DROUGHT IMPACTS TO CRITICAL INFRASTRUCTURE

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PREPARED BY: OPERATIONAL ANALYSIS DIVISION

SCOPE

The Department of Homeland Security's Office of Cyber and Infrastructure Analysis (DHS/OCIA)[1] produces Critical Infrastructure Security and Resilience Notes in response to changes in the infrastructure protection community's risk environment from terrorist attacks, natural hazards, and other events. This product focuses on the impacts from persistent drought conditions throughout the United States. This Critical Infrastructure Security and Resilience Note supports DHS leadership, the DHS Protective Security Advisors, and other Federal, State, and local agencies.

This note was developed in coordination with the DHS National Protection and Programs Directorate (NPPD) Office of Infrastructure Protection's Sector Outreach and Programs Division and Protective Security Coordination Division.

OCIA will continue to monitor conditions, and will produce additional incident-specific analysis if significant drought occurs.

KEY FINDINGS

- **OCIA assesses that Water and Wastewater Systems, Energy, and Food and Agriculture are the critical infrastructure Sectors most vulnerable to drought conditions.**
- **OCIA assesses that all sectors may be impacted by cross-sector dependencies and cascading impacts from the loss of water, agricultural, and energy services.**
- **OCIA assesses that while there is little that can be done to influence the weather patterns that cause drought, some preparatory measures and policies may help communities and infrastructure assets and systems to cope with the impacts.**

OVERVIEW

Drought is an insidious natural hazard to critical infrastructure. Although progress has been made to better understand drought, it is sometimes difficult to define because its impacts can vary from region to region. Its occurrences are complex, involving numerous interacting climate processes and various land-atmosphere reactions. Generally, it is characterized as a deficiency of precipitation over an extended period of time, usually a season or more, resulting in a water shortage for some activity, group, or environmental sector.[2]

Paleoclimate studies, which track climate changes across different geologic eras, indicate that the United States is historically susceptible to drought. Such studies look to major droughts in the past, such as the Dust Bowl of the

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[1] In February 2014, NPPD created the Office of Cyber and Infrastructure Analysis by integrating analytic resources from across NPPD including the Homeland Infrastructure Threat and Risk Analysis Center (HITRAC) and the National Infrastructure Simulation and Analysis Center (NISAC).
[2] NDMC, "What is Drought" www.drought.unl.edu/DroughtBasics/WhatisDrought.aspx, accessed January 2015.

1930s or the drought of the 1950s. These historic examples serve as guideposts to highlight vulnerabilities to drought.

The transition between fundamentally different climates may occur at national and regional levels simultaneously and within only a few years. For example, the United States experienced a major, national-level drought in 2012, and improvements were observed in 2013. The national drought area expanded during spring 2014, but was followed by a contraction later in the year (Figure 1). In 2014, the western United States saw a return of severe drought conditions with no notable recovery as of early winter 2014.

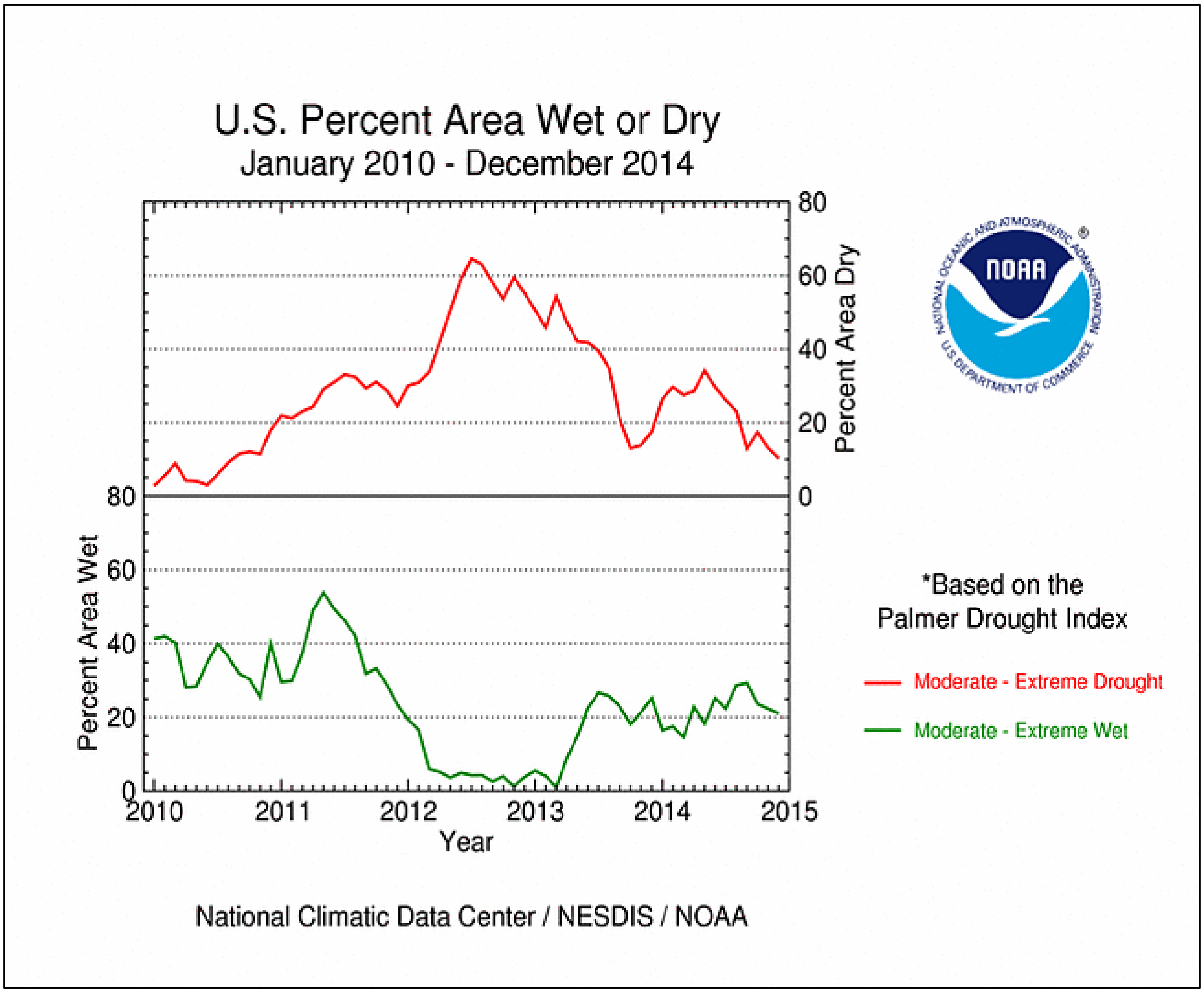

FIGURE 1—TREND OF NATIONAL RECOVERY FROM THE MAJOR DROUGHT OF 2012.[3]

[3] NOAA, "Trend of National Recovery", www1.ncdc.noaa.gov/pub/data/cmb/sotc/drought/2014/13/Reg110_wet-dry_xy_01101214-mod.gif, accessed January 2015.

TYPES OF DROUGHT

All droughts originate from a deficiency of precipitation, referred to as meteorological drought, but other types of drought and impacts can cascade from this initial deficiency. Figure 2 depicts the sequence of drought occurrence and impacts for commonly accepted drought types.

- **Meteorological drought:** When precipitation departs from the long-term normal.
- **Agricultural drought:** When there is insufficient soil moisture to meet the needs of a particular crop at a particular time.
- **Hydrological drought:** When deficiencies occur in surface and subsurface water supplies.
- **Socioeconomic drought:** When human activities are affected by reduced precipitation and related water availability.[4]

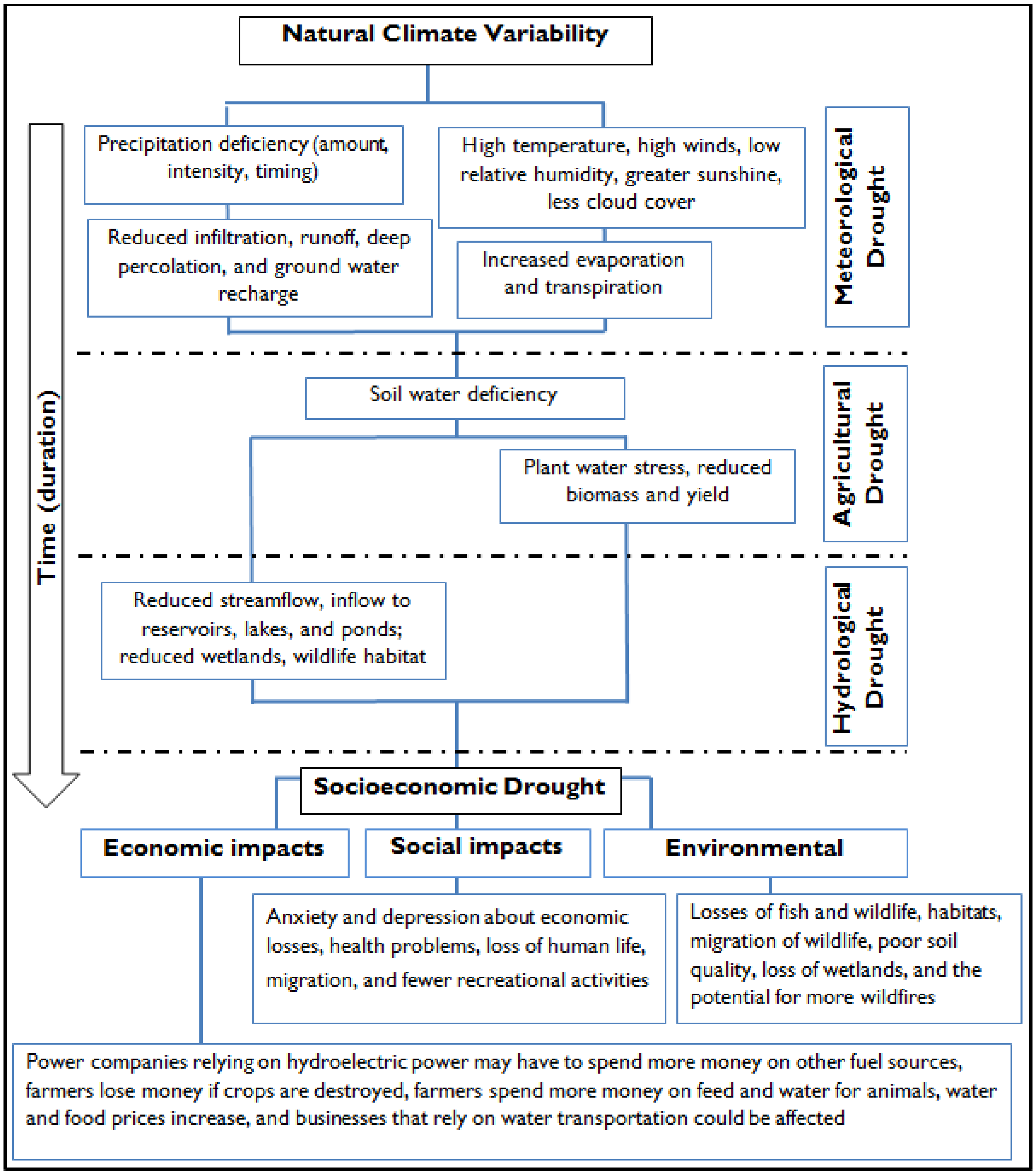

FIGURE 2—DROUGHT OCCURRENCE AND IMPACTS FOR COMMONLY ACCEPTED DROUGHT TYPES.[5]

[4] FAO, "Types of Drought", www.fao.org/docrep/017/aq191e/aq191e.pdf, accessed January 28, 2015.

MEASURING DROUGHT

The Palmer Drought Index, a widely used measure of drought, uses numerical values derived from weather and climate data to classify moisture conditions throughout the contiguous United States. If those weather patterns last a short time (e.g., a few weeks to a couple of months), the drought is considered "short-term." But if the weather or atmospheric circulation pattern becomes entrenched and the precipitation deficits last for several months to several years, the drought is considered "long-term." The impacts of both long-term and short-term drought result from the interplay between the natural event (less precipitation than expected) and the demand placed on the water supply. Furthermore, human activities such as agriculture, household use, and recreation can significantly exacerbate the impacts of drought.[6] For example, in California, over 50 percent of household water use was for non-indoor uses such as landscaping and other outdoor uses.

Another form of measuring drought is by classifying its intensity using the Drought Scale (D-scale). With the D-Scale, drought intensity is measured on a scale of D0-D4, with D1 (moderate drought) being the least intense and D4 (exceptional drought) being the most intense (Figure 3). Drought watch areas, D0, are characterized by the following:

- Drying out and possibly heading for drought;
- Are recovering from drought but not at normal conditions; or
- Are suffering long-term impacts such as low reservoir levels.[7]

According to the National Oceanic and Atmospheric Association's (NOAA's) Drought Monitor, as of March 31, 2015, approximately 31 percent of the country is experiencing moderate to exceptional drought (Figure 3).[8]

[5] NDMC, "Natural Climate Variability", www.drought.unl.edu/DroughtBasics/TypesofDrought.aspx, accessed January 28 2015.
[6] NDMC, "What is Drought", www.drought.unl.edu/DroughtBasics/WhatisDrought.aspx, accessed January 2015.
[7] NDMC, "U.S. Drought Monitor Classification Scheme", www.droughtmonitor.unl.edu/AboutUs/ClassificationScheme.aspx, accessed January 2015.
[8] NOAA, "U.S. Drought Monitor: Drought Condition (Percent Area): United States", www.droughtmonitor.unl.edu/MapsAndData/DataTables.aspx, accessed February 2015.

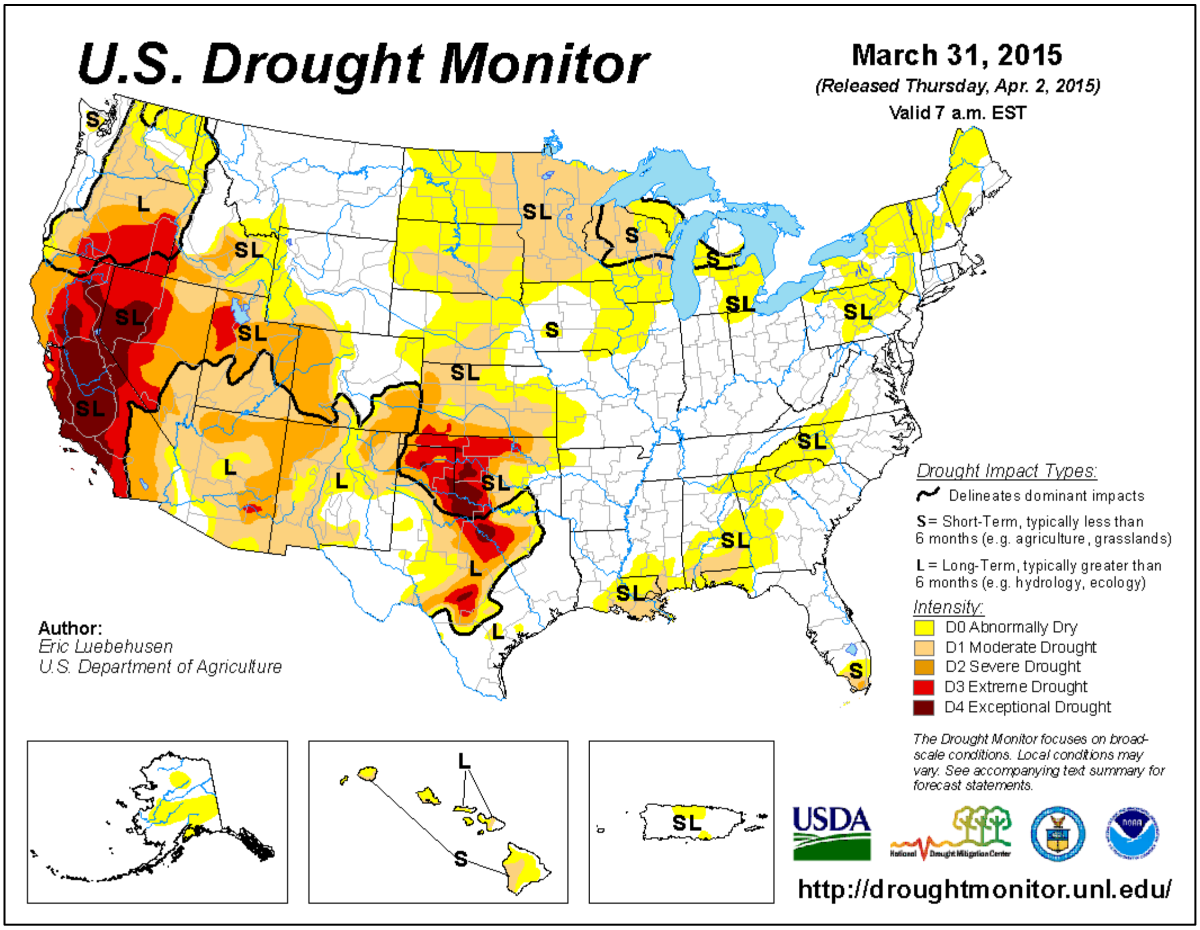

FIGURE 3—DROUGHT CONDITIONS FROM U.S. DROUGHT MONITOR.[9]

U.S. SEASONAL DROUGHT OUTLOOK

According to NOAA's seasonal assessment published on March 19, 2015 (Figure 4), with the gradual winding down of the wet season in the West, prospects for drought relief during the spring are low. Persistence or intensification of drought conditions is anticipated across the West, with drought development favored in western sections of both Washington and Oregon. In Arizona, Utah, and western portions of both Colorado and New Mexico, drought persistence or intensification is deemed most likely, as spring tends to be a relatively dry time of year, in advance of the summer monsoon.[10]

[9] NDMC, "U.S. Drought Monitor", www.droughtmonitor.unl.edu/, March, 2015.
[10] NOAA, "U.S. Seasonal Drought Outlook", www.cpc.ncep.noaa.gov/products/expert_assessment/sdo_summary.html, accessed April 2, 2015.

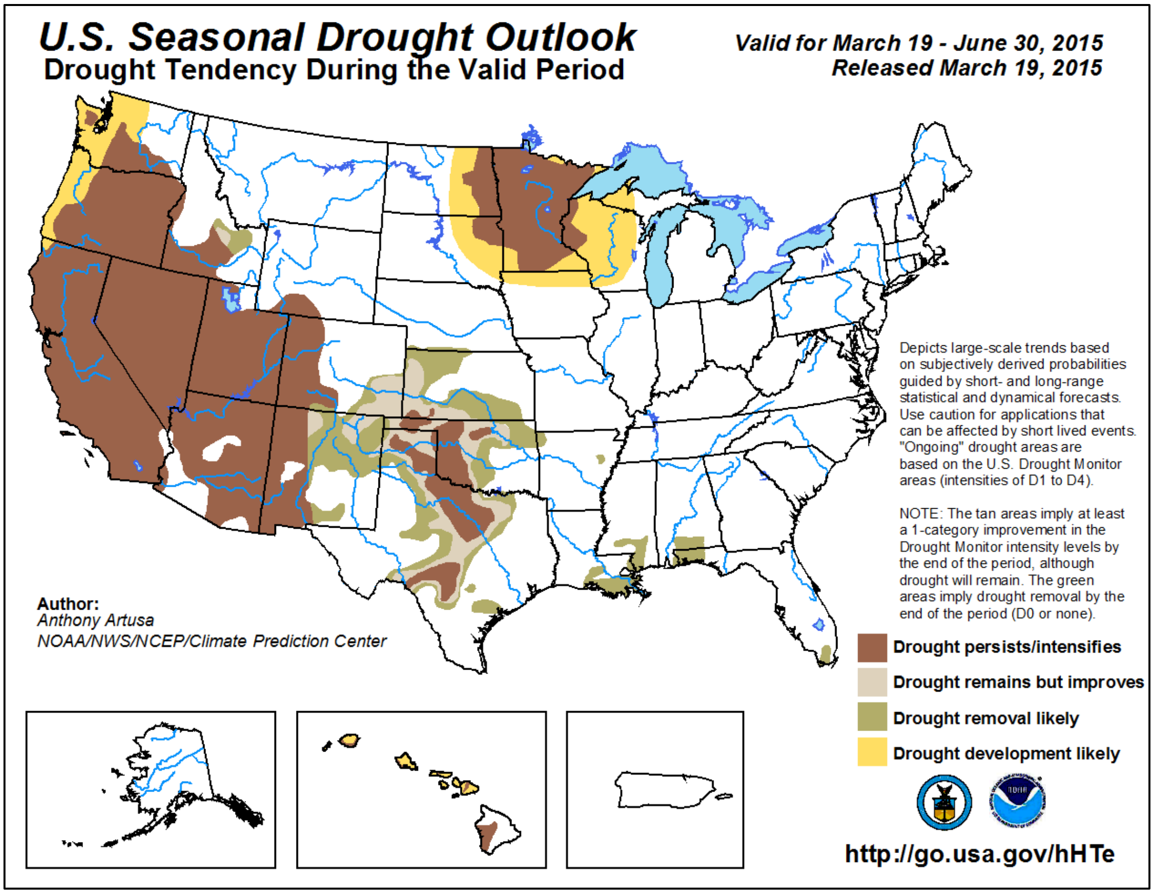

FIGURE 4—U.S. SEASONAL DROUGHT OUTLOOK - VALID FOR MARCH 19 - JUNE 30, 2015.[11]

For much of the southern Rockies and south-central Plains, drought improvement or removal is predicted, based on the latest precipitation outlooks from the Climate Prediction Center (CPC) for April-June. Persistence or intensification of drought is forecast for the core drought areas of the south-central Plains, which are currently experiencing extreme or exceptional drought conditions. These core drought areas will need significant amounts of rain to offset the long duration and severity of present drought conditions.[12]

In the upper Midwest, the areal coverage of moderate drought has expanded in the past week, and a sizable region of drought development is anticipated around it. With a relatively dry antecedent autumn and winter, soils in the region have become very dry, and a lack of snowpack has likely contributed to the record warm temperatures that occurred late March, 2015. The CPC monthly and seasonal precipitation outlooks favor the continuation of below-median precipitation across the upper Midwest, which would lead to further expansion of drought.[13]

In contrast, the CPC precipitation outlooks anticipate enhanced odds of above-median precipitation across the lower Mississippi Valley and central Gulf Coast region, prompting a forecast for removal of drought in those areas.[14]

For the Florida Everglades, the climatological onset of the rainy season in late May warrants the removal of drought conditions.[15] In Hawaii, though above-median rainfall is expected during April-June by CPC, it will be

[11] NOAA, "U.S. Seasonal Drought Outlook", www.cpc.ncep.noaa.gov/products/expert_assessment/sdo_summary.html, accessed April 2, 2015.
[12] Ibid.
[13] Ibid.
[14] Ibid.
[15] Ibid.

difficult to obtain a one-category improvement on the Palmer drought index. Therefore, Figure 4 shows areas of drought persistence or intensification and drought development.[16]

IMPACTS TO CRITICAL INFRASTRUCTURE

OCIA assesses that Water and Wastewater Systems, Energy, and Food and Agriculture are the critical infrastructure Sectors most vulnerable to drought conditions. In addition to direct drought impacts, all sectors may be affected by cross-sector dependencies and cascading impacts from the loss of water, agricultural, and energy services.

WATER AND WASTEWATER SYSTEMS

Nationally, groundwater from aquifers supplies about 33 percent of the public water supply and provides drinking water for more than 97 percent of the rural population.[17] If groundwater is depleted more quickly than it is replenished, which may happen during a drought, aquifer levels can drop, making water unavailable for irrigation and consumption. In areas that rely on surface water, hot and dry weather exacerbates the situation by increasing the amount of water lost to evaporation. The town of Groesbeck, Texas, made the national news in November 2011, when it came within 2 weeks of exhausting its water supply. The State had to install temporary pipelines to augment the water supply for the town of 4,300, at a cost of approximately $410,000 for 6 months.[18]

Besides physical scarcity, contamination of water sources can occur during drought conditions. Water reservoirs may experience increased pollutant levels and lower levels of oxygen, contributing to higher concentrations of illness-causing bacteria and protozoa, as well as toxic blue-green algae blooms.[19] Reduced flow levels in rivers and aquifers can allow saltwater to move inland and also contaminate the water supply. Most water treatment plants are not equipped to remove salts, which can cause problems not only for potable water but also for industrial uses. In July and August 2012, saline intrusion into drinking water was reported in Florida, South Carolina, and Louisiana.[20]

In States like Florida, Texas, and Oregon, which have relatively shallow underground karst aquifers, droughts may increase the likelihood of subsidence or sinkhole formation, as aquifers are depleted and unsupported ground collapses.[21,22] When these collapses occur, they may result in water or wastewater pipe breaks buried nearby. These breaks can result in unfiltered water entering from lakes and streams and, eventually, aquifers used as drinking water sources, sullying the drinking water supply.

Since drought conditions began to worsen in 2014, increased water prices for consumers are also a rising concern when it comes to persistent drought. Some northern California residents have seen price hikes as much as 33 percent. According to the Santa Clara Valley Water district, in the southern San Francisco Bay Area, water agencies are losing revenue due to consumers using less water as drought conditions persist, resulting in increased water prices for consumers.[23]

FOOD AND AGRICULTURE

The most immediate consequence of drought is a decrease in crop production, due to inadequate and poorly distributed rainfall. Drastically reduced rainfall and triple-digit temperatures throughout the Nation have the

[16] NOAA, "U.S. Seasonal Drought Outlook", www.cpc.ncep.noaa.gov/products/expert_assessment/sdo_summary.html, accessed April 2, 2015.
[17] U.S. Geological Survey, "Effects of Drought on Groundwater," ga.water.usgs.gov/edu/droughtandgw.html, accessed January 2015.
[18] CNN-U.S., "Texas Town Still Suffers Effects of Heat, Drought; Water Supply Down to Two Weeks," November 21, 2011, www.cnn.com/2011/11/21/us/texas-dry-town/index.html, accessed January 2015.
[19] Protozoa, "A subkingdom comprising the simplest organisms of the animal kingdom, consisting of unicellular organisms ranging in size from submicroscopic to macroscopic", www.medical-dictionary.thefreedictionary.com/protozoa, accessed April 2, 2015.
[20] The Island Packet, "DHEC Director: Draw Line in Sand with GA on Saltwater Intrusion," July 24, 2012, www.islandpacket.com/2012/07/23/2144231_dhec-director-draw-line-in-sand.html?rh=1, accessed January 2015.
[21] St. Johns River Water Management District, "Water Supply: How Sinkholes Form," www.sjrwmd.com/watersupply/howsinkholesform.html, accessed August 2012.
[22] Karst - a terrain with distinctive landforms and hydrology created from the dissolution of soluble rocks, principally limestone and dolomite.
[23] CBS San Francisco, "Drought Forcing Water Price Hikes As Much As 33 Percent for Bay Area Residents", www.sanfrancisco.cbslocal.com/2015/03/08/california-drought-forcing-water-price-hikes-bay-area-residents/, accessed March 2015.

potential to damage corn and other crops, which will have significant impacts on supplies and prices for animal feed, livestock, meat and dairy products, and processed grain products, including ethanol. A significant amount of corn production is used to produce ethanol, which makes up about 10 percent of the motor gasoline pool by volume and provides 6–7 percent of the gasoline's energy content.[24]

In addition, some indirect impacts of drought such as reduced income for farmers has a ripple effect. Retailers and others who provide goods and services to farmers face reduced business. This leads to unemployment, increased credit risk for financial institutions, capital shortfalls, and eventual loss of tax revenue for Federal, State and local Governments. Prices for food, energy, and other products increase as supplies are reduced. In some cases, local shortages of certain goods result in importing these goods from outside the drought-stricken regions.

Drought is also associated with insect infestations, plant disease, and wind erosion.[25] Some of these effects are short-term. Other environmental effects such as seawater reverse osmosis (SWRO), brine discharge on marine ecosystems, and a reduction in carbon dioxide fixation in photosynthesis can last for an extended period of time and may even become permanent.[26,27]

ENERGY

In today's economies, the Energy and Water and Wastewater Systems Sectors are tightly linked. Recent drought condition developments have focused national attention on the connections between water and energy infrastructure. For example, when severe drought affected more than a third of the United States in 2012, limited water availability constrained the operation of some power plants and other energy production activities.[28] All sources of energy (including electricity) require water in their production processes including extracting raw materials, cooling in thermal processes, cleaning processes, cultivating of crops for biofuels, and powering turbines.[29] Because of the interdependency between the Energy Sector and the availability of water, drought greatly affects the resilience of energy systems. Water is particularly important in the Rankine Cycle for thermoelectric electricity generation. [30] Thermoelectric use currently constitutes more than 40 percent of the United States freshwater withdrawals (138 BGD) and 4 percent of freshwater consumption (4.3 BGD).[31]

Additionally, a study conducted by the Department of Energy's Argonne National Laboratory discovered that severe drought could curtail power production in the Pacific Northwest, which is strongly dependent on hydroelectric power, by up to 22 percent. Under the same drought conditions, the Texas Gulf Coast Basin would lose 25 percent of its production, due to its dependence on water for cooling its fossil-fuel plants.[32]

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24 EIA, "Worst drought in decades could affect U.S. energy market", August 28 2012, www.eia.gov/todayinenergy/detail.cfm?id=7730, accessed January 2015.
25 The Ojos Negros research Group, "Impacts of Drought", www.ponce.sdsu.edu/three_issues_droughtfacts02.html, accessed March 2015.
26 The National Center of Excellence in Desalination Australia, "Assessing and Mitigation Environmental Impacts of SWRO outfalls on key benthic Marine Organisms" www.desalination.edu.au/research/projects/social-environmental-economic-issues/, accessed March 2015.
27 Long-term Drought Effects on Trees and Shrubs, "Drought Effects on Plants", www.extension.umass.edu/landscape/fact-sheets/long-term-drought-effects-trees-and-shrubs, accessed March 2015.
28 Department of Energy, "The Water Energy Nexus: Challenges and Opportunities 2014," accessed February 2015.
29 United Nations Department of Economic and Social Affairs (UNDESA), "Water for Life", www.un.org/waterforlifedecade/water_and_energy.shtml, accessed March 12, 2015.
30 Rankine Cycle - the hypothetical cycle of a steam engine in which all heat transfers take place at constant pressure and in which expansion and compression occur adiabatically, www.dictionary.reference.com/browse/rankine+cycle, accessed, April 20, 2015
31 Department of Energy, "The Water Energy Nexus: Challenges and Opportunities 2014", accesses April 20, 2015
32 Argonne National Laboratory, Analysis of Drought Impacts on Electricity Production in the Western and Texas Interconnections of the United States, December 2011.

TRANSPORTATION SYSTEMS

Persistence drought conditions have the potential to limit port and waterway transportation operations by reducing routes available and limiting cargo carrying capacity, resulting in increased transportation cost. The most critical of these waterways is the Mississippi River. In 1988, drought forced a temporary closure of a 100-mile stretch of the Mississippi River south of Memphis, Tennessee, when river levels fell to a record low. That closure cost the U.S. barge industry an estimated $1 billion.[33] With a loss such as this, cost could potentially be passed on to consumers, resulting in higher retail prices for goods normally moved by inland waterway.

When high temperatures coexist with drought, subsidence can occur and affect additional transportation assets. Extreme heat and higher temperatures can cause rail line buckling (sun kinks) causing derailments. Roads and airport runways are also vulnerable to extreme heat and temperatures, which can soften and deteriorate asphalt.

COMMUNICATIONS

Communications equipment and information technology data centers use water for cooling. Data centers, for example, often use high-tonnage heating, ventilating, and air conditioning systems that require drinkable water to operate in order to keep their computer systems cool.[34] A sustained loss of water to a communications facility, which could happen during a drought, can cause equipment shutdown or failure, resulting in a degradation of communication capabilities. The loss of one Communications Sector segment data center is generally not critical to the operation of that segment, but it could disrupt some services for minutes to hours while requests for information are routed to operating data centers.[35] In addition, submarine telecom cables in fresh water (rivers and lakes) could possibly be damaged if water levels are low, resulting in communication outages.

Wildfires also pose a risk to the Communications Sector. In the Southwest, drought conditions make wildfires more likely and dangerous, damaging electric transmission and distribution systems as well as wooden electrical and communication poles and aerial equipment, including fiber optic and copper lines, microwave towers, and equipment in vaults.

EMERGENCY SERVICES

Drought conditions and record heat have fueled damaging and sometimes deadly wildfires in Arizona, Colorado, and in New Mexico.[36] Because of the extraordinary dry conditions and the environment, Fire Services are met with challenging restraints and there is a need for additional coordination between the Public Works and the Fire Services disciplines within the Emergency Services Sector.

Reduced freshwater availability would be more likely to complicate firefighting efforts in urban and suburban areas where standard wildfire-fighting tactics, such as chemical retardants and controlled burns, are less suitable. Some fire suppression equipment requires a minimum level of water pressure to activate and work properly.[37]

An immediate consideration in fighting structure fires is electric power and transmission line outages. Electricity may be required to maintain water pressure in municipal hydrants systems. If electric transmission lines are affected by wildfire, and are unable to provide power to an urban area, there may be insufficient power to produce water pressure for the fire hydrants; consequently, fighting structure fires in settled areas may be difficult without the use of tanker fire trucks.

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33 Associated Press, "Drought-stricken Mississippi River Flows Are Polar Opposite of 2011," July 16, 2012, www.kearneyhub.com/news/local/drought-stricken-mississippi-river-flows-are-polar-opposite-of/article_7ff72198-cf71-11e1-a07a-0019bb2963f4.html, accessed February 2015.
34 DHS, 2012 Risk Assessment Report for Communications, 2012, accessed March 5, 2015.
35 Ibid.
36 C2ES, "Drought and Climate Change", www.c2es.org/science-impacts/extreme-weather/drought, accessed February 2015.
37 U.S. Fire Administration, Water Supply Systems and Evaluation Methods, Volume I: Water Supply System Concepts, October 2008, at www.usfa.fema.gov/downloads/pdf/publications/Water_Supply_Systems_Volume_I.pdf, accessed January 2015.

HEALTHCARE AND PUBLIC HEALTH

Under extreme drought conditions, where local water supplies are depleted and water utilities are unable to supply adequate water pressure, hospitals could be impacted. Healthcare facilities, including hospitals, clinics, and nursing homes, rely on water for heating, cooling, and ventilation systems, as well as for equipment sterilization, sanitation, water-based patient treatments, fire suppression, and hazmat-decontamination.[38] For this reason, hospitals are a top priority for restoration following a disruption to the water supply. Without adequate water supplies, healthcare facilities would be forced to close and move patients elsewhere.

According to the Center for Disease Control and Prevention, a number of adverse public health effects and conditions can also be attributed either directly or indirectly to drought. For example, people exposed to dust clouds are at increased risk for acquiring "dust pneumonia," an often fatal type of pneumonia caused when dust fills the lungs and inflames them, resulting in high fever, coughing, chest pain, and difficulty breathing.[39]

During droughts, dry soils and often wildfires increase the amount of airborne particles, such as pollen and smoke. These particles can irritate the airways and worsen chronic respiratory illnesses such as asthma. Poor air quality can also increase the risk of respiratory infections, such as bacterial pneumonia and valley fever, a fungal infection and common cause of pneumonia in many areas of the southwestern United States, Mexico, Central and South America.[40]

In addition to reduced air quality, drought poses many far reaching health implications. Some drought-related health effects occur in the short-term and can be directly observed and measured. But drought can also result in lasting, indirect health implications that are not always easy to anticipate or monitor.[41]

CHEMICAL AND CRITICAL MANUFACTURING

Water is used in manufacturing for fabricating, processing, washing, diluting, cooling, and transporting products. Water is also incorporated into products and used for sanitation needs within manufacturing facilities. Food, paper, chemicals, refined petroleum, and primary metal manufacturers all use large amounts of water. Industry uses about 4 percent of all water used (9 percent if hydroelectric generation is excluded).[42] Depletion or interruption of the water supply could lead to reduced productivity or even temporary closures of key facilities, with impacts reverberating down supply chains.

PREPAREDNESS MEASURES

While there is little that can be done to influence the weather patterns that cause drought, some preparatory measures and policies may help communities and infrastructure assets and systems to cope with the impacts. In general, infrastructure in good condition will be less vulnerable and voluntary water conservation measures can help stretch the water supply for consumers and industry. Drought contingency planning can also ensure continuity of public services and quality of life.

In addition, educational campaigns can be used to raise awareness among residential and commercial customers of the benefits of water conservation. Consumers can reduce their water use by employing lower-flow appliances, using native plants in landscaping, watering more efficiently, capturing and using rainwater for non-potable applications, and covering pools and hot tubs. Manufacturers may be able to reduce dependence on surface water by tapping more plentiful groundwater sources, using reclaimed water, or introducing recycling or recirculating technology.

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38 Healthcare and Public Health Sector Coordinating Council, “Planning for Water Supply Interruptions: A Guide for Hospitals & Healthcare Facilities,” www.phe.gov/Preparedness/planning/cip/Documents/CIP-WaterSupply.pdf, accessed January 2015.
39 Center for Disease Control, "Public Health and Drought: Challenges for the Twenty-First Century, " www.cdc.gov/features/Drought/index.html, accessed April 2, 2015.
40 Ibid.
41 Ibid.
42 USGS, “Industrial Water Use,” ga.water.usgs.gov/edu/wuin.html, accessed January 2015.

Because agricultural irrigation uses approximately 80 percent of the Nation's consumptive water (over 90 percent in many western states), improved irrigation efficiency is an expeditious way to conserve significant amounts of water. According to one estimate, 70 percent of irrigation water never reaches crops, lost to leaking irrigation channels, draining into rivers, or seeping back into groundwater. Using drip irrigation methods, repairing leaks, irrigating only when actually necessary, and using reclaimed or recycled water can all help save large amounts of water.[43]

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[43] The Economist, "Running Dry," September 18, 2008, www.economist.com/node/12260907?story_id=12260907, accessed January 2015.

Homeland Security

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