TODD GROUNDWATER

February 24, 2016

MEMORANDUM

**To:** Mike Kelley, Mendocino City Community Services District

**From:** Michael Maley, PE, PG, CHg

**Re:** Mendocino 2016 Groundwater Management Update

Todd Groundwater is pleased to submit this technical memorandum documenting the 2016 Groundwater Management Update for the Mendocino City Community Services District (MCCSD or District).

## 1. Scope

The scope of this update is based on an agreement between MCCSD and Todd Groundwater dated December 8, 2015, and authorized by MCCSD on December 22, 2015. The scope consists of the following tasks:

- Evaluate current groundwater conditions based on local groundwater and climate data collected by the District.
- Update the Mendocino Groundwater Model to the most recent groundwater modeling software package to take advantage of new, advanced features.
- Update the Mendocino Groundwater Model with recent data to assess the impacts to groundwater conditions resulting from the recent drought.

To better evaluate groundwater conditions in the context of California's climate, data are evaluated over a water year defined as the period from October through the following September. This period captures the cause and effect relationship on groundwater conditions of the typical rainy winter season followed by the low rainfall and higher pumping during the summer. A water year is differentiated from a calendar year in this report by adding the "WY" prefix to the year.

## 2. Background

The Town of Mendocino is located on the Mendocino Headlands along the Pacific Coast (Figure 1). The Mendocino Headlands Aquifer consists of hard, dark-colored rock (Franciscan Formation) containing numerous fractures overlain by sand layers (terrace deposits). The distribution of the terrace deposits plays a key role in maintaining groundwater levels by acting as a reservoir that recharges the underlying fractured bedrock throughout the year (DWR, 1985; Questa and ETIC, 2004; Kennedy/Jenks, 2006).

Precipitation is the primary source of groundwater recharge for the Mendocino Headlands Aquifer via direct infiltration into the soil. A major portion of the annual groundwater recharge discharges every year through the springs along the cliffs (Questa and ETIC, 2004; Kennedy/Jenks, 2006). Due to the ongoing discharge to springs and low-porosity of the fractured rock, the aquifer has a limited ability to retain groundwater from year to year. Because of this, groundwater recharge from the previous year has a limited influence for sustaining groundwater levels during a subsequent dry year, which leaves Mendocino vulnerable to a single drought season. Conversely, these same characteristics allow the aquifer to recover quickly from a drought with just one season of average to above average precipitation (Questa and ETIC, 2004, Questa, 2006, Kennedy/Jenks, 2006). Therefore, groundwater conditions in Mendocino are closely associated with year-to-year precipitation.

Groundwater is pumped from a privately-owned well at each individual residence and business in Mendocino resulting in several hundred water supply wells located within the District. Typical flow rates range from 1 to 10 gallons per minute (gpm) and well depths typically range between 20 to 200 feet, but newer wells are generally completed deeper with depths ranging from 100 to 150 feet. Each year, some wells run dry in the late summer months and this occurrence is more prevalent during drier than normal years. A WY2014 survey of local well owners showed that shallow wells (less than 35 feet deep) were the most vulnerable to go dry, but a few deep wells were also affected (Kennedy/Jenks, 2015).

The District developed a Water Shortage Contingency Plan (WSCP) that provides guidelines for implementing water conservation measures during drought years (Questa, 2006). For the WSCP, winter precipitation was correlated to summer groundwater conditions. The timing of rainfall was also found to be significant so that a wet spring may ease the impacts to groundwater, whereas a dry spring can exacerbate conditions (Kennedy/Jenks, 2006). As a result, the WSCP requires tracking both total rainfall for the water year starting in October and a spring (February through May) subtotal of (Questa, 2006).

## 3. Recent Drought Overview

The Mendocino area has experienced an extended drought period since WY2012 characterized by significantly below average rainfall. Average annual rainfall for Mendocino is about 40 inches based on precipitation records extending back to 1901 (Figure 2). Below is a brief summary for each year since WY2012 for the recent drought:

- WY2012 had 32.6 inches of total rainfall (82% of average) for the water year and 14.7 inches of spring rainfall (90% of average). A Stage 1 Water Shortage was in effect for most of WY2012.
- WY2013 had 32.2 inches of total rainfall (80% of average) for the water year but only 5.6 inches of spring rainfall (33% of average). A Stage 2 Water Shortage was in effect for most of WY2013.
- WY2014 had 24.2 inches of total rainfall (60% of average) for the water year, but 17.5 inches of spring rainfall (105% of average). A Stage 4 Water Shortage was in effect for most of WY2014.
- WY2015 had 31.1 inches of total rainfall (78% of average) for the water year, but 6.7 inches of spring rainfall (40% of average). A Stage 2 Water Shortage was in effect for most of WY2015.

To address a Water Shortage Emergency, the District Superintendent recommends a declaration of a Stage 1 (least severe) to Stage 4 (most severe) Water Shortage to the Board of Directors based on a schedule of rainfall amounts and groundwater data outlined in the WSCP (Questa, 2006). After Board approval, the District implements the water conservation measures following the guidelines in the WSCP for the appropriate water shortage stage (MCCSD, 2007).

WY2015 started as a Stage 4 (most severe) water shortage because of the extremely low rainfall totals for WY2014, but higher rainfall in WY2015 resulted in a Stage 2 water shortage condition being declared in April 2015. The water shortage condition was changed to Stage 1 in September 2015 based on higher groundwater levels attributed to reduced groundwater pumping as a result of implementation of WSCP water conservation measures, similar to the effect shown in WY2014 (Kennedy/Jenks, 2015).

## 4. Update to Model Software

The Mendocino Groundwater Model is a computer model that simulates groundwater conditions in the Mendocino Headlands Aquifer. The Model was originally constructed using MODFLOW 2000 (Harbaugh and others, 2000), a public domain modeling code developed by the United States Geological Survey (USGS). In 2008, the Model was upgraded to MODFLOW-SURFACT (Version 3, Hydrogeologic, 2006) to take advantage of advanced model features that allow model cells to resaturate after water level declines below the bottom of the uppermost model layer during the dry season (Kennedy/Jenks, 2009). However, MODFLOW-SURFACT is a proprietary code that requires maintaining a separate, expensive software license from a private company.

This year, the Mendocino Groundwater Model was updated using MODFLOW-NWT (Niswonger et al., 2011), which is the latest version of MODFLOW from the USGS. The change to MODFLOW-NWT provides the same or improved functionality as MODFLOW-SURFACT (e.g., advanced mathematical solver, rewetting of dry model cells, handling unconfined conditions and groundwater-surface water interactions). Moreover, MODFLOW-NWT is public-domain software, so it does not require additional licensing fees. MODFLOW-NWT is included with the commercial MODFLOW processor Groundwater Vistas (Version 6, ESI, 2011) that is used to run the Mendocino Groundwater Model. The Mendocino Groundwater Model was updated for WY2012 through WY2015 using MODFLOW-NWT.

To verify the accuracy of the model update, the WY2013 and WY2014 water balance results were compared between MODFLOW-NWT and MODFLOW-SURFACT. In brief, the differences between the model simulations with the two different codes were nominal with percentage differences of less than one percent for each water balance component. The MODFLOW-NWT solver provides a more robust simulation that is able to reach simulation convergence with higher resolution.

## 5. Groundwater Model Update

The Mendocino Groundwater Model was originally constructed in 2004 as part of a state grant to the District (Questa and ETIC, 2004). The Model has been updated periodically since 2006 to evaluate drought conditions (Kennedy/Jenks 2006, 2014 and 2015) and assess remaining groundwater pumping capacity in the District (Kennedy/Jenks 2008, 2009, and 2010). The procedures used for this Model update follow the same methods as previous updates. For the Model update, the primary data and methods used are summarized as follows:

- Monthly rainfall totals are the primary input for estimating groundwater recharge. Rainfall data are collected on a daily basis by MCCSD.
- Initial pumping rates are estimated by MCCSD, and pumping is distributed to individual parcels based on the land use. Updated well locations and land use data were used for WY2015.
- Monthly groundwater elevations measured by MCCSD at 24 wells located throughout the District are used to evaluate model calibration.
- Data input and model calibration followed the procedures used and documented in the initial model study (Questa and ETIC, 2004).
- The eastern boundary condition was changed from a constant head to a specified flux following the same procedures as were used for the modeling to assess drought conditions for the WSCP

(Kennedy/Jenks, 2006). This was done to better estimate groundwater inflows during the drought. The model output was updated for WY2012 through WY2015.

One of the requirements of the Stage 4 Water Shortage declared in WY2014 was to install meters on remaining unmetered water connections. This provides a more complete data set for assessing pumping in the District. The District provided Todd Groundwater with the monthly metered totals and updated information on estimated water use. However, after review and preliminary input of this data into the Model, it became apparent that there are some potential discrepancies between the metered data and the previous assumptions used for the model. Therefore, a more systematic implementation of these data into the Model (including some recalibration to adjust for changes in the pumping distributions) is recommended before these data can be utilized properly. In the meantime, for the 2016 Groundwater Model update applies the same methodology used in all previous model updates, and these procedures will continue to be employed until this more systematic implementation is performed.

## 6. GROUNDWATER MANAGEMENT ASSESSMENT

The Mendocino Groundwater Model was updated for WY2015 using MODFLOW-NWT. Figure 3 provides the simulated groundwater contour map for September 2015. In general, groundwater flows from the highland areas along the center of the District towards the sea cliffs that surround the town. A major portion of the annual groundwater recharge discharges every year through the springs along the cliffs (Questa and ETIC, 2004, Kennedy/Jenks, 2006), which limits the ability of the aquifer to retain groundwater from year to year. Based on this groundwater flow pattern, five groundwater subareas were developed to evaluate more localized conditions (Kennedy/Jenks, 2009).

The Model provides a mechanism to evaluate the effectiveness of water conservation during the recent drought. For this analysis, multiple model scenarios are run using various percentage reductions in groundwater pumping. The scenario that produces the residual mean (average difference between measured and simulated groundwater levels) closest to zero is selected as the appropriate pumping rate. Using this process, it was concluded that local pumping was reduced by 25% and 40%, respectively, for WY2013 and WY2014 (Kennedy/Jenks, 2015). For WY2015, the best fit with the measured groundwater levels occurred by reducing the estimated water demand by 25%. The percentage reduction is consistent with the 20% reduction required for the Stage 2 Water Shortage in effect during the summer of WY2015.

Table 1: Comparison of the Full and Reduced Pumping Scenario Hydrologic Budgets (in acre-feet per year) for WY2015

| | INFLOW (acre-ft) | | | OUTFLOW (acre-ft) | | | | |
|---|---|---|---|---|---|---|---|---|
| **Water Year** | **Ground water Recharge** | **Ground water Inflow** | **Total Inflow** | **Natural Seepage** | **ET** | **Pumping Wells** | **Total Outflow** | **Change in Storage** |
| 2015 - Full | 850 | 16 | 866 | 618 | 134 | 204 | 964 | -90 |
| 2015 - Reduced | 850 | 16 | 866 | 636 | 142 | 154 | 932 | -66 |
| **Difference** | 0 | 0 | 0 | 18 | 8 | -50 | -32 | 24 |

**Note:** Full – assumes groundwater pumping equals projected water demand
Reduced – assumes reduced groundwater pumping reflecting water conservation

Table 1 compares the hydrologic budgets for WY2015 for both the full and reduced water demand Model scenarios. The total inflow is the same, so the difference reflects the effects of reduced groundwater pumping. For WY2015, the estimated groundwater pumping is 50 acre-feet (25%) lower. As a result, there are an additional 24 acre-feet (48%) in aquifer storage and a 26 acre-feet (52%) increase to natural outflows from the aquifer. The additional 24 acre-feet of groundwater remaining in aquifer storage is reflected in the higher groundwater levels.

Table 2 summarizes the annual hydrologic budget from WY1998 through WY2015. The WY2012 through WY2015 values reflect the results of water conservation. As indicated, below-average rainfall occurred in WY2012 and WY2013 leading to lower recharge compared to normal conditions and a loss in groundwater storage. Despite a storage increase in WY2014, the four-year decline of groundwater storage amounted to 145 acre-feet which is about 13% of the long-term average total groundwater inflow. The estimates of groundwater pumping during the recent drought are also significantly lower than in previous years, presumably representing the implementation of the WSCP water conservation measures. As a result of these measures, declines of groundwater in aquifer storage have been lower than would have been anticipated.

Table 2: Model-based hydrologic budget summary (in acre-feet per year) for WY1998 through WY2015

| | INFLOW (acre-ft) | | | OUTFLOW (acre-ft) | | | | |
|---|---|---|---|---|---|---|---|---|
| Water Year | Ground water Recharge | Ground water Inflow | Total Inflow | Natural Seepage | ET | Pumping Wells | Total Outflow | Change in Storage |
| 1998 | 1,589 | 15 | 1,604 | 957 | 355 | 252 | 1,564 | 39 |
| 1999 | 1,390 | 17 | 1,407 | 830 | 297 | 252 | 1,379 | 28 |
| 2000 | 1,148 | 19 | 1,168 | 694 | 223 | 252 | 1,169 | -1 |
| 2001 | 738 | 26 | 764 | 524 | 130 | 252 | 906 | -142 |
| 2002 | 1,083 | 22 | 1,105 | 729 | 202 | 263 | 1,194 | -89 |
| 2003 | 1,370 | 18 | 1,388 | 816 | 297 | 234 | 1,346 | 42 |
| 2004 | 1,165 | 20 | 1,185 | 751 | 225 | 238 | 1,214 | -28 |
| 2005 | 1,237 | 18 | 1,255 | 730 | 266 | 201 | 1,197 | 59 |
| 2006 | 1,589 | 15 | 1,603 | 983 | 367 | 200 | 1,550 | 53 |
| 2007 | 1,013 | 21 | 1,034 | 671 | 193 | 192 | 1,055 | -22 |
| 2008 | 895 | 24 | 919 | 643 | 166 | 191 | 1,000 | -81 |
| 2009 | 702 | 24 | 725 | 454 | 115 | 195 | 763 | -38 |
| 2010 | 1,379 | 17 | 1,396 | 768 | 282 | 194 | 1,244 | 152 |
| 2011 | 1,284 | 18 | 1,301 | 826 | 286 | 194 | 1,305 | -4 |
| 2012 | 945 | 18 | 964 | 648 | 192 | 193 | 1,033 | -69 |
| 2013 | 866 | 16 | 882 | 643 | 148 | 144 | 935 | -53 |
| 2014 | 781 | 15 | 795 | 513 | 124 | 115 | 752 | 43 |
| 2015 | 850 | 16 | 866 | 636 | 142 | 154 | 932 | -66 |
| **18-year Average** | 1,112 | 19 | 1,131 | 712 | 223 | 206 | 1,141 | -10 |
| **Percent of Total** | 98% | 2% | | 62% | 20% | 18% | | |

Figure 4 presents three representative hydrographs that compare the simulated and measured groundwater levels. The hydrographs all show generally lower groundwater levels during the drought with the lowest groundwater levels occurring in WY2014. The graphs show the close correlation of reduced water demand results in matching the measured data.

To further assess the effectiveness of the reduced water demand on the Mendocino Headlands Aquifer, Figure 5 shows the difference in simulated groundwater levels between the full and reduced water demands model scenarios for September WY2015. This map indicates that groundwater levels for the reduced water demand scenario are 6 to 12 feet higher in the downtown area and over 3 feet higher other portions of town. Less densely populated areas and areas near the sea cliffs are less affected.

Figure 6 provides the change in simulated groundwater levels between September 2011 and September 2015 assuming reduced pumping. Estimated groundwater pumping followed the procedure outlined above for estimating the percentage of reduced pumping. The results show that groundwater level declines in the downtown area were on the order of 5 to 10 feet lower over the course of the drought. The model results showed declines of 10 to 20 feet in the southeastern portion of the District.

For comparison, Figure 7 provides the change in simulated groundwater levels over the same period using the full pumping assumption. These results show that groundwater level declines in the downtown area would have been on the order of 10 to 20 feet lower over the course of the drought. This illustrates the effects of reduced pumping in sustaining groundwater levels in the downtown area during the drought. Conversely, the declines in the southeastern portion of the District are similar, indicating that this mostly undeveloped area is more sensitive to the loss of recharge due to the drought.

A comparison of the results shown on Figures 7 and 8 imply that without the reduced groundwater pumping, additional wells would have gone dry and more imported water would have been required, especially in the downtown area. Although other factors may influence decreased water use (including variations in economic activity primarily associated with the number of tourist visits, and the rate of housing occupancy including vacant houses and part-time residents), the Model results indicate that the water conservation measures required by the WSCP are generally being implemented by District residents and businesses.

## 7. GROUNDWATER ZONE ASSESSMENT

The Model was used to develop hydrologic budgets for the five groundwater zones that were defined for the District (Kennedy/Jenks, 2009) to provide a more localized analysis of inflows and outflows. Figure 8 shows the distribution of the groundwater zones relative to the known well density in Mendocino. Table 3 summarizes the zonal hydrologic budgets and the differences in the hydrologic budgets between the full and reduced pumping scenarios for each of the zones to better illustrate the potential effects of the drought and water conservation.

The bottom half of Table 3 provides a summary of the difference between the full and reduced WY2015 simulation by zone. In general, the areas with the largest decrease in groundwater pumping showed the highest increases in aquifer storage. In Zones 1, 2 and 3, representing the downtown area, reduced pumping is estimated at 39 acre-feet, of which 21 acre-feet (54%) remained in groundwater storage at the end of the year. In comparison, Zones 4 and 5, located on the upland areas east of Highway 1, pumping is estimated 10 acre-feet lower, and 3 acre-feet (30%) remained in groundwater storage at the end of the year. This suggests that the water conservation efforts are more effective in the higher well density areas in Zones 1, 2 and 3 (west of Highway 1) primarily due to the density of pumping in the downtown area.

Table 3: Model-based hydrologic budgets (in acre-feet per year) by groundwater zone

| | INFLOW (acre-ft) | | | OUTFLOW (acre-ft) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Zone** | **Ground water Recharge** | **Ground water Inflow** | **Total Inflow** | **Natural Seepage** | **ET** | **Pumping Wells** | **Ground water Outflow** | **Total Outflow** | **Change in Storage** |
| **Water Balance Summary for Reduced Pumping Scenario** | | | | | | | | | |
| **1** | 176 | 27 | 207 | 120 | 7 | 69 | 30 | 226 | -19 |
| **2** | 130 | 65 | 196 | 114 | 35 | 35 | 22 | 207 | -11 |
| **3** | 196 | 41 | 237 | 198 | 15 | 20 | 19 | 252 | -15 |
| **4** | 183 | 19 | 202 | 83 | 60 | 19 | 51 | 212 | -10 |
| **5** | 164 | 40 | 200 | 121 | 25 | 12 | 55 | 212 | -12 |
| **Relative Difference of Reduced Pumping to Full Pumping Scenario** | | | | | | | | | |
| **1** | 0 | -1 | -1 | 7 | 1 | -21 | 1 | -11 | 11 |
| **2** | 0 | 1 | 1 | 4 | 2 | -11 | 1 | -5 | 6 |
| **3** | 0 | 0 | 0 | 2 | 1 | -7 | -1 | -4 | 4 |
| **4** | 0 | 0 | 0 | 3 | 3 | -6 | -1 | -1 | 2 |
| **5** | 0 | 0 | 0 | 1 | 1 | -4 | 1 | -1 | 1 |

**Note:** Groundwater inflow and outflow includes exchange between zones
Natural Seepage – includes outflows to springs, streams, and other drainages
ET – evapotranspiration

## 8. WY2016 GROUNDWATER CONDITIONS

Groundwater conditions are based an assessment of monthly groundwater level data collected by MCCSD staff from 24 monitoring wells located across the District. As a measure of the effects of the drought and the extent of the recovery, Figures 9 and 10 are net change maps for October 2015 and January 2016 relative to the long-term averages for their respective month.

Figure 9 shows the relative difference in measured groundwater levels for October 2015 compared to the long-term average October groundwater levels over the period of record for each of the MCCSD monitor wells. Groundwater levels are generally 1 to 5 feet below the long-term average October groundwater levels in the western part of the District with the greatest negative difference in the western downtown area. A second area of negative difference is located east of Highway 1. A localized area of positive difference is located in the eastern downtown area.

Figure 10 shows the relative difference in measured groundwater levels for January 2016 compared to the long-term average January groundwater levels over the period of record for each of the MCCSD monitor wells. The January 2016 groundwater levels were above average across the District. The distribution of the relative difference indicates that the areas on the west of Highway 1 showed the greatest positive difference. A large portion of the western portion of the District has 5-foot higher groundwater levels.

## 9. EVALUATION OF WY2016 WATER SHORTAGE POTENTIAL

WY2016 started as a Stage 1 water shortage, but was changed to Stage 2 due to limited rainfall in October and low groundwater levels in early November 2015. However, due to heavy rains in December and January along with high measured groundwater levels in December 2014, the water shortage was lifted in January 2016.

The total rainfall from October 2015 through January 2016 is 29.3 inches (140% of average for the period). However, dry conditions returned in February 2016 which is projected to end with well below average rainfall for the month. To provide some preliminary guidance on the likelihood of drought conditions continuing in WY2016, Todd Groundwater evaluated rainfall records from Mendocino and Fort Bragg dating back over 100 years. The probability that the total and spring rainfall requirements for each water shortage category (as defined by the WSCP) will be reached by May 31, 2016 is summarized as follows:

- The rainfall totals for both the Stage 3 and Stage 4 Water Shortage have already been exceeded for WY2016.
- A Stage 2 Water Shortage would require rainfall of less than 2.7 inches of rain during February through May. Based on 104 years of records from Mendocino and Fort Bragg, there has never been an occurrence of less than 2.7 inches of rain during February through May. Therefore, a Stage 2 Water Shortage would require an unprecedented low rainfall total over this period.
- A Stage 1 Water Shortage would require rainfall between 2.7 and 5.7 inches during February through May. Based on 104 years of records, this amount of rainfall has occurred 2% of the time over this period.
- A No Water Shortage Condition would require rainfall in excess of 5.7 inches during February through May. Based on 104 years of records, this amount of rainfall has occurred during the period 98% over this period.

For the period of February through May in Mendocino, the median rainfall is 14.6 inches and the lowest recorded rainfall was 4.6 inches in WY1988. The current long-range forecasts call for average to above-average rainfall for the region. Therefore, the likelihood of a No Water Shortage Condition for Mendocino during WY2016 is considered to be very high.

## 10. Conclusion

The overall conclusion the 2016 Groundwater Management Update concludes that the water conservation measures required under the WSCP are generally being implemented local residents and businesses, resulting in higher groundwater levels across most of the District. Through the implementation of the WSCP, MCCSD has performed sustainable groundwater management during the recent severe drought. Without these water conservation measures, additional wells would have gone dry and more imported water would have been required.

## 11. References

California Department of Water Resources (DWR), 1985, Town of Mendocino Ground Water Study, California Department of Water Resources, June 1985, 53 pp.

ESI, 2011, Guide to Using Groundwater Vistas: Version 6, Environmental Simulations, Inc., Reinholds, PA, 221p.

Harbaugh, A.W., E.R. Banta, M.C. Hill and M.G. McDonald, 2000. MODFLOW 2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-water Flow Process, U.S. Geological Survey Open-File Report 00-92, Reston, Virginia.

Hydrogeologic, Inc., 2006, MODFLOW-SURFACT Software (version 3.0) overview: installation, registration, and running procedures, Hydrogeologic Inc., Herndon, VA.

Kennedy/Jenks, 2006, Mendocino Drought Scenarios, technical memorandum to Mendocino City Community Services District, November 16, 2006.

Kennedy/Jenks, 2008, Mendocino 2007 Model Updates, technical memorandum to Mendocino City Community Services District, January 17, 2008.

Kennedy/Jenks, 2009, Mendocino 2008 Model Updates, technical memorandum to Mendocino City Community Services District, May 1, 2009.

Kennedy/Jenks, 2010, Mendocino 2009 Model Updates, technical memorandum to Mike Kelley, Mendocino City Community Services District, June 23, 2010.

Kennedy/Jenks, 2014, Mendocino 2014 Drought Assessment, technical memorandum to Mendocino City Community Services District, April 2, 2015.

Kennedy/Jenks, 2015, 2015 Groundwater Management Update, technical memorandum to Mendocino City Community Services District, April 24, 2014.

Mendocino City Community Services District (MCCSD), 2007, Ordinance No. 07-4 – Prohibition of Water Wastage, Year-Round Water Conservation Measures, Establishment of Provisions of Water Shortage Emergency Conditions, dated June 25, 2007.

Niswonger, R.G., S. Panday, and M. Ibaraki, 2011, MODFLOW-NWT, A Newton Formulation for MODFLOW-2005, U.S. Geological Survey Techniques and Methods G-A37, 44p.

Questa Engineering, 2006, Water Shortage Contingency Plan, technical report to Mendocino City Community Services District. December 26, 2006.

Questa Engineering and ETIC Engineering, Inc., 2004, Groundwater Modeling Study of the Mendocino Headlands, Mendocino, California, Final Report, May 2004, technical report to Mendocino City Community Services District.

## TABLES



## FIGURES