Drought and Climate Change in Pima County and Western States

Office of Sustainability, Conservation and Historic Preservation – December 2017

PIMA COUNTY

Drought and Climate Change: Implications for Pima County and Western States

INTRODUCTION

Arizona experienced the onset of sustained drought in 1996.[i] Above average temperatures aggravated the emerging drought.[ii] Governor Fyfe Symington signed an emergency declaration (PCA 95006) May 1996, requesting federal assistance due to the extremely dry conditions- PCA 95006 was subsequently extended through 1998. In 1999, Governor Jane Dee Hull signed a declaration of drought emergency (PCA 99006), the state's mechanism for receiving federal assistance, which still remains in effect today. By 2002, other western states would be impacted by extreme and exceptional drought that would persist over the next several years. The past two decades of drought include some aberrations, however, the overall trend has been below or well below average precipitation and above or well above average temperatures in Pima County and across the West.

The western states are rapidly growing and typically have growth rates above the national average. The population served by the Colorado River is expected to grow between 9 million and 35 million by 2060, depending on growth scenarios. Western municipal water demand will increase to serve population growth, with a majority of that demand occurring in Arizona.[iii] The Lower Basin states, Arizona, California and Nevada, already have demand exceeding their annual 7.5 million acre-feet (maf) allotment and use more water (1.2 maf) than is released into Lake Mead each year. An overall Basin imbalance between supply and demand by 2060 is projected to be 3.2 maf a year; changes in climate and streamflow will reduce the reliability of the Colorado River system.[iv] As reliability diminishes and Lake Mead continues to decline, the probability of a water shortage poses a significant risk to Arizona given its junior water right in the Lower Basin. Within the state, Central Arizona Project (CAP) water allocations would constitute a vast majority of shortage curtailment.

Drought is a natural climate variable, as such, climate research cannot establish a link between any specific drought event and climate change. However, the high temperatures identified with the current Southwest drought have caught researchers' attention and those temperatures and aridity are consistent with greenhouse warming models. Widespread persistent aridity and prolonged drought are associated with higher temperatures. While past droughts have been severe and prolonged, this drought is different in terms of the magnitude of warming and evapotranspiration stress.[v] With climate data alluding to an exaggerated influence that high temperature exerts on drought potential and impacts, changes in drought management strategy may be needed. A reduction in greenhouse gas emissions, and change in rising global temperature, may reduce the future probability, extent, duration and/or severity of drought.

The West is facing rapid population growth, increasing water and energy demands and reduced Colorado River Basin hydrology during an extended drought while relying on an already overallocated water management framework that has large annual supply deficits with larger supply imbalances forecasted due to climate change.

Pima County's Drought Management Program was established ten years ago. This report summarizes recent and long term drought impacts, both local and regional. Assessing climate, water supply, wildfire and ecosystem health, human health and other environmental research, overall drought conditions have not eased and are expected to worsen with rising temperatures. The following is a review of drought conditions over the past year and longer for both the County and western states, impacts, drought implications as a result of climate change, conclusions for drought management and any recommendations.

DROUGHT IN PIMA COUNTY 2016-2017

Weather (NWS-Tucson)

Reviewing from the 2016 monsoon season, Pima County experienced a severe heat wave in June from a strong high pressure system that rapidly built up temperatures to highs of 115-117°F. The monsoon was active, however, with heavy rain contributing to one of the wettest June months ever recorded. This helped ease short term drought conditions somewhat; Pima County began June with Moderate and Severe drought but July saw some lessening of Severe drought. Heat and rain continued through July so that by August, Pima County was in mostly Moderate drought. August brought cooling and below average rain despite Hurricane Newton's impact in southeast Arizona. Tropical storm systems continued in September with some cooling and increased rainfall. Overall, the monsoon was warmer and wetter than average. Drought improved to mixed Moderate/Abnormally Dry conditions.

Record heat and localized below average rain in October kept short term drought status static with the County's long term drought status as Abnormally Dry. The 2016 Water Year ended with a +1.42" precipitation surplus. Heat continued in November, interrupted by Pacific storms that brought rain and high-elevation snow. Any worsening of drought was forestalled but more substantial improvement would depend on decent winter storms. Pima County short term drought status remained mixed Moderate/Abnormally Dry. The situation continue into December- more warmth and Pacific storms but insufficient to improve drought.

The year began with cooling and decent winter storms in January but with building high-pressure dryness going into February, heat returned with well above average temperatures and interspersed Pacific storms with below average rain. Overall, the winter was warm and -0.27" below average rainfall with a lack of drought improvement for all southern Arizona including Pima County.

March was another record warm month and drier than average, adding to wildfire danger from winter growth drying out. Again, continued warmth in April and no rain- drought status remained the same. Pacific storms brought some cooling in May but little rain. The dry spring season brought worsening drought with all of Pima County now in Moderate status. June was the hottest recorded and went on to break numerous temperature records as dangerous heat waves spread across the West. July was the wettest on record with +4.55" rain surplus but the monsoon faltered in August and September as heat returned. The 2017 Water Year ended slightly above average (+0.27"). The fall season ranked as the warmest and driest with no rain in October and record heat in November- drought worsened and expanded.

Precipitation

The cumulative precipitation surplus over the last 18 months, to include two monsoon seasons (June 2016-November 2017) is +0.37".

Temperature

October 2016 was the warmest October ever recorded; similarly, March 2017, June 2017 and November 2017 were each the warmest respective months of the historical record.

Drought

The last time Pima County was mostly out of drought was during the 2015-16 winter season, having only a small section of Abnormally Dry condition.

Precipitation (NWS-Tucson)

	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17
Precip"	1.59	3.32	1.09	1.60	0.10	0.50	1.08	1.18	0.20	0.21	0.00	0.02	0.00	6.80	1.74	0.03	0.00	0.09
HNorm	0.20	2.25	2.39	1.29	0.89	0.57	0.93	0.94	0.86	0.73	0.31	0.23	0.20	2.25	2.39	1.29	0.89	0.57
D+/-	+1.39	+1.07	-1.30	+0.31	-0.79	-0.07	+0.15	+0.24	-0.66	-0.52	-0.31	-0.21	-0.20	+4.55	-0.65	-1.26	-0.89	-0.48
C	+1.39	+2.46	+1.16	+1.47	+0.68	+0.61	+0.76	+1.00	+0.34	-0.18	-0.49	-0.70	-0.90	+3.65	+3.00	+1.74	+0.85	+0.37
Rank	2nd Wet	24th Wet	26th Dry	38th Wet	39th Dry	58th Wet	37th Wet	36th Wet	29th Dry	43rd Dry	Driest	10th Dry	Driest	1st Wet	52nd Dry	11th Dry	Driest	34th Dry

Average Temperature (NWS-Tucson)

	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17
TempF	88.4	90.3	85.4	80.6	77.5	64.0	56.2	52.9	59.5	67.8	71.1	76.5	89.7	87.5	87.2	83.0	77.3	69.1
HNorm	84.8	87.0	85.3	81.6	71.0	59.8	51.9	52.6	55.3	60.1	67.0	76.0	84.8	85.3	85.3	81.6	71.0	59.8
D+/-	+3.6	+3.3	+0.1	-1.0	+6.5	+4.2	+4.3	+0.3	+4.2	+7.7	+4.1	+0.5	+4.9	+0.5	+1.9	+1.4	+6.3	+9.3
Rank	6th Hot	3rd Hot	36th Hot	57th Cool	1st Hot	6th Hot	7th Hot	33rd Hot	8th Hot	1st Hot	4th Hot	24th Hot	1st Hot	31st Hot	8th Hot	14th Hot	2nd Hot	1st Hot

2016-17 Pima County Drought (USDM)

	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17
Short Term	Mod-Severe	Mod-Severe	Mod-Severe	Abnorm-Mod	Abnorm-Mod	Abnorm-Mod	Abnorm-Mod	Abnorm-Mod	Abnorm-Mod	Abnorm-Mod	Abnorm-Mod	All Mod	All Mod	Mod-Abnorm	Mod-Abnorm	Mod-Abnorm	Mod-Severe	Mod-Severe
Long Term	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry	Abnorm Dry

2016-17 Pima County Season Ranking (NWS-Tucson)

	Winter	Spring	Summer	Monsoon	Fall
Precip Rank	49th Wet	10th Dry	5th Wet	11th Wet	Driest
Temp Rank	4th Warm	2nd Warm	4th Warm	5th Warm	1st Warm

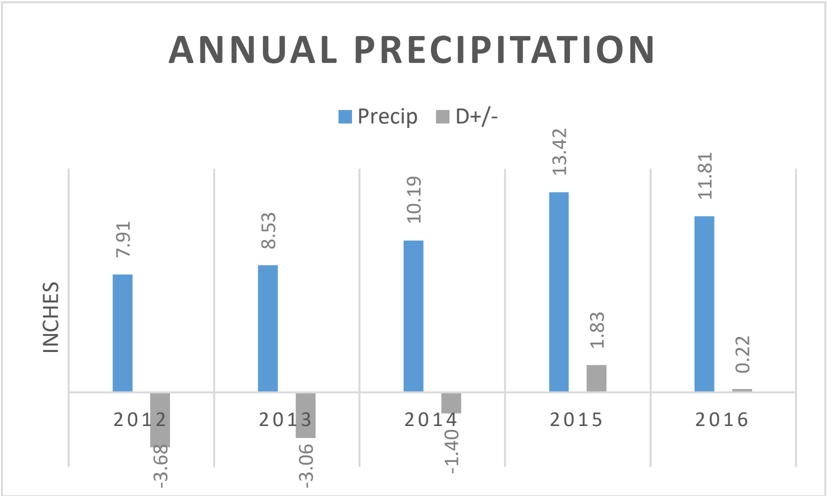
DROUGHT IN PIMA COUNTY 2012-2016

At the time, 2012 was the 2nd warmest year on record and the 18th driest. In 2013, it was cooler though the year still set some temperature records, including the hottest June then ever recorded. A large precipitation deficit continued from 2012. Again, warmth continued as 2014 set the record for hottest year- and would remain a record year when tied with 2016. Precipitation improved in 2014 though still below average. Above average rain in 2015 was also accompanied by heat; 2015 bumped 2012 from 2nd hottest to 4th on record.

Precipitation (NWS-Tucson)

The historical annual average precipitation recorded for the Tucson region is 11.59". The cumulative precipitation deficit over the five year period is -6.09".

After an average 2012 monsoon and 2012/13 winter precipitation, a very dry 2013 monsoon and 2013/14 winter season caused significant precipitation deficit. The 2014 monsoon returned to average and the following 2014/15 winter was wet, allowing for drought improvement. An overall average 2015 monsoon and somewhat below average winter season broke even. The wet 2016 monsoon was the only significant monsoon season in this five year period; similarly, the 2014/15 winter season.



	Rain"	(Departure)	Ranked
2012	7.91	-3.68	18th Dry
2013	8.53	-3.06	22nd Dry
2014	10.19	-1.40	51st Dry
2015	13.42	+1.83	28th Wet
2016	11.81	+0.22	46th Wet

	(Departure)	
	Monsoon	Winter
2012	-0.06	+0.05
2013	-2.34	-1.89
2014	0.00	+2.39
2015	+0.55	-0.55
2016	+1.32	-0.27

Temperature (NWS-Tucson)

The historical annual average temperature recorded for the Tucson region is 69.4°F.

2016, 2015 and 2014 is the warmest three year period on record.

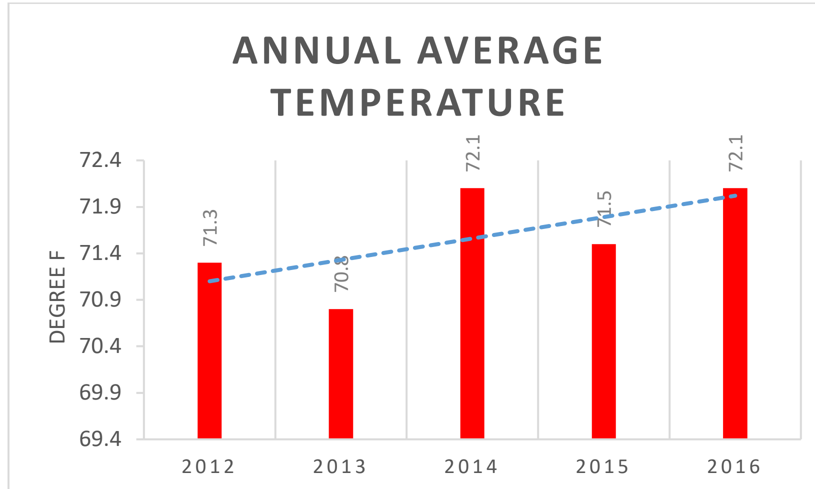
The 2013/14 winter season was the warmest on record and tied with the following 2014/15 winter. The 2015 monsoon ranked as 2nd warmest monsoon. Winter 2016/17 was 4th warmest. Of the ten monsoon/winter rankings, six are in the top ten warmth records and only winter 2012 recorded a below average temperature.

	AvgTempF	(Departure)	Ranked
2012	71.3	+1.9	5th Warm
2013	70.8	+1.4	8th Warm
2014	72.1	+2.7	1st Hottest
2015	71.5	+2.1	3rd Warm
2016	72.1	+2.7	1st Hottest

	(Departure)	
	Monsoon	Winter
2012	+0.4	-1.8
2013	+1.1	+3.8
2014	+1.0	+3.8
2015	+2.3	+1.8
2016	+1.1	+2.9

Pima County Drought (USDM)

	Monsoon	Winter
2012	Moderate	Moderate/Severe
2013	Moderate/Severe	Moderate/Severe/Extreme
2014	Moderate/AbnormalDry	Moderate/AbnormalDry/None
2015	AbnormalDry/None	AbnormalDry/None
2016	Moderate/AbnormalDry	Moderate/AbmormalDry



Overall, drought has improved in Pima County within the last five years as evident in the US Drought Monitor percent area timescale graph (Figure 1). While 2000-2005 was one of the worst drought periods for western states, Pima County drought peaked between 2006-2008 (Figure 2). However, any improvement should be considered in the context of the cumulative impacts of a two decades long drought, the probability of a continual "megadrought" and potential for increased severity.

The rising long term temperature trend in Pima County is the dominant climate signal. Average decadal temperatures have risen 4.4°F from 1900 averages to the record warm decade of 2000-09 when average temperature reached 71°F.[vi] The past three year period averages to a temperature approaching 72°F.

US DROUGHT MONITOR CLASSFICATION

Source: *http://droughtmonitor.unl.edu/AboutUSDM/DroughtClassification.aspx*

Indicators

The accompanying drought severity classification table shows the ranges for each indicator for each dryness level. Because the ranges of the various indicators often don't coincide, the final drought category tends to be based on what the majority of the indicators show and on local observations. The analysts producing the map also weigh the indices according to how well they perform in various parts of the country and at different times of the year. Additional indicators are often needed in the West, where winter snowfall in the mountains has a strong bearing on water supplies. It is this combination of the best available data, local observations and experts' best judgment that makes the U.S. Drought Monitor more versatile than other drought indicators.

What You See

The Drought Monitor summary map identifies general areas of drought and labels them by intensity. D1 is the least intense level and D4 the most intense. Drought is defined as a moisture deficit bad enough to have social, environmental or economic effects. D0 areas are not in drought, but are experiencing abnormally dry conditions that could turn into drought or are recovering from drought but are not yet back to normal.

Category	Description	Possible Impacts	Palmer Drought Severity Index (PDSI)	CPC Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)
D0	Abnormally Dry	Going into drought: • short-term dryness slowing planting, growth of crops or pastures Coming out of drought: • some lingering water deficits • pastures or crops not fully recovered	-1.0 to -1.9	21 to 30	21 to 30	-0.5 to -0.7
D1	Moderate Drought	• Some damage to crops, pastures • Streams, reservoirs, or wells low, some water shortages developing or imminent • Voluntary water-use restrictions requested	-2.0 to -2.9	11 to 20	11 to 20	-0.8 to -1.2
D2	Severe Drought	• Crop or pasture losses likely • Water shortages common • Water restrictions imposed	-3.0 to -3.9	6 to 10	6 to 10	-1.3 to -1.5
D3	Extreme Drought	• Major crop/pasture losses • Widespread water shortages or restrictions	-4.0 to -4.9	3 to 5	3 to 5	-1.6 to -1.9
D4	Exceptional Drought	• Exceptional and widespread crop/pasture losses • Shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0 to 2	0 to 2	-2.0 or less

Short-term drought indicator blends focus on 1-3 month precipitation. Long-term blends focus on 6-60 months. Additional indices used, mainly during the growing season, include the USDA/NASS Topsoil Moisture, Keetch-Byram Drought Index (KBDI), and NOAA/NESDIS satellite Vegetation Health Indices. Indices used primarily during the snow season and in the West include snow water content, river basin precipitation, and the Surface Water Supply Index (SWSI). Other indicators include groundwater levels, reservoir storage, and pasture/range conditions.

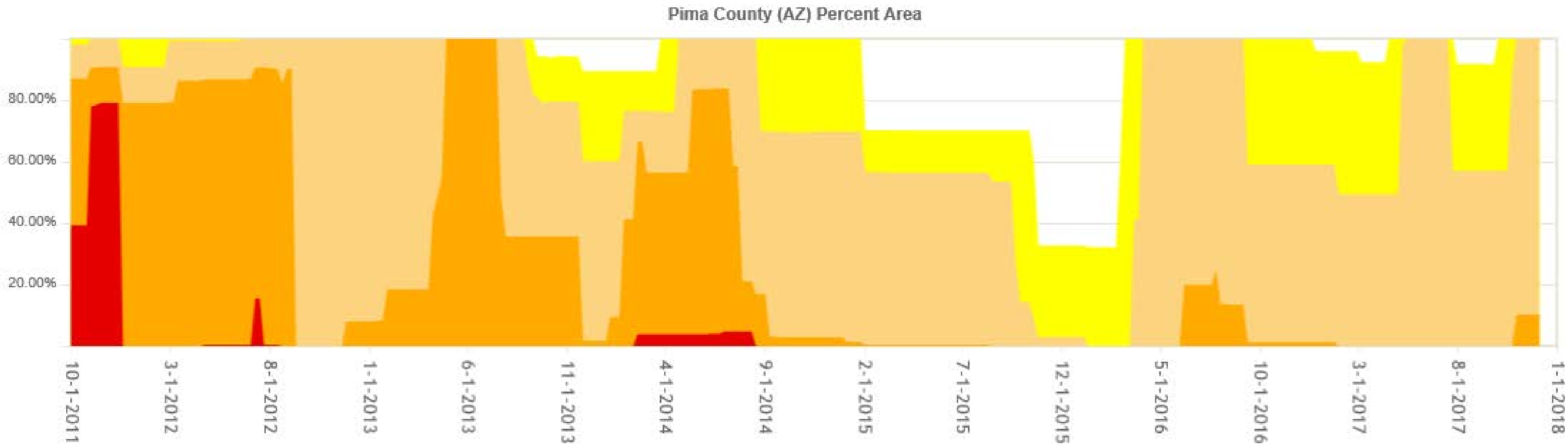


Figure 1. Pima County Drought 2012-2017 (U.S. Drought Monitor)

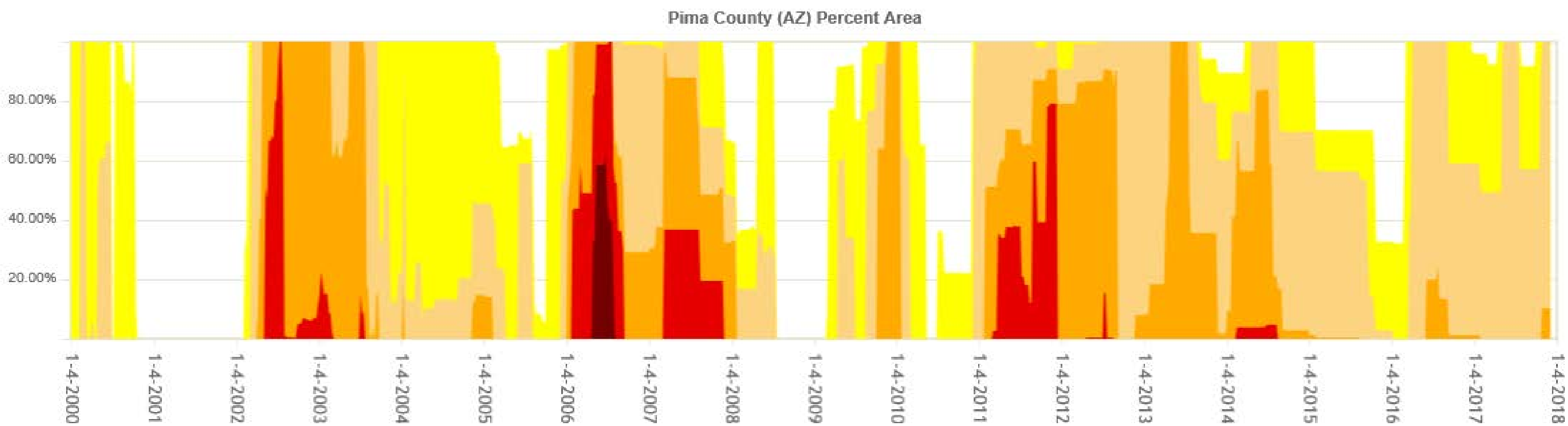


Figure 2. Pima County Drought 2000-2017 (U.S. Drought Monitor)

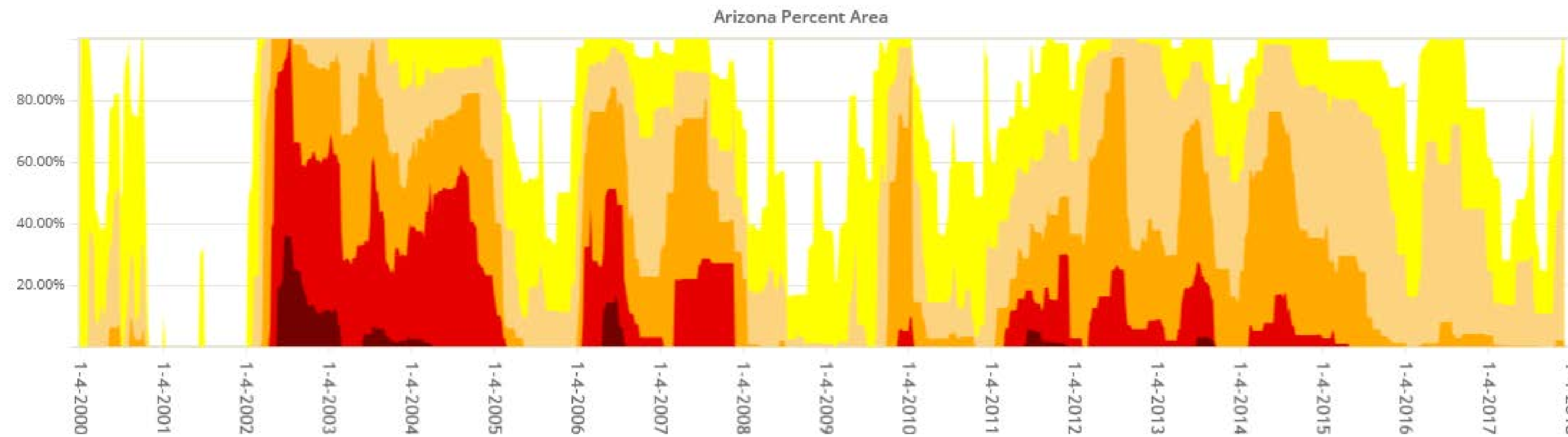


Figure 3. Arizona Drought 2000-2017 (U.S. Drought Monitor)

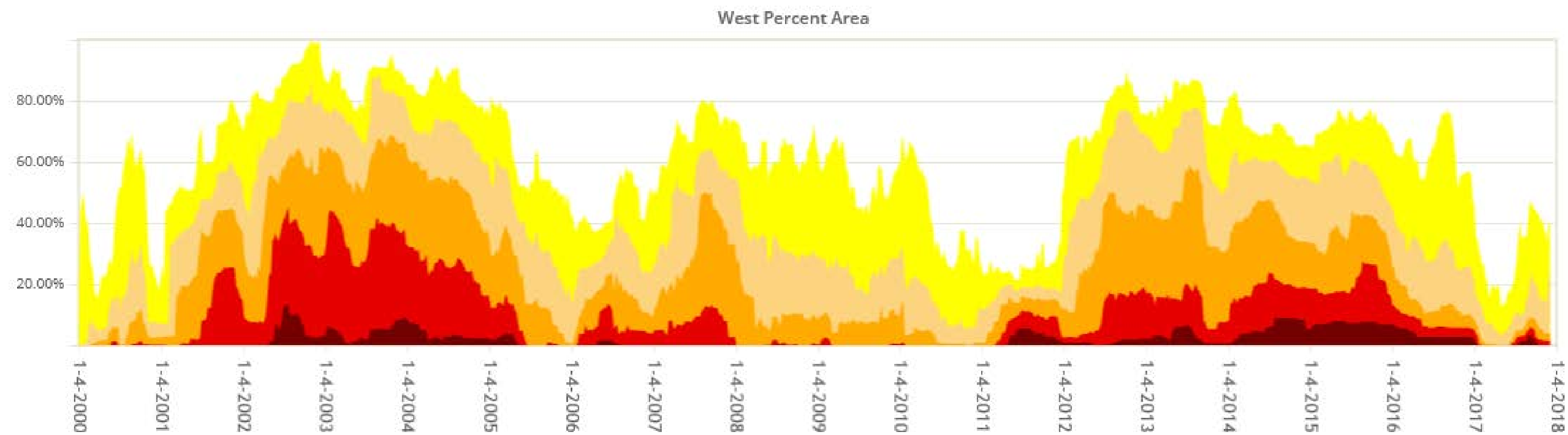


Figure 4. Western States Drought 2000-2017 (U.S. Drought Monitor)

PIMA COUNTY DROUGHT IMPACTS AND RESPONSE

In 2006, the Board of Supervisors approved a Drought Response Plan and Water Wasting Ordinance under Title 8, Section 8.70 of Pima County Code that included the formation of a Drought Monitoring Committee. The Committee met regularly to coordinate drought public awareness, provide impact assessment information to local and state leaders and to implement and initiate local mitigation and response actions. The Committee continues to meet, now functioning as Pima County's Local Drought Impact Group (LDIG) for the Arizona Statewide Drought Program.

In 2007, Pima County declared a Drought Stage One, in coordination with the region's water providers, which remains in effect today. The response actions associated with this declaration consist of asking the public to voluntarily reduce water use, asking restaurants to provide water only by customer request and urging hotels and motels to conserve water. Drought declarations are recommended by LDIG and the County Administrator and approved by the Board of Supervisors.

Impacts

Wildfire

The 2017 wildfire season began with two significant southern Arizona wildfires, the Sawmill and Mulberry fires. As is typical, winter precipitation led to substantial vegetative growth which dried out during high spring temperatures before the monsoon season, priming fuel loads for wildfire. There were 29 large wildfires in southeastern Arizona burning more than 180,000 acres and 8 wildfires in Pima County consumed over 80,000 acres.

The Sonoita/Las Cienegas NCA affected area totaled more than 50,000 acres following six wildfires and numerous smaller, contained blazes. The Burro fire on Mt. Lemmon burned 27,238 acres. The Arivaca area experienced numerous smaller wildfires collectively burning 6,134 acres. The Frye fire, on Mt Graham, was one of the largest at 48,443 acres. Overall, the Safford/Cochise area had the most wildfires and acreage, 13 fires consuming 91,707 acres.

Cienega Creek and Empire Gulch may be impacted by ash runoff from the Sawmill fire burn scar after monsoon rains; a potential for fish and frog die-off was anticipated after the fire but significance is unknown without assessment.[vii]

A cursory accounting of wildfire in Pima County over the last five years discerns some recent increase in occurrence but no proven trend. In 2016, the County experienced increased activity with eight wildfires, twice the number occurring in 2015. In all, about 22 wildfires were ignited during the 2012-2016 period.

Heatwaves

In both 2016 and 2017, June temperatures became dangerous during historic heatwaves with mid-month highs approaching 117°F. June 2017 was the hottest on record with numerous temperature records set. Scientists have seen a "substantial increase in concurrent droughts and heatwaves" across the Southwest and the simultaneous event "could lead to a compound extreme event with significant impacts."[viii][ix]

Heat related illness/death

According to the Pima County Health Department, about 300 County residents a year experience heat stress that requires emergency room treatment, though that doesn't account for all heat induced illness. Unfortunately, in 2016 and 2017 several hiking deaths were reported.[x]

Human health impacts

Study has shown that during high-severity worsening drought conditions, mortality in western states statistically increases.[xi]

Air quality

Heat and a lack of rainstorms propagate high ozone and particulate levels as stagnant air and inversion layers build up pollution in areas experiencing drought impacts.[xii] Pima County Department of Environmental Quality (PDEQ) issued an air quality advisory in July due to possible elevated levels of particulate matter from the Burro fire.

Agricultural Loss

From 1995 to 2014, Pima County farmers and ranchers received $5.7 million in disaster related assistance funding from the U.S Department of Agriculture (USDA) for crop and livestock damages. Over $2.25 million of those funds were received in 2014, following three consecutive dry winters and a severe period of the current drought in Pima County.

Other direct costs such as increased pumping costs due to lowering of groundwater levels and costs to expand water infrastructure to compensate for reduced yields or to develop alternative water sources are a significant factor but difficult to estimate due to a lack of documentation.

Environmental impacts

Southern Arizona is experiencing significant natural resource impacts from multi-decadal drought. At the same time vegetation composition, or species mix, is shifting, plant communities are moving upslope threatening established communities at the upper elevations. Conditions are more suitable for spreading invasive species, such as buffelgrass, in lower elevation upland communities. Overall, species are shifting in abundance, distribution and phenology.[xiii]

The warming and more arid climate produces less water for valley-bottom aquatic and riparian systems and impairs hydrological function. Such impacts are most evident in the County's Cienega Creek Natural Preserve where the condition of riparian and aquatic plants have declined with loss of cottonwood trees and mesquite forests, changes that will likely impact threatened species such as the yellow-billed cuckoo.

Cienega Creek

The 32 shallow groundwater areas in Pima County are important for riparian areas that are dependent on groundwater. Sustained drought conditions can adversely impact groundwater levels if nearby well owners pump more groundwater to mitigate drought effects on their property. Invasive species like buffel grass and tamarisk and fewer birds, Gila Topminnows and aerial arthropods are still being observed in Pima County. Pima Association of Governments' (PAG) stream wet-dry mapping protocols and shallow groundwater outreach are now available to help increase understanding of drought and water use in riparian systems.

Cienega Creek, in eastern Pima County, continues to show the impacts of sustained drought. PAG's drought reporting uniquely depicts the localized drought impacts on a shallow groundwater dependent system, important for habitat and rural residents dependent on this water source. Streams and rivers are rare exceptionally productive systems in the arid landscape of Arizona that are especially sensitive to changes in water availability. PAG has consistently monitored the shallow groundwater-dependent riparian area of Cienega Creek Preserve on a monthly and quarterly basis since 1989 and reported the findings to ADWR for compilation into state records. PAG documented pre-monsoon (May/June) conditions in the Riparian Health Assessment, 2017:

“Since 2010, Cienega Creek’s seasonal baseflow has ranged from approximately one to four miles within the course of a year, while Davidson has ranged from zero to just under one mile.

In 2017, PAG observed a decrease in Cienega Creek’s perennial flow extent following improvement in 2016. This year, June creek flows were present in 15% of the 9.5 mile monitoring area, which had flowed perennially in 1985. This result fits the long-term downward trend, but is improved since record lows were observed between 2011 and 2015. Davidson Canyon saw an increase, with the second highest perennial flow observed since 2006. Davidson results include the length of both flowing segments and phreatic pools.”

Agua Caliente Park

Located northeast of Tucson, Agua Caliente Park has historic and cultural significance for its 150,000 annual visitors. The park’s focal point is a natural artesian spring that feeds a creek and produces an abundant variety of oasis vegetation and a habitat for native species. The natural spring has been historically pumped to feed a pond which produces a recreational element for neighborhood residents and park visitors. Over the last several years, water levels have declined making pumping ineffective and eventually unable to keep the pond filled. Plastic liners have been installed in both ponds to limit seepage. Well pumping could only sustain one pond after failure of the spring but with both liners and improved hydrology it may be feasible to keep two ponds filled at least part of the year.

Drought Response

Pima County has advanced drought mitigation and adaptation strategies through numerous policies and action plans involving various departments and multi-jurisdictional groups.

- Pima County Office of Emergency Management has reviewed all hazard risk profiles to include drought and its impacts in the Multi-Jurisdictional Hazard Mitigation Plan, which establishes a comprehensive County-wide, all-hazards structure to provide for successful and well-organized coordination of Pima County mitigation activities. The 2017 update addresses drought risk and this year Pima County and surrounding jurisdictions approved the plan. The Pima County Community Wildfire Protection Plan has been developed in accordance with requirements of the Healthy Forests Restoration Act of 2003.
- Pima County Health Department collaborated with other departments to distribute heat safety tips through brochures and placards at favorite attractions, hotels, places of recreation and County service buildings.
- The Lower Santa Cruz River Basin Study is a three year partnership between federal, state and local water managers to identify supply-demand imbalance in the Tucson management area through 2060 due to climate change and other factors. The study will develop strategies to improve water reliability for all water use sectors under different scenarios of climate change and growth. Pima County is a co-manager of the study in partnership with the US Bureau of Reclamation.
- A Lower Santa Cruz River Management Plan seeks to balance uses of the river and manage its water resources to protect the riparian and aquatic habitat along the effluent-dependent Santa Cruz while maximizing the beneficial and efficient use of effluent. This effort is informed by the Sonoran

Institute's Living River report series which has documented the river's changing conditions since treatment upgrades have improved water quality. A public and stakeholder comment period is underway.

- An Underground Storage Facility (USF) application was completed for the County Avra Valley Water Reclamation Facility Black Wash project. This recharge facility is now operational, replenishing the aquifer and earning long term storage credits. A Green Valley facility USF is pending due to additional hydrologic study.
- The Conservation Effluent Pool (CEP) is an effluent allocation set aside pursuant to intergovernmental agreements between the City of Tucson and Pima County for use in riparian restoration projects.
- Conserve to Enhance (C2E) urges water conservation that translates into donations to support environmental enhancement. C2E participants have saved 10 million gallons of water since the program inception in 2011, through conservation strategies ranging from behavioral changes to rainwater harvesting installations. C2E has awarded funding to local neighborhood projects totaling approximately $100,000 in investment.
- The land conservation, management and monitoring goals of the Sonoran Desert Conservation Program and Conservation Land System are advancing the stewardship of wildlife habitat and water.
- Pima County partners with ranch managers to improve drought resilience by lining stock tanks to prevent seepage while simultaneously establishing new colony sites for the threatened Chiricahua leopard frog.

In 2010, Pima County and the City of Tucson completed the Water & Wastewater Infrastructure, Supply and Planning Study (WISP). An important outcome of the study was the 2011-2015 Action Plan for Water Sustainability. The final year of the action plan has been implemented and a report card itemized successful completion toward shared goals and recommendations. Pima County will continue reporting on water resource management activities that advance the Action Plan and water sustainability efforts.

In addition to the WISP Study, Pima County prepared the Water Resources Asset Management Plan (WRAMP) in 2012, a distinct water resource planning process to guide the County in maximizing its water assets. WRAMP, drafted by the County's Water Management Committee, is designed to provide direction in executing County Board of Supervisor Policy F 54.9 Water Rights Acquisition, Protection and Management. WRAMP includes directives to maintain an up to date central database of all water rights and wells, map and inspect wells and develop strategic plans for the County's reclaimed water, long term storage credits and surface and groundwater rights. The Strategic Plan for Use of Reclaimed Water has been developed and accepted by the County Administrator; multiple recommendations support the objective of maximize the County's water resources asset value and the production and use of reclaimed water to sustain and protect the natural environment.

Pima County's Regional Wastewater Reclamation Department (RWRD) effluent production and management has contributed to the future reliability of the region's water resources through the use of reclaimed water for groundwater recharge, reuse, and environmental restoration throughout the community. From 2005-2016, over 500,000 acre feet (af) of high-quality reclaimed water has been released into the Lower Santa Cruz River with 169,000 af permanently dedicated to the local aquifer; approximately 1,500 af/year is accounted towards riparian evapotranspiration, benefiting the river habitat and over 2,000 af has been directed towards County environmental purposes; RWRD has delivered over 175,000 af to the Tucson Water reclaimed system, which water providers have used to replace potable use and the County has wheeled 12,000 af to its parks and turf areas; recharge efforts have led to the development of a flexible, renewable water supply of over 150,000 af.

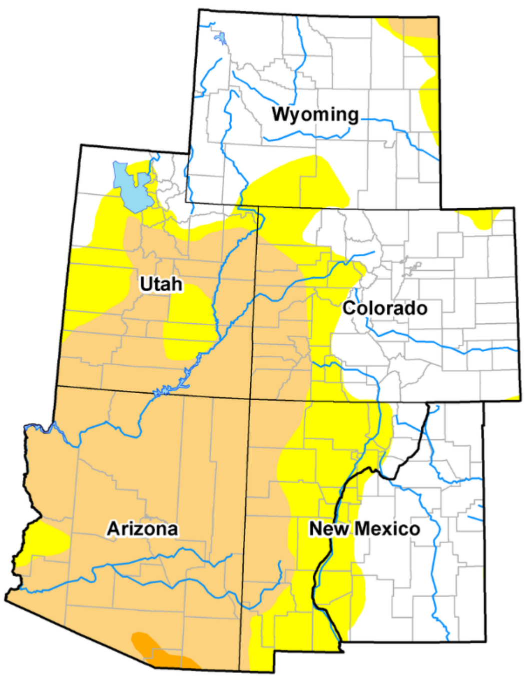
WEST-WIDE DROUGHT 2012-2016

"Recent drought throughout the West has affected economies and communities in ways both visible and hidden. Fallowed fields, bare streambeds and near-empty reservoirs provide stark reminders of drought's effects, but they do not tell the full story. Drought has also resulted in lost tourism revenues, increased fire risk, decreased quality of wildlife habitat, unemployment and livestock losses." – Western Governors' Association Drought Forum Report, 2015

The five year drought period California is currently recovering from was the worst in over 400 years. Drought in other western states, especially those of the Colorado Basin, affects Arizona and Pima County with various direct and indirect impacts from water supply to wildland fire funding. As an example, with recent historic precipitation surpluses, California is able to conserve more water in Lake Mead, helping in the overall effort to forestall a Basin water shortage.

Colorado River Basin - Inter-Mountain West Drought Early Warning System (DEWS)

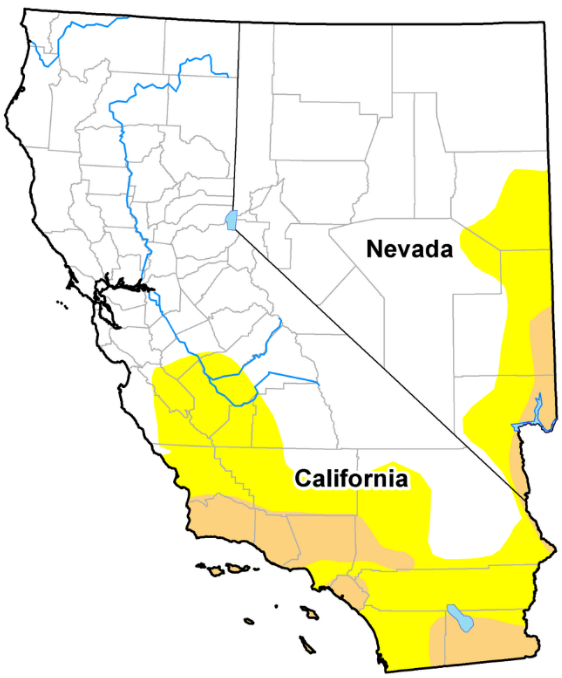
As of December 2017, 37.2% of the Inter-Mountain West is drought-free, 20.5% is Abnormally Dry, 41.9% is in Moderate drought and 0.5% is in Severe drought.



Week	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current (12/17)	37.19%	62.81%	42.36%	0.51%	0.00%	0.00%
Last Week	47.33%	52.67%	18.22%	0.51%	0.00%	0.00%
Three Months Ago	67.36%	32.64%	5.41%	0.08%	0.00%	0.00%
Start Cal Year	47.82%	52.18%	20.83%	1.71%	0.00%	0.00%
Start Water Year	60.65%	39.35%	5.23%	0.00%	0.00%	0.00%
One Year Ago	28.37%	71.63%	26.33%	2.66%	0.00%	0.00%

Colorado River Basin - California/Nevada DEWS

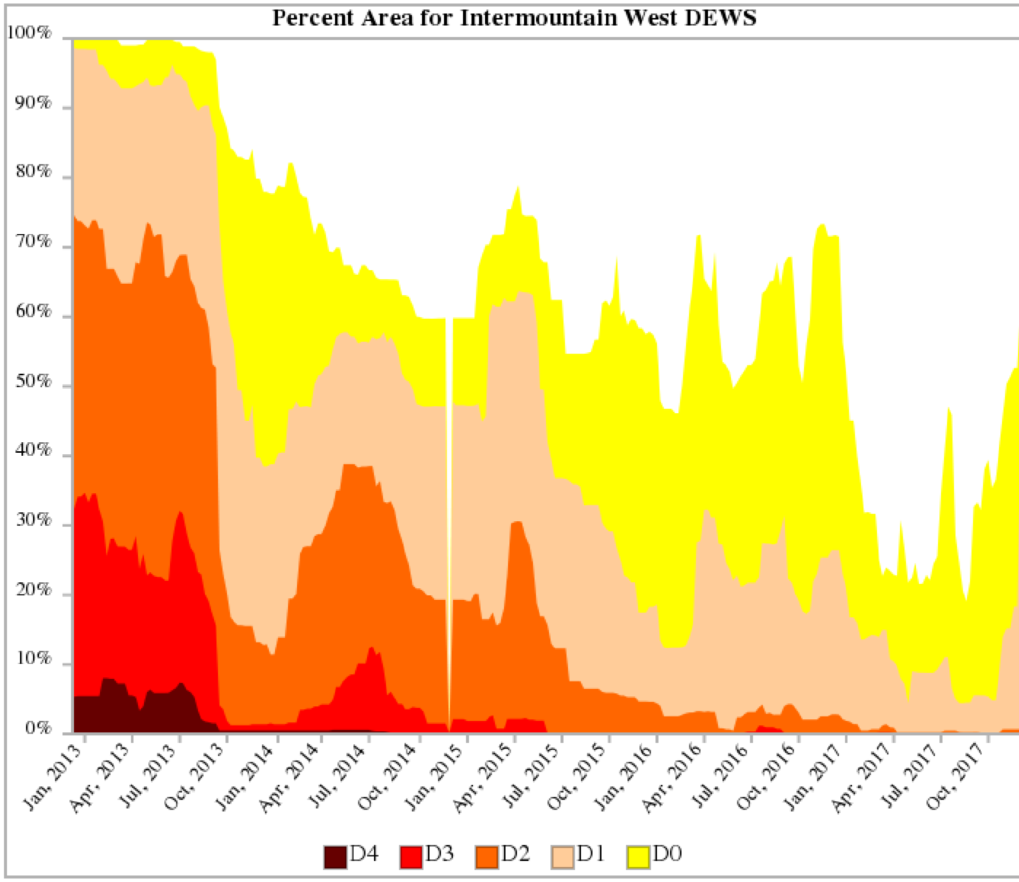
As of December 2017, 72.7% of the California/Nevada West is drought-free, 20.1% is Abnormally Dry, 7.2% is in Moderate drought and there is no Severe drought.

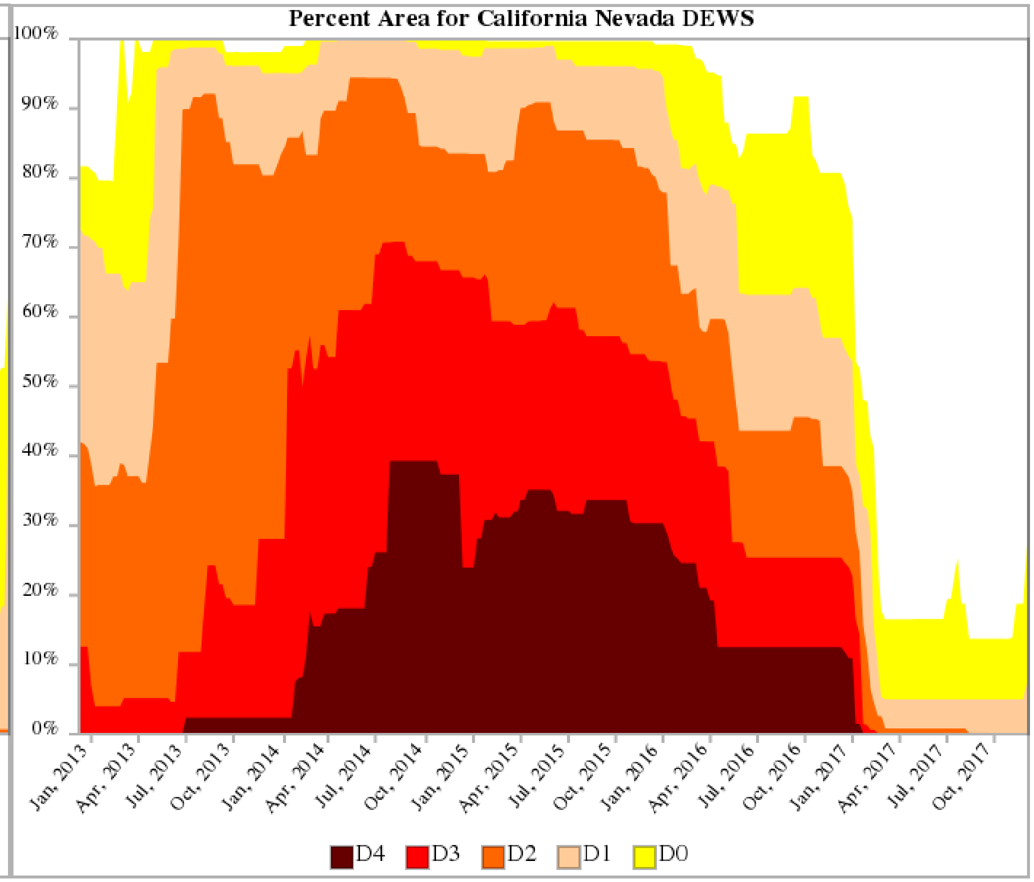


Week	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current (12/17)	72.70%	27.30%	7.21%	0.00%	0.00%	0.00%
Last Week	81.39%	18.61%	4.85%	0.00%	0.00%	0.00%
Three Months Ago	86.44%	13.56%	4.85%	0.02%	0.00%	0.00%
Start Cal Year	25.81%	74.19%	53.63%	34.73%	22.54%	10.77%
Start Water Year	86.44%	13.56%	4.85%	0.00%	0.00%	0.00%
One Year Ago	19.11%	80.89%	57.03%	38.55%	25.30%	12.38%

Drought in the Inter-Mountain West peaked in 2012-2013 with Extreme and Exceptional drought while Severe drought persisted through 2015.

The California/Nevada West drought was only recently ameliorated by several atmospheric river events that left record snowpack. Drought peaked in California in 2014-2015 with over 75% of the state in Exceptional or Extreme drought; conditions improved slightly though southern California still struggled with Exceptional drought into 2017.





WEST-WIDE IMPACTS

Western states are generally more arid with variable precipitation and thus rely on large infrastructure projects to store winter runoff during specific times of the year to meet agricultural and municipal demands. The West is experiencing a long-term decline in precipitation and runoff, the last 15 years the driest of historic record. Warmth, common to recent western drought, is shifting the timing of snowmelt runoff, impacting the predictable and reliable delivery of water when it is needed for agriculture and other sectors. Western rivers, wetlands and forests are facing accelerated decline from drought and record high temperatures. Water scarcity among highly competitive use sectors impacts policy and stakeholder negotiation as water managers and legislators weigh tradeoffs in response to water use imbalance.[xiv]

Wildfire and Ecosystem

Wildfire, especially in the West, is becoming a more severe and prolonged threat. The seven Colorado Basin states experienced 72,950 wildfires during the 2012-2016 period, burning over 8.3 million acres. Trends have emerged over the historical wildfire record: the number of wildfire events have not increased and remain variable but the total acres burned and average acres per fire have increased since the 1990s to twice the 54-year average.[xv] The six worst fire seasons of record, dating to 1960, have occurred since 2000, in part due to changing climate- high temperatures, widespread drought, early snowmelt, spring growth and insect and disease damaged trees.

Consequently, the cost of wildfire protection and suppression nationally has risen from $1 billion annually in the 1990s to an average of $3 billion since 2002, or nearly half the US Forest Service budget.[xvi] A majority of wildfires occur in California which necessarily absorbs almost half of suppression funding in the West.[xvii] Such rising costs have forced federal agencies to transfer funds from hazardous fuels reduction, rehabilitation and other programs that benefit forest management.[xviii] Healthy forest watersheds are vital to the water supply and water quality of the Colorado Basin.

Vast timber die-off is occurring; the US Forest Service estimates there are 6.3 billion dead trees in 11 western states. Bark beetle infestations, bolstered by high temperatures and lack of hard freezes, account for approximately 20 percent of the die-off, the rest succumbing to drought, fire and other causes. About 17 percent of all standing trees in the 11 states are dead, double the proportion measured in the 1990s.[xix]

Heatwaves

All the Basin states experienced the same heatwave that Pima County endured in June. In August, the Pacific Northwest reached record high temperatures during another heatwave event.

Agricultural Loss

Colorado Basin state agriculture received approximately $888 million in USDA disaster payments between 2012-2014. More than 78 percent of those funds were received in 2014 alone, or $696 million. Claims for New Mexico, Colorado and California comprised 70 percent of funding.[xx]

Energy Generation

The Western Area Power Administration (WAPA) sources 56 hydropower plants. Poor hydrology during drought episodes limits power generation forcing WAPA to rely on power purchases to cover the gap in committed power resulting in increased expense and rates.[xxi] Hydroelectric generation across California and the Pacific Northwest dropped 32 percent between 2011 and 2015 causing a shift to reliance on natural gas generators. Hydropower generation started to recover in 2016 above the previous five-year average.[xxii] In 2011, power was cut to 2.7 million California customers for 12 hours when high temperatures drove demand above capacity, tripping transformer and transmission infrastructure in Yuma.[xxiii]

River Recreation

Recreational activity along the Colorado River Basin states generates $17 billion in retail sales, $1.6 billion in federal taxes and another $1.6 billion in state and local taxes. The total value of spending from recreational expenditure totals $25.6 billion with businesses and employees earning $10.4 billion annually. If Colorado River recreation ceased, unemployment rates in Arizona would increase 2 percent.[xxiv]

IMPLICATIONS OF CLIMATE CHANGE FOR DROUGHT & WATER SUPPLY

A greater understanding of the link between warmer temperatures and drought impacts is being revealed by recent published research.

An Overpeck/Udall study found Colorado River average flows declined 19 percent between 2000 and 2014 based upon the 1906-1999 average. Higher temperature in the basin (+1.6°F) induced by climate change is responsible for approximately one-third of that reduced streamflow. Where previous comparable drought periods were caused by a precipitation deficit, the past 15-year drought is indicative of Colorado River flow sensitivity to high temperature. Climate model projections show continued warming will drive temperature induced streamflow reductions further to 20-30 percent by 2050 and 35-55 percent by 2100.[xxv]

A USGS study substantiates a decline in Upper Colorado River Basin (UCRB) streamflow correlated to recent warming. Runoff efficiency (the ratio of streamflow to precipitation) has been substantially reduced since the late 1980's, due to increases in temperature. The UCRB reductions are being driven by the larger effect of warm season (April-September) temperature increases- evaporation or snowmelt rather than changes from snow to rain during the cooler season is the cause. The study warns of the likelihood of unprecedented UCRB drought as the "results suggest that if temperatures continue to increase, as projected by climate models (Udall and Overpeck, 2017), there will be an increasing negative effect of temperature in driving larger magnitude streamflow declines in the UCRB."[xxvi]

Additional research has found higher regional temperature in the Southwest will increase the risk of megadrought (lasting 35+ years) to a 20-50 percent chance this century. Where surface moisture is lost most dramatically to evapotranspiration, megadrought is 70-99 percent probable. This probability is evident in the modeling regardless of precipitation - whether a slight increase, no change or decrease. A significant reduction in greenhouse gas emissions could cut megadrought risk almost in half.[xxvii]

Climate change has been linked to declining western snowpack. Obviously, snowpack has a direct connection to streamflow; snowpack loss results in decreased streamflow. One study found a 10-20 percent drop in snowpack between 1980-2000. Climate modeling matched the historical record for snowpack loss, indicating climate change and not natural factors alone as cause. Within 30 years, snowpack could further decline by as much as 60 percent though the future range may fluctuate.[xxviii]

As droughts are discrete events, scientists are cautious in making direct connections between any specific drought event and climate change. However, there are connections that can be drawn between the probability of increased drought and severity of impacts due to rising temperatures, increasing aridity and diminishing hydrology.

As an example, in 2015 the Pacific Northwest experienced what was called a "wet drought". While winter precipitation was only 30 percent below average, record high temperatures exaggerated the precipitation deficit, reducing snowpack and causing earlier snowmelt. The snowpack averaged 25 percent of normal and in some areas only 3 percent or absent entirely. In eastern Oregon, reservoir managers warned junior water rights users of a 40 percent or greater reduction in allocations.[xxix]

As climate change reduces the snowpack and streamflow of the Colorado River Basin that feeds system reservoirs and the CAP canal that Pima County relies upon for its renewable water supply, rising temperatures are impacting the region's source of local supply- monsoon precipitation that recharges groundwater aquifers.

Monsoon Implications

The monsoon season provides half of local annual rainfall. There is no dominant predictive signal to forecast monsoon events similar to the meteorological tools used for winter season forecasts. A new study has recognized a terrain feature likely responsible for directing monsoon low-level moisture from the Gulf of Mexico from the east into Arizona. The Chiricahua Gap is a break separating mountain ranges of the Continental Divide on the Arizona-New Mexico-Mexico border. Moisture is funneled through the gap between the Rocky Mountains and the Sierra Madres instead of moving over and down the ranges, which typically warms and dries the air. Roughly 75 percent of the heaviest monsoon rain days originate through this gap moving west into Arizona; the gap facilitates 80 percent of the total low-level water vapor transport between the Continental Divide.[xxx]

Continued warming will affect the lower atmosphere's ability to develop monsoon thunderstorms and precipitation. According to improved climate modeling of North American monsoon physics, annual monsoon rainfall could decrease by up to 40 percent, in turn reducing total annual rainfall by 20 percent. The monsoon represents 25 percent of supply that recharges groundwater aquifers.[xxxi]

Further research has found long term precipitation changes have resulted in less frequent but more extreme and damaging monsoon storms and flooding. Though intensity has increased, statewide total rainfall has declined. The Tucson region is outside the area of increased intensity, which in part, stretches from Phoenix to the Tohono O'odham Nation.[xxxii]

Wildfire and Ecosystem Implications

Drought and seasonal temperature and precipitation affect fire potential. Wildfires are becoming larger, more intense with extreme fire behavior consuming more acreage as fire season starts earlier and lasts longer than in previous decades. Rising temperature associated with climate change is impacting wildfire occurrence and behavior.[xxxiii]

While a number of factors, such as historical fire suppression and natural climate variability, could contribute to increased wildfire activity, researchers have found that climate change has "significantly enhanced fuel aridity" across the West and contributed to an additional 4.2 million ha loss of forest from 1984-2015, concluding that "climate change has emerged as a driver of increased forest fire activity and should continue to do so while fuels are not limiting."[xxxiv]

Study indicates an increase in wildfires could double soil erosion in western watersheds by 2050. Sedimentation of headwater supply negatively affects water quality and transmission infrastructure. Hydrophobic and hard soils prevent rain and snow from percolating into the ground affecting stream channel stability and aquatic ecosystems.[xxxv]

Wildfire, air quality and human health impacts are directly related. Increased wildfire activity will raise levels of fine particulate matter (PM2.5) which will interact within an increasing greenhouse gas environment to create "Smoke Waves", or episodes of high air pollution from wildfire. Adjusting for climate change, a study indicates that more than 80 million people in the West could experience a 57 percent increase in the frequency and 31 percent increase in intensity of "Smoke Waves", thus having a significant impact on human health.[xxxvi]

Drought recovery will become more challenging as frequency, duration and severity increases, the time required for an ecosystem to recover to a pre-drought functional state increases. Full ecosystem recovery may not occur leading to chronic impairment and "widespread degradation of the land carbon sink".[xxxvii]

Heatwave Implications

Researchers believe heatwave lethality was previously underestimated and as the climate changes, such heatwaves will become more frequent and worsen causing more lethal heat events.[xxxviii]

Air Quality Implications

As the Southwest becomes drier, dust storms will become more prevalent and the frequent dust storm events will drive an already increasing Valley fever infection rate. Over the past two decades there has already been a 240 percent increase in large dust storms, leaving researchers concerned with the potential for desertification and "Dust Bowl" events.[xxxix]

Energy Generation Implications

The potential for future extreme heat and drought events threatens the electrical grid that supplies the Southwest. High temperatures ramp up peak electricity demand to power air conditioners, which can overload generation and transmission capacity. Such heat reduces the efficiency of power plants, transmission lines and substations. Power transmission corridors located approximate to wildfire prone areas are subject to damage. Increased blackouts and brownouts are possible.[xl] As for hydropower, it is of course dependent on reservoir storage and streamflow and the projected decrease in both due to climate change will negatively affect energy generation during increasing demand in a warming region. A policy study of climate and the Colorado River Basin recognizes "hydropower capacity relies on consistent stream flows and reservoir storage, both of which are threatened by a disparity between supply and demand enshrined in current basin water policy" and suggests "sustaining hydropower at its current level may prove untenable."[xli]

Agriculture Implications

In the event of significant water shortages and/or reallocation, changes in western agricultural productivity would have direct implications for food supply and security. Such would include loss of agricultural sector sustainability, rural socioeconomic decline, increased food prices, decreased food choice and security, increased carbon footprint for imported food and decreased trade balance.[xlii]

Policy Implications

Sustainable water resource management in the West requires new technologies, market-based solutions and policies that both increase supply and decrease demand in a planning and integration process that surpasses previous efforts in scope, jurisdictional and multi-sectoral engagement and planning timelines. Multi-decadal droughts occur on different timescales to most drought and water planning. Cooperative efforts for a sustainable water strategy should be comprehensive and trans-regional. Preserving ecosystem services and biodiversity during decreasing water supply options for other demands will be challenging. As climate change increases aridity and reduces available water resources, the Southwest is likely to incur some of the highest economic expenses and environmental losses.[xliii] In this light, adaptation/mitigation of climate change is a cost avoidance strategy.

Economic Implications

Previous efforts to predict the economic costs of climate change have proven difficult given levels of uncertainty, but advances in computer modeling provide new data on the negative economic impact expected from rising temperatures, impacts that would be highly unequal among the states and most severe for Arizona. Nationwide, researchers estimate economic damages of 0.7 percent of gross domestic product (gdp) per year by 2080 for every 1°F rise in global temperature. The greatest degree of loss will occur in states and counties with existing warm climates; Arizona could experience losses worth 10-20 percent of gdp and experts caution the model may be conservative in some conclusions given it does not factor reduced labor productivity compounded over time nor migration impacts.[xliv]

Corporations are aware of increased competition for water and the long term emerging risk of water scarcity impacting operations, production and supply chains. Industries are integrating water risk management into their internal governance to communicate comprehensive water stewardship and risk reduction to investors.[xlv] Risk assessments of local water supply, water infrastructure, governance and conservation will inform corporate site selection and investment.

Credit ratings for state and local bonds now incorporate climate change exposure and mitigation considerations according to Moody's Investment Services. Municipalities could face credit rating downgrades and higher interest rates based on their exposure to climate risks and inaction to manage those risks.[xlvi]

CONCLUSIONS FOR PIMA COUNTY & RECOMMENDATIONS

Drought will be a persistent and increasingly intensive challenge for Pima County and western states. Southwest droughts will become hotter, more severe and more frequent as warming continues with longer and hotter heatwaves resulting in reduced runoff and streamflow, reduced soil moisture and changes in land cover and ecosystem function.[xlvii]

Wildfires are becoming larger, more intense with extreme behavior as wildfire season starts earlier and lasts longer. The end of wildfire season in Pima County is dependent upon the start of an active monsoon pattern. Locally increased aridity and weak monsoons could extend the wildfire season. Regionally, wildfire crews, assets and infrastructure have been considerably stretched with a potential to exhaust all agency fire resources. Also under strain is federal funding for wildfire suppression and prevention. Longer, more intense local wildfire seasons could occur in a scenario of limited or severely curtailed national resources and federal funding.

It is important to distinguish between destructive and beneficial wildfire impacts. Fire is of course a natural part of the ecosystem; when it occurs at low-intensity in healthy systems it reduces fire danger and contributes to habitat health, returning nutrients to the soil and encouraging ecological diversity. The recent Burro fire serves as an example of a lower-intensity fire burning in an appropriately healthy area.

Extreme heat and heatwaves in Pima County have already proven deadly. More frequent and extreme heat events would pose an additional risk to public health. Energy generation and transmission is taxed during these events; subsequent brownouts and blackouts would subject residents to extreme heat without air conditioning. Such intense heat also reduces air quality, compounding public health concerns.

In the future, current levels of hydropower generation may not remain tenable at a time of rising energy demand serving an increasing population drawing power from an aging grid. Disruption to power wholesale markets and required power purchases to cover gaps in reliable electric service will drive costs higher and increase greenhouse gas (GHG) emissions. Large power users prioritize the diversification of their power portfolio, making strategic long term power purchase agreements. Solar power generation serves as mitigation of GHG and an alternative, drought insensitive power supply, increasing reliability.

Drought persists in Pima County with continual impacts which could worsen. The County has a policy framework and Drought Management Program in place which is integrated within Pima Prospers and the County Hazard Mitigation Plan that can escalate response should drought worsen. Continued diligence in assessing drought and its varied impacts and staying apprised of the latest scientific understanding of drought and climate change will better position the County for effective response.

Drought has been defined in terms that primarily describe drought effects on sectors that intersect human activity, such as agricultural and socioeconomic drought. Researchers, having found current definitions lacking, focused on the impact of drought on nature and human communities, how the two interact and the ecosystem services that benefit both. Ecological drought is an episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems. The definition is to illustrate "1) the roles that both people and nature play as drivers of ecosystem vulnerability, 2) that ecological drought's impacts are transferred to human communities via ecosystem services, and 3) these ecological and ecosystem service impacts will feed back to both natural and human systems."[xlviii]

Pima County Resolutions 2017-39 and 2017-51 reaffirm the County's commitment to address climate change and align County operational efforts with the Paris Agreement to reach carbon emissions reduction targets by 2025 in cooperation with a broad coalition of state and local governments, institutions and businesses. The County will accelerate solar installations by as much as 42 megawatts, improve energy efficiency of its facilities and fleet, create a Downtown Energy District served by the County's Central Plant and install green infrastructure on County property and rights of way – all part of the effort to reduce County operational emissions by 40 percent.

Staff will continue to 1) monitor local, state and regional drought conditions, assess direct and indirect impacts and analyze cascading effects, 2) stay apprised of climate and drought research and accepted adaptation and mitigation strategies, 3) participate, through County LDIG, in state drought monitoring, outreach and planning, 4) collaborate with local water providers in coordinating County drought declarations, 5) participate in water users' advisory groups, 6) monitor relevant local, state and federal water policy and legislative proposals, 7) evaluate trends in key resources such as surface water, groundwater and vegetation to inform assessments, and 8) incorporate, where relevant, drought programming with other County sustainability efforts to align with climate change mitigation.

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