Drain cells in yellow cover most of layer 1. The head in these Drain cells equals the ground surface and conductance is very high. When the groundwater table reaches the ground surface, the Drain boundary removes it from the model domain. These cells are apparently designed to prevent the water level in the aquifer from extending above the ground surface, in an effort to simulate rejected recharge (West-Yost 2003). The Drain cells remove about half of the recharge in the current model. O8a-60a cont.

The dark blue boundary on the far east is a constant head boundary for flow through the moraine bounding the east end of the valley. During the calibration run, the discharge through this end in the model is about 660 af/y. The conceptual model estimate for flow through the moraine was 220 af/y (Williams 2001). In 2003 the simulated flow across the moraine for model calibration was 83 af/y. The boundary was originally applied only in layers 2 and 3 (West-Yost 2003, Williams 2001), now is in layer 1. I found no description of why layer 1 was added but it may have been necessary to accommodate the much larger recharge running through the current model as compared to the earlier model.

Groundwater contours show a steep water table near the mountain front on the western third of the model (Figure 3). Groundwater would flow perpendicular to the contours, directly toward the center of the model domain and the green stream boundary. This steepness would require substantially lower conductivity in that area, but the K in this area (Hundt and Williams 2014, Figure 6) is over 200 ft/d in some areas. The steep contours are not observed in layer 2 (Figure 4). The thinness of layer 1 near the edge, as can be seen in the cross-section (Figure 3), probably reduces the transmissivity which requires the steep gradient. Layer 2 is no flow, and the groundwater contour in layer 1 is actually lower than the bottom of the layer. This probably does not cause a problem with the overall simulation results, but it does suggest localized water balance issues in the west end of the model. O8a-60b

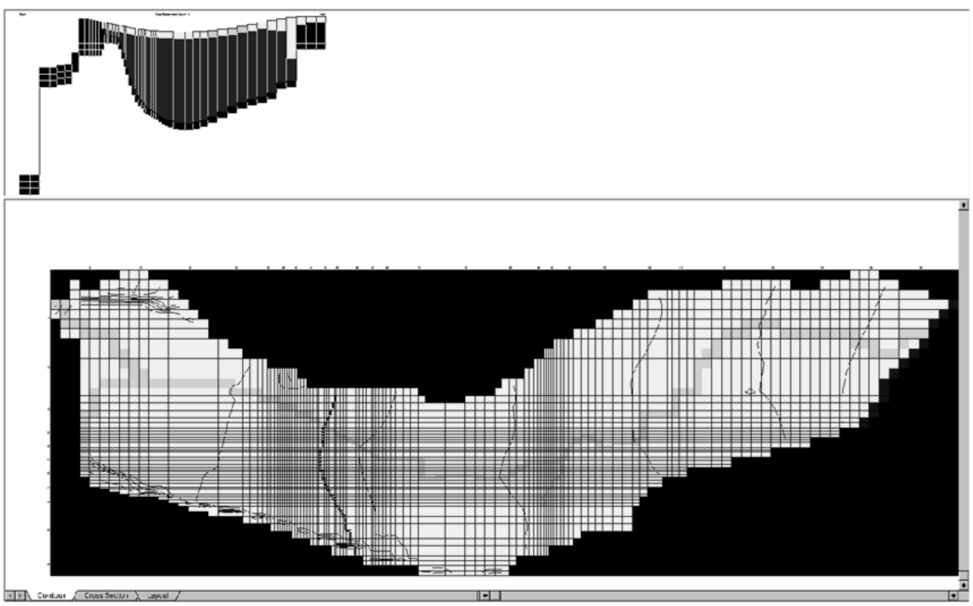

Figure 3: Screen capture of Squaw Valley model layer 1 and cross-section along column 17

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Figure 4 shows the plan for layer 2 and a longitudinal profile along row #17. The dark blue boundary on the east is the constant head boundary as discussed for layer 1. There is also one cell of stream boundary in the in the middle toward the bottom (south) of the layer. It lies adjacent to the boundary cells in layer 1, and has flows similar to that stream reach, so it is probably part of that stream reach. The figure also shows one GHB cell in the north boundary on the east. Flow through GHB cells are minor and this boundary is probably irrelevant. The cross section shows the changes in thickness of the alluvial aquifer varies substantially. The aquifer thickness would help control the location that water enters and leaves the stream by constricting the thickness of the alluvium and the area of the cross-section through which the groundwater flows. The area just west of the meadow where groundwater levels become higher and intersect with the stream bottom corresponds with the west end of the thinner section just west of the middle of the cross-section (Figure 4).

The purple line about a third of the distance east from the west boundary is a fault, or slurry wall as modeled in GWVistas™ as 1 foot thick with K= 0.3603 ft/d, which is not very impermeable but is significantly less conductive than the K values in the model cells around, which are generally greater than 14 ft/d and range to greater than 200 ft/d. The fault appears in all three layers. It apparently flattens the groundwater table west of the fault and causes a several foot step to lower levels east of the fault.

O8a-60b cont.

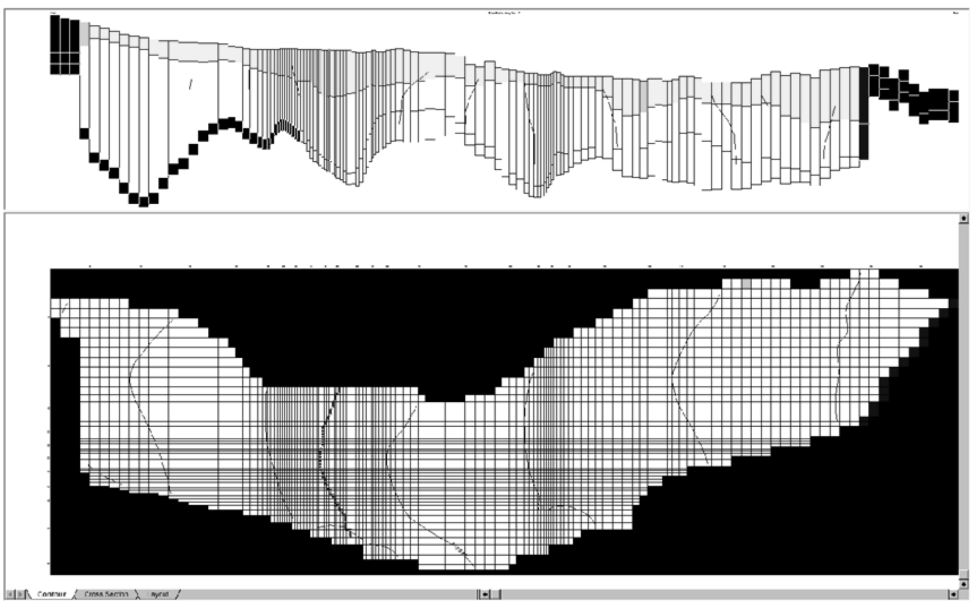

Figure 4: Screen capture of Squaw Valley model layer 2 and profile along row 17.

Layer 3 does not extend as far to the west (Figure 5) as does the layer 1 and 2 model domain (Figures 3 and 4). Hundt and Williams (2014) Figure 1 shows the bottom elevation of layer 2 in the west is approximately the same as layer 3 just to the east. The profile in Figure 4 shows that layer 3 pinches to west but the aquifer thickness undulates but averages the same as further east. This western area is the

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location of many of the pumping wells, so this domain configuration would require that most wells pump from just layer 2. Pumping may be more efficient this way because water would not have to flow between layers which would be limited by the vertical anisotropy; this could minimize the drawdown caused by the wells. Now that the model uses MNW routine for wells, the pumping can be as efficient from two as from one layer so the model should have layer 3 extend as far west as layer 2 to better account for differing vertical conductivity.

Groundwater contours in the cross-section at column 109 suggest a vertical circulation from layer 1 near the boundary through layer 3 and back to discharge to the stream in layer 1 (Figure 5).

O8a-60b cont.

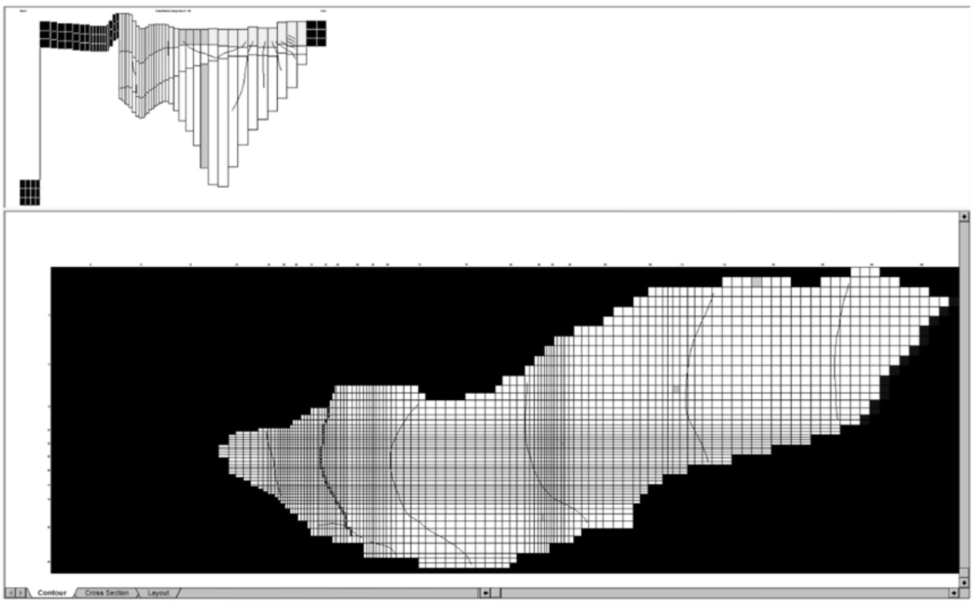

Figure 5: Screen capture of Squaw Valley model layer 3 and cross-section along column 109.

Figure 6 shows how Williams defined recharge zones and Figure 7 shows the most recent (Hundt and Williams 2014) variation. Recharge zones are specified flux boundaries, meaning the modeler specifies the rate in length/time. Williams (2001) apparently set constant values (Figure 6) meaning that water entered the model distributed evenly over the area of the zone. Recharge as applied to the model apparently includes many sources of water, including distributed recharge from precipitation on the spot, irrigation, leaks from sewer pipes, and others. Currently, recharge is estimated as a percent of monthly precipitation as discussed below. Zone 9 (Figure 7) covers the current development which means the model assumes recharge through the parking lots, which is impossible. The differing zones along the edges of the domain suggests simulation of mountain front recharge.

O8a-60c

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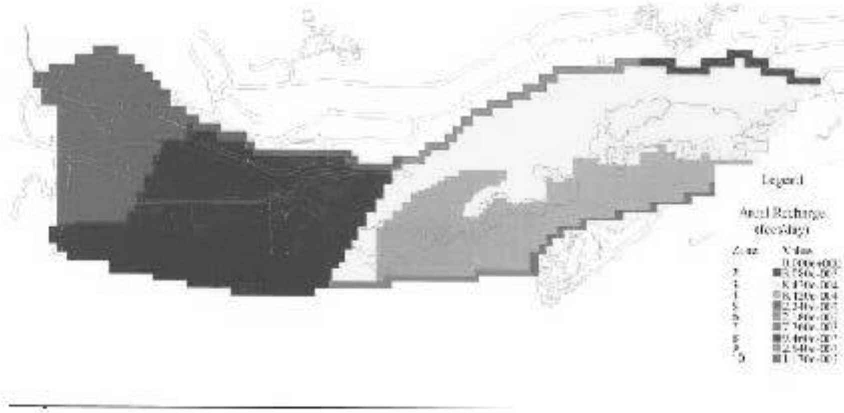

Figure 6: Williams, Figure 32 showing recharge zones.

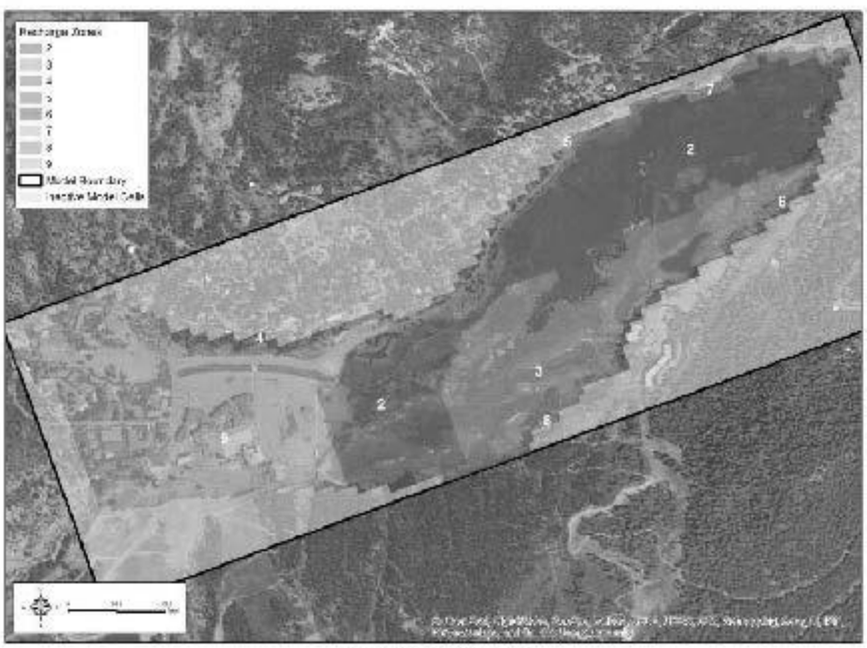

Figure 7: Recharge Zones

Figure 7: Handz and Williams (2014) recharge zones.

O8a-60c cont.

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Distribution of recharge through the year depends on the availability of precipitation or snowmelt, so Hundt and Williams (2014) distributed precipitation availability during winter as 50% of precipitation during the month it occurs and 25% in the following two months. All precipitation which falls in December is available to recharge by the end of February; all precipitation in February is available for recharge by the end of April. March percentages are 60 and 40%, respectively, so all March precipitation is also available to recharge by the end of April. From April through November, all recharge occurs during the month the precipitation falls. I use "available" with recharge because it will runoff if there is no soil moisture capacity available. It seems unreasonable to assume that all December precipitation melts and recharges by the end of February; this could cause the simulated water levels to recover too soon. More importantly, the excessive precipitation estimate drives the recharge used in the model. O8a-60d

Figure 3 in Hundt and Williams (2014) show precipitation and delayed infiltration in inches (presumably per month) but is unclear whether each value is actual recharge or precipitation. I plotted two years of recharge from the model files for recharge zone 9 (Figure 7); the values the model tries to input into the aquifer exceed an inch per day during winter months (Jan-93) and also during Oct-94, a month during which all precipitation is available for recharge.

Figure 8 shows the monthly recharge variation as simulated from 1993 through 2011 by month in the calibration model. Some months there is barely any recharge, with values less than 20,000 ft^3/day, and other months more than 3,000,000 ft^3/ day (Figure 9). The currently estimated recharge converts to about 3900 af/y, which is much larger than that used in the first editions of the model, which were 688 af/y (West-Yost 2003, Williams 2001). The current recharge amount is a gross overestimate due to the gross overestimate of precipitation. O8a-60e

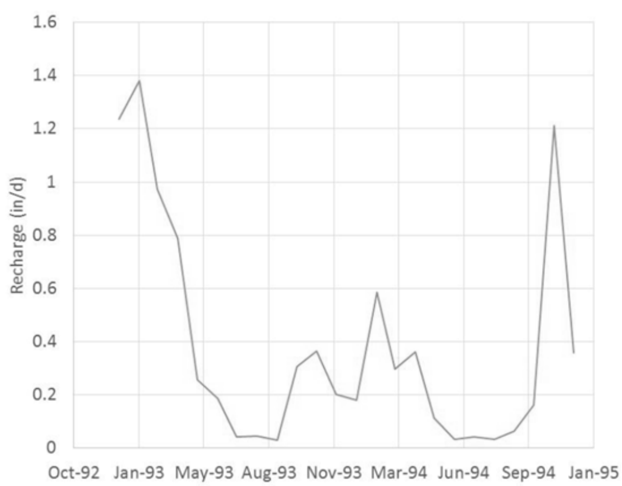

Figure 8: Recharge to model zone 9 for the first two years of the baseline simulation, converted to in/day.

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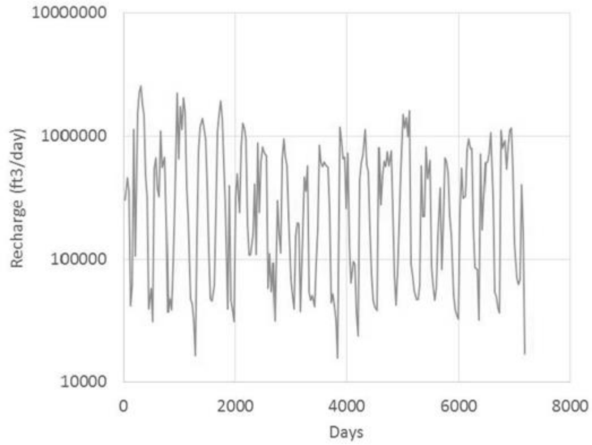

Figure 9: Recharge to the model domain, by month, for the calibration run from 1993 to 2011.

O8a-60e cont.

Williams (2001, p 19) simulated inflow from the bedrock using general head boundaries (GHBs). Recent studies have concluded little water enters the basin from the bedrock, therefore simulating this with a GHB is inappropriate. GHB flow in the current water balance is miniscule, but there is really no reason for these boundaries to continue to be in the model.

O8a-60f

Hundt and Williams (2014) estimated conductivity using pilot points, a method which essentially establishes parameter fields across the model domain. The methodology needs more description than provided in the report (Hundt and Williams 2014, p 11). The number of wells used for calibration does not seem to be sufficient to create up to 78 pilot points per layer for calibration (Id.). The resulting parameter fields do not resemble hydrogeologic patterns, however, as can be seen on the circular patterns shown on Figures 10 and 11. Figure 10 shows circular areas with horizontal conductivity exceeding 100 ft/d in the middle of areas with conductivity much less than 100 ft/d. Vertical anisotropy has fewer circular zones, but those that occur in layers 2 and 3 are areas where the model will simulate very little vertical flow. It is also very unusual to have the very high anisotropy in surface layers (layer 1 in Figure 11) because surface formations tend to be sorted rather than exhibiting continuous layers.

O8a-60g

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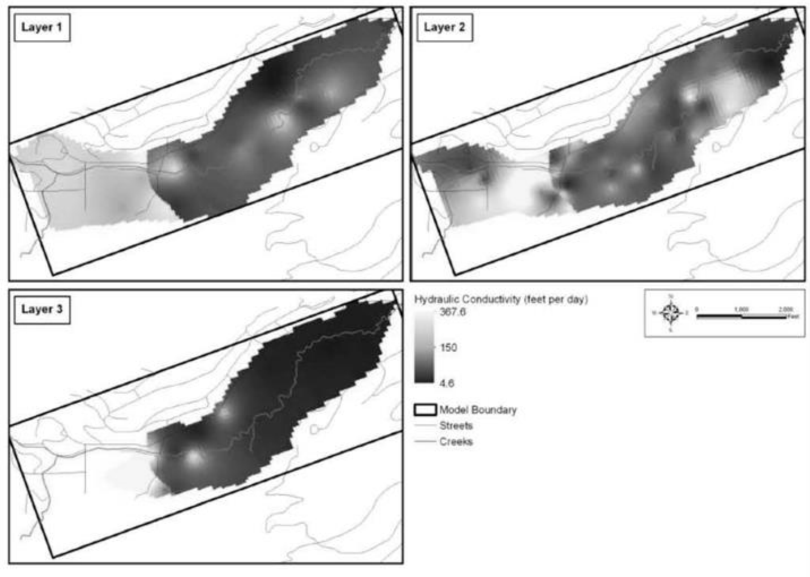

Figure 10: Figure 12 from Hundt and Williams (2014) showing the distribution of horizontal hydraulic conductivity.

O8a-60g cont.

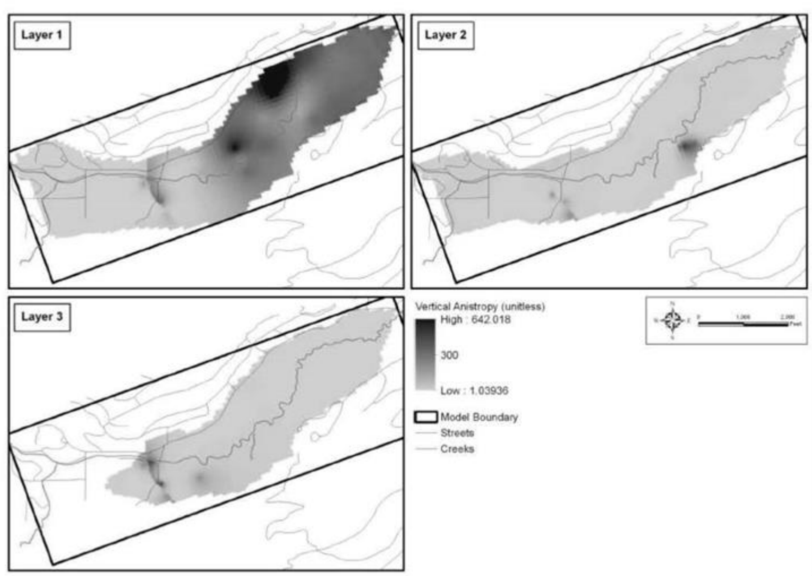

Figure 11: Figure 13 from Hundt and Williams (2014) showing vertical anisotropy, or the ratio of horizontal to vertical conductivity.

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The model calibration also reveals inaccuracies in the model. Hundt and Williams (2014) considered the model "calibrated when simulated results match the measured data within an acceptable measure of accuracy, and when successive calibration attempts did not notably improve the calibration statistics" (p 10). Usually, calibration is considered complete when various test statistics are minimized to less than a specified value. Hundt and Williams Figure 11 and the test statistics show that the new calibration is pretty good, although they utilized more than one observation from each well which raises questions about the independence of the observations. Groundwater levels at a well are highly autocorrelated which means individual observations are not independent. Using a set of observations for each well may be a form of pseudoreplication which could artificially improve the test statistics, especially if the observations are made frequently. O8a-60h

Hydrographs of simulated water levels are best used for simple graphical comparison. The hydrographs often indicate potential problems not indicated by calibration test statistics or scatter plots. Simulated water levels in some wells are consistently higher or lower than the observations, apparently by as much as ten feet. This is a problem if the areas of over or underestimation affects flows to the creek or the thickness of the saturated zone. There is insufficient information to assess these effects.

The discussion on stream conductance is very confusing – the statement "[t]he final values obtained from calibration equate to average streambed hydraulic conductivity values of 1.1×10^{-3} feet per day and 1 foot per day" (Hundt and Williams 2014, p 12) is confusing. It is impossible to know what these values refer to – the two values differ by three orders of magnitude. There is no information regarding discharge to the stream, which conductance would control. The calibration file shows that conductance in the stream boundary is based on a one-foot thickness with conductivity from about 10 to 75 feet per day. The conductance for each cell then would depend on the cell size. The values used are high enough that conductance does not limit flow into or from the stream boundary. O8a-60i

<u>Water Balance</u>

The model report should present final water budget amounts, including recharge, pumping, and discharge to the stream, but the reports since 2003 have not done so other than to show graphs of recharge similar to the ones I constructed below. Hundt and Williams (2014) only mention water budget in reference to small changes being made to the recharge input regarding sewer leakage (Id., p 7). A graph showing where the model simulates flow to or from the stream is essential, and should be completed for representative time periods (wet conditions, late summer baseflow conditions). This section considers those water balance issues. O8a-61a

Water balance hydrographs for all fluxes were downloaded from the provided output files for each of the runs – calibration, baseline, and WSA. Recharge, drain outflow, well outflow, stream outflow, and CH out (constant head outflow) were the largest fluxes for the three scenarios (Table 1, Figure 12). The recharge, about 3900 af/y, is much larger than that used in the first editions of the model, which had been estimated at 688 af/y (West-Yost 2003, Williams 2001), probably due to the overestimated precipitation. O8a-61b

Drain outflow, simply water being removed from the model surface, exceeds the fluxes to the well and stream; this of course suggests much water remains that could be exploited in the model; the Drain out flow is not simulated as streamflow so it is not possible to compare it to measured streamflows. GWVistas™ allows the user to observe flux from each Drain model cell, but it is difficult to display in a O8a-61c

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figure; most Drain flux occurs during wet years or months (Figure 12) and observations of the locations on the GWVistas™ screen show that most Drain flux occurs very near the stream in the west and over much of the meadow in the east. During dry periods Drain flux occurs east in the meadow if at all. Because the Drain boundary is set equal to the ground surface elevation, the water table at these discharging cells is slightly above ground surface.

Constant head discharge barely changes between scenarios (Table 1), which reflects the fact the boundary is in the far east end of the model domain, away from the pumpage.

Small fluxes include GHB in, Stream in, and GHB out, at 3, 229, and 0.4 af/y (Figure 13). The GHB flux is not important, which reflects the fact that fractured bedrock flow is not a significant part of the water balance (Moran 2013). Stream in is less than a third of the Stream out value, which means the model simulates much more flow to the stream than from the stream, and the streams in the model provide only a small amount of recharge from the stream. However, as noted above, increasing pumpage does induce flow from the stream to the model domain.

Table 1: Average water balance fluxes for the calibration, baseline, and WSA model simulation. Diff is the difference between baseline and WSA. All values are acre-feet/year. Flux terms are described in the text.

Flux terms	Calibration	Baseline	WSA	Diff
CH out	-660.3	-659.9	-659.6	-0.2
Drain out	-1871.0	-1868.7	-1755.3	-113.4
GHB in	3.1	3.1	3.1	0.0
GHB out	-0.4	-0.4	-0.4	0.0
Recharge	3903.4	3881.0	3928.2	-47.3
Storage in	585.2	574.3	650.4	-76.1
Storage out	-579.1	-581.4	-654.8	73.4
Stream in	229.6	249.7	364.4	-114.7
Stream out	-921.2	-887.2	-741.6	-145.6
Well out	-690.1	-710.8	-1137.8	427.0
Wells in	0.9	0.3	3.3	-3.0
Total out	4722.1	4708.3	4949.5	
Total in	-4722.1	-4708.3	-4949.5	
Error	0.03	0.02	0.02	

O8a-61c cont.

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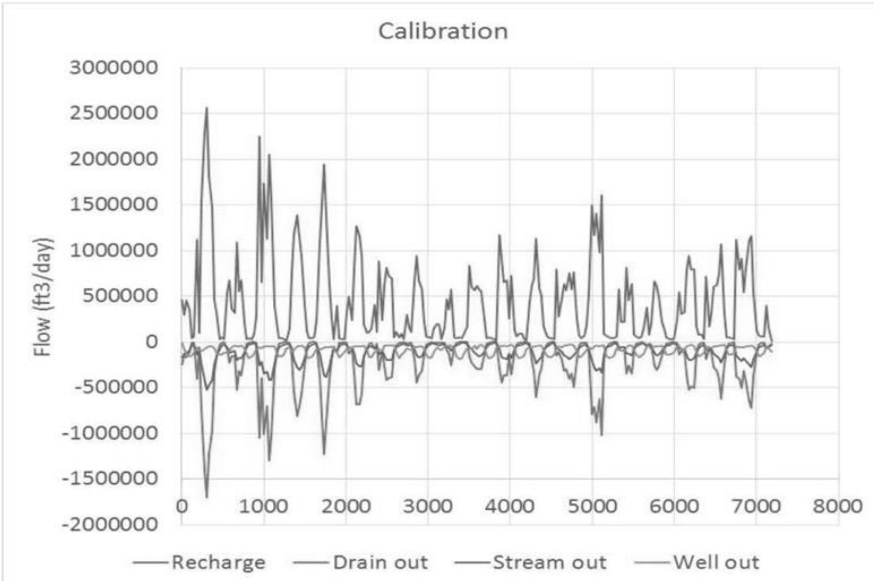

Figure 12: Hydrograph of model fluxes for the calibration model run. This figure shows the larger fluxes; see Figure 13 for the smaller fluxes.

O8a-61c
cont.

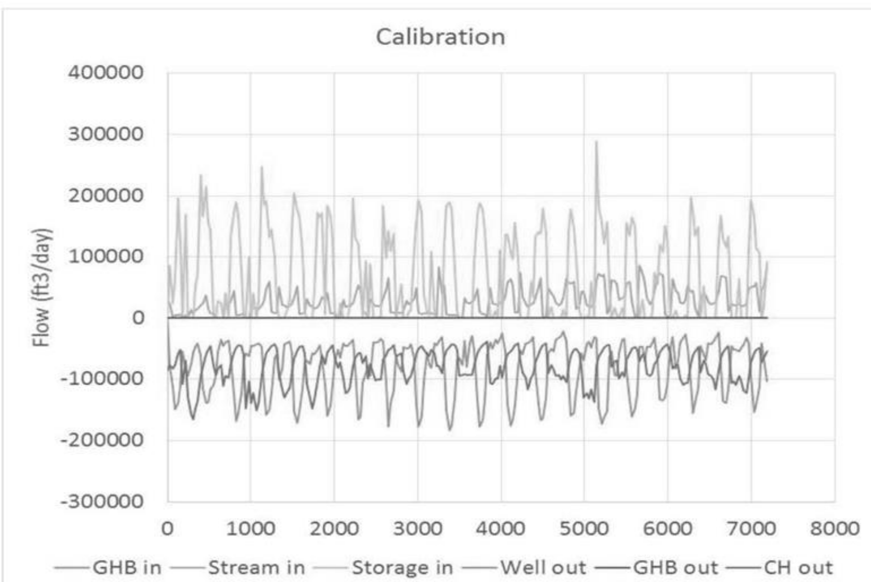

Figure 13: Hydrograph of model fluxes for the calibration model run. This figure shows the smaller fluxes; see Figure 12 for the larger fluxes

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Well out for baseline is close to observed pumping from 1993 through 2011, not including water sources from the horizontal bedrock wells (Table 1, Figure 12). It is similar to the well pumpage for the calibration run except the observed pumpage for calibration is more variable (Figure 14). Pumpage for the WSA is close to the anticipated 2040 demand and is almost the same from year to year (Figure 14). The difference between Well out for Baseline and for WSA is the pumpage expected for the project, or about 427 af/y in the model (Table 1, fifth column). O8a-61c cont.

Increasing pumpage by an average 427 af/y draws water from other fluxes. The largest changes are to both Stream in and Stream out, meaning that more and less water draws from the stream and discharges to the stream, respectively. The decreased discharge to the Drain boundary reflects a decreased water level in the alluvial aquifer. Discharge to the stream decreases the most, and discharge to the Drains and induced recharge from the streams are about the same in second place.

Recharge controls the discharge to the Drains and to the streams (Figure 12). The observed pumpage during the calibration run was a small proportion of the recharge, much less than 20%. If recharge were still estimated as it was in 2003, the calibration pumpage would be very close to the recharge. The overestimate of recharge effectively controls the large amount of discharge to the streams and to the drains.

Curiously, recharge to the model increased by 47.3 af/y from the baseline to the WSA run. It is probably because the modelers included some additional recharge from onsite sources such as sewage or irrigation return flow, but the additional recharge effectively accounts for 10% of the additional pumpage. As shown on Figure 15, the increase primarily occurs during the low recharge portion of the year. Additional recharge during late summer would enter the aquifer and counter the ongoing drawdown, since even with the excessive recharge simulated for this model significant drawdown occurs during late summer.

O8a-61d

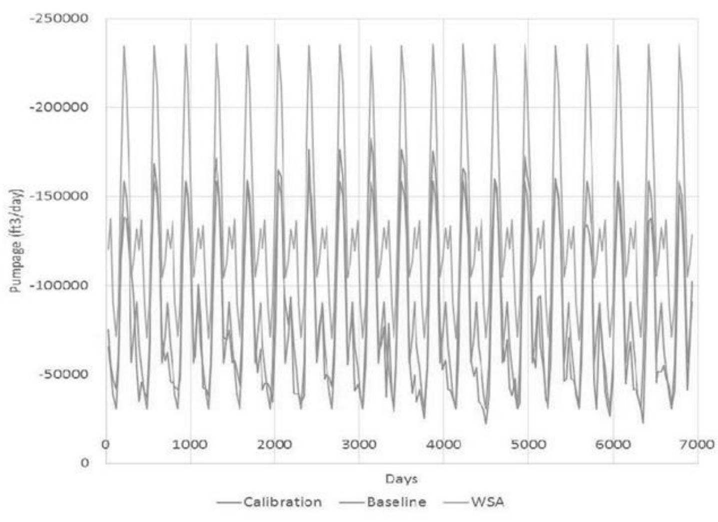

Figure 14: Hydrograph of model pumpage for the three scenarios.

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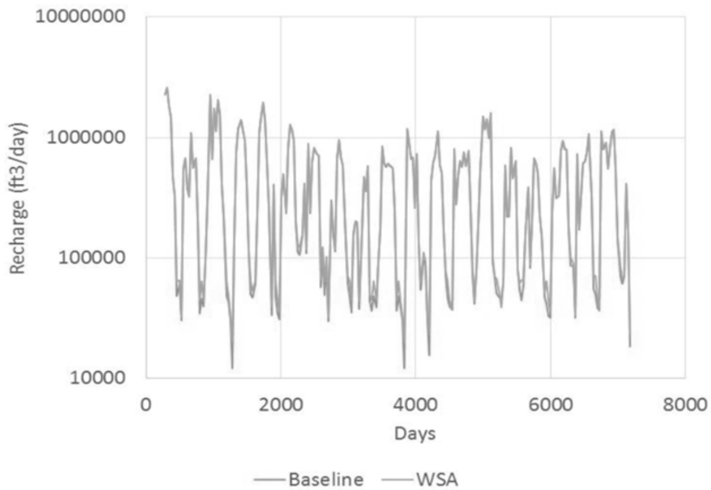

O8a-61d cont.

Figure 15: Hydrograph of simulated recharge for the baseline and WSA model runs. Calibration recharge is almost exactly equal to the baseline recharge.

Water flowing in and out of storage increases with pumpage too, but changes in Storage in and out effectively cancel each other. For the calibration run, storage in and storage out were approximately equal at 582 and 576 af/y, respectively, as they should be over a long time period; the small difference indicates the aquifer has lost a small amount of water with time since Storage in means water leaving storage and entering the water balance calculation. The flux is similar for the baseline run because the amounts are similar. For the WSA scenario, the amount has increased by from 73 to 76 af/y (Table *) reflecting the increased movement of water from and to storage.

O8a-61e

Figures 16 and 17 show examples of inflow and cumulative streamflow to the stream for periods during which the upstream inflow is vastly different (less than 40,000 ft^3/d for Oct, 2011 (Figure 16) and greater than 3,000,000 ft^3/d during June, 1994 (Figure 17))[1]. The steps in the graphs reflect the two confluences in the stream boundary (Figure 3). During the drier period, little flow added to the stream from the south at the upstream most confluence (Figure 16). For the upper 5000 feet, the stream generally lost flow, from about 40,000 to 30,000 ft^3/day. From about 5000 to 7200 feet, or about the eastern confluence (which is in the meadow), about 20,000 ft^3/d discharge to the stream. A step of almost 80,000 ft3/d added to the stream at the confluence. Below that it increased relatively steadily about another 20,000 ft^3/d. The flow magnitude is much higher in the wetter period (Figure 17), so small changes are difficult to see. Groundwater discharged to the reach through the domain but the main changes were at the confluence. During the wetter period, flow almost doubled at the upper confluence which reflects the large surface water flow simulated to enter the model domain. The stream trended up about 200,000 ft^3/d between confluences and then stepped up about 100,000 ft^3/d

[1] The graphs in Figures 16 and 17 have been adjusted to accommodate a model coding error. The model input files did not show stream segment 3 as a tributary to segment 10. This error applies only for the calibration files because there is no stream segment 10 in the baseline and WSA runs.

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in the meadow. The small step reflects that reach carrying only discharge from the groundwater into the short reach before it joins the main stream. In general, the stream boundary performs similar to that expected from the streamflow synoptic studies (Hydrometrics 2013c), although the model was calibrated only at the upstream and downstream end (Taylor and Reilly 2014).

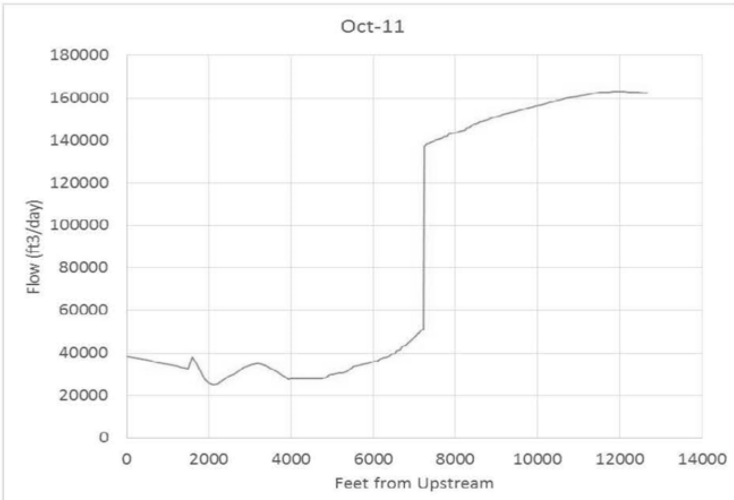

Figure 16: Streamflow along the stream boundary for conditions in October 2011 for the calibration run.

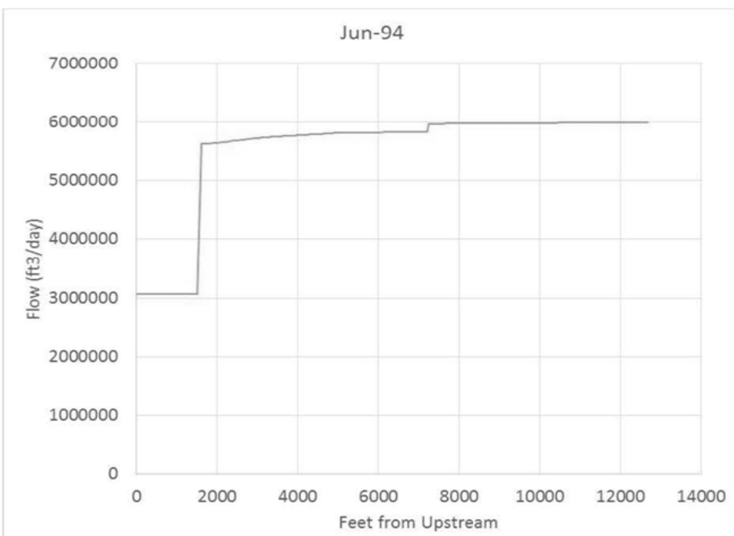

Figure 17: Streamflow along the stream boundary for conditions in June 1994, for the calibration run.

O8a-61e cont.

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Consequences of Increased Simulated Recharge

I have mentioned several times through this review that the DEIR and WSA use an incorrect precipitation estimate for Squaw Valley, based on a faulty precipitation reading for the Squaw Valley Snotel site, overestimating precipitation by about three times. Simulated recharge increased from about 680 to 3800 af/y from modeling completed in 2003 to modeling completed in 2014 due to consideration of this additional precipitation. During some months much more than a foot of water enters the aquifer. Now, much more water runs through the model than when the model was first conceptualized and parameterized. The calibrated hydraulic conductivity had to be increased by an order of magnitude to allow more water through the aquifer while maintaining observed water levels. The amount of drawdown simulated by pumping with higher conductivity is less than with lower conductivity, so the model accommodates more pumping with less drawdown and less environmental effect on the river than before when a lower recharge had been used.

About half of the recharge leaves the model through Drain cells as rejected recharge. Additional simulated project pumping can simply use this rejected recharge rather than causing additional drawdown. The earlier model reports (West Yost 2003) do not report the amount leaving through Drain cells, but they may have been combining it with stream discharge; either way the amount would have been much less than currently simulated to leave the model. O8a-62

Flow through the moraine, modeled as a constant head boundary, on the east end increased by four times due to the additional recharge. It scarcely changes due to increased pumping which indicates the pumping is able to draw water from other sources.

Precipitation generally becomes available to recharge in October. The extra precipitation primarily allows recharge to substantially recover the aquifer in October and allows the recharge to replenish ongoing pumping later in the spring and early summer. The overall effect of the overestimated precipitation is to limit the time the stream is dry and groundwater levels are deeper than threshold values. This effect will increase as pumping rates increase because the excess recharge can simply replace the pumping when it occurs.

In summary the recharge overestimate provides much more water over a longer time period which offset pumping demands and causes the model to have a much higher conductivity so that less drawdown occurs for the pumping. It generally causes the DEIR to grossly underestimate the effects of increased pumping on the aquifer.

Climate Change

The DEIR has a chapter concerning climate, but it mostly deals with greenhouse gas emissions from the project. The chapter notes potential changes in snowfall and runoff due to climate change, but there is no consideration of climate change with future groundwater model simulations or other consideration of the effect of climate change on the hydrogeology of the valley or how climate change will combine with the project to significantly impact the environment. The WSA acknowledges the climate change could change the patterns of runoff, but also does not complete any simulations that include expected changes in recharge. In fact, the WSA notes there is so much recharge due to the incorrect precipitation estimate that the changes in timing will not matter. O8a-63

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Climate change is likely to affect precipitation and snowmelt timing in ways that will lengthen the dry, or no-recharge, period of a year. As the snow shifts to rain and snowmelt occurs earlier, there will likely be longer periods during the summer during which there is no runoff recharging the aquifer, which will increase the seasonal period during which drawdown can affect the aquifer. Climate change may not change the precipitation but will provide for less available water during the later dry part of the summer. O8a-63 cont.

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ATTACHMENT 1
Squaw Valley G.c. (784)
California SNOTEL Site - 8029 ft

	Oct Precipitation Increment - Snow-adj (in)	Nov Precipitation Increment - Snow-adj (in)	Dec Precipitation Increment - Snow-adj (in)	Jan Precipitation Increment - Snow-adj (in)	Feb Precipitation Increment - Snow-adj (in)	Mar Precipitation Increment - Snow-adj (in)	Apr Precipitation Increment - Snow-adj (in)	May Precipitation Increment - Snow-adj (in)	Jun Precipitation Increment - Snow-adj (in)	Jul Precipitation Increment - Snow-adj (in)	Aug Precipitation Increment - Snow-adj (in)	Sep Precipitation Increment - Snow-adj (in)	Total
1980												2	
1981	1.9	3.7	5.3	13	6.3	11.5	2.1	3.6	0.5	0	0	1.1	49
1982	8.2	24	24	16.1	10.8	25.9	14.7	0.8	3	0.2	0.4	8.3	136.4
1983	10.4	15.2	17.8	14.2	25.4	17.7	15.3	2.1	1.2	0.7	2	2.7	124.7
1984	5.8	23.5	22	1.5	5.8	8.8	4.8	2	3.2	1.1	0.6	0.2	79.3
1985	5	15.9	2.1	1.2	7	9.1	2.4	0.3	0.4	0.9	0	4.5	48.8
1986	3.5	11.7	9.1	10.6	30.4	11.1	2.6	1.1	0.1	0.2	0	5.7	86.1
1987	0.8	1.6	2.6	7.7	11.2	9.5	1.2	1.6	0.8	0.1	0.1	0.2	37.4
1988	1.9	4	12.4	12.7	0.8	1.5	3.1	3.9	0.9	1.3	0.3	0.2	43
1989	0.2	18.3	10.9	3.4	8.1	19.6	2.6	2.2	2.4	0	2.4	4.9	75
1990	6.2	4.8	0.1	8	12.2	3.8	3.8	6.9	0.9	0.5	0.8	2.5	50.5
1991	1.8	1.7	3.2	1.4	3.1	24.2	3.2	4.8	1.1	0.5	0.2	0.7	45.9
1992	6.1	4.9	3.8	1.7	15.5	3.1	1.7	0.8	3.6	1	0.9	0.5	43.6
1993	6.8	1.3	29.4	29.6	26.7	7.7	3.4	3.4	2.5	0.5	0.4	0.3	112
1994	4.9	5.1	6.5	4.2	15.1	2.1	3.5	3.1	0.4	0	0	1.2	46.1
1995	1.6	16.5	15.2	36	2.4	33.7	11.9	4.6	0.6	0	0	0	122.5
1996	0	1.5	15.6	27.3	17	17.1	4.7	8.9	0.3	0.7	0.2	1.3	94.6
1997	3.3	12.7	53	29.3	5.1	2.8	3.6	1	3.8	0.2	0.2	0.2	115.2
1998	4.1	6.9	5.7	24.5	30.5	12.6	5.4	6.1	2.6	0.8	1.3	4.5	105
1999	1.6	14.3	4.4	20.5	23.6	6.3	5.3	2.2	1.3	0	1.8	0.2	81.5
2000	4.3	5.7	4.1	20.6	23.5	3.9	3.5	4.6	0.4	0	0	2.2	72.8
2001	5.5	3.6	7.1	5.3	11.1	3.6	6.5	1	0.2	0	0	0.9	44.8
2002	1.8	12.3	27.2	6.6	5.4	14.2	4	2.2	0	0	0	0	73.7
2003	0.3	12.3	24.7	9.5	3.1	6.5	13.1	3.6	0.3	0.2	1.8	0.4	75.8
2004	1.8	5.1	23.3	7.1	12.5	2.3	3.1	2.1	0.3	0.2	0.1	0.5	58.4
2005	8.6	4	18.4	18.5	7.8	16	5	10.7	3.5	0.2	0.3	0.7	93.7
2006	2.6	8.4	34.4	17.6	8.8	15.9	13.2	1.8	0.2	0.3	0.2	0.2	103.6
2007	0.4	9.8	8.8	2.7	18.2	2.6	4.5	2.2	0.5	0.3	0.6	1.5	52.1
2008	5.4	1.4	9.3	17.5	8.6	4	0.7	2.8	0	0.7	0.3	0	50.7
2009	3.6	6.9	13.8	4.1	13.3	13.1	2.3	7.1	2.4	0.2	0.9	0	67.7
2010	6.8	2.7	13.6	11.3	5.6	10.5	8.7	5	1.6	0	0	0.1	65.9
2011	13.2	12.5	23.1	1.8	7.5	20.5	8.1	4.8	4	0	0.1	0.3	95.9
2012	5.8	2.8	0.2	9.1	5	19.3	5.1	0.6	0.9	0.9	0.5	0.5	50.7
2013	5.4	11.7	16.4	1.5	0.9	4.3	1.8	3.1	2.8	1.4	0.5	2.1	51.9
2014	1.4	1.2	2.8	3.8	13.9	5.9	4.1	1.2	0.3	0.3	0.7	2.3	37.9

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ATTACHMENT 2

Technical Memorandum
Review of Water Supply Assessment
Village at Squaw Valley

July 13, 2015

Prepared for: Sierra Watch
Prepared by: Tom Myers PhD
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Summary

The Olympic Valley aquifer is small compared to the demand imposed on it, with recharge from rainfall on the alluvial valley, runoff in streams onto the alluvial valley including from Squaw Creek, and from mountain runoff percolating into the aquifer at the mountain front. During runoff periods, stream reaches in the western part of the valley percolate water to the aquifer and groundwater levels rise. As runoff and stream water level decreases, groundwater begins to discharge into the creek maintaining flows for a period. The stream in this area has been channelized such that the stream bottom is lower than it had been prior to channelization. Groundwater discharges to the stream probably more frequently than it did prior to channelization and therefore naturally lowers easily to the bottom of the stream channel. Late in the summer season in most years, the groundwater level falls below the stream bottom so that groundwater discharge to the stream ceases. Pumping in this area increases the rate that groundwater levels decrease. Rapid recharge of the first runoff in the fall causes the groundwater level to rise rapidly. O8a-64

Further east is a meadow and a non-channelized, meandering stream. Through this area, the stream gains flow from groundwater discharge most of the time and groundwater levels remain high most of the year. There is little pumping in the middle of the meadow to cause drawdown and affect streamflow.

Because the stream in the west part of the valley already reaches dry or near-dry conditions, groundwater development currently increases the time period that low flow conditions occur. Additional development could draw groundwater levels deeper than previously experienced and extend the length of stream reaches affected by low flows and probably lengthen the time during the fall until recovering groundwater levels restore flows to the stream. Climate change that causes the proportion of precipitation to fall as rainfall to increase and snowmelt to occur earlier will increase the length of the dry part of summer during which the groundwater does not discharge to Squaw Creek in the western part of the valley.

The WSA estimated project and non-project water demands for the next 25 years, commencing in 2015. The annual average occupancy rate of 55.2% was determined based on just the recession period 2009 O8a-65

through 2011 when occupancy would have been lower than average. Although the per capita demand of 100 gpd could be inaccurate, underestimating occupancy by up to 80% would cause a much higher error in the total demand estimate. There is simply insufficient description of how the commercial water use demand, rated at 0.24 gpd/sf, was estimated so its effect on total demand is unclear. Demand timing, with more of the total 1135 af/y demand occurring in late summer after recharge, could affect the water sufficiency estimates more than expected if these potential errors occur. More demand especially in late summer would cause even more drawdown lengthening dry periods and the length of dry stream. Significant drawdown could carry over from year to year during dry periods and cause significant water supply issues. O8a-65 cont.

The WSA considers water supply sufficiency based on maintaining saturated thickness at 65% of the maximum saturated thickness. The maximum saturated thickness is considered to be historic conditions, including the existing pumping, with no consideration of whether the aquifer is currently stressed. It was determined with model simulations of existing pumping. The 65% of maximum saturated thickness is an operational limit which maintains well pumping efficiency and is meaningless with respect to basinwide groundwater management, such as maintaining a yield or not causing other deleterious impacts to the basin.

The test for water supply sufficiency involved groundwater modeling of pumping the expected 2040 demand from existing and proposed new wells. The modeling used nine new municipal wells even though the WSA determined that only six would be needed. This spread the pumping over more wells than will occur so that the average pumping rate per well was actually lower than the existing pumping rate in some cases. Their simulation shows that the 65% criteria is met on average over the well field and for individual wells although percent saturation varies widely. The analysis of water sufficiency does not account for changes in streamflow that occur because of a connection between surface and groundwater or changes in wetland conditions. It would be useful to compare both existing baseline and project future WSA 2040 conditions with a simulated no development condition in the valley to show just how development has affected true natural conditions. O8a-66

Recharge depends on the precipitation in the valley reaching the valley flow, but the high mountain precipitation reported in the WSA is grossly wrong, being estimated as 263 inches per year for 1993 through 2011. The Snotel site for the valley shows that that the annual average for that period is 80.6 in/y. If all 263 inches fell as snow at a 1:10 ratio it would be 219 feet of snow. This erroneous precipitation estimate is prominent in documents and analyses since 2011. This large amount of precipitation is about 50 times the water demand so the WSA concludes there will always be sufficient water for the project. O8a-67

Analysis of pump test data allowed the suggestion that only a small proportion of pumpage would draw from the creek if they use 8-hour pumping cycles. This ignores that drawdown that exists when pumpage ceases will continue to draw streamflow into the aquifer. O8a-68

There is no consideration of climate change with future simulations, although it is likely to affect precipitation and snowmelt timing in ways that will lengthen the dry, or no-recharge, period of a year. As the snow shifts to rain and snowmelt occurs earlier, there will likely be longer periods during the summer during which there is no runoff recharging the aquifer, which will increase the seasonal period during which drawdown can affect the aquifer. Changing climatic conditions expected in the 21st century renders bare reliance on the recent historical record insufficient to assure adequate future O8a-69

2

supplies. The WSA should acknowledge this fact and simulate groundwater pumping under conditions representative of future climate change scenarios. As it is, the simulations of future conditions considering the period 1993 to 2011 does not even include the ongoing 2012 to present drought. The WSA results should be amended to include simulations that at least include the ongoing drought to be more realistic. O8a-69 cont.

The Olympic Valley aquifer groundwater appears to be flowing in a subterranean stream, in that (1) there is a subsurface channel present, (2) the channel has relatively impermeable bed and bands, (3) the course of the channel is known, and (4) groundwater flows in the channel. The Olympic Valley aquifer is alluvium that lies in a glacial-carved valley of granitic bedrock. The granitic bedrock forms a subsurface channel and defines its banks. Groundwater flows in the aquifer from west to east where it discharges in Squaw Creek or the Truckee River. The groundwater in the aquifer originates almost exclusively from recharge into the alluvium from snowmelt or runoff in Squaw Creek or a tributary and is less than a year old. Very little groundwater enters the aquifer from bedrock fractures in the alluvium. O8a-70

Introduction

This technical memorandum reviews the Water Supply Assessment (WSA) for the Village at Squaw Valley Specific Plan (Farr West Engineering et al. 2014) (hereinafter WSA). The WSA estimates the current water usage from the Olympic Valley aquifer, projects increased demand for the Village at Squaw Valley and other reasonably foreseeable development, discusses the most recent hydrogeology studies for the aquifer including revisions of a numerical groundwater model, and estimates whether the water supply will meet the water demand until 2040 for the proposed project and other development using the numerical groundwater model. This memorandum reviews the adequacy of the hydrogeology assessment, the conceptual flow model for the Olympic Valley aquifer, the numerical groundwater model, the current and future demand for water, and the supply sufficiency analysis. The memorandum reviews the WSA and supporting documents completed since 2001, although specific issues of those reports and the groundwater model are discussed only in regard to usefulness of the current WSA

The first step in understanding the hydrogeology of an aquifer is to write a conceptual flow model (CFM) for the aquifer; that is the first section of this review. The review of the CFM includes specific sections regarding recharge, precipitation, and stream/aquifer interactions. Then, there are sections on water supply sufficiency, water demand, and specific criticisms of the groundwater model. There have been some substantial changes in thinking about the aquifer with time. The review focuses on the current considerations of the CFM but it some cases it is essential to consider how thinking on various issues evolved over time. O8a-71

Conceptual Flow Model

The development of a CFM is the first step in understanding the hydrogeology of an aquifer or groundwater basin, herein defined as Olympic Valley including the mountain side slopes draining to the valley. A CFM is simply a description of the flow paths through an aquifer including the geologic formations, from recharge to discharge, quantifying flow rates where possible.

Olympic Valley is glacially carved and about 2.5 miles long by 0.4 miles wide. The valley drains ridges of the Sierra Nevada east to the Truckee River. The total area is 5146 acres with the Olympic Valley floor