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Water Resources Planning and Management

EVALUATION OF ALTERNATIVE APPROACHES TO INCREASE PUMPING FROM FELTON DIVERSION TO LOCH LOMOND RESERVOIR

EXECUTIVE SUMMARY

The WSAC process has provided an opportunity to explore in detail ways to more effectively capture excess winter flows. As part of that exploration, the Confluence® model was used to evaluate a range of alternatives to determine their effectiveness in increasing pumping from Felton to Loch Lomond and improving water supply reliability. Two operational changes and three infrastructure improvements were analyzed, both separately and in combination, as follows:

Felton Operational Changes

- Removing current first flush constraint
- Removing current turbidity constraint

Infrastructure Improvements

- Replacing existing pipe between Felton and Loch Lomond
- Adding a second pipe between Felton and Loch Lomond
- Improving the pump configuration at the Felton diversion

The evaluation resulted in the following key conclusions:

- If the Water Department determines it is feasible to relax the first flush constraint or remove it completely in dry years, lake fill and water supply reliability could improve significantly.

- Replacement of the current hydraulically-limited pipe with one that does not suffer from such limitations also provides important benefits, but if the first flush constraint remains, the new pipe would not reduce shortages in the worst year.

- Once the pipe is replaced, improving the current pump configuration at the Felton diversion to enable full utilization of the permitted pumping rate will further improve system reliability, but again as long as the City cannot divert prior to first flush, there are no worst-year benefits.

- Combining these three actions would provide even greater benefits, including significant reductions in worst-year shortages.

- Neither removing the Felton turbidity constraint or adding a second pipe between Felton and the lake provides any additional benefits.

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Table ES-1 summarizes the reliability benefits that could be achieved, and also shows the peak-season shortages that remain, which would need to be addressed with other investments in supply or infrastructure.

Table ES-1. Comparison of Peak-Season Shortages

Configuration	Worst-Year Peak Season Shortage		Average-Year Peak Season Shortage	
	Volume (mg)	Percent	Volume (mg)	Percent
Current	1110	57%	340	17%
No First Flush	950	49%	230	12%
Replacement Pipe	1110	57%	250	13%
No First Flush & Replacement Pipe	780	40%	130	7%
Replacement Pipe & Pump Improvements	1110	57%	190	10%
No First Flush, Replacement Pipe & Pump Improvements	650	33%	80	4%

INTRODUCTION

The WSAC process has provided an opportunity to explore in detail ways to more effectively capture excess winter flows. As part of that exploration, the Confluence® model was used to evaluate a range of operational and infrastructure alternatives to determine their effectiveness in increasing pumping from Felton to Loch Lomond and improving water supply reliability. The purpose of this document is to report the results of that analysis.

It is critical to emphasize that increased Felton pumping is not the ultimate goal. Rather, the goal is to improve the reliability of water deliveries to customers. One way to improve this reliability is to maximize the contents of Loch Lomond at the beginning of the dry season, and increasing pumping from Felton to the lake is often considered a good strategy to achieve this. However, depending on hydrologic conditions, increased pumping at Felton may or may not result in commensurate increases in either lake levels or deliveries to customers. This will become clearer in the discussions that follow.

CURRENT SITUATION

All of the results shown in this document assume that available flows are limited by DFG-5 fish flow requirements and both flows and weather correspond to our climate change scenario. With these assumptions, the modeled distribution of peak-season shortages with current infrastructure and operations is shown in Figure 1.

Figure 1. Distribution of Peak Season Shortages: Current Infrastructure and Operations

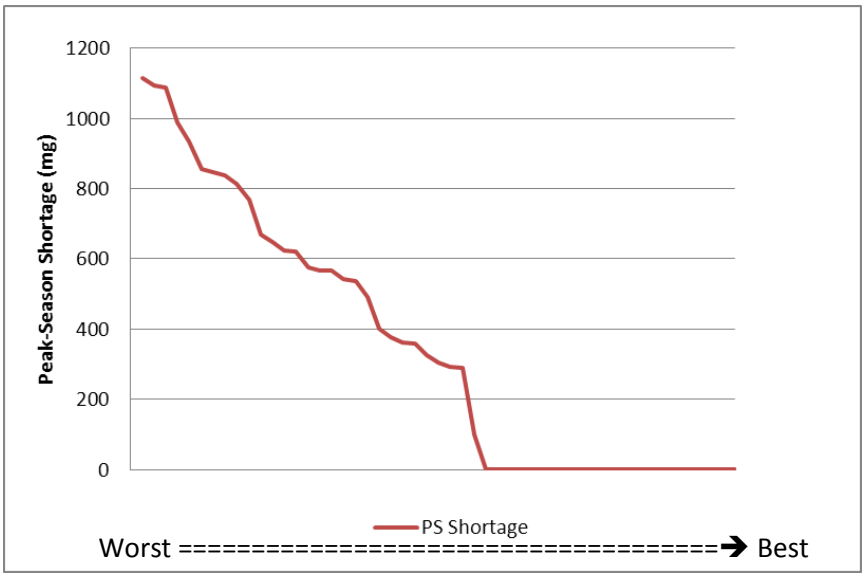
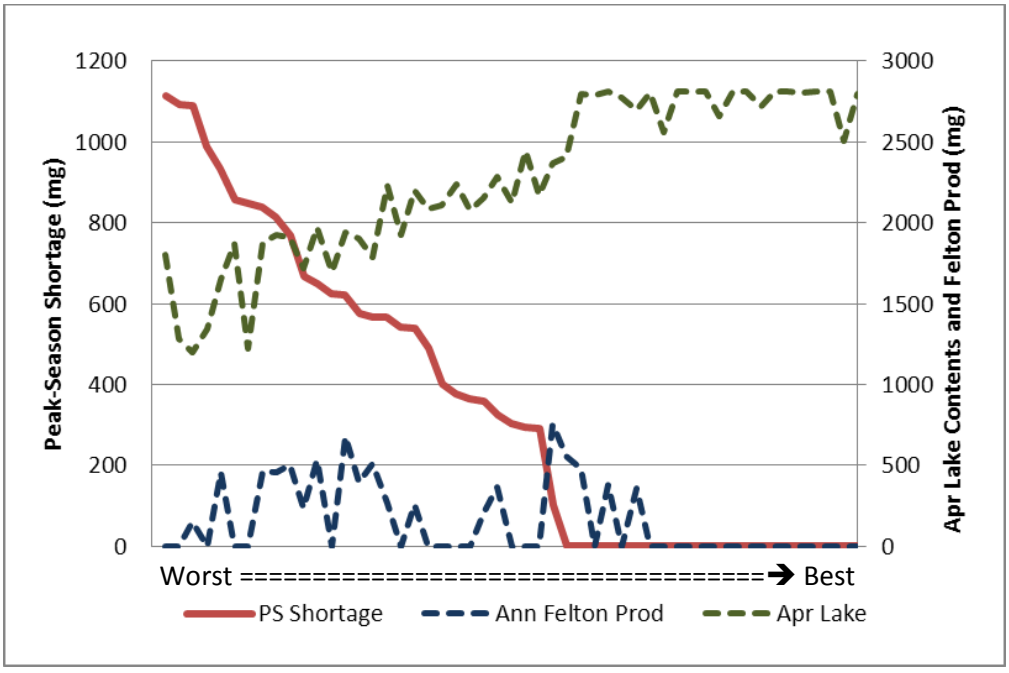


Figure 2 overlays the annual Felton pumping and the end-of-April (start of dry season) lake levels on this shortage distribution.

Figure 2. Shortage Distribution with Overlay of Annual Felton Pumping and End-of-April Lake Contents



Three important conclusions can be drawn:

- The years with small shortages tend to be those in which the lake level at the start of the dry season is higher.

- The volumes pumped are near zero in the wetter years. This is due in part to hydraulic constraints in the existing pipeline between Felton and the lake, and in part to there being much less room in the lake in those years. In any event, added pumping in those years would result in little increase in the lake volume available in the dry months and no improvement in reliability to customers (since shortages are already zero).

- The volumes pumped are also near zero in the driest years. This is due largely to the current first-flush operating constraint that will be discussed below.

POTENTIAL CHANGES IN INFRASTRUCTURE AND OPERATIONS

This paper evaluates the effectiveness of the following operational changes and infrastructure improvements in increasing Felton diversions and, ultimately, improving reliability of water deliveries to customers:

Operational Changes

- First Flush. The Water Department currently does not divert from Felton in the fall until after there have been sufficient flows to "flush" solids and other contaminants that have accumulated in the river over the dry season. The specific modeled constraint is that diversions cannot start until there have been two days of flow at Big Trees that are at least 100 cfs. With climate change, there are few if any days with flows that high in the driest years. Thus, there are virtually no diversions in those years.

  The Water Department is investigating the possibility of relaxing that constraint, considering such issues as exposing the rubber dam at Felton to major debris flows, water quality issues associated with storing pre-flush water in the lake, and others. For purposes of this evaluation, we assessed the impacts on lake fill and water supply reliability of completely removing the first flush requirement.

- Turbidity. Felton is currently turned out on days when turbidity levels are too high (>25 ntu). We evaluated the extent to which removing that constraint would improve lake fill and reliability.

Infrastructure Improvements

The water right at Felton allows diversion rates of up to 20 cfs in most months.[1] Current infrastructure does not allow the City to take maximum advantage of this water right. We evaluated the effectiveness of several infrastructure investments that have the potential of enabling better use of the right. Two of

[1] Diversions at Felton are also limited to 3000 acre-feet (978 mg) per year.

these improvements focus on the pipe between Felton and Loch Lomond. The third improves the pumps at the diversion.

- Replacement Pipe. The current pipe between Felton and Loch Lomond is old and limited in the pressures it can withstand. This limits the rate at which the lake can be filled, especially when lake levels are higher. We evaluated the impacts of replacing this pipe so as to remove those constraints.

- Second Pipe. The current single-pipe configuration precludes pumping from Felton on any day that the lake is being drawn down to serve demand. There are two situations in which the lake will be drawing down:

    1. The river flows at Tait Street on a particular day are not sufficient to fully meet demand. On this kind of day, Felton will not divert in any event, since all flows are needed at Tait.

    2. River turbidity precludes diversion at Tait Street. Currently, the turbidity constraints at Felton and Tait are assumed to be the same. Thus, on this type of day, we also could not divert at Felton. However, if the turbidity constraint at Felton is relaxed or removed, then a second pipe could allow the lake to fill on days on which high turbidity shuts down Tait Street and the lake is drawn down. We therefore evaluated the benefits of a second pipe assuming removal of the Felton turbidity constraint.

- Pumping upgrades. The current pump configuration at the Felton diversion limits the maximum diversion rate and only allows diversions at certain rates below that maximum. Replacing the pipe creates the possibility of additional benefit from upgrading the pumps.

Following are discussions of how these operating and infrastructure changes affect system reliability. Alternatives are first evaluated separately and then particular operating and infrastructure changes are combined.

REMOVING FIRST FLUSH CONSTRAINT

If the Water Department was able to completely remove the first flush constraint, substantially more water could be diverted to the lake, especially in the driest years. Figure 3 shows the improvement in Felton pumping volumes if this constraint were removed. The average annual volume pumped increases by 140 mg. In the driest year, the pumping volume goes from zero to more than 500 mg.

Figure 4 shows the resulting improvement in the distribution of peak-season shortages. The worst-year peak-season shortage is reduced by 160 mg.[2] On average, the peak-season shortage decreases by just over 100 mg.

[2] The worst-year peak-season shortage reduction is considerably less than the increased pumping volume for several reasons:

- A small fraction of the pumped volumes is lost to evaporation.
- A portion of the increased diversion is used in the off-peak season.
- The peak-season shortage in the year that was worst prior to removal of the first flush constraint is reduced to a point where another year (which does not benefit as much from the removal of this constraint) becomes the worst year.

Figure 3. Added Felton Pumping from Removing First Flush Constraint

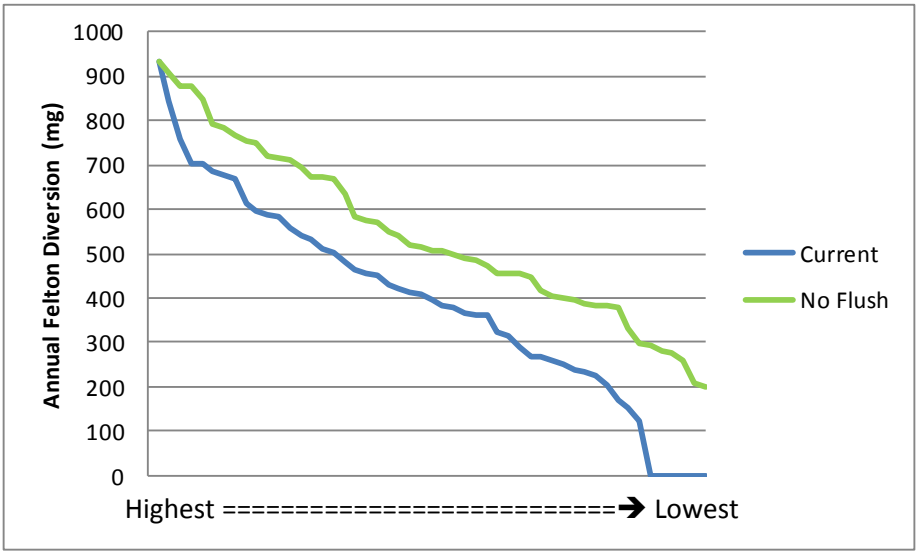
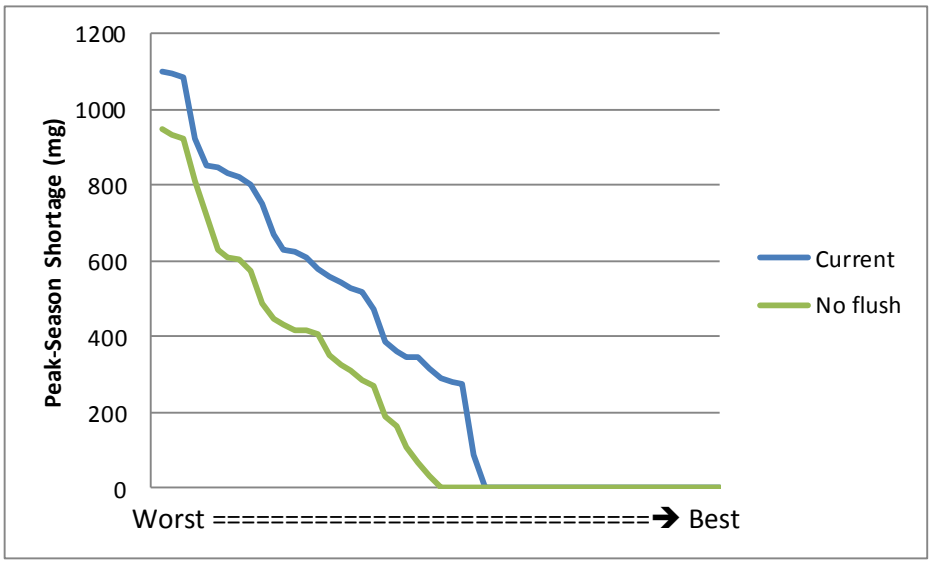


Figure 4. Improvements in Peak-Season Shortages from Removing First Flush Constraint



Summary

A determination by the Water Department that water could be diverted from Felton without waiting for a first flush could result in significant increased diversion volumes and improvements in system reliability.

REMOVING TURBIDITY CONSTRAINT

As discussed above, simply removing the Felton turbidity constraint without a second pipe that would allow for simultaneous lake fill and drawdown does not provide any benefit. The combination of these two changes will be discussed below.

REPLACING EXISTING PIPE

Figure 5 shows the increase in Felton diversions that results from replacing the existing pipe with one that does not have the hydraulic limitations of the current pipe. Figure 6 shows the resulting peak-season shortage reductions.

Figure 5. Added Felton Pumping from Replacing Felton-Loch Lomond Pipe

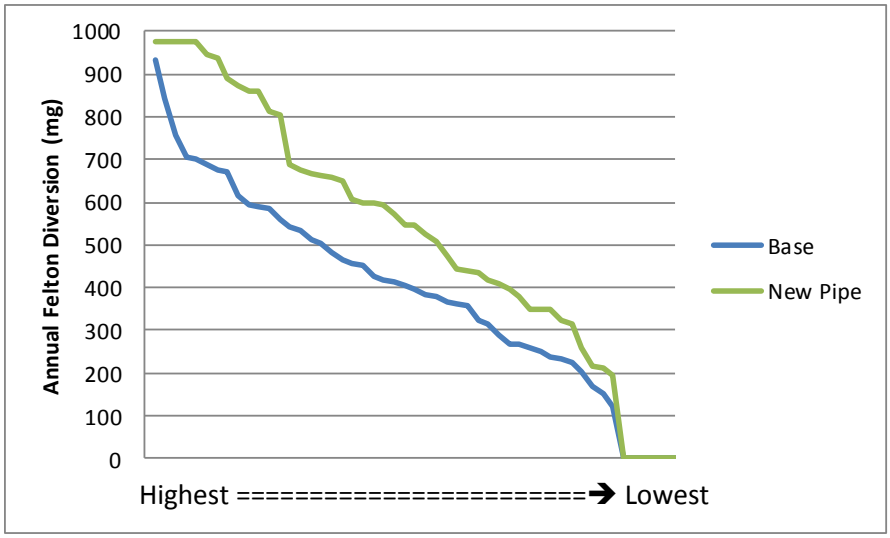
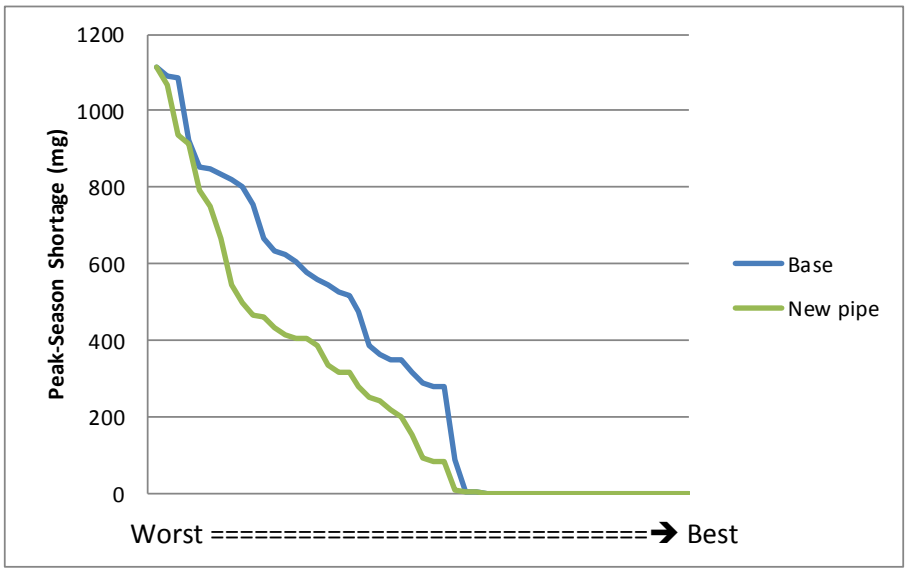


Figure 6. Peak-Season Shortage Improvements from Replacing Felton-Loch Lomond Pipe



Summary

Replacing the pipe between Felton and Loch Lomond results in a noticeable improvement in the system reliability profile. It does not provide a benefit in the driest year because the first-flush constraint precludes any diversion in that year.

ADDING SECOND PIPE and REMOVING TURBIDITY CONSTRAINT

As discussed above, any benefit of adding a second pipe is only realized if at the same time the constraint on diverting turbid water at Felton is relaxed. It is assumed that the second pipe provides the same hydraulic improvements as the replacement pipe (see above). Figure 7 compares the Felton diversion profiles with a second pipe (and no turbidity constraint) and with a replacement pipe (from Figure 5). Figure 8 shows the corresponding peak-season shortages.

Summary

A second pipe provides virtually no added benefit. This can be understood as follows:

- The days on which there could be a benefit from a second pipe are those on which Loch Lomond could potentially fill and draw down, i.e. days of excessive turbidity.
- In the driest years, there are very few such events, particularly with climate change.
- Most of those events tend to occur in the wetter years, when the lake is close to full and there is little opportunity to divert.
- Even in the years when there is some small additional diversion, there is no system reliability benefit because those are years in which the lake would have filled or nearly filled in any event.

Figure 7. Annual Felton Diversions with Replacement Pipe and Second Pipe

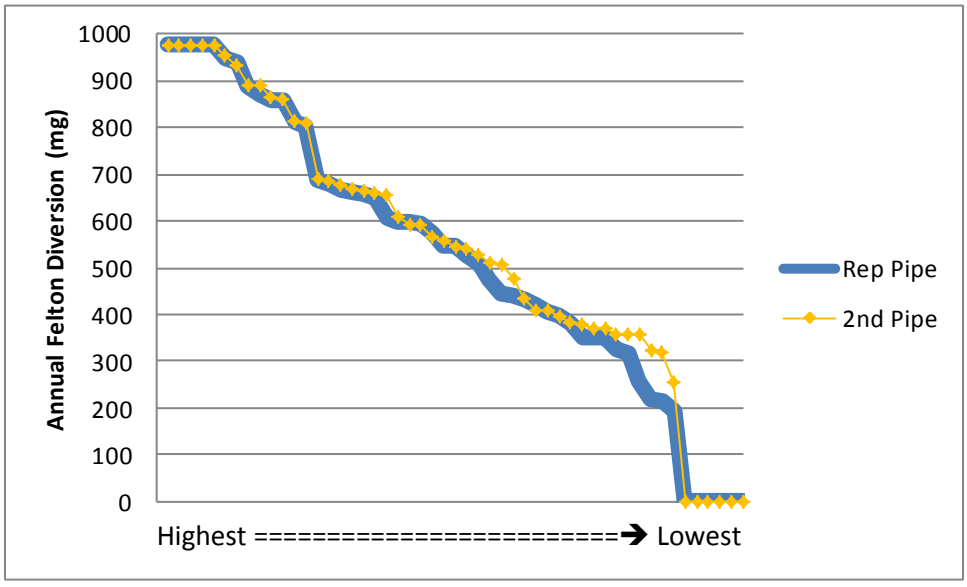
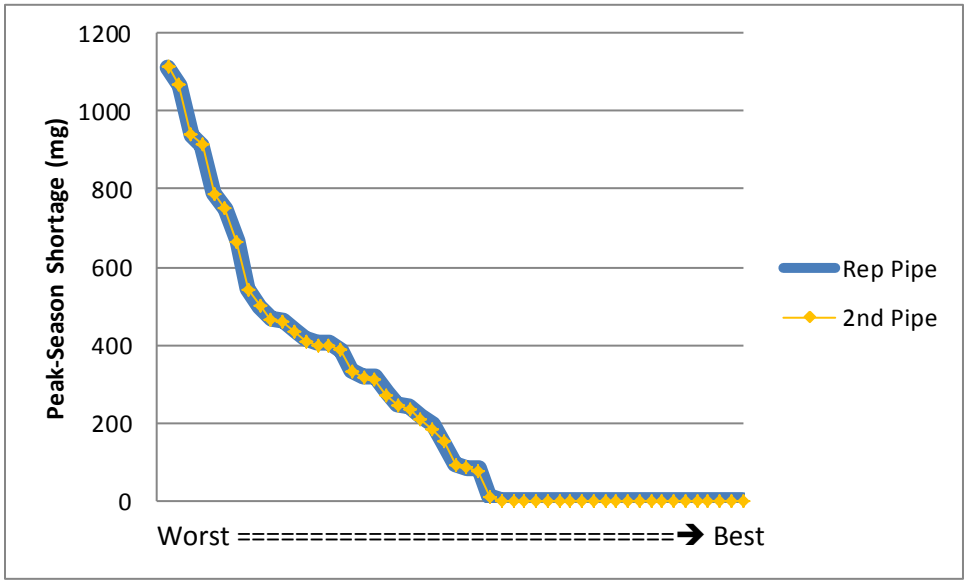


Figure 8. Peak-Season Shortages with Replacement Pipe and Second Pipe



REPLACING EXISTING PIPE and IMPROVING PUMPS

Once the pipe has been replaced, Figure 9 shows the added Felton pumping volumes that result from improving the pump configuration at the diversion to enable maximum usage of the 20 cfs water right. Figure 10 shows the resulting improvement in system reliability.

Figure 9. Annual Felton Pumping with Replacement Pipe and Pumping Improvements

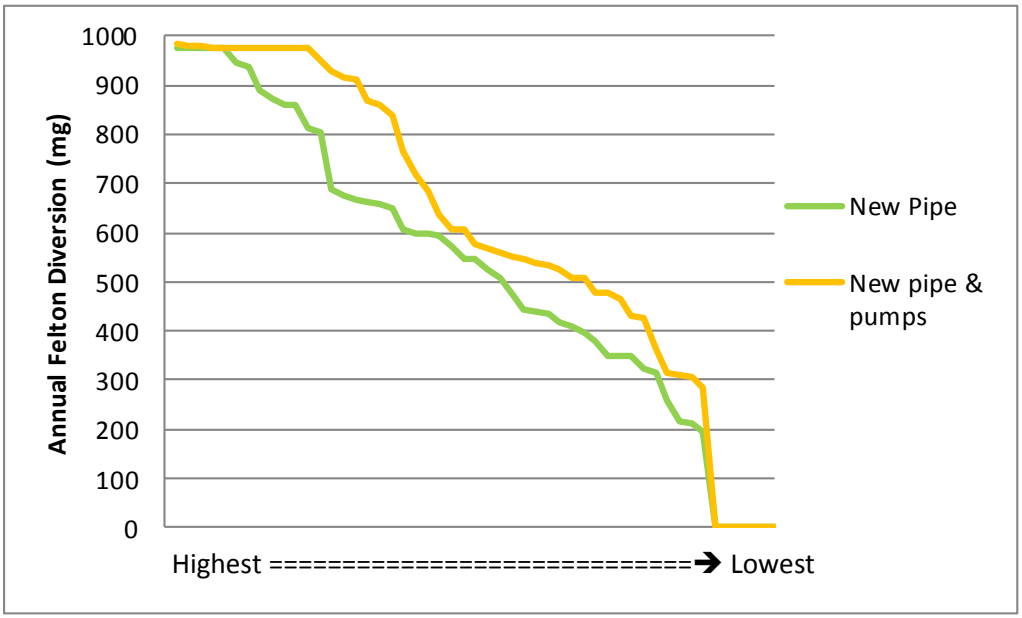
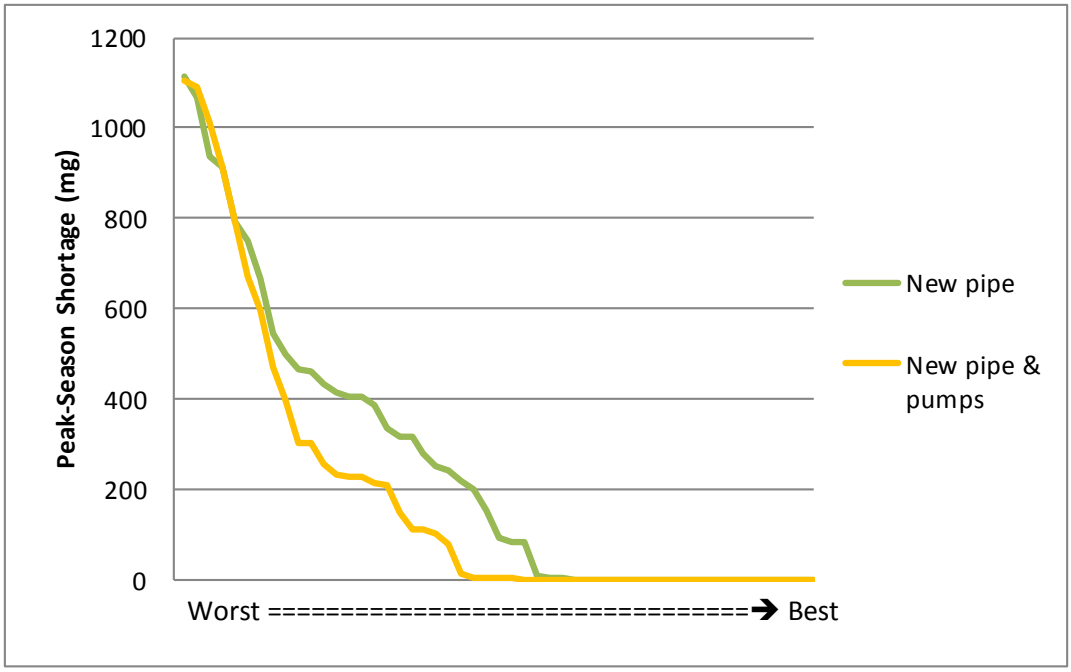


Figure 10. Peak-Season Shortages with Replacement Pipe and Pumping Improvements



Summary

Once the current pipe is replaced, upgrading the pumps at the diversion further improves reliability, but once again, there is no benefit in the driest year as long as the first-flush constraint remains.

REMOVING FIRST FLUSH CONSTRAINT and REPLACING EXISTING PIPE

Figure 11 shows the increased Felton diversion volumes that result from removing the first flush constraint and replacing the existing pipe. Figure 12 compares the corresponding peak-season shortages.

Figure 11. Felton Diversion with No First Flush Constraint and New Pipe

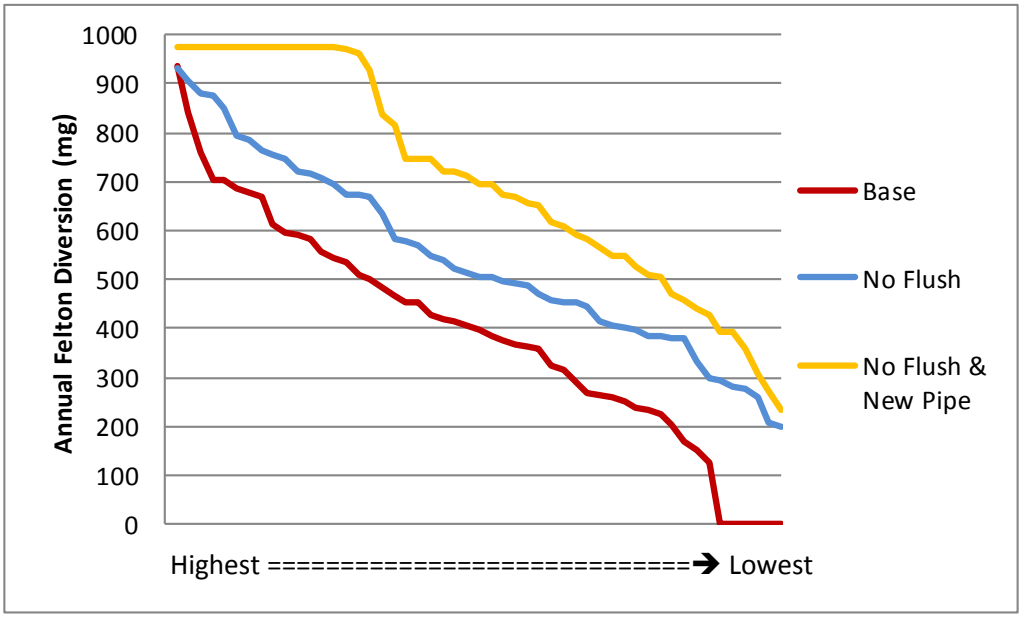
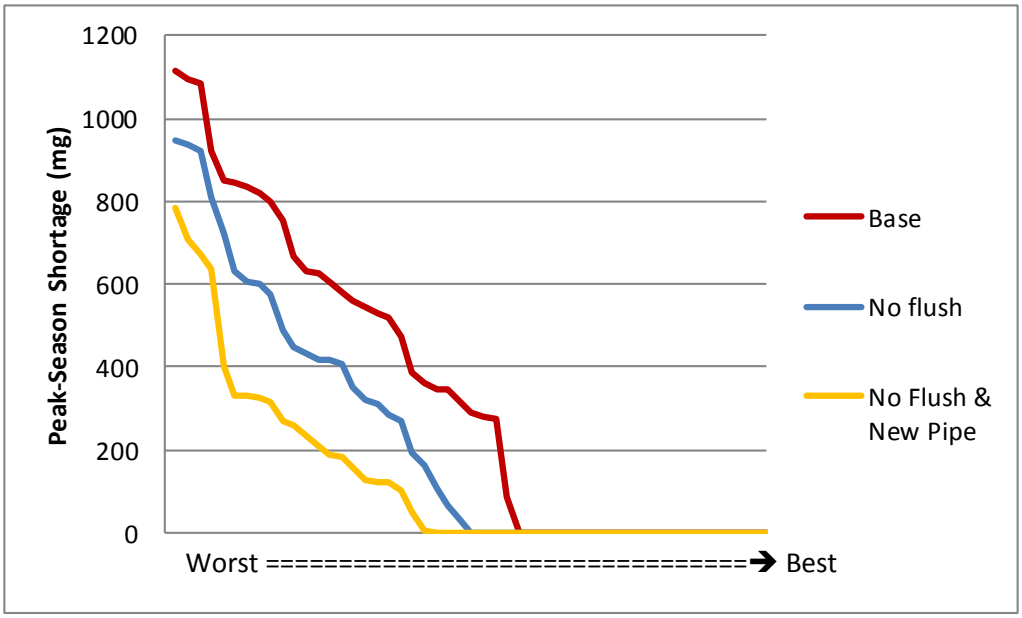


Figure 12. Peak-Season Shortages with No First Flush Constraint and New Pipe



Summary

Combining the removal of the first flush constraint at Felton with pipe replacement significantly improves the shortage profile, reducing the worst-year peak-season shortage to less than 800 mg, which is 300 mg less than the current situation.

REPLACING EXISTING PIPE and IMPROVING PUMPS and REMOVING FIRST FLUSH CONSTRAINT

Figure 13 compares the annual Felton diversion volumes that result from (1) removing the first flush constraint, (2) combining that with replacing the existing pipe, and (3) combining those actions with pump improvements. Figure 14 compares the resulting distributions of peak-season shortages.

Figure 13. Felton Diversion with No First Flush Constraint, New Pipe, and New Pumps

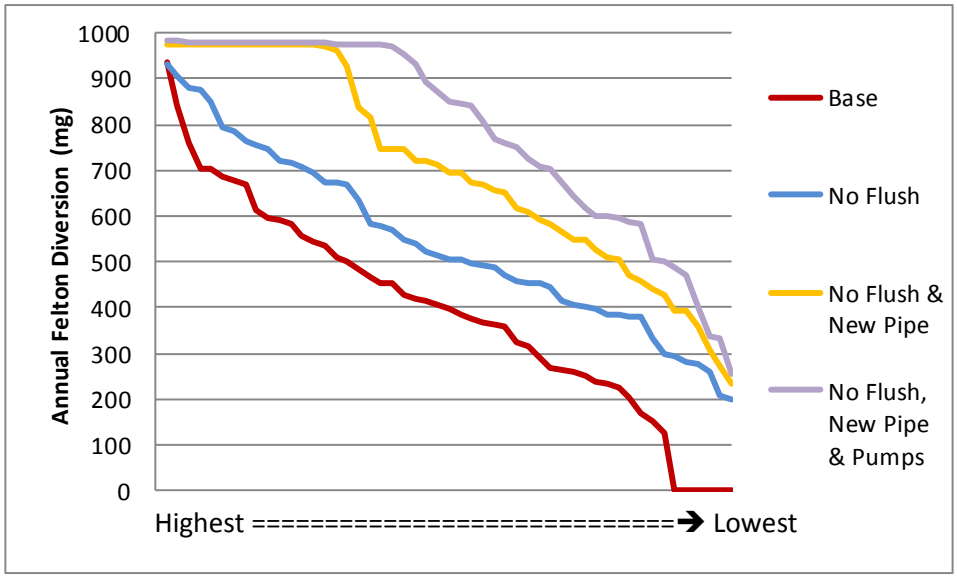
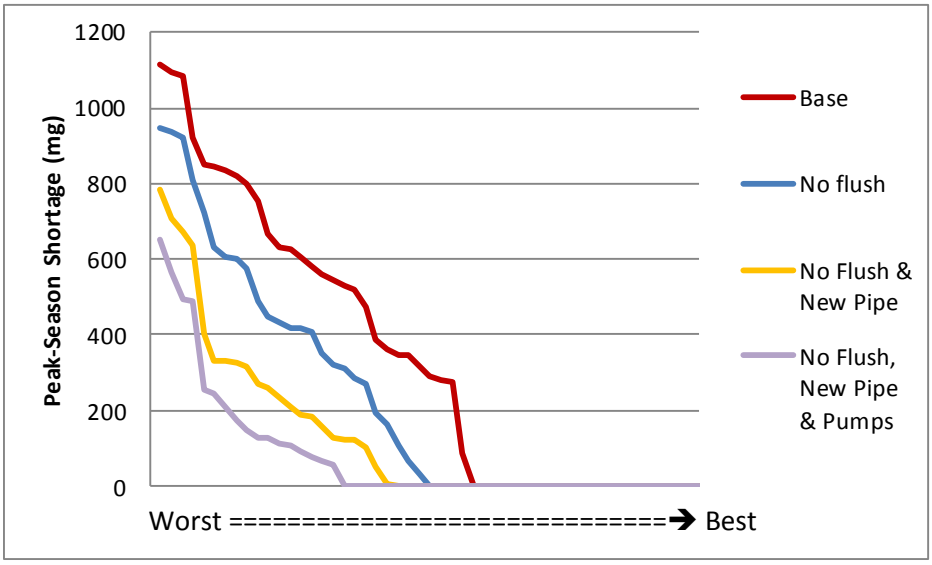


Figure 14. Peak-Season Shortages with No First Flush Constraint, New Pipe, and New Pumps



Summary

If each action proves feasible, then removing the first flush constraint, replacing the pipe to the lake, and improving the pumps at the diversion each result in added diversions at Felton and improvements in system reliability. The combination of these three actions reduces the worst year peak-season

shortage from about 1100 mg to 650 mg and reduces the average peak-season shortage from 340 mg to 80 mg.

CONCLUSIONS

It behooves the Water Department to thoroughly explore any operational or infrastructure alternatives that might result in increased diversions from Felton to Loch Lomond that would improve water supply reliability. The foregoing analysis has shown that there are alternatives that show promise:

- If it proves operationally feasible to relax the current first flush constraint at Felton or completely remove it in dry years, significantly more water could be diverted to the lake with corresponding benefits to system reliability.

- Replacing the existing pipe between Felton and Loch Lomond with one that is not burdened with the same hydraulic constraints also yields notable benefits.

- Pump improvements at the Felton diversion further increase diversions and reduce customer shortages.

Neither removing the current turbidity constraint at Felton or adding a second pipe provides added benefits to Santa Cruz customers.

Table 1 compares the peak-season shortages with the current system configuration to those that the model forecasts with these separate and combined alternatives. The combined alternative significantly improves water supply reliability. However, we are still left with peak-season shortages that must be addressed with other supply or infrastructure investments.

Table 1. Comparison of Peak-Season Shortages

Configuration	Worst-Year Peak Season Shortage		Average-Year Peak Season Shortage	
	Volume (mg)	Percent	Volume (mg)	Percent
Current	1110	57%	340	17%
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