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August 31, 2015

Subject: Soquel Creek Monitoring and Adaptive Management Plan Baseline Report

Dear Taj:

This letter report documents the baseline assessment of streamflow conditions in the Soquel Creek prior to the City of Santa Cruz's Beltz #12 well and Soquel Creek Water District's O'Neill Ranch well being brought online in 2015. A voluntary monitoring and adaptive management plan (MAMP; HydroMetrics WRI, 2012) for the Soquel Creek has been implemented due to its designation as critical steelhead habitat. The elements of the MAMP include monitoring Soquel Creek flow and shallow groundwater levels both upstream and downstream of potential pumping impacts. The report also assesses whether recorded data show effects of pumping from existing pumping, specifically from the Main Street well.

Monitoring System Description

Before monitoring could commence for the MAMP, certain elements of the monitoring system needed to be installed. This included a stream water level gauge downstream of pumping impacts near the existing Nob Hill shallow monitoring well, a shallow well on the west side of Soquel Creek along Soquel Wharf Road, and a weather station at the Main Street well site. An existing stream gauge at the Main Street well site, the USGS stream gauge at Bridge Street, and existing shallow wells at the Main Street well site and the Nob Hill shopping center east of Soquel Creek are also part of the MAMP monitoring system (Figure 1).

The downstream gauge near the Nob Hill monitoring site was installed by the District's consulting surface water hydrologist Brook Kraeger and District staff on July 5-6, 2012 (Figure 2). This location is downstream of most of the anticipated drawdown effects from pumping the Main Street, O'Neill Ranch, and Beltz #12 wells. The location is expected to be upstream of tidal effects from Monterey Bay. During the annual monitoring period from May to October, the gravel bar that makes the pool should not move much. However, the gravel bar can be eroded and filled during and after storm events, changing the pool elevation. Also, children often play in the pool and build small dams in the outlet, resulting in changes in pool elevation so water level changes similar to the effect of the debris jam in riffle shown in Figure 4 may be common.

To continuously record stream water levels, District staff installed a Baro Diver water level logger in the Nob Hill stream gauge in July 2012. We had expected that the operational accuracy of the Baro Diver sensor would usually outperform the manufacturer's specified accuracy range, but the data collected indicated all measurements show random variation over the full accuracy range specified. These measurement errors are compounded by measurements recorded by the sensor used to measure barometric pressure and compensate the data for barometric pressure changes. The resulting accuracy of +/- 0.032 feet is too large for measuring the stream levels. Therefore, we decided to replace the sensor with a vented Stevens sensor that has a specified accuracy of +/- 0.01 feet, although data collected by the Stevens sensor in the Main Street gauge show a smaller range of accuracy. The Nob Hill stream gauge was modified by Brook Kraeger for the Stevens sensor December 2012. Brook Kraeger and District staff installed a Stevens PS2100 in the Nob Hill stream gauge January 8, 2013.

The shallow well on Soquel Wharf Road was drilled and constructed May 3, 2012 by Exploration Geoservices with oversight provided by HydroMetrics Water Resources Inc. (HydroMetrics WRI, 2014). The well was drilled to a depth of 60 feet and was screened from 40 to 50 feet below ground surface (bgs). The well was developed, sampled, and its monument installed May 7, 2012 by Bradley and Sons with oversight provided by HydroMetrics Water Resources Inc. A Mini Diver data logger to continuously record groundwater levels was installed in the well in July 2012. The logger was removed and re-installed in October 2012 to test its accuracy. The Mini Diver's accuracy of +/- 0.032 feet is sufficient for monitoring shallow groundwater levels.

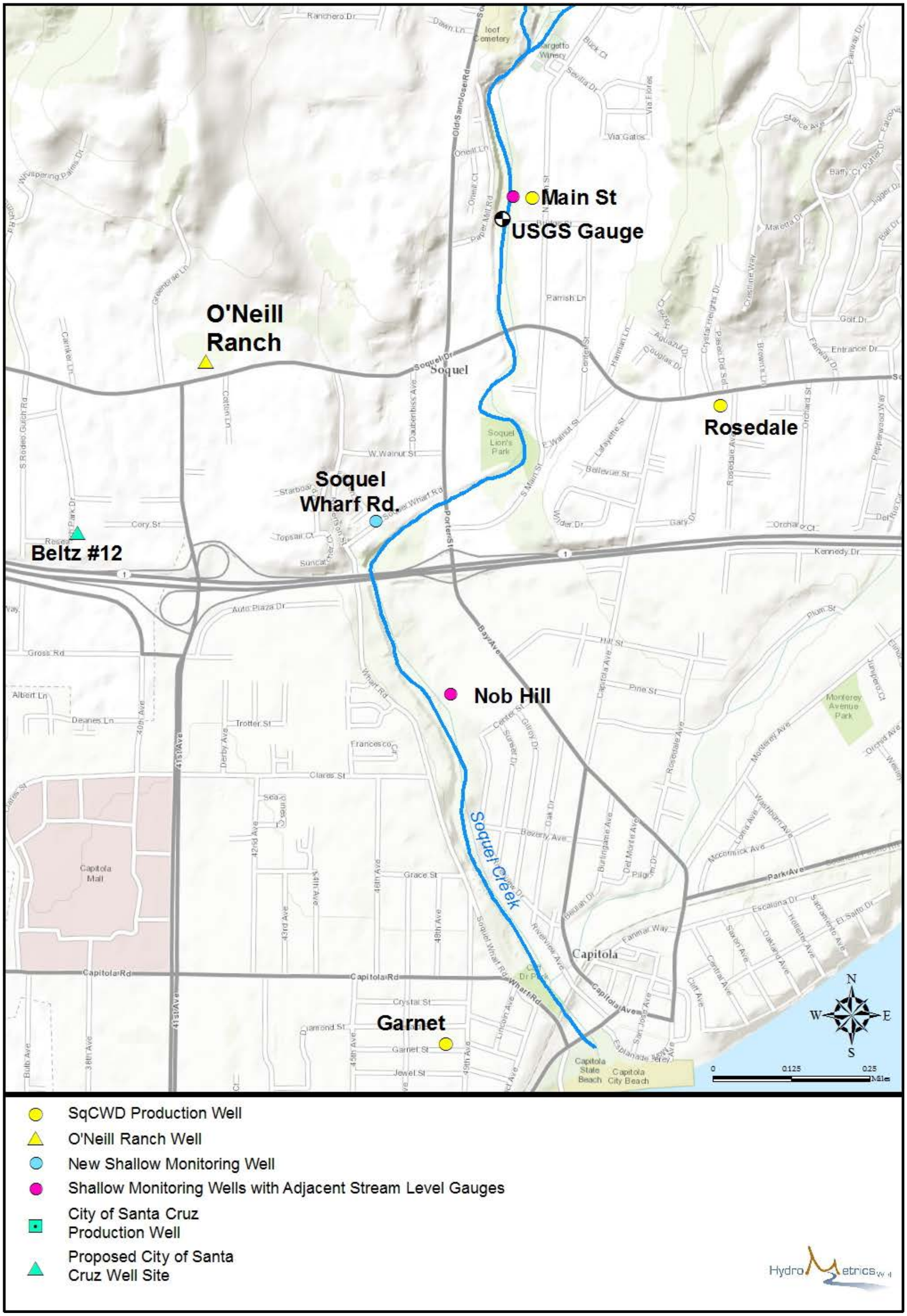

Figure 1: Monitoring Feature Locations

Figure 2: Stream Gauge at Nob Hill Monitoring Site

The weather station at the Main Street monitoring site was installed by Brook Kraeger and District staff on October 5, 2012. It records wind, wind direction, temperature, humidity, barometric pressure, solar radiation, and rainfall. The purpose of the weather station is to assist in the evaluation of weather conditions such as summer fog (radiation), or cold or warm fronts (temperature or changes in air pressure) that may impact the streamflow measurements.

Existing monitoring features included in the monitoring system are a water level gauge in Soquel Creek adjacent to the Main Street monitoring site, the Main Street shallow monitoring well, and the shallow Nob Hill monitoring well. Data from the USGS gauge just downstream of the Main Street site are also used in the analysis. Figure 1 shows the location of all monitoring features that are part of the MAMP.

The shallow well at Nob Hill had to be relocated because of the planned construction of a transmission main and a tie-in to the nearby sewer pump station building. The relocated well was drilled and constructed May 28, 2014 by Exploration Geoservices with oversight provided by HydroMetrics WRI (HydroMetrics WRI, 2014). The well was completed to a depth of 44 feet and screened between 32 and 42 feet below ground surface (bgs) so that the top of the filter pack lines up with the sandstone contact similar to the original well (LKA and LSCE, 2003). The well was developed, sampled, and its monument installed August 15, 2014 by Maggiora Brothers Inc. with oversight provided by HydroMetrics WRI. There is a Mini Diver recording groundwater levels in the original well, and a second Mini Diver was installed in the new well November 20, 2014.

The stream water level gauge adjacent to the Main Street well is upstream of the anticipated effects of the O'Neill Ranch well. Children playing in the riverbed sometime rearrange the gravel bar that controls pool elevation so water changes at this upstream gauge may be common.

Small potential inaccuracies recorded by the 12 year old Stevens sensor in the Main Street stream water level gauge were identified in February 2013. The sensor failed in June 2013. A new Stevens PS7000 sensor was installed by Brook Kraeger and District staff on September 26, 2013. A Baro Diver is also installed in the Main Street stream water level gauge, which does not provide data accurate enough for analysis, but is used to check data from the Stevens sensor. Mini Diver data loggers are installed in the Main Street and Nob Hill shallow monitoring wells to continuously monitor data. The full set of monitoring equipment, particularly the Stevens sensors with the requisite accuracy for monitoring stream level sensors, has been installed since September 26, 2013 so data beginning at that time are presented and analyzed in this report.

Pumping Effects Analyses Overview

This report covers data collected from September 27, 2013 through November 1, 2014. This period covers both autumn 2013, when stresses on the region's aquifers are greatest, and winter 2013/14, which was relatively dry compared to most other years. After March 11, 2014, the Main Street well was taken offline for the rest of the period, but was pumped intermittently as part of its rehabilitation. Analyses entails plotting data collected from the monitoring features described in the section above, and comparing their similarities and differences, with the objective of being able to identify municipal pumping effects on Soquel Creek baseflow.

The analysis methodology included:

1. Plot water elevation hydrographs from upstream and downstream water level gauges, USGS stream gauge, shallow monitoring wells' groundwater levels, and climate data.
2. Plot relative change in hydrographs and overlay on one another.

3. Identify and remove influences other than municipal pumping from the hydrographs. These would include factors such as precipitation, sand bar changes, debris jams, or other incidents.
4. Identify where hydrographs differ to identify influences from municipal pumping.

The methodology compares upstream and downstream water level changes by using relative stream water levels. This approach eliminates the need to establish and maintain ratings curves for each of the gauges. It should be noted that a unit change in relative stream water level at different gauges does not result in an equal unit change in stream flow for those gauges. This is because each gauge's hydraulics are different based on gauge type, substrate, and cross-sectional area.

Figure 3 shows three charts covering the data period (September 27, 2013 through November 1, 2014). The top chart is a hydrograph of streamflow at the USGS gauge just downstream of the Main Street gauge with daily precipitation plotted as columns in blue and analysis periods as black lines; the middle chart includes hydrographs of groundwater elevations in three shallow wells; and the bottom chart reflects pumping at the Main Street well. Each analysis period in the top chart was selected based on when there was no rainfall to influence creek flows and there was pumping at the Main Street well.

The hydrograph of streamflow shows how flows in Soquel Creek at this gauging location are strongly influenced by rainfall. Of note is that the amount of rainfall occurring during this period was much less than usually occurs at this time of year. Only 1.16 inches of rainfall was recorded between September 27, 2013 and January 31, 2014, and 7.15 inches of rainfall for the month of February 2014 at the Main Street weather station. The MAMP is designed to monitor for pumping effects on low flows in Soquel Creek so the period evaluated for pumping effects on streamflow is through February 2, 2014 before streamflow rose above 1.9 cubic feet per second for the rest of the period through March 11, 2014 with the Main Street well online.

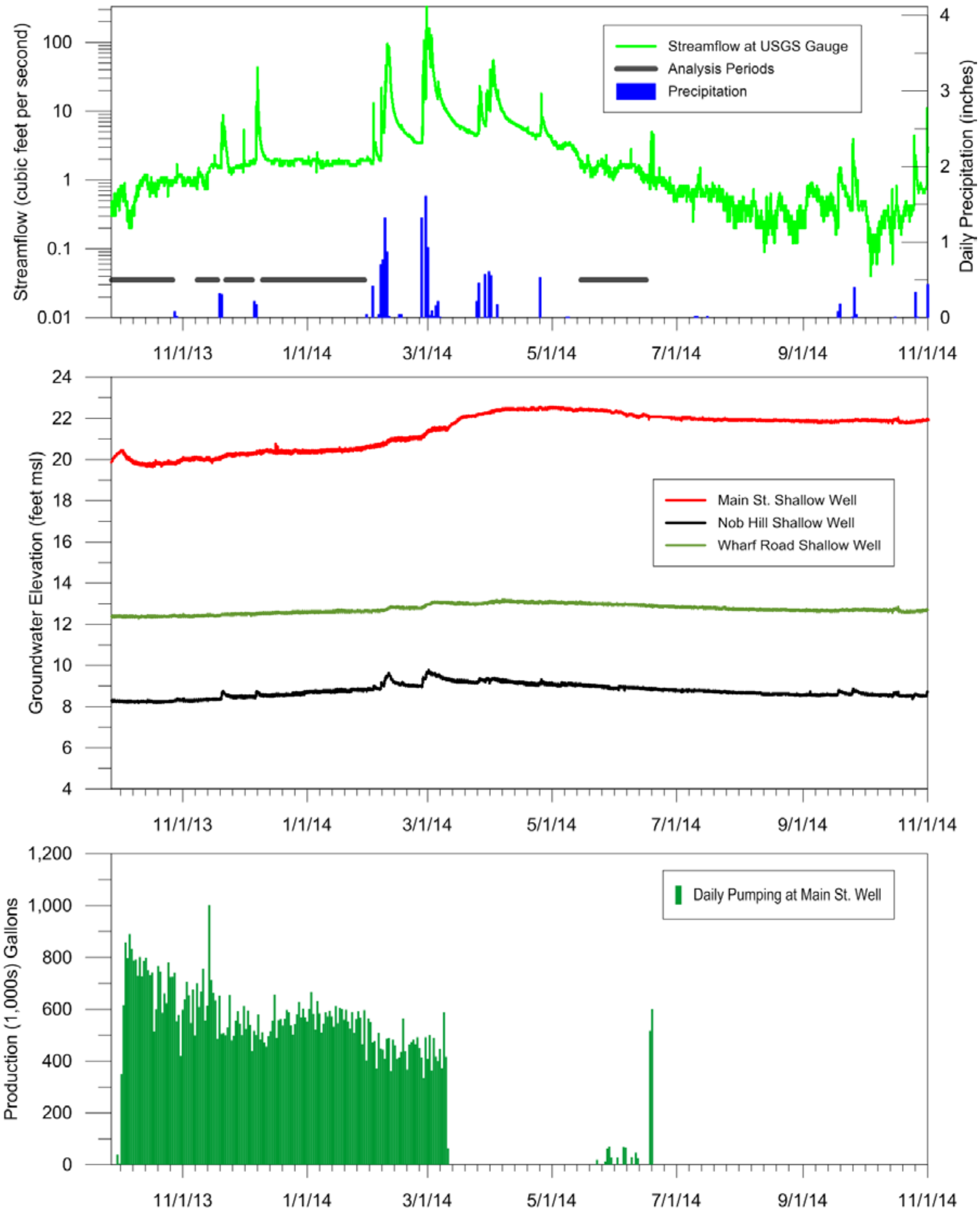

Figure 3: Streamflow, Precipitation, Analysis Periods, Shallow Groundwater Elevations, and Main Street Well Production

Groundwater elevations in the shallow wells do not have large fluctuations. Main Street shallow well groundwater levels are mostly influenced by Main Street production well pumping and less so by rainfall. The increase observed in shallow groundwater levels in the Main Street well over the study period is probably related to the seasonal recovery of groundwater levels after the high demand of summer pumping. Wharf Road well groundwater levels increased very slightly after rainfall in the beginning of February 2014, with the Nob Hill well groundwater levels experiencing slightly greater increases in response to rainfall than Wharf Road well groundwater levels. The Wharf Road and Nob Hill well groundwater levels show no apparent influence from Main Street production well pumping.

When the three streamflow gauges' water level data are compared to one another, it is apparent that the Nob Hill streamflow gauge and the USGS gauge have similar flow patterns. The Main Street gauge is more sensitive and responds with greater fluctuations. Five relative change in creek stage plots are used to identify where potential differences in flow occur between gauges.

The detailed analysis plots (Figure 4 through Figure 8) include pumping at the Main Street production well. At the beginning of each plot, the relative change in creek elevation is reset for all gauges at zero so the plot shows the change in creek stage relative to the plot's start time for all gauges. The groundwater level plotted for the Main Street shallow monitoring well represents the groundwater level relative to the starting creek elevation at the Main Street gauge. The negative values for the groundwater level relative to the creek elevation indicate that shallow groundwater levels are lower than the Creek at the Main Street site and the Creek is a losing stream in this location.

In general, the plots show a response in shallow groundwater levels in the Main Street shallow monitoring well from pumping at the Main Street production well. There is a possible response in stream levels to Main Street pumping as observed at the Main Street stream gauge, however, the response was not consistent over time. The response to pumping was also limited in areal extent as it was less evident in stream levels at the USGS gauge, which is only approximately 200 feet downstream of the Main Street gauge, and also not evident farther downstream at the Nob Hill gauge. Main Street pumping may have an effect on streamflow in Soquel Creek but any effect appears limited in temporal and areal extent as it appears stream levels equilibrate with regional shallow groundwater levels within a short amount of time and a short distance downstream.

This effect is different from what the MAMP anticipated as a result that would show pumping effects on streamflow. The MAMP anticipated greater stream level changes downstream as the cumulative effect of pumping would be greatest downstream. This is not the case for the Main Street well adjacent to the Creek, but may still be the case for the O'Neill Ranch and Beltz #12 wells at greater distances from the Creek.

Pumping Effects Analyses by Period between Rainfall Events

Each of the relative change plots (Figure 4 through Figure 7) are presented with a description of the differences in creek stage at each of the three gauges, along with the identification of any non-municipal pumping influences.

September 27 – October 27, 2013

The relative change plot in Figure 4 represents the beginning of the analysis period where there was no pumping at the Main Street production well for the first three days of the analysis period. The Main Street Stevens sensor recorded spurious data between October 2 and October 4 and therefore these data were excluded from the plot. However, a review of the Baro Diver data from the gauge confirmed water level differences before and after the spurious data.
In this analysis period, the USGS and Main Street gauges show similar relative changes up until October 2 when the Main Street well began pumping. From this point on, water levels at both gauges begin to decline with the Main Street gauge water levels having a slightly greater decline that causes a small amount divergence from the USGS gauge. The water levels at both gauges begin to increase again on October 7. Meanwhile, the downstream Nob Hill gauge water levels does not show a decline after October 2, but shows a similar increase after October 7.

The decline at the two gauges and divergence coincide with the decline in Main Street shallow groundwater levels and the startup of pumping. Unlike the USGS and Main Street gauges, the shallow groundwater levels remain lowered over the analysis period shown on Figure 4 as pumping continued. However, divergence between the USGS and Main Street gauge creek levels continue as the creek levels rise so a pumping effect cannot be ruled out. The lack of evident creek level declines at the Nob Hill gauge indicate that any pumping effect is limited in extent.

The USGS gauge has a noticeable change in creek stage on October 16. This decline in creek stage corresponds with County staff clearing a leaf and debris blockage in the control riffle downstream of the gauge on that day (Ricker, 2013). After the decline, the slope of the relative change hydrograph is similar to the Main Street and Nob Hill gauges' hydrographs.

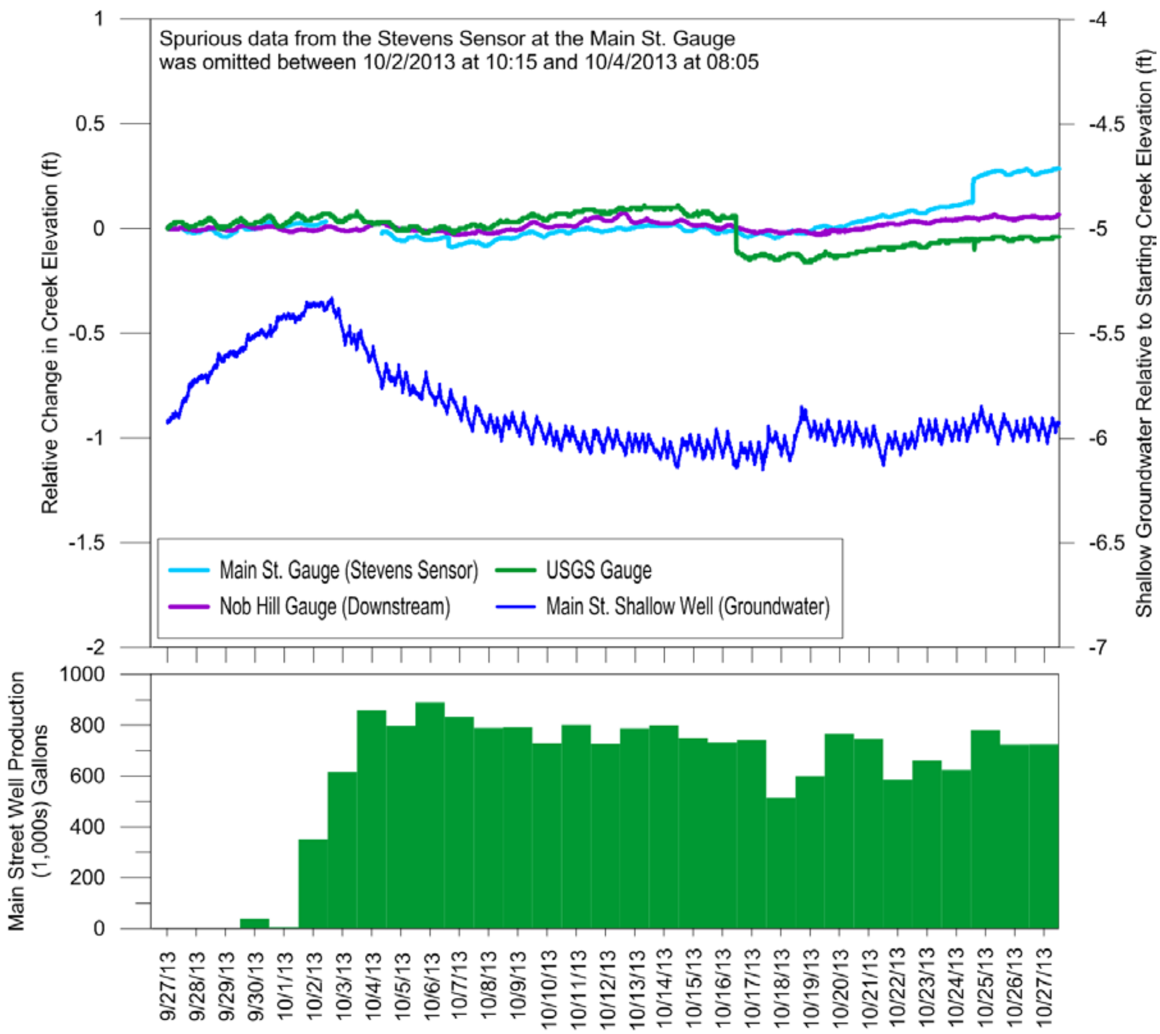

Figure 4: Main Street Well Production and Relative Change in Water Levels from September 27 – October 27, 2013

From October 18, the Main Street gauge creek stage began to diverge and increase at a higher rate than the USGS and Nob Hill gauge stages. This may be related to lower pumping at the Main Street production well and slightly higher shallow groundwater levels at the Main Street well.

On October 24, there is a sudden rise at the Main Street gauge and thereafter creek stage remains high. The USGS gauge has a very small decline in water levels that corresponds directly with the Main Street gauge's rise. This event could have been triggered by debris in the creek causing some localized ponding above the Main Street gauge.

November 6 – November 18, 2013

Figure 5 represents the second analysis period from November 6 through November 18, 2013. There are four divergence events during this period, which do not appear to be related to changes in pumping at the Main Street well. The first overall event occurs on November 7 where the Main Street and USGS gauges have some temporary water level changes that reestablish themselves a few hours later. There is no associated change in Main Street production well pumping and shallow groundwater levels during this event.

The second event on November 8 causes Main Street gauge water levels to decrease and USGS gauge water levels to increase. The USGS gauge relative change in creek elevation is greater than the downstream Nob Hill levels; the Main Street creek elevation drops approximately 0.3 feet relative to stream levels at the Nob Hill gauge. There is no associated change in Main Street production well pumping and shallow groundwater levels. It is likely there was some local activity in the creek that caused this event.

The third event occurred on November 14 when there was a main break on Cindy Lane, north of the Main Street well. Water from the ruptured pipe made its way to Soquel Creek and caused the almost 0.4 foot temporary rise in creek stage. This did coincide with declining shallow groundwater levels with higher pumping on that day but any pumping effect is masked by the water from the main break.

The fourth event, took place on November 16 and is represented by mirrored increases in creek stage at both the Main Street and USGS gauges. There is no associated change in Main Street production well pumping and shallow groundwater levels during this event. This, like the other events, is probably due to a local activity in the creek.

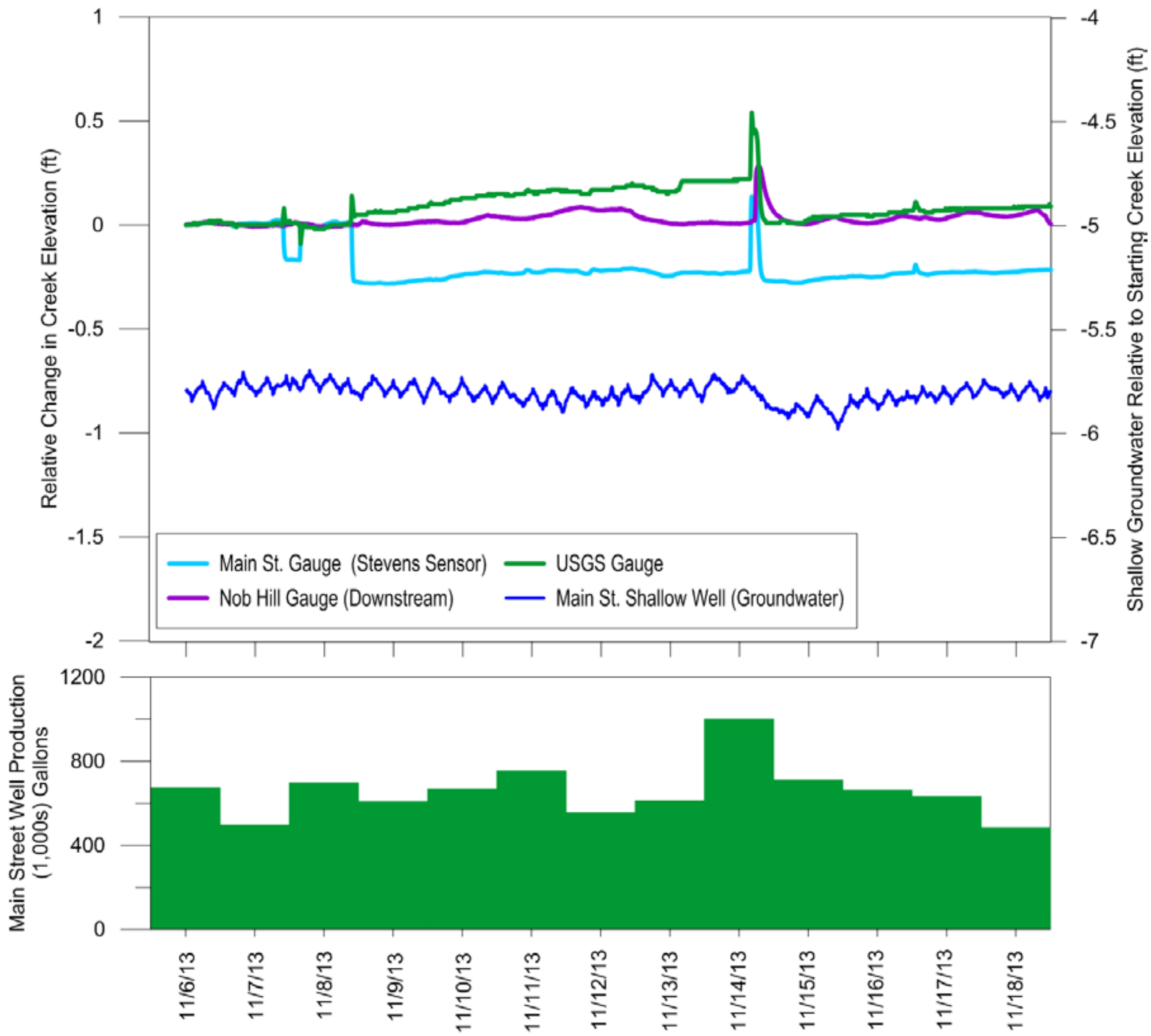

Figure 5: Main Street Well Production and Relative Change in Water Levels from November 6 – November 18, 2013

November 22 – December 5, 2013

The relative change in creek elevation at the three stream gauges was mostly the same for the analysis period between November 22 and December 5, 2013 (Figure 6). For most of the period, relative change in creek elevations at the three gauges were similar. The most significant event occurred on December 1 where there was a sudden increase in stage at all three gauges However, after the temporary rise, the relative change in creek elevations in all three gauges return to the same level. Due to the shapes of the recession curves, it is likely that the sudden rise is due to an unknown discharge into the creek. There is no associated change in Main Street production well pumping and shallow groundwater levels during this event. On December 3, the Nob Hill gauge showed an increase in creek level that was not mirrored by the other gauges.

There is no associated change in Main Street production well pumping and shallow groundwater levels during this event, and thus increased creek levels could be attributable to debris buildup causing local ponding near the gauge.

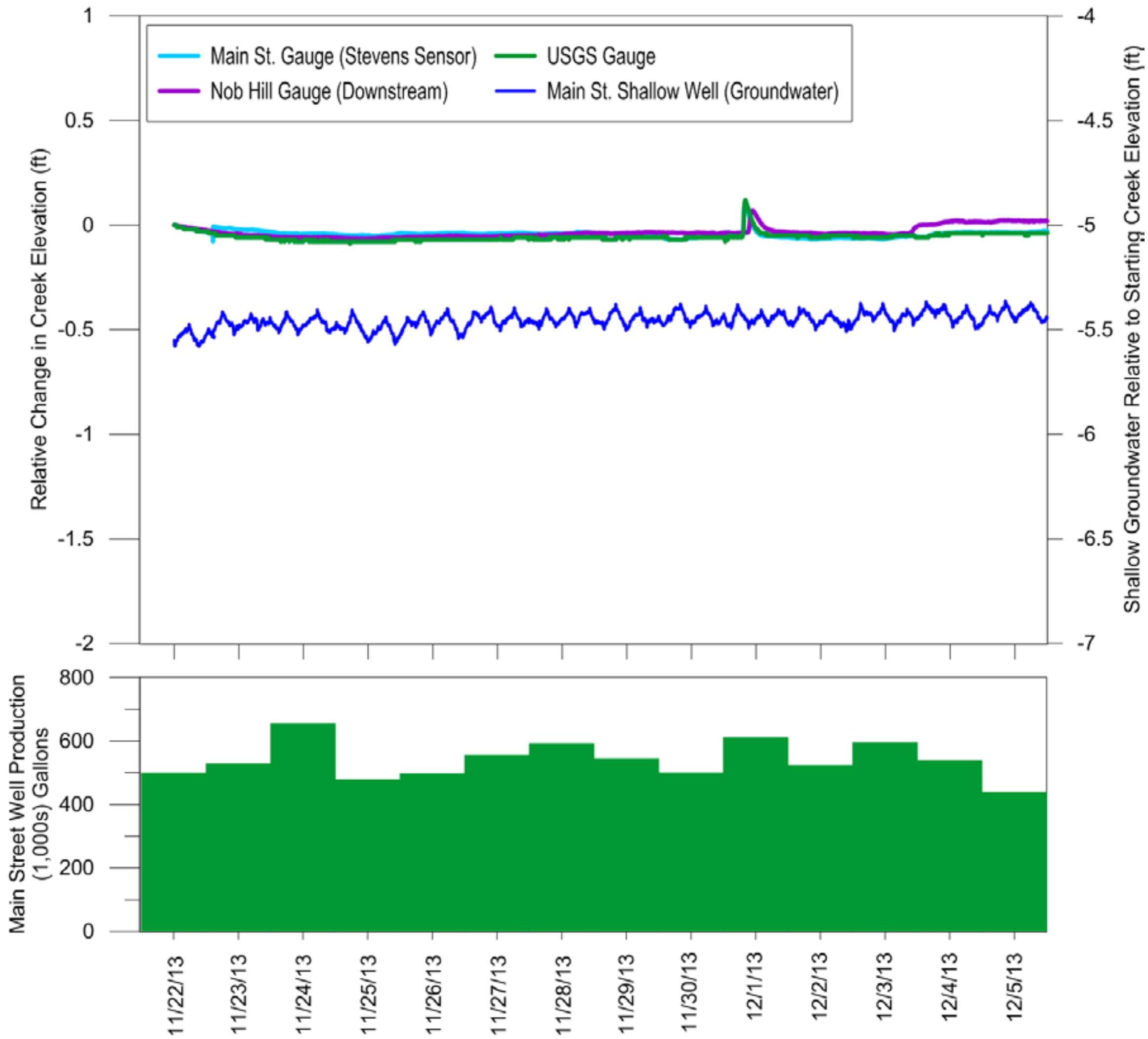

Figure 6: Main Street Well Production and Relative Change in Water Levels from November 22 – December 5, 2013

December 10, 2013 – January 29, 2014

The longest period without rainfall during our analysis period was from December 10, 2013 through January 29, 2014 (Figure 7). During this period, the divergence of water levels observed at the start of the period may be related to flow recession after the previous storm event. Apart from a divergence on January 3, 2014, the USGS and Nob Hill gauges show similar relative changes until January 7 when the relative change in the USGS gauge gradually increases while Nob Hill gauge remains more steady.

The Main Street gauge relative change is similar to the the USGS gauge until January 3 when it continues to increase over the remainder of the period. A sudden increase around January 6 at the Main Street gauge was also registered by the USGS gauge. This time corresponded to a day of increased groundwater production, however the Main Street gauge remained at a higher stage for the remainder of the analysis period while levels at the USGS gauge gradually recovered to levels similar to the downstream Nob Hill gauge. Since the rise in water levels at the Main Street gauge lasted multiple days, it appears unrelated to the groundwater production increase on January 6, which also did not result in a decline in shallow groundwater levels.

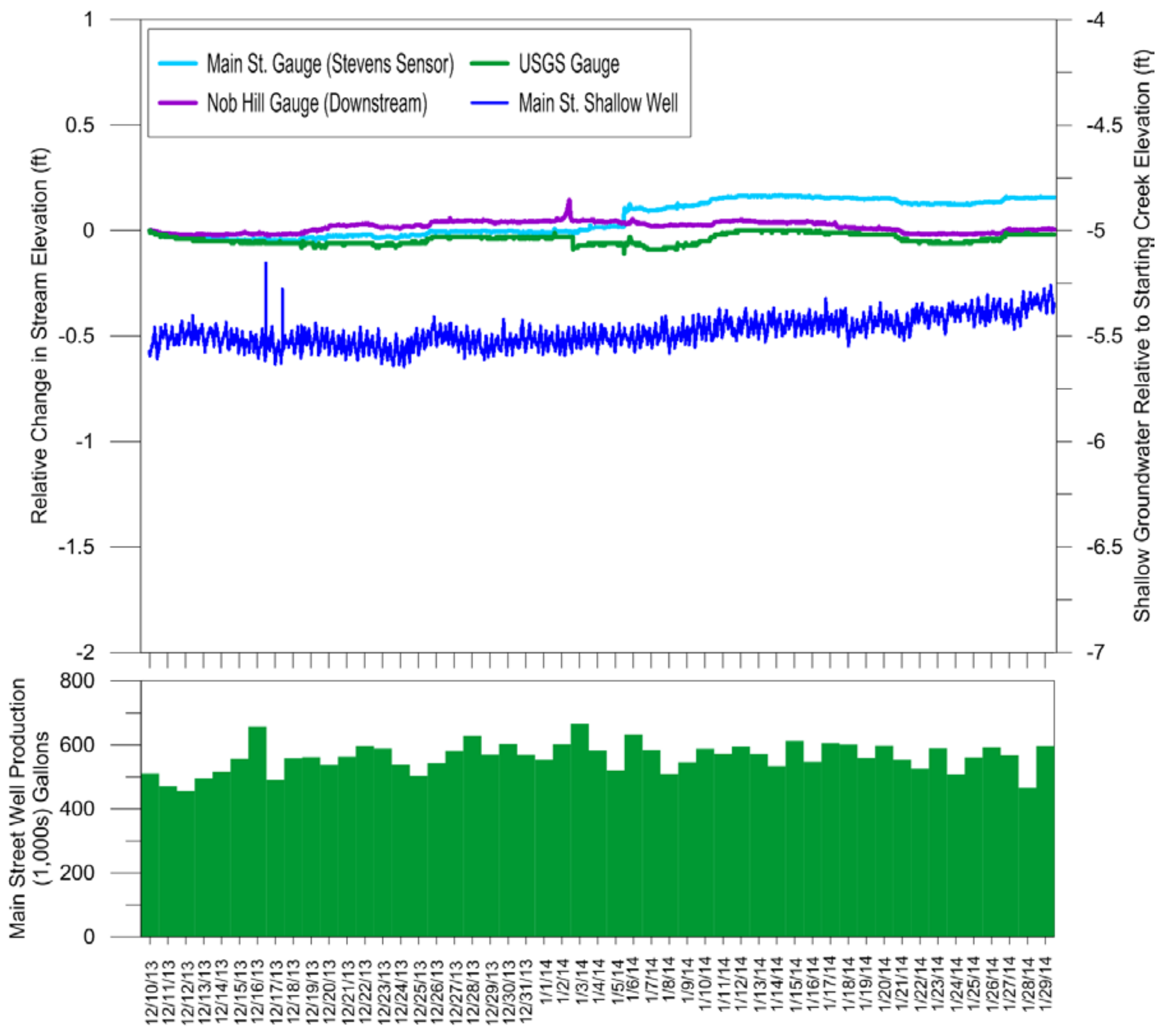

Figure 7: Main Street Well Production and Relative Change in Water Levels from December 10, 2013 – January 29, 2014

May 6, 2014 –June 16, 2014

This period over late spring and early summer was when the Main Street production well was temporarily taken out operation for rehabilitation. The pump was removed from the well in early March. Minimal groundwater production related to well rehabiliation occurred between May 23 and June 12. The amount pumped from the well was approximately seven times less than normal production. A aquifer test took place on June 18 and 19, and the discharge was pumped into the creek. This time period was therefore excluded from the analysis.

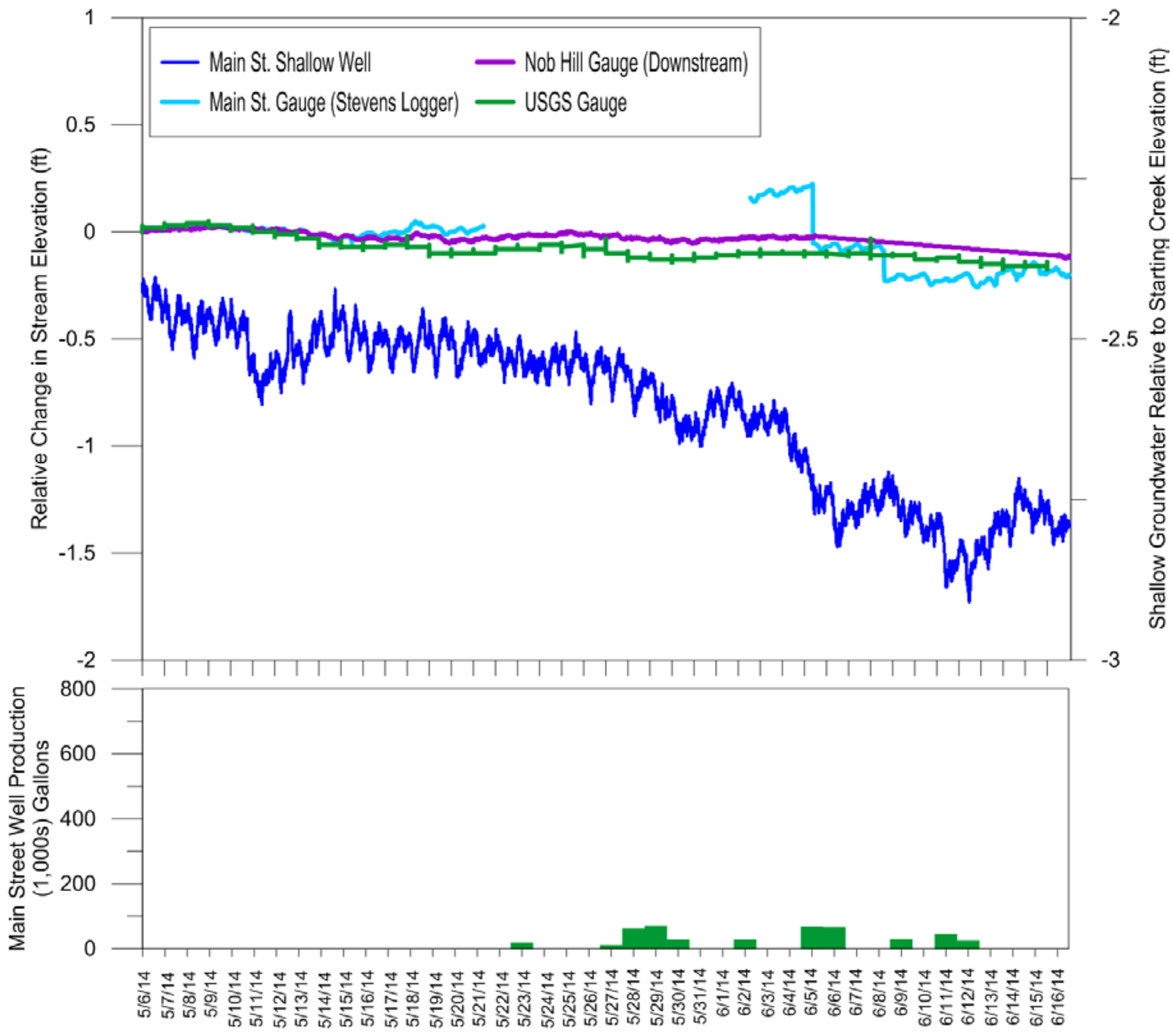

Figure 8: Main Street Well Production and Relative Change in Water Levels from May 6, 2014 – June 16, 2014

Figure 8 shows the seasonal trend of shallow groundwater in the Main Street monitoring well declining over the summer as expected. Even though the amount pumped from the well is small during rehabilitaion, on June 5 – 6, there is a noticeable decline in shallow groundwater levels. Relative declines in stream elevations are not seen in the stream gauges. The Main Street gauge experiences two rapid delines, which are not seen at the USGS gauge, but appear to be too sudden to be related to groundwater pumping.

Recommendations

Based on the data analyzed for this baseline report, there is not a consistent correlation between changes in creek levels to pumping at the Main Street production well. Monitoring of creek data along with groundwater levels from nearby wells should continue, and be analyzed again regularly as pumping commences. Data to be included in that analysis will include the data from after the O'Neill Ranch and Beltz #12 production wells come online in 2015. If that analysis shows a more consistent relationship between creek levels and pumping, we will recommend a pumping test as outlined in the MAMP to confirm the pumping effects by controlling pumping to identify effects on streamflow.

If you have any questions, do not hesitate to contact me.

Sincerely,

Cameron Tana

Cameron Tana, Vice-President
HydroMetrics Water Resources Inc.

References:

HydroMetrics WRI, 2012, Soquel Creek Monitoring and Adaptive Management Plan, prepared for Taj Dufour, Soquel Creek Water District, May 17.

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