

2.11 DROUGHT

Drought is a normal, recurrent feature of climate that originates from a deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental sector. Within the State of Ohio, drought is equally as possible to occur in one section of the state as it is in another. The effects of drought within the state vary though, based on land use (agricultural production as opposed to urban areas), economy (dependence on drought-impacted business such as farming), geology (presence of an aquifer or ground structure that limits well production), and water source (public water supply, private well, or cistern).

There are four primary types of drought: agricultural, hydrological, meteorological, and socioeconomic. The State of Ohio is most often affected by agricultural and hydrological types of drought, and is often affected by both simultaneously. Below, these two types of drought are described in more detail.

Agricultural Droughts— Agricultural drought links characteristics of hydrological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and reduced groundwater or reservoir levels. The amount of water available for agricultural use demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. A good definition of agricultural drought accounts for the variable susceptibility of crops during different stages of crop development, from emergence to maturity. Deficient topsoil moisture at planting may hinder germination, leading to low plant populations per acre and a reduction of final yield.

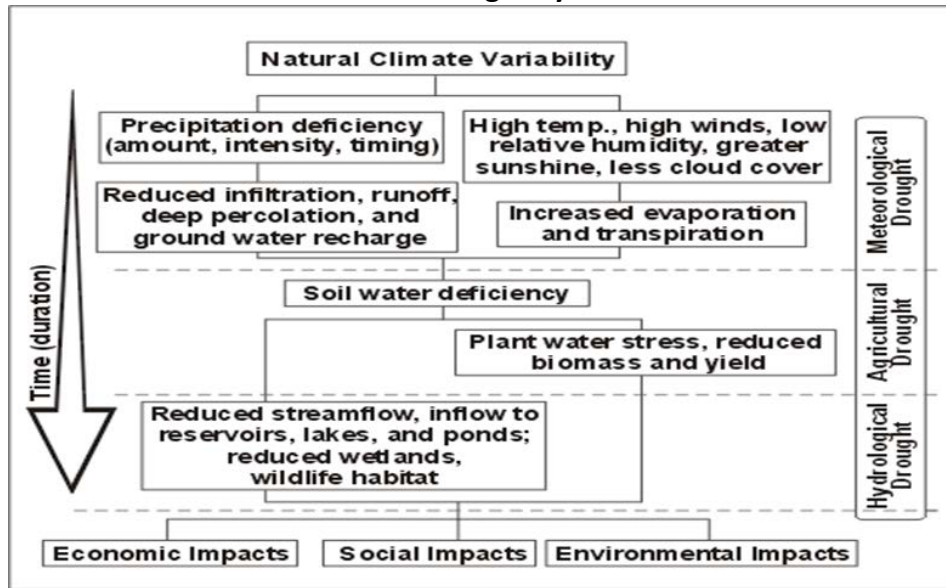
Hydrological Drought— Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on the surface or subsurface water supply – stream flow, reservoir, and lake levels and groundwater. The frequency and severity of hydrological drought are often defined on a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system.

Water in hydrologic storage systems (e.g., reservoirs, rivers) is often used for multiple and competing purposes (e.g., flood control, irrigation, recreation, navigation, hydropower, or wildlife habitat), further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought and conflicts between water users increase significantly.

Although the climate is a primary contributor to hydrological drought, there are other factors such as changes in land use, deforestation, land degradation, and the construction of dams, which can all affect the hydrological characteristics of a basin. Because regions are interconnected by hydrologic systems, the impact of meteorological drought may extend well beyond the borders of the precipitation- deficient area.

The flow chart below illustrates the progression of drought and the relationship between meteorological, agricultural, and hydrological drought. Economic, social, and environmental impacts are shown at the bottom of the chart, independent of the time scale, indicating that such impacts can occur at any stage during a drought.

Figure 2.11.a
The Drought Cycle



Source: Source: National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A.
<http://www.drought.unl.edu/droughtbasics/typesofdrought.aspx>

MEASURING DROUGHT

The Palmer Drought Severity Index (PDSI) is a soil moisture algorithm. The PDSI was developed by W.C. Palmer in 1965. Many U.S. government agencies and states rely on the PDSI to trigger drought relief programs and responses. Most of the agency-based actions within the Ohio Emergency Operation Plan’s Drought Incident Annex are triggered by the PDSI.

Figure 2.11.b

Palmer Drought Severity Index Classifications	
4.0 or greater	Extremely Wet
3.0 to 3.99	Very Wet
2.0 to 2.99	Moderately Wet
1.0 to 1.99	Slightly Wet
0.5 to 0.99	Incipient Wet Spell
0.49 to -0.49	Near Normal
-0.5 to -0.99	Incipient Dry Spell
-1.0 to -1.99	Mild Drought
-2.0 to -2.99	Moderate Drought
-3.0 to -3.99	Severe Drought
-4.0 or less	Extreme Drought

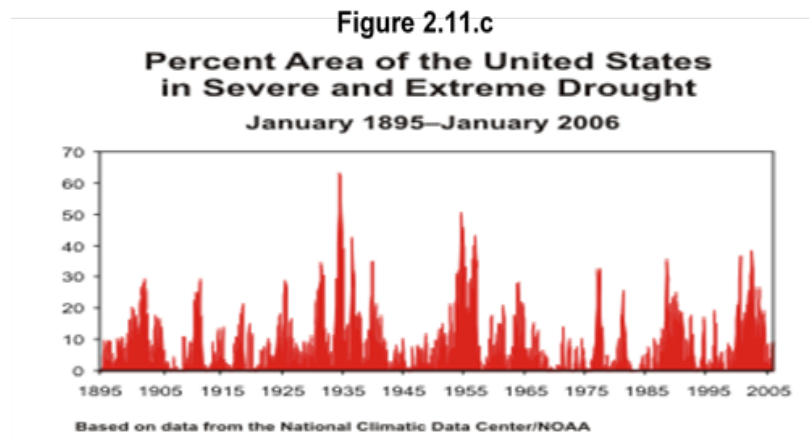
The PDSI is based on the supply-and-demand concept of the water balance equation, taking into account more than just the precipitation deficit at specific locations. The objective of the PDSI is to provide standardized measurements of moisture conditions, so that comparisons using the index can be made between locations and between time periods (usually months). The PDSI is calculated based on precipitation and temperature data, as well as the local Available Water Content of the soil. The Palmer Index is designed so that a -4.0 in South Carolina has the same meaning in terms of the moisture departure from a climatological normal as a -4.0 does in Ohio.

The Palmer Index is typically calculated on a monthly basis, and a long-term archive of the monthly PDSI values for every climate division in the United States exists with the National Climatic Data Center from 1895 through the present. Weekly Palmer Index values are calculated for climate divisions (the State of Ohio has ten climate divisions) during every growing season.

RISK ASSESSMENT

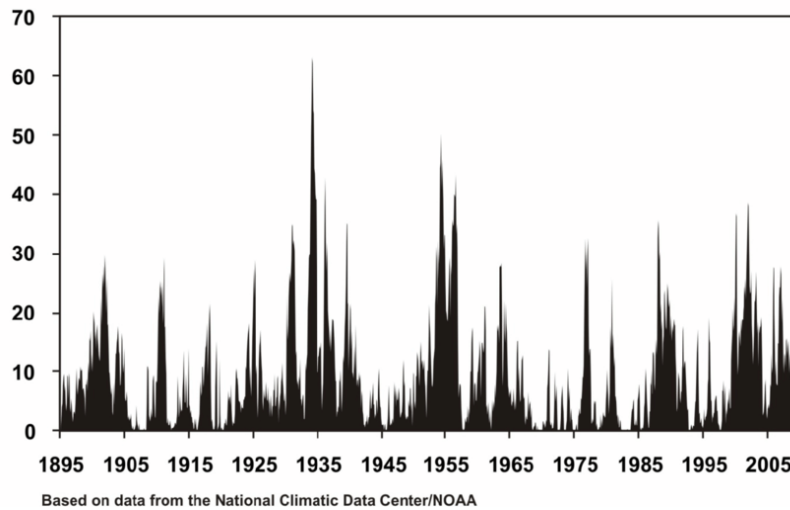
LOCATION

The National Drought Mitigation Center (NDMC) has calculated values showing the spatial extent of drought based on historical Palmer Drought Severity Index (PDSI) data. The annual average of 18.1% was calculated by selecting the month of each year from 1895 to 1995 with the greatest spatial extent of severe or extreme drought and averaging the values. Using PDSI data, the NDMC created data indicating the percent of time each climate division in the United States was in severe or extreme drought, from 1896–1994. The data show the spatial extent of drought for various time periods.



The worst recent drought event occurred in July 1988, with 36% of the country in severe or extreme drought. The worst drought event ever recorded occurred in July 1934, with 65% of the United States experiencing severe to extreme drought.

**Percent Area of the United States in Severe and Extreme Drought
January 1895 – May 2010**



Source: *Quantification of Agricultural Drought for Effective Drought Mitigation and Preparedness: Key Issues and Challenges*
<https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1081&context=droughtfacpub>

LHMP DATA

Hamilton County

The Hamilton County 2018 Hazard Mitigation Plan states that while the hazard is considered “Not Probable/Not Frequent”, there are some areas in the county that may have special vulnerabilities for the hazard. In Crosby Township, there are four major farms that are vulnerable to drought. Similarly, a drought would greatly impact the township with its large agricultural economy in Whitewater Township.

Richland County

According to the Richland County 2017 Hazard Mitigation Plan, Agriculture is a major contributor to Richland County’s economy. The county’s 160,000 acres of farmland account for 40% of all land use in the county. Corn, soybeans, and wheat are the most prevalent crops. While Richland County rarely experiences drought conditions, the County’s greatest vulnerability to drought is a reduction in crop yields.

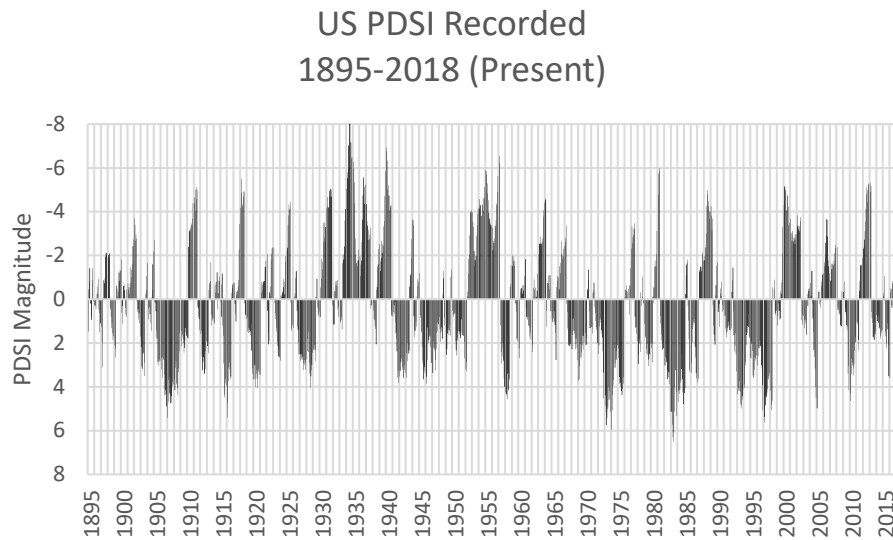
Shelby County

The Shelby County 2017 Hazard Mitigation Plan states Shelby County has a low risk of incurring damage from droughts and extreme heat. By itself, a drought does not damage developed property. However, over a long period of time, certain soils can expand and contract resulting in some structural damage to buildings. A small percentage of buildings in areas with such soils suffer minor damage during their “useful lives.” Therefore, the overall impact on the County’s infrastructure will be very low. When droughts do occur, the economic losses will be countywide affecting the farming community the most.

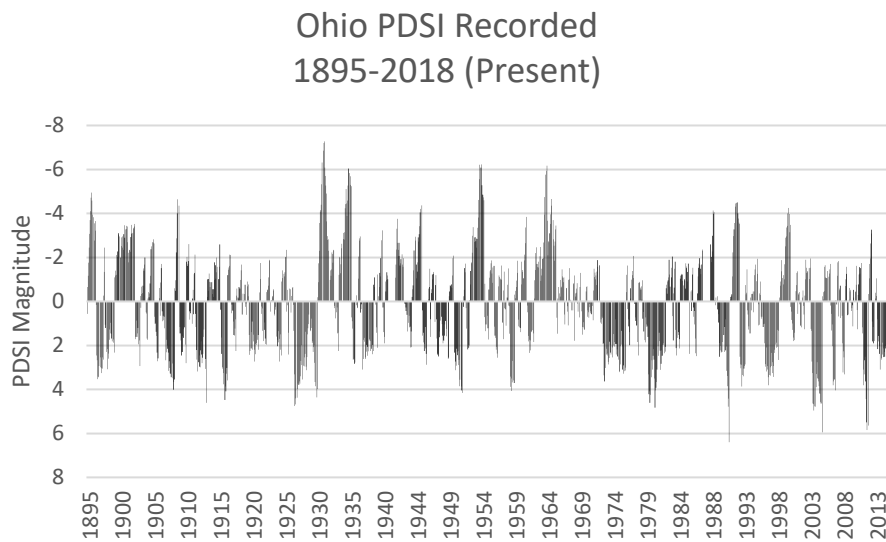
PAST OCCURRENCES

The NOAA National Climatic Data Center has calculated values showing the spatial extent of drought based on historical Palmer Drought Severity Index (PDSI) data. The period of record is from 1895 through the latest month (February 2018). Data was derived from area-weighted averages from interpolated

estimates across the United States. Table 2.11.a tabulates the PDSI in Ohio since from January 1895 to February 2018 by month.



Source: Monthly Palmer Drought Severity Index for States and Climate Divisions; NOAA National Climatic Data Center
<https://www.drought.gov/drought/data/noaa-national-climatic-data-center/monthly-palmer-drought-severity-index-states-and-climate>



Source: Monthly Palmer Drought Severity Index for States and Climate Divisions; NOAA National Climatic Data Center
<https://www.drought.gov/drought/data/noaa-national-climatic-data-center/monthly-palmer-drought-severity-index-states-and-climate>

Table 2.11.a: Ohio PDSI Recorded by Month, January 1985 to February 2018

Year	January	February	March	April	May	June	July	August	September	October	November	December
1895	0.57	-0.65	-1.16	-1.76	-2.45	-3.07	-3.7	-4.1	-4.72	-4.95	-4.58	-3.94
1896	-3.83	-3.55	-2.76	-3.22	-3.65	0.16	2.45	2.68	3.54	3.41	3.45	2.94
1897	2.55	3	3.26	3.04	3.06	2.54	2.65	-0.26	-1.34	-2.44	1.06	1.21
1898	2.29	2.16	3.08	2.6	2.37	1.74	1.28	1.46	0.97	1.47	1.69	1.81
1899	1.87	1.73	2.32	-1.1	-1.18	-1.4	-1.21	-2.11	-2.03	-2.27	-3.03	-3.1
1900	-2.96	-2.01	-1.98	-2.52	-2.91	-2.96	-2.45	-2.35	-3.05	-3.47	-2.9	-3.28
1901	-3.29	-3.44	-3.4	-2.69	-2.21	-1.77	-2.33	-2.34	-2.26	-2.92	-3.48	-3.09
1902	-3.11	-3.35	-3.3	-3.41	-3.53	1.62	1.71	0.87	1.61	1.45	1.21	1.95
1903	1.78	2.94	-0.25	0.29	-0.67	-0.34	-0.38	-0.71	-1.5	-1.4	-1.68	-2
1904	0.5	0.55	1.68	1.75	-0.14	-0.43	-0.19	-0.36	-0.81	-1.16	-2.37	-2.5
1905	-2.69	-2.68	-2.83	-2.64	0.7	1.02	0.97	1.38	1.57	2.33	2.72	2.59
1906	-0.15	-0.62	0.65	-0.86	-1.52	-1.71	0.45	0.9	0.66	0.85	0.7	1.22
1907	2.67	1.75	2.31	2.15	2	2.32	3.16	2.72	3.03	3.27	3.3	3.45
1908	2.82	3.49	4.01	3.66	3.55	-0.6	-0.48	-0.96	-2.23	-2.87	-4	-4.64
1909	-4.35	1.46	1.16	1.46	1.78	2.45	2.3	2.29	1.59	1.66	1.26	1.18
1910	1.96	2.8	-1.8	-2.03	-1.61	-1.71	-1.84	-2.6	0.45	0.83	0.53	0.43
1911	1.02	-0.13	-0.52	0.58	-1.24	-1.29	-2.13	0.57	1.16	2.21	2.64	3.19
1912	2.76	2.46	2.96	3	2.22	1.81	2.42	2.8	2.56	2.38	1.61	1.28
1913	3.07	2.61	4.61	-0.02	-0.2	-1.01	-0.48	-1.02	-1.27	-0.89	-0.66	-0.88
1914	-0.87	-0.34	-0.56	-0.21	-0.56	-0.97	-1.77	-1.04	-1.64	-1.33	-2	-1.58
1915	-0.99	-1.02	-1.57	-2.59	-0.02	0.38	1.64	2.39	2.98	3.06	3.25	3.76
1916	4.48	3.87	4.09	3.28	3.03	3.59	-1.2	-1.44	-1.54	-1.62	-2.12	-2.11
1917	0.54	0.15	0.4	0.42	0.91	1.52	1.55	1.24	0.81	2.25	-0.27	-0.58
1918	-0.18	-0.13	-0.65	-0.6	-0.59	-0.97	-1.41	-1.67	0.6	0.6	-0.35	-0.04
1919	-0.34	-0.76	0.25	0.08	0.61	-0.68	-0.91	-0.23	-0.77	1.53	2.43	2.25
1920	2.14	1.39	0.92	2.19	1.51	1.82	2.19	2.73	2.4	1.93	1.98	1.89
1921	1.75	1.52	2.2	-0.02	-0.41	-1.02	-1.75	0.23	0.57	0.32	1.34	1.8
1922	1.3	0.96	1.68	1.94	1.96	-0.42	-0.51	-0.54	-0.72	-1.1	-1.9	-1.85

Table 2.11.a: Ohio PDSI Recorded by Month, January 1985 to February 2018 (Continued)

Year	January	February	March	April	May	June	July	August	September	October	November	December
1923	0.46	-0.05	-0.02	-0.25	-0.19	-0.49	-0.56	0.56	0.64	0.37	0.24	1.6
1924	2.03	1.74	1.86	1.35	1.7	2.73	2.2	1.49	2.46	-0.91	-1.41	-1.07
1925	-1.25	-1.14	-1.33	-2.01	-2.02	-2.34	0.46	-0.53	0.17	1.43	2.42	-0.58
1926	-0.56	0.51	-0.25	-0.03	-0.62	-0.65	0.16	1.33	3.31	4.76	4.69	4.41
1927	4.38	3.98	3.73	3.8	3.79	3.63	3.74	3.4	2.71	1.99	2.9	3.55
1928	2.92	2.95	2.54	2.38	1.38	2.97	3.13	2.53	1.5	1.22	1.03	0.6
1929	1.35	1.31	0.78	1.2	1.89	1.81	2.29	2.08	1.99	2.79	3.67	3.86
1930	4.36	3.99	-0.19	-0.88	-1.74	-2.3	-3.56	-4.07	-4.15	-4.4	-5.33	-6.31
1931	-6.86	-7.21	-7.28	-6.09	-5.7	-5.27	-4.91	-3.64	-2.97	-2.79	-2.83	-2.3
1932	-0.97	-1.41	-1.17	-1.46	-2.23	-2.15	-1.76	-2.34	-2.32	0.2	0.3	0.77
1933	0.49	0.28	1.45	1.43	2.25	-1.21	-2.02	-1.98	-1.28	-1.69	-2.42	-2.62
1934	-2.84	-3.11	-2.81	-3.15	-4.24	-4.42	-5.11	-4.46	-3.89	-4.59	-5.27	-6.04
1935	-5.84	-5.69	-5.3	-5.24	0.73	0.9	1.24	2.64	2.63	2.6	2.84	2.78
1936	-0.28	0.17	0.28	0.31	-1.04	-2.04	-2.77	-2.87	-2.95	0.51	0.35	0.13
1937	3.1	2.62	1.75	1.83	1.66	2.55	2.62	2.28	1.98	2.47	2.06	2.27
1938	1.71	1.78	2.26	1.8	2.13	2.17	2.4	1.97	2.26	-0.76	-0.66	-1.09
1939	0.14	1.18	1.43	2.11	-1.22	-0.24	-0.03	-0.66	-1.3	-1.13	-1.97	-2.78
1940	-3.23	0.28	0.28	1.39	1.61	1.9	-0.9	-0.46	-0.97	-1.32	-1.18	-1.01
1941	-1.08	-1.68	-2.36	-3.3	-3.76	-2.67	-2.35	-2.07	-2.66	-1.63	-1.73	-1.92
1942	-2.14	-1.68	-1.57	-1.96	-0.02	0.08	0.12	0.28	0.44	0.27	0.61	1.36
1943	0.98	0.65	1.17	1.15	2.09	1.37	2.08	-0.2	-0.56	-0.73	-1.41	-2.32
1944	-2.94	-2.76	-1.67	-1.05	-1.35	-1.78	-2.91	-2.72	-3.06	-3.42	-4.05	-4.21
1945	-4.36	0.41	1.56	1.42	1.86	2.26	1.93	1.16	2.14	2.39	2.88	-0.01
1946	-0.58	-0.1	-0.65	-1.49	0.81	1.61	-0.38	-0.55	-1.23	-1	-1.25	-1.34
1947	0.93	-0.75	-1.2	0.82	1.68	2.42	2.34	2.5	2.42	1.63	1.36	0.87
1948	0.7	1.03	1.55	1.9	1.78	1.79	1.55	1.04	0.89	0.89	1.25	1.58
1949	2.62	2.56	-0.23	-0.45	-0.73	-0.72	-0.65	-0.78	-0.62	-1.18	-1.96	-2.08
1950	2.32	3.12	2.74	2.92	2.15	2.29	2.44	2.26	2.9	2.66	3.86	3.56
1951	3.87	4.04	4.16	0.01	-0.24	0.25	-0.52	-1.52	-1.32	-1.72	0.3	1.24
1952	2.18	1.97	2.11	2.01	-0.05	-0.78	-1.39	-1.77	-1.73	-2.22	-2.98	-3.38
1953	-2.71	-2.91	-2.93	-2.73	-2.45	-2.86	-2.84	-3.35	-3.82	-4.62	-5.56	-6.22
1954	-6.08	-6.23	-5.29	-4.86	-4.85	-4.73	-4.6	0.71	-0.8	1.35	1.04	1.05
1955	0.65	1.22	1.73	-0.54	-1.08	-1.37	-1.43	-1.74	-1.86	-1.27	-0.85	-1.55
1956	-1.62	1.15	1.56	1.65	2.19	2.07	2.37	2.56	-0.04	-0.68	-1.18	-1.11
1957	-1.04	-0.99	-1.63	0.94	0.97	1.72	-0.5	-1.36	0.31	0.34	0.36	1.1
1958	-0.18	-0.76	-1.5	0.19	0.21	1.47	3.41	3.88	4.07	3.51	3.68	2.7
1959	3.59	3.71	-0.31	-0.15	-0.48	-0.95	-0.66	-1.3	-1.85	0.83	1.13	1.18
1960	1.21	1.39	-0.77	-1.81	-1.43	-1.34	-1.04	-1.06	-1.87	-2.12	-2.65	-3.37
1961	-3.85	0.18	0.5	1.81	1.57	1.75	2.34	2.23	1.78	1.4	1.35	1.31
1962	1.46	1.85	-0.14	-0.96	-1.43	-2.2	-1.71	-2.46	-1.71	-1.56	-1.55	-1.8
1963	-2.06	-2.47	-0.93	-1.18	-1.49	-1.94	-1.93	-1.96	-2.68	-3.94	-4.74	-5.76
1964	-5.94	-6.17	-3.67	-2.09	-2.73	-2.7	-3.1	-3.08	-3.52	-3.96	-4.66	-4.35
1965	-3.7	-2.83	-2.53	-1.85	-2.72	-3.28	-3.45	0	0.74	1.47	-0.14	-0.66
1966	-0.36	-0.22	-0.98	-0.63	-0.67	-1.45	-1.14	-1.06	-0.88	-1.1	0.6	1.04
1967	-0.61	-0.6	0.47	0.22	1.09	-0.97	-1.01	-1.51	0.01	-0.08	0.04	0.41
1968	0.41	-0.79	-0.83	-1.18	1.79	-0.22	-0.37	-0.4	-0.59	-0.83	0.1	0.46
1969	0.72	-0.66	-1.29	0.02	0	0.45	1.51	1.16	1.17	0.95	1.26	1.3
1970	-0.45	-0.66	-0.68	0.69	0.41	0.49	0.74	0.11	0.26	0.53	0.45	0.58
1971	0.2	0.86	-0.5	-1.49	-1.11	-1.31	-1	-1.18	-0.75	-1.36	-1.88	-1.57
1972	-1.64	-1.63	0.03	0.96	0.82	1.01	0.69	0.76	1.93	1.9	3.36	3.63

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Year	January	February	March	April	May	June	July	August	September	October	November	December
1973	3.03	2.41	2.15	2.37	2.45	2.75	2.87	2.57	1.83	1.98	2.33	2.42
1974	2.54	2.1	2	1.48	1.85	2.05	0.81	1.93	2.41	1.94	2.18	2.5
1975	2.65	3.17	3.22	2.86	2.03	1.96	1.34	2.05	3.09	3.29	2.91	3.17
1976	3.14	3.01	-0.43	-1.21	-1.63	0.35	0.82	1.14	1.39	1.99	-0.14	-0.6
1977	-0.99	-1.39	-1.19	-1.07	-2.07	0	0.12	0.73	0.89	1.12	1.07	1.84
1978	2.46	-0.85	-0.89	-0.85	-0.63	-0.54	-0.68	-0.08	-0.96	0.79	0.48	1.36
1979	1.76	1.86	0.73	1.05	1.15	1.1	1.61	3.31	4.22	4.08	4.61	4.25
1980	3.45	2.67	3.09	2.47	2.16	2.65	3.5	4.83	4.04	3.93	3.67	3.1
1981	2.04	2.47	1.43	1.8	2.24	3.11	2.84	2.22	2.47	2.45	1.97	1.91
1982	2.36	2.06	2.28	-0.6	-0.76	-0.35	-0.91	-0.96	-1.09	-1.89	-1.22	-0.67
1983	-1.1	-1.53	-2.04	0.67	1.77	-0.36	-0.63	-1.49	-1.81	1.3	2.12	2.46
1984	1.65	1.4	1.53	1.72	2.13	-1.04	-1.17	-1.19	-1.25	-1.23	-0.94	-0.73
1985	-1.01	-0.94	-0.58	-1.73	-1.51	-1.59	-1.34	-0.9	-1.72	0.03	2.38	-0.02
1986	-0.46	0.44	-0.51	-1.23	-1.53	0.28	0.69	0.43	1.04	1.69	2.36	2.49
1987	-0.36	-1.13	-1.53	-1.72	-1.97	-1.65	-1.49	-1.24	-1.67	-1.68	-2.3	-2.36
1988	-2.59	-1.79	-2.03	-2.27	-2.98	-4.14	-3.99	-4.06	-0.05	-0.04	0.17	-0.18
1989	-0.24	0.36	0.58	0.96	1.89	2.51	2.22	2.02	2.32	2.28	2.29	1.85
1990	1.52	2.3	1.16	0.81	2.23	2.05	3.15	3.39	3.86	4.79	4.42	6.4
1991	-0.09	-0.21	-0.23	-0.32	-1.14	-2.23	-2.97	-3.27	-3.28	-3.56	-4.31	-4.45
1992	-4.48	-4.51	-4.01	-3.77	-3.58	-3.52	2.52	2.86	3.04	2.88	3.87	3.34
1993	3.4	3.05	2.93	2.87	-0.74	-0.32	-0.4	-1.45	0.41	0.59	1.28	1.14
1994	1.45	-0.17	-0.33	0.4	-0.35	-0.34	-0.45	0.5	-0.46	-1.2	-1.46	-1.67
1995	-0.92	-1.25	-1.94	0.13	1.09	1.06	-0.36	-0.29	-0.91	0.7	0.78	0.69
1996	1.16	1.03	1.02	1.9	2.85	2.97	3.19	2.1	3.09	2.94	3.44	3.81
1997	3.35	3	3.37	2.34	2.94	3.25	2.76	3.43	2.93	2.34	2.19	1.96
1998	2.11	1.88	1.3	2.06	1.34	2.66	-0.18	-0.04	-0.9	-0.72	-1.37	-1.88
1999	-1.06	-0.77	-1.2	-1	-1.69	-2.5	-2.89	-2.95	-3.37	-3.43	-4.01	-4.25
2000	-3.98	-3.14	-3.48	0.25	0.47	0.84	1	1.29	1.8	1.64	1.43	1.76
2001	-0.47	-0.75	-1.29	-1.37	0.57	-0.31	-0.37	-0.43	0.13	1.08	1.12	1.18
2002	-0.18	-0.49	0.2	0.6	1.27	-0.26	-1	-1.9	-1.53	-1.29	-1.39	-1.32
2003	-1.52	-1.02	-1.53	-1.95	1.25	1.34	2.74	3.26	4.64	4.67	4.96	4.77
2004	4.78	3.89	3.3	2.76	3.49	3.52	3.63	3.85	4.18	4.21	4.57	4.64
2005	5.95	-0.23	-0.42	-0.09	-0.47	-1.57	-1.65	-1.1	-1.06	-1.06	-1.05	-1.39
2006	-1.12	-1.27	-1.45	-1.71	0.19	0.57	1.32	1.05	2.03	3.81	3.63	3.55
2007	4.04	-0.06	0.13	0.15	-1.17	-1.77	-1.83	0.68	-0.51	-0.59	-0.71	0.75
2008	0.65	1.91	3.23	2.27	2.54	3.32	-0.06	-0.7	-1.01	-1.25	-1.58	0.62
2009	0.59	-0.07	-0.61	-0.45	-0.53	0.07	0.43	0.31	0.17	1.13	-0.53	-0.18
2010	-0.43	-0.45	-0.76	-1.62	0.39	1.27	-0.3	-0.77	-1.22	-1.56	-1.27	-1.51
2011	-1.75	1.17	1.45	3.09	3.81	3.31	2.68	2.52	3.64	4.44	5.5	5.84
2012	5.64	-0.34	-1.05	-1.7	-1.95	-2.63	-3.08	-3.26	0.92	1.81	1.16	1.91
2013	1.8	-0.14	-0.4	-0.25	-1.05	0.82	2.17	1.81	1.57	2.04	2.39	3.09
2014	2.64	2.58	1.88	2.42	2.14	2.53	2.3	2.52	2.02	2.13	1.89	1.81
2015	1.65	1.14	1.23	1.5	0.86	2.57	2.87	-0.26	-0.31	-0.14	-0.48	0.45
2016	-0.44	0.49	-0.02	-0.1	-0.25	-0.61	-1.04	-0.97	-0.83	-0.86	-1.84	-1.84
2017	0.58	0.21	0.67	0.47	1.02	1.22	2.34	1.79	1.11	1.44	2.47	1.99
2018	1.74	2.95										

Source: Monthly Palmer Drought Severity Index for States and Climate Divisions; NOAA National Climatic Data Center
<https://www.drought.gov/drought/data/noaa-national-climatic-data-center/monthly-palmer-drought-severity-index-states-and-climate>

The table 2.11.b lists the number of years that the United States has had a severe or extreme drought in the 100 years from 1896 to 1995, based on the Palmer Drought Severity Index (PDSI). The data is divided and analyzed based on NOAA river basins. The chart shows that some part of the United States has experienced a severe or extreme drought in each year from 1896 to 1995, and that in 72 years, droughts covered more than 10% of the country.

Table 2.11.b

Number of Years with Severe or Extreme Drought between 1896 and 1995									
% area of basin/region	>0%	>10%	>25%	>33%	>50%	>66%	>75%	>90%	100%
United States	100	72	27	13	1	0	0	0	0
Upper Mississippi	77	55	43	30	19	12	9	3	1
Mid-Atlantic	69	49	32	24	12	5	4	0	0
South Atlantic/Gulf	79	47	25	15	9	3	3	0	0
Ohio	67	51	34	28	16	12	9	4	3
Missouri	90	70	43	33	17	10	4	3	0
Pacific Northwest	86	61	42	33	23	14	9	1	0
California	53	45	40	30	14	9	5	3	3
Great Basin	71	65	43	37	19	6	3	1	1
Lower Colorado	56	54	35	28	16	11	10	4	3
Upper Colorado	50	50	42	34	27	25	16	9	8
Rio Grande	58	47	32	24	15	8	5	2	2
Texas Gulf Coast	49	48	38	26	22	13	10	9	7
Arkansas-White-Red	65	48	27	23	14	7	4	0	0
Lower Mississippi	56	38	19	15	4	1	0	0	0
Souris-Red-Rainy	66	57	38	29	19	10	8	5	2
Great Lakes	73	58	32	23	9	3	2	2	0
Tennessee	31	31	27	24	21	16	13	5	5
New England	56	44	27	13	8	5	4	0	0

Source: National Climatic Data Center, *Understanding Your Risk and Impacts – A Comparison of Droughts, Floods, and Hurricanes in the United States*. <http://www.drought.unl.edu/risk/us/compare.html>.

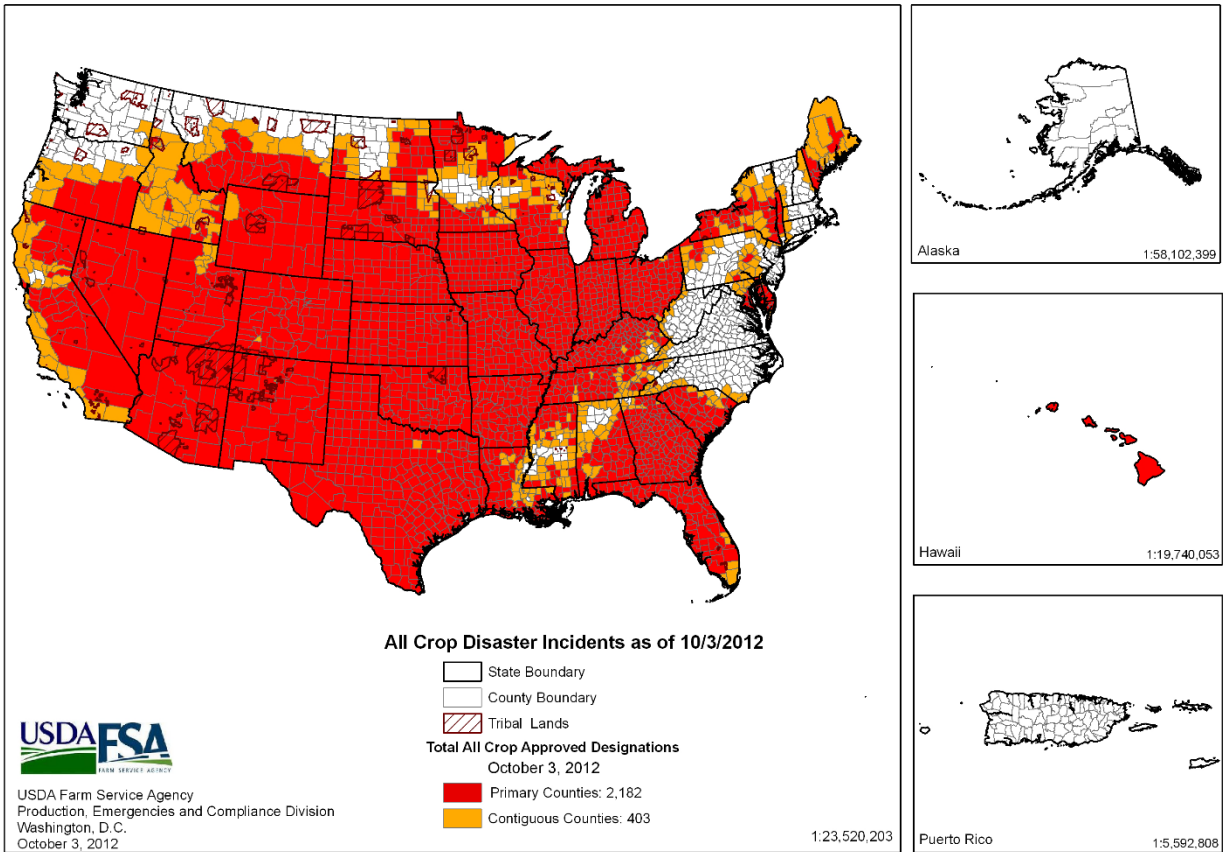
2012 NORTH AMERICAN DROUGHT

The 2012-2013 North American Drought was an expansion of the 2010-2012 United States Drought which began in the spring of 2012 when the lack of snow caused very little meltwater to absorb into the soil. The drought included most of the United States and all of Ohio. Several counties in the state were designated with moderate drought conditions by mid-June of 2012. Its effects were equal to similar droughts which occurred in the 1930s and 1950s, but the 2012 event did not last as long. Nonetheless, the 2012 North American Drought inflicted catastrophic economic ramifications on the state. In most measures, the 2012 drought exceeded the 1988-1989 North American Drought, which was the most recent comparable drought.

On July 30th, 2012, the Governor of Ohio sent a memorandum to the U.S. Department of Agriculture State Executive Director requesting primary county natural disaster designations for eligible counties due to agricultural losses caused by drought during the 2012 crop year. The USDA reviewed the Loss Assessment Reports and determined that there were sufficient production losses in 85 counties to warrant a Secretarial disaster designation on September 5th, 2012. By December 2012, all 88 counties received such a designation.

Secretarial Disaster Designations - CY 2012

Primary and Contiguous Counties Designated for 2012 Crop Disaster Losses



The USDA – National Agricultural Statistics Service (NASS) was used to compare a regular crop production period (Crop Year 2011) and the affected crop production period during drought conditions. Commodities were selected through the NASS Program Survey, Crops sector and then by Group: Field Crops, Vegetables, and Fruit & Tree Nuts. Table 2.11.c shows the difference in crop production in Ohio.

Table 2.11.c

Field Crop Losses						
Commodity	Measurement	2011 Quantity	2012 Quantity	Difference	% Change	Trend
Grain Corn - Planted	Acres	3,400,000	3,900,000	500,000	15%	More
Grain Corn - Harvested	Acres	3,220,000	3,650,000	430,000	13%	More
Grain Corn- Production	Bushels	508,760,000	448,950,000	-59,810,000	-12%	Less
Grain Corn - Yield	BU/Acre	158	123	-35	-22%	Less
Hay - Harvested	Acres	1,120,000	1,100,000	-20,000	-2%	Less
Hay - Production	Tons	2,772,000	2,330,000	-442,000	-16%	Less
Hay - Yield	Tons/Acre	2.48	2	0	-19%	Less
Maple Syrup	Number of Taps	405,000	410,000	5,000	1%	More
Maple Syrup - Production	Gallons	125,000	100,000	-25,000	-20%	Less
Maple Syrup - Yield	Gallons/Tap	0.309	0	0	-100%	Less
Soybeans - Planted	Acres	4,550,000	4,600,000	50,000	1%	More
Soybeans - Harvested	Acres	4,540,000	4,590,000	50,000	1%	More
Soybeans - Production	Bushels	217,920,000	206,550,000	-11,370,000	-5%	Less
Soybeans - Yield	BU/Acre	48	45	-3	-6%	Less
Tobacco, air-cured light burley - Harvested	Acres	1,600	1,800	200	13%	More
Tobacco, air-cured light burley - Production	Bushels	3,360,000	3,600,000	240,000	7%	More
Tobacco, air-cured light burley - Yield	BU/Acre	2,100	2,000	-100	-5%	Less
Fruit Losses						
Commodity	Measurement	2011 Quantity	2012 Quantity	Difference	% Change	Trend
Apples	Acres Bearing	4,300	4,000	-300	-7%	Less
Apples - Production	Pounds	66,600,000	33,000,000	-33,600,000	-50%	Less
Apples - Yield	Pounds/Acre	15,500	8,250	-7,250	-47%	Less
Grapes	Acres Bearing	1,900	1,900	0	0%	(No Change)
Grapes - Production	Tons	7,480	5,335	-2,145	-29%	Less
Grapes - Yield	Tons/Acre	3.94	2.81	-1	-29%	Less
Peaches	Acres Bearing	1,200	1,400	200	17%	More
Peaches - Yield	Tons	6,030	4,960	-1,070	-18%	Less
Peaches - Production	Tons/Acre	5.03	3.54	-1	-30%	Less
Vegetable Losses						
Vegetable	Measurement	2011 Quantity	2012 Quantity	Difference	% Change	Trend
Cucumbers - Planted	Acres	2,600	7,100	4,500	173%	More
Cucumbers - Harvested	Acres	2,600	7,000	4,400	169%	More
Cucumbers - Production	Cwt (Hundredweight)	17,910	31,290	13,380	75%	More
Cucumbers - Yield	Cwt/Acre	6.89	4.47	-2	-35%	Less
Bell Peppers - Planted	Acres	3,200	3,200	0	0%	(No Change)
Bell Peppers - Harvested	Acres	3,100	3,100	0	0%	(No Change)
Bell Peppers - Production	Cwt (Hundredweight)	1,004,000	567,000	-437,000	-44%	Less
Potatoes - Planted	Acres	2,000	1,500	-500	-25%	Less
Potatoes - Harvested	Acres	1,700	1,400	-300	-18%	Less
Potatoes - Production	Cwt (Hundredweight)	459,000	308,000	-151,000	-33%	Less
Potatoes - Yield	Cwt/Acre	270	220	-50	-19%	Less
Squash - Planted	Acres	1,900	1,800	-100	-5%	Less
Squash - Harvested	Acres	1,800	1,700	-100	-6%	Less
Squash - Production	Cwt (Hundredweight)	360,000	304,000	-56,000	-16%	Less
Squash - Yield	Cwt/Acre	200	180	-20	-10%	Less
Sweet Corn - Planted	Acres	15,900	16,400	500	3%	More
Sweet Corn- Harvested	Acres	15,100	15,100	0	0%	(No Change)
Sweet Corn - Production	Cwt (Hundredweight)	1,737,000	1,586,000	-151,000	-9%	Less
Sweet Corn - Yield	Cwt/Acre	115	105	-10	-9%	Less
Fresh Market Tomatoes - Planted	Acres	4,500	4,300	-200	-4%	Less
Fresh Market Tomatoes - Harvested	Acres	3,200	4,100	900	28%	More
Fresh Market Tomatoes - Production	Cwt (Hundredweight)	752,000	697,000	-55,000	-7%	Less
Fresh Market Tomatoes - Yield	Cwt/Acre	235	170	-65	-28%	Less

Source: U. S. Department of Agriculture - National Agricultural Statistics Service

PROBABILITY OF FUTURE EVENTS

The probability of future occurrences of drought in Ohio is difficult to predict; however, there are two factors that may influence future drought conditions: The El Niño–Southern Oscillation (ENSO), and climate change.

EL NINO AND LA NINA SOUTHERN OSCILLATION

A great deal of research has been conducted in recent years on the role of interacting systems, or teleconnections, in explaining regional and even global patterns of climatic variability. These patterns tend to recur periodically with enough frequency and with similar characteristics over a sufficient length of time that they offer opportunities to improve our ability for long-range climate prediction, particularly in the tropics.

Every 2 to 7 years, off the western coast of South America, ocean currents and winds shift, bringing warm water westward, displacing the nutrient-rich cold water that normally wells up from deep in the ocean. The invasion of warm water disrupts both the marine food chain and the economies of coastal communities that are based on fishing and related industries. Because the phenomenon peaks around the Christmas season, the fishermen who first observed it named it El Niño (“the Christ Child”). In recent decades, scientists have recognized that El Niño is linked with other shifts in global weather patterns. The intensity and duration of an ENSO event is varied and hard to predict. Typically, it lasts anywhere from 14-to-22 months, but it can be much longer or shorter. El Niño often begins early in the year and peaks between the following November.

During an El Niño–Southern Oscillation (ENSO) event, the Southern Oscillation is reversed. Generally, when pressure is high over the Pacific Ocean, it tends to be low in the eastern Indian Ocean, and vice versa. It is measured by gauging sea-level pressure in the east (at Tahiti) and west (at Darwin, Australia) and calculating the difference. El Niño and Southern Oscillation often occur together, but also happen separately. High positive values of the SOI indicate a La Niña, or “cold event”. La Niña is the counterpart of El Niño and represents the other extreme of the ENSO cycle. La Niña years often (but not always) follow El Niño years.

Table 2.11.d, ENSO Phases 1900 to 2005

ENSO PHASE		Negative PDO: 1900-1924, 1947-1976, 1999-2002	Warm phase PDO: 1925-1946, 1977-1998, 2003- 2005
	La Niña (Cool)	1904, 1907, 1909, 1910, 1911, 1917, 1918, 1921, 1923, 1950, 1951, 1955, 1956, 1963, 1965, 1968, 1971, 1972, 1974, 1975, 1976, 1999, 2000, 2001	1925, 1932, 1934, 1938, 1939, 1943, 1944, 1945, 1984, 1985, 1986, 1989, 1996
	ENSO Neutral	1901, 1902, 1908, 1913, 1916, 1922, 1947, 1948, 1949, 1953, 1954, 1957, 1960, 1961, 1962, 1967, 2002	1927, 1928, 1929, 1933, 1935, 1936, 1937, 1946, 1979, 1981, 1982, 1990, 1991, 1993, 1994, 1997, 2004
	El Niño (Warm)	1900, 1903, 1905, 1906, 1912, 1914, 1915, 1919, 1920, 1924, 1952, 1958, 1959, 1964, 1966, 1969, 1970, 1973	1926, 1930, 1931, 1940, 1941, 1942, 1977, 1978, 1980, 1983, 1987, 1988, 1992, 1995, 1998, 2003, 2005

Source: Climate Impacts Group, Joint Institute for the Study of the Atmosphere and the Ocean, University of Washington

Understanding the connections between ENSO (and La Niña) events and weather anomalies around the globe can help in forecasting droughts, floods, tropical storms, and hurricanes. NOAA estimates that the economic impacts of the 1982–83 El Niño, perhaps the strongest event in recorded history, conservatively exceeded \$8 billion worldwide, from droughts, fires, flooding, and hurricanes. This event and its associated disasters have been blamed for 1,000 to 2,000 deaths. In addition, the extreme drought in the United States' Midwest during 1988 has been linked to the “cold event”, or La Niña, of 1988 that followed the ENSO event of 1986–87.

It is possible that the direct impacts of climate change on water resources might be hidden beneath natural climate variability. With a warmer climate, droughts, and floods could become more frequent, severe, and longer-lasting. The potential increase in these hazards is a great concern given the stresses being placed on water resources and the high costs resulting from recent hazards. The drought of the late 1980s showed what the impacts might be if climate change leads to a change in the frequency and intensity of droughts across the United States. From 1987 to 1989, losses from drought in the United States totaled \$39 billion. More frequent extreme events such as droughts and floods could end up being more cause for concern than the long-term change in temperature and precipitation averages.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

Drought risk is based on a combination of the frequency, severity, and spatial extent of drought and the degree to which a population or activity is vulnerable to the effects of drought. The degree of a region's vulnerability depends on the environmental and social characteristics of the region and is measured by the ability to anticipate, cope with, resist, and recover from a drought.

Society's vulnerability to drought is determined by a wide range of factors, both physical and social, such as demographic trends and geographic characteristics. People and activities will be affected in different ways by different hazards.

There is a sequence of impacts associated with meteorological, agricultural, and hydrological droughts in Ohio. When drought begins, the agricultural sector is usually the first to be affected because of its heavy dependence on stored soil water, which can be rapidly depleted during extended dry periods. If precipitation deficiencies continue, then people dependent on other sources of water will begin to feel the effects of the shortage. Those who rely on surface water (reservoirs and lakes) and subsurface water (groundwater) are usually the last to be affected. A short-term drought that persists for 3 to 6 months may have little impact on these sectors, depending on the characteristics of the hydrologic system and water use requirements.

When precipitation returns to normal and meteorological drought conditions have abated, the sequence is repeated for the recovery of surface and subsurface water supplies. Soil water reserves are replenished first, followed by stream flow, reservoirs and lakes, and groundwater. Drought impacts may diminish rapidly in the agricultural sector because of its reliance on soil water, but linger for months or even years in other sectors, dependent on stored surface or subsurface supplies. Groundwater users, often the last to be affected by drought during its onset, may be last to experience a return to normal water levels. The length of the recovery period is a function of the intensity of the drought, its duration, and the quantity of precipitation received as the episode terminates.

Socioeconomic definitions of drought associate the supply and demand of some economic goods with elements of meteorological, hydrological, and agricultural drought. It differs from the other types of

drought because its occurrence depends on the time and space processes of supply and demand to identify or classify droughts. The supply of many economic goods, such as water, forage, food grains, fish, and hydroelectric power, depends on the weather. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

FEMA estimated in 1995 that drought costs the United States \$6– 8 billion annually. Other studies have indicated that drought losses average \$200 million to \$1.24 billion annually in the Great Plains. This range is based on crop losses and other direct and indirect losses. According to NOAA's National Climatic Data Center, in 1999, a drought that affected twenty-eight Ohio counties caused \$200 million in crop damages.

The Dust Bowl years of the 1930s and the drought of 1988–89 are both contenders for the worst drought on record in the United States. Economic losses are often hard to calculate and compare for a variety of reasons: lack of historical records and economic models, and past and present costs that are often based on different criteria. Today, many different types of losses are often included in an economic analysis, such as energy losses, ecosystem losses, and consumer purchasing losses, but they were not typically included in previous analyses and are difficult to assess in retrospect.

STATE-OWNED AND STATE-LEASED CRITICAL FACILITIES VULNERABILITY ANALYSIS & LOSS ESTIMATION

Drought does not pose a specific threat to state-owned or state-leased facilities. The larger threat from drought would be based on the agricultural and drinking water demands with a limited supply. Additionally, drought can play a major role in occurrences of wildfires throughout the state (Section 2.7).