COMMUNICATING DROUGHT-RELATED WATER RESOURCES FORECAST INFORMATION IN CALIFORNIA – HOW DROUGHT HAS DRIVEN IMPROVEMENTS IN THE DELIVERY OF WATER RESOURCES FORECAST INFORMATION FOR WATER MANAGERS, THE MEDIA, AND THE PUBLIC

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ABSTRACT

Drought is a seemingly straightforward concept, essentially a prolonged lack of sufficient precipitation over a given area. California has one of the most highly managed water systems in the world and it is difficult for municipal water users to be connected to the origin of their water or the extent of drought when there is such an intensive reliance on irrigation and the water always flows when the tap is turned on. The California Nevada River Forecast Center (CNRFC) uniquely combines weather, hydrology, and climate every day to create water resources forecasts that extend out to one year in the future for California (and much of Nevada). However, the secondary mission is to provide water resources forecast information for the enhancement of ecological and economic interests. Hydrologic forecasting becomes more difficult under low flow conditions at the same time that scrutiny of the forecasts increases. One product used to help convey the extent of the drought was the DWR's Major Reservoirs Daily Graph. Another product that was especially useful to highlight in communicating the extent of the drought was the DWR's 8-Station Northern Sierra Precipitation Index. Additionally, the use of social media allowed the CNRFC to interpret conditions for the general public. Future drought-driven improvements in CNRFC products and services include the ability to view three year look-back plots of seasonal and water year hydrologic forecasts. Since droughts reflect cumulative multi-year precipitation deficits, drought visualizations should include corresponding cumulative deficits and the CNRFC offered these depictions. (KEYWORDS: drought, CNRFC, forecasting)

INTRODUCTION

Drought is a seemingly straightforward concept, essentially a prolonged lack of sufficient precipitation over a given area. However, in California, the concept of drought is complicated by several factors including the seasonal nature of precipitation in this region, the high year-to-year variability of precipitation and the geographic displacement between where precipitation falls, is collected and stored, and its ultimate use, which can be hundreds of miles away or more. Furthermore, there is often a mixture of local and distant sources of water, including extensive groundwater pumping in some areas. California has one of the most highly managed water systems in the world and it is difficult for municipal water users to be connected to the origin of their water or the extent of drought when there is such an intensive reliance on irrigation and the water always flows when the tap is turned on. To highlight the issue, consider a water user in the Los Angeles Basin potentially receiving a mixture up to five unique sources of their drinking water. It could come from the Northern Sierra Nevada Mountains, the Southern Sierra Nevada Mountains, the North Coast Mountains of California, the Colorado Rocky Mountains, or local groundwater, but probably some combination of these sources. Given that local rainfall is relatively light for the populous coastal plain of Southern California, what does a drought mean to them? A drought where? Thus, communicating the concept of drought to the media and the public involves connecting people to the source of their water and to the current state of supply. Over the past couple of years, the drought in California eventually brought the urgency needed to get the media and the public to be receptive to being educated on these connections.

The California Nevada River Forecast Center (CNRFC) uniquely combines weather, hydrology, and climate every day to create water resources forecasts that extend out to one year in the future for California (and much of Nevada). Being part of the National Weather Service, the primary mission of the CNRFC is the protection of life and property, which means forecasting flooding conditions and providing flood management officials with hydrologic forecasts to better manage flood waters. However, the secondary mission is to provide water resources forecast information for the enhancement of ecological and economic interests. Under drought conditions, much attention has been directed at determining how much water to expect and interest in leveraging the CNRFC forecasts

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has grown. Some rivers that normally have sufficient base flow to sustain surface flow through the summer, including the Eel River on the North Coast of California, ran dry in the late summer of 2014, an unprecedented event. Even in coastal rivers where flow continued through the summer of 2014, the flow levels were too low to meet all needs and interest in long-term volumetric forecasts expanded beyond the normally snowmelt-fed regions of the state. Furthermore, hydrologic forecasting becomes more difficult under low flow conditions at the same time that scrutiny of the forecasts increases, which has caused the CNRFC to more closely examine data sources and modeled processes to ensure better accuracy of the forecasts. Additionally, the CNRFC chose to better package some forecast information to be of optimal use by water resources managers.

DEPICTING AND COMMUNICATING DROUGHT

During the spring of 2014, when drought conditions were starting to seriously impact reservoir storage, water deliveries were curtailed to zero for holders of post-1914 appropriative water rights in much of the North Coast and Central Valley of California. In the San Joaquin Valley, many farmers had to drill deeper and pump more ground water to avoid losing permanent crops such as nut trees. Furthermore, the lack of winter rain throughout much of the state meant that ranchers had to supplement their cattle with imported feed. Later in 2014, some communities lost their water supply entirely as wells dried up. These impacts drew much attention both in California and nationally. The media started inquiring about the drought conditions and the National Weather Service and especially the California Department of Water Resources (DWR) had to step up their messaging on drought. Drought couldn't be explained without connecting the source regions of water to the end users and the media did a good job of communicating these messages. Many people learned the importance of the annual Sierra snowpack in water supply, something that was especially highlighted by the April 2015 Snow Survey media event attended by California Governor Jerry Brown, where the backdrop showed a landscape devoid of a snow cover, corresponding to the lowest water content of the Sierra snowpack on record at five percent of the April 1st average for the period of record, dating back more than 60 years in many locations.

One product used to help convey the extent of the drought was the DWR's Major Reservoirs Daily Graph shown in Figure 1, which graphically depicts reservoir storage as a gage-like reading, allowing a user to quickly visualize current storage compared to both reservoir capacity and to historical average for the date. Another product that was especially useful to highlight in communicating the extent of the drought was the DWR's 8-Station Northern Sierra Precipitation Index (Figure 2), which has a long period of record and serves as a proxy for the general state of observed precipitation in the Northern Sierra Nevada Mountains, a big source for much of the state's water supply. To help convey the extent of the drought, customized plots of the three-year cumulative 8-Station precipitation were made (Figure 3), highlighting the cumulative deficits. People needed to be connected to the source region of their water and to the cumulative impacts on storage. Additionally, the use of social media allowed the CNRFC to interpret conditions for the general public, while also introducing them to routine CNRFC hydrologic forecasts. Although the daily CNRFC hydrologic forecasts account for the effects of recently observed precipitation and short-term forecasts of precipitation, these forecasts don't receive much utility outside of the water resources community.

A heavy rain event in December of 2014 drew much attention as people wondered about its impact on alleviating the drought and the CNRFC used social media to put that event in the context of the drought. One example of this was a Facebook post on December 13th that illustrated the change in reservoir storage at three large Northern California reservoirs due to the storm (Figure 4). It is clear in the graphic that the storm helped, but that there was a long way to go to fill the reservoirs.

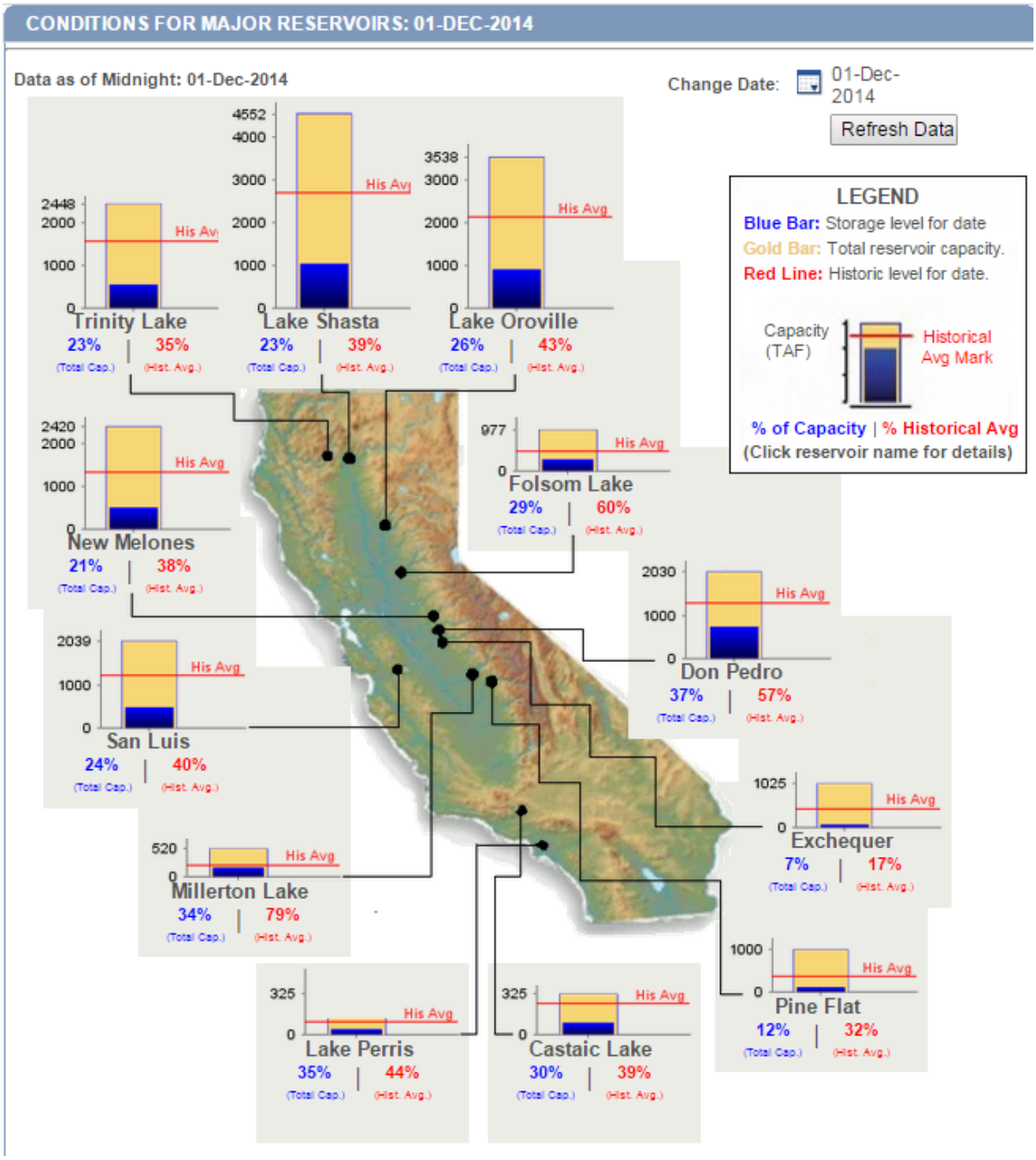

Figure 1. Reservoir conditions on December 1, 2014.

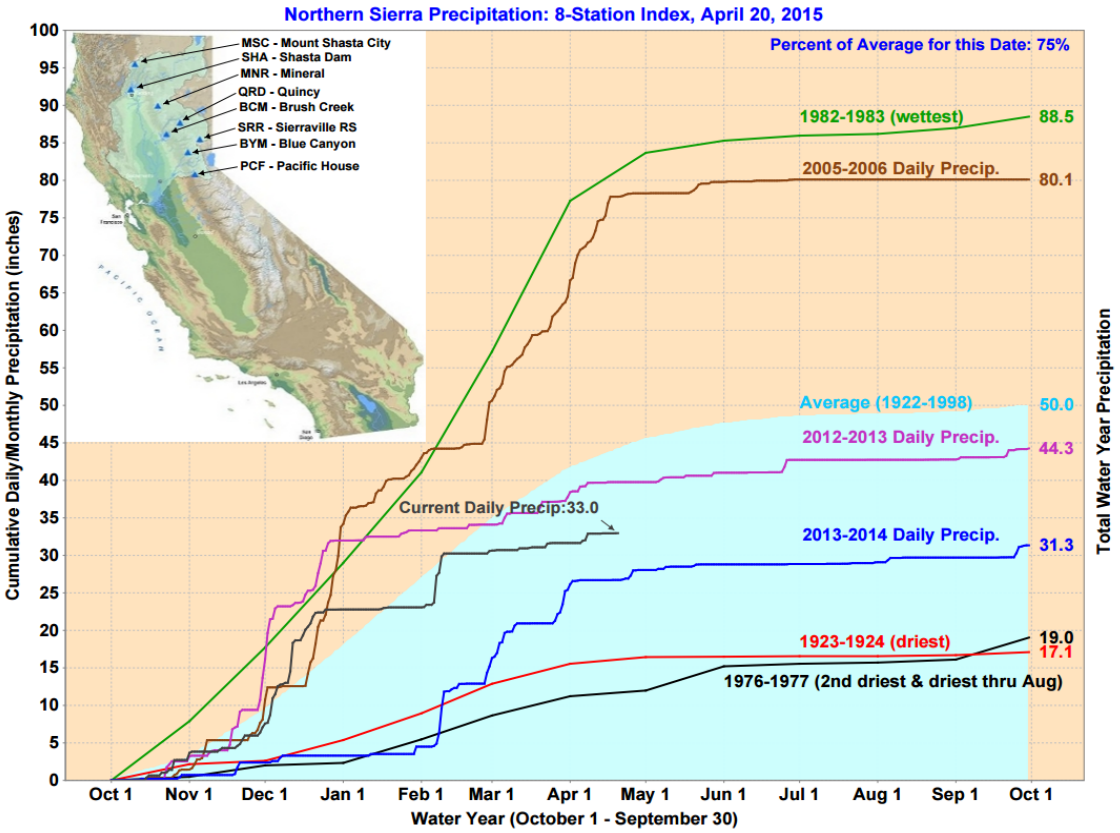

Figure 2. Northern Sierra precipitation: 8-Station Index on April 20, 2015.

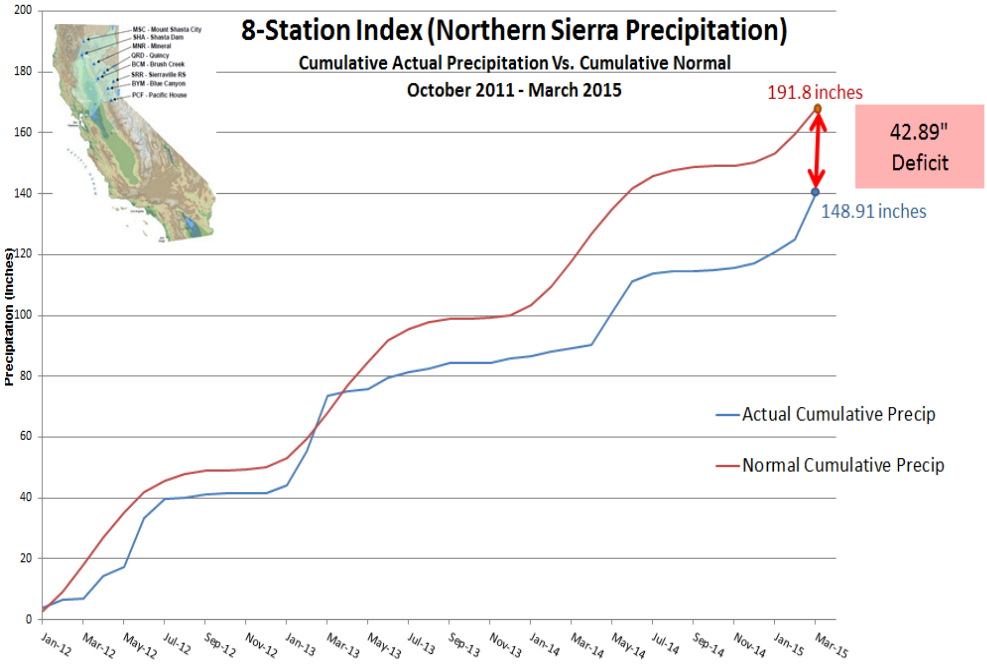

Figure 3. Northern Sierra precipitation 8-Station Index: cumulative actual precipitation vs. cumulative average precipitation.

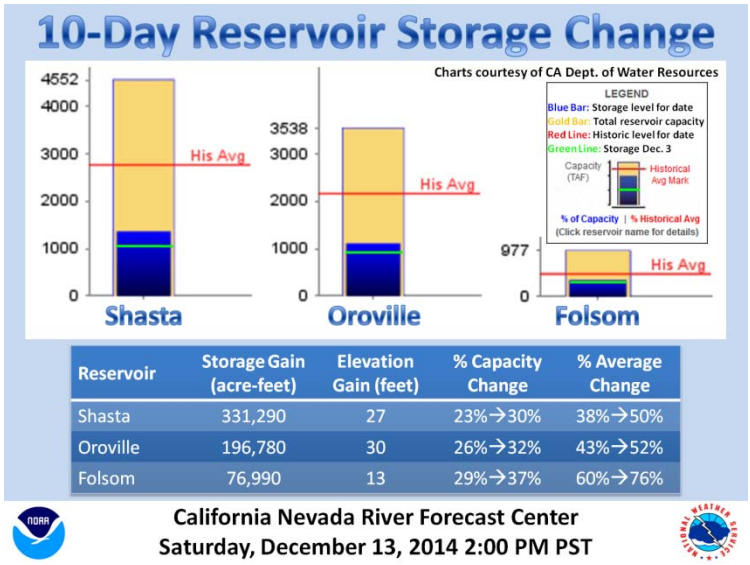

Figure 4. Facebook post on Dec. 13th 2014 showing the impact of a heavy precipitation event on reservoir storage.

One issue that complicates the meaning of drought and the communication of drought-related conditions involves the extensive use of groundwater in irrigation. Figure 5 shows the cumulative groundwater depletion in California's Central Valley. Groundwater pumping has not historically been regulated in California, the last western state to adopt groundwater regulations, and there is frequently a connection between groundwater and surface water that becomes more apparent in times of low flow. What will happen in future droughts if groundwater availability is greatly reduced? The severity of the drought prompted California to take action; Governor Jerry Brown signed into law in 2014 a package of bills instituting comprehensive groundwater management in California, perhaps the most significant change to California water law since the adoption of the California Water Code and the establishment of the state water rights structure in 1914. Prior to passage of the groundwater bills, California was one of only two states, and the only state in the Western U.S. that did not regulate groundwater rights.

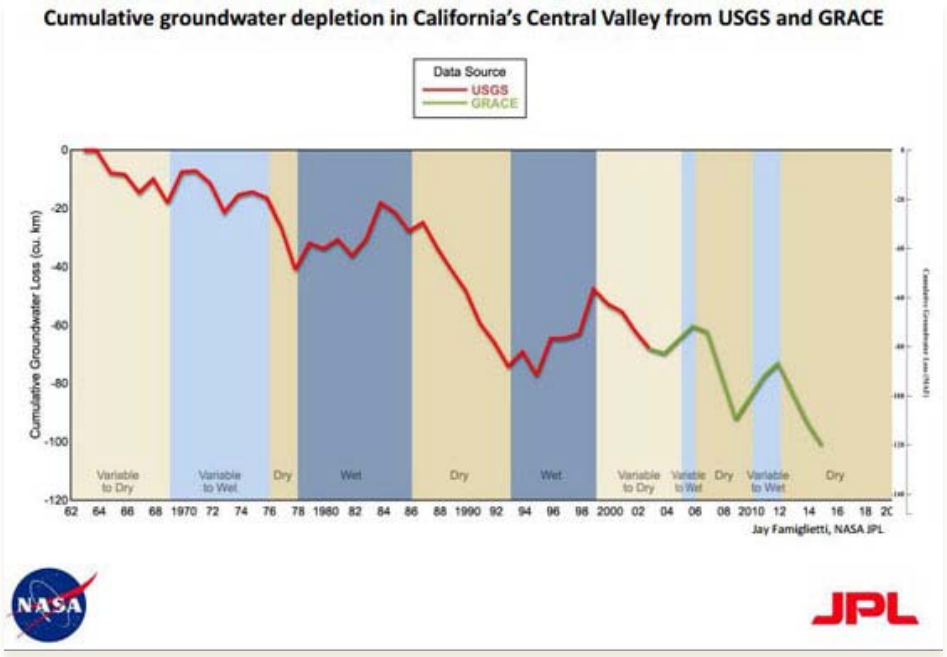

Figure 5. Cumulative groundwater depletion in California's Central Valley.

THE EXPANDED USE OF WATER RESOURCES FORECASTS FROM THE CALIFORNIA NEVADA RIVER FORECAST CENTER

Under drought conditions, much attention has been directed at determining how much water to expect and interest in leveraging the CNRFC forecasts has grown. Some rivers that normally have sufficient base flow to sustain surface flow through the summer, including the Eel River on the North Coast of California, ran dry in the late summer of 2014, an unprecedented event. Even in coastal rivers where flow continued through the summer of 2014, the flow levels were too low to meet all needs and interest in long-term volumetric forecasts expanded beyond the normally snowmelt-fed regions of the state.

Just as groundwater issues complicate the assessment and communication of drought, another complicating issue that was brought to the surface during the ongoing drought is the over-allocation of water rights and the lack of complete water rights accounting information (Figure 6). One study (Grantham and Viers, 2014) showed that water rights granted in California are five times the average annual runoff. Theoretically, California could receive an average amount of rainfall over a period of time and not have enough water to go around. Such a condition could certainly make recovery from a drought less clear; especially since the different areas that Californians receive water from will likely recover at different rates. Again, California is taking action on this issue due to the alarming drought. In 2014 the California State Water Resources Control Board commissioned an experiment in developing a more formal system for determining surface water availability and allocations. The UC Davis Center for Watershed Sciences developed a pilot model of allocations (Lund et al., 2014) on the Eel and Russian rivers, using forecasts of flow availability from the CNRFC and newly available data on surface water diversions. Thus, this represented a significant expansion of the use of CNRFC volumetric hydrologic forecasts beyond the normally snowmelt-fed

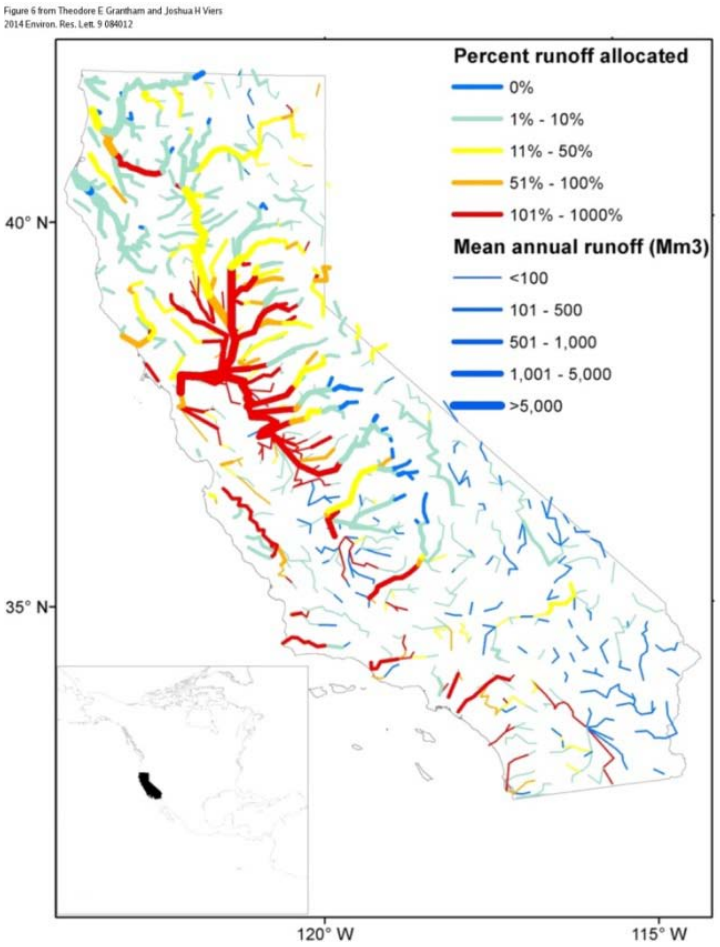

Figure 6. Cumulative water rights allocations relative to mean annual runoff, excluding water rights for hydropower generation.

regions such as the Sierra Nevada. Most of the skill in seasonal volumetric hydrologic forecasts comes from knowledge of the water content of a large snowpack, a condition in California normally associated with the Sierra Nevada, Trinity, and Cascade mountains. However, CNRFC forecasts for regions such as the Russian and Eel watersheds still utilize knowledge of current soil moisture states and short-term weather forecasts to quantify volumetric forecasts for these areas.

Hydrologic forecasting becomes more difficult under low flow conditions at the same time that scrutiny of the forecasts increases, which has caused the CNRFC to more closely examine data sources covering diversions and modeled processes to ensure better accuracy of the forecasts. Flow levels that would normally be at the noise level during high water or flood conditions become significant at low flows. Water resources managers who must make decisions on who gets water based on tight thresholds have been closely scrutinizing the low flow forecasts; thus these water resources managers helped identify gaps in the CNRFC's forecast capabilities which were then addressed. This is an ongoing effort at the CNRFC.

Another area that close scrutiny of water resources forecasts has driven CNRFC improvements is in how forecast information is packaged. Many water resources managers use locally developed decision support tools to help manage water resources. These tools typically either have a basis in spreadsheets or are designed to ingest spreadsheet-compatible inputs. The CNRFC has chosen to package its ensemble-based probabilistic hydrologic forecast information in a spreadsheet-compatible format. Thus, many water managers have been able to use CNRFC forecasts as input to their decision support tools. These managers make decisions daily and the CNRFC forecasts are updated daily, so they appreciate having easy access to the forecasts as input to their tools. Another way that the CNRFC has packaged its forecast information is in geographic grouping of discreet forecast points. For example, the CNRFC was able to group the four major rivers draining into the Sacramento basin, including the main stem Sacramento, Feather, Yuba, and American rivers. This particular grouping closely matches the rivers used in an index used by the State Water Resources Control Board in helping to determine water allocations based on runoff into the Sacramento river system, thus giving water user agencies a rough forecast of the index trend, thus potentially signaling likely future trends in allocation decisions. Knowing where allocations are likely headed helps water management agencies in their planning efforts.

GAPS BEING ADDRESSED AT THE CALIFORNIA NEVADA RIVER FORECAST CENTER

Future drought-driven improvements in CNRFC products and services include the ability to view three year look-back plots of seasonal and water year hydrologic forecasts, thus giving more insight into the evolution of the forecasts throughout a drought such as the one California is currently in. Another capability will be for a user to specify forecast points to group together for generating hydrologic forecasts, such as the grouping used to mimic the components used in the Sacramento Index discussed above. Although primarily intended for creating a proper spatial analysis of probabilistic hydrologic forecasts, the user will be able to select any combination of forecast points and have the appropriate probabilistic thresholds computed for the selected grouping. Additional information that will become available is the inclusion of reliability data associated with the CNRFC probabilistic forecasts. Given that the drought is currently ongoing, there will likely be additional gaps identified that can be opportunities to further improve CNRFC forecasts.

SUMMARY

Drought is a complicated phenomenon to describe in California for a variety of factors including the seasonality of precipitation, high year-to-year variability in precipitation amount, and disconnection between the source of water and the end user. Since droughts reflect cumulative multi-year precipitation deficits, drought visualizations should include corresponding cumulative deficits and the CNRFC offered these depictions. During the drought, water resources managers have more closely scrutinized hydrologic forecasts and this has led to improvements in underlying data sources used in the forecasts, such as data relating to diversions and to modeled hydrologic processes. Furthermore, water resources managers have become interested in CNRFC daily hydrologic forecasts to account for short-term changes in the hydrologic outlook and they've become interested in forecasts for areas outside of the classic water supply regions such as those with significant spring and summer runoff of a winter snowpack. Other changes to CNRFC forecasts as a result of the drought are related to how the information is packaged. The CNRFC has made probabilistic hydrologic forecasts available in a spreadsheet compatible format to

facilitate their use as input into various decision support models. The CNRFC has added forecasts that package the main tributaries of the Sacramento river system in a probabilistic form and will be offering the capability to package any desired grouping of individual forecast points by the 2016 water year. Additional improvements are expected as interest continues to grow in CNRFC forecasts, which brings more scrutiny of the forecasts, therefore helping to reveal areas that can benefit from the added attention.

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