HYDROLOGICAL STUDY

FOR

PARCELS: 015-380-05, 015-070-45, & 015-070-51

AT

31502 N. HIGHWAY 1
FORT BRAGG, CALIFORNIA

MENDOCINO COUNTY

Prepared for

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Project #270177

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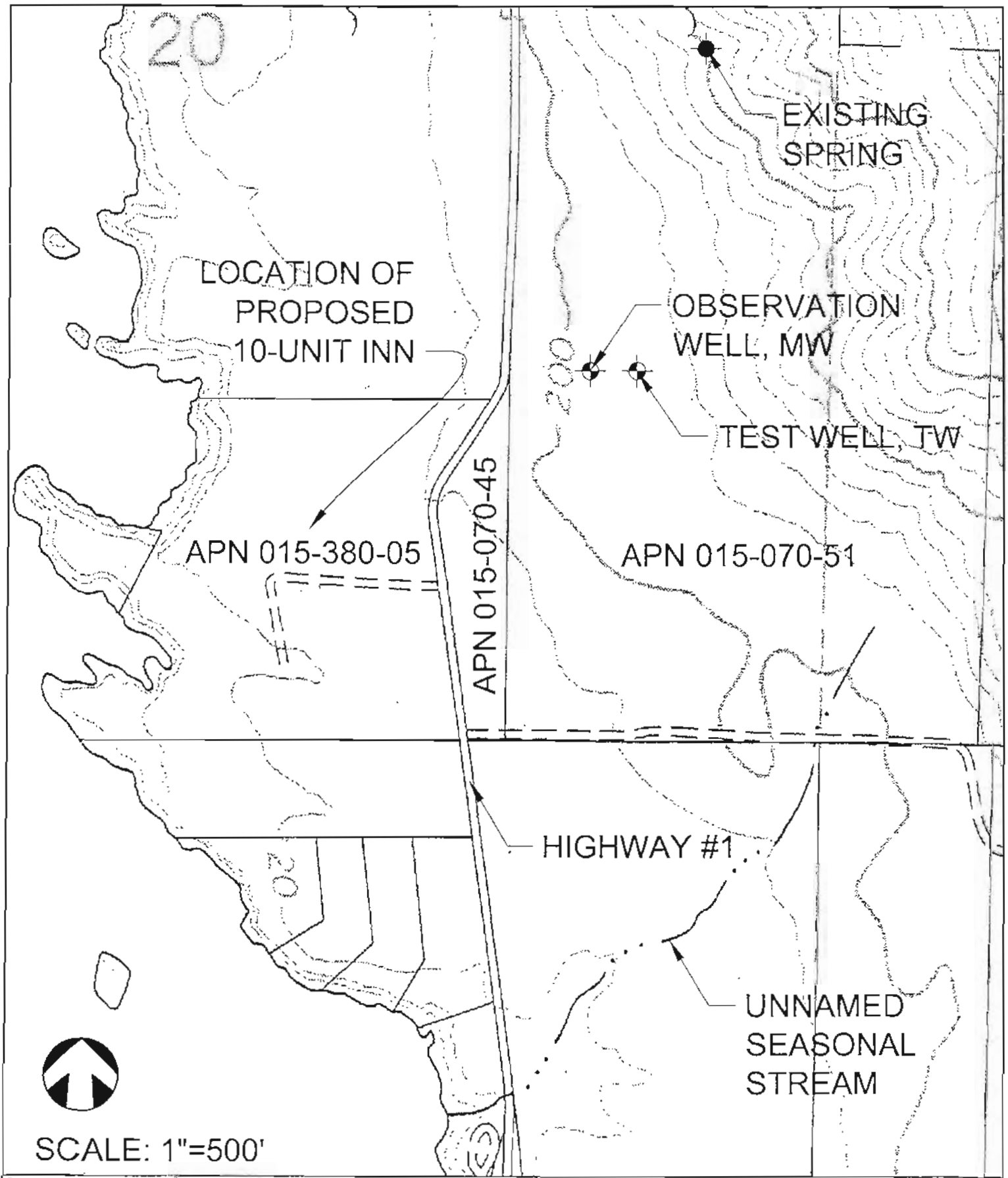

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SITE MAP
31502 N. HIGHWAY #1
FORT BRAGG, CA
Jackson-Grube Family, Inc.

FIGURE
2

Drilling, on the project site (APN 015-070-51); they are located as shown in **Figure 2**. The well construction details for each of the wells are summarized in **Table 1**. A copy of the Well Completion Report (i.e., Driller's Log) for each well is provided in **Appendix A**. As indicated, both wells have a 5-inch diameter casing and a 20-foot annular seal. The proposed supply well (TW) is 60-feet deep; and Well MW, the observation well, is 100-feet deep. The drilling logs indicate similar subsurface conditions at the two wells; the main difference is a greater thickness of terrace materials at Well TW (40 feet) as compared with Well MW (31 feet). Of particular note is the difference in the gray gravel layer, which is 18-feet thick (22 to 40 feet) at Well TW, and is only 5-feet thick (26 to 31 feet) at Well MW. This appears to be the primary water-bearing layer; and the difference in thickness likely explains the higher yield for TW. At the time of installation the well driller reported a yield of approximately 5 gpm at TW, and only 2 gpm at MW. In his 1994 study, Clark conducted a 72-hour pumping test of Well TW and documented a yield of better than 6 gpm. Well MW was used as an observation well during his test. For the present study, a repeat testing of Well TW was conducted to verify the current well yield, again using MW as an observation well.

Table 1. Onsite Well Construction Details

CHARACTERISTIC	WELL TW	WELL MW
Well Completion Report No.	419974	419973
Date Installed	10/26/2004	10/24/2004
Type of Well	Composite (Supply Well)	Composite (Monitoring Well)
Total Depth (ft)	60	99
Casing Diameter (in)	5	5
Annular Seal Depth (ft)	20	20
Screened Interval	20' to 60'	20' to 99'
Depth to Water at Time of Drilling (ft)	20	15
Depth to Bedrock (ft)	40	31
Saturated Thickness of Terrace Deposits (ft)*	20	16

* *At time of drilling*

PUMPING TEST PROCEDURES

Carl Rittiman and Associates conducted a 72-hour pumping test for Well TW during the period of October 9-12, 2007. During the pumping of Well TW, Well MW served as an observation well. The pumping test was conducted to determine the sustained yield and drawdown characteristics of Well TW and the local aquifer according to the following testing procedures.

- **Pumping Equipment.** A pump was installed in Well TW, approximately 8 feet from the bottom of the well. A valve was installed on the discharge line to adjust the flow rate from the

well. The flow from the well was discharged approximately 200 feet downslope of Well TW into a drainageway, outside the immediate well recharge area.

- **Flow Metering.** Flow metering was done manually at periodic intervals throughout the pumping test. A bucket and stop watch were used to determine the instantaneous flow rate. Typically, measurements were made every five minutes during the first 20 minutes of pumping, then every 10 minutes for about 80 minutes, then every 20 minutes for 80 minutes, then every 30 minutes for 180 minutes, then every 60 minutes for 8 hours, and then every 120 minutes for the duration of the 72 hours.

- **Drawdown Measurements.** Drawdown measurements were taken at both wells throughout the duration of the test at the same time intervals as the flow metering. While Well TW was being pumped, the water levels in Well MW were monitored. Measurements of the water levels were made with a water level probe, referenced to the wellhead.

- **Pumping Rate.** Well TW was tested at a constant pumping rate of approximately 6.3 gpm for the full duration of the 72-hour test.

- **Recovery.** At the conclusion of pumping, periodic readings of water level recovery in pumping Well TW were made for 28 hours, during which time Well TW recovered 96% of the entire drawdown depth experienced during pumping. Recovery was also monitored at Well MW for a 28-hour period following pumping, during which time it recovered 92% of the entire drawdown experience during pumping.

- **Monitoring of Neighboring Wells.** Notice of the pumping test was provided to neighboring property owners (see **Appendix A**). However, the nearest neighboring wells are more than ¼-mile south of Well TW, far beyond the expected zone of influence of the test well. Therefore, no neighboring wells were monitored during the pumping test. Also, no neighbors reported any apparent effects on their wells at the time of the pumping test.

PUMPING TEST ANALYSIS

Pumping Data

The data recorded from the pumping tests are provided in **Appendix B**. The pertinent data from the test are shown in **Table 2**.

Table 2. Pumping Test Data

Test Data	Well TW	Well MW
Well Depth (feet)	60	99
Total Pumping Duration (minutes)	4,320	-
Total Volume Pumped (gallons)	27,041	-
Average Pumping Rate (gpm)	6.3	-
Initial Depth to Water (feet)	22.58	12.0
Water Level at End of Test (feet)	37.71	13.73
Maximum Drawdown Achieved (feet)	15.13	1.73
Total Saturated Thickness of Aquifer (feet)*	37.42	87.0

** At time of pumping test*

Well and Aquifer Characteristics

- **Drawdown and Recovery**. The time-drawdown and recovery plots for pumping Well TW are shown in **Figures 3** and **4**. The time-drawdown and recovery plots for observation Well MW are shown in **Figures 5** and **6**. A review of the time-drawdown data for the test wells follows.

  1. **Pumping Well TW.** Time-drawdown data for Well TW (**Figure 3**) reveal that at the beginning of the pump test, the pumping rate was approximately 6.63 gpm for the first 5 minutes, before it was adjusted to a little less than 6.3 gpm, which was maintained for the remainder of the test. The average pumping rate over the entire duration of the test was 6.26 gpm. At this pumping rate, the water level drawdown in the pumping well stabilized over the last 22 hours of the test at approximately 15 feet below the initial static level; the final drawdown measurement was 15.13 feet.

     Recovery of Well TW (plotted in **Figure 4**) was monitored immediately following the end of pumping. The well recovered 96 percent of the drawdown (15.13 feet) within 28 hours after pumping ended.

  2. **Monitoring Well MW.** The time-drawdown and recovery plots for observation Well MW are shown in **Figure 5** and **6**, respectively. Maximum drawdown achieved near the end of the test was measured to be 1.73 feet.

     Recovery of Well MW (plotted in **Figure 6**) was monitored immediately following the end of pumping. The well recovered 92 percent of the drawdown (1.73 feet) within 28 hours after pumping ended.

- **Transmissivity**. Transmissivity of the aquifer, in the immediate area of the pumping well, can be calculated from the time-drawdown and recovery data according to the following formula:

$$T = \frac{264\ Q}{\Delta s}$$

Where:

T = Transmissivity (gpd/ft)
Q = Constant pumping rate (gpm)
Δs = Drawdown or recovery in the pumping well for one log cycle (feet)

Using the steepest slope of the drawdown curve over one log cycle, between 100 and 1,000 minutes, the value Δs was determined graphically to be 1.5 feet, and the transmissivity was calculated to be approximately 1,109 gpd/ft as follows (see **Appendix C**):

$$T = \frac{(264)(6.3\ gpm)}{1.5\ ft} = 1{,}109\ gpd/ft$$

In his 1994 study Clark reported a transmissivity value of 1,300 gpd/ft for Well TW, which compares closely to the current test results. Both results are indicative of permeable conditions and a productive aquifer at the location of Well TW.

- **Aquifer Storage**. The DWR Groundwater Study (1982) estimated the average specific yield of the terrace deposits in the Westport Subunit, to be approximately 9.0% (0.09), and substantially less in the Franciscan bedrock.

For site-specific validation, the Theis non-equilibrium equation was used to estimate the storativity from the observed drawdown of Well MW during the 72-hour pumping test of Well TW. By trial-and-error, we determined that a storativity of 0.2% (0.002) yields the best match between the predicted drawdown and observed drawdown at Well MW (1.73 ft.) during the 72 hours of pumping. Supporting calculations are provided in **Appendix C**. In his 1994 study, Clark determined a lower aquifer storativity of 0.00132. Both of these results for storativity are substantially lower than the average value (0.09) estimated by DWR for the terrace materials. The lower values reflect conditions influenced by bedrock geology and possible partial confinement of the aquifer.

The total volume (V) of water in aquifer storage within the limits of the property can be estimated using: (1) the storativity value of 0.2% determined above; (2) an estimated saturated aquifer thickness of 62 feet (based on the average between Well TW and MW); and (3) the 148-acre parcel size. The calculation is given below:

V = (148 acres)[(62 ft)(0.002)](325,851 gallons/acre-feet)
V = (18.35 acre-feet)(325,851 gallons/acre-feet)
V = 5,979,365 gallons

The above calculation gives only a very rough approximation of the amount of groundwater in storage on the property, since it is based solely on conditions found at the pumping and monitoring well location. Also, not all of this water is necessarily available for extraction from pumping Well TW, since the well cannot realistically draw water from the entire 148-acre parcel. By inspection of the topography we estimate groundwater occurring within about 25% of the property (approximately 37 acres) supplies water to the area of Well TW. Accordingly, the effective volume of groundwater in storage and available for extraction (at the end of the dry season) is on the order of about 1.5 million gallons (0.25 x 5.98 million gallons = 1.5 million gallons).

- **Sustained Yield**. Equilibrium conditions were achieved for Well TW during the 72-hour pumping test and, thus, the sustained long-term yield of the well is approximated by the final, stabilized pumping rate of 6.26 gpm. The stabilized pumping rate of 6.26 gpm equates to a daily yield of about 9,000 gpd, or roughly 2.4 times the projected maximum daily water use of 3,800 gpd for the project. In his 1994 study, Clark estimated the yield for Well TW to be about 6 gpm, which is consistent with the results of the current updated testing of the well.

- **Specific Capacity.** The specific capacity (Q/d), the discharge per unit of water table drawdown, is calculated from the stabilized pumping rate or discharge (Q) and the total drawdown (d) for the pumping well at the end of the test as follows:

  Q/d = 6.26 gpm/15.13 ft
  Q/d = 0.41 gpm/ft

  For the projected peak water demand of 2.64 gpm, the resulting drawdown in supply Well TW would be approximately 6.4 feet (2.64 gpm/0.41 gpm/ft = 6.4 ft).

DISCUSSION AND CONCLUSIONS

Well Yield

The pumping test demonstrated a stabilized yield of 6.26 gpm for Well TW over a sustained 72-hour pumping period at the end of a below average rainfall year. This pumping rate corresponds to a daily pumping volume of 9,014 gallons per day. The well is planned to supply a 10-unit inn and caretaker residence, which are expected to have maximum daily water supply needs of about 3,800 gpd. The long-term or average water demand would be less than this amount, due to fluctuations in occupancy. An annual average occupancy of 80 percent would translate to an average daily water demand of approximately 3,000 gpd. The pumping tests results are similar to those documented by Clark in 1994, showing that the proposed supply Well TW has more than ample capacity to meet the water demands for the project, considering both average and peak usage.

Water Table Drawdown Effects

Since there are no existing neighboring wells within about ½-mile of the proposed supply Well TW, no monitoring of water table drawdown at neighboring properties was conducted during the pumping test. Instead, water table drawdown was monitored at observation Well MW, located about 190 feet from the test well. The drawdown data from Well MW were then used to calculate the theoretical

drawdown effects for different (longer) pumping periods and for different rates of pumping. The calculations are provided in **Appendix D**. The following assumptions and approach were used in this analysis.

- **Pumping Rates and Duration.** Drawdown calculations were made assuming pumping of Well TW at various pumping rates of 2.0, 3.0 and 4.0 gpm, for a duration of 90 days and 180 days during the dry (fall) period. This provides projected drawdown impacts for a range of potential conditions pumping conditions.

- **Distances.** Calculations of drawdown effects were made for distances of 190 feet and 400 feet from Well TW to estimate the effects, respectively, at Well MW and at the westerly property line of parcel 015-070-51 (the well parcel).

- **Transmissivity.** The transmissivity value of 1,109 gpd/ft., as determined from the time-drawdown data for pumping Well TW was used for the calculations.

- **Storativity.** The storativity value of 0.002 determined (as previously described) from the pumping test observation well data was used in the calculations.

The calculated drawdown influences are summarized in **Table 3** for the different pumping scenarios. In the last column, the percent drawdown is shown, which indicates the relative amount as a function of the available saturated thickness of the aquifer. The saturated thickness

Table 3. Summary of Calculated Drawdown Effects From Pumping of Supply Well TW

Affected Location	Distance from Pumping Well TW (ft)	Pumping Rate (gpm)	Pumping Duration (days)	Calculated Drawdown (ft)	Percent Drawdown (%)*
MW	190	2.0	90	1.25	3.3
Property Line	400	2.0	90	0.94	2.5
MW	190	3.0	90	1.87	5.0
Property Line	400	3.0	90	1.41	3.8
MW	190	4.0	90	2.49	6.7
Property Line	400	4.0	90	1.88	5.0
MW	190	2.0	180	1.39	3.7
Property Line	400	2.0	180	1.08	2.9
MW	190	3.0	180	2.08	5.6
Property Line	400	3.0	180	1.62	4.3
MW	190	4.0	180	2.78	7.4
Property Line	400	4.0	180	2.16	5.8

** Based on available saturated thickness of 37.4 per hydrogeologic conditions at Well TW*

of the aquifer at Well TW, determined at the time of pumping to be 37.4 feet, was used for all of the percentage drawdown calculations to be conservative (safe). The results show the drawdown effect to be in the range of 2.5 to 6.7 percent of the available drawdown across the range of pumping conditions considered in these calculations. This amount of projected drawdown impact falls within the 10-percent drawdown criterion contained in the Mendocino County Coastal Groundwater Development Guidelines. Since drawdown effects decrease exponentially at distance from the pumping well, the projected impacts on the water table at the nearest neighboring wells, more than ¼-mile from Well TW, would be negligible and much smaller than the results shown in **Table 3** for locations near the well.

Regional Aquifer Impact

The effects on the local groundwater aquifer due to the proposed addition are determined to be negligible. This is based on the following considerations.

- **Adequate Well Yield.** Based on the stabilized rate achieved during the pumping test, Well TW shows a sustained yield of 6.26 gpm, respectively. Since the projected peak water use is 3,800 gpd (2.64 gpm), there is a sufficient supply from the well to meet the needs of the project. Other supplemental sources will not be needed.

- **Percentage of Groundwater Replenishment.** The proposed supply well draws groundwater from both the deeper Franciscan formation and the shallow terrace deposits. The source of groundwater replenishment includes principally on-site percolation of rainwater, plus some amount of lateral groundwater inflow from the watershed area to the east. Based on an average year-round occupancy of 80 percent, the annual extraction of groundwater for the project is estimated to be as follows:

  (365 days)(3,000 gpd) = 1,095,000 gallons per year

  The annual replenishment of the aquifer solely from on-site percolation of rainfall over the approximately 37-acre groundwater recharge area for Well TW is estimated to be:

  (37 acres)(43,560 ft^2/acre)(1.0 ft/yr recharge)(7.48 gal/ft^3) = 12,055,665 gallons

  This calculation assumes an available recharge area of 37 acres (as previously discussed), and an annual onsite deep percolation (i.e, recharge) of 12 inches of rainfall, which is a reasonable assumption for the gently sloping terrain, permeable terrace deposits and rainfall conditions at the site. The Fort Bragg area has an average annual rainfall of about 40 inches.

  The average rate of groundwater extraction (1,095,000 gal/yr.) is, therefore, estimated to be about 9.1 percent of the annual replenishment of the aquifer from on-site rainfall percolation. This demonstrates that the extraction of groundwater for the proposed project is safely within the estimated average annual amount of on-site recharge to groundwater within the portion of the property tributary to the supply well.

- **Percentage of Groundwater in Storage.** The annual groundwater pumpage for the proposed 10-unit inn and caretaker residence (1,095,000 gal/yr.) is estimated to equal about 73 percent

of the minimum amount of water in aquifer storage (estimated to be about 1.5 million gallons) at the end of the dry season. This considers only the groundwater within the approximately 37-acre aquifer area surrounding the proposed supply well (TW); it does not include groundwater in storage throughout the remainder of the 148-acre parcel on which the well is located.

Water Quality

A water sample was obtained from the proposed supply Well TW on November 7, 2007 by Carl Rittiman and Associates. The water sample was tested for standard mineral analysis by Alpha Analytical Laboratories, Inc. The laboratory results are provided in **Appendix E**. The results for all constituents tested fall safely within the primary and secondary drinking water standards, except for iron, manganese and hardness, which were found at levels above the recommended consumer acceptance concentrations. The turbidity reading was also high; this was likely a result of the sampling process (bailer method). The water quality test results indicate the groundwater to be suitable for domestic uses and typical of conditions along the Mendocino Coast; however a treatment system for iron and manganese will likely be needed to reduce the staining effects normally caused by these constituents at concentrations above the consumer acceptance limits.

REFERENCES

- Driscoll, Fletcher, G. Groundwater and Wells. Johnson: 1986.
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