Memorandum

To: Water Supply Advisory Committee members

From: Karen Raucher and Robert Raucher, Stratus Consulting Inc.; and Gary Fiske, Gary Fiske and Associates

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Subject: Winter flows: New information

1. Additional Information Regarding Water Available from Winter Capture and Storage

This memorandum provides a summary of additional information developed by Gary Fiske using the *Confluence* model (with input from Shawn Chartrand and others) on the amount of winter water flows available for capture and storage and the associated improvements to system reliability. This analysis examines the potential yields from winter flows and system reliability gains by removing several current infrastructure constraints, including transmission, treatment, and most importantly, availability of storage. The consolidated alternatives (CAs) that address this opportunity are listed in Figure 1. Additional information is provided in the detailed background memoranda provided in Attachments 1 and 2.

CA-9. Winter Flows Capture
CA-16. Aquifer Restoration/Storage
CA-18. Off-Stream Water Storage
CA-19. Ranney Collectors

Figure 1. CAs referenced in this analysis.

Several simplifying assumptions were made to the set of proposed CAs listed in Figure 1 in order to utilize the *Confluence* model to address three fundamental planning questions:

1. How much stream water is available to capture and store – above and beyond fish requirements, current customer demands, and storage in Loch Lomond – *if infrastructure limitations are removed?*

2. How much additional supply – above and beyond fish requirements and current customer demands – is available for storage in Loch Lomond – *if you remove the turbidity constraint from water collection at the Felton diversion?*

3. How much water is available to capture and store above and beyond fish requirements, current customer demands, and storage in Loch Lomond – *if an additional storage facility is only filled from Felton?*

2. Winter Flows Available for Capture if Infrastructure Limitations Are Removed

In order to answer the fundamental planning question – How much water is available for capture and storage from winter flows? – we made the modeling assumptions that (1) winter flows can be captured up to the full limitation set by current water rights at both Felton and Tait Streets, and (2) we will find a place to store this water. These simplifying assumptions allow us to model the system response to CA-9, CA-16, and CA-18 without infrastructure constraints because all three of these alternatives divert the available winter flows to new surface or groundwater storage facilities. For modeling purposes, we call this new storage capacity a virtual reservoir, and allow for use of water in the virtual reservoir in dry years when current supplies are insufficient to meet customer demands.

By assuming away the element of where the water is stored and how it is treated and transported, and placing available water in the virtual reservoir, we can identify the volume of potentially available stream water to meet City water needs. All three of these alternatives are considered equal in this analysis as they all have same fundamental element – we capture as much winter flow as we can and store it somewhere. These CAs are dissimilar in other important ways.

Other assumptions used in this *Confluence* model run are listed in Figure 2.

Key findings

If the City has a way to store winter flows and develops the necessary infrastructure to divert, convey, treat, store, and withdraw water as needed, then projected future shortages occurring from current demand projections are reduced to zero. That is, all demands as currently projected can be served, even in the driest years, with DFG-5 flows and hydrological changes due to climate change.

This conclusion holds once the virtual reservoir reaches a "steady state," i.e., once a sufficient number of years has passed to fill the empty storage site. Even with the reduced flows under climate change, this does not require many years. A detailed explanation of why this result occurs is provided in Attachment 1.

The worst-year yield of this alternative (i.e., the amount by which it reduces worst-year peak-season shortages) is about 1,360 million gallons (mg) with historical flows, and 1,150 mg with climate change. Across all hydrologic conditions, the *average* reduction in peak-season shortage is about 60 mg with historical flows, and 420 mg with climate change. The yield is a measure of how well this alternative does in reducing peak-season shortages as currently defined.

- ***Unlimited infrastructure capacity***. There are existing limits regarding diversion capacity at Felton and Tait Streets; transmission capacity between Felton and the virtual reservoir; transmission capacity between Tait Street and the virtual reservoir; and transmission capacity between the virtual reservoir and Graham Hill. These infrastructure-related constraints are removed in these model runs, so that we can see how much water could conceivably be provided based on existing rights and available flows.
- ***Current water rights***. Water rights at Felton limit daily diversions to 20 cubic feet per second (cfs) in all months other than September; in September the right is 7.8 cfs. The annual diversion limitation at Felton of 3,000 acre-feet (AF; 978 mg). At Tait, the diversion right is 12.2 cfs year-round with no annual limit.
- ***Fish flow requirements***. DFG-5 fish flow requirements are assumed, and are applied both under current hydrology and under the climate change – impacted hydrology.
- ***Storage capacity***. Based on preliminary work conducted by Pueblo Water Resources, maximum potential storage capacity at the virtual reservoir is limited to 5 billion gallons (bg). (Note the findings show that less storage capacity is actually needed so this assumption is not a limiting restriction on the problem.)
- ***Storage losses***. Eighty percent of stored water is assumed to be recoverable. That is, for each 100 gallons stored, the City can withdraw and receive 80 gallons when needed. (The assumed 20% loss includes evaporation from surface storage and/or "leakage" from aquifer storage.)
- ***All other current modeling assumptions*** regarding operation of the current sources (e.g., turbidity constraints, flush flows) are retained and included in the analysis.
- ***Demand projections*** do not yet include the most recent revisions to the University of California, Santa Cruz, forecast. The change in estimated demands is unlikely to make an appreciable difference in the findings.

Figure 2. Key modeling assumptions for winter flow capture and storage in a virtual reservoir.

Infrastructure needs

One of the pieces of information that we can draw from this model run is a sense of the capacity needed for some of the critical infrastructure required to realize the diversion and ultimate use of these winter flows.

Infrastructure needs based on this modeling run include:

- ***Diversions***. In this model run, diversions at Felton and Tait Streets are limited only by the maximum water rights of 20 cfs at Felton and 12.2 cfs at Tait.
- ***Virtual reservoir capacity***. For this exercise, we assumed new storage has up to a 5 bg capacity. However, the drawdown in the worst year is just over 3 bg under both historical

and climate change flows. This means that 3 bg is likely to be the upper end of the range of total new storage capacity needed, if all else remains equal.

- ***Virtual reservoir production (conveyance and treatment)***. The maximum daily production from the virtual reservoir needed to meet demands with and without climate change is around 13 million gallons per day (mgd). This means the delivery capacity from the storage site and the transmission capacity between the storage site and the treatment plant needs to be around 13 mgd. This requires infrastructure to extract, pump, transport, and treat this volume.

The key outcome of this analysis is that the harvesting and storage of winter flows has the potential to address the City's water supply challenges and enable the City to meet projected future demands *– if diversion capacity, storage capacity, and production capacity can be increased and all else remains equal.*

3. Water Available for Capture and Storage in Loch Lohman if Turbidity Constraints are Removed from Water Collection at the Felton Diversion

In this model run we address the question – How much water is available to capture and store above and beyond fish requirements and current customer demands? – *for storage in Loch Lomond, if diversions at Felton are no longer limited by a turbidity constraint?* This analysis is part of addressing the larger question – *How much water is available from the Felton diversion if turbidity was not a constraint and you had a place to store it*? The answer to this broader question is addressed in the next section.

The modeling assumptions made for this *Confluence* model run include base assumptions made above (Figure 2) as well as:

- Ranney collectors allow San Lorenzo River flows to be collected in a manner that turbidity levels no longer constrain the system
- Diversions from the Felton diversion are limited by the existing Felton water rights
- Current turbidity constraints at the Tait Street diversion remain in place
- Flows available from the Tait Street diversion in excess of what is needed to serve current demand are not available for storage anywhere other than Loch Lomond. i.e., the virtual reservoir opportunity is removed for this model run.

Key finding regarding removal of the turbidity constraint

Removing the turbidity constraint from water taken from the San Lorenzo River by using Ranney collectors does *not* provide significant additional fill to Loch Lomond. This is because the turbidity constraint at the Tait Street diversion is assumed to be the same as at Felton – so you need to also remove the turbidity constraint at the Tait Street diversion in order to remove the entire constraint related to turbidity. That is, on the days on which the Felton constraint is removed, the Tait Street diversion is still constrained. This means that since water from the San Lorenzo River cannot be used to meet demand, water must be drawn down from Loch Lomond. This in turn means that water cannot be pumped into Loch Lomond on those days.

However, even when the turbidity constraint is also removed from the Tait Street diversion, and there are noticeable increases in Felton production and marginally increased lake levels occur in some years, the benefits to system reliability are still very small. A key reason for this is that the turbidity constraint arises more frequently during relatively wet years (i.e., turbidity events occur when it rains), and even with the inability to capture water from the San Lorenzo River when turbidity levels are high, the reservoir can still be filled. Conversely, during dry years, when turbidity is a less-frequent constraint, it is still difficult to access adequate flows to fill the reservoir.

Additional information is provided in Attachment 2.

4. Water Available for Capture from Felton Diversion for Storage Somewhere Other than Loch Lomond

As part of the model run looking at how removing the turbidity constraint from the San Lorenzo River impacts system reliability, a broader question was also addressed: How much water is available to capture and store above and beyond fish requirements, current customer demands, and storage in Loch Lomond *if the virtual reservoir is only filled from Felton?*

In order to identify the water available for capture from Felton if you remove the turbidity and Loch Lomond storage capacity constraints, an analysis of the system was conducted using CA-19. The modeling assumptions made for this *Confluence* model run include many of the ones above as well as:

- Diversions from Felton are limited solely by the Felton water rights and can be used to fill an additional storage site (referred to here as the virtual reservoir).
- Diversions at Felton are no longer limited by any turbidity constraint; as discussed above, this provides little benefit.

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

Key findings

CA-19 has the ability to divert and store excess Felton flows in sufficient amounts to eliminate all shortages assuming historical hydrology. However, with climate change, significant shortages remain.

The worst-year yield of this alternative (i.e., the amount by which it reduces worst-year peak-season shortages) is about 1,360 mg with historical flows, but only 115 mg with climate change flows. Since we are relying only on diversions of excess flows at Felton, it is very difficult to keep water in the virtual reservoir 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 projection used includes such an event; this accounts for the small worst-year benefit of this alternative with climate change.

Additional information is provided in Attachment 2.

Infrastructure needs are as follows:

- ***Diversions***. The daily diversions at Felton and Tait Streets 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. The *Confluence* model allowed us to identify that under historical flows, the maximum amount of storage needed to meet demands is just over 3 bg; a storage capacity of 3 bg will meet demands all else being equal. With climate change flows, the system only has the capacity to divert about 1 bg to charge the virtual reservoir. These figures provide preliminary estimates of the required storage capacity with DFG-5 instream flow requirements.

- ***Virtual reservoir production***. The maximum daily virtual reservoir production is between 12 and 13 mgd. This provides an estimate of the required delivery capacity of the virtual reservoir itself and the transmission between the virtual reservoir and the treatment plant.

Attachment 1. Modeling Results: Harvesting Winter Flows

Attachment 2. Modeling Results: Ranney Collectors