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RUSSIAN RIVER INTEGRATED WATER MANAGEMENT

Preliminary Results for Raising Coyote Valley Dam

Prepared for:

Mendocino County Russian River Flood Control and

Water Conservation Improvement District

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SECTION 1. INTRODUCTION

Managing sustainable water resources systems has been defined as a multidisciplinary and interdependent problem, which requires meeting the objectives for both society and the environment now and in the future (Loucks D. , 2005). Nevertheless, current water management practices may not be sufficiently adequate to secure a reliable water supply and to mitigate the impacts of climate change over flood risk, health, agriculture, energy generation and aquatic ecosystems (Palmer, et al., 2008). Consequently, changes in hydrological regimes can be expected to have an effect on the storage and management of reservoirs (Christensen, Wood, Voisin, Lettenmaier, & Palmer, 2004), which will affect the reliability of water supply, hydropower production (Park & Kim, 2014) and the risk of floods due to a more variable hydrology (Bates, Kundzewicz, Wu, & Palutikof, 2008). Recent climate change studies and extreme flood and drought events determine the proper time frame to re-evaluate current policies and management procedures for rivers and infrastructure that should be assess by decision makers in order to adapt (Pahl-Wostl, 2007).

In like manner, water managers have different alternatives to cope with climate variability that go from structural change (increase water supply and/or storage) to management alternatives with potential benefits for society and the environment (Watts, Richter, Opperman, & Bowmer, 2007). Presently, reservoirs should have been optimized to operate under different levels of water availability (Park & Kim, 2014). However, their effective operation may not be attainable under the anticipated climate-change predictions (Kim, Tachikawa, Nakakita, & Takara, 2009) (Kim et al., 2009). Therefore, different initiatives have been analyzed to address water supply shortages and improve the long-term reliability of the system. In like manner, additional storage enables to manage and capture a variable hydrology while attaining a more reliable water supply system (Association of California Water Agencies, 2015). On the other hand, reoperation alternatives allow water managers to address hydrologic variability "through more flexible infrastructure and management systems" (Watts, Richter, Opperman, & Bowmer, 2007).

Nowadays, the Russian River basin faces operating constrains that were not part of the original design and allocation of its water resources. Climate change, population growth, environmental constrains, and reductions on the PVP diversion flows will either reduce the available water resources or increase the stress over current water allocation. Correspondingly, the current infrastructure and operation of the system may be compromised, which may impact the water supply reliability of CVD. The Coyote Valley Dam Project was originally intended to be constructed in two phases. The first one was finished in 1959 and its purpose was first flood control but over time the water store at Lake Mendocino played an important role on the basin development. The second phase aimed to raise the reservoir to a nearly 200,000 acre-feet storage capacity at the spillway crest (original design at 122,400 acre-feet). Additionally, the system was design based on the PVP operation that first diverted water into the Russian River basin in the early 1900s and it has been since then one of the main inputs of the system. However, its flows have been considerably reduced over the past years, and eventually they may be constrained again in the future. Therefore, raising CVD appears to be one of the alternatives that would improve the water supply reliability of the system. Assessing the impact that these changes may have over the current system is the main objective of this report.

Based on this approach, this report aims to provide guidance over three specific objectives. First, to determine if the current reservoir capacity is efficiently used under the baseline conditions of the watershed. It is expected to answer if the hydrologic conditions of the basin upstream of the reservoir will provide a reliable water supply for the system based on the current and augmented capacity of the reservoir. Second, to determine the significance of PVP diversion flows under baseline scenario. We expect to find out if the reliability of the system is sustained by the PVP flows, and what would be the consequences if no PVP flows were diverted under the baseline and augmented capacity scenario. Finally, we intend to determine the role of the current Rule Curve over the reservoir storage. Our expectations are to determine if the current flood control operations between January and June play a role over the reliability of the system under the baseline and augmented capacity conditions.

This analysis illustrate the significance of developing an integrated water resources model which allows to sustainable manage the system and to evaluate different alternatives to improve the reliability of it. The extended flow and climate change data that has been gathered will provide a comprehensive analysis that has not been done before for the Russian River. Based on the outlined expectations, changes on the capacity of the reservoir and the top of conservation pool might be feasible solutions that can meet the current flood control operations and improve the water supply reliability for both society and the environment. Finally, the outcomes of this research will be directly communicated to the Russian River water agencies. This basin has a distinguished importance in the agricultural economy of the state ($1 billion industry), and also provides water supply to more than 600,000 people in Mendocino, Sonoma and Marin Counties. Results from this research will provide supportive information for water managers and stakeholders that can assist the upcoming decisions that will be taken related with minimum in-stream flows, development of new hydrologic index, reoperation of the reservoir, and water use and allocation throughout the system.

SECTION 2. BACKGROUND

The Russian River basin is located in southeast region of Mendocino County and the northern area of Sonoma County. The basin drains an area of approximately 1,485 square miles, including most of Sonoma and Mendocino Counties (U.S. Army Corps of Engineers; Sonoma County Water Agency, August 18, 2000). The Russian River headwaters are located about 16 miles north of the city of Ukiah, and extend 110 miles before entering the Pacific Ocean at Jenner. The main stem of the river begins about 3 miles north of Ukiah, where the East and West Fork converge at a location known as the Forks, draining Potter and Redwood Valleys, respectively. Downstream, it flows south through Ukiah, Hopland, Alexander and Healdsburg Valleys, and 22 miles before its mouth, it bends westwards and flows through the northwestern region of the Santa Rosa plain, crossing the Coast Ranges (U.S. Geological Survey; CA Department of Water Resources, 1965). The Russian River basin is a highly agricultural productive area, where more than 80,000 acres of vineyard (74%) and pasture (19%) and orchards (7%) are grown in the basin (Sonoma County Water Agency, 2013). These represent an agricultural industry of half billion dollars. Also, the Russian River provides water supply to more than 600,000 people in Mendocino, Sonoma and Marin Counties.

The geology of the Russian River watershed is characterized by northwest trending mountains ranges, which are parallel to the main structural formations of the region (U.S. Geological Survey; CA Department of Water Resources, 1965). Altitudes in the basin vary from sea level up to 4,344 feet on Mount St. Helena. Hills and mountains comprise about 85 percent of the basin, and alluvial valleys characterize the reminder area (U.S. Geological Survey; CA Department of Water Resources, 1965). The main tributaries on the upper section of the river (i.e., above the confluence with Dry Creek) include the East Fork, Big Sulphur Creek and Maacama Creek. On the lower section of the river, the main tributaries are Dry Creek and Mark West Creek (U.S. Army Corps of Engineers; Sonoma County Water Agency, August 18, 2000). From 1908, diversions from the Eel River through a tunnel to the East Fork began as part of the Potter Valley Project, owned and operated by PG&E since 1930. These diversions subsequently increased after Scott Dam and Lake Pillsbury were constructed on the Eel River (1921), allowing reliable agricultural production and urban development in Mendocino and Sonoma Counties (MCWA, 2010).

The basin lies on a Mediterranean climate region characterize by warm summers and wet winters, with a highly fog-influenced coastal region and hot interior valleys, dry during the summer. Precipitation occurs mainly as rainfall, with snow falling only on the higher ridges and occasionally on the upper valleys. Nearly 90 percent of runoff occurs between November and April (U.S. Army Corp of Engineers, 1986) due to Pacific winter storms. Winter precipitation usually results in flashy floods due to low evapotranspiration conditions and the reduced permeability of the rocks in the mountainous areas of the basin (U.S. Geological Survey; CA Department of Water Resources, 1965).

There are two reservoirs in the Russian River basin. Coyote Valley Dam (CVD) was constructed in 1959 by the USACE on the East Fork, approximately 1 mile upstream of the Forks, and controls a drainage area of 105 square miles (U.S. Army Corps of Engineers; Sonoma County Water Agency, August 18, 2000). Warm Spring Dam (WSD) is located on Dry Creek and controls a drainage area of about 130 square miles and it was completed in 1983 by the USACE. The influence of CVD over the 1.5-year recurrence interval flood on the upper section of the river decreases downstream and is negligible at Healdsburg due to the limited drainage area that controls (U.S. Army Corps of Engineers; Sonoma County Water Agency, August 18, 2000). On the other hand, WSD has reduced flood flows to nearly 25 percent of the unregulated flows, based on both the 1.5-year flows and the 5-year recurrence interval flood (U.S. Army Corps of Engineers; Sonoma County Water Agency, August 18, 2000). Lake Mendocino is administered by the USACE, and the SCWA and RRFCAWCD as the local sponsors. The USACE maintain and coordinate releases from CVD during flood management operations according to the Water Control Manual that was published after the construction and revised in 1986. SCWA controls and coordinates releases to meet water rights permits associated with agricultural, commercial and residential users, SCWA and several public water systems, and minimum instream flow requirements under Decision 1610. Storage in the reservoir is controlled by its Rule Curve, which defines the conservation pool (storage below the Rule Curve) and the flood control pool (storage above the Rule Curve).

PVP diversions from the Eel River changed the runoff regime at the East Fork and the upper sections of the Russian River into a perennial water course (MCWA, 2010). The combined effect of the reservoirs operation and the Eel River imported waters reduced winter flow peaks and substantially increased summer flows (MCWA, 2010). Together with the hydrologic regime alteration, PVP diversions had been reduced significantly since the implementation (2006) of a Biological Opinion issued by the National Marine Fisheries Service (NMFS) in 2002 (National Marine Fisheries Service, 2002)[1]. The water supply reliability for agricultural and municipal uses of the system has been seriously compromised after its implementation. As a response, SCWA has filed five Temporary Urgency Change Petition (TUCP) with the SWRCB requesting temporary reductions on the minimum instream flows of the Russian River to “preserve adequate water supply storage in Lake Mendocino” (Sonoma County Water Agency, 2015). The May 1, 2013 Order issued by the SWRCB after the third TUCP requested a water supply reliability study for Lake Mendocino, and was included as Term 17 in the Order. Term 17 was required to evaluate the long-term reliability of the system to meet environmental and water demands, considering potential impacts of climate change, land use and water demands projections (Order Approving Temporary Urgency Change, 2013).

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[1] After the Biological opinion was issued in 2002, in 2004 the Federal Energy Regulatory Commission (FERC) amended the PVP license No.77, which was finally implemented in 2006 (FERC Order Amending License, 106 FERC ¶ 61,065, 2004)

SECTION 3. METHODS

3.1. Lake Mendocino Allocation Model

To meet the SWRCB requirement of Term 17, the SCWA developed a water supply model of the Upper Russian River, to evaluate the long-term reliability of the system to meet environmental and water supply demands. The Upper Russian River extends from the head waters in Redwood Valley and Potter Valley to the junction of Dry Creek with the main stem, south of Healdsburg. The model was divided in seven control points where gains and losses were computed, five of which are reaches named after the correspondent USGS streamflow gaging stations.

The model estimates on a monthly time step the gains and losses that are required to meet the environmental and minimum stream flows at each of the seven control points. The model was developed to estimate the reliability of the reservoir under both current and future (2045) demand conditions. It was assumed that the Rule Curve developed by the USACE defines the maximum stored level of the reservoir, and therefore, releases were made to either meet this threshold or the downstream demands and minimum instream flow requirements. On every reach, unimpaired flows were used to account of the natural input of the system, “unaffected by man-made influences such as water diversions or reservoir operation” (Sonoma County Water Agency, 2015). These datasets were developed for historical climate (1910 to 2013) and potential climate change impact (2000 to 2099) by the USGS (Flint, Flint, Curtis, Delaney, & Mendoza, 2015). PVP diversions from the Eel River were estimated using the Eel River model version 2.5 developed between the Natural Resources Consulting Engineers (Oakland, CA) and the SCWA. The significant reductions in PVP diversions since 2006 due to FERC license amendment were accounted in the model by an approximation of the post-2006 operations as the current PVP operation.

The model also considered three main water demands of the Russian River system: municipal and industrial, riparian, and agricultural water use for every reach. Municipal water use was estimated based on the current population and the water use of the existing nine public water systems. Surface water and groundwater pumping from the Russian River aquifer is the primary source of water supply for this system. The current conditions were stablished based on the 2009-2013 period and the water production records submitted to DWR in the annual Public Water system Statistics (PWSS). The average over this five-year period was considered as the current demand, and water use projections were estimated based on either future water demands or population growth, depending on the size of the supply system. High and low water demand conditions were included to asses alternative development strategies. On the other hand, riparian water losses were considered as a monthly scaling factor of the total agricultural water demands between May and October for every reach. It was based on a riparian vegetation delineation done using May 2013 USGS Landsat 8 imagery data (USGS, December 2013) and ETa based on the

SEBAL (Surface Energy Balance Algorithm for Land)[2] results from the Davids Engineering report. Monthly patterns were obtained for wet and dry years and replicated for the whole evaluation period.

Agricultural water use was developed based on land use and water use category (irrigation, frost protection and post-harvest application). Water that was used by irrigation was estimated based on seasonal crop water duties, for each of the main crops that are grown on this region. These crop water duties were based on an agricultural water model developed by Davids Engineering for the SCWA (Sonoma County Water Agency, 2013). Monthly irrigation requirements based on evapotranspiration (ET) were aggregated on an annual basis to obtain the annual water demand. Due to frost control protection during the spring after bud break, water is often used in the Upper Russia River to protect vineyards and orchards. Although storage ponds have reduced the instantaneous flow diverted from the river or pumped from groundwater, the use of overhead sprinklers requires high applications over extended periods of time (hours) which reduces the monthly streamflow. The overall volume of water that is monthly diverted for this purpose was estimated based on the number of frost events and the net water use, also considering an estimation of the acreage that is frost protected. Post-harvest applications were based on the UC Cooperative Extension – Ukiah (UCCE –Ukiah) report for the Mendocino county, and ad estimation of 50 percent over vineyards on Sonoma county. Projections in agricultural water use was based on land use changes, were all new developed fields were assumed to be vineyards, which is the dominant crop in the watershed. On Mendocino County, the growth approach was site specific due to their confined area. The Sonoma County historical trends were used for growth projections, were the average rate was assumed to be the increase in vineyard acreage to 2045. The differences between Low and High water demand relied on the vineyard acreage, since water use in vineyards is lower than in other crops.

The operation of Coyote Valley Dam was incorporated into the model though the Rule Curve developed by the USACE, and also considering the environmental constrains defined by Decision 1610 and the Russian River Biological Opinion. First, the Rule Curve has a seasonal storage threshold to meet both flood control operations during the rainy season and water conservation during the dry season. As detailed above, the model assumes that the storage may not be higher than the Rule Curve, and so sufficient water will be released in case of storage above it to maintain the storage level at the top of conservation pool. Second, to maintain minimum instream flow requirements, the hydrologic Water Supply Condition index defined under Decision 1610 sets the monthly minimum instream flow for the Russian River. Flows defined by Decision 1610 constrain minimum flow between November and April, and the interim flow requirements of the Biological Opinion constrain flows between May and October.

Eight scenarios were developed to assess the reliability of the system, considering potential impacts of climate change, changes in land use, water demands projections, and PVP operations.

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[2] http://davidsengineering.com/projects/remote-sensing/kaweah-delta-water-conservation-district-remote-sensin/

These scenarios analyze both Current (2015) conditions and Projected 2045 for the Upper Russian River system. The Current scenario approximate the Baseline conditions of the system in both water demands and operation. The Projected 2045 approximates a 30-year planning period and the impacts over water demand during this period. Water demands for this Projected 2045 scenario were approximated as High and Low growth, as well as climate conditions projected as future Dry or Wet. Finally, an additional scenario was developed to analyze current conditions with no PVP diversions from the Eel River and its impact on water supply reliability.

This assessment will be based on the described model, but will analyze different scenarios and management alternatives for the water supply reliability of the reservoir. Further details of the SCWA model can be found on the TERM 17 report, published by SCWA in April 30, 2015 (Sonoma County Water Agency, 2015). Additionally, an overview of the analysis performed for this report is presented on the next section.

3.2. Raising Coyote Valley Dam Assessment

Lake Mendocino was originally design in two construction phases. The first one, constructed in 1959 had an original storage capacity of 122,400 acre-feet that based on the sedimentation rate measured in 2001, is currently capable of storing 116,500 acre-feet (Sonoma County Water Agency, 2015). The second phase, originally intended to be completed in the 1960s was never constructed. It was design to raise the reservoir 36 additional feet from the current 160 feet earth embankment dam height, which would have increased the storage capacity in approximately 75,000 acre-feet. Nowadays, there is an undergoing evaluation led by the USACE to evaluate raising Coyote Valley Dam. It is part of the Corps SMART[3] Planning 3x3x3 policy that assesses the raising feasibility under the current dam safety standards. This study should be completed within 3 years (began in December, 2014) and for $3 million or less.

Provided that CVD could be raised, a water supply reliability study was developed based on the current SCWA model. As it was described on the previous section, the SCWA model considers water supply from both the Upper Russian River basin and diversions from the Eel River (PVP). Additionally, water demands were divided in municipal and industrial, agricultural, and riparian water losses for every reach. Finally, minimum instream flow requirements based on the D1610 and BO were included on the model. In order to analyze the reliability of the augmented capacity reservoir, the same conditions were considered for this assessment. However, only four scenarios were evaluated on this study, which aims to compare the baseline conditions with the augmented storage conditions, and the influences of PVP diversions over the system.

The baseline scenario was defined based on the same conditions described by the SCWA model. In the same way, PVP diversions were either considered or completely excluded for its influence assessment. On the other hand, the augmented storage capacity scenario was done based on the

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[3] SMART: Specific, Measurable, Attainable, Risk-informed and Timely.

originally project for CVD. The Augmented Storage scenario considers an additional capacity of 75,000 acre-feet. As an illustration, the maximum of the current conservation pool is augmented from 111,000 acre-feet to 186,000 acre-feet. With respect to the Hydrologic indexes, the same Dry Spring conditions and Water Supply Conditions were used, but including the additional storage capacity on the thresholds already defined. Finally, in order to provide an evaporation rate for the bigger reservoir, the current curve of elevation versus storage and elevation versus area were extrapolated to include the additional 36 feet in elevation and 75,000 acre-feet.

Therefore, the scenarios that were analyzed on this report are:

- Current Storage conditions: Baseline scenario with current PVP operations.
- Current Storage conditions with PVP Off: Baseline scenario without PVP diversions.
- Augmented Storage conditions with PVP On: Baseline conditions with augmented storage capacity and current PVP diversions.
- Augmented Storage conditions with PVP Off: Baseline conditions with augmented storage capacity and without PVP diversions.

SECTION 4. RESULTS

4.1. Performance Criteria

In order to evaluate the results of this assessment, three performance criteria were selected. First, to compare the Current Storage capacity with the Augmented Storage capacity of the reservoir, the water supply reliability of the system was use. It is defined as the percentage of the number of years that the reservoir went dry at least once over the course of the year. As it is shown in section 4.2, the results are presented for the Current Storage versus the Augmented Storage Capacity and for both current and no PVP operations.

Second, the storage of the reservoir under the defined scenarios was analyzed using the probability distribution functions. The comparison was presented using the frequency distribution curves and the non-exceedance probability (section 4.3). The Current and Augmented capacity conditions were presented on the same figure for the different PVP operation conditions. Additionally, the non-exceedance probability analysis focused especially on the lower end of the curve where the reservoir was empty, and on the flat regions where the reservoir was at the top of conservation.

Finally, the results for the monthly storage were also analyzed and presented in three additional ways. The first one compares the observed storage and the respective Rule Curve between January and June. This comparison was done to assess the percentage of time that the reservoir was at the top of conservation during the rainy season and beginning of the spring, where the Rule Curve followed its raising limb. Second, a comparison of the observed storage and the current Rule Curve between January and June was done to assess the percentage of time when the storage under the augmented capacity scenario was at the Rule Curve or above it. In other words, it represent the number of times when under the same hydrologic conditions, the current reservoir was releasing water during these months instead of storing it. Finally, a comparison of the monthly distribution of the reservoir storage under the current and the augmented capacity plotted with the average values for the given month and the Rule Curve for both storage conditions

4.2. Reliability

The reliability of the system is presented in Figure 1 and Figure 2 for the Baseline Scenario with PVP on and off respectively. It can be observed that with PVP maintain as current conditions, the system is fully reliable for both the current storage capacity and the augmented one. Based on the observed storage, under the current capacity scenario the reservoir went dry (below 2,000 acre-ft) only once (Nov 1977) whereas under the augmented capacity scenario it did not reached this point.

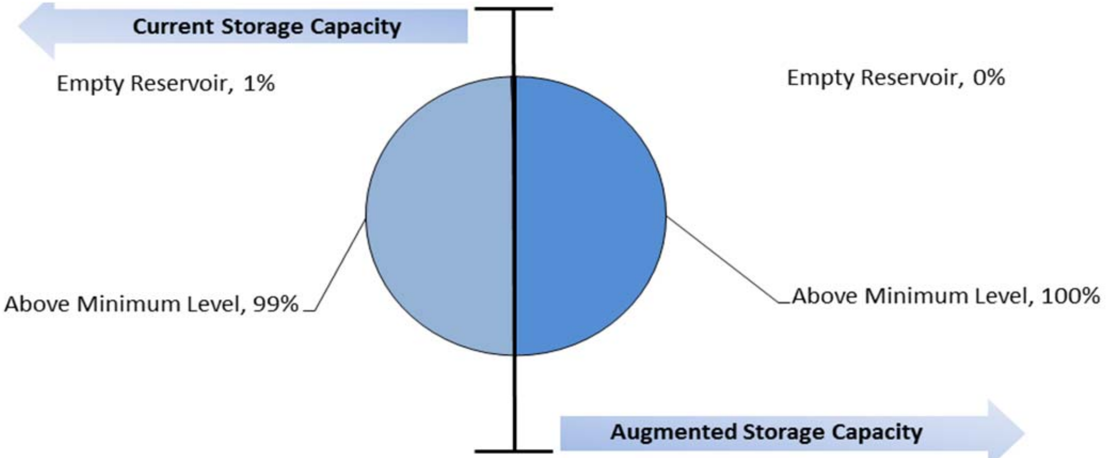

Figure 1 Reliability for the Baseline scenario with PVP On

On the other hand, the reliability decreases for both the current and the augmented storage capacity when the system is modeled with PVP off. It can be observed in Figure 2 that for the current capacity, the reservoir went dry 70 percent of the time at least once during the year, in contrast with 16 percent of the time under the augmented capacity conditions.

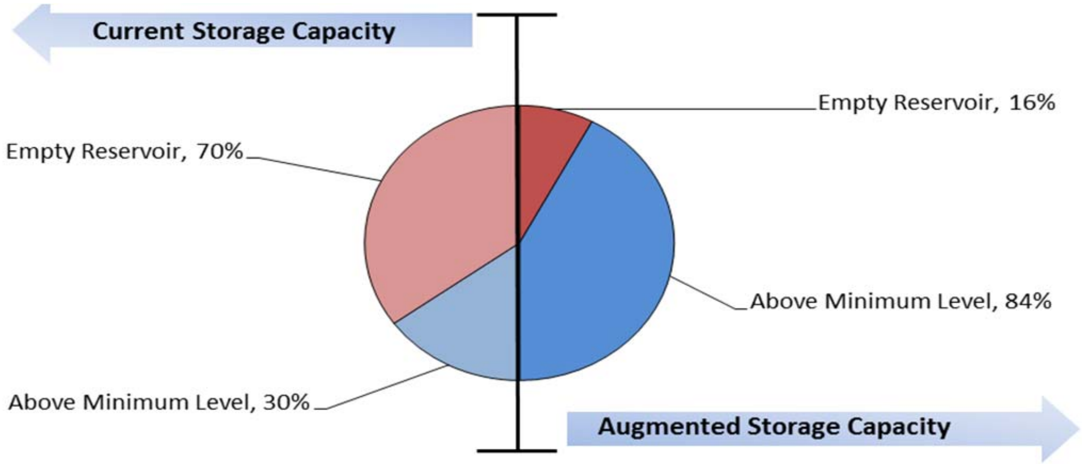

Figure 2 Reliability for the Baseline scenario with PVP Off

4.3. Probability Distribution Functions

4.3.1. Histogram

Based on the frequency distribution analysis for the Baseline Scenario with PVP On in Figure 3, it can be observed that the monthly storage has a similar distribution on both the current and the augmented capacity, but with the latter one shifted up to higher volumes.

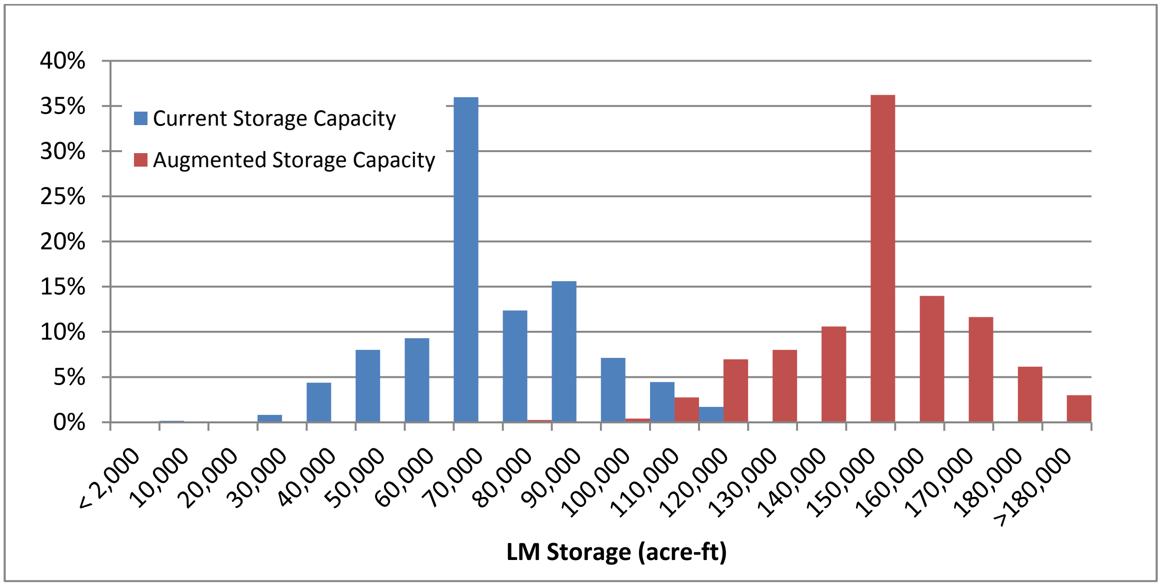

Figure 3 Histogram for the Baseline scenario with PVP On comparing the current storage capacity with the augmented storage capacity

The average for the current storage capacity scenario was 70,441 acre-ft, in contrast with the 145,005 acre-ft for the augmented capacity (Table 1). Although the demands and inflows are the same, the difference is slightly less than the 75,000 acre-ft increased in storage, due to the higher evaporation explained by the bigger reservoir area. The storage for both scenarios is highly concentrated on the range that contains the top of conservation pool volume (68,400 acre-ft and 143,400 acre-ft).

Table 1 Statistical information for the Baseline scenario with PVP On comparing the current storage capacity with the augmented storage capacity

	Baseline Scenario with PVP On			
	Current Storage Capacity		Augmented Storage Capacity	
Average	70,441		145,005	
St. Deviation	17,882		18,212	
Median	68,400		143,400	
Mode	68,400	296	143,400	291

In contrast, the distribution for the Baseline Scenario with PVP Off differs between the current and the augmented storage capacity. As displayed on Figure 4, the observed storage for the current capacity is significantly skewed to the lower volumes whereas the storage for the augmented capacity was more equally distributed through the whole reservoir range.

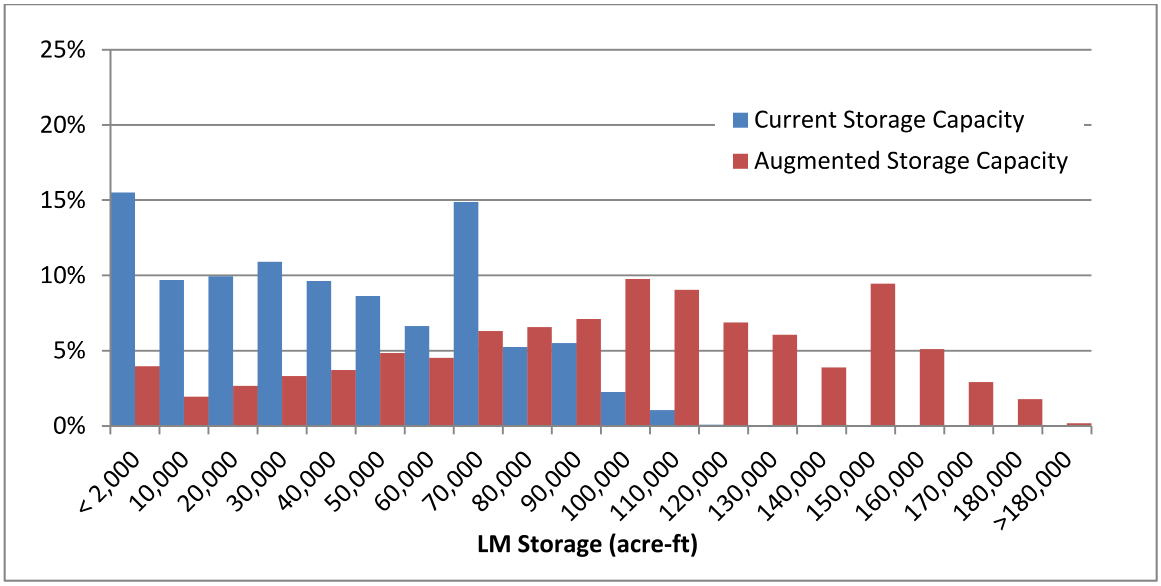

Figure 4 Histogram for the Baseline scenario with PVP Off comparing the current storage capacity with the augmented storage capacity

The average for the current storage capacity scenario was 37,848 acre-ft, in contrast with the 91,692 acre-ft for the augmented capacity (Table 2). As it was presented on the previous section, under these scenarios the reservoir went dry 16 percent and 4 percent of the time, compromising the reliability of the system. Furthermore, it can be noticed that this difference is mainly explained because the augmented capacity provided additional storage (higher standard deviation) that was available during the times when the reservoir under the current capacity scenario was empty.

Table 2 Statistical information for the Baseline scenario with PVP Off comparing the current storage capacity with the augmented storage capacity

	Baseline Scenario with PVP Off			
	Current Storage Capacity		Augmented Storage Capacity	
Average	37,848		91,692	
St. Deviation	28,905		45,515	
Median	33,872		94,108	
Mode	2,000	192	143,400	64

4.3.2.Non-exceedance probability

The non-exceedance probability analysis for the Baseline scenario shows a very similar trend between the current and the augmented storage capacity conditions. It can be observed on Figure 5 that both curves have a very distinguished region at the top of conservation volume that goes approximately between the 34 percent and 58 percent. It can also be noticed that the lower end of both curves followed the same trend, but with a slight difference on the lowest value. The current storage capacity curve reached the minimum capacity of 2,000 acre-ft, whereas the augmented storage condition had still more than 70,000 acre-ft stored. The greatest difference between these two conditions was observed during the end of the 1976-1977 water year drought, were under the current storage capacity it went empty whereas the augmented capacity had enough water to meet the downstream demands.

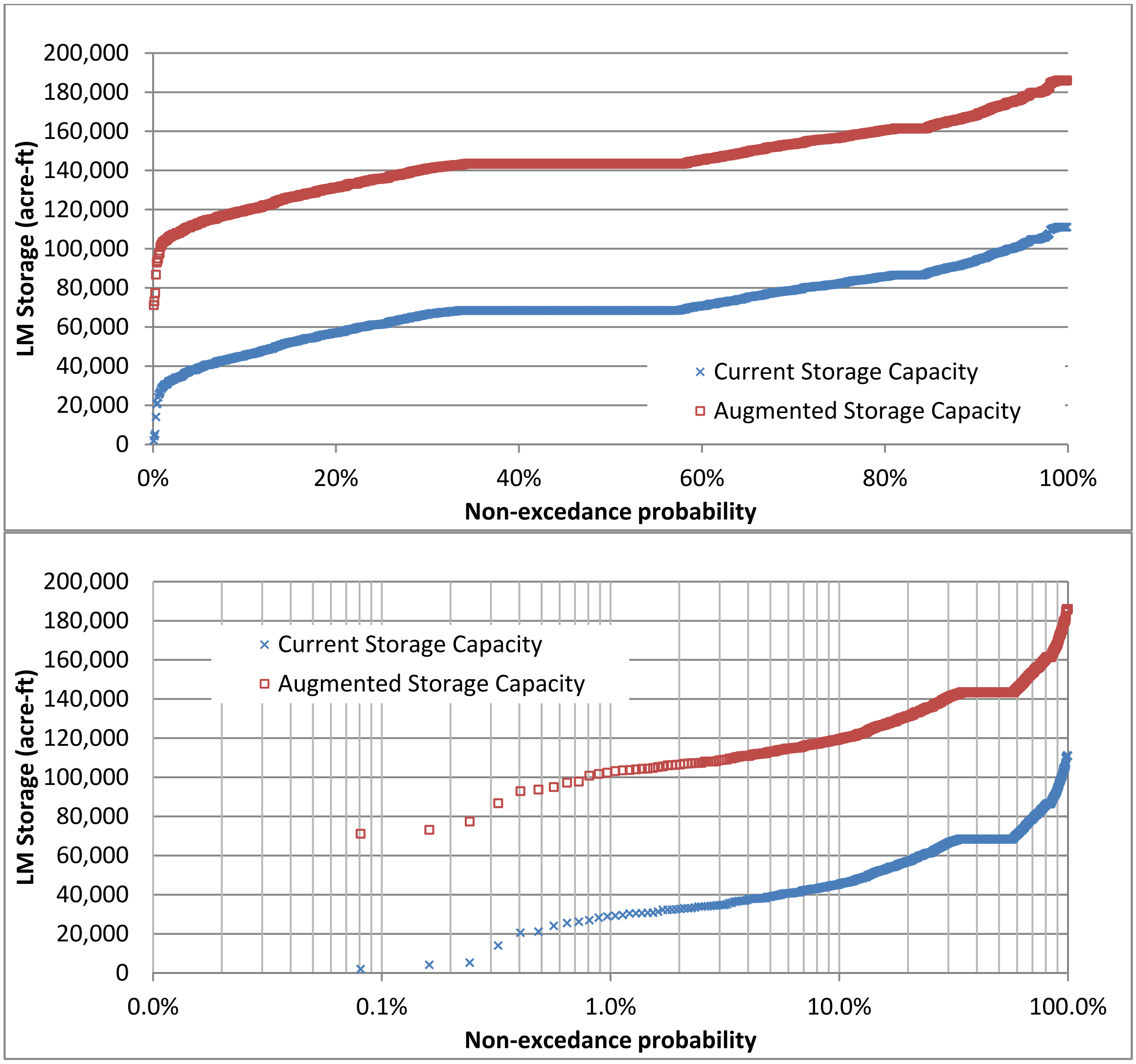

Figure 5 Non-exceedance probability for the Baseline scenario with PVP On comparing the current storage capacity with the augmented storage capacity

Regarding the Baseline scenario with PVP Off, the results showed a similar distribution than the observed on the histogram. The storage is highly concentrated on the lower end where the reservoir was empty, and near the top of conservation. Correspondingly, the current storage capacity result in a less reliable system (16 percent of the time is empty) and an overall lower stored volume, where approximately 50 percent of the time the volume is below 34,000 acre-ft in comparison with 94,000 acre-ft under the augmented capacity conditions.

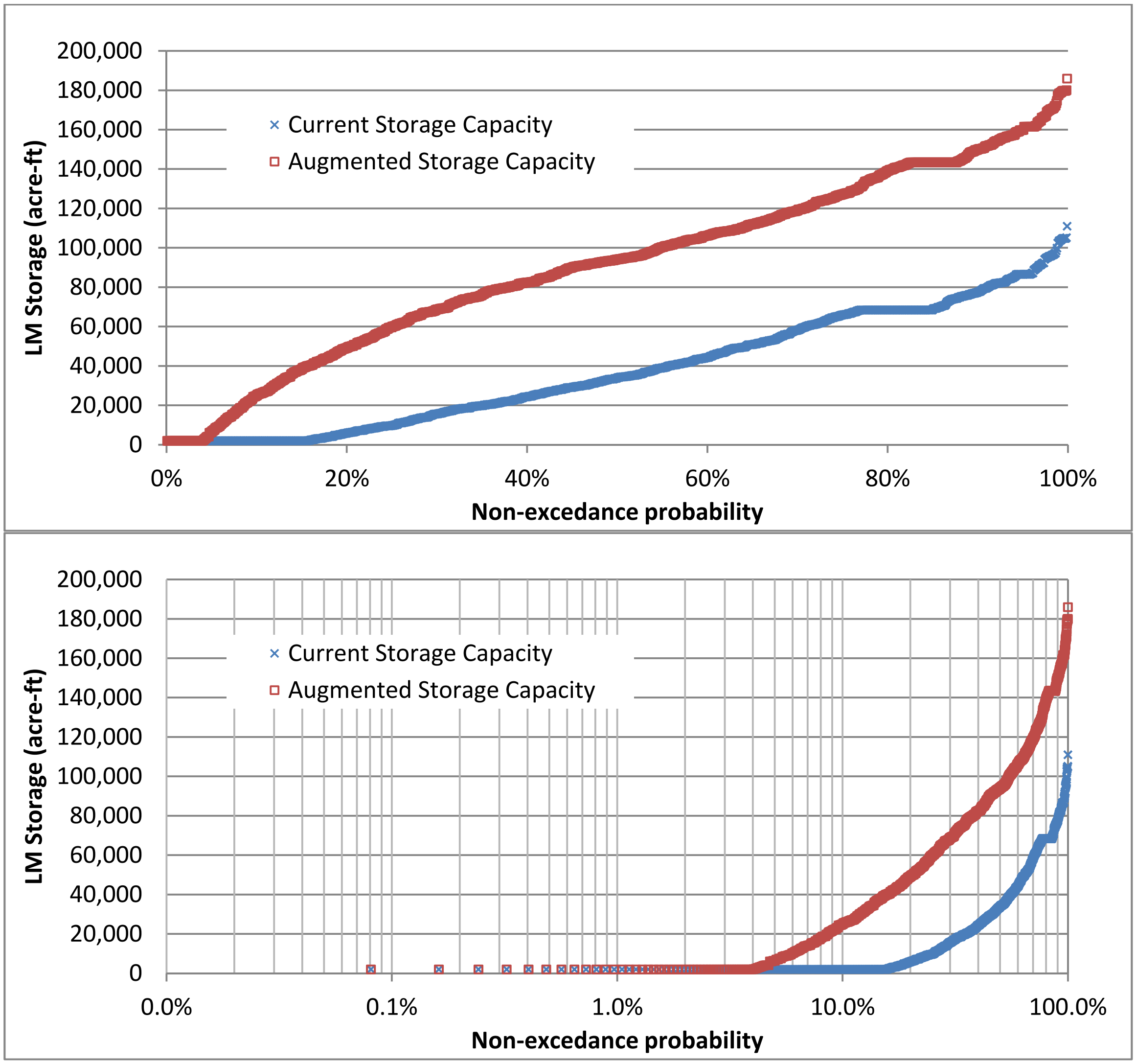

Figure 6 Non-exceedance probability for the Baseline scenario with PVP Off comparing the current storage capacity with the augmented storage capacity

4.4. Storage

4.4.1. Observed storage compared with the respective Rule Curve between January and June

First, Figure 7 shows the results for the Baseline scenario with PVP On. It shows that the share of time that the storage level was at the Rule Curve is the same for both the current and the augmented capacity conditions. As it was observed on the previous sections, the differences between these scenarios were marginal and explain the similarities of this result. As can be observed for both scenarios, 46 percent of the time the storage was at the maximum possible level for the given month (Rule Curve).

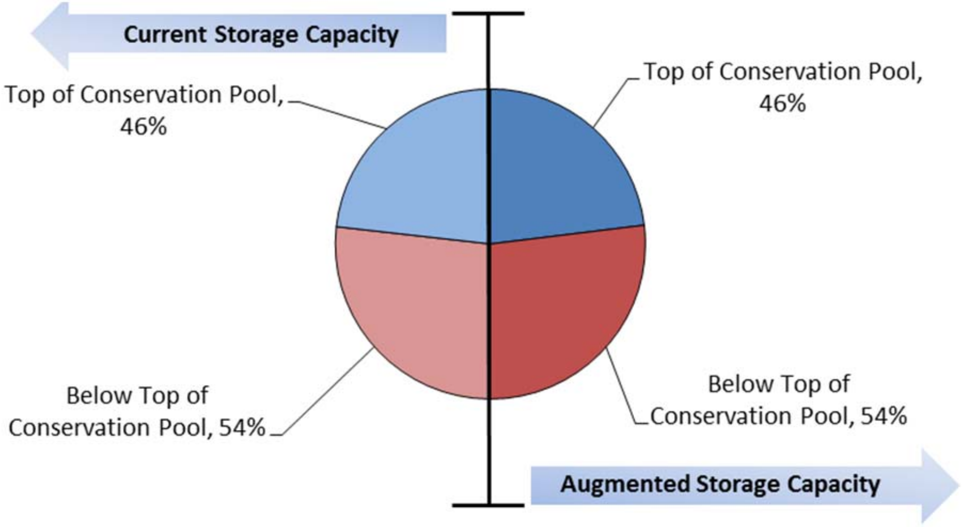

Figure 7 Percentage of time when the reservoir storage was at the Top of Conservation for both the current storage capacity and the augmented storage capacity under the Baseline Scenario with PVP On

On the other hand, the results for the Baseline scenario with PVP Off are presented on Figure 8. In this case, only 20 percent of the time under the current storage capacity the reservoir was at the top of conservation pool. When compared with the results displayed on Figure 7, there is significant reduction on the stored volume which accounts for the reduction on this maximum capacity indicator. At the same time, under the augmented storage capacity conditions, the reduction from the PVP On scenario is higher, and only 13 percent of the time the storage capacity was at the top of conservation pool. This means that without PVP inflows, the reservoir will not fill as often as it did on the previous scenario. Although it is a significant reduction in the percentage of time the reservoir was at the maximum capacity, the reliability of the system was reduced only 4 percent.

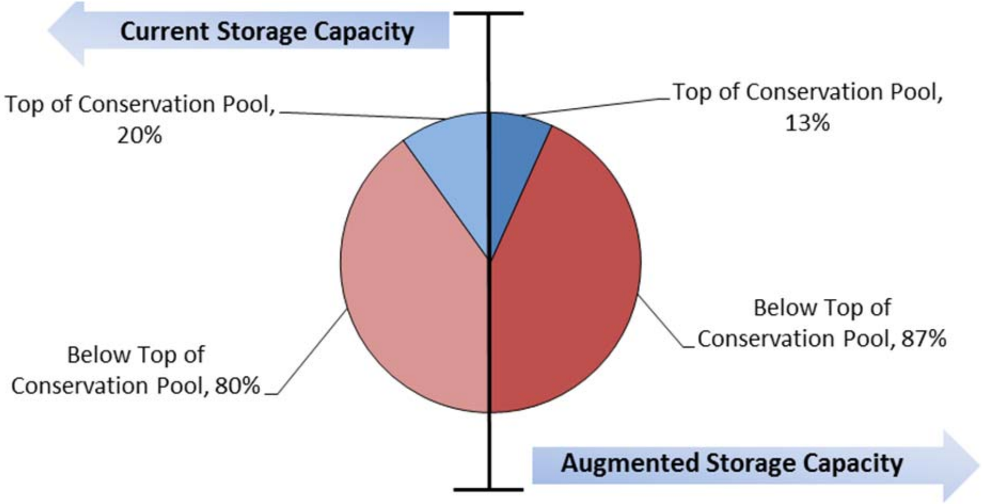

Figure 8 Percentage of time when the reservoir storage was at the Top of Conservation for both the current storage capacity and the augmented storage capacity under the Baseline Scenario with PVP Off

4.4.2. Observed storage compared with the current Rule Curve between January and June

Second, the results for the observed storage compared with the current Rule Curve are presented on Figure 9 and Figure 10 for the period between January and June. For the current storage capacity conditions, the results under the Baseline scenario with PVP On are the same to the ones presented on Figure 7. However, when the storage of the augmented capacity scenario is comparted with the current Rule Curve, it can be noticed that 100 percent of the time the volume was above this level for the analyzed period.

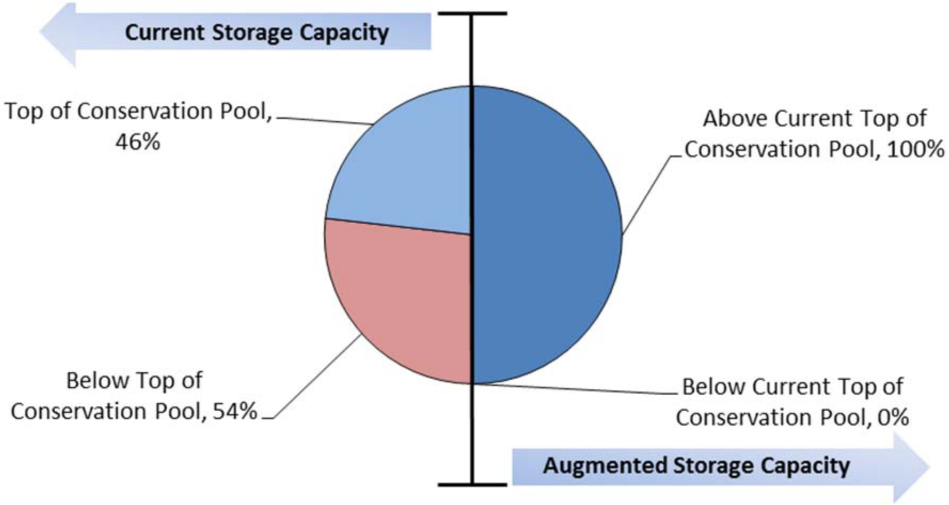

Figure 9 Percentage of time when the reservoir storage for both the current storage capacity and the augmented storage capacity was at or above the current Top of the Conservation pool under the Baseline Scenario with PVP On

Likewise, for the Baseline scenario with PVP Off the results shown on Figure 10 present a similar outcome. The observed storage under the augmented capacity was 71 percent of the time above the current top of conservation level.

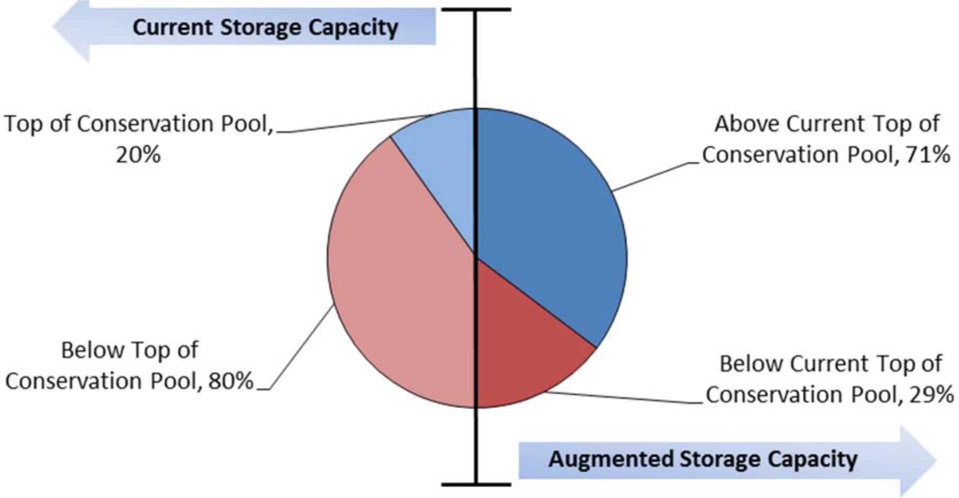

Figure 10 Percentage of time when the reservoir storage for both the current storage capacity and the augmented storage capacity was at or above the current Top of the Conservation pool under the Baseline Scenario with PVP Off

4.4.3. Monthly distribution comparison of the reservoir storage under the current and the augmented capacity

Finally, the results presented on Figure 11 and Figure 12 compare the monthly distribution for each storage capacity under both scenarios, complementing the previous analysis. It can be observed on Figure 11 that for the Baseline scenario with PVP On the average storage for the end of the winter and beginning of spring was close to the top of conservation pool which explains the results shown on Figure 3.

On the other hand, for the baseline scenario with PVP Off the results vary depending on the analyzed months. For the period between February and June, the monthly distribution is similar for both the current and the augmented capacity scenarios, although the latter has a greater dispersion due to the higher capacity of the reservoir. On the contrary, the monthly distribution between July and January for the current capacity scenario is substantially skewed to the minimum capacity of the reservoir, and is intensified between October and December. The period between September and January accounts for almost 90 percent of the months that the reservoir was empty. During the same period, the monthly distribution for the augmented capacity scenario has a more disperse range with an average that is high above the minimum level. Finally, it can be observed that the influence of PVP maintained the monthly average storage closer to the top of conservation during winter and spring, and always above the current Rule Curve. However, if PVP is off the average storage decreases considerably, although a substantial amount of time the storage is above the current top of conservation (71%, see Figure 10)

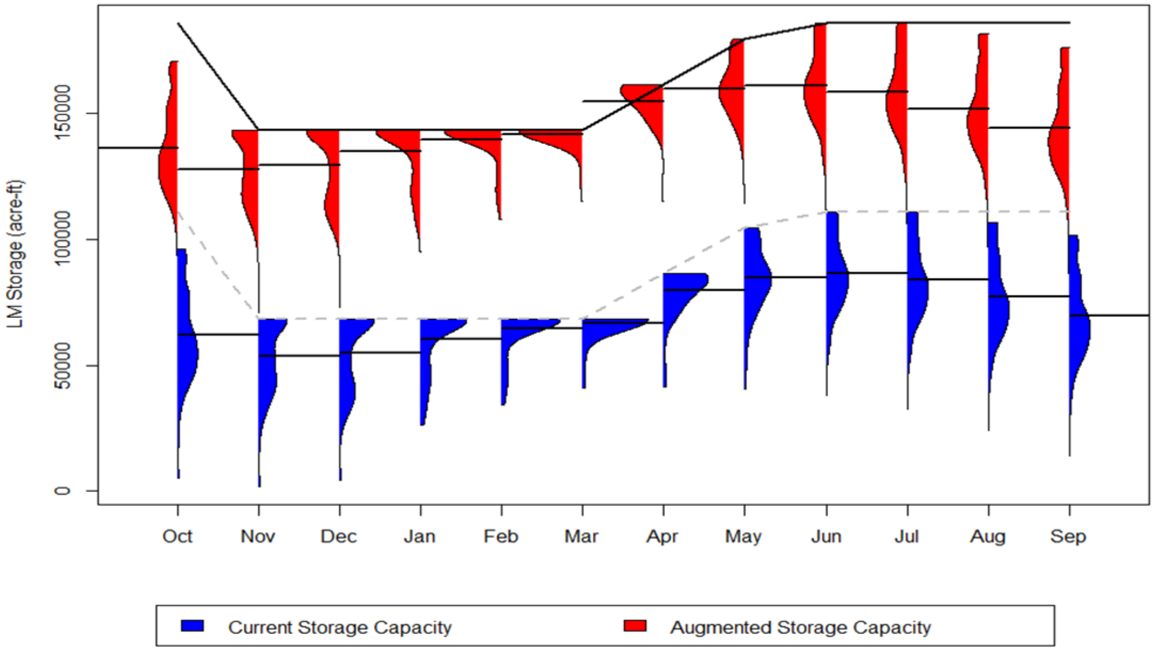

Figure 11 Monthly distribution of reservoir storage for both the current storage capacity and the augmented storage capacity under the Baseline Scenario with PVP On

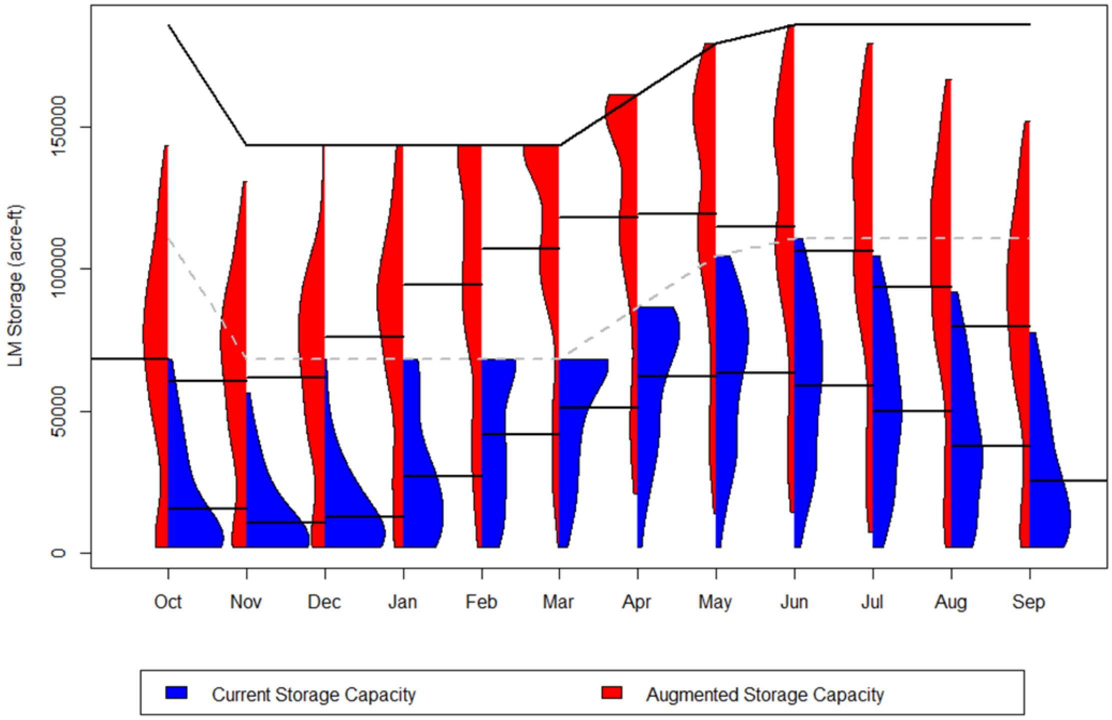

Figure 12 Monthly distribution of reservoir storage for both the current storage capacity and the augmented storage capacity under the Baseline Scenario with PVP Off

SECTION 5. DISCUSSION

The reliability of the system to meet environmental and water supply requirements is directly related with the storage capacity of the reservoir. Coyote Valley Dam was originally constructed for flood control purposes, but over the time the development of the Russian River watershed has relied on the water stored at this dam. During this period, changes in water demands, water inputs and diversions from the Eel River through PVP had influence the management of the system. Results presented on this report demonstrate the strong dependence of the Russian River basin with PVP diversions. Moreover, the reliability of the reservoir could be seriously compromised without it. However, changes in the storage capacity of the reservoir suggest opportunities to improve the water supply reliability of the system.

PVP diversions from the Eel River had sustained the reservoir storage since its construction. Nevertheless, recent reductions of the diverted flow have compromised the stored volume. Baseline simulation results comparing the reliability of the reservoir with PVP diversions and without them showed the strong dependence of the current system where 16 percent of the time the reservoir will go dry, but more than 70 percent of the years will have a dry month. The effect is concentrated between September and January, time when the reservoir starts to fill again only if there is enough winter precipitation. On the other hand, the flood risk will be reduced if there are no PVP diversions and if the reservoir is managed with the current Rule Curve, because it will have a lower average storage during the flood season.

The current storage capacity reservoir under the Baseline scenario showed to be a more reliable system than without PVP. During periods of sufficient inflows and high storage, both human and environmental objectives were supplied. Nevertheless, when the system faced drought periods of consecutive dry years those objectives under current conditions were at risk to be not fully supplied. Recent changes in PVP diversions, persistent population growth and land use changes may drive the system more often into these conditions of water supply shortage. Although raising the dam is under current feasibility evaluation due to dam safety standards, it was originally design to be raised approximately 36 feet, which correspond to 75,000 acre-ft. Results indicate that under the Baseline scenario, if PVP diversions were kept as they are currently, the system will have an almost equal response regardless of the storage capacity, but augmented approximately the same volume that the reservoir was raised.

On the other hand, there are substantial differences for the Baseline scenario without PVP diversions. Under these circumstances, the system relies entirely on water inflows within the watershed. The study results indicate that the water supply reliability will be compromised with the current storage capacity, and less compromised with a bigger reservoir. Specifically, under severe conditions the augmented capacity reservoir will be able to store enough water to meet environmental and water supply demands longer, but if the dry period extends long enough, the reservoir will go dry. Additionally, whenever the reservoir goes dry, the results showed that the augmented capacity reservoir recovers faster than under the current conditions because the latter usually reaches the top of conservation threshold whereas the greater capacity of the augmented one allows storing a higher volume. Although a higher capacity will not prevent it to go dry, more than 70 percent of the months the storage will be above the current capacity threshold. Finally, the hydrology and water inflows to the system suggest that the reservoir gets filled during the late winter and early spring, when the top of conservation is at the lowest level or gradually increasing. Therefore, the main water inputs of the systems are not fully stored due to flood control operations. During this period, the reservoir storage would be usually above the current Rule Curve if no flood control releases were performed or, as the augmented capacity simulation results indicated, allow the system to keep a higher storage. Ultimately, a bigger reservoir allows not only to store water from the wet season to be used during the dry and high demand season, but also to transfer the remaining storage annually, improving the water supply reliability.

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APPENDIX A

Table 1 Storage distribution for Baseline Scenario comparing current and augmented storage capacity for both PVP on and off conditions

		Baseline Scenario with PVP On				Baseline Scenario with PVP Off			
		Current Storage Capacity		Augmented Storage Capacity		Current Storage Capacity		Augmented Storage Capacity	
Bins		***Frequency***	***%***	***Frequency***	***%***	***Frequency***	***%***	***Frequency***	***%***
-	2,000	1	0%	0	0%	192	16%	49	4%
2,000	10,000	2	0%	0	0%	120	10%	24	2%
10,000	20,000	1	0%	0	0%	123	10%	33	3%
20,000	30,000	10	1%	0	0%	135	11%	41	3%
30,000	40,000	54	4%	0	0%	119	10%	46	4%
40,000	50,000	99	8%	0	0%	107	9%	60	5%
50,000	60,000	115	9%	0	0%	82	7%	56	5%
60,000	70,000	445	36%	0	0%	184	15%	78	6%
70,000	80,000	153	12%	3	0%	65	5%	81	7%
80,000	90,000	193	16%	1	0%	68	5%	88	7%
90,000	100,000	88	7%	5	0%	28	2%	121	10%
100,000	110,000	55	4%	34	3%	13	1%	112	9%
110,000	120,000	21	2%	86	7%	1	0%	85	7%
120,000	130,000	0	0%	99	8%	0	0%	75	6%
130,000	140,000	0	0%	131	11%	0	0%	48	4%
140,000	150,000	0	0%	448	36%	0	0%	117	9%
150,000	160,000	0	0%	173	14%	0	0%	63	5%
160,000	170,000	0	0%	144	12%	0	0%	36	3%
170,000	180,000	0	0%	76	6%	0	0%	22	2%
180,000	200,000	0	0%	37	3%	0	0%	2	0%
Total		1237	100%	1237	100%	1237	100%	1237	100%

APPENDIX B

Key Water Balance Model Assumptions

The following assumptions were considered by the SCWA when developing their model. These assumptions are described in detail in the SCWA Reliability Report (TERM 17) submitted in April 30, 2015, Appendix B, and attached here as they were written on the Term 17 Report (Lake Mendocino Water Supply Reliability Evaluation Report, SCWA, 2015, p. 16):

- "When Lake Mendocino storage is within the conservation pool, reservoir releases are made to meet downstream demands along, and the minimum instream flow requirements (including a buffer release) for the Upper Russian River.
  - No additional releases are made to meet demands along, or the minimum instream flow requirements for, the Lower Russian River.
- All system gains and losses are defined with the input datasets for the model.
- The water loss datasets are applied in the model as annually repeating patterns of system
- Losses.
  - Current system loss alternatives incorporate Normal and Dry year types which are determined through an analysis of springtime precipitation.
  - Projected 2045 system loss alternatives use a single annually-repeating pattern based on average loss.
- To approximate losses in surface water flows for the projected 2045 alternatives, scaling factors were developed correlating observed reach losses to current estimated applied water demands.
- Losses from riparian vegetation water use are the same for all current and future scenarios.
- All estimated current and projected municipal demands directly impact surface water flows in the river.
- No conservation water is stored in Lake Mendocino above the limits of the Corps' Rule Curve."