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Water Resources Planning and Management

Date: April 19, 2015
From: Gary Fiske
To: Water Supply Advisory Committee
Re: Modeling Results: Ranney Collectors

This memo reports the results of the Confluence modeling of CA-19, Ranney Collectors. In CA-19, Ranney Collectors are installed near the Felton diversion. Water diverted from Felton through these collectors is then stored either in Loch Lomond or in another surface or groundwater storage facility (called a Virtual Reservoir or VR in this memo) for use in dry years when current supplies are insufficient to meet customer demands.

The supply impacts of this alternative differ from the winter flow harvesting alternatives in two ways:

- Diversions at Felton are no longer limited by any turbidity constraint.
- The VR is only filled from Felton. Diversions from Felton are limited by the Felton water right. Flows at Tait Street that are in excess of what is needed to serve demand are not available to charge the VR.

Modeling Approach

The Confluence system schematic for this alternative is shown in Figure 1. Note that, in contrast to the schematic for the winter flow harvesting alternatives shown in another memo, there is no transmission link between Tait Street and the VR. The only path for filling the VR is from Felton. While the Ranney collectors are not shown in this schematic, their presence is accounted for by removing the turbidity constraint at Felton.[1]

The altered modeling assumptions are the same as in the previous analysis, namely:

- Unlimited infrastructure capacity;
- Current water rights;
- 5 billion-gallon VR storage capacity; and
- 20% storage losses in the VR.

[1] Also note that diversions from Felton are constrained to go either to Loch Lomond or to the VR. There is no direct diversion from Felton to the treatment plant.

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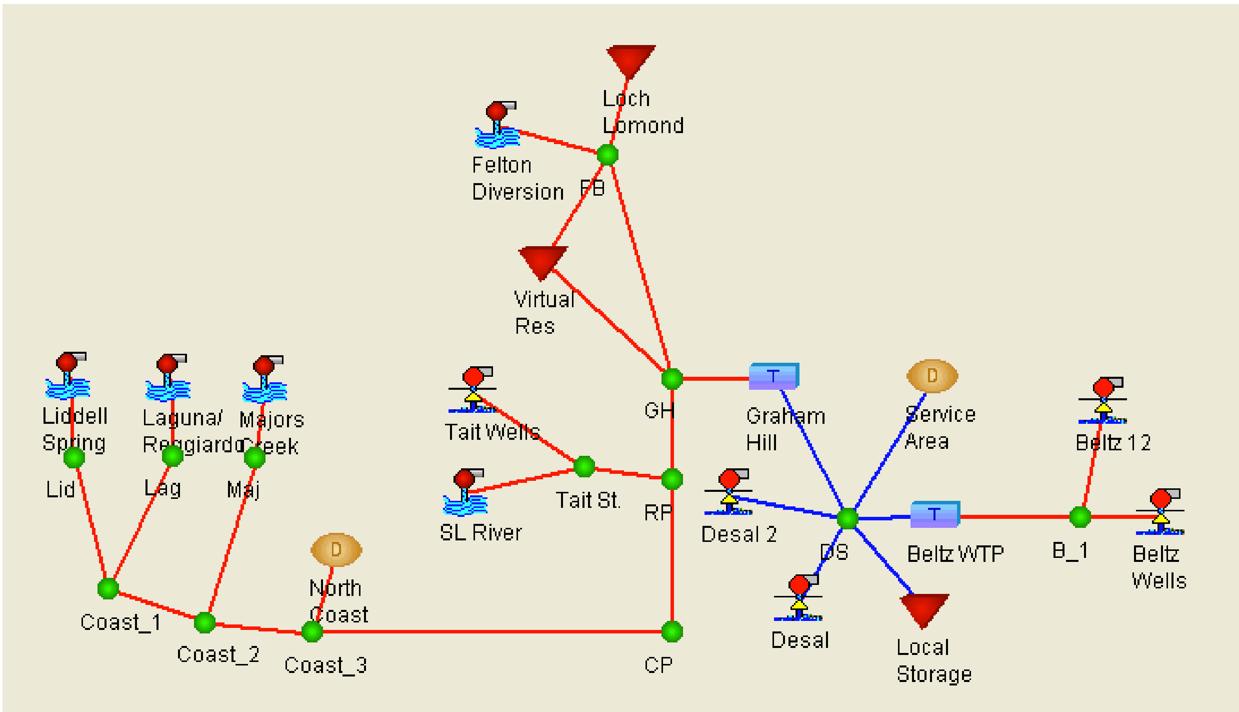
Figure 1. Confluence System Schematic for CA-19



Impacts on System Reliability

Figure 2 shows the peak-season shortage duration curves assuming DFG-5 flows with current supplies that we have seen before (see my March 9 memo). This is one depiction of the reliability "problem" that we want to solve with our alternatives and ultimately resource portfolios.

Figure 2. Peak-Season Shortage Duration Curves with Current System: DFG-5 Flows

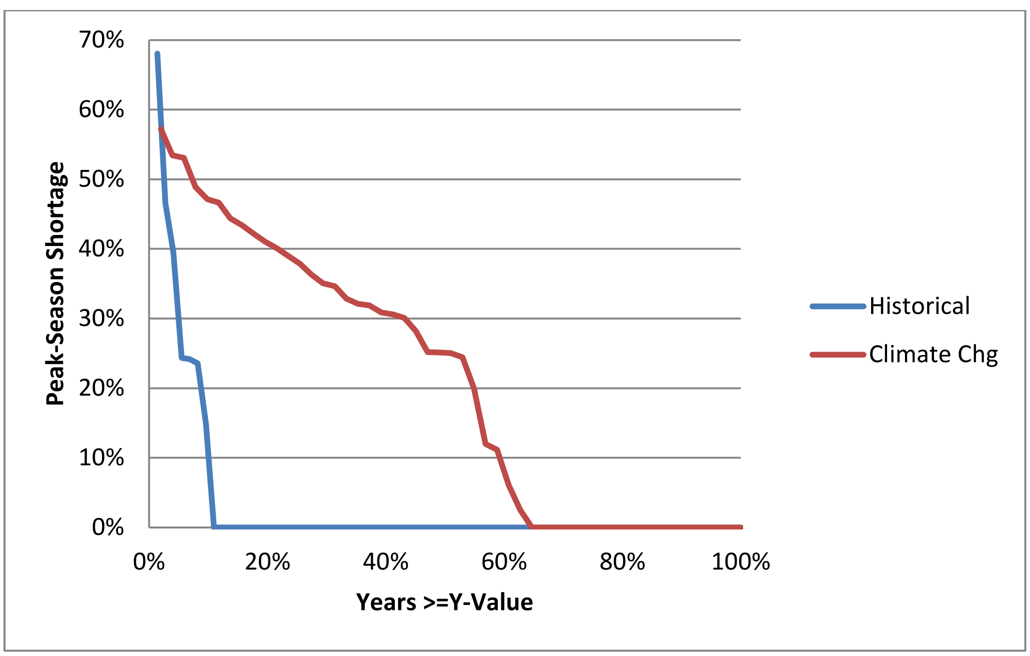


Figure 3 shows how these curves are improved through this supply alternative. With historic flows, this alternative's ability to divert and store excess Felton flows is sufficient to eliminate all shortages. However, with climate change, significant shortages remain.

Tables 1 and 2 summarize the information shown in these curves in two different ways. Table 1 shows the probabilities of exceeding designated shortages in any year. Table 2 shows the probabilities of each shortage event occurring at least once over the next 30 years. Thus, for example, with historic flows, there is a 3% likelihood of a peak-season shortage greater than 5% in any year. Over the next 30 years, there is a 57% likelihood of experiencing at least one year with that size peak-season shortage.

Figure 3. Peak-Season Shortage Duration Curves with Ranney Collectors & Virtual Storage: DFG-5 Flows

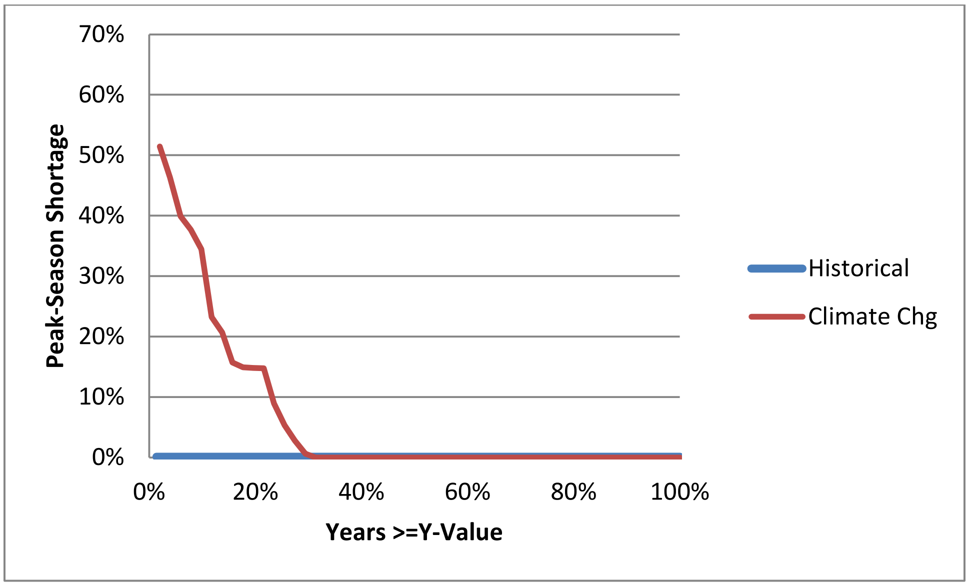


Table 1. Probabilities of Peak-Season Shortage Events in Any Year: DFG-5 Flows

Shortage Event	Historic	Climate Change
>50%	0%	2%
>25%	0%	10%
>15%	0%	16%
>5%	0%	25%

Table 2. Probabilities of Occurrence of Peak-Season Shortage Events Over 30-Year Period: DFG-5 Flows

Shortage Event	Historic	Climate Change
>50%	0%	45%
>25%	0%	95%
>15%	0%	99%
>5%	0%	100%

The remainder of this memo explains these results.

Source of Reliability Benefits

This supply alternative includes two potential water supply enhancements to the current system:

- The Ranney collectors remove the turbidity constraint at Felton which is intended to allow diversions on more winter days.

- The VR allows diversions of excess flows at Felton to be banked for later use in dry years.

The reliability improvements in Figure 3 are due almost solely to the ability to divert and store water in the VR. The curves in both Figure 2 and Figure 3 look virtually the same with or without a turbidity constraint. To understand why, we must first understand the nature of the turbidity constraint. The constraints at all the diversion points are based on daily rainfall. On days when the rainfall exceeds a specified threshold the diversion is shut down for a designated number of days. We make the following observations:

- The number of turbidity days differs across hydrologic years. With historic rainfall patterns, the average annual number is around 40; the number ranges from about 10 to 90.

- The winters with more turbidity days tend to be the wetter years, which also tend to be the years when both Loch Lomond and the VR fill. Once these storage facilities are full, there can be no further diversion at Felton.

- Removing the turbidity constraint by installing Ranney Collectors at Felton does allow any added fill of Loch Lomond. This is because the turbidity constraint at Tait Street will still be in effect. Thus, on the days on which the Felton constraint is removed due to the Ranney Collectors, Tait Street will still be turned out, which means that Loch Lomond will have to be drawn down, which in turn means that water cannot be pumped to Loch Lomond because there is a single pipe into and out of Loch Lomond.[2]

- The fill benefit for the VR is also extremely limited due to several factors:
    - For historic flows, the VR fills in 80% of hydrologic years (see Figure 5), with or without a turbidity constraint.
    - With climate change, because of much lower rainfall, there are very few turbidity days. The average number across all hydro years is about 7, with almost 40% of hydrologic years having none. The maximum number of days is around 20. Moreover, the annual water right diversion limit of 3000 AF from Felton is reached in over 50% of hydro years with or without a turbidity constraint, and those few hydro years with a somewhat higher number of turbidity days tend to be among the years in which this maximum is reached.

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[2] Even if the turbidity constraint is also removed at Tait Street, while we do see some noticeable increases in Felton production and marginally-increased lake levels in some years, the benefits to system reliability are still very small.

While one can quibble with the details of the various modeling assumptions, the key point is that improving the city's ability to use turbid water, whether with Ranney Collectors or enhanced treatment, is not an effective approach to dealing with future water shortages in Santa Cruz.

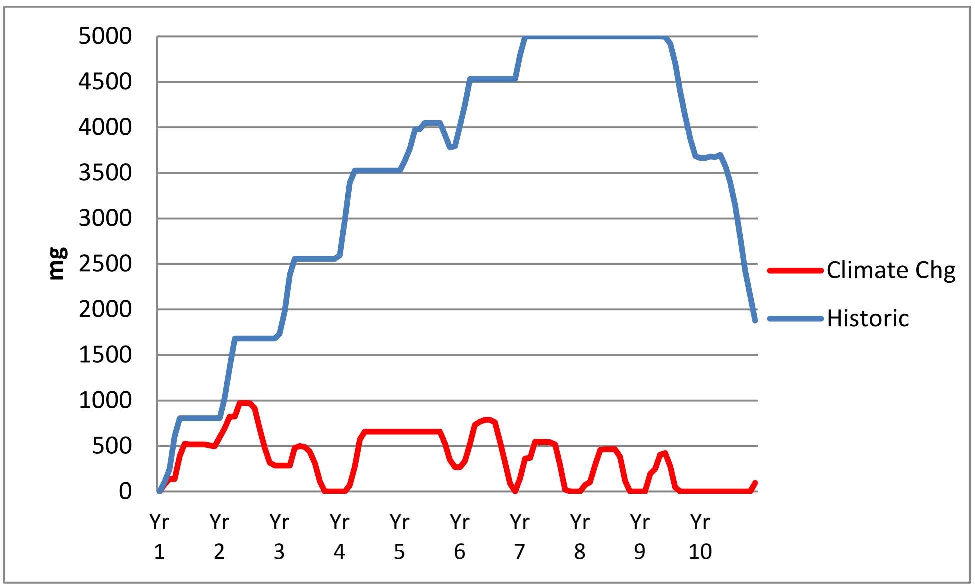
Virtual Reservoir Fill and Drawdown

Figure 4 shows the VR fill and drawdown in the 10 years leading up to the worst drought events in the historic and climate change records.[3] In each case, the VR starts at zero.

The differences are large. With historic flows, the VR fills by year 7 of the sequence. With climate change, the excess flows cannot bring the VR level above 1 billion gallons.

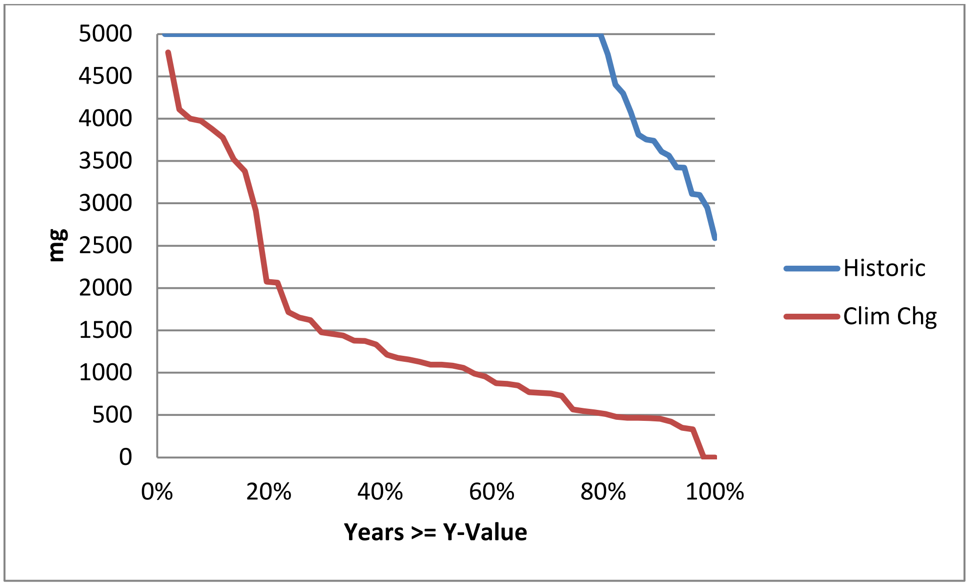
Figure 5 compares duration curves of the end-of-April VR levels. Whereas the VR fills under 80% of hydrologic conditions with historic flows, it never fills with climate change.

Figure 4. Virtual Reservoir Fill and Drawdown in 10 Years Leading to Worst Drought Year



[3] Year 10 is the end of the worst drought sequence. For the historic record, the 10-year period shown is 1968-77.

Figure 5. Duration Curves of End-of-April Virtual Reservoir Contents



Increased Diversion from Felton

Figure 6 compares the average annual incremental production at Felton to charge the VR over a 10 year period beginning with an empty VR. The initial year diversions are high as the VR fills. Then they settle into a steady state of between 150 and 200 mgy with historic flows and 400 mgy with climate change.

Figure 7 shows the duration curves of the steady state incremental Felton annual production with and without climate change. The maximum added diversions are between 800 and 900 mg. But as expected, there are many more hydrologic years with significant added diversions with climate change.[4]

[4] The few negative results in this chart are years in which both the VR and Loch Lomond are quite full and little VR drawdown is needed, which leads to low diversions from Felton.

Figure 6. Incremental Felton Diversions in First 10 Years of VR Fill: Historic Flows

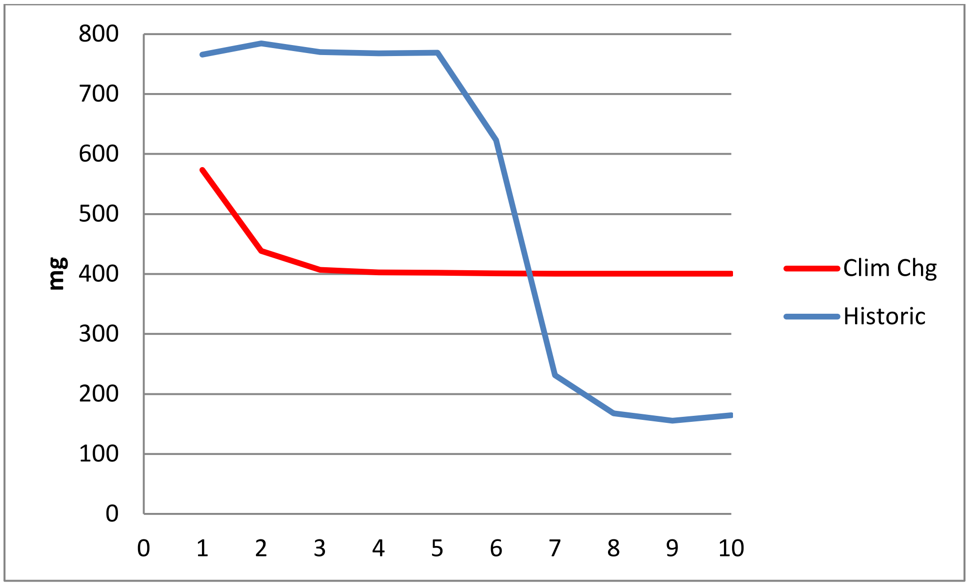
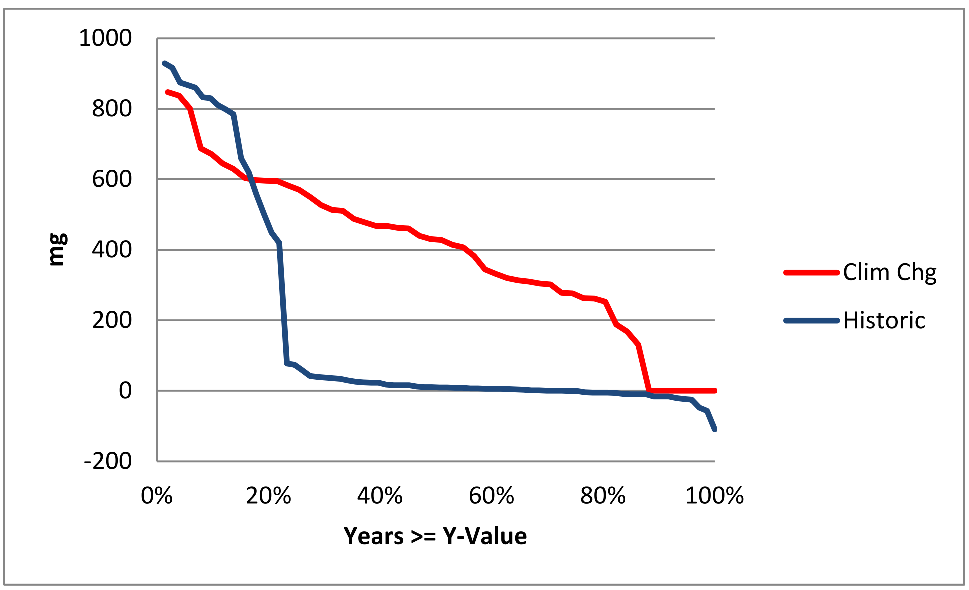


Figure 7. Felton Annual Incremental Production Duration Curves



Project Yield

The difference between the highest points in Figure 2 and Figure 3 tells us the worst-year yield of this alternative, i.e., how well this alternative does in reducing the worst-year peak-season shortage. Expressed volumetrically, this difference is about 1360 mg with historic flows, but only 116 mg with climate change. Since we are relying only on diversions of excess flows at Felton, it is very difficult to keep water in the VR through an extended very dry period. Thus, this alternative does not contribute much to reducing shortages in the final year of such a sequence. The climate change record includes such an event; this accounts for the small worst-year benefit of this alternative with climate change.

Across all hydrologic conditions, the average reduction in peak-season shortage is about 60 mg with historic flows and 290 mg with climate change.

These benefits accrue for two reasons:

- The production (less losses) of the VR itself plus
- The change in production of Loch Lomond (which in many hydrologic years is negative)[5]

The second point is important. In dry years, the benefit of these alternatives derive not only from the VR itself but also from added production from Loch Lomond. In those years, Loch Lomond begins at higher elevations because use of the VR in previous years allowed the lake to "rest".

Needed Infrastructure Capacities

One of the pieces of information that we can draw from these runs is a sense of how much capacity is needed for some of the critical required infrastructure. Following are brief discussions of these.

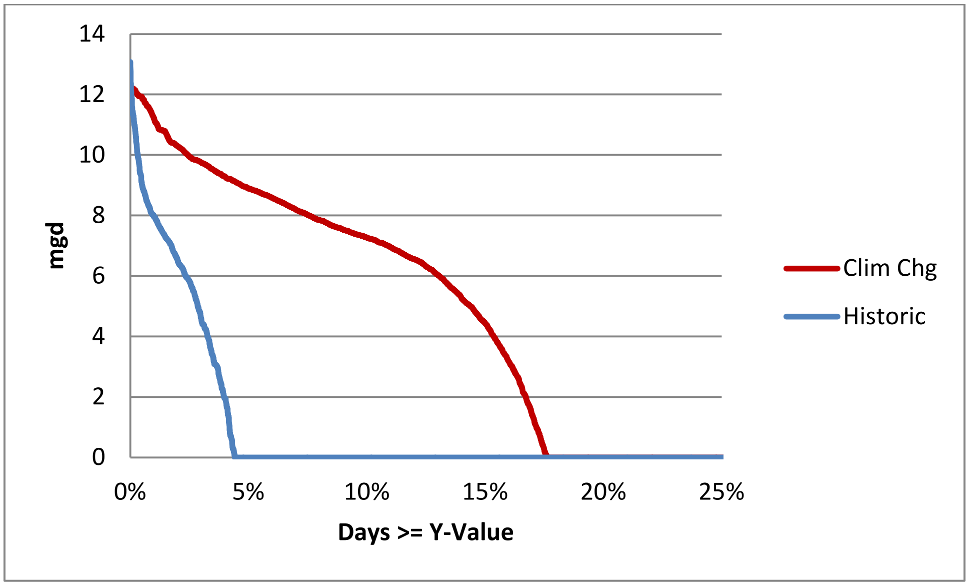
Diversions. The daily diversions at Felton and Tait Street are limited by the maximum water rights, 20 cfs at Felton and 12.2 cfs at Tait. Both of these are larger than the current capacities.

Virtual Reservoir Capacity. For this exercise, we assumed a 5 bg storage capacity. However, as illustrated in Figures 3 and 4, with historic flows the maximum drawdown is just over 3 bg. With climate change, it is only about 1 bg, reflecting the inability to divert sufficient flows at Felton to effectively charge the VR. These figures provide preliminary estimates of the required storage capacity with DFG-5 instream flow requirements.

Virtual Reservoir Production. Figure 8 compares portions of the daily production duration curves for the VR. The maximum daily production is between 12 and 13 mgd. This provides an estimate of the required delivery capacity of the VR itself and the transmission between the VR and the treatment plant.

[5] The total also includes a slight increase in Tait Street production sent to GHWTP because of the assumed unlimited diversion capacity.

Figure 8. Daily Production Duration Curves of Virtual Reservoir



Conclusion

There are two important conclusions that can be drawn on the supply benefits of this alternative:

- With current water rights and with historic flows modified to conform to DFG-5 flow rules, there are sufficient excess flows at Felton to charge a virtual reservoir so as to eliminate all supply shortages. This is decidedly not the case with climate change, where we still see significant remaining unserved demand.
- Eliminating turbidity constraints at either or both San Lorenzo River diversions does not significantly improve system reliability.