EXHIBIT F-1
37 Pages

OLYMPIC VALLEY
PUBLIC SERVICE DISTRICT

CLIMATE CHANGE MODELING – OLYMPIC VALLEY GROUNDWATER MODEL

DATE: February 27, 2024

TO: District Board Members

FROM: Dave Hunt, District Engineer

SUBJECT: Climate Change Modeling – Olympic Valley Groundwater Model

BACKGROUND: On January 29, 2023, the District submitted a letter to Placer County (County) regarding comments on the Partially Revised Draft EIR for the Village at Palisades Tahoe Specific Plan. In that letter, it was requested that the County direct the District to prepare climate change modeling to supplement information contained in the 2015 Water Supply Assessment (WSA)(Farr West et al, 2015) and Sufficiency of Supply Assessment (Todd Groundwater, et al, 2015).

The County has yet to respond to the District's request for climate change modeling and given the vulnerability of the community's sole source of water supply to predicted climate change scenarios, the District feels that it is critical to update the Olympic Valley groundwater model and reevaluate the findings of the current WSA with the publicly available resources and guidance issued by the California Department of Water Resources (DWR) at this time.

DISCUSSION: On December 22, 2023, the Board approved a proposal from UES for the preparation of climate change groundwater modeling. The scope of work included conducting an assessment of climate change to supplement and compare with information contained in the 2015 WSA and Sufficiency of Supply Assessment. The analysis was performed using the numerical flow model for the Olympic Valley aquifer along with the guidance and datasets provided by DWR in 2018.

UES has completed the groundwater modeling and issued a Draft Memorandum entitled *Climate Change Modeling – Olympic Valley Ground Water Model*, a copy of which is attached. The results of the Draft Memorandum will be presented at the February 20, 2024 Board meeting by the District's hydrogeologist, Dwight Smith. A copy of the PowerPoint presentation is attached.

A Final Memorandum will be prepared based on input received from the Board and public.

ALTERNATIVES: No action is requested of the Board; this is an information item only.

FISCAL/RESOURCE IMPACTS: The District signed a Professional Services Agreement with UES for this work with a fee of $33,288. The work is budgeted as an operating expense and will be funded through the water operating budget.

RECOMMENDATION: No action is requested of the Board.

ATTACHMENTS:

- Draft Memorandum Climate Change Modeling – Olympic Valley Groundwater Model (UES, February 20, 2024)
- PowerPoint presentation – Climate Change Assessment for Future Water Supply (UES, February 27, 2024)

DATE PREPARED: February 20, 2024

MEMORANDUM

To: Dave Hunt, PE, OVPSD District Engineer

CC: Mike Geary, PE, OVPSD General Manager

From: Dwight L. Smith, PG, CHg, Principal Hydrogeologist
Kaimana Peredo, Hydrogeologist

Date: February 20, 2024 (DRAFT)

Subject: **Climate Change Modeling - Olympic Valley Groundwater Model**

This technical memorandum summarizes an evaluation undertaken by UES (formerly McGinley & Associates) to simulate climate change effects on water supply management from the Olympic Valley aquifer. The Olympic Valley Public Service District (OVPSD) Board approved the work plan to conduct the climate change evaluation on December 22, 2023.

1.0 INTRODUCTION

In 2018, the California Department of Water Resources (DWR) published a guidance document and datasets to facilitate evaluation of climate change in groundwater sustainability plans (DWR 2018a, 2018b). The datasets and guidance documents provide a means to assess potential climate change implications for future water supply using conventional numerical groundwater flow models, such as the model developed for Olympic Valley by HydroMetrics (2007, 2014, 2015).

As recommended by the Olympic Valley Groundwater Management Plan Implementation Group, the 2023 Six-Year Review and Report (SRR) for Olympic Valley (McGinley, 2023) identifies consideration of climate change for long-term water planning reviews as a high priority recommendation. The SRR recommendation is specifically as follows:

> *Complete a climate change assessment for water supply planning and long-term aquifer management considerations. CA DWR has developed guidance documents, tools, and climatic and hydrologic datasets to facilitate making climate change assessments for projected aquifer water budget determinations (DWR, 2018). These resources include monthly streamflow change factors that can be applied to historical data and used to estimate future water budgets and climate conditions by 2070. Data available from DWR include specific values for unimpaired streamflow (up-stream of dams) for watersheds tributary to the Truckee River from Lake Tahoe to the CA-NV Stateline (HUC8 Watershed #16050102), which includes the Olympic Valley aquifer and watershed. Climate datasets also include future (2030 and 2070) projections of precipitation and reference evapotranspiration. The climate change datasets include a central tendency developed as an ensemble of 20 climate change predictive models for the west coast, and two extreme scenarios (one drier-warmer, and one wetter-moderately warmer) for 2070. A climate change analysis could be completed using the numerical flow model for Olympic Valley, using change factors applied to Washeshu Creek flows input to the model. A focus on the predicted 2070 central tendency*

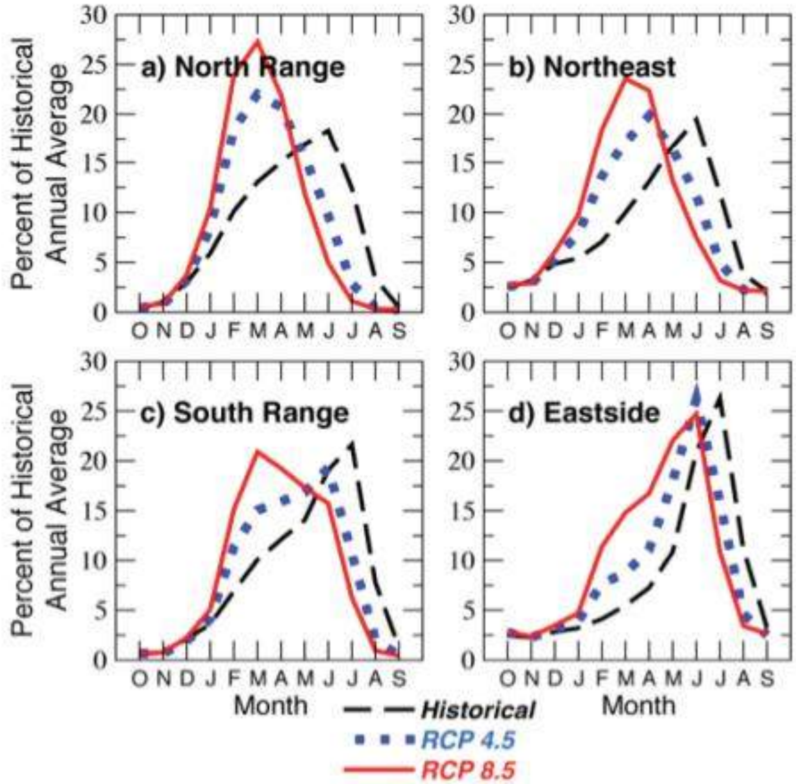
projection is recommended, although the climate extremes could be run in the model also for general knowledge.

1.1 CLIMATE CHANGE RESEARCH IN THE SIERRA NEVADA

Climate change and its effects on hydrology have become a topic of increasing concern around the world. In the western United States, the Sierra Nevada range is a key natural resource that provides water to California and Nevada, with about half of that amount of water being derived from the mountain snowpack (Reich et al., 2018). Several studies have been conducted on the Sierra Nevada to understand the hydrological impacts associated with a warming climate. Historical data and observations are used to track trends such as temperature, snowpack, snowmelt, precipitation, and peak runoff times. With that information, scientists can use models to predict the trajectory of peak runoff times into the end of the century under different scenarios.

In 1987, DWR Chief Hydrologist Maury Roos developed a method to quantify snowpack loss and corresponding flow during spring months using unimpaired flow from April to July (Roos, 1987). This method of analysis is used in the 2021 Water Year Hydroclimate Report (DWR, 2022) to indicate a trend in snowmelt and flow loss over the past 100 years. Over a 100-year period, the Sacramento and San Joaquin River systems show declines of 9.0 and 9.8 percent, respectively (DWR, 2022). Similar findings were exhibited in the Indicators for *Climate Change in California Fourth Edition* report (OEHHA, 2022) which showed an overall decline in April to July runoff over the last century. Monthly average runoff data on the Sacramento River from the last 30 years (1991-2020) illustrate a shift in peak runoff from April to March compared to the data from 1931-1960, and the earlier onset of spring runoff resulting in less available water during warmer months. Warmer winter temperatures cause a greater proportion of precipitation to fall as rain and drives the snowline to higher elevations thus reducing the snowpack and spring runoff (OEHHA, 2022). Temperatures are projected to warm by 6 to 9 degrees Fahrenheit on average which could raise the snowline by 1,500 to 3,000 feet (Dettinger et al., 2018).

Some studies have used Representative Concentration Pathways (RCPs) with their models to simulate different climate change scenarios based on future greenhouse gas emissions management. In the Sierra Nevada Region Report by Dettinger et al (2018), a modeled scenario (RCP4.5) is presented in which action was taken to reduce emissions by 2040 resulting in low-level stabilized emissions by 2080. A modeled scenario (RCP8.5) is also considered in which no mitigation measures were taken and emissions continue to increase resulting in high-level stabilization by 2100. The "North Range" subregion defined by this report is approximately between Lassen and Yosemite, incorporating the Olympic Valley area. Monthly average runoff between 2070-2099 for the North Range is projected to peak in March for both RCP4.5 and RCP8.5, and Summer runoff is projected to effectively end about 1 to 2 months earlier for both RCP4.5 and RCP8.5, as illustrated in Dettinger et al (2018) Figure 2.8 shown below.



Ensemble averages of 2070-2099 runoff hydrographs for the subregions shown in Fig. 1.1a—with each month's runoff shown as a percentage of the historical (1961-1990) annual-total norms--from ten climate models responding to two greenhouse-gas futures, where "runoff" is the water that avoids evaporation and use by plants to flow off or into land surfaces (essentially, surface water flows and groundwater recharge generated by a given area). Notably (d) Eastside responses shown mostly reflect snowmelt and runoff from the eastern slopes of the Sierra Nevada.

Figure 2.8 from Dettinger et al (2018).

Schwartz et al (2017) projected runoff timing changes over global climate models from the Coupled Model Intercomparison Project Phase 5 (CMIP5) using hybrid dynamical-statistical downscaling. Two scenarios were used in projections: RCP8.5 (or "business as usual") and RCP4.5 (or "mitigation"). Under RCP8.5, warming shifted snowmelt-driven surface runoff as much as 80 days earlier in 2091-2100 compared to 1991-2000. RCP4.5 showed shifts of up to 30 days earlier. All projections revealed that rising temperatures will lead to more liquid precipitation and earlier snowmelt, which contribute to advancing surface runoff.

The Bureau of Reclamation (BOR) Truckee Basin Study (2015) developed models using the US Geological Survey (USGS) Precipitation Runoff Modeling System (PRMS) code for three sub-basin watersheds including Lake Tahoe, Martis Creek, and the Little Truckee River. The BOR modeled monthly and annual runoff for five climate scenarios with a "Reference" simulated from historical data for comparison. Peak snowmelt runoff has historically occurred in April and May in the Truckee River near Farad, CA. As temperatures increase, snowfall and snowmelt patterns will change and shift runoff toward earlier months with higher precipitation. Toward the latter portion of the century (2070-2099), peak runoff times are predicted to shift consistently to March in all projections, as illustrated in BOR (2015) Figure 3.36 presented below. As runoff shifts toward earlier months, runoff during the summer to early fall will end earlier as well, shifting by as much as two months earlier in the Hotter-Drier condition.

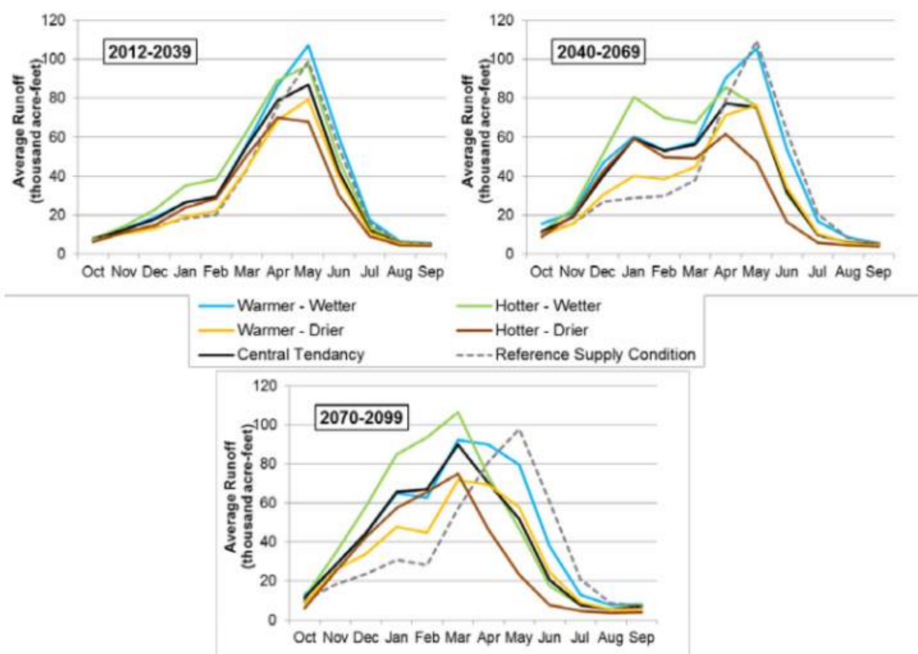


Figure 3-36. Monthly Average Runoff at Truckee River at Farad Gage for Water Years 2012 – 2039, 2040 – 2069, and 2070 – 2099

Figure 3-36 is from the BOR Truckee Basin Study (2015).

1.2 CA DWR (2018) Climate Change Modeling Resources

The California Department of Water Resources (DWR) has several resources related to simulation of future climate in water supply availability and modeling (DWR, 2018a and 2018b). These resources have been developed to aid in the integration of climate change considerations into sustainable groundwater management planning for CA basins, which is a requirement for hydrographic basins that are required to have a Sustainable Groundwater Management Plan (SGMP) under the California Sustainable Groundwater Management Act (SGMA).

The DWR-provided hydrologic change factors for climate change is based on the results from the California Water Commission's Water Storage Investment Program (WSIP) climate change analysis. The change factors are derived from 20 global circulation models from the Coupled Model Intercomparison Project

Phase 5 (CMIP5) and provides climate change factors for precipitation reference and evapotranspiration (ET) for two climate periods: 2030 and 2070. The 2030 period includes a central tendency scenario and the 2070 period includes a central tendency scenario, a drier with extreme warming (DEW) scenario, and a wetter with moderate warming (WMW) scenario. Climatological factors are provided as gridded cells over the entire state. For areas of California outside of the Central Valley, unimpaired streamflow change factors are provided on a USGS Hydrologic Unit Code (HUC) 8 watershed scale. These monthly change factors are used as multipliers on their respective historical datasets, spanning from 1915 to 2011. Factors have not been developed by DWR to apply to historical conditions after 2011, but DWR plans to update the climate change resources and factors on an 8 to 10 year basis (DWR, 2018).

2.0 IMPLEMENTATION OF DWR CLIMATE CHANGE VARIABLES IN THE OLYMPIC VALLEY GROUNDWATER FLOW MODEL

2.1 OLYMPIC VALLEY NUMERICAL GROUNDWATER FLOW MODEL

The climate change analysis for Olympic Valley groundwater availability evaluation has been conducted using the numerical groundwater flow model for Olympic Valley as most recently updated in 2015 (Hydrometrics WRI, in Farr West, et al, 2015). The numerical flow model uses the USGS MODFLOW code and simulates historical groundwater conditions from October 1992 through January 2015, including historical pumping, natural recharge, and the associated responses of potentiometric water levels in the aquifer. The time period for which DWR climate change factors can be directly applied in the Olympic Valley model is October 1992 through December 2011. The Olympic Valley model also uses monthly stress periods with inputs of monthly averages for water budget components (pumping, streamflow, and precipitation recharge). The DWR climate change factors are provided on a monthly average basis, which is complimentary to the stress periods used in the Olympic Valley groundwater flow model.

Aquifer recharge is the primary variable of the water budget represented in the Olympic Valley groundwater flow model for which climate change will affect. The recharge to the basin occurs via two primary mechanisms, as illustrated conceptually in **Figure 1**:

- Streamflow infiltration recharge, primarily from Washeshu Creek, but also from secondary tributaries around the valley, and
- Infiltration of precipitation falling directly on the valley floor (called direct precipitation recharge).

Deep groundwater inflow is assumed to be minor given the low permeability of underlying granite bedrock and is not explicitly represented in the model. Infiltration from Washeshu Creek is represented in the model using the MODFLOW Stream Package. Flows are input at the North Fork and South Fork of Washeshu Creek at the western boundary of the aquifer, near locations where historical stream flow gages have been operated. Stream flows are then simulated to continue through the valley, with a portion of the streamflow infiltrating to the aquifer depending on flow rates, and gradients between the streambed and the aquifer. Streamflow infiltration is governed by hydraulic conductivity values at the streambed that were developed during model calibration. The DWR (2018) climate change factors for streamflow can be applied directly to the model input values (historical monthly average flow rates), and modify the historical peak flow timing and magnitudes based on the 2070 climate projections.

In the numerical flow model, recharge is also applied to the land surface that represents direct infiltration of precipitation and recharge from the smaller tributaries than Washeshu Creek that produce runoff flowing onto the valley floor. The DWR (2018) precipitation change factors for 2070 are applied directly to the simulated magnitudes from this recharge source.

Evapotranspiration is not directly simulated in the Olympic Valley groundwater flow model, but has a physical effect on the availability of summer precipitation to become recharge. The DWR (2018) ET climate change factors are not directly applied in the model, but are indirectly factored into consideration, as detailed later in this report.

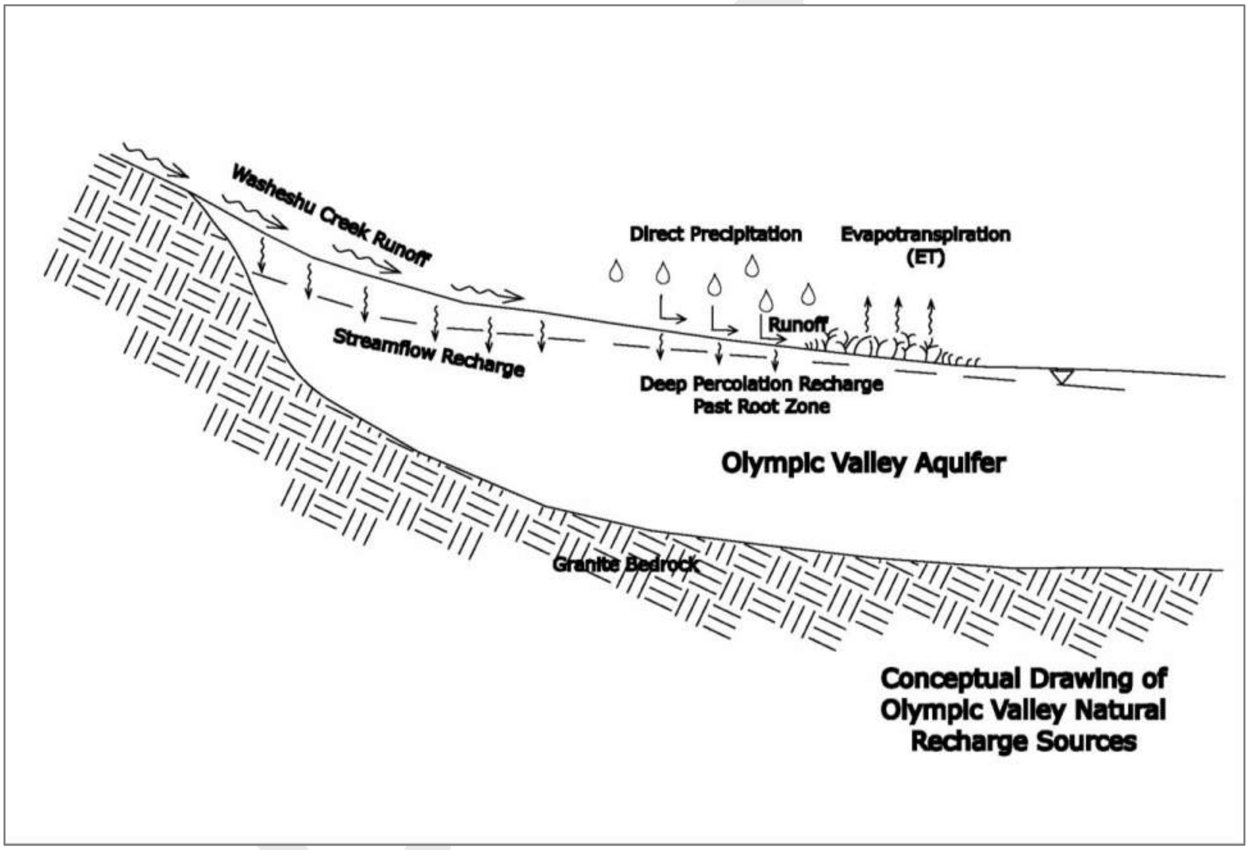
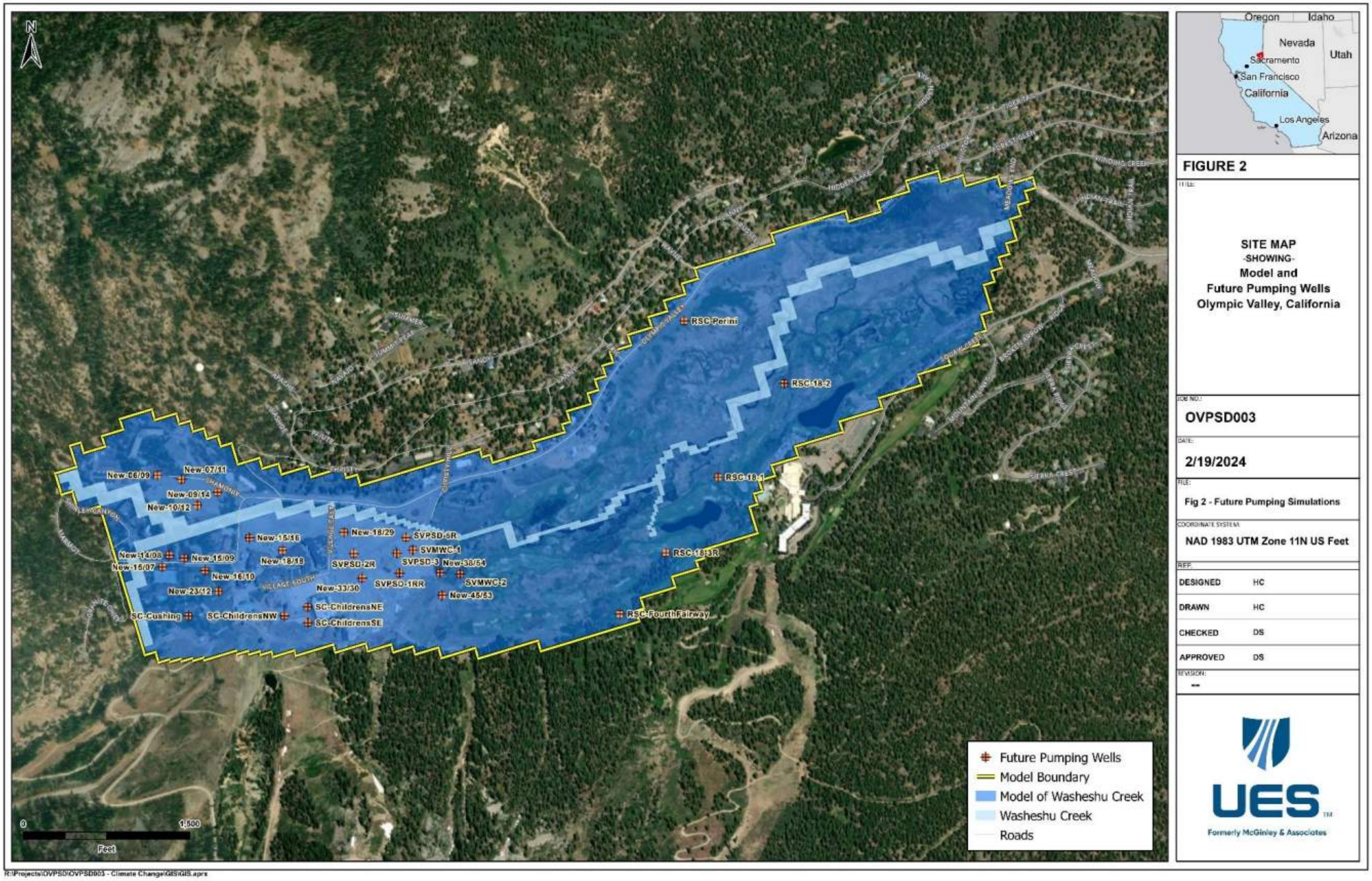


Figure 1 – Conceptual modeled recharge to the Olympic Valley aquifer.

The Water Supply Assessment (WSA) Update and Updated Sufficiency of Supply Assessment prepared for the Village at Olympic Valley project (Todd Groundwater, et al, 2015) presents a simulation of future pumping from the Olympic Valley aquifer that includes pumping from existing wells to meet current water demands plus reasonably foreseeable additional future pumping over a 25 year horizon, including pumping to meet the projected water demands for the Village project at build-out. This WSA version of the Olympic Valley MODFLOW groundwater flow model ("WSA model") with the future predicted pumping is used to simulate future climate change for the evaluation presented herein. Pumping is distributed amongst existing and planned wells. The simulated wells include the Everline Resort golf course irrigation wells 18-1, 18-2, 18-3R, and planned wells at Everline Resort Perini and Fourth Fairway locations. Pumping for snowmaking continues at the Palisades wells near the Childrens Camp / Village including Childrens SE, NW, NE, and the Cushing well. Municipal wells operated by OVPSD and Squaw Valley Mutual Water Company (MWC) continue to be pumped at existing locations, with the exception of a replacement well location for OVPSD 1R (labeled 1RR). Additionally, there are nine (9) proposed new municipal wells located in the western Olympic Valley aquifer to support the WSA projected increase in water demand in the valley. Locations of these new wells were derived based on development plans at the time of the WSA evaluation (2014-2015) and through trial and error model testing of aquifer performance / simulated drawdown at proposed new well locations. Locations of simulated pumping wells in the WSA model are shown in **Figure 2**. Pumping distributions are generally uniform in distribution amongst the simulated municipal wells, but vary monthly based on seasonal water demands. For more information on the simulated pumping distribution, the reader is referred to the WSA Sufficiency of Support report by Todd Groundwater (2015, Table 3)


N
Oregon
Idaho
Nevada
Utah
Sacramento
San Francisco
California
Los Angeles
Arizona
FIGURE 2
SITE MAP
-SHOWING-
Model and
Future Pumping Wells
Olympic Valley, California
OVPSD003
2/19/2024
Fig 2 - Future Pumping Simulations
NAD 1983 UTM Zone 11N US Feet
DESIGNED HC
DRAWN HC
CHECKED DS
APPROVED DS
UES
Formerly McGinley & Associates
RSC-Perini
RSC-18-2
RSC-18-1
RSC-18-3R
RSC-FourthFairway
New-08/09
New-07/11
New-09/14
New-10/12
New-15/16
New-18/29
SVPSD-5R
SVMWC-1
New-14/08
New-15/09
New-15/07
New-18/18
SVPSD-2R
SVPSD-3
New-38/54
New-16/10
SVPSD-1RR
SVMWC-2
New-23/12
New-33/30
New-45/53
SC-Cushing
SC-ChildrensNW
SC-ChildrensNE
SC-ChildrensSE
Future Pumping Wells
Model Boundary
Model of Washeshu Creek
Washeshu Creek
Roads
0
1,500
Feet
R:\Projects\OVPSD\OVPSD003 - Climate Change\GIS\GIS.aprx

2.2 2070 Climate Implementation for Washeshu Creek Streamflow

The approach to implementing the climate change into the Olympic Valley model is to apply DWR monthly change factors for unimpaired streamflow to the North Fork and South Fork of Washeshu Creek. Flows in these tributaries of Washeshu Creek are input to model at the western edge of the Olympic Valley (see **Figure 2**), and for model construction and calibration have been based on historical gaged flows near the flow input locations. The simulated streamflow then becomes available to infiltrate and recharge the Olympic Valley aquifer, with a portion flowing through the valley and out to the Truckee River.

The HUC8 watershed area #16050102 specific climate change factors for unimpaired streamflow are used. Olympic Valley resides in the southern portion of this HUC8 watershed area, as shown in **Figure 3**. The 2070 climate conditions are modeled by multiplying the monthly 2070 change factors for the central tendency, DEW and WMW climate predictions by the historical average monthly flow data from October 1992 to December 2011 for the North Fork and South Fork of Washeshu Creek.

The HUC8 specific change factors vary monthly, and from year to year based on past variabilities in weather and climate. **Figure 4** contrasts the average historical (WY1993-2011) streamflow for Washeshu Creek with the 2070 simulated change flows. Notable is a predicted shift in peak runoff from May to February or January (3 to 4 month shift). This is a notable shift in the timing of peak runoff from the Washeshu Creek watershed, being 1 to 2 months earlier than studies for the Truckee River and northern Sierra Nevada regional watersheds that are summarized in Section 1.1.

The WSA model runs to January 2015, and DWR (2018) does not provide climate change factors to be applied to historical data beyond 2011. For the last 3 years of WSA model simulation, the WY1993-2011 average climate change monthly factors were applied to the respective months from January 2012 to January 2015. This produces an undefined level of inaccuracy in the simulation of climate change influences in the model for the last 3 years of model simulation (2012-2014).

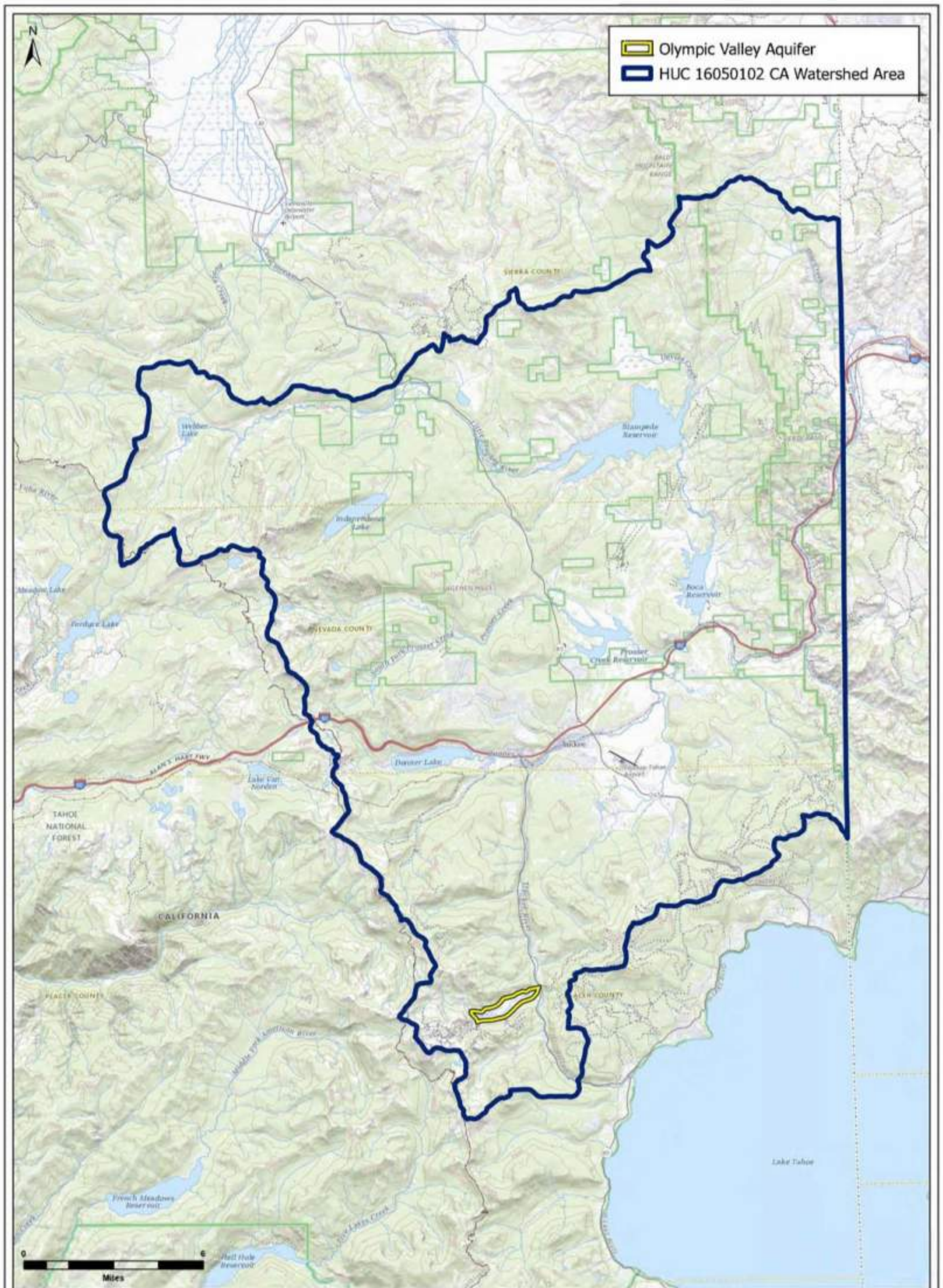


FIGURE 3

TITLE: SITE MAP -SHOWING- HUC 16050102 California Watershed Area

FILE: HUC 16050102 CA Watershed Area

COORDINATE SYSTEM: NAD 1983 UTM Zone 11N US Feet

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OVPSD003	2/9/2024	DESIGNED	HC	CHECKED	DS	-
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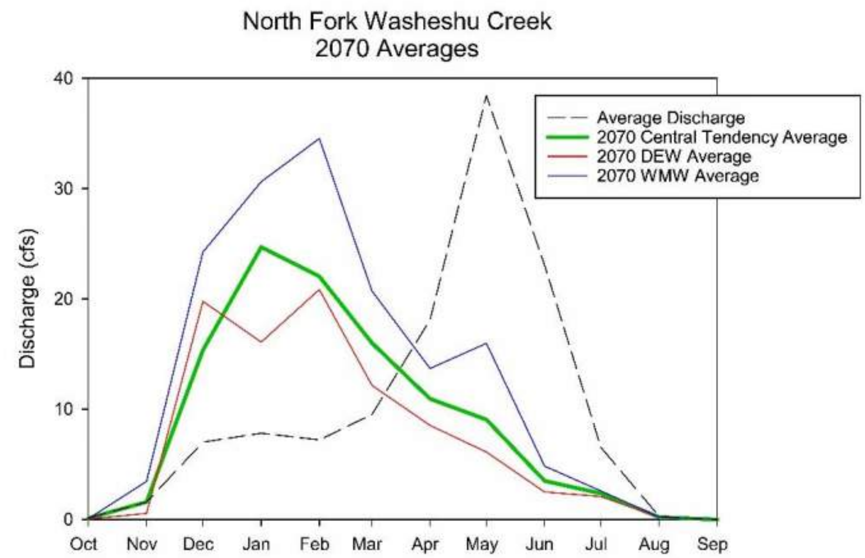

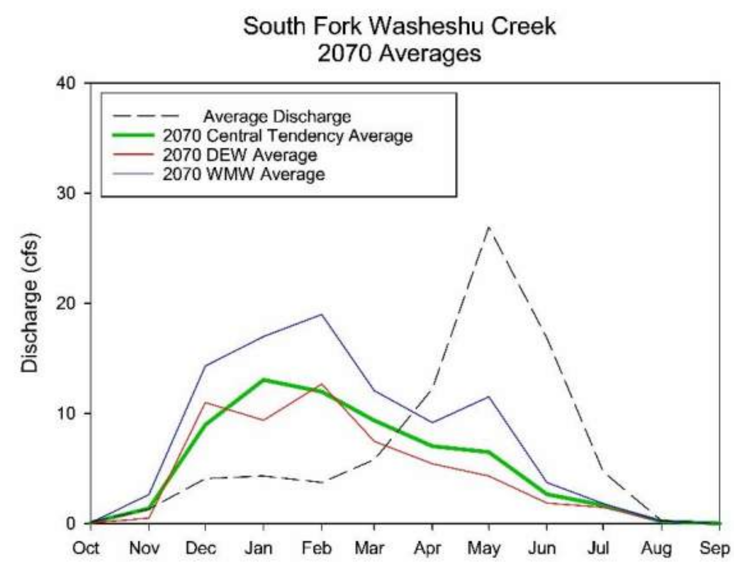

Figure 4 – Historical (1993-2011) Average Monthly Discharge compared to 2020 Predicted Discharge of Washeshu Creek.

Washeshu Creek is an intermittent (seasonal) stream where it enters the western edge of Olympic Valley. Normal conditions for Washeshu Creek at the western edge of the valley are for streamflow to cease in mid-summer once snowpack has melted. Streamflow resumes in the fall or early winter when significant precipitation has occurred.

The DWR (2018) scaling factors do not specifically represent a shift in no-flow conditions for an intermittent stream like Washeshu Creek (no scaling factors drop to zero), however, this condition is important for management of the Olympic Valley aquifer as the streamflow constitutes a primary source of groundwater recharge. Each year, once the streamflow goes dry, pumping from water supply wells primarily withdraws groundwater from aquifer storage until streamflow resumes in the fall or winter. The seasonal occurrence and cessation of streamflow in Washeshu Creek is illustrated in **Figure 5**.

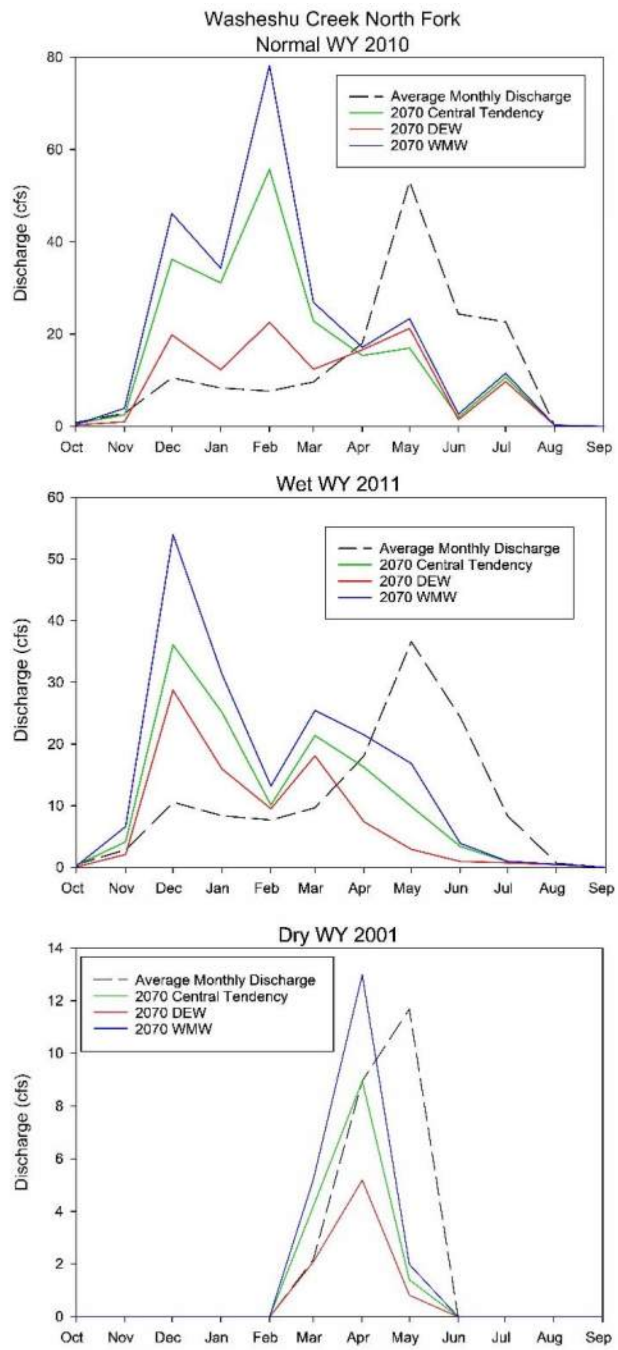

Figure 5 – Representative "normal" year, wet and dry year runoff hydrographs for the North Fork of Washeshu Creek.

The DWR unimpaired streamflow factors for 2070 climate conditions as applied to the historical occurrence of runoff will propagate (extend) the occurrence of runoff in a different manner than actually exists, where the runoff recedes from the peak flow condition down to zero flow within a few months. To address this physical reality of the Washeshu Creek watershed, the trailing tails of the 2070 synthesized hydrograph are truncated to mimic a more rapid decline and cessation of flow that occurs in Washeshu Creek. The truncation of flows occurs on the trailing edge of the hydrograph when synthesized flows have receded to less than about 2 cfs, but otherwise would be simulated as low flows for several months. The hydrograph truncation varies for each year and for the three 2070 climate scenarios, being less significant in the WMW scenario, and more substantial (commonly 2 months) in the central tendency and DEW scenarios. An example of the truncation of the hydrograph is presented in **Figure 6**.

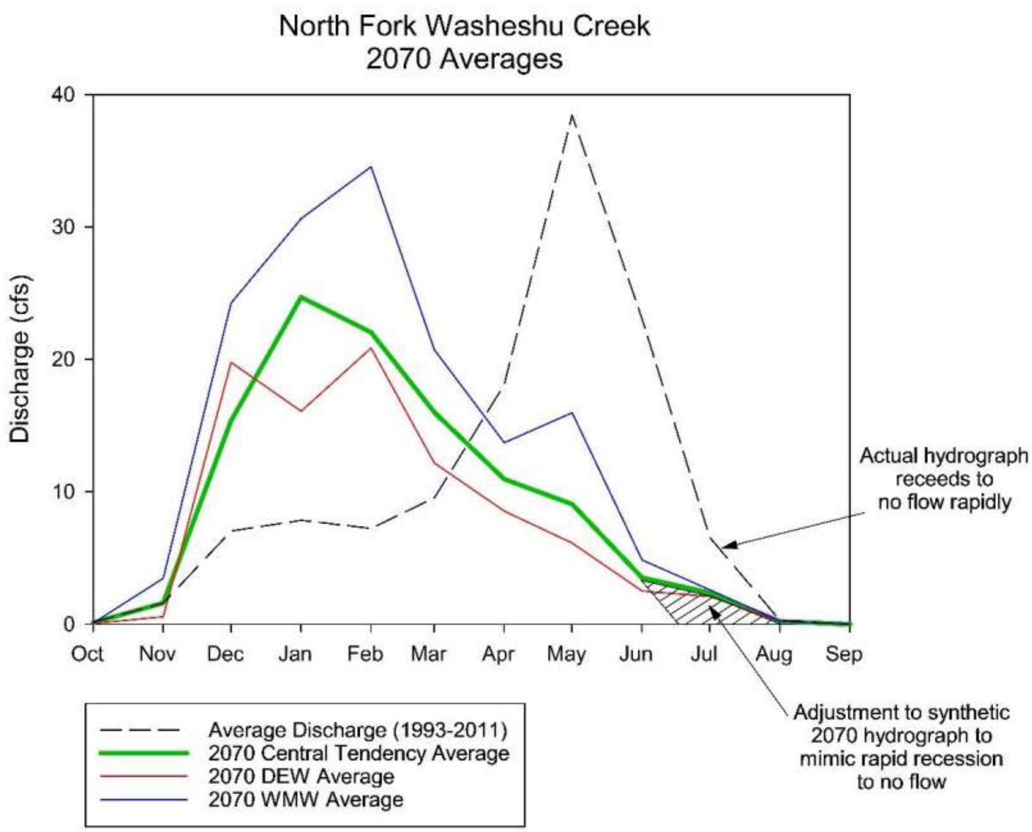

Figure 6 – Illustration of Washeshu Creek simulated summer flow truncation approach applied to 2070 synthetically generated streamflow using the DWR (2018) HUC8 #16050102 scaling factors.

2.3 2070 Climate Precipitation and Evaporation Factors Application

Additionally, recharge from direct precipitation falling on the land surface of the basin is represented in the Olympic Valley model, with a simulated lag in recharge from precipitation in the winter months resulting from snowpack accumulation (HydroMetrics 2014). Input of direct precipitation recharge in the Olympic Valley model is adjusted taking into consideration the DWR (2018) projected 2070 precipitation and reference ET change factors.

Under the 2070 climate conditions, precipitation totals are predicted to increase over historical conditions (**Figure 7**). The annual average precipitation is predicted to increase by approximately 9% to 23% in the 2070 climate change scenarios. The timing of the occurrence of precipitation is simulated to be very similar in 2070 to the historical conditions, with peak precipitation occurring in the winter months of December through March, and very little precipitation occurring in summer months of June through September.

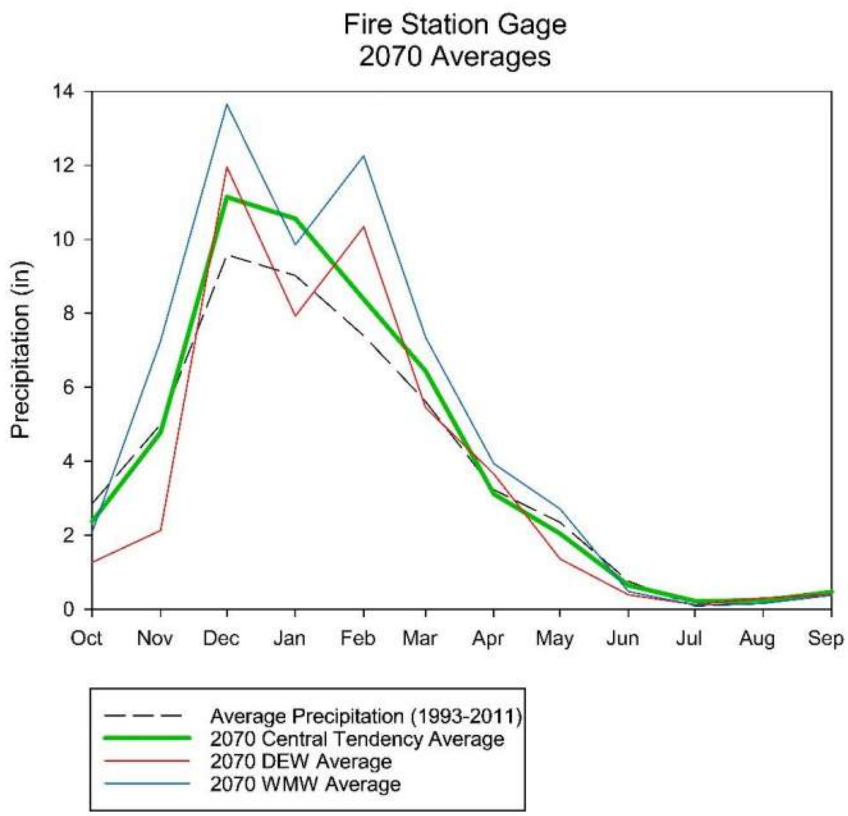

Figure 7 – DWR 2070 predicted monthly precipitation at the Olympic Valley floor using the historical (1993-2011) precipitation recorded at the Fire Station gage.

ET water consumption by vegetation is predicted to increase under warmer future climate conditions, notably for the months of May through November (**Figure 8**). ET in 2070 is predicted to be about 9% greater in summer months under the climate change central tendency, but may increase as much as 20-

21% greater under the 2070 DEW climate change scenario. Given the predicted trends of 2070 precipitation and ET, it is unlikely or rare that direct precipitation falling in the summer months would produce significant groundwater recharge in 2070 climate conditions.

Groundwater recharge for simulated 2070 climate change conditions is adjusted in the Olympic Valley model by scaling the direct precipitation recharge input for October 1992 through December 2011 by the DWR (2018) monthly 2070 climate change precipitation scaling factors. For January 2012 through January 2015 when DWR (2018) climate change scaling factors are not available, the 1993-2011 average monthly precipitation change scaling factors were applied. This results in an undefined degree of uncertainty for climate change simulation results for January 2012 through January 2015. To account for the increased ET under 2070 climate conditions, any simulated direct precipitation recharge input for the months of May through September is removed in all simulation years.

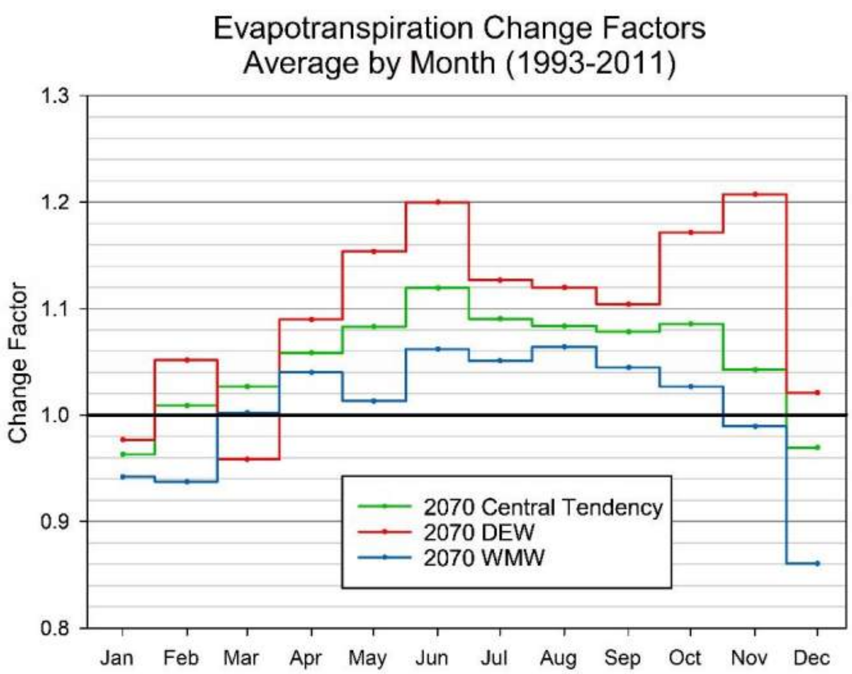

Figure 8 – DWR (2018) change factors for ET in 2070 for HUC8 #16050102 watershed.

3.0 MODELING SIMULATION RESULTS

Each set of future 2070 climate change attributes as described previously were input into the 2015 WSA model version. No changes to pumping distribution or magnitudes were made, so that the results presented in the 2015 Updated Sufficiency of Supply Assessment for Village at Squaw Valley and Other Growth (Todd Groundwater, 2015) can be directly compared with the climate change simulations presented herein.

Plots of model predicted percentage of aquifer saturation are presented as **Figures 9 through 12** for all simulated future municipal wells. **Figure 9** presents the 2015 WSA results and **Figure 10** presents the future 2070 climate change central tendency. **Figures 11 and 12** present the simulated percentage of aquifer thickness for the 2070 DEW and WMW climate scenarios.

A goal of the 2015 WSA was to identify and confirm that a pumping distribution can be presented that would maintain a minimum of 65% saturated aquifer thickness at all municipal wells at all times during the predicted future water supply period that was based on historical climate conditions. The simulated full aquifer saturated thickness at municipal wells ranges from 78.34 ft to 152.69 ft, with an average saturated thickness of 123.5 ft (Todd Groundwater, 2015). At the 65% threshold, the saturated aquifer thickness would be reduced to an average of approximately 80.3 ft. The actual pumping water levels in wells are lower than the model simulated aquifer water levels, due to model grid size limitations and continued flow convergence within the model cell toward the well. There is also additional water level drawdown due to head losses from water flow through the well gravel pack and screen. **Figure 13** presents an illustration of simulated pumping drawdown in the model, contrasted with the actual pumping water level in a well. Technical work on the proposed Water Management Action Plan (WMAP) by OVPSD in 2023 determined that there is an additional ~20 ft of pumping water level drawdown in the existing OVPSD and MWC wells, over what is simulated in the groundwater flow model (UES/McGinley, Draft 2023). Pumping water levels in the wells simulated in the future 2070 climate can be assumed to have similar additional pumping water levels over what is predicted in the model.

The future pumping scenario presented in the 2015 WSA required the addition of nine (9) new municipal wells to the existing municipal well network in order to meet the future predicted water demand and maintain the 65% minimum aquifer saturated thickness. The 65% threshold assumes that pumps can be operated near the bottom of the wells, with pumping water levels about mid-depth in the aquifer, while maintaining well production capacity. The 2015 WSA simulation also assumes that all municipal wells fully penetrate the thickness of the alluvial aquifer down to bedrock. Future new wells will need to be designed to accommodate the expected operational parameters and existing municipal wells may need to be re-equipped or re-drilled to accommodate the assumed 2015 WSA operating conditions.

The future 2070 model conditions are developed by applying change factors to the historical variabilities observed between October 1992 through January 2015. In the 2015 WSA model, the most critical water supply year was observed in late 2001 (beginning months of water-year 2002), when simulated aquifer thickness at a few municipal wells was predicted to approach the 65% minimum saturated thickness threshold. Wells New-07/11, SVPSD-2R and New-15/07 were simulated to experience lower than 70% saturated thickness but did not drop below 65%.

The beginning of WY2002 remains the most critical year in regard to maintaining the minimum 65% aquifer saturated thickness in the 2070 climate scenarios. The simulated aquifer saturated thickness in 2070 climate conditions drops below the 65% threshold for several wells, as summarized in **Table 1**. In the central tendency 2070 climate condition, four wells are simulated to experience aquifer saturated thicknesses below 65% in the critical dry year. The viability of pumping these wells at the simulated pumping rates is questionable, but might be managed/mitigated by shifting some simulated pumping to other wells.

Notable in the 2070 future climate simulations is that aquifer storage continues to substantially refill each winter, even in the driest of simulated water-years. Water-year 2001 represents the lowest winter refill condition, with 87% average saturated thickness recovery in the 2015 WSA modeling, contrasted with 83-87% in the 2070 future climate scenarios. This modeling result indicates that the aquifer storage will continue to be replenished each winter. The key to management of groundwater in the Olympic Valley aquifer on the western side will continue to be dry season management of pumping from aquifer storage, until the winter recharge replenishes the aquifer. The proposed WMAP by OVPSD is envisioned to become a more critical aquifer storage management tool to overcome future climate conditions which are predicted to experience longer and warmer seasonal dry periods, especially when coupled with the potential for future increased water demands from the aquifer associated with the Village project, other potential development, or an increase in seasonal pumping for snowmaking.

Table 1 – Summary of Simulated Aquifer Saturated Thickness

Aquifer Attribute	Model Scenario			
	WSA (2015)	2070 Climate Change Central Tendency	2070 Climate Change DEW	2070 Climate Change WMW
Overall Average Percentage of Aquifer Saturated Thickness at Simulated Municipal Wells	89%	87%	86%	88%
Average Monthly Saturated Thickness Low	77%	72%	70%	74%
Average Monthly Saturated Thickness High	99%	100%	101%	102%
Lowest Simulated Aquifer Thickness at an Individual Municipal Well	65% (New-7/11)	59% (New-7/11)	57% (New-7/11)	62% (New-7/11)
WY2001 (Critical Water Supply Year) Average Aquifer Refill Saturated Thickness	87%	84%	83%	87%
Number of Simulated Municipal Wells Experiencing Below 65% Aquifer Saturated Thickness	0	4 (New-7/11, OVPSD-2R, New-15/07, New-9/14)	5 (New-7/11, OVPSD-2R, New-15/07, New-9/14, New-10/12)	2 (New-07/11, OVPSD-2R
Number of Years out of 19 (WY1993-2011) with at least One Municipal Well Experiencing Below 65% Aquifer Saturated Thickness	0	2	6	2

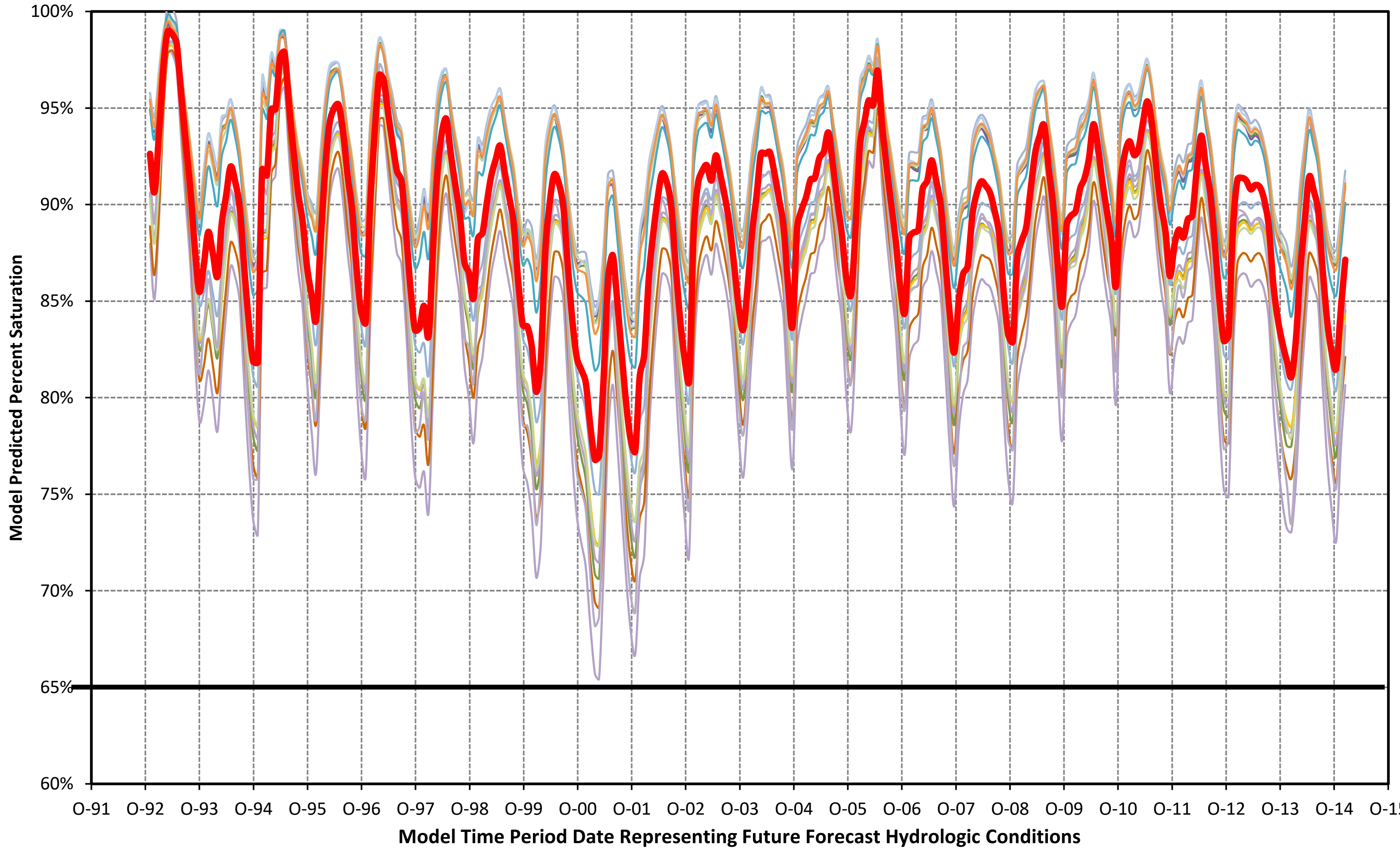

Figure 9 – 2015 WSA Simulated Percentage of Aquifer Saturate Thickness at Pumping Wells

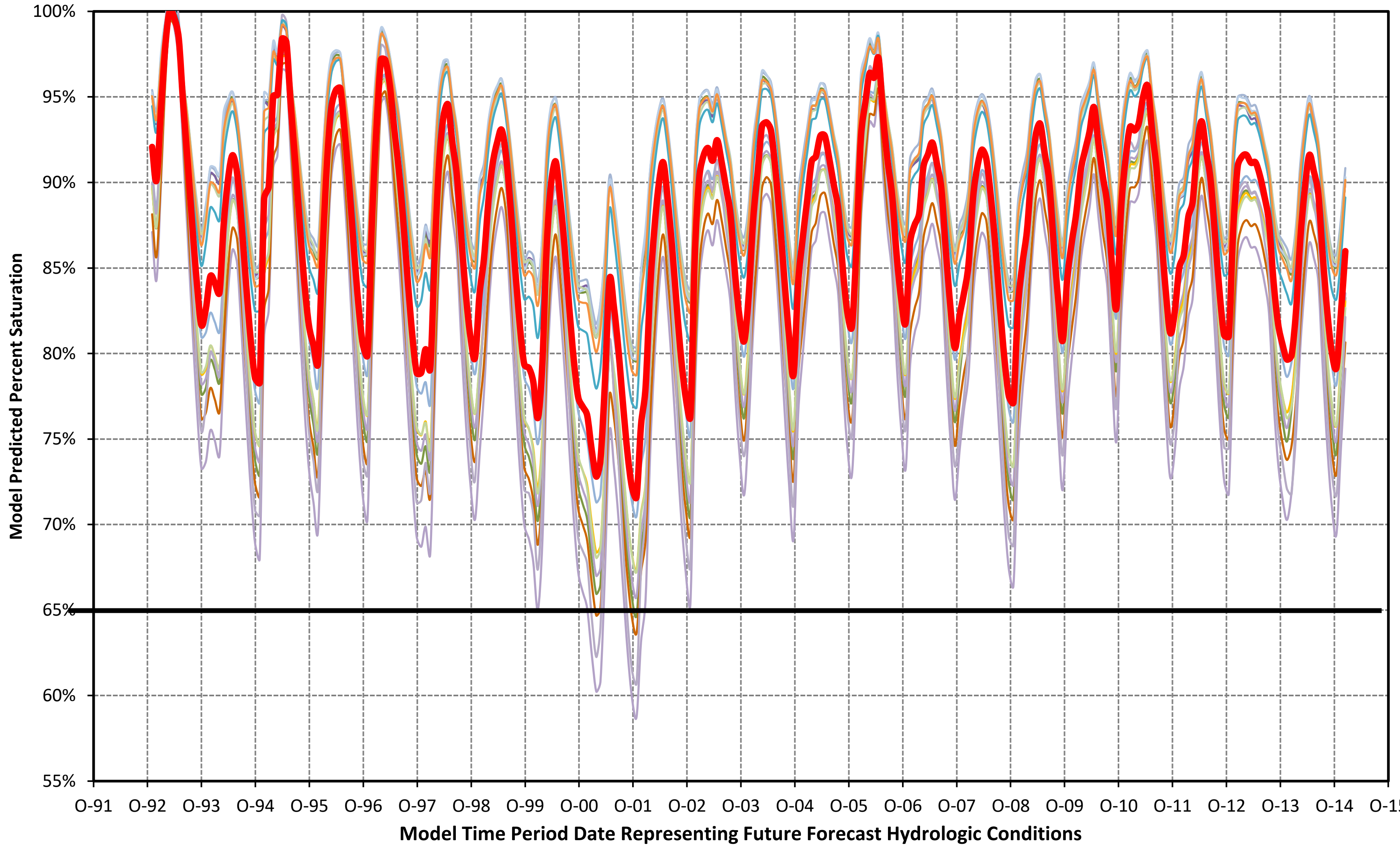

Figure 10 – 2070 Climate Change Central Tendency Simulated Percentage of Aquifer Thickness at Pumping Wells

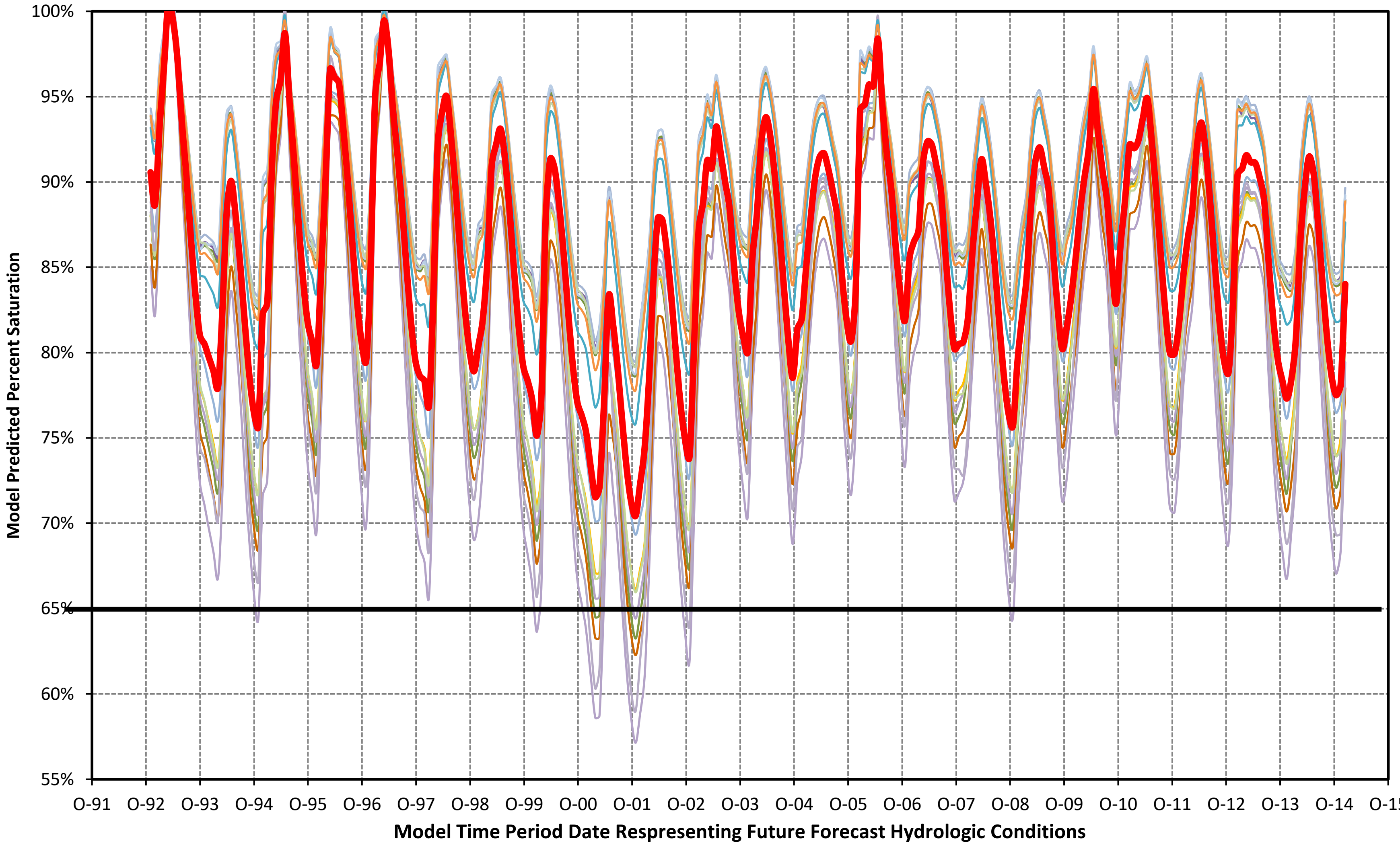

Figure 11 – 2070 Climate Change DEW Simulated Percentage of Aquifer Thickness at Pumping Wells

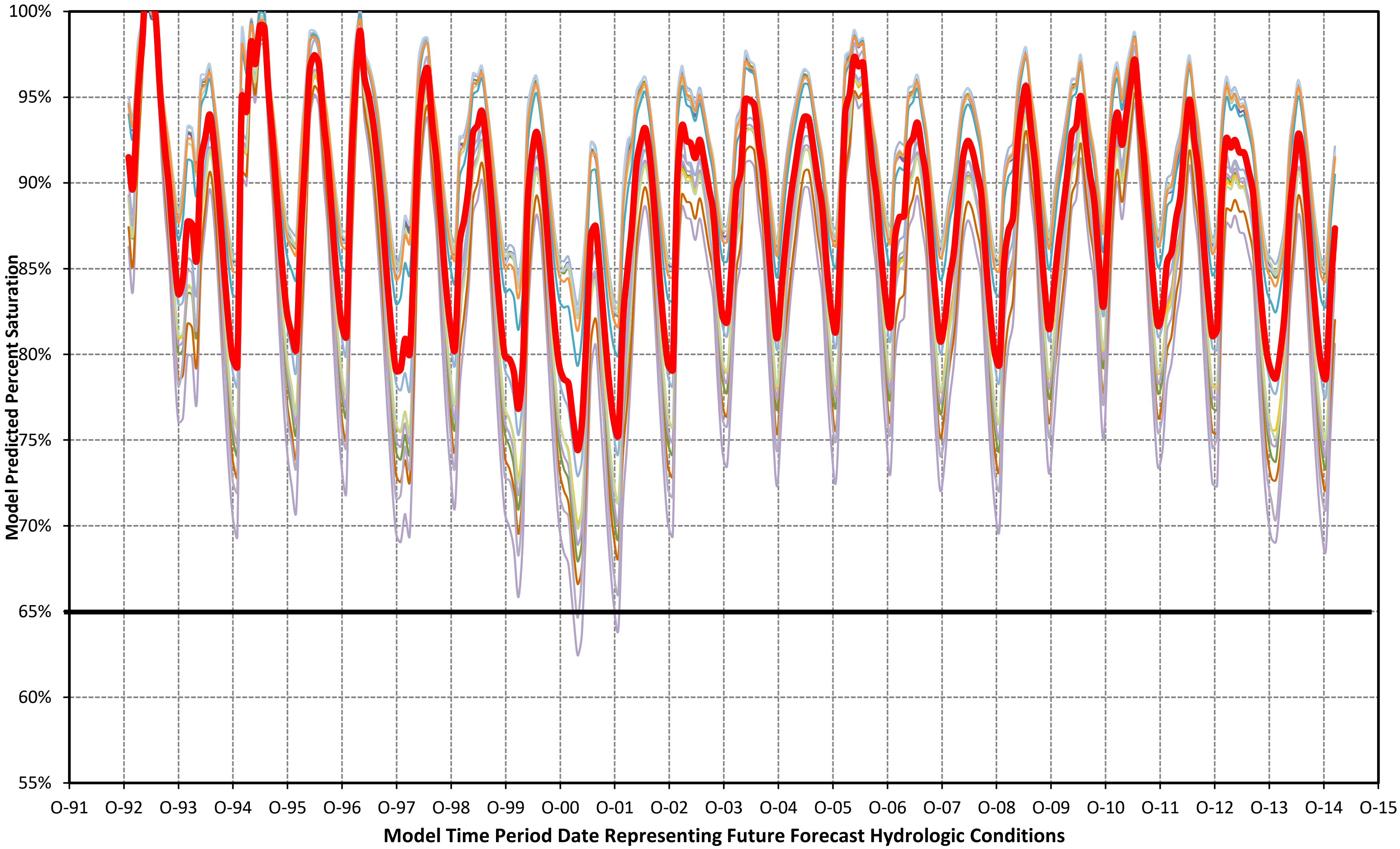

Figure 12 – 2070 Climate Change WMW Simulated Percentage of Aquifer Thickness at Pumping Wells

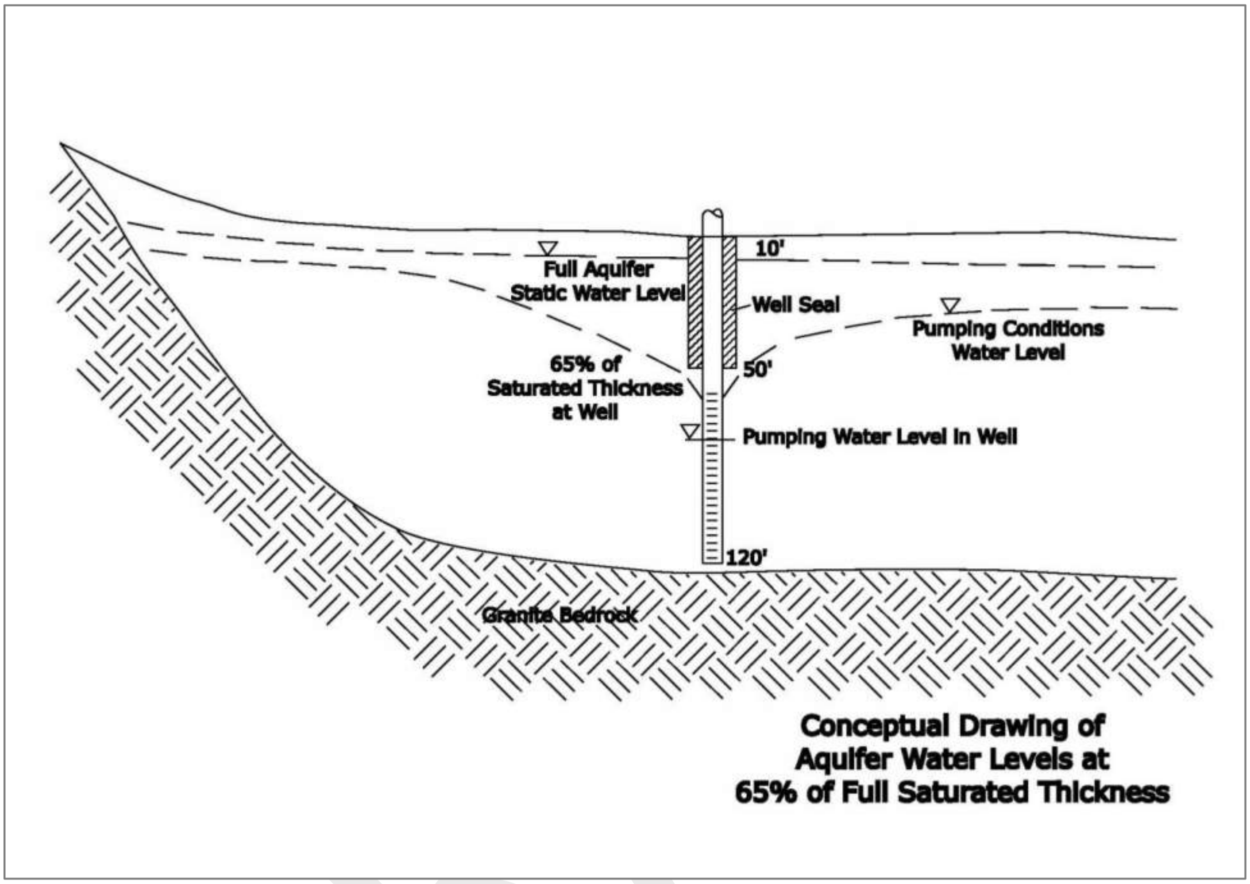

Figure 13 – Conceptual illustration of aquifer saturated thickness and well pumping drawdown.

4.0 MODELING LIMITATIONS

By definition, a numerical flow model is a simplification of complex processes and geologic conditions. Even in the areas with refined geologic detail, the model still represents approximations of actual field conditions, which can vary significantly over very small distances. At the scales at which numerical flow modeling can be undertaken, the relevant equivalent volume approach must be applied, whereby, on a regional basis, modeled hydraulic properties represent a generalization of more intricately distributed hydraulic conditions. This is the only practical way to approach numerical flow modeling, and as such, modeling results must be viewed as approximations of real-world future conditions.

Climate change projections rely upon sophisticated models with similar simplifications of complex climate variables and interactions. The DWR (2018) guidance document summarizes assumptions and limitations in data sets provided and methods employed to derive the climate change factors. The reader is referred to the DWR (2018) climate change guidance documents for detailed information in this regard.

Future pumping in the model occurs at nine (9) new simulated municipal wells, for which precise information on aquifer thickness and hydraulic properties is not currently available. Future well locations and numbers of wells will need to undergo technical reviews as precise locations of new wells are determined, and as wells are drilled and tested. As discussed in this report, the Olympic Valley model produces output of water levels at pumping well locations that do not fully reflect actual pumping water levels in wells, due to model grid / cell size limitations and abilities to represent near well inflow hydraulics and head losses. Estimates have been provided to convert model cell water levels and drawdown to potential pumping water levels in wells, assuming typical well efficiencies as observed in Olympic Valley. It is also important to recognize that the model results are monthly average values, and daily values are expected to show greater variability.

Model audits and updates should be undertaken periodically, as additional data become available, in order to maintain the best-available aquifer management and water supply planning tool for Olympic Valley. The Olympic Valley SSR report (McGinley, 2023) makes further recommendations in this regard. As conveyed in the DWR (2018) climate guidance document, DWR anticipates updating the climate change factors periodically. As updated climate change factors are published it is recommended that the updated DWR work be reviewed and run in the Olympic Valley model so that future water supply planning can be based on the most current science.

5.0 SUMMARY AND CONCLUSIONS

Climate change impacts to water supply capability from the Olympic Valley aquifer have been reviewed using the Olympic Valley groundwater flow model coupled with the year 2070 climate change factors published by DWR (2018). Three climate change scenarios are modeled, a central tendency derived from an ensemble of 20 climate change models, and two bounding climate scenarios to the central tendency, being a wetter moderately warm condition (WMW) and a drier extremely warmer condition (DEW). The central tendency can be viewed as the most probable condition, based on the available science and modeling at the time of DWR (2018) reporting.

DWR (2018) developed monthly change factors that can be applied to modify common inputs to numerical groundwater flow models, allowing representation of water budgets in the future climate conditions projected for 2070. Climate change factors used in the Olympic Valley modeling of climate change include unimpaired streamflow, precipitation and reference evapotranspiration. DWR (2018) 2070 unimpaired streamflow scaling factors have been applied to Washeshu Creek flow inputs to the Olympic Valley model. Direct infiltration recharge from precipitation falling on the valley has been adjusted based on DWR (2018) 2070 future precipitation scaling factors. The climate change factors are specific to the Truckee River watershed area that incorporates Olympic Valley. ET scaling factors are not directly applied in the Olympic Valley model, but the predicted trends of increased ET due to warmer temperatures are factored into consideration in the direct precipitation recharge inputs in the model for the summer months of May to September. The occurrence of future 2070 precipitation is predicted to remain similar seasonally, with December through March receiving the greatest precipitation. Future 2070 annual precipitation totals are predicted to increase by 9 to 23%, however, occurring more dominantly as rainfall rather than snow.

Peak runoff in future 2070 climate conditions is predicted to shift from May under historical conditions to January or February by 2070 conditions, reflecting warmer temperatures and a significant shift from precipitation occurring as snowfall to rainfall, with a subsequent reduction in snowpack accumulation and snowmelt runoff. This shift in the timing of runoff directly affects the timing of Olympic Valley aquifer recharge occurring from Washeshu Creek runoff.

Washeshu Creek is an intermittent stream, in that runoff entering the valley at the western edge ceases for part of the year, typically from mid-summer to fall. The earlier peak runoff occurrence predicted for the future 2070 climate conditions is interpreted in this evaluation to result in an earlier cessation of flow in the summer by an average of 1 to 2 months. This lengthens the seasonal period when the Olympic Valley aquifer is receiving no significant recharge from streamflow and groundwater that is being pumped is derived from aquifer storage.

The cumulative effects of the modifications made to the model to represent future climate conditions of 2070 is that the saturated aquifer thickness during summer months will decrease. The average aquifer saturated thickness decrease is only a few percent lower under future 2070 climate conditions as contrasted with aquifer conditions predicted without climate change considerations (2015 WSA). The Olympic Valley aquifer is predicted to refill each winter similarly to conditions observed historically, reaching at least 84% total fill under the 2070 climate central tendency scenario. The future projected aquifer water levels at some simulated new well locations represented in the 2015 WSA model will drop below the desired minimum aquifer saturated thickness threshold of 65%. For the 2070 central tendency climate change scenario, four of the simulated fifteen pumped municipal wells operating in the western part of the Olympic Valley aquifer will fall below an aquifer saturated thickness of 65% during late-summer and fall conditions of severely dry years. Out of the nineteen years simulated for the climate change shift (WY1993-2011), two years have well conditions experiencing <65% aquifer saturated thickness, and the remaining years have aquifer saturated thickness >65% at all municipal wells. The DEW and WMW future 2070 climate scenarios produce similar modeling results, with moderately more saturated aquifer thickness maintained in the WMW, and moderately less saturated thickness predicted in the DEW. In the DEW 2070 future climate condition, five wells experience <65% aquifer saturated thickness in the most critical dry year (WY2002).

The climate change modeling results of this evaluation places an emphasis on the importance of advancing the WMAP effort amongst groundwater pumpers in Olympic Valley, particularly if future water demands increase as predicted in the 2015 WSA. The future pumping conditions represented in the 2015 WSA will likely require more rigorously managed pumping distributions and magnitudes under future climate conditions to enable municipal wells to sustain pumping through the dry seasons and critically dry years.

6.0 REFERENCES

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Climate Change Assessment for Future Water Supply

February 27, 2024

OLYMPIC VALLEY
PUBLIC SERVICE DISTRICT

UES | McGinley & Associates
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1

Approach of Climate Change Modeling

- Use currently available information on Climate Change from the CA DWR Guidance Document (2018) to evaluate future water supply impacts to Olympic Valley.
- Use the groundwater flow model developed for Olympic Valley by HydroMetrics (2007), most recently update in 2014 and 2015, representing historical climate conditions of October 1992 through January 2015.
- Apply to Future Pumping represented in the Water Supply Assessment (WSA) for future water supply for the Village Project (Todd Groundwater, 2015).

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Background

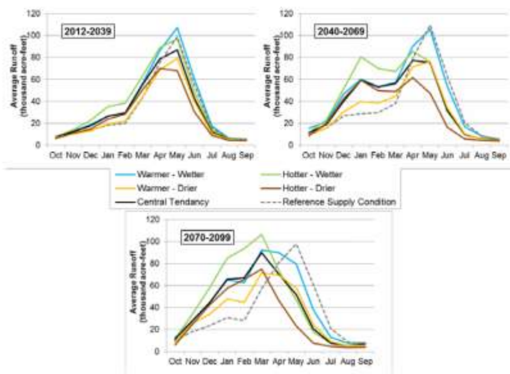
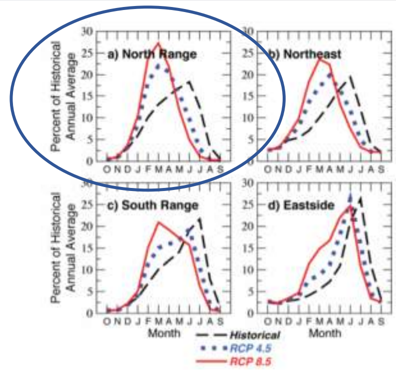


Figure 3-36. Monthly Average Runoff at Truckee River at Farad Gage for Water Years 2012 – 2039, 2040 – 2069, and 2070 – 2099

BOR, 2015



Ensemble averages of 2070-2099 runoff hydrographs for the subregions shown in Fig. 1.1a—with each month's runoff shown as a percentage of the historical (1961-1990) annual-total norms–from ten climate models responding to two greenhouse-gas futures, where "runoff" is the water that avoids evaporation and use by plants to flow off or into land surfaces (essentially, surface water flows and groundwater recharge generated by a given area). Notably (d) Eastside responses shown mostly reflect snowmelt and runoff from the eastern slopes of the Sierra Nevada.

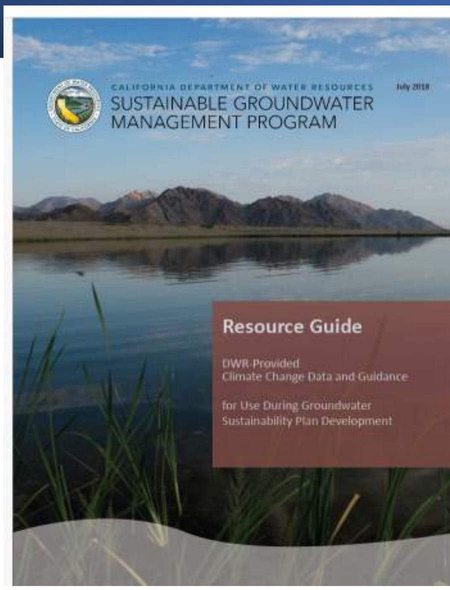
Dettinger et al (2018)

3

3

CA Climate Change Resource Guide (2018)

- Monthly average climate change factors developed for:
  - 2030 central tendency predicted climate
  - 2070 central tendency predicted climate
  - 2070 drier with extreme warming (DEW) scenario
  - 2070 wetter with moderate warming (WMW) scenario
- Hydrologic scaling factors to apply to historical data to simulate future climate conditions:
  - Unimpaired Streamflow Runoff
  - Precipitation
  - Evapotranspiration (ET)
- Published to apply to historical data from 1915 through 2011
- Specific for the Truckee River watershed



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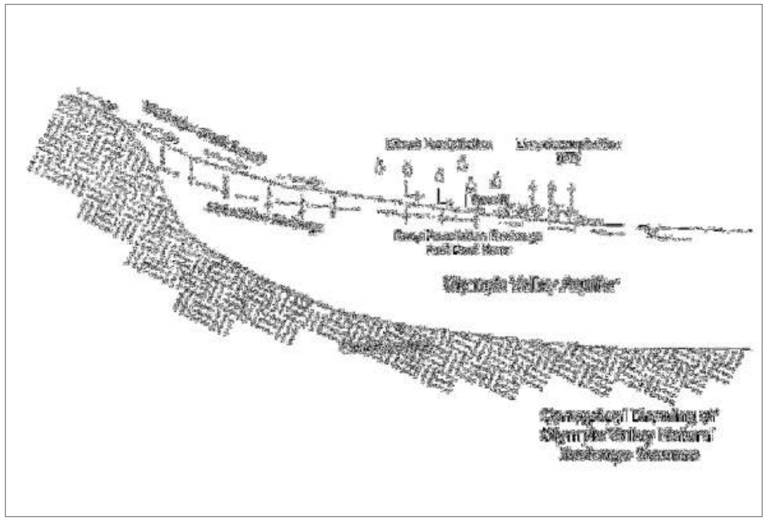
Model Variables for Climate Adjustments

- Recharge from Runoff in Washeshu Creek
- Recharge from direct precipitation falling on the valley floor
- Recharge from runoff in minor tributaries around the model periphery
- Deep subsurface inflow – assumed negligible



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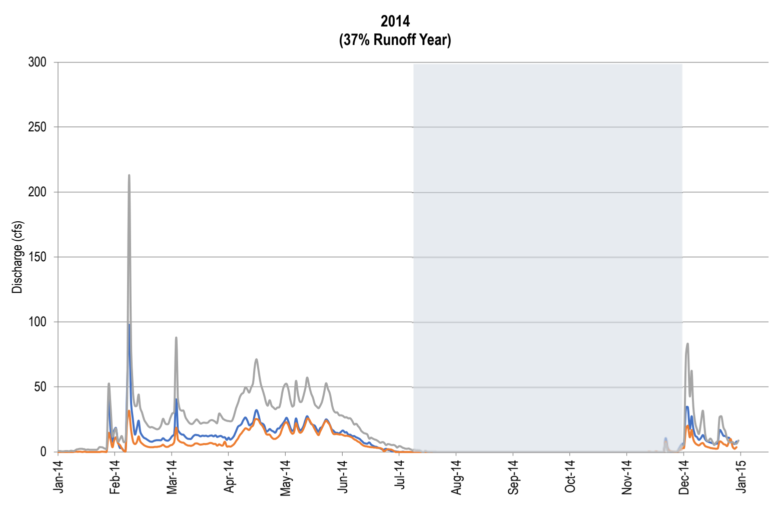
Seasonal Dependence on Aquifer Storage

- When no flows are present in Washeshu Creek – no recharge is occurring to aquifer.
- All pumping is from stored groundwater in the aquifer.
- Aquifer storage seasonally depletes until stream flow resumes.



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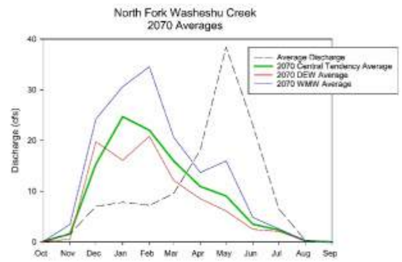
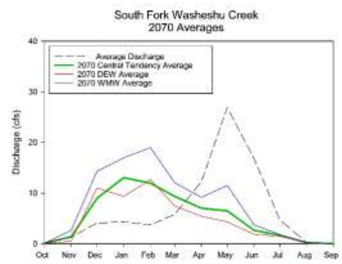
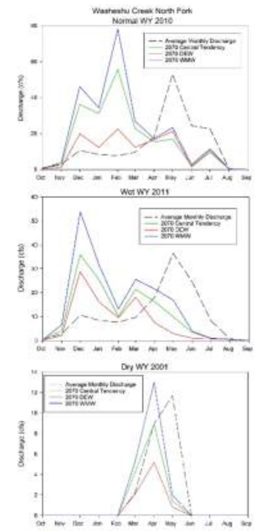
2070 Streamflow for Washeshu Creek – Peak Runoff Shift

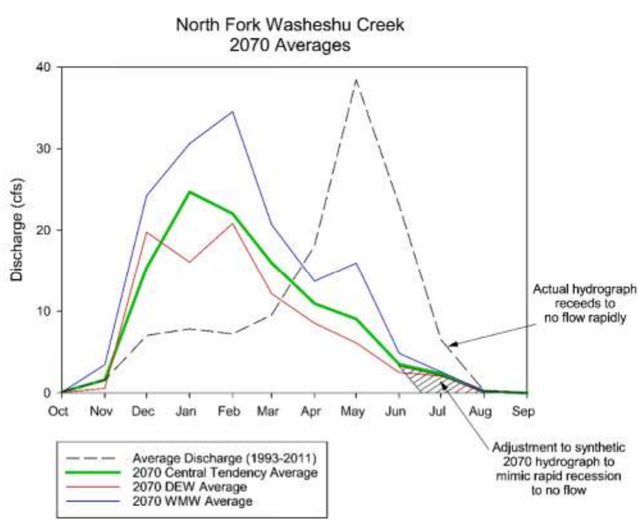
- DWR 2070 Climate Factors for Unimpaired Runoff for the Truckee River watershed area
- Applied to Monthly Average Values used in Model
- Applied to Oct 1992 – December 2011 Historical Values
- Average Change Factors used for 2012-2014







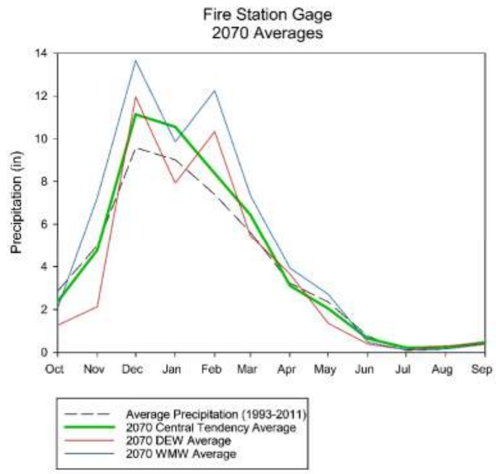
2070 Streamflow for Washeshu Creek – Cessation of Flow Shift

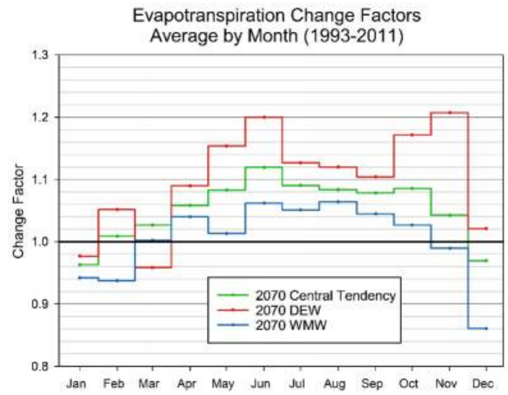


- Specific Adjustment for Runoff from Washeshu Creek – Intermittent Streamflow Condition.
- Truncate hydrograph tails consistent with historical runoff.
- 1-2 month shift in cessation in Central Tendency Scenario.

8

2070 Predicted Precipitation & ET – Adjustment to Direct Precipitation Recharge in the Model





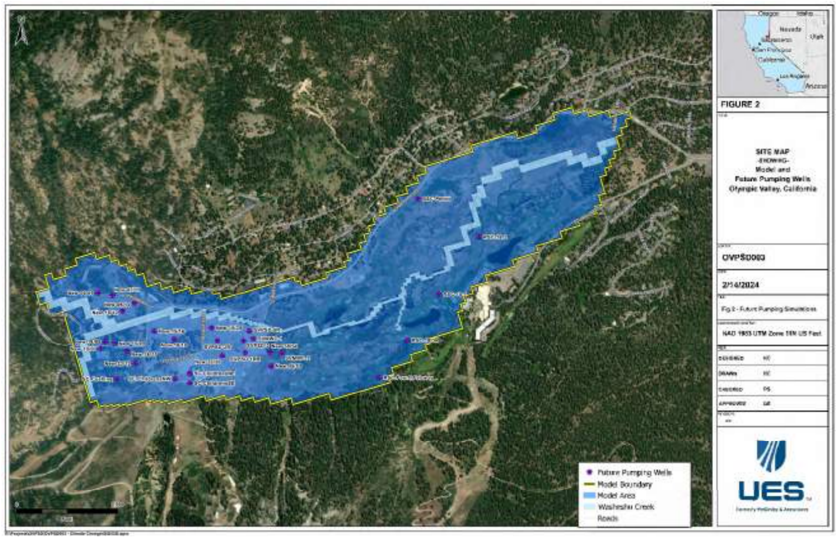
Modeling Results

Comparison of model simulated water levels under future (2070) predicted climate conditions with prior WSA (2015) water level modeling for the Village project.

The WSA (2015) modeling assumes future hydrologic conditions will be the same as historical conditions.

Future Water Demand Pumping Wells (WSA, 2015)

- Uses Existing Municipal Wells for OVPSD and MWC
- Addition of Nine New Municipal Wells in Western Aquifer to Meet Future Water Demands with the Village Project
- Four Existing Palisades Snowmaking Wells in Western Aquifer
- Existing Everline Resort Golf Course Wells plus Two Additional



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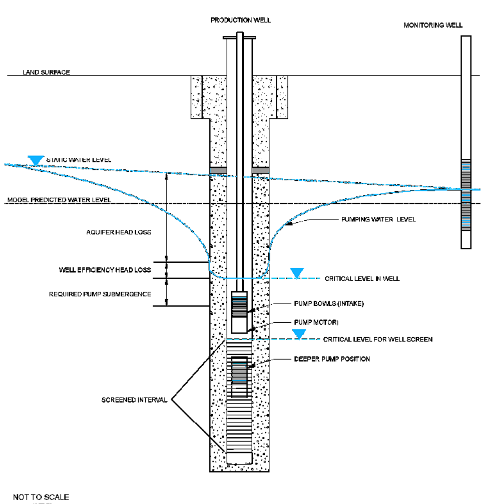
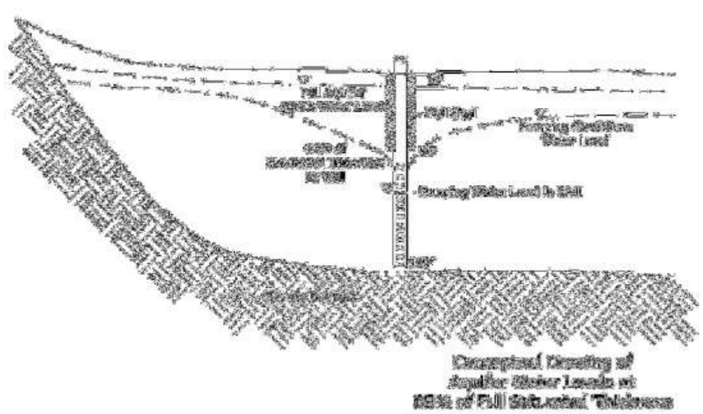
Modeled Water Level vs Actual Water Levels & WSA 65% Aquifer Saturated Thickness





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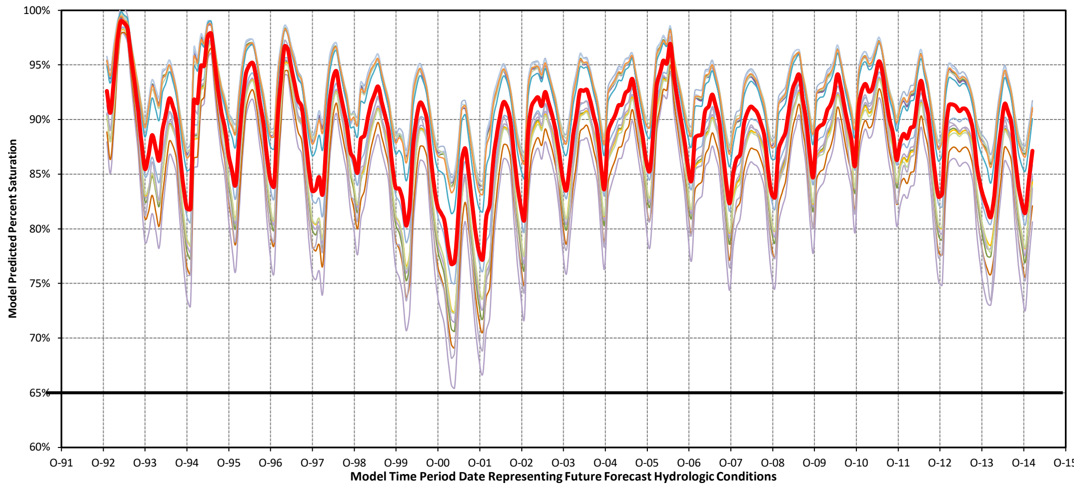
WSA (2015) Simulated Water Levels at Municipal Wells



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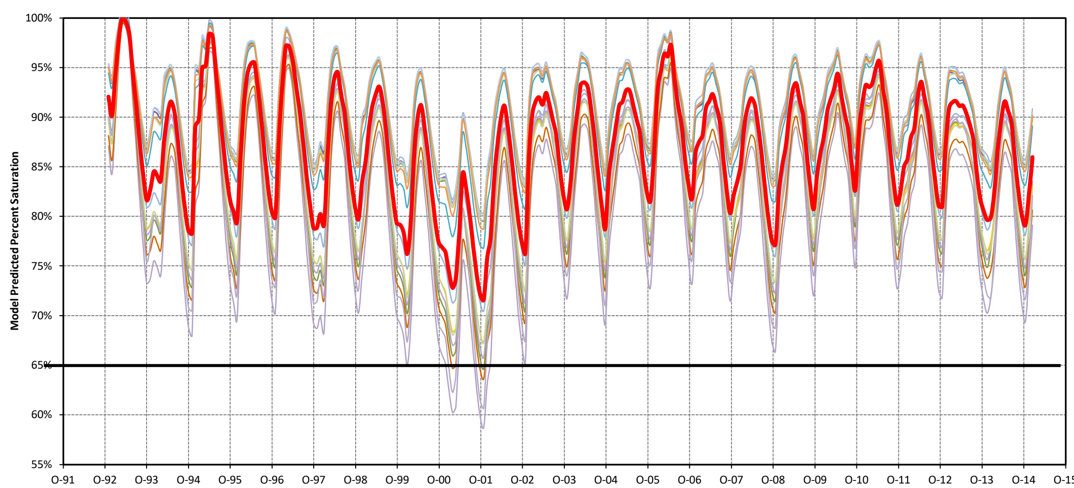
2070 Central Tendency Climate



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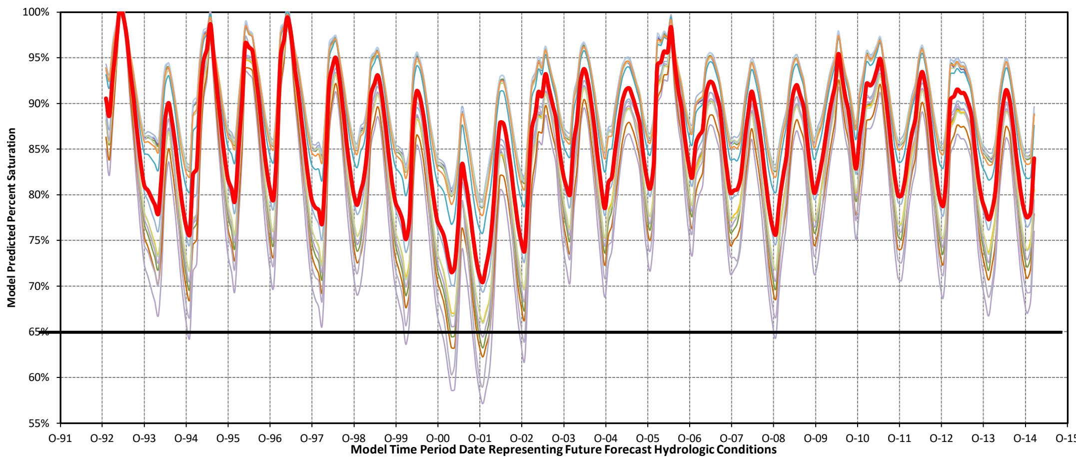
2070 DEW Climate Scenario



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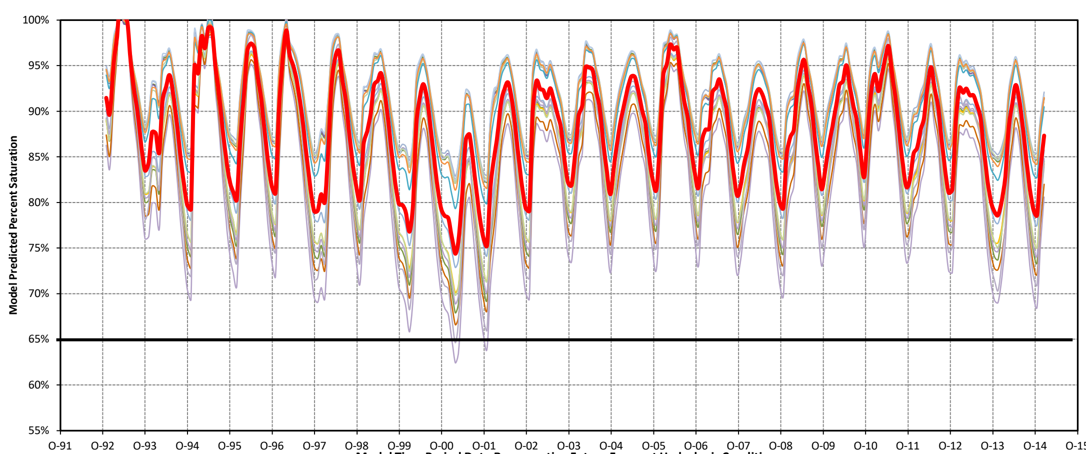
2070 WMW Climate Scenario



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Summary Statistics

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Number of Simulated Municipal Wells Experiencing Below 65% Aquifer Saturated Thickness	0	4 (New-7/11, OVPSD-2R, New-15/07, New-9/14)	5 (New-7/11, OVPSD-2R, New-15/07, New-9/14, New-10/12)	2 (New-07/11, OVPSD-2R
Number of Years out of 19 (WY1993-2011) with at least One Municipal Well Experiencing Below 65% Aquifer Saturated Thickness	0	2	6	2

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Conclusions

- Critical Year under 2070 future climate remains the simulated 2001 climate condition.
- 2070 Central Tendency Climate results in four simulated municipal wells with model water levels below 65% aquifer saturated thickness in the 2001 condition.
- DEW and WMW Climate Scenarios produce similar results, with five and two wells falling below 65% aquifer saturated thickness in 2001.
- Olympic Valley aquifer simulated to substantially refill (up to at least 84%) in all years.
- The proposed WMAP will become progressively more important to management of water supply and well functionality, since peak runoff will shift earlier in time and the seasonal dry period for pumping from storage will become longer.

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