CALIFORNIA-NEVADA DROUGHT EARLY WARNING SYSTEM STRATEGIC PLAN

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2017 – 2018 Strategic Plan

Document prepared by the National Integrated Drought Information System (NIDIS) in partnership with the California-Nevada Climate Applications Program (CNAP) and Western Regional Climate Center (WRCC).

Table of Contents

California-Nevada Drought early warning system

The National Integrated Drought Information System and Drought Early Warning Systems

In 2006, Congress authorized the National Integrated Drought Information System (NIDIS) with a mandate for interagency coordination and integrated drought research that builds upon existing federal, tribal, state, and local partnerships to create a national drought early warning system (DEWS). NIDIS is working toward this goal by developing a network of regional DEWS (see map, below). These regional DEWS utilize existing networks to make climate and drought science readily available, easily understandable, and usable; and to improve regional capacity to respond to and cope with drought.

A regional DEWS is supported by stakeholders, comprised of relevant partners and community members across the region, including universities, the private sector, and federal, tribal, state, and local entities. Stakeholders participate in the NIDIS consultation process, and they support NIDIS priorities by leveraging existing resources, programs, and partnerships. This relationship ensures a robust, "ground-up" regional DEWS that is well-networked and responsive to the specific needs of each region. NOAA and the NIDIS program did not establish the DEWS and do not control or manage the DEWS functions or operations; rather, the DEWS constitute the continuation, and leveraging, of existing partnership networks.

WHAT IS NIDIS?

The National Oceanic and Atmospheric Administration's (NOAA) National Integrated Drought Information System (NIDIS) was authorized by Congress in 2006 (Public Law 109-430) with an interagency mandate to develop and provide a national drought early warning information system, by coordinating and integrating drought research, and building upon existing federal, tribal, state, and local partnerships.

WHAT IS A DEWS?

A Drought Early Warning System (DEWS) utilizes new and existing networks of federal, tribal, state, local, and academic partners to make climate and drought science accessible and useful for decision makers; and to improve the capacity of stakeholders to monitor, forecast, plan for, and cope with the impacts of drought.

The California-Nevada DEWS

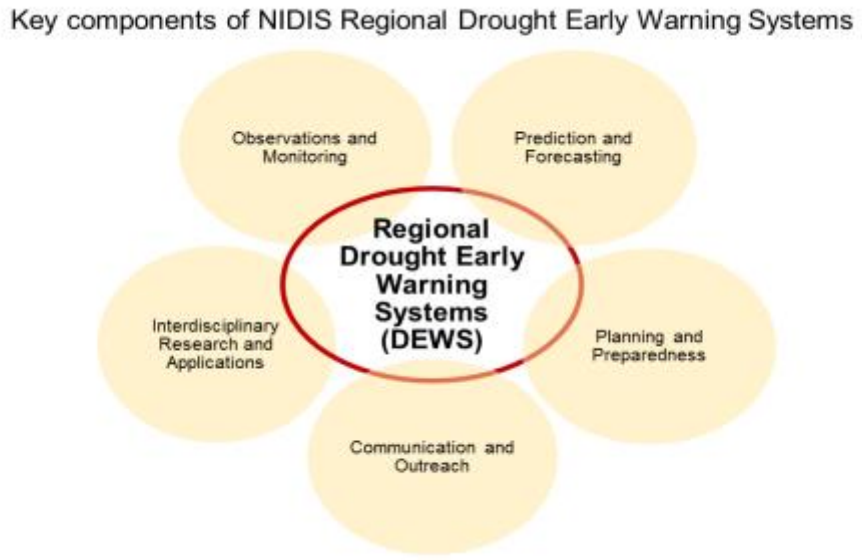
Drought in California and Nevada is a common occurrence that can last for multiple years and impact a variety of economic sectors. California and Nevada climate is characterized by a distinct dry season (mid-May to late-September/early October) and wet season (October - April) defined by a few large precipitation events. Additional peaks in precipitation can occur, such as the peak in summer precipitation in southern Nevada due to the North American monsoon. Topography within the region creates a diverse set of climate conditions, from the snowy peaks of the Sierra Nevada Range to the Mojave Desert, to the numerous mountains and valleys of the Basin and Range. Given the extreme variability of climate in California and Nevada, both spatially and temporally, efficiently using and effectively managing the finite water resource is a high priority, and is key to successful drought mitigation and management.

As NIDIS works to improve national drought resilience, several regional drought early warning systems (DEWS) were formed to pilot innovations, resources, and lessons to be transferred to a national DEWS. A California DEWS pilot began in 2010 and evolved as California was on the cusp of a historic and ongoing drought. The California DEWS focused on four regions where drought has substantial effect on the state's communities and economies; including drought monitoring in Southern California, the hydrologic extremes of the Russian River, fallowed field tracking in the Central Valley, and a hydrologic dashboard for the Klamath Basin. As California headed deeper into drought, NIDIS co-hosted two 2014 meetings (February, May) of a California Drought Forum to continue building a drought early warning system framework for the region. Projects expanded to include improved seasonal forecasting, groundwater monitoring, and water supply status monitoring in California. Many of these projects are ongoing and will continue as part of the newly joined California and Nevada DEWS.

California-Nevada Drought Early Warning System

During his time as chair of the Western Governors' Association (WGA), Nevada Governor Brian Sandoval spearheaded the WGA Drought Forum to promote a regional dialogue on best management practices for drought policies, practices and management. Building off of the WGA Drought Forum's success, in April 2015 Governor Brian Sandoval formed the Nevada Drought Forum through Executive Order 2015-03 to address water resource challenges related to severe and sustained drought conditions that have affected much of the state. During a series of listening sessions held throughout Nevada, improved drought monitoring and research data emerged as a central need and theme. The Forum agreed that narrowing information gaps through the use of additional and new state-of-the-art monitoring could provide the critical information needed for more flexible resource management strategies and enhance coordination between various stakeholder groups. The Forum recommended that Nevada work with NIDIS to explore the implementation of new technologies such as remote sensing to improve drought monitoring, enhance drought early warning systems and forecasts, and the use and understanding of tools like the U.S. Drought Monitor (USDM) to better represent local conditions and meet the needs of stakeholders impacted by rangeland and hydrologic drought. The DEWS will continue and expand local stakeholder-driven activities encompassing data collection and monitoring; research; planning for climate extremes; and communication, education, and outreach. DEWS activities in Nevada complement California efforts, in addition to supporting the recommendations and outcomes of the Nevada Drought Forum.

The California-Nevada DEWS (CA-NV DEWS) incorporates each state's needs, and extends new and previously developed California DEWS efforts. Given the many connections the two states share with respect to geography, climate, water, and drought, drought early warning efforts in Nevada were integrated with those of California in 2016, and a joint CA-NV DEWS was developed to support enhanced drought early warning across the region and to build out NIDIS's national drought early warning system.



Purpose of the California-Nevada DEWS

The CA-NV DEWS is a collaborative federal, tribal, state and local interagency effort to improve early warning capacity and resilience to drought events throughout the region. Local stakeholder-driven needs around data collection and monitoring; research; planning for climate extremes; and communication, education, and outreach present opportunities for designing collaborative early warning activities.

Specific objectives of the CA-NV DEWS include:

- Provide a forum for a diverse group of federal, tribal, state, and local stakeholders representing all economic sectors, including water and land resource management, to strategize and develop appropriate, relevant, useful, and readily available drought, climate, weather and water-related information.
- Expand interactions and dialogue between the research community and decision-makers on the latest weather, climate, and drought science.
- Develop an active professional network that improves coordination and training among federal, state, and local agencies related to drought early warning and resiliency.

THE CALIFORNIA-NEVADA DEWS STRATEGIC PLAN

Plan Purpose and Development

The CA-NV DEWS Strategic Plan outlines priority tasks and activities that build upon existing stakeholder networks to improve drought early warning capacity and long-term resilience in California and Nevada. It includes a list of current partners (listed in Appendix A), outcomes, and key milestones. This Plan is a “living document” to which additional actions and partners may be added as needed.

Dedicated partners across California and Nevada contributed to the development of the CA-NV DEWS Strategic Plan, including federal, tribal, state, local, academic, and non-profit organizations and entities such as: California-Nevada Climate Applications Program (CNAP), a NOAA Regional Integrated Sciences and Assessments (RISA) team; Desert Research Institute (DRI); and NOAA's Western Regional Climate Center (WRCC).

In addition to the findings resulting from Governor Sandoval's 2015 Nevada Drought Forum, NIDIS and its partners held three regionally focused Drought and Climate Outlook meetings across California in the fall of 2016 to obtain input on priority needs and actions to improve drought early warning and resilience in the region. Participants represented federal, tribal, state, local, academic and non-profit organizations with diverse interests spanning drought monitoring and management, water supply and conservation, fisheries, agriculture, land management, forest health and wildfire, and emergency management. Feedback from these Outlooks and the Nevada Drought Forum was included with information collected since the inception of the original California DEWS, to form the basis of the Plan.

Additionally, recommendations made by key partners and stakeholders both in and outside of NOAA (such as NOAA's California Drought – 2014 Service Assessment and the Western States Water Council's report on improving sub-seasonal to seasonal precipitation forecasts for water management) were considered in shaping this Plan and will be key to the evolution of the CA-NV DEWS.

California-Nevada DEWS Priorities and Activities

The CA-NV DEWS prioritizes the following aims necessary to building drought early warning capacity and long-term drought resilience throughout California and Nevada:

- **Priority 1 – Optimize the Collaborative DEWS Network -** This priority focuses on improving collaboration and coordination among stakeholders to leverage resources, eliminating duplication, and optimizing the CA-NV DEWS partner network. Related actions include facilitating coordinated communication among federal and state agencies and those responsible for outreach and communication within those agencies.

- **Priority 2 – Develop Drought Monitoring and Research -** This priority focuses on strengthening drought and water resources data collection and its applications for drought risk management. To improve drought monitoring that enhances management decisions related to rapid changes in soil moisture states and vegetative stress across rangelands and forests, the CA-NV DEWS will develop and deliver new state-of-the-art cloud computing tools that provide user-friendly drought monitoring data to decision-makers. The CA-NV DEWS will also work to expand satellite-based crop data for fallowed lands monitoring, develop drought and wildfire-related decision support tools, enhance water supply monitoring, research improvements to real-time groundwater monitoring in California's Central Valley, and investigate the information inputs and practices needed to improve drought resiliency at the watershed scale.

- **Priority 3 – Develop Forecast and Decision Support Tools for Resource Managers -** Water, land, and emergency managers are often responsible for making long-term decisions with the best available information and forecasts. Unfortunately, the skill associated with seasonal (3-9 month)

and sub-seasonal (1-3 month) climate forecasts is often quite low for precipitation, which limits the ability to make confident decisions. This priority focuses on research activities to improve some of the inputs into seasonal and sub-seasonal forecasts, as well as collaborative efforts pairing the developers of forecasts directly with practitioners.

- **Priority 4 – Improve Drought Early Warning Communication and Outreach -** This priority focuses on coordinated communication, outreach, capacity building and training across various regions and sectors in the CA-NV DEWS. This effort will support the regular dissemination (virtually and in-person) of drought, climate, and forecast information that stakeholders in the region have identified as a high priority need.

For each priority, some of the associated activities outlined this plan have been started, while others will be initiated over the next two years. The corresponding schedule summarizes the expected timeframe for each activity's implementation. Milestone dates are based on the following quarters, designated by seasons: Winter (Jan, Feb, Mar); Spring (Apr, May, Jun); Summer (Jul, Aug, Sep); and Fall (Oct, Nov, Dec).

Additionally, some of the activities are funded while other activities will require efforts to acquire funding. Funding sources may include NIDIS and DEWS partners. As the CA-NV DEWS continues to develop, it will be important to identify and leverage resources and available funding among DEWS partners.

Coordination with NIDIS Working Groups

Vital to the mission of NIDIS are its six Working Groups, each focused on a different component of NIDIS activities within and across agencies and throughout the country. These six areas of focus are: (i) education and public awareness, (ii) monitoring and observations, (iii) predictions and forecasting, (iv) interdisciplinary research and applications for risk assessment, (v) planning and preparedness, and (vi) the U.S. Drought Portal for improving accessibility to usable drought risk information. More information on these Working Groups is provided in the NIDIS Implementation Plan December 2016 Update.

Coordination, communication, and transferability of information and actions between the NIDIS Working Groups and the DEWS is essential to the overall process of building a collaborative information system. The NIDIS Program Office supports a network of regular communication and exchange of information between these entities to ensure meaningful engagement and effective collaboration on priorities and activities. Appendix B illustrates how each of the activities in this Plan correlates with the Working Group(s).

Priority 1 – Optimize the Collaborative DEWS Network

The CA-NV DEWS utilizes existing and new partner networks to optimize the expertise of a wide range of federal, tribal, state, local, and academic partners in building drought early warning and resiliency. This priority focuses on improving collaboration and coordination on drought issues to optimize the CA-NV DEWS collaborative network. Related actions include the CA-NV DEWS' unique role in

supporting the coordination of federal, state, local, tribal, and academic partners' drought early warning efforts and coordinating and carrying out communication and outreach activities with the collaborative network.

In response to the 2014 California Drought Service Assessment, the CA-NV DEWS provides a mechanism to aid in the internal drought service coordination of NOAA partners in the region, which lends to better coordination with other regional experts. The CA-NV DEWS offers cross-collaboration opportunities in which meteorologists, climatologists, hydrologists, coastal habitat planners, fisheries managers, decision-makers, and others can engage with each other to provide consistent messaging, media and stakeholder coordination, and internal communication and education.

NIDIS and partners will also broaden participation in CA-NV DEWS activities, including webinars, in-person outlooks, and other activities. This outreach will engage tribal nations as well as professionals in agriculture, fisheries, public health, and off-project water systems (e.g. Central Coast).

Activity 1.1 Improve Drought Coordination among Federal, State, Tribal, and Local Agencies

Activity 1.1a Quarterly Stakeholder Calls

The CA-NV DEWS collaborative network consists of a diverse group of federal, state, local, tribal, and academic partners. On a quarterly basis, a conference call will be held to bring together a broad spectrum of stakeholders in the region and discuss progress and updates to the DEWS strategic plan, agency activities, and identify opportunities to leverage resources.

Activity 1.1a Outcomes

- Quarterly calls with key stakeholders, and call notes distributed to participants within one week of call [ongoing].

Activity 1.1b Develop a Matrix of Federal, Tribal, State and Local Drought Related Activities and Resources

Partner agencies at the federal, tribal, state, and local levels are actively engaged in a variety of drought-related activities. To improve awareness, collaboration, and avoid duplicating efforts, NIDIS will utilize the regional network to document current drought activities and resources in California and Nevada. This activity will also help identify sectors and communities lacking attention and highlight potential opportunities to leverage resources to enhance their benefit. NIDIS will develop a template matrix and circulate among CA-NV DEWS stakeholders to collect information on existing and planned drought response activities. Information collected will include: lead agency/organization, funding, associated timelines, and primary contact(s). The completed matrix will be made available on the U.S. Drought Portal's CA-NV DEWS page as a reference tool, and it will be updated quarterly.

Activity 1.1b Outcomes

- First version of matrix completed and posted to U.S. Drought Portal, updated with feedback

from the CA-NV DEWS network on a quarterly basis [Winter 2018].

Activity 1.1c Support Drought Outreach and Communication Coordination across the Collaborative Network

CA-NV DEWS stakeholders bring with them a diverse set of existing outreach and communication tools within their organizations, focused on the needs of different audiences. To improve outreach and reduce redundancy, NIDIS, CNAP, DRI, WRCC, and other partners will convene regular calls to coordinate outreach activities and materials with personnel in federal and state agencies whose responsibilities include outreach and communication in their respective organizations. Participants will include regional federal climate initiatives (including but not limited to CNAP, Department of the Interior (DOI) Landscape Conservation Cooperatives (LCC) and Southwest Climate Science Center (SWCSC), and U.S. Department of Agriculture (USDA) Climate Hubs) as well as state climatologists and drought coordinators from California and Nevada, Nevada State Engineer's Office, and others.

Activity 1.1c Outcomes

- Routine correspondence between NIDIS and the entities described above to coordinate with the collaborative network to streamline outreach and communication needs and activities related to CA-NV DEWS [ongoing].

Activity 1.2 Host Annual CA-NV DEWS Coordination Workshop

While the states of California and Nevada have unique DEWS needs, the region benefits from improved collaboration and information sharing across the region as a whole. NIDIS and the CA-NV DEWS stakeholders will host an annual CA-NV DEWS Coordination Workshop. Current and planned DEWS activities will be discussed, and new partner outreach and drought resilience activities will highlight and reinforce the DEWS.

The first workshop was held in June 2017 in Reno, NV, to evaluate how the CA-NV DEWS can continue to best address priority drought-related water resource, land, and emergency management topics. Challenges and lessons learned from the most recent drought and drought relief provided a setting for an in-depth discussion on regional drought efforts. NIDIS and CA-NV DEWS partners shared developments in integrating monitoring, research, tool development, and outreach to mitigate the impacts of drought. Discussion topics included drought monitoring, seasonal to sub-seasonal forecasts, marine and coastal ecosystem impacts, forest health, wildfire management, and groundwater management.

Activity 1.2 Outcomes

- Host annual CA-NV DEWS Coordination Workshop beginning Summer 2017.
- Meeting report shared with participants and posted to drought.gov within two months of the meeting [Fall 2017].

Activity 1.3 Strengthen the CA-NV U.S. Drought Monitor with Contributions from the CA-NV DEWS

The U.S. Drought Monitor (USDM) is a weekly map of drought conditions jointly produced by NOAA, USDA, and the National Drought Mitigation Center (NDMC). Each week, a USDM author compiles measurements of climatic, hydrologic, and soil conditions, as well as reported impacts and observations from many other contributors in a "convergence of evidence approach" to produce the map. In California and Nevada, a bi-weekly or monthly USDM call takes place to compile this information for the region. CNAP, WRCC, NIDIS, and other interested CA-NV DEWS partners will collaborate with current CA-NV USDM call organizers (primarily from NWS Weather Forecast Offices and the CA-NV River Forecast Center (CNRFC)), USDM authors, and regional and state climatologists and drought coordinators on how the CA-NV DEWS can better contribute to the recommendations resulting from these calls. Potential activities include: expanding the network of participants, better supporting the USDM authors' needs, enhancing collection and dissemination of impacts (such as the Drought Impact Reporter (DIR)), and providing venues and vehicles to communicate findings and recommendations. These potential activities themselves are a vehicle for improving the DEWS collaborative and connect DEWS efforts to the USDM.

Activity 1.3 Outcomes

- NIDIS will organize a series of conference calls between key CA-NV DEWS partners (i.e. CNAP, CA DWR, USDA, and WRCC) and CA-NV USDM call organizers (i.e. NWS, CNRFC, State Climatologists) [Fall 2017].
- Identify action items and define deliverables for how the CA-NV DEWS network can strengthen the CA-NV USDM [Winter 2018].

Activity 1.4 Integrate Drought and Climate Science into Wildfire Management

The relationship between drought and wildfire can seem simple, but the drought and wildfire nexus encompasses many human and environmental factors. Because of the regional variations in fire regimes and fuel models, and the number of cross-sector local, state, tribal and federal agencies involved in wildfire management in the western United States, understanding the impacts of drought at state and regional levels, as well as coordinating at this scale among agencies will be vital to successful wildfire management in the face of drought.

In October 2015, NIDIS, WRCC, DRI, NDMC and other partners hosted the *Integrating Drought Science and Information into Wildfire Management Workshop* in Boise, Idaho. Seventeen federal, state, NGO and academic organizations from across the West attended to discuss the role drought plays in fire and its impacts on wildfire planning, fire behavior, and post-fire restoration.

To improve the current use of drought information in wildfire management, one of the resulting recommendations from this workshop was to hold additional, regionally-focused workshops to further discuss the use of drought indicators and impact information by the wildfire management community. These subsequent workshops will also provide an opportunity to connect the drought and wildfire management communities at the regional level and address regional concerns. WRCC, DRI, and NIDIS will hold the follow-up workshops in the CA-NV DEWS region within two years, incorporating findings of the research completed under the NOAA Sectoral Applications Research Program (SARP) grant to

develop a wildfire component for the CA-NV DEWS (see Activity 2.4).

The goals of the SARP project are to (1) interact with stakeholders to determine specifically what type of drought information is most pertinent for them to manage potential wildfire risk; (2) collaborate with a key stakeholder(s) to develop drought-related, decision-support information and tools; and (3) enhance the CA DEWS. The SARP project also includes some quantitative analysis of relationships between drought and fire indices. The goals of the drought-fire nexus workshops focus on (1) the communication opportunities and challenges in exchanging information between drought and fire communities; (2) the definition of drought from a fire management perspective and its meaning for fuel management fire behavior, and ecosystem responses; and (3) how drought information can inform fire management. Outputs from the SARP project will be presented in the workshops.

Activity 1.4 Outcomes

- Regional Drought Indicator and Impact Workshops for Wildfire Management workshop(s) in CA-NV DEWS [Fall 2017-Fall 2018].

Activity 1.5 Leverage CA-NV DEWS Network to Support Drought Planning

NIDIS and CA-NV DEWS stakeholders will support ongoing and emerging state, tribal, and local drought planning initiatives. Several programs, such as Federal Emergency Management Agency's (FEMA) Pre-Disaster Mitigation program and the U.S. Bureau of Reclamation (BOR) Drought Response Program can be utilized to support drought planning across the CA-NV DEWS, and other partners at all levels of government can often provide technical support and other resources. NIDIS will work with partners including BOR, FEMA, U.S. Geological Survey (USGS), Natural Resource Conservation Service (NRCS), NDMC, and others to identify meaningful ways their programs and the technical, regional expertise within the CA-NV DEWS network, as well as the NIDIS Planning and Preparedness Working Group, can be leveraged to support more comprehensive drought planning and ultimately reduce impacts experienced during drought events. Appendix E features current examples of CA-NV drought planning efforts utilizing the BOR's Drought Response Program that are already underway or being planned.

Activity 1.5 Outcomes

- With information collected in Activity 1.1b, NIDIS will promote drought planning funding announcements and other resources through drought.gov, CA-NV DEWS webinars, and other partner communications vehicles [ongoing].

Priority 2 – Develop Drought Monitoring Metrics and Research

This Priority will focus on improving drought data and information collection and its use for drought risk management. To enhance management decisions related to rapid changes in soil water levels and vegetative stress across rangelands and forests in California and Nevada, the CA-NV DEWS will develop and deliver cloud computing tools that incorporate key drought monitoring data and information (such as evaporative demand drought products, snowpack and precipitation, and fire danger indices) and that are easily accessible to decision makers. Additionally, the CA-NV DEWS will support research to improve estimates of real-time monitoring of groundwater levels in California's Central Valley, expand

satellite-based crop data for fallowed lands monitoring, develop drought and wildfire related decision support tools and informational products, and enhance water supply monitoring to improve drought resiliency at the watershed scale.

Activity 2.1 Cloud Computing of Climate and Remote Sensing Data

Specific activities will focus on enhancing and leveraging Climate Engine, a web application developed jointly at the DRI, and the University of Idaho (UI) in collaboration with Google[1] (found at ClimateEngine.org). Climate Engine enables users to process, visualize, and download global, regional, and place-based climate, meteorological, and remote sensing products using Google Earth Engine's massively parallel cloud computing platform. This state-of-the-art tool overcomes many of the hurdles that limit users from working with large gridded datasets using a simple web-based interface. Users of Climate Engine can select and customize data from a range of remote sensing, meteorological, and climate variables. Targeted outreach and training for CA-NV DEWS stakeholders (outlined in Activity 4.7) on Climate Engine and other tools over multiple years will advance place-based environmental monitoring to enhance drought monitoring and decision making, while also allowing incorporation of stakeholder feedback in tool development.

The following activities outline specific drought monitoring products to be enhanced through newly available assets, on-demand custom calculations, and place-based visualizations provided by Climate Engine. This activity is being led by the DRI with support from NIDIS.

Activity 2.1a Precipitation and Snow Cover Monitoring

Improved access to snowpack and precipitation data and observations is paramount to any resource managers' ability to better plan and prepare for drought. Precipitation-based drought indices are commonly used to assess drought status. Common precipitation-based indices include the Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), and Standardized Precipitation Evapotranspiration Index (SPEI). Snow cover indices such as the Normalized Difference Snow Index (NDSI) are commonly used to assess snowpack conditions and to inform stream and river forecasts. Previously, maps and area average time series of these indices have been static and analysis time periods fixed. This activity will focus on making commonly used precipitation and snow cover indices available and customizable via Climate Engine.

Activity 2.1a Outcomes

- Added precipitation and snow cover indices into Climate Engine [Fall 2018].
- Stakeholder engagement and outreach to train stakeholders on use of the datasets for place-based monitoring (see Activity 4.7).

[1] A public-private partnership between NIDIS, DRI, WRCC, and Google has fostered unique opportunities for advanced climate and drought monitoring. At the White House Climate Data Initiative launch event in March 2014, Google committed to provide cloud-computing resources (50 million Earth Engine CPU hours and 1PB storage) for climate-related analyses. This commitment, in part, has made Climate Engine and collaboration with NIDIS possible. Climate Engine and the public-private partnership between DRI, WRCC, and Google was recently featured at the White House Water Summit in March of 2016.

Activity 2.1b Evaporative Demand

One of the most promising drought indices for drought early warning is the Evaporative Demand Drought Index (EDDI). EDDI is a new drought index, being developed at NOAA, that can serve as an indicator of both rapidly evolving "flash" droughts (developing over a few weeks) and sustained droughts (developing over months but lasting up to years). EDDI has been shown to offer early warning of drought stress relative to current operational drought indices like the USDM. A strength of EDDI is in capturing the precursor signals of water stress at weekly to monthly timescales, which makes EDDI a potent tool for rangeland drought preparedness. EDDI will be made operational and integrated within the Climate Engine framework for easy and dynamic visualizations, regional and place-based analyses, and product downloading capabilities.

Activity 2.1b Outcomes

- Incorporate EDDI dataset into Climate Engine [Spring 2017].
- Stakeholder engagement and outreach on training of use of EDDI for hydrologic and rangeland drought monitoring, including tools like User's Guide to EDDI (see Activity 4.7).

Activity 2.1c Rangeland, Agricultural, and Forest Vegetation Monitoring

Many of the data products currently available on Climate Engine are ideal for rangeland and forest drought monitoring and applications (i.e. satellite based Landsat and MODIS[2] land surface temperature (LST), Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Normalized Difference Wetness Index (NDWI)). Precipitation, solar radiation, temperature, humidity, wind speed, and American Society of Civil Engineers Penman-Monteith evaporative demand data (ASCE-PM ET_o; Allen et al. 2005) are also available and based on the UI's gridded meteorological data. Drought monitoring and assessment can be dramatically enhanced with an ability to review climate, meteorology, and small scale groundwater dependent ecosystem features over time (1985 to present), while simultaneously monitor larger scale features like entire rangeland allotments or counties, all within a single processing platform.

A customized version of Climate Engine for rangeland and agricultural drought monitoring will be built to include, for example, all Bureau of Land Management (BLM) grazing allotments to address rangeland-monitoring needs, hydrographic boundaries to address State of Nevada water and agricultural monitoring needs, and other management units for spatial averaging. The development of a custom ClimateEngine.org application page will primarily be driven by needs of stakeholders, state, local, and federal agencies such as the Nevada Department of Conservation and Natural Resources, local water and natural resource agencies, BLM, U.S. Forest Service (USFS), and U.S. Fish and Wildlife Service (USFWS). Planned additions and enhancements to Climate Engine will include EDDI and remote sensing information that can provide enhanced early warning and monitoring of rangeland and agricultural drought.

[2] MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra and Aqua satellites. Learn more here: https://modis.gsfc.nasa.gov/about/

Activity 2.1c Outcomes

- Customized version of ClimateEngine.org for rangeland and agricultural management [Summer 2017].
- Addition of stakeholder requested averaging polygons, datasets, and indices into Climate Engine [Spring 2018].
- Stakeholder engagement and outreach on training and use of climate and vegetation indices and spatial averaging time series for agricultural and rangeland drought monitoring (see Activity 4.7).
- Update customized version of ClimateEngine.org as needed based on stakeholder feedback [ongoing].

Activity 2.1d Fire Danger Indices

Fire danger indices are used to assess wildfire potential for short-term wildland fire management decision-making (e.g., large fire potential) and used by the research community as a numerical measure of fuel aridity. Four sets of daily fire-danger indices using the US National Fire Danger Rating System are available via Climate Engine, including the Energy Release Component (ERC). ERC is a proxy for daily potential fire radiative energy that integrates temperature, precipitation, humidity and solar radiation over the preceding several weeks and which exhibits strong links to the occurrence of very large fires and seasonal burned area, particularly across forested regions during drought periods.

CA-NV DEWS efforts related to fire danger will focus on: 1) improving fire danger early warning and dead fuel moisture indicators; 2) optimizing EDDI time scales that are most appropriate for providing late winter/early spring early warning of summer soil moisture and wildfire conditions; and 3) collaborating with NIDIS and stakeholders from USFS, CAL FIRE, and Predictive Services to provide near real-time drought and wildfire monitoring information and visualization through Climate Engine.

Activity 2.1d Outcomes

- Analysis in Climate Engine for place-based drought and wildfire monitoring [Fall 2017].
- Stakeholder engagement and outreach on training and use of fire danger indices (see Activity 4.7).

Activity 2.2 Improve Near Real Time Groundwater Monitoring in California's Central Valley

To improve groundwater monitoring and management within California's Central Valley, the USGS in collaboration with CNAP and NIDIS is working to provide near real-time and projected future information on surface inflows, groundwater level changes, and land subsidence. The Central Valley Hydrological Model (CVHM) is an extensive, three-dimensional numerical model of the hydrologic system of the Central Valley, the region in California with the largest agricultural footprint and the greatest amount of ground water withdrawal. CVHM calculates groundwater pumping as the remaining irrigation demand estimate after surface-water deliveries are taken into account as well as deriving an estimate of the amount of subsidence of the ground surface overlying the groundwater aquifers. These surface-water deliveries are central to calculating groundwater pumping in CVHM;

however, it often takes years to compile this delivery data.

To enable simulations of near-real time pumping in the Central Valley, the project will develop a near-real time data stream, data processing, and estimates of surface-water components based on a statistical model between historical surface-water deliveries, reservoir releases, and climatic variables to estimate surface water inputs and diversions and deliveries as inputs to CVHM. The real-time data stream of surface water inputs to CVHM will be automated for incorporation into an online tool in collaboration with USGS to provide up-to-date CVHM estimates of groundwater use, ground subsidence, and other associated products for decision makers, planners and other stakeholders. This online tool will eliminate the multi-year lag in Central Valley water use information, until official data and estimates can be compiled. Tools and procedures that will be developed should be applicable to other settings that are challenged with problems in sustainable conjunctive surface and groundwater use. This work is of interest to many stakeholders, including the Groundwater Resource Agency, BOR Central California Office, who manages major parts of the surface water supplies that are provided to water users (mainly farmers) in the Central Valley, and the development of mass transport via high speed rail (HSR) that will connect southern and northern California through the Central Valley.

Activity 2.2 Outcomes:

- Initial results presented to stakeholders in the region through CNAP, DEWS, and USGS collaboration and networks [ongoing].
- 2 page outreach handout on project goals and progress as well as partnerships [Winter 2018].
- Online tool in collaboration with CNAP and USGS for decision makers, planners and other stakeholders [Fall 2018].

Activity 2.3 Fallowed Agricultural Field Tracking

One of the pilot activities of the CA DEWS was demonstrating the feasibility of using satellite imagery on a monthly basis to track the extent of fallowed land for drought impact reporting in California's Central Valley. Operational fallow field identification is important for water use monitoring and accounting, agricultural production statistics, and monitoring the effects of drought. Landsat satellite imagery has proven to be an effective and efficient source of data for classification of fallow field conditions. However, scaling automated fallow field identification algorithms to regional scales have proven to be difficult due to large data archive requirements, computational limitations, and need for automatic Landsat archive updating.

With support from NIDIS and National Aeronautics and Space Administration (NASA), work conducted by California State University Monterey Bay (CSUMB), NASA, USDA, and USGS with the California Department of Water Resources (CA DWR) over the past three years has demonstrated an approach for the California Central Valley that meets the requirements for timeliness and accuracy specified by CA DWR. However, the large data volumes and computational requirements have presented a barrier to sustained operational use of these capabilities by state agencies. Cloud computing using Google Earth Engine avoids costly data storage and computing times, and will allow for operational fallow field tracking.

With continuing NIDIS support, this activity builds upon the pilot project for the California Central Valley, expanding into Nevada, to deliver and validate an operational near real-time fallow field tracking tool for CA-NV DEWS study areas using Google Earth Engine and archives of Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM+), and Landsat 8 Operational Land Imager (OLI). Accuracy assessment for maps and data products for fallow (and non-fallow) fields will be quantified through field campaigns, where team members will validate that fallow field classifications are accurate. Validation will take place in major agricultural areas in California's Central Valley, and in major Nevada agricultural areas, such as Mason Valley, Antelope Valley, Lovelock Valley, Fallon, Carson Valley, and Winnemucca Valley. These efforts will be complementary to State of Nevada and California crop inventories, and researchers from DRI, WRCC, and CSUMB will work with each state agency to ensure that leveraging of resources takes place where field verification can help both CA-NV DEWS validation and state crop inventory efforts. Finally, training and reference materials will be developed to assist state agencies in California and Nevada to integrate these new tools and data resources into operational drought monitoring and decision making processes for drought mitigation.

Activity 2.3 Outcomes

- Development and implementation of algorithms on Google Earth Engine [Winter 2018].
- Accuracy assessment field campaigns to validate fallow field classifications [Fall 2018].
- Operational production of fallow field tracking maps via a dynamic web based interface [Winter 2018].
- Training and reference materials for state agencies developed [Spring 2019].

Activity 2.4 Develop a Wildfire Component for the CA-NV DEWS

The CA-NV DEWS will leverage a two-year project funded through the NOAA SARP program entitled: "Developing a wildfire component for the NIDIS CA DEWS[3]". The goals of the project are to:

- interact with stakeholders to determine specifically what type of drought information is most pertinent for them to manage potential wildfire risk;
- collaborate with key stakeholders to develop drought-related, decision-support information and tools; and
- enhance the CA-NV DEWS by integrating outputs and outcomes from both the SARP project and the drought-wildfire nexus workshops (Activity 1.4) to provide information and tools to inform wildfire management planning and decision-making.

The project will be oriented around a deliberate co-production-of-science approach with stakeholders from several groups, including Predictive Services[4], USFS, California Department of Forestry and Fire Protection (CAL FIRE). Two innovations will be used in the project: (1) introducing EDDI to the wildfire community; and (2) improved visualization and analysis by incorporating EDDI and other drought indices into Climate Engine. The physical atmospheric components of EDDI (i.e., temperature,

[3] This project was awarded prior to the establishment of the CA-NV DEWS

[4] Predictive Services is a branch of the USFS charged specifically with producing National and Area-wide fire weather, fire danger and fire behavior outlook products. Learn more: https://gacc.nifc.gov/predictive_services/predictive_services.htm

humidity, wind and solar radiation) are strongly linked to vegetation fuel moisture, and hence fire potential. Therefore, EDDI can provide an early warning of wildfire potential that can be tied to the National Fire Danger Rating System.

Activity 2.4 Outcomes

- Provide stakeholders recommendations on which drought indices provide the best lead time for wildfire risk early warning [ongoing].
- Engage with stakeholders during workshops and trainings (Activities 4.3 and 4.7) to test EDDI for real-time wildfire applications.
- Provide Predictive Services experimental EDDI products in Spring 2017 to use during the 2017 wildfire season. Conduct follow up evaluation in Winter 2018 to understand how well EDDI products worked and how they could be improved.
- Incorporate new drought information into the National Fire Danger Rating System based on stakeholder feedback [Fall 2018].

Activity 2.5 Water Supply Status Updates for Drought Monitoring

Many of the rivers of Sierra Nevada and Colorado River basin are managed with man-made reservoirs that have been developed over many decades. These reservoirs are sized and operated so as to take advantage of the even larger natural, but very seasonal, "reservoirs" comprised by the snowpacks of the mountain ranges in these areas. USGS, with NIDIS, CNAP, Center for Western Weather and Water Extremes (CW3E), and other partners will continue to develop and expand tools and procedures to track and anticipate the joint status of reservoir and snowpack water contents across the Sierra Nevada. Similar tools will be initiated for the Colorado River Basin. These tools are used to inform decision makers and public of the current status of drought in the region and provide historical context that may be useful in helping prepare for and cope with drought and its impacts.

The below activities will be integrated into various CA-NV DEWS outreach and communication strategies (Priority 4) through webinars, in-person meetings, and web interfaces (drought.gov, cnap.ucsd.edu). Additionally, to facilitate tool utilization, one factsheet will be developed by USGS and CNAP for each activity explaining and providing scientific basis for the ongoing products will be developed.

Activity 2.5a

During winter 2017, USGS with CNAP began producing and distributing (by the CNAP website and social media) quasi-weekly updates of a figure showing total water storage in representative reservoirs and in the snowpack of the western Sierra Nevada. Based on CA-NV DEWS stakeholder feedback, these tools are currently being extended by USGS and CNAP to develop and distribute similar monitoring graphics for several separate parts of the Sierra Nevada (e.g., northern, central, southern and—to extent possible—eastern Sierra) as well as initial efforts for key parts of the Colorado River basin. Strategies and graphical designs for regularly, clearly and efficiently reporting reservoir storage and reservoirs-plus-snowpack storage are also being designed and implemented.

Activity 2.5b

During 2016-2017, USGS with CW3E and CNAP produced and developed upon methods to describe the historical odds of reaching various water-year precipitation totals, conditioned on precipitation already measured in the water year to date, for selected climate divisions in California and Nevada. These odds were reported on a monthly basis through the CW3E website (e.g., http://cw3e.ucsd.edu/odds-of-reaching-100-water-year-precipitation-apr-update/). This activity compares and contrasts the ways that these odds have evolved within each of the past several years, i.e., in a severe drought year, in a near-normal year, and in a drought-breaking year. The evolution of odds for various water-year totals is a straightforward way to communicate the "competition" between the always-increasing accumulations of precipitation that might lead into or out of drought conditions, and the always-decreasing time left in any given wet season in the strongly Mediterranean hydroclimate of California and parts of Nevada.

USGS with CW3E, CNAP with NIDIS will continue to develop new procedures and graphical presentations to present the month-to-month evolution of odds of getting into, or out of, drought conditions in the climate divisions of the two states to increase their value to the public and decision makers.

Activity 2.5 Outcomes

- NIDIS with USGS, CNAP, and CW3E will continue to integrate water supply status updates into outreach and communication strategies, including the CNAP website, the drought portal, the CA-NV DEWS Drought & Climate Outlook Webinars (Activity 4.1) and other outreach (Activity 4.3) [ongoing].
- For each activity, USGS and CNAP will generate a tool factsheet and documentation of the procedures for producing these monitoring graphics [Fall 2018].

Activity 2.6 Improve Understanding of Russian River Valley's Future Risk to Drought & Best Practices on Landscapes

CW3E, CNAP, USGS, and Sonoma County Water Agency (SCWA) have an ongoing collaboration to better understand the Russian River Watershed's future risk to drought through a NOAA SARP[5] project with three main tasks:
(1) Understand how extreme precipitation events, specifically atmospheric rivers (ARs), will change in the future and their role in ending droughts;
(2) Produce extreme drought scenarios to understand how the urban and natural landscapes will respond; and
(3) Work with stakeholders to understand drought mitigation measures that are currently being executed and what can be done to make the area more resilient to drought in the future.

CNAP and SCWA are working with land managers to discuss the results of the drought scenarios and collect feedback on potential mitigation measures. This project includes communicating best practices for various landscapes in the region. CNAP, SCWA, and other partners will further explore lessons

[5] This project was awarded prior to the establishment of the CA-NV DEWS

learned from this project, particularly the difference between water supply drought and landscape drought. NIDIS and CNAP will also investigate replication in other regions and explore the roles other partners can play in building on the success of this activity.

Activity 2.6 Outcomes

- Drought Readiness Report by the SARP project team for the region [Fall 2017].
- CNAP and other partners will explore with leaders in Sonoma County mechanisms for sharing (such as websites) best practices to mitigate drought on natural and working landscapes [ongoing].

Priority 3 – Develop Forecast and Decision Support Tools for Resource Managers

Seasonal (2-9 months) and sub-seasonal (2 week-2 months) climate forecasts can be used by water and land managers to help guide important decisions such as reservoir operations, groundwater management, and livestock grazing schedules. Forecast skill for forecasts at these lead times is often quite low for precipitation, which limits the ability to make confident decisions. While NOAA's Climate Prediction Center (CPC) and Environmental Modeling Center (EMC), other federal agencies, the academic community, and others are working to improve seasonal and sub-seasonal forecasts, incorporating new drought-related variables with higher skill could add great value and confidence to operational seasonal drought forecasts. In addition, existing seasonal forecast products and tools are typically provided as National-scale static maps, at coarse spatial resolution, and with only categorical probabilistic information (e.g., above average/below average/normal chance), making it difficult for resource managers to use the information at the local scale, and make specific, constrained decisions. Providing higher-resolution and more-reliable information along with forecast uncertainty (probabilities and forecast skill) to resource managers will improve decision-making based on forecast information.

This priority will focus on developing and incorporating objective monitoring and prediction products and indices, new targeted prediction products, new observational datasets, improved models, improved understanding of the predictability of drought events, real-time evaporative demand forecasts, downscaled North American Multi-Model Ensemble (NMME) seasonal forecasts.

This priority also involves working directly with decision makers (water managers, reservoir operators etc.) to understand how these forecasts are used and how they can be improved and integrated into decision-making processes.

Activity 3.1 Develop Real-Time Evaporative Demand Forecasts

Seasonal forecasts of evaporative demand (ET_0)[6] offer potential to provide improved seasonal drought predictions across the contiguous U.S. (CONUS). Currently, there are no operational products of seasonal ET_0 forecasts for the western U.S. or any of CONUS. Through EDDI, DRI/WRCC with NIDIS support will develop a CONUS-wide real-time seasonal ET_0 forecast application using the NOAA's Climate Forecast System Version 2 (CFSv2). Forecasts will be downscaled to spatial resolutions that

[6] Evaporative demand is derived from temperature, humidity, wind speed, and solar radiation.

can be applied at the regional and local scale (Activity 2.2). Other new ET_0 forecast products will include probability forecasts from CFSv2 ensembles and skill maps to assist with resource manager decision making.

Weather forecasts out to a 7-day lead-time of ET_0 are currently available through NOAA. The product is called Forecast Reference EvapoTranspiration[7] (FRET) and includes ET_0 values and anomalies that can be used for short-term water resource and agricultural management decisions. This product will also be made available through the drought portal.

Activity 3.1 Outcomes

- Post and promote FRET products on CA-NV DEWS webpages on drought.gov [Fall 2018].
- Provide operational seasonal ET_0 forecasts (leads 0-9 months) over CONUS [Fall 2018].

Activity 3.2 Provide Downscaled NMME Seasonal Forecasts

Researchers at DRI and WRCC will enhance an existing place-based operational seasonal forecast tool developed at UI that uses NMME forecasts and the UI gridded meteorological data (gridMET) (Abatzoglou, 2013) to provide bias-corrected and downscaled seasonal forecasts at 4-km spatial resolution for the western U.S. The NMME combines 7 different state-of-the-art seasonal forecast models developed at research institutes throughout the U.S. and Canada. DRI and WRCC, in collaboration with other CA-NV DEWS partners and stakeholders, will develop and enhance a number of features for this place-based operational seasonal forecast web application. The biggest addition will be incorporating CFSv2 ET_0 anomaly forecasts, which provide additional skill over precipitation for drought forecasting. Whereas most NMME models are only operationally producing monthly temperature and precipitation forecasts, proposed enhancements include application of an approach similar to the Multivariate Adapted Constructed Analogs (MACA) approach of Abatzoglou and Brown (2012) for temporally disaggregating monthly data to daily data, as well as for estimating other variables such as downward shortwave radiation at the surface, wind speed, and surface humidity needed for producing NMME derived ET_0 products. New ET_0 products will be added to the existing framework using both CFSv2 forecasts and the analog approach.

Other new planned additions to the existing place-based operational seasonal forecast tool will include a dynamic mapping interface that allows users to pan and zoom over all spatial maps. Time series tool enhancements to the web application will be made by incorporating watershed and hydrographic area boundaries, agricultural areas, and grazing allotments, to help managers extract place-based information needed for the local decision making process. DRI and WRCC will closely collaborate with other key stakeholders to ensure developments and enhancements meet forecasting needs of multiple sectors and DEWS regions (beyond the CA-NV DEWS).

Activity 3.2 Outcomes

- Add ET_0 forecasts as an additional product to UI's existing downscaled NMME web interface

[7] http://go.usa.gov/ctBRC

[Winter 2018].

Activity 3.3 Forecast-Informed Reservoir Operations (FIRO)

FIRO is a proposed management strategy that uses data from watershed monitoring and modern weather and water forecasting to help water managers selectively retain or release water from reservoirs in a manner that reflects current and forecasted conditions. FIRO is being developed and tested as a collaborative effort focused on Lake Mendocino, engaging experts from several federal, state, and local agencies, universities, and others including: NOAA's Earth System Research Laboratory - Physical Sciences Division (PSD), NIDIS, US Army Corps of Engineers (USACE), Sonoma County Water Agency (SCWA), CA DWR, CW3E and Scripps Institution of Oceanography (SIO) at UC San Diego, BOR, and USGS. A Preliminary Viability Assessment (PVA) is being developed to describe an approach for using modeling, forecasting tools and improved information to determine whether Lake Mendocino operations can be adjusted to enhance water supply reliability without compromising flood control. If viable, FIRO has the potential to be an important drought mitigation strategy.

NIDIS and PSD helped lay the groundwork for FIRO several years ago through NOAA's Sectoral Applications Research Program (SARP) to provide stakeholders like SCWA with drought monitoring technology and information that is relevant across heavily regulated, imported, and unmanaged water supplies, providing early warnings to reservoir regulators.

Activity 3.3 Outcomes

- Preliminary Viability Assessment (PVA) released [Spring 2017].
- FIRO PVA outreach beginning [Spring 2017 and ongoing].
- NIDIS and partners will communicate and promote FIRO at regional and national levels [ongoing].

Activity 3.4 Support Water Resource Management & Decision Making in Southern Nevada

Water resource management in the West is a combination of decision-making based on supplies originating in other parts of the West as well as local supplies and demand. CNAP, in collaboration with the Southern Nevada Water Authority (SNWA), is examining historical and future climate variability in southern Nevada, an area oftentimes overlooked in climate studies because much of the drinking water for the region is currently imported from the Colorado River. Yet, climate variability and drought is important to southern Nevada because it influences local water demand. The most extreme bounds of the variability can cause flooding and heat waves that could impact infrastructure, energy and health. The jointly authored assessment of the region will provide southern Nevada a comprehensive look at the climatology and provide information on how different climate variables important to water demand, infrastructure resilience, and health may change in the future. This work continues development of a new stakeholder relationship with the largest water supplier to the most populated area in Nevada, which is important in the development of the CA-NV DEWS. SNWA anticipates that this climate and drought information will inform their adaptation efforts.

Activity 3.4 Outcomes

- Assessment report jointly authored by CNAP and SNWA on historical and projected future climate variability in Clark County (NV) [Fall 2017].

Activity 3.5 Operational Drought Monitoring and Prediction to Improve the CPC Seasonal Drought Outlook

Activity 3.5a Improve Seasonal Precipitation Forecasts to Support the CPC Seasonal Drought Outlook

Improved seasonal precipitation forecasts are an important but challenging component of strengthening seasonal drought outlooks. Currently, precipitation forecast skill from both statistical and dynamical forecast tools independently are generally low, outside of at least moderate El Niño Southern Oscillation (ENSO) events. Forecast skill from the CPC official seasonal precipitation outlooks, on average, is also generally low and over the last decade or more, there has been little if any discernable increase in outlook forecast skill. To improve precipitation forecast skill that supports the CPC Seasonal Drought Outlook, researchers at CPC, with support from NIDIS, will provide alternate hybrid statistical-dynamical forecasts of precipitation for North America, honing the drought monitoring capability on seasonal scales by exploiting the linkage among precipitation, geopotential heights, and near-surface air temperature forecasts. This research will help improve the input information that supports the NWS operational drought outlooks. Forecast tool development, formatting, and usefulness will be reviewed by the NIDIS Prediction and Forecasting Working Group, NDMC, and other stakeholders.

This project will also leverage other projects at CPC to address sub-seasonal and seasonal prediction of precipitation and drought, including projects funded under the NOAA Climate Program Office in the focus areas of the Climate Test Bed Sub-seasonal NMME.

Activity 3.5a Outcomes

- Development of hindcast and real-time predictions of seasonal precipitation based on a number of methodologies along with an evaluation report of historical and real-time forecast skill. The metrics used will be those currently used at CPC to evaluate current tools and official outlooks (i.e., Heidke Skill Score, Ranked Probability Skill Score, AC, RMSE, etc.).
- Report on first year accomplishments [Fall 2017].

Activity 3.5b Improve Drought Monitoring Indices

To improve the current nationwide drought monitoring and prediction system, CPC, with support from NIDIS, is testing new procedures to monitor and forecast precipitation, air temperature, soil moisture, runoff, evaporation and drought indices. Improved drought indices will provide users with the capacity to determine the current status of drought. Better dynamical forecasts will give the decision makers and Drought Outlook authors enhanced tools needed to better prepare for and mitigate the impacts of drought.

Drought indices will be provided in percentiles and classified in D0-D4 categories with

uncertainties given. This work will also support the NWS operational drought outlooks. Information on soil moisture and runoff will give stakeholders additional information on the development of agricultural and hydrologic drought, which is an expressed need by stakeholders in the land management community, in Nevada particularly.

Forecast tool development, format, and usefulness will be reviewed by the NIDIS Prediction and Forecasting Working Group, NDMC, and other stakeholders.

Activity 3.5b Outcomes

- Integrated drought index with concurrence measure to monitor droughts from weekly to monthly time scales to support CPC Drought Outlook operations.
- Tests whether the combination of Global Ensemble Forecast System (GEFS)-CFSv2 will improve precipitation, air temperature, soil moisture, evaporation weekly and monthly forecasts to support the CPC week 3-4 forecasts and the drought outlook operation.
- Report on accomplishments and lessons learned to NIDIS [Summer 2018].

Activity 3.6 Improve the NOAA Drought Amelioration Product Suite

Determining how much rain and snow must fall to end a current drought and return the system to normal is a multi-faceted challenge, yet it is a question routinely asked, owing to drought's far-reaching societal and economic impacts. In 2016 and 2017, NOAA's National Centers for Environmental Information (NCEI) updated the Drought Amelioration Product Suite following guidance from stakeholders. These revisions include production of drought termination outlooks, upgrading current graphics to include regional perspectives, and promoting the delivery of these new products through the CA-NV DEWS. The goal of this effort is to provide reasonable support information to aid in interaction with the media and the public when communicating about the uncertainty around the amelioration of drought and its impacts.

Activity 3.6 Outcomes

- Improved drought termination outlooks on the NOAA website following stakeholder guidance [Summer 2017].
- Follow up stakeholder meeting (co-organized with CNAP) in California in June 2017 for feedback [Summer 2017].
- Report on stakeholder meeting to determine next steps [Fall 2018].

Activity 3.7 Integrate Water Resource-Related Data and Predictive Information

For decades, NOAA's River Forecast Centers (RFCs) have been providing forecasts of seasonal streamflow at hundreds of locations across the western United States. Water managers have requested improved information to visualize the forecasts, obtain related data including forecast verification, and in particular, obtain longer-range water outlooks based on seasonal forecasts. A new online toolset, the Water Resources Monitor and Outlook (WRMO), being developed by NOAA in partnership with NIDIS, will provide uniform access to ensemble streamflow prediction (ESP) water supply forecasts along with a suite of climate and hydrological information, visualization, and analysis

of observed and seasonal forecast data; forecast evolution; and verification tools to improve water resource information delivery to water managers.

The WRMO will also integrate hydrometeorologic monitoring and outlooks, and recent scientific advances in weather and climate prediction into the product suite, as well as facilitate experimental use. Ultimately, the product suite will contain three web-based elements: 1) water resources monitoring 2) water resources outlook (both updated daily) and 3) sub-seasonal to seasonal climate outlooks for water resources. The seasonal water outlooks will leverage the existing operational forecasts at CPC together with forecast verification tools, with the aim to provide enhanced products during the critical runoff season. The current skill in CPC temperature outlooks is an opportunity to translate these products into information about the snowpack and potential runoff timing, even where the skill in precipitation is low. Temperature is an important consideration for whether precipitation falls as snow or rain, which is critical for streamflow forecasts, especially in the melt and runoff season in snowpack-dependent watersheds.

The WRMO will be introduced to potential users and stakeholders at CA-NV DEWS meetings and workshops as well as with existing RFC users (e.g. the Colorado Basin River Forecast Center (CBRFC) annual stakeholder meeting), and other professional society meetings. This stakeholder engagement and evaluation being conducted will help refine the WRMO to better meet user needs.

Activity 3.7 Outcomes

- Beta version of the on-line WRMO tool available for use and feedback. This version will provide uniform access to ensemble streamflow prediction (ESP) water supply forecasts, a suite of hydrological information, visualization, and analysis of observed and seasonal forecast data; forecast evolution (early FY2018); verification tools will be available in a later version.
- Stakeholder engagement and socialization of the WRMO to CA-NV DEWS stakeholders [Ongoing]*.
- Develop and design prototypes for the Water Outlook component in partnership with CPC and PSD [Winter 2018]*.
- Evaluate and document use of products [Ongoing 2018]*.
- Report to NIDIS on findings [Fall 2018]*.
- Reengage with stakeholders to evaluate product refinements and prototype new climate-based Water Outlook products [Fall 2017/Fall 2018]*.

** Pending FY18 funding*

Priority 4 – Improve Drought Early Warning Communication and Outreach

Participants of Governor Sandoval's 2015 Nevada Drought Forum called for "Information Sharing and Outreach." Forum members as well as the CA-NV DEWS network agreed that additional and more consistent outreach is needed regardless of the state's drought status. To help meet that need, the CA-NV DEWS will support workshops, trainings, and seminars that focus on drought status and impacts reporting, advances in drought monitoring, and accessing and interpreting new place-based drought products in the region. Many of the technical tools and innovative research that will be socialized as a part of this coordinated outreach have been previously addressed in this Plan, and will also be

incorporated into many of the following activities.

Activity 4.1 CA-NV Drought & Climate Outlook Webinar Series

NIDIS regional partners (such as CNAP, DRI, NWS, and WRCC) will provide a regular and timely webinar series throughout the water year on the drought and climate status update and outlook. The agenda of each webinar will be tailored to reflect recent, current, and forecasted conditions and climatic events, and discussions of observed impacts and other relevant updates from sectors and communities throughout the region. Webinars will periodically feature NOAA initiatives (i.e. NCEI state of the climate, explanation and discussions of CPC forecasts, WRCC Quarterly Climate Impacts and Report) as well as those from NIDIS partners. Webinars and recordings and other supporting materials will be posted on drought.gov. NIDIS will also co-host specialty drought webinars with interested partners from state and federal agencies.

Activity 4.1 Outcomes

- CA-NV DEWS Bi-Monthly Drought & Climate Outlook Webinars [scheduled for the 4th Monday of every other month starting January 23, 2017].
- Webinars will be recorded and posted on drought.gov with supporting materials.

Activity 4.2 Colorado Basin River Forecast Center Water Supply Forecast Monthly Briefings

Each year from December through June, the Colorado Basin River Forecast Center (CBRFC) holds monthly water supply forecast briefings for stakeholders throughout the region. These briefings are held via webinar and are often available as recordings after each live broadcast. CBRFC conducts monthly briefings for both the Colorado River Basin and Great Basin (both are relevant to stakeholders in the CA-NV DEWS) to review and discuss water supply forecasts and current conditions. Additional briefings (including a peak flow briefing usually in mid-March and an annual verification reviewing the state and evolution of monitoring metrics and forecasting products) will be scheduled as needed reflecting changing conditions or expressed interest.

Registration information and archived briefings can be found on CBRFC's webpage (cbrfc.noaa.gov) and will also be posted on the CA-NV DEWS pages on drought.gov.

Activity 4.2 Outcomes

- Monthly briefings for both the Colorado River and Great Basins held via webinar/conference call.

Activity 4.3 In-person Drought, Climate, and Water Year Outlooks & Workshops

The CA-NV DEWS will coordinate with the collaborative regional network to hold as needed a series of Drought, Climate and Water Outlooks and stakeholder-requested topical workshops at various times and locations throughout the region. These Outlooks will provide a recap of recent events, an update on current conditions, climate outlook, highlight new and developing research and tools, and provide a forum for stakeholders to discuss observed and anticipated impacts. Additional topics and themes will be considered for these and additional workshops to reflect current conditions in the region, including: ENSO forecasts and anticipated impacts to the region; explanations of CPC seasonal outlooks; post-

mortem looks at forecasts and outcomes; snowpack and spring runoff forecasts; wildfire season outlook/recap; reservoir status; groundwater/aquifer monitoring etc.

NIDIS will convene a group of key stakeholders identified by the CA-NV DEWS network to create a dynamic two-year calendar for in-person Outlooks and other workshops. This calendar will be based on key climatic times of the year and decision making timelines based on sectors and/or regionally specific needs.

Activity 4.3 Outcomes

- Dynamic two-year calendar of in-person outlooks and workshops developed by the CA-NV DEWS network [Fall 2017].
- All meeting/workshop presentations and associated materials (agendas etc.) will be posted on drought.gov within one month.

Activity 4.4 Development of a Communication Framework for the CA-NV DEWS

NIDIS, CNAP, DRI, WRCC, and other interested partners will develop a streamlined communication network plan including email templates, contact lists, social media, and multi-lingual resources including strategies for efficiently leveraging various existing listservs and other communication networks.

Activity 4.4 Outcomes

- CA-NV DEWS Communication framework developed [ongoing].

Activity 4.5 National Weather Service Briefings to Emergency Management Networks

Briefings by the NWS to emergency management and other interested groups have become vital to seasonal resource planning across the country. In California and Nevada, the NWS in-person briefings occur primarily in September-October before the winter season when most precipitation falls. This timing is based on flood preparation and wildfire, but as the most recent drought worsened, other related concerns grew including temperature, high wind, and post-fire precipitation events. In response to the historic California drought, the NWS Western Region has also held statewide monthly drought calls with the California Office of Emergency Services (CalOES).

Upon request, NIDIS and other CA-NV DEWS partners will support and partner in these NWS briefings. NWS briefings will be reflected in the general outreach calendar (Activity 4.4) to limit overlap and ensure the efficient use of resources.

Activity 4.5 Outcomes

- NWS Western Region – CalOES Monthly Drought Calls [Ongoing].
- Partner on in-person fall briefings as needed [Fall 2017; Fall 2018].

Activity 4.6 Update and Maintain the CA-NV DEWS Information on the U.S. Drought Portal

NIDIS will work with its partners to update and maintain the CA-NV DEWS pages of the U.S. Drought Portal. This site provides up-to-date information on DEWS activities (e.g., workshop dates and summaries, research, outreach activities, etc.) Additional information will be added to the U.S. Drought Portal as it becomes available, to include innovative drought research, drought vulnerability assessments, best management practices (BMPs), success stories, and lessons learned from drought mitigation and response.

NIDIS will work with CA-NV DEWS stakeholders as well as subject matter experts of the NIDIS Drought Portal Working Group to provide recommendations for CA-NV DEWS webpage improvements, using Google analytics data to inform discussion. Suggested improvements may include the selection of specific climate tools to post on the site that are useful for stakeholders, and/or measures to enhance the user experience through diverse, interactive mediums.

Activity 4.6 Outcomes

- Regular enhancements to the CA-NV DEWS webpage, to include timely updates, relevant content, and visual improvements in layout and formatting. [Winter 2017 – Fall 2018].

Activity 4.7 Drought & Rangeland Management in Nevada Trainings

Participants at the Nevada Drought Forum called for improved availability of information in decision-making processes, particularly in drought response and early warning. Forum members recommended ways to better inform the public and other decision-makers of current conditions and other drought-related issues. Participants also agreed that communication with the public and other stakeholders should occur on an ongoing basis, regardless of the state's drought status, with an emphasis on the relationships between drought and rangeland management. To meet this need, NIDIS, DRI, WRCC, CNAP, and other CA-NV DEWS partners will host a series of in-person trainings on new and existing tools and technologies to enhance drought monitoring, preparedness, and planning activities of stakeholders in the region.

These Nevada trainings will focus on the basics of climate, meteorology, seasonal forecasts, and remote sensing, and how these products can be used to perform drought, fallow field tracking, and environmental assessments. Workshops will also include instruction on how to interpret place-based map and time series products such as EDDI, PDSI, NDVI, SPI, SPEI, and surface temperature. These workshops will focus on specific stakeholder needs such as integrating new monitoring and early warning tools into field assessments and the rangeland management decision-making process. These activities will be coordinated with the Nevada Department of Conservation, University of Nevada Cooperative Extension, BLM, and other partner organizations.

Activity 4.7 Outcomes

- Development of training workshop calendar [Spring 2017].
- Development of initial training materials and tools [Summer 2017, ongoing].
- Ongoing post-workshop analysis and lessons learned.

- Final report and recommendations [Summer 2019].

APPENDIX A: CALIFORNIA-NEVADA DEWS PARTNERS

The development of this California-Nevada DEWS Strategic Plan and its associated implementation reflects the knowledge and experience of dedicated individuals, organizations, and partners. Collaboration is the key to improving drought early warning capacity and long-term resilience through implementation of the California-Nevada DEWS. This list of partners is not exhaustive and will evolve as new regional partnerships are formed.

Table A – California-Nevada DEWS Partnerships

Partner Agencies and Organizations
California Department of Water Resources
California Department of Forestry and Fire Protection
California Landscape Conservation Cooperative
California-Nevada Climate Applications Program
California Office of Emergency Services
California State Climate Office
California State University Monterey Bay
Center for Western Weather and Water Extremes
Desert Research Institute
Eureka County
Federal Emergency Management Agency
Great Basin Landscape Conservation Cooperative
Google
Metropolitan Water District
National Aeronautics and Space Administration
National Drought Mitigation Center
National Interagency Fire Center
National Oceanic and Atmospheric Administration ▪ Climate Prediction Center ▪ California Nevada River Forecast Center ▪ Colorado Basin River Forecast Center ▪ National Center for Environmental Information ▪ National Marine Fisheries Service ▪ National Weather Service ▪ Western Regional Climate Center
Nevada Department of Agriculture
Nevada Department of Conservation and Natural Resources
Nevada Division of Water Resources
Nevada State Climate Office
Nevada State Engineer's Office
Scripps Institution of Oceanography
Sonoma County Water Agency
Southern Nevada Water Authority

Truckee Meadows Water Authority
U.S. Army Corps of Engineers
U.S. Department of Agriculture ▪ Agricultural Research Service ▪ California Climate Hub ▪ Forest Service ▪ Natural Resources Conservation Service
U.S. Department of the Interior ▪ Bureau of Land Management ▪ Bureau of Reclamation ▪ Fish and Wildlife ▪ Geological Survey ▪ Southwest Climate Science Center
U.S. Environmental Protection Agency
U.S. Geological Survey
University of California Davis
University of California San Diego
University of California Santa Barbara
University of Idaho
University of Nevada Cooperative Extension
University of Nevada Reno
Western Governors Association
Western States Water Council
Western Water Assessment

APPENDIX B: NIDIS WORKING GROUPS

Coordination, communication, and transferability of information and actions between the NIDIS Working Groups and the California-Nevada DEWS is essential the overall process of building a collaborative information system. The table below highlights how each of the Activities in the California-Nevada DEWS Strategic Plan corresponds with the individual Working Groups. As the California-Nevada DEWS and the NIDIS Working Groups continue to develop, activities amongst each of these groups will be leveraged and coordinated.

Table B – California-Nevada DEWS and NIDIS Working Groups

Activity	NIDIS Working Groups					
	Education and Public Awareness	Monitoring and Observations	Predictions and Forecasting	Interdisciplinary Research Applications for Risk Assessment	Planning and Preparedness	U.S. Drought Portal
Priority 1 – Optimize the Collaborative DEWS Network						
Activity 1.1 Improve Drought Coordination Among Federal, State, Tribal, and Local Agencies						
Activity 1.1a Quarterly Stakeholder Calls	X				X	
Activity 1.1b Develop a Matrix of Federal, Tribal, State and Local Drought Related Activities and Resources	X				X	X
Activity 1.1c Support Drought Outreach and Communication Coordination Across the Network	X					X
Activity 1.2 Annual CA-NV DEWS Coordination Workshop	X	X	X		X	X
Activity 1.3 Strengthen CA-NV DEWS U.S. Drought Monitor with	X	X			X	

Contributions from the CA-NV DEWS						
Activity 1.4 Integrate Drought and Climate Science into the Wildfire Management Community	X	X	X	X	X	
Activity 1.5 Leverage CA-NV DEWS Network to Support Drought Planning		X		X	X	
Priority 2 – Develop Drought Monitoring Metrics and Research						
Activity 2.1 Cloud computing of climate and remote sensing data		X		X	X	X
Activity 2.1a Precipitation and snow cover monitoring		X		X	X	X
Activity 2.1b Evaporative Demand		X	X	X	X	X
Activity 2.1c Rangeland, agricultural, and forest vegetation monitoring		X	X	X	X	X
Activity 2.1d Fire danger indices		X	X	X	X	X
Activity 2.2 Improve near real time groundwater monitoring in the Central Valley		X	X	X	X	
Activity 2.3 Fallowed agricultural field tracking		X		X	X	
Activity 2.4 Developing a wildfire component for the CA-NV DEWS	X	X	X	X	X	
Activity 2.5 Water Supply Status Updates for Drought Monitoring	X	X			X	X

Activity 2.6 Russian River Valley's future risk to drought & emerging focus on best practices on various landscapes		X			X	
Priority 3 – Develop Forecast and Decision Support Tools for Resource Managers						
Activity 3.1 Develop of real-time evaporative demand forecasts		X	X	X	X	
Activity 3.2 Provide Downscaled NMME Seasonal Forecasts			X	X	X	
Activity 3.3 Forecast-Informed Reservoir Operations (FIRO)		X	X	X	X	
Activity 3.4 Support water resource management & decision making in Southern Nevada			X	X	X	
Activity 3.5 Operational drought monitoring and prediction to improve the CPC Seasonal Drought Outlook		X	X	X	X	
Activity 3.5a Improve seasonal forecasts to support the CPC Seasonal Drought Outlook		X	X	X	X	
Activity 3.5b Improved Drought Monitoring Indices		X	X	X	X	
Activity 3.6 Improve the NOAA drought amelioration product suite	X	X	X	X	X	X
Activity 3.7 Integrate water resource-related data and predictive information		X	X	X	X	X
Priority 4 – Improve Drought Early Warning Communication and Outreach						

Activity 4.1 CA-NV Drought & Climate Outlook webinar series	X	X	X		X	X
Activity 4.2 Colorado Basin River Forecast Center Water Supply Forecast Monthly Briefings	X	X	X		X	X
Activity 4.3 In-person Drought, Climate and Water Year Outlooks	X	X	X	X	X	X
Activity 4.4 Development of a Communication Framework for the CA-NV DEWS	X				X	X
Activity 4.5 National Weather Service Briefings to Emergency Management Networks	X				X	
Activity 4.6 Update and Maintain the CA-NV DEWS Information on the U.S. Drought Portal						X
Activity 4.7 Drought & rangeland management in Nevada trainings	X	X	X		X	

APPENDIX C: PROJECT LIST

Table C – California-Nevada DEWS Projects and Timelines

APPENDIX D: ACRONYMS

ASCE- PM ET_o	American Society of Civil Engineers Penmen-Monteith evaporative demand data
BLM	U.S. Bureau of Land Management
BMP	Best management practice
BOR	U.S. Bureau of Reclamation
CA DWR	California Department of Water Resources
CAL FIRE	California Department of Forestry and Fire Protection
CalOES	California Office of Emergency Services
CBRFC	Colorado Basin River Forecast Center
CFSv2	Climate Forecast System Version 2
CNAP	California-Nevada Climate Applications Program
CNRFC	California-Nevada River Forecast Center
CONUS	Contiguous United States
CoCoRaHS	Community Collaborative Rain, Hail and Snow Network
CSUMB	California State University Monterey Bay
CPC	Climate Prediction Center
CVHM	Central Valley Hydrological Model
CW3E	Center for Western Weather and Water Extremes
DEWS	Drought Early Warning System
DIR	Drought Impact Reporter
DOI	Department of the Interior
DRI	Desert Research Institute
EDDI	Evaporative Demand Drought Index
ENSO	El Niño Southern Oscillation
ERC	Energy Release Component
ESP	Ensemble Streamflow Prediction
ET_0	Evaporative Demand
EVI	Enhanced Vegetation Index
FEMA	Federal Emergency Management Agency
FIRO	Forecast Informed Reservoir Operation
FRET	Forecast Reference EvapoTranspiration
GEFS	Global Ensemble Forecast System
HSR	High Speed Rail
LCC	Landscape Conservation Cooperative
LST	Land surface temperature
MACA	Multivariate Adapted Constructed Analogs
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NCEI	National Center for Environmental Information
NDMC	National Drought Mitigation Center
NDSI	Normalized Difference Snow Index
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Wetness Index
NIDIS	National Integrated Drought Information System
NMFS	National Marine Fisheries Service
NMME	North American Multi-Model Ensemble

NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resources Conservation Service
NWS	National Weather Service
PDSI	Palmer Drought Severity Index
PVA	Preliminary Viability Assessment
RCC	Regional Climate Centers
RFC	River Forecast Center
RISA	Regional Integrated Sciences & Assessments
S2S	Seasonal to sub-seasonal
SARP	Sectoral Applications Research Program
SCWA	Sonoma County Water Agency
SIO	Scripps Institution of Oceanography
SNWA	Southern Nevada Water Authority
SPEI	Standardized Precipitation Evapotranspiration Index
SPI	Standardized Precipitation Index
SWCSC	Southwest Climate Science Center
UI	University of Idaho
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USDM	U.S. Drought Monitor
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WGA	Western Governors Association
WRCC	Western Regional Climate Center
WRMO	Water Resources Monitor and Outlook

APPENDIX E: EXAMPLES OF STATE AND LOCAL DROUGHT PLANNING ACTIVITIES

The following section describes state and local drought planning activities currently underway with support from the Bureau of Reclamation's Drought Response Program.

California: Elsinore Valley Municipal Water District is located within the Santa Ana River Watershed in Southern California. The District serves a 96-square mile area in Riverside County along the eastern foothills of Santa Ana Mountains and serves a population of over 146,000. The District imports 65 percent of its water supply from the Colorado River and the State Water Project, making it vulnerable to drought related price increases. Groundwater, the District's second largest water source, is increasingly contaminated with arsenic due to overdraft. Current exceptional drought conditions affecting the District have exposed numerous risks in the geographic area including risks to water supplies, drinking water availability and quality, ecology, the environment, ranching, recreation and tourism, and the economy. Working together with several local municipalities and water purveyors, the District will build on existing planning efforts to develop a drought contingency plan that will systematically outline drought monitoring, perform a vulnerability assessment, identify mitigation actions, and provide a framework for response actions, and will encourage stakeholder involvement.

Five large municipal and industrial water agencies with Central Valley Project water service contracts will collaborate in the development of a regional drought contingency plan covering northern Sacramento and western Placer Counties in northern California. The planning area covers approximately 550 square miles with 17 water suppliers serving a population of more than 1,000,000. The plan will incorporate climate information from the ongoing Sacramento-San Joaquin Basin Study, while focusing on municipal and industrial water supplies. Current drought conditions in California have revealed substantial risks to the public water supply system in the greater Sacramento region and the need to prepare a regional drought plan. The Placer County Water Agency will coordinate closely with Reclamation to develop the plan and is exploring the establishment of a water bank to increase use of available aquifer space in the basin.

The Monterey Peninsula Water Management District will partner with several Monterey County agencies, districts, and government and non-governmental entities to prepare a drought contingency plan for the northern portion of Monterey County, California. The plan area is located on the California coast south of San Francisco and includes part of the Salinas Valley, the western portion of Carmel Valley, and the urbanized Monterey Peninsula. Major land uses include agriculture, rangeland, forest and urban development. Water supply is provided by surface and groundwater sources as well as recycled water. The area has experienced severe drought conditions for the past four years. Over-drafted groundwater aquifers and state-mandated reductions in pumping, in combination with the drought, have galvanized local stakeholders to jointly prepare a drought contingency plan. The development of a regional drought contingency plan will combine elements of local plans, add missing elements, and foster cooperative relationships among the stakeholders.

The East Bay Municipal Utility District will work together with other regional water management agencies within the Bay Area to develop a drought contingency plan to improve water supply reliability during times of shortage. By taking a regional approach to drought contingency planning, the agencies will be able to enhance water supply reliability, leverage existing infrastructure investments, facilitate water transfers during critical shortages, and improve climate change resiliency. The plan will cover nine counties surrounding the San Francisco Bay.

Bay Area water agencies provide water to 6 million customers for municipal, industrial, and agricultural uses. Currently, the area is experiencing 'exceptional' drought, according to the U.S. Drought Monitor, and snowpack is at the lowest level in recorded history. Given the unprecedented supply shortages, curtailments have been issued. Reduced surface water supplies to municipal and agricultural water users increase competition for groundwater supplies, leading to increased salinity and impaired water quality.

The Inland Empire Utilities Agency, located in Southern California, will update its existing Drought Contingency Plan to account for economic impacts to customers, increased reclaimed water supplies, conservation, climate change, population and other factors not considered in their original plan. The updated plan will incorporate five regional water management plans in order to provide a holistic approach to improving water resources management for the region rather than relying solely on imported water supply as written in their original drought plan. Given the region's susceptibility to drought and the wide-ranging impacts of recent drought on the surrounding communities, the Agency will partner with regional cities and its member agencies to conduct planning activities.

Nevada: The Truckee Meadows Water Authority, located in northern Nevada, will update its current drought contingency plan to incorporate climate projections recently developed through a WaterSMART Basin Study and to specify mitigation actions to adapt to short-term changes in hydrologic conditions caused by drought. This update includes development and implementation of a decision support tool that will help water managers identify potential drought mitigation and response actions. The Truckee River is the primary water source for several cities, is used by the largest industrial park in the United States, feeds agricultural production and livestock grazing, and is home to several endangered fish species. In the past 115 years, the area has experienced two eight-year droughts and several shorter multi-year droughts - the past four years have exceeded the worst drought on record. The Authority will update its plan by engaging stakeholders through established and successful stakeholder groups representing Federal, state, and local governmental organizations, tribes, agricultural producers, industries, and environmental and recreational interests.