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 (farming and cattle production as opposed to urban areas), economy (dependence on drought-impacted business (farming), geology (presence of an aquifer or ground structure that limits well production), and water source (public water supply, private well, cistern).

There are four primary types of drought: meteorological, hydrological, agricultural 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 ground water 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 surface or subsurface water supply – stream flow, reservoir and lake levels and ground water. The frequency and severity of hydrological drought is 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.

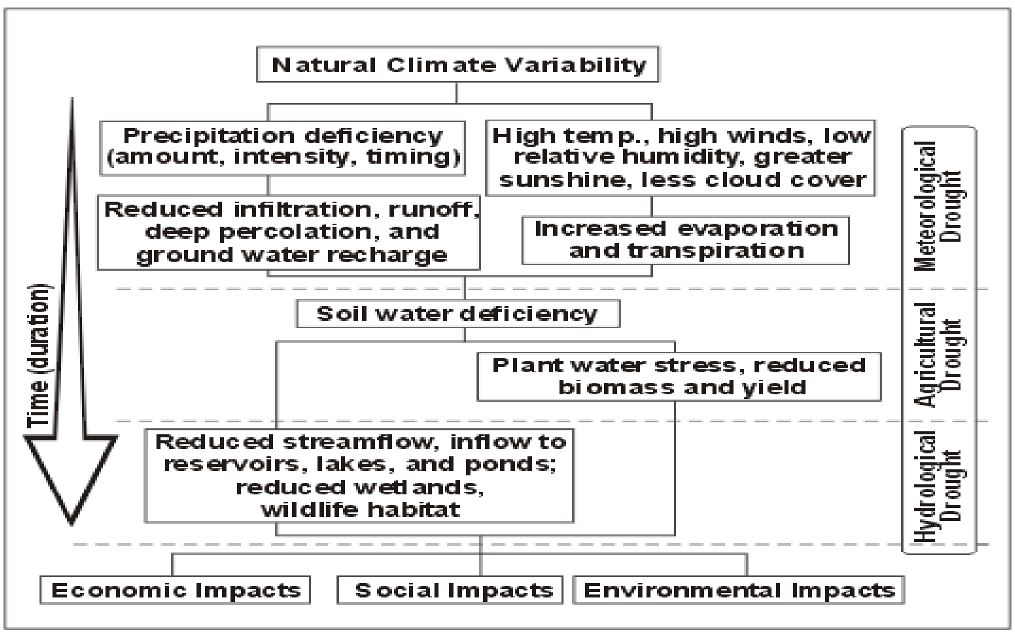
Hydrological droughts are usually out of phase with, or lag the occurrence of, meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, stream flow, and ground water and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors. For example, a deficiency in reservoir levels may not affect hydroelectric power production or recreational uses for many months.

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, 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 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: National Weather Service – Public Fact Sheet, August 2006
http://www.nws.noaa.gov/om/brochures/climate/Drought.pdf

National Drought Mitigation Center, http://www.drought.unl.edu/whatis/concept.htm

Measuring Drought

The Palmer Drought Severity Index (PDSI) is a soil moisture algorithm. The PDSI was d*eveloped 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

Source: Palmer Drought Severity Index
http://www.math.montana.edu/~nmp/materials/ess/mountain_environments/intermediate/ystone/palmer_more.html

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

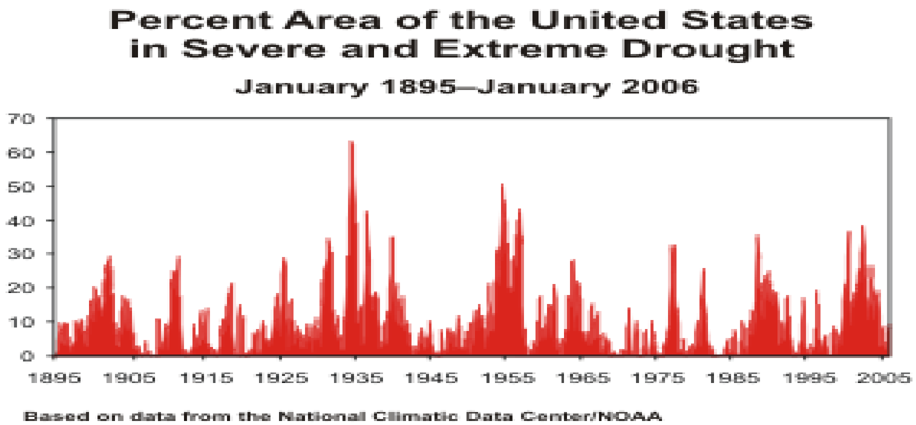
Location

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.

Figure 2.11.c



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.

LHMP Data

Scioto County. The Scioto County Hazard Mitigation Plan of 2012 states a drought of any length of time can cause significant damage to crops and harm the local economy. Drought impact would prompt marked decreases in agricultural production, which is the most prevalent industry in the county. This would also cause consumers to pay more for food and negatively impact the whole county. An exact cost could not be determined, however, it is projected that the loss of one year's crops would total several hundreds of thousands of dollars for the farm community.

Medina County. The updated 2011 All Hazard and Flood Mitigation Plan provides a description of similar impacts from a prolonged drought as the Scioto County Plan. According to the HIRA, the rural and farm areas not served by public water systems will be affected the most. Significant impacts may also occur to the municipalities that utilize wells due to their lack of recharge. In addition to the lack of water, power outages are also likely to occur due to the reduced electric transmission efficiency and the significant increase in demand for power as the use of air conditioning. The plan goes on to identify that the county has a large agricultural base and viewed as a countywide industry. Economic impact will be felt on losses from crop failure, undernourished livestock and wildlife, land value decline and potential unemployment.

SHARPP. Hazard identification data were queried from SHARPP to evaluate each hazard and its frequency. As indicated in Chart 2.2.a, drought ranks relatively low in terms of frequency. However, this hazard ranked second for magnitude, with a few respondents indicating significant impact countywide. This is most likely due to the effects drought can have on agriculture in counties with a large agricultural base. For most factors, this hazard ranked in the lower 50 percent, which resulted in an overall ranking of 10th out of 15 hazards. These and additional HIRA data queried from SHARPP can be found in Appendix J.

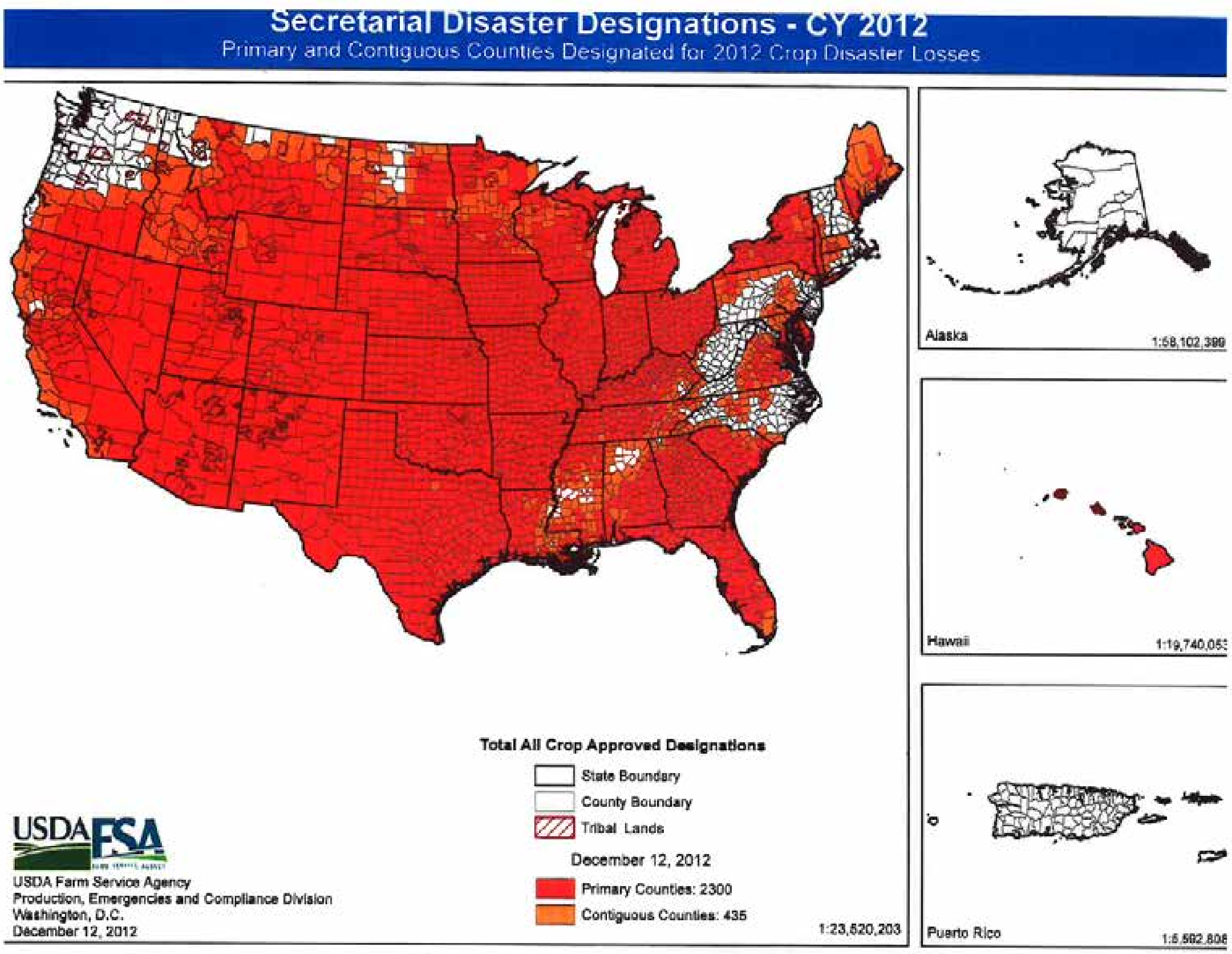
Past Occurrences

The table below lists the number of years that the United States has had 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.

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 show caused very little melt water 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 1930s and 1950s, but the 2012 event did not last as long. None the less 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 30, 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 5, 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
Alaska
1:58,102,399
Hawaii
Puerto Rico
1:6,592,808
Total All Crop Approved Designations
State Boundary
County Boundary
Tribal Lands
December 12, 2012
Primary Counties: 2300
Contiguous Counties: 435
1:23,520,203
USDA FSA
USDA Farm Service Agency
Production, Emergencies and Compliance Division
Washington, D.C.
December 12, 2012

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:

Field Crop Losses					
Commodity	**Measurement**	**2011 Quantity**	**2012 Quantity**	**Difference**	**Trend**
Grain Corn - Planted	Acres	3,400,000	3,900,000	500,000	More
Grain Corn - Harvested	Acres	3,220,000	3,650,000	430,000	More
Grain Corn- Production	Bushels	508,760,000	448,950,000	59,810,000	Less
Grain Corn - Yield	BU/Acre	158	123	35	Less
Hay - Harvested	Acres	1,120,000	1,100,000	20,000	Less
Hay - Production	Tons	2,772,000	2,330,000	442,000	Less
Hay - Yield	Tons/Acre	2.48	2	0.36	Less
Maple Syrup	Number of Taps	405,000	410,000	5,000	More
Maple Syrup - Production	Gallons	125,000	100,000	25,000	Less
Maple Syrup - Yield	Gallons/Tap	0.309	0	0.065	Less
Soybeans - Planted	Acres	4,550,000	4,600,000	50,000	More
Soybeans - Harvested	Acres	4,540,000	4,590,000	50,000	More
Soybeans - Production	Bushels	217,920,000	206,550,000	11,370,000	Less
Soybeans - Yield	BU/Acre	48	45	3	Less
Tobacco, air-cured light burley - Harvested	Acres	1,600	1,800	200	More
Tobacco, air-cured light burley - Production	Bushels	3,360,000	3,600,000	240,000	More
Tobacco, air-cured light burley - Yield	BU/Acre	2,100	2,000	100	Less

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

Fruit and Vegetable Losses					
Fruit	**Measurement**	**2011 Quantity**	**2012 Quantity**	**Difference**	**Trend**
Apples	Acres Bearing	4,300	4,000	300	Less
Apples - Production	Pounds	66,600,000	33,000,000	33,600,000	Less
Apples - Yield	Pounds/Acre	15,500	8,250	7,250	Less
Grapes	Acres Bearing	1,900	1,900	0	(No Change)
Grapes - Production	Tons	7,480	5,335	2,145	Less
Grapes - Yield	Tons/Acre	3.94	2.81	1.13	Less
Peaches	Acres Bearing	1,200	1,400	200	More
Peaches - Yield	Tons	6,030	4,960	1,070	Less
Peaches - Production	Tons/Acre	5.03	3.54	1.49	Less
Vegetable	**Measurement**	**2011 Quantity**	**2012 Quantity**	**Difference**	**Trend**
Cucumbers - Planted	Acres	2,600	7,100	4,500	More
Cucumbers - Harvested	Acres	2,600	7,000	4,400	More
Cucumbers - Production	Cwt (Hundredweight)	17,910	31,290	13,380	More
Cucumbers - Yield	Cwt/Acre	6.89	4.47	2.42	Less
Bell Peppers - Planted	Acres	3,200	3,200	0	(No Change)
Bell Peppers - Harvested	Acres	3,100	3,100	0	(No Change)
Bell Peppers -Production	Cwt (Hundredweight)	1,004,000	567,000	437,000	Less
Potatoes - Planted	Acres	2,000	1,500	500	Less
Potatoes - Harvested	Acres	1,700	1,400	300	Less

Potatoes - Production	Cwt (Hundredweight)	459,000	308,000	151,000	Less
Potatoes - Yield	Cwt/Acre	270	220	50	Less
Squash - Planted	Acres	1,900	1,800	100	Less
Squash - Harvested	Acres	1,800	1,700	100	Less
Squash - Production	Cwt (Hundredweight)	360,000	304,000	56,000	Less
Squash - Yield	Cwt/Acre	200	180	20	Less
Sweet Corn - Planted	Acres	15,900	16,400	500	More
Sweet Corn- Harvested	Acres	15,100	15,100	0	(No Change)
Sweet Corn - Production	Cwt (Hundredweight)	1,737,000	1,586,000	151,000	Less
Sweet Corn - Yield	Cwt/Acre	115	105	10	Less
Fresh Market Tomatoes - Planted	Acres	4,500	4,300	200	Less
Fresh Market Tomatoes - Harvested	Acres	3,200	4,100	900	More
Fresh Market Tomatoes - Production	Cwt (Hundredweight)	752,000	697,000	55,000	Less
Fresh Market Tomatoes - Yield	Cwt/Acre	235	170	65	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: 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.

Table 2.11.a
Number of Years with Severe or Extreme Drought between 1896 to 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.

Every 2 – 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. A table listing the El Niño and La Niña events since 1900 can be found on the next page.

Table 2.11.b
ENSO Phases Since 1900

		Negative PDO: 1900-1924, 1947-1976, 1999-2002	Warm phase PDO: 1925-1946, 1977-1998, 2003-2005
ENSO Phase	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, http://www.cses.washington.edu/cig/pnwc/compensopdo.shtml.

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 (see map, below), conservatively exceeded $8 billion worldwide, from droughts, fires, flooding, and hurricanes. This event and its associated disasters have been blamed for 1,000 - 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 their ability to anticipate, cope with, resist, and recover from 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 (ground water) 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 ground water. 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. Ground water 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 good 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 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.

A 1975 study noted that the 1930s droughts were considered to be the most economically damaging droughts to affect the United States. It is estimated that total costs due to the 1988 drought, including losses in agriculture, energy, water, ecosystems, and other sectors of the economy, were roughly $39 billion, making it the most expensive natural disaster ever to affect the nation.

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).