks 6 to 18 month rainfall deficits in its calculation of drought severity. If one thinks of the soil as a sponge, shorter dry periods and more prolonged wet periods result in the sponge being full more frequently. This makes it less capable of handling additional rainfall which in turn increases the potential for flooding on the state's rivers and streams. Basins that have experienced considerable urbanization will have far less capacity to handle the additional runoff compared to a basin in which there remains considerable natural storage or less urbanization over time. Similarly, basins which may have flood control structures may not necessarily see an increase in the severity of flooding but may see in increase in the frequency of less severe floods. Rhode Island has a mixture of all of these types of issues.

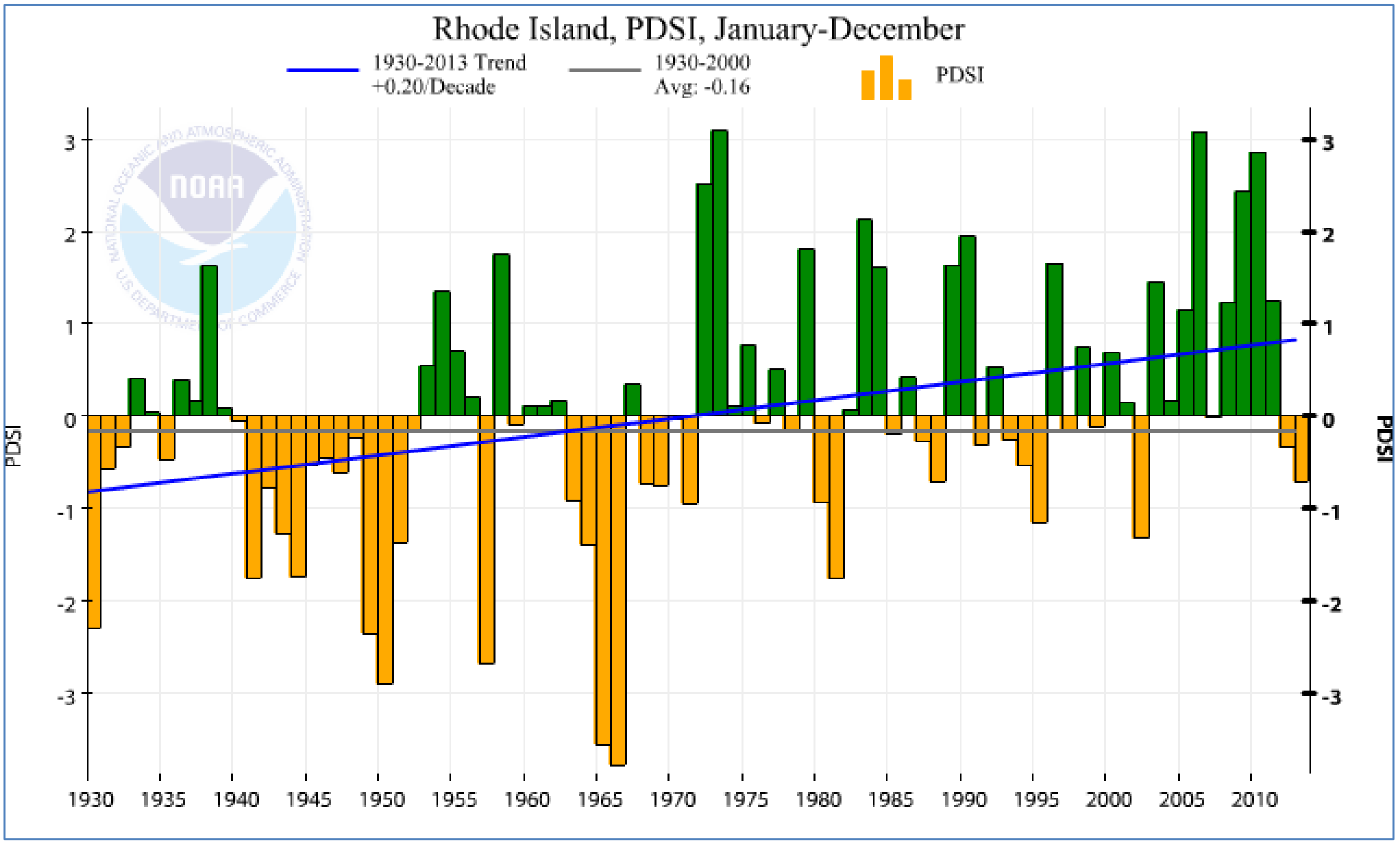

Figure 3. Palmer Drought Severity Index for Rhode Island for the period 1930 to 2013. Data provided by the National Climatic Data Center at ***http://www.ncdc.noaa.gov/cag*.**

Rhode Island has seen the increase in precipitation and frequency of intense rainfall events play itself out in a variety of ways. The vast majority of the state's storm drainage infrastructure was designed based on rainfall frequencies that were derived in the early 1960s. In addition, considerable urbanization has taken place along much of the I-95 corridor in the past 40 years. The combined effects of urbanization and increased rainfall have resulted in increased urban and larger river system flooding. Urban areas are seeing increased issues with flash flooding in poor drainage areas where systems are likely undersized for the new rainfall amounts and intensities. The devastating floods of 2010 illustrated the challenges of the total wetter regime as multiple heavy rain storms impacted the state over the span of 5 weeks. The net result was some of the worst flooding in the state's history along rivers large and small, and in normally dry areas removed from stream channels as ground water levels rose to fill basements with water. Figure 4 is just one example for the Pawtuxet River at Cranston, RI, which illustrates just how dramatically flood frequency and flood magnitude have changed since the early 1940s. The lower portion of the Pawtuxet has experienced dramatic urbanization over the past 40 years.

The Blackstone River in Woonsocket is a basin with flood control projects in place at its headwaters in Worcester and by the West Hill Dam in Uxbridge. These structures were designed to retain runoff during high flow events and to release that water gradually after the flood wave has moved downstream. As depicted in Figure 5, in spite of flood control projects established in the 1960s, this basin has also seen an increase in flood frequency but not necessarily magnitude.

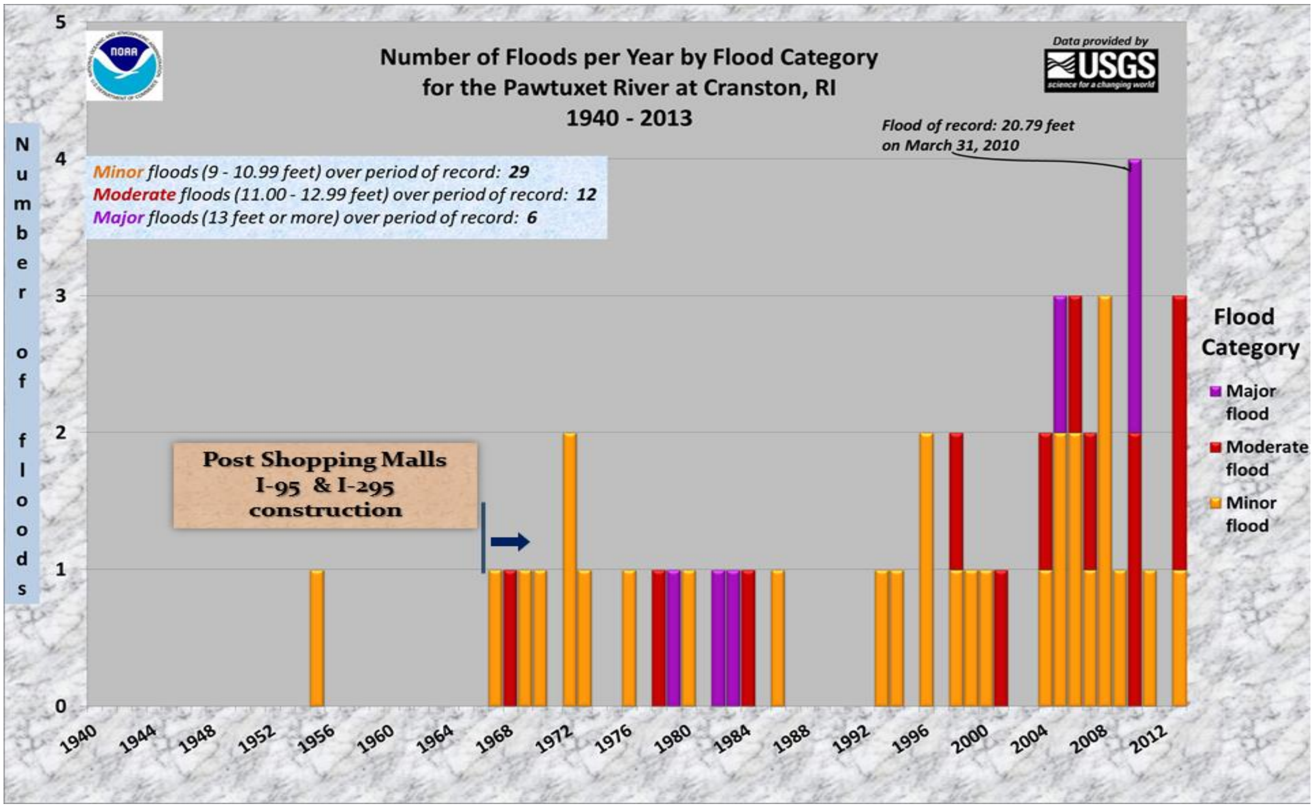

Figure 4. Flood history at the USGS gage location in Cranston, RI on the Pawtuxet River. The color of the bar indicates the severity of the flood. Notice the dramatic increase in both frequency of flooding since the late 1960s, the frequency of multiple floods in a given year, and the severity of these floods. Floods in the major category approximate the 100 year base flood elevation based on the local Flood Insurance Rate Maps.

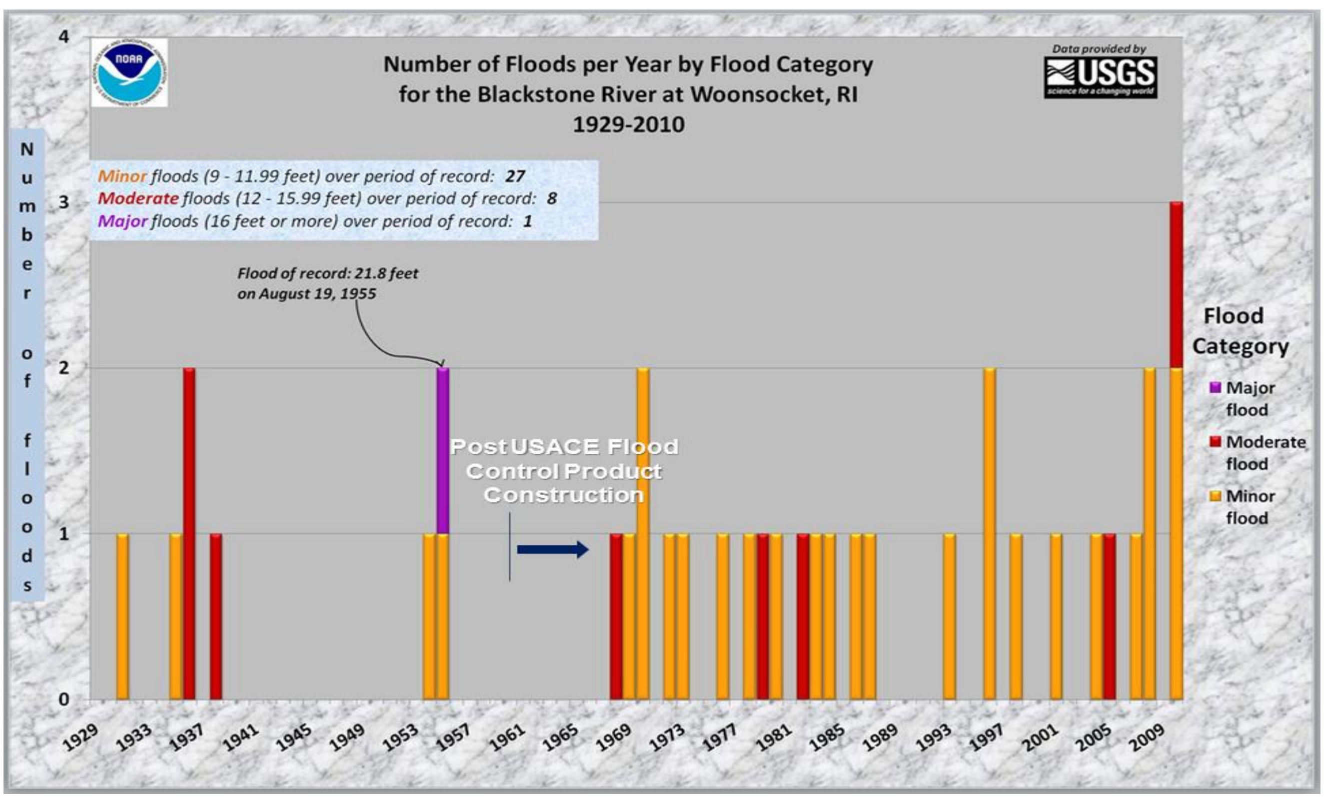

Figure 5. Flood history at the USGS gage location in Woonsocket, RI on the Blackstone River. Color bars indicate the severity of flooding. Notice the increased frequency of floods since 1970 compared to the period from 1929 to 1970.

The Pawcatuck watershed is another unique and complex system with considerable natural storage through its eastern headwaters in the Wood River Junction area to the tidal affected lower reach through Westerly. Figures 6a and 6b provide an overview of the basin's flood history. At Wood River Junction, flood frequency increased dramatically after 1970 but has diminished again after 1986 with just one outstanding event: the record floods of 2010. This shift suggests perhaps that water management practices were implemented in this portion of the watershed that have resulted in a dampening of the climate signal. Westerly, however, is more representative of other rivers in the state, with an increase in the magnitude and frequency of flooding after 1970.

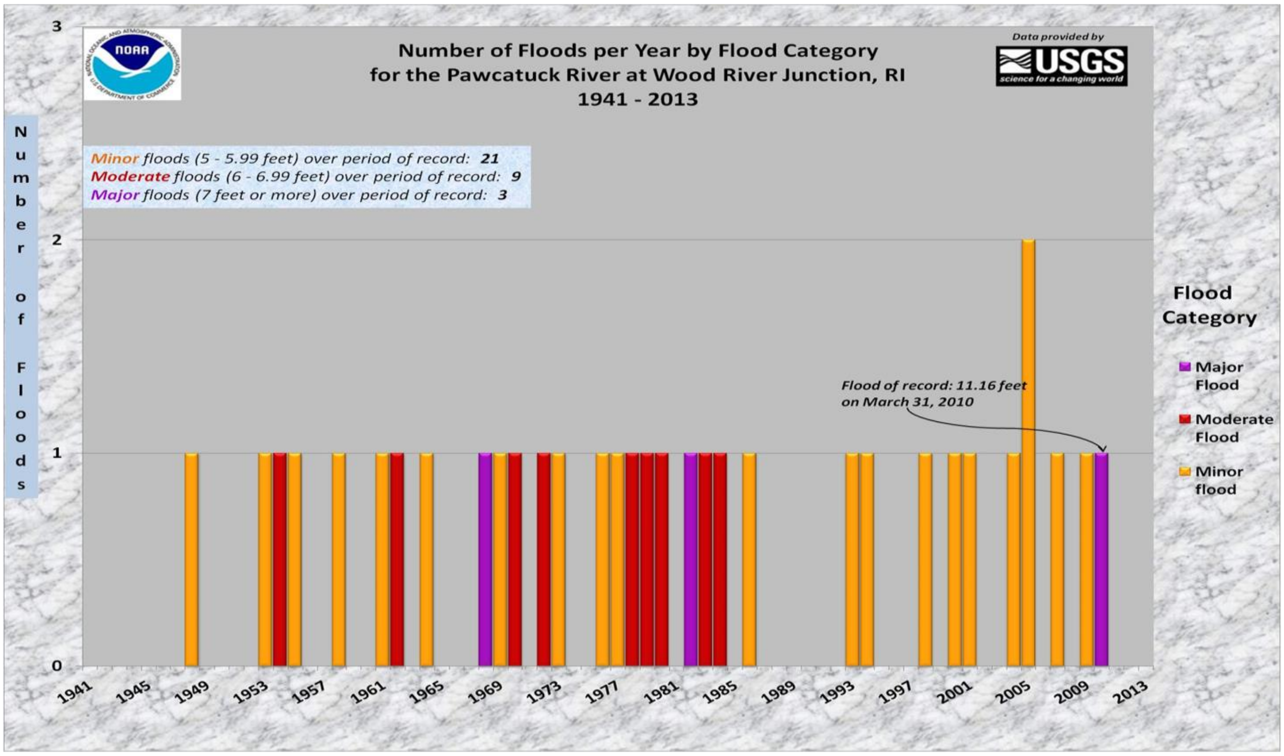

Figure 6a. Flood history at the USGS gage location in Wood River Junction, RI on the Pawcatuck River. Color bars indicate the severity of flooding.

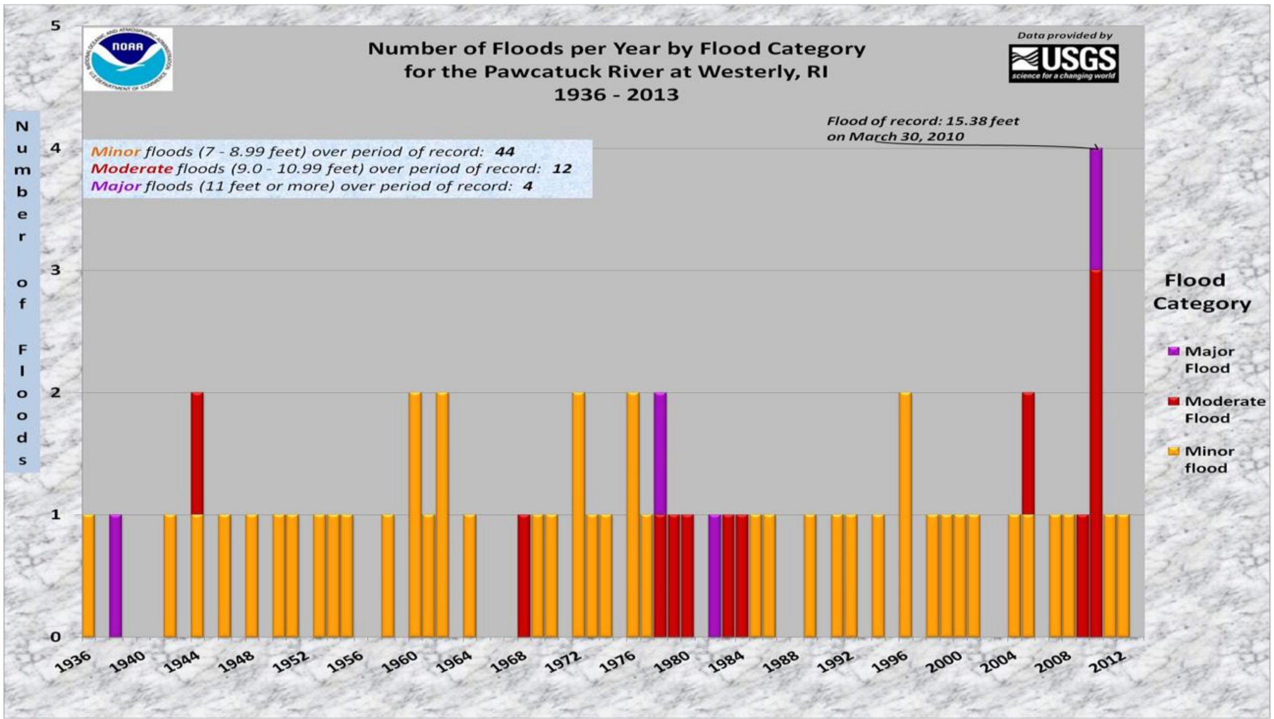

Figure 6b. Flood history at the USGS gage location in Westerly, RI on the Pawcatuck River. Color bars indicate the severity of flooding.