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Evaporation Study for Colusa, California

**Location: Laux Road at River Road in
Colusa California, Colusa County, 95932**

Date: July 5 – 27, 2007

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Table of Contents

1.	Project Overview	1
2.	Detailed Weather Analysis	6
2.1	Temperatures	6
2.2	Relative Humidity	9
2.3	Winds	10
2.4	Precipitation	11
3.	Water Trough Evaporation Analysis	12
3.1	Water Trough Specifications	12
3.2	Evaporation Formula	14
3.3	Daily Evaporation Rates	16
3.4	Daily Water Evaporation / Consumption	17
4.	Conclusion	18

Tables

Table 1:	Weather Observation Sites Used for Study	3
Table 2:	Daily Mean Temperature Summary, 5 to 27 July 2007	6
Table 3:	Daily Maximum Temperature Summary, 5 to 27 July, 2007	7
Table 4:	Daily Minimum Temperatures, 5 to 27 July 2007	8
Table 5:	Daily Precipitation for July 5 through 27, 2007	11
Table 6:	Calculated Daily Evaporation Rates	16
Table 7:	NWS Evaporative Pan Studies	17
Table 8:	Water Trough Depletion Summary	18
Table 9:	Water Trough Depletion Daily Chart	18

Figures

Figure 1:	Overview Map of Site of Interest	1
Figure 2:	Aerial of Site of Interest	2
Figure 3:	Weather Stations Used for Study	3
Figure 4:	Inverse Distance Weighting Function	4
Figure 5:	Daily Mean Temperatures	6
Figure 6:	Daily Maximum Temperatures	7
Figure 7:	Daily Minimum Temperatures	8
Figure 8:	Analyzed Site Hourly Temperatures	9
Figure 9:	Analyzed Site Hourly Relative Humidity	10
Figure 11:	Daily Total Precipitation	12

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1. Project Overview

This project involved the analysis of historical weather for the dates of 5 to 27 July 2007 for the vicinity of the intersection of Laux Road and River Road, in Colusa County, California, hereafter known as the “site of interest”. The site of interest is located just to the east of the Sacramento River (figure 1) at:

Latitude: 34.25 N

Longitude: 122.00 W

Elevation: 62 feet (above sea level)



Figure 1: Overview Map of Site of Interest

The site is also annotated on figure 2, an aerial view of the area from Google Earth™. Figure 2 indicates the site of interest is located in a fairly open area, surrounded primarily by crop and pasture land with a low trees scattered to the west near the Sacramento River.



Figure 2: Aerial of Site of Interest

The objective of this analysis was to attempt to determine the most probable evaporation rate for a 300 gallon animal water trough, Rubbermaid model 4247, given the observed weather conditions for the period of interest, 5 to 27 July, 2007.

To produce the most accurate analysis, a multi-station analysis was performed using nine weather-reporting sites in the region (Table 1 and figure 3). These sites provided an adequate coverage of the area, with sites located in a spatial pattern that framed the site of interest's location. The below table denotes all weather stations used for this study.

Table 1: Weather Observation Sites Used for Study

Station Name	Callsign	Latitude	Longitude	Distance to Site (mi)	Elevation (feet)
BEALE AFB	KBAB	39.13 N	121.43 W	31.3	11.6
MARYSVILLE	KMYV	39.1 N	121.57 W	24.9	5.8
OROVILLE	KOVE	39.49 N	121.62 W	26.2	17.4
RED BLUFF	KRBL	40.15 N	122.25 W	63.9	32.4
SACRAMENTO	KSAC	38.52 N	121.5 W	56.8	1.4
SACRAMENTO METRAPOLITIAN AIRPORT	KSMF	38.7 N	121.6 W	43.3	2.1
SANTA ROSA	KSTS	38.5 N	122.82 W	68.0	11.6
UKIAH	KUKI	39.13 N	123.2 W	65.0	57.5
VACAVILLE	KVCB	38.38 N	121.96 W	59.9	10.4

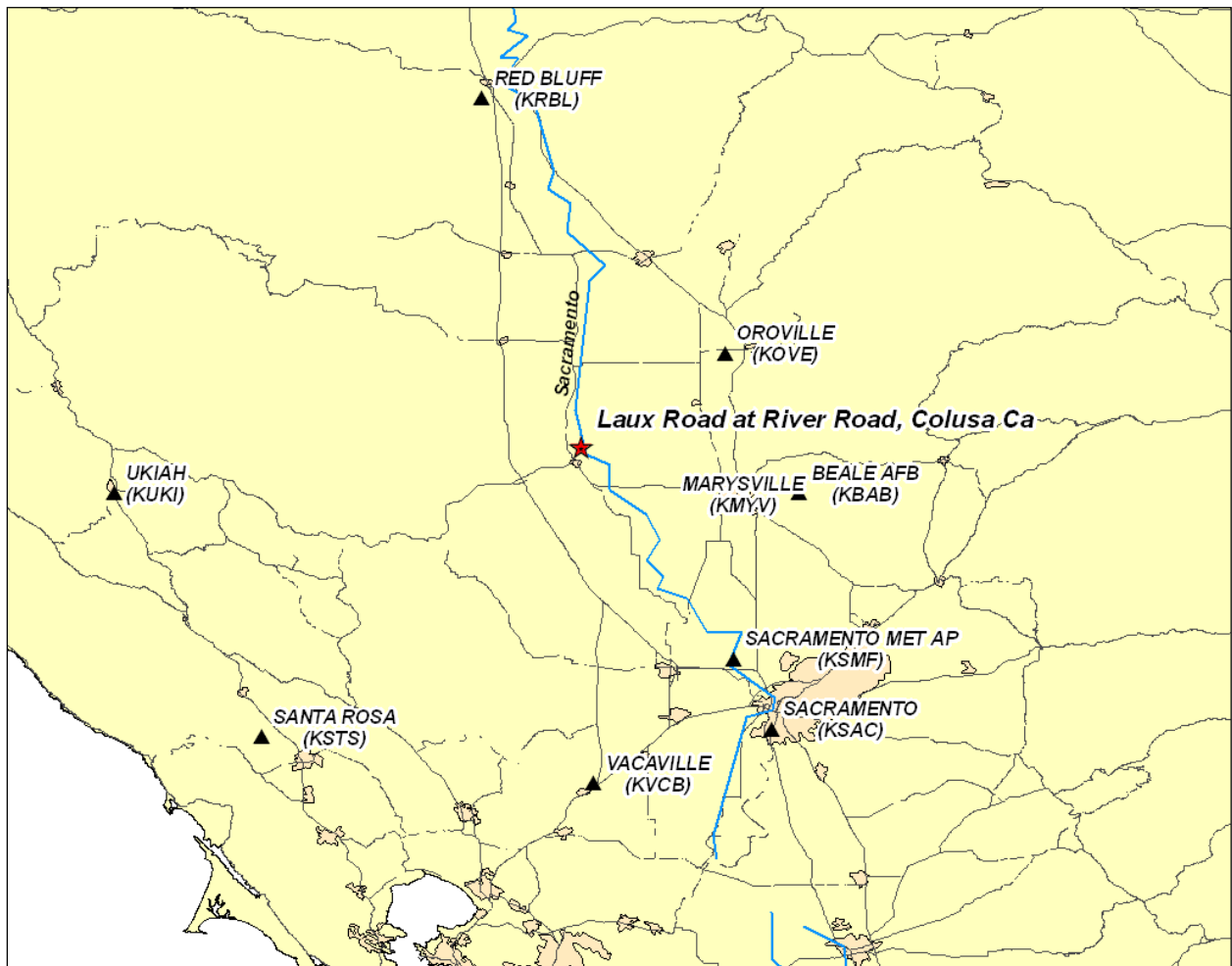


Figure 3: Weather Stations Used for Study

Conditions at the site of interest were calculated by utilizing these station's reported observations. A standard Shepard's Method of the inverse distance weighted model was used to reanalyze the weather observations to the site of interest. This technique applies a weighting to all observations based on the distance from the observing station to the site of interest. Station observations closer to the site of interest are weighted heavier than those farther from the site of interest.

The form of this model is:

$$\text{Site Weather Element} = \sum_{i=1}^n W_i \times O_i$$

Where W_i is the weighting function at the observation site and O_i is the weather element observed at the observation site. The weighting function is of the form:

$$\text{Weighting Function} = \frac{d_i^{-2}}{\sum_{j=1}^n d_j^{-2}}$$

Where d is the distance from the observation site to the site of interest.

The weighting function rapidly reduces the influence of each observation as the distance between the observation site and the site of interest increases. Figure 4 depicts this weighting function, versus the distance between the observation site and the site of interest.

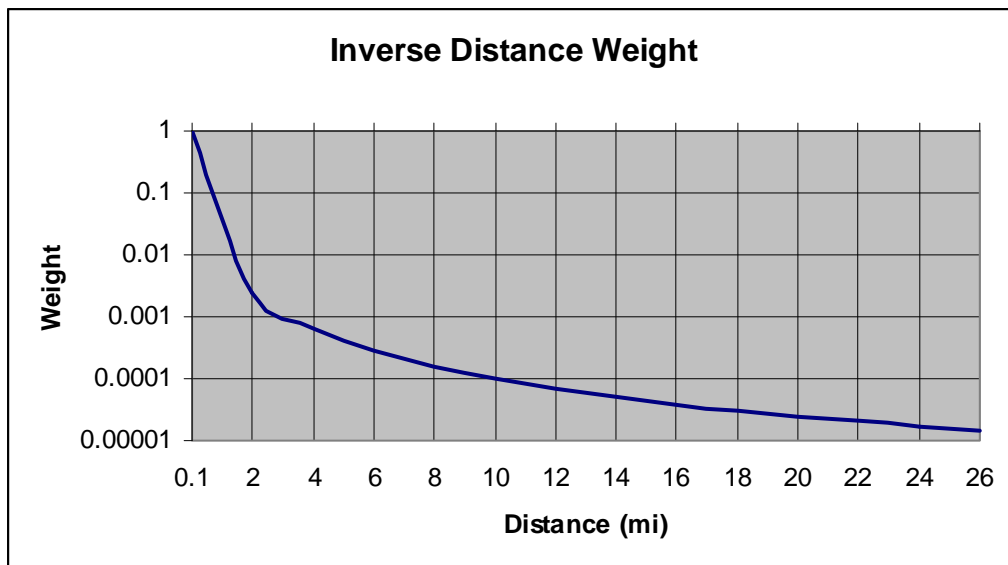


Figure 4: Inverse Distance Weighting Function

2. Detailed Weather Analysis

During the period in question, 5 to 27 July 2007, the area experience typical conditions for the season. Temperatures were hot, afternoon humidity was very low, skies predominately clear, winds light to moderate, and precipitation was very light over the area.

Temperatures

Recorded temperatures at the nine weather observation sites in the region reviewed for this study indicated that mean daily temperatures averaged between 60 F, 68 miles to the west at Santa Rosa (KSTS), to 94 F at Red Bluff, 64 miles to the north. Mean daily temperatures at the site of interest were calculated utilizing the Standard Shepard's Method and are indicated as the dark line on figure 5. Mean temperatures at the site most probably averaged between 89 F and 71 F, with a average mean of 77 F, or near normal for the region for the month. A table of mean daily temperatures may be found in appendix A. As a comparison, mean daily temperatures for July are expected to be approximately 75 F, based on the 30 year climate summary for Sacramento (1971 to 2000), Appendix D.

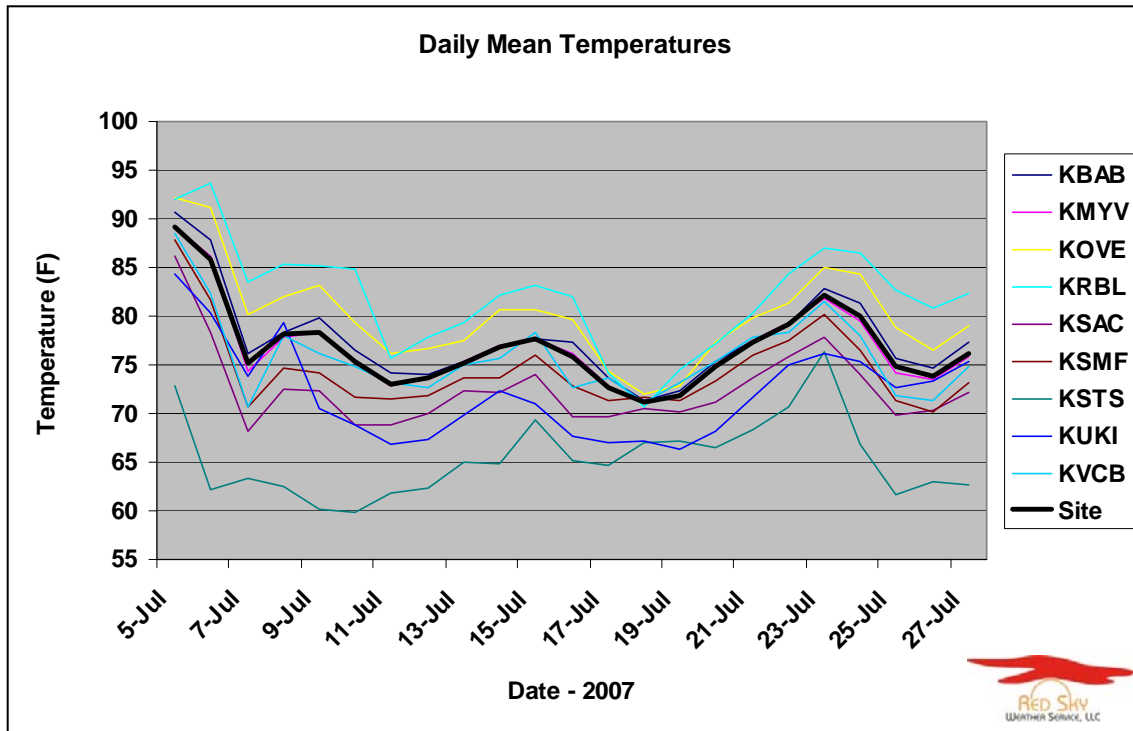


Figure 5: Daily Mean Temperatures

Table 2: Daily Mean Temperature Summary, 5 to 27 July 2007

	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
Max	90.7	89.1	92.1	93.6	86.2	87.9	76.3	84.4	88.5	89.2
Min	71.4	71.2	72	70.7	68.2	70.2	59.8	66.4	70.6	71.1
Avg	77.7	76.8	80.0	82.0	72.5	74.5	65.4	72.2	75.9	76.9

Although maximum temperatures recorded over the region during the period were quite high, figure 6 and table 3, as with the observed mean temperatures, maximum temperatures were also as expected for the month. Daily maximum temperatures ranged between 109 F at Red Bluff and 72 F at Santa Rosa. An analysis of maximum temperatures at the site of interest, dark red line on figure 5, indicated that daily maximum temperatures most probably ranged between 106 F, which occurred on July 5, and 82 F, which occurred on July 18, with an average maximum of 93 F during the 5 to 27 July, 2007 period. Again, these maximum temperatures were near normal, as compared to the normal maximum of 92 F for Sacramento. A comparison of the extreme temperature expected for the area, 114 F, is also similar to that observed during the period of 109 F. A comprehensive table of daily maximum temperatures is included in Appendix A.

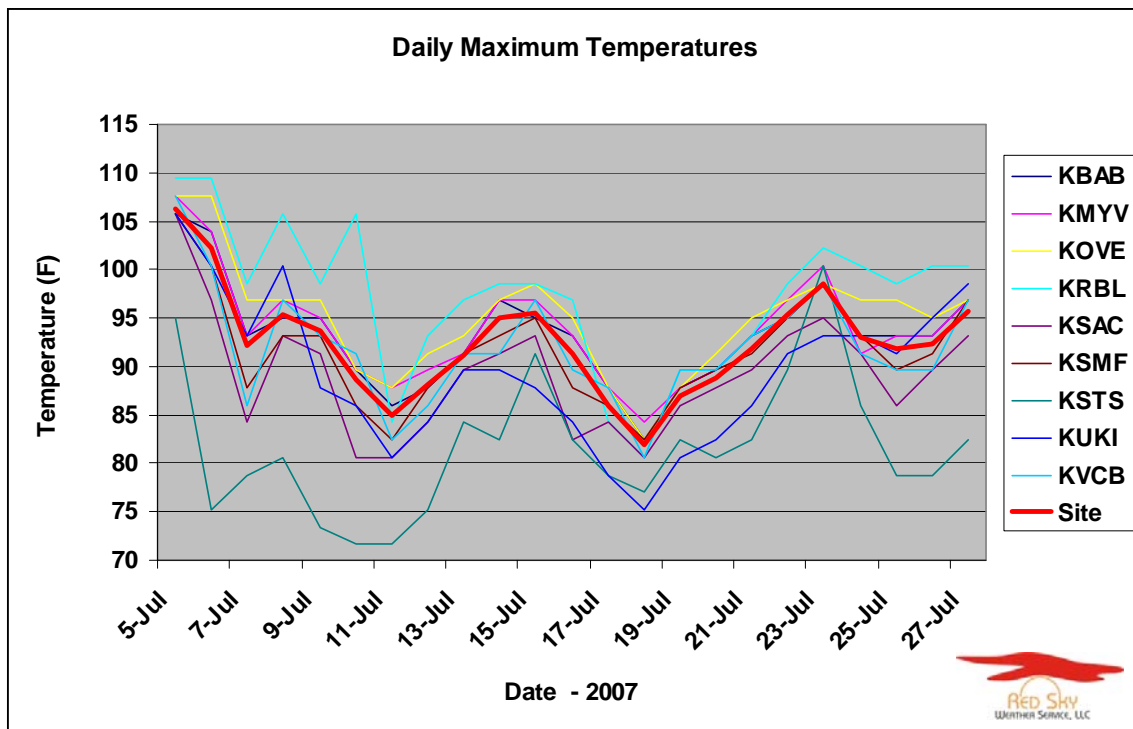


Figure 6: Daily Maximum Temperatures

Table 3: Daily Maximum Temperature Summary, 5 to 27 July, 2007

	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
Max	105.8	107.6	107.6	109.4	105.8	105.8	100.4	105.8	107.6	106.3
Min	82.4	84.2	82.4	80.6	80.6	82.4	71.6	75.2	80.6	81.9
Avg	93.2	93.7	94.9	97.1	89.1	91.6	81.7	89.4	91.9	92.5

Daily minimum temperatures over the region were also seasonal, with minimum temperatures ranging between 77 F at Red Bluff and Oroville, and 48 at Santa Rosa, figure 7 and table 4. At the site of interest, analysis indicates that daily minimum temperatures most probably ranged between 72 F, which occurred on July 5 and 57 F, which occurred on July 26, with an average minimum of 62 F for the period 5 to 27 July 2007. As a comparison, normal daily lows are expected to be approximately 58 F, and not fall below 48 F.

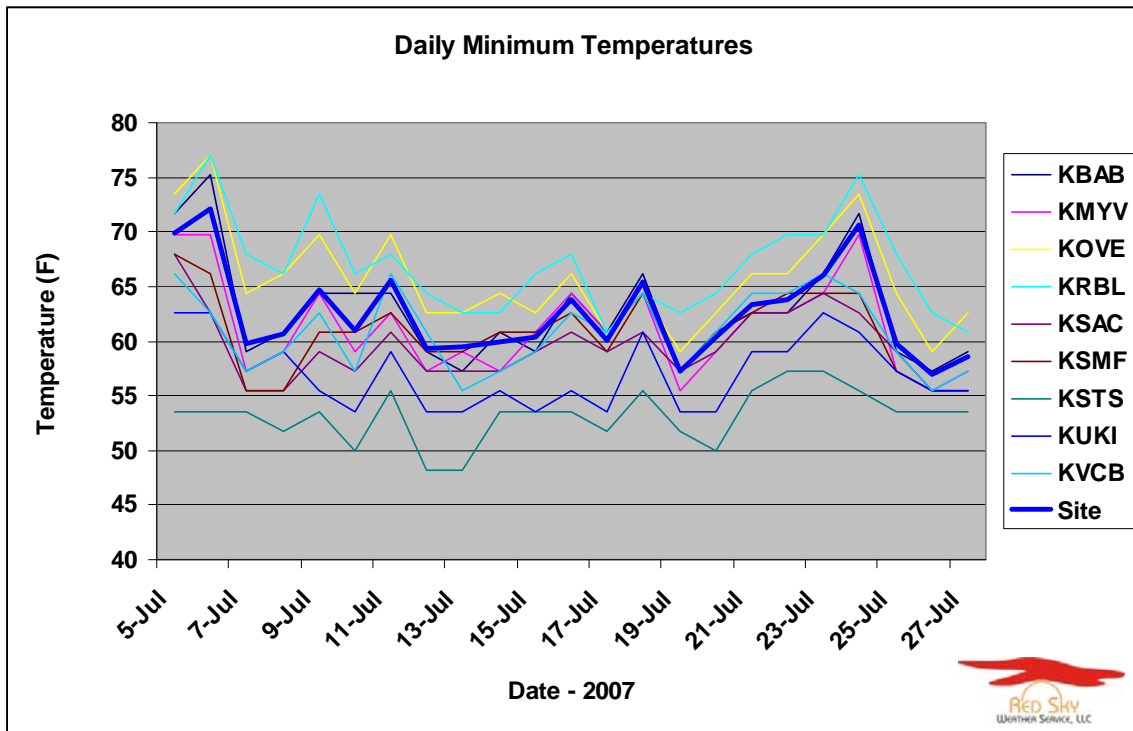


Figure 7: Daily Minimum Temperatures

Table 4: Daily Minimum Temperatures, 5 to 27 July 2007

	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
Max	75.2	69.8	77	77	68	68	57.2	62.6	66.2	72.1
Min	57.2	55.4	59	60.8	55.4	55.4	48.2	53.6	55.4	56.9
Avg	62.8	61.3	65.7	67.0	59.5	60.7	53.2	57.0	60.9	62.6

A complete time series of the analyzed hourly temperatures for the site of interest is depicted in figure 8. Note that the highest temperatures of the period occurred at the beginning of the period, and that the trend for the period through about July 12 was for a decrease in temperatures. Light precipitation was recorded in the area on July 10, as winds became more westerly, bringing in cooler and moist air off of the Pacific. As winds became more southerly, there was a slight rise in temperatures over the 13 through 16 July period. From 16 through 19 July, another shift of the winds towards the west brought cooler temperatures, and light precipitation into the area.

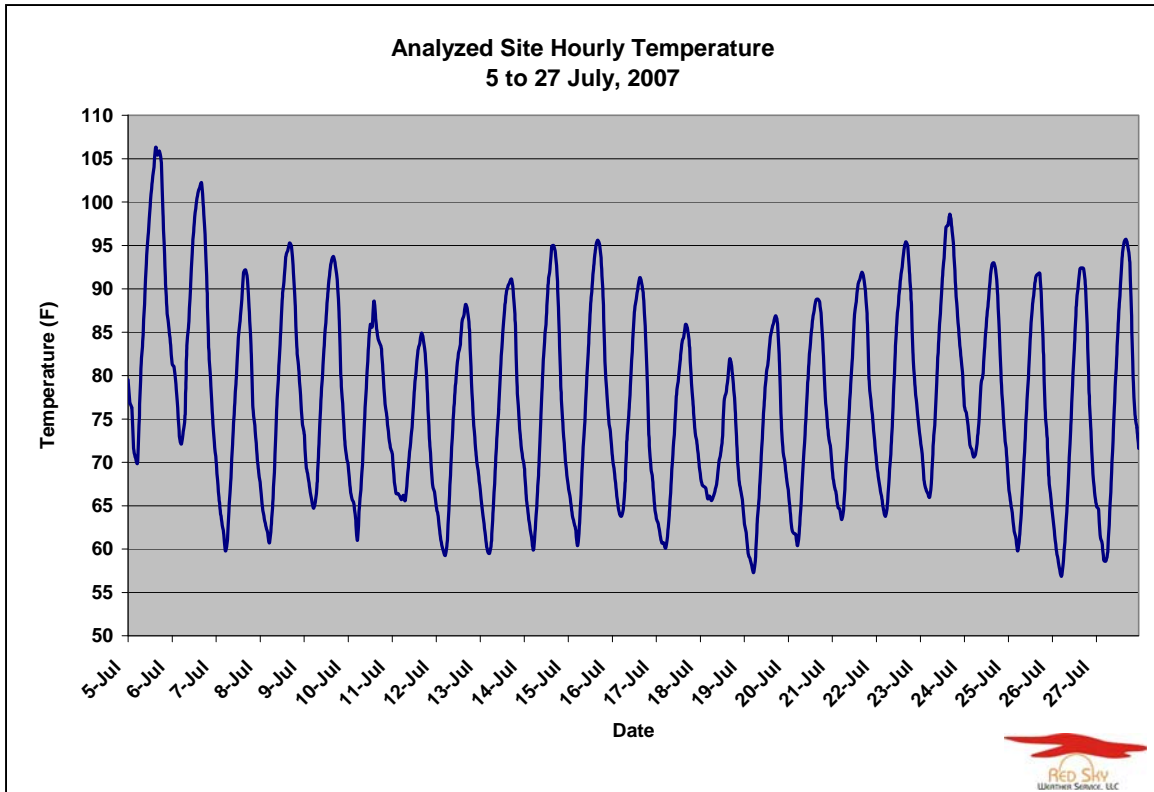


Figure 8: Analyzed Site Hourly Temperatures

Relative Humidity

A review of the observed dew points for the nine weather observation sites was also conducted to determine the relative humidity for the site. The relative humidity of the air is a measure of the amount of water vapor that is present in the air, as compared to the maximum amount that may be present at the observed temperature. When the maximum amount of water vapor is present, the air is known as saturated. To calculate the relative humidity, the vapor pressure of the air at the observed dew point temperature (known as the saturation vapor pressure, e_s) and at the observed ambient air temperature (known as the actual vapor pressure, e) were calculated using standard meteorological formulas. Once e_s and e were calculated, Relative Humidity (RH) could be calculated using the formula:

$$RH = \frac{e_s}{e} \times 100$$

An analysis of the relative humidity (RH) at the site of interest indicated that RH most probably ranged from a low of 15%, which occurred on July 27, and a high of 88%, that occurred on July 26. Note that the maximum temperatures analyzed at the site of interest, 106 F, occurred on July 5. During that same afternoon, a calculated RH of 16% was obtained. The combination of

extremely high temperatures, and very low relative humidity, would have made conditions extreme at the site, and resulted in significant water evaporation.

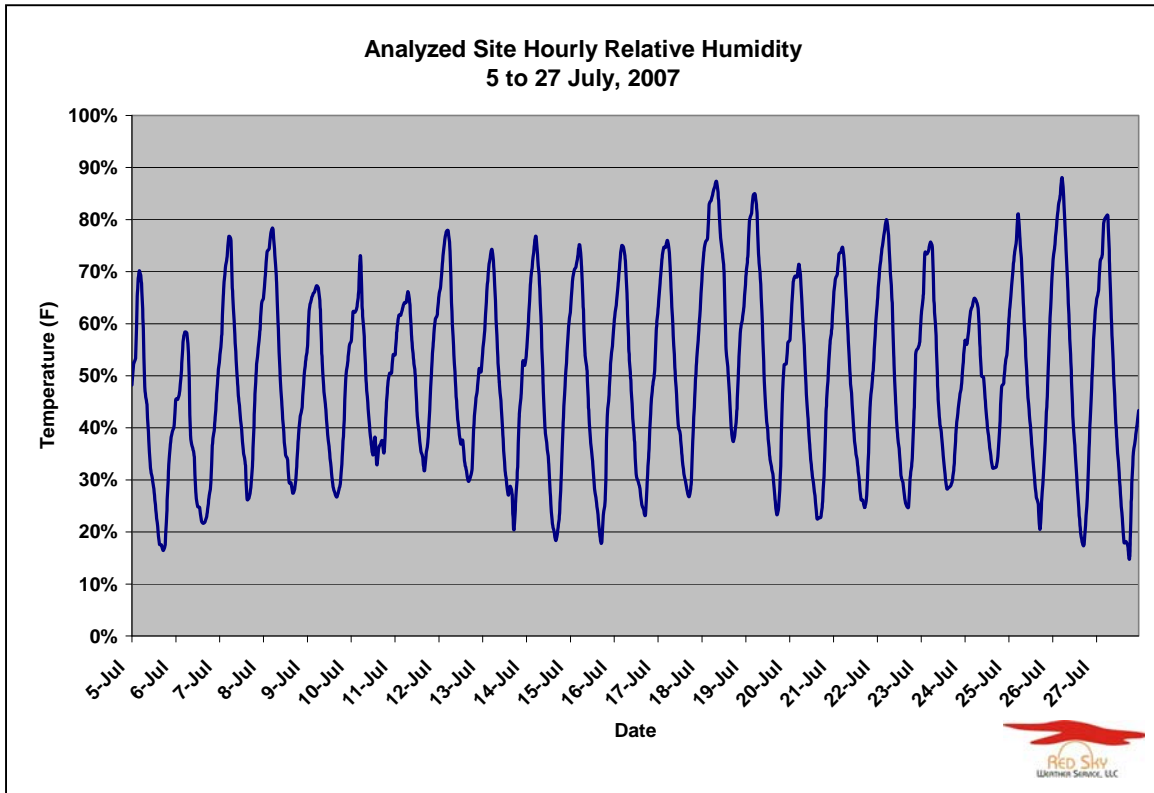


Figure 9: Analyzed Site Hourly Relative Humidity

Winds

Climatically, winds over the area during the month of July are predominately southerly to southwest, light and variable with occasional gusty conditions due to strong afternoon heating. Occasionally winds become westerly during the period however, bringing cooler and moister air from the Pacific into the area. These periods are responsible for the scant precipitation that is recorded in the area during the summer. Winds during the period 5 to 27 July 2007 followed this typical pattern. Winds were predominately light to moderate, averaging between 2 and 17 mph, figure 10, and southerly to southwesterly.

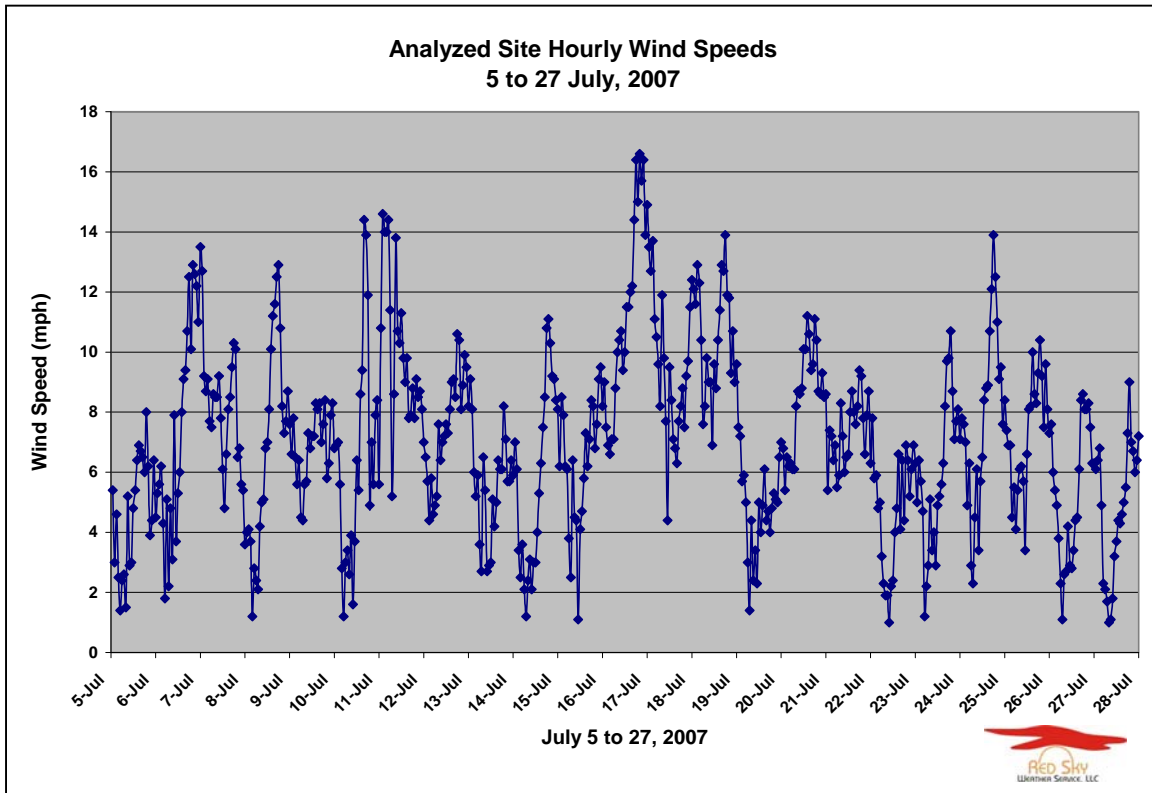


Figure 10: Analyzed Site Hourly Wind Speeds

Precipitation

Precipitation events during the month of July are extremely rare. On average there is less than one day per month with recorded precipitation, and overall only a total of about 0.05 inches of precipitation may be expected to fall during the month. During the period 5 to 27 July 2007 however precipitation conditions were slightly above normal. There were two periods during the time in question when precipitation was recorded in the area, July 10 through 12, and July 17 and 18. Highest precipitation in the area was recorded at Red Bluff and Beale Air Force Base, with period totals of 0.79 inches, and 0.82 inches respectively for the 5 to 27 July period, table 5 and figure 11.

Table 5: Daily Precipitation for July 5 through 27, 2007

	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
Period Total	0.82	0.04	0.43	0.79	0.01	0.00	0.11	0.12	0.09	0.30
Max Daily	0.81	0.03	0.43	0.79	0.01	0.00	0.06	0.10	0.09	0.16
Mean Daily	0.04	0.00	0.02	0.03	0.00	0.00	0.00	0.01	0.00	0.01

An analysis of conditions at the site of interest however indicates that the area most probably only received 0.30 inches of precipitation during the period. This small amount however was still 0.25 inches higher than expected based on climatology.

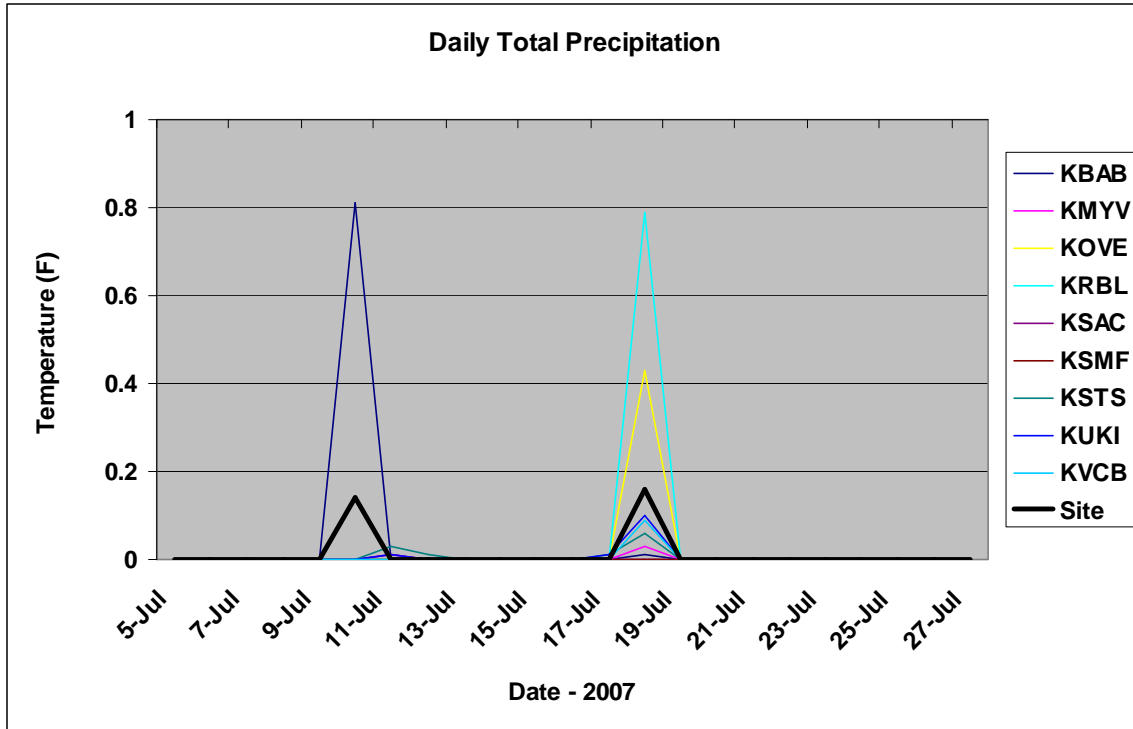


Figure 11: Daily Total Precipitation

3. Water Trough Evaporation Analysis

Water Trough Specifications

The objective of this study was to determine the evaporation rate for an open water trough, given the meteorological conditions present at the site of interest. Water evaporation is governed by three factors:

- Difference between actual and saturation vapor pressure
- Wind speed
- Surface area of the container

In this case, the container was a Rubbermaid trough, model number 4247. The specifications for this tank are as follows:

4247 300 U.S. gal Stock Tank



SPECIFICATIONS

	U.S.	Metric
Length:	63 1/4 in	160.7 cm
Width:	69 in	175.3 cm
Height:	25 in	63.5 cm
Volume Capacity [Nom]:	300 gal	1135.6 L
Volume Capacity [Max]:		
Volume Capacity [Min]:		
Carton Length:		
Carton Width:		
Carton Height:		
Carton Cube:	63.20 ft ³	1.79 m ³
Ship Weight/Carton:	83 lb	37.65 kg
Pack Quantity:		1
Cartons Per Pallet:		

The given metric units were used to facilitate the calculation of the evaporation rates utilizing standard engineering calculations. Although the overall length and width of the trough indicated a maximum surface area of 2.8 square meters, it was noted that the sides of the container were angled. Therefore, the surface area of the water exposed to the atmosphere will vary according to the depth of the water. To mitigate potential over estimations of water evaporation quantities, the total volume of the trough, 1,135.6 liters and height of the trough, .635 meters inches were used to determine and average surface area. The calculated average surface area used for this study was 1.788 square meters.

Evaporation Formula

To calculate the evaporation rate, the following empirical engineering equation was used:

$$W = \left((P_w - P_a) * \frac{(0.089 + 0.0782 * V)}{Y} \right) * 3600$$

Where:

- W = Rate of evaporation at the surface of the water level (kg/h m²)
- P_w = Vapor pressure at saturation taken at the temperature of surface of water, in kPa
- P_a = Vapor pressure at the dew point according to the temperature of the ambient air of the room, in kPa
- V = Air velocity above at the surface of water, in m/s
- Y = Latent heat necessary according to the change of state of the water vapor at the temperature of surface of water, in kJ/kg

This equation is taken from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRE) handbook. This equation is used by engineers to determine the evaporate rate from actively agitated water features and as such was taken as the high estimate for the evaporation rate. Further experimental research conducted by Smith, et al. (Solar Energy, vol 53, 1984) indicates that the equation may overestimate evaporation rate by as much as 28% for still water features. A range therefore was calculated using the analyzed meteorological conditions (temperature, dew point, and wind speed) at the site of interest and the above formula to determine an estimated hourly evaporation rate, placing the lower bound of the range at 72% of that calculated by the given ASHRE formula.

Daily Evaporation Rates

The calculations for the evaporation rate for the period 5 to 27 July 2007, indicate that the average daily evaporation rate was most probably between 8 and 12 gpd, with a maximum rate of 14 to 19 gpd and a minimum daily rate of 5 to 7 gpd. Table 6 depicts the calculated daily evaporation rates in gallons per day (gpd):

Table 6: Calculated Daily Evaporation Rates

Date	High Estimate	Low Estimate
5-Jul	16.3	11.8
6-Jul	19.3	13.9
7-Jul	11.0	7.9
8-Jul	13.9	10.0
9-Jul	11.9	8.5
10-Jul	10.1	7.3
11-Jul	10.7	7.7
12-Jul	10.6	7.6
13-Jul	9.3	6.7
14-Jul	11.8	8.5
15-Jul	11.5	8.3
16-Jul	16.7	12.0
17-Jul	10.2	7.3
18-Jul	8.3	6.0
19-Jul	6.6	4.8
20-Jul	13.1	9.5
21-Jul	11.8	8.5
22-Jul	9.0	6.5
23-Jul	12.9	9.3
24-Jul	13.4	9.7
25-Jul	11.3	8.1
26-Jul	9.4	6.8
27-Jul	10.3	7.4
Average	11.7	8.4
Max	19.3	13.9
Min	6.6	4.8

These calculated daily evaporation rates correspond well with a series of evaporative pan experiments performed in the region during the 1940s through 1970s period by the U.S. National Weather Service. An examination of seven of the NWS stations in the area used for the evaporative pan study indicate that based on the average evaporation rate obtained by the NWS for these sites, that the water trough in this study would lose approximately 7.2 gpd, with a maximum of 8.8 gpd and a minimum of 6.2 gpd through evaporation. These numbers are within the lower bound of those calculated for this study. A review of the weather however, during this NWS study indicates that the NWS evaporation rates may be slightly low due to different climatic conditions experienced during the study period.

Table 7: NWS Evaporative Pan Studies

Station	Evaporation (inches)		Evaporation (ft)		Volume Loss (cu ft)		Gallon Loss	
	July	Per Day	July	Per Day	July	Per day	July	Per Day
Oroville	12.32	0.4	1.0	0.0	30.6	1.0	229.1	7.4
Red Bluff	10.29	0.3	0.9	0.0	25.6	0.8	191.3	6.2
Chico	11.3	0.4	0.9	0.0	28.1	0.9	210.1	6.8
Lake Solano	12.87	0.4	1.1	0.0	32.0	1.0	239.3	7.7
Newville	14.61	0.5	1.2	0.0	36.3	1.2	271.6	8.8
Red Bluff	10.39	0.3	0.9	0.0	25.8	0.8	193.2	6.2
Stony Gorge	12.55	0.4	1.0	0.0	31.2	1.0	233.3	7.5
							Average	7.2
							Max	8.8
							Min	6.2

Daily Water Evaporation / Consumption

For this study, it was understood that the water trough in question did have a source of water from a well to refill the trough. However, at some point during the 5 to 27 July 2007 period, the well connection to the trough either failed or was inadvertently disconnected by the horses in the corral. As an exact date for this disconnection is not known, the average evaporative loss calculated over the period was used to estimate how long the trough would have been able to provide water once disconnected. It is assumed that the trough was full, with 300 gallons of water, at the point when the well source was disconnected. In addition, a range of water consumption for the horses was used, 10, 20 and 30 gpd per horse, to perform the daily water evaporation / consumption calculation. To check on other potential sources of water, a calculation was also made to determine how much water may have been added to the trough on the two rain dates during the period, July 10 and 18. It was calculated that these precipitation events would not have added more than 3 gallons per event, or a total of six gallons. This potential six gallon addition, approximately 2% of the total volume of the trough, was deemed insignificant, and it was therefore decided to not include this water source in the final calculations.

The summary of final calculations for the length of time it took the water trough to become depleted, based on horse daily water consumption, and calculated average evaporation rates, indicates that the water trough should have been able to sustain the horses for at least 5 days, and not more than 10 to 11 days, table 8.

Table 8: Water Trough Depletion Summary

Horse Consumption Gallons per Day per Horse	Days to Water Trough Depletion
10	10 to 11
20	6 to 7
30	5

Note: Assumes that water trough was full at time of well water source disconnection / failure

Table 9 details the water depletion time series, per day. This table depicts probable water levels, based on horse water consumption and a range of water evaporation rates from 8.4 gpd to 11.7 gpd.

Table 9: Water Trough Depletion Daily Chart

Day	Total Evaporation Estimate Per Day		Daily Water Depletion Estimate						Rain Addition	Water Remaining 10 gpd per horse		300 Start (gallons)			
	Low	High	10 gpd per horse		20 gpd per horse		30 gpd per horse			Low	High	20 gpd per horse		30 gpd per horse	
			Low	High	Low	High	Low	High		Low	High	Low	High	Low	High
1	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	271.6	268.3	251.6	248.3	231.6	228.3
2	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	243.2	236.6	203.2	196.6	163.2	156.6
3	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	214.8	204.9	154.8	144.9	94.8	84.9
4	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	186.4	173.2	106.4	93.2	26.4	13.2
5	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	158.0	141.5	58.0	41.5	-42.0	-58.5
6	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	129.6	109.8	9.6	-10.2	-110.4	-130.2
7	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	101.2	78.1	-38.8	-61.9	-178.8	-201.9
8	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	72.8	46.4	-87.2	-113.6	-247.2	-273.6
9	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	44.4	14.7	-135.6	-165.3	-315.6	-345.3
10	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	16.0	-17.0	-184.0	-217.0	-384.0	-417.0
11	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-12.4	-48.7	-232.4	-268.7	-452.4	-488.7
12	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-40.8	-80.4	-280.8	-320.4	-520.8	-560.4
13	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-69.2	-112.1	-329.2	-372.1	-589.2	-632.1
14	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-97.6	-143.8	-377.6	-423.8	-657.6	-703.8
15	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-126.0	-175.5	-426.0	-475.5	-726.0	-775.5
16	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-154.4	-207.2	-474.4	-527.2	-794.4	-847.2
17	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-182.8	-238.9	-522.8	-578.9	-862.8	-918.9
18	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-211.2	-270.6	-571.2	-630.6	-931.2	-990.6
19	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-239.6	-302.3	-619.6	-682.3	-999.6	-1062.3
20	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-268.0	-334.0	-668.0	-734.0	-1068.0	-1134.0
21	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-296.4	-365.7	-716.4	-785.7	-1136.4	-1205.7
22	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-324.8	-397.4	-764.8	-837.4	-1204.8	-1277.4
23	8.4	11.7	28.4	31.7	48.4	51.7	68.4	71.7	0.0	-353.2	-429.1	-813.2	-889.1	-1273.2	-1349.1

4. Conclusion

Although conditions for this period of July, 2007 were hot, and dry, with extreme temperatures of 106 F most probably experienced at the site of interest, and average temperatures in the upper 70s F, conditions were not unseasonable for the area for this time of year. In fact, the total precipitation experienced on July 10 and 18 was above approximately 0.25 inches above normal for the month of July at the site. A review of climatic normals for Sacramento, located some 45 miles to the southeast of the site of interest, and in the same climatic regime, correlates well with this assertion.

Evaporation rates are driven by moisture content in the air, as measured by the vapor pressure, and wind flow over the surface of the water. Since conditions in the area were near normal for July, calculated evaporative rates therefore should be similar to those obtained by the U.S. National Weather Service during its evaporative pan studies in the 1940s through 1970s. Evaporative rate calculations for the 5 to 27 July 2007 period, based on the analyzed weather conditions at the site of interest, utilizing the ASHRE evaporative rate formula and adjusted by

further research by Smith, et al., were between 8.4 gpd and 11.7 gpd. These rates are in line with those obtained by the NWS for July, of 6.2 gpd to 8.8 gpd, for their historic study. The rates calculated for the study therefore indicate that the 300 gallon water trough would have been able to sustain the two horses in the corral for at least 5 days and most probably not more than 10 to 11 days after the well ceased refilling the water trough.

Appendix A: Temperatures

Daily Mean Temperature (F)

Date	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
5-Jul-07	90.7	89.1	92.1	92	86.2	87.9	72.8	84.4	88.5	89.2
6-Jul-07	87.9	86.2	91.2	93.6	78.4	81.7	62.2	80.3	82.3	85.9
7-Jul-07	76.1	74.4	80.1	83.5	68.2	70.6	63.3	73.9	70.6	75.2
8-Jul-07	78.4	77.8	82	85.4	72.5	74.6	62.5	79.3	78	78.2
9-Jul-07	79.8	78.4	83.2	85.1	72.4	74.2	60.2	70.5	76.2	78.3
10-Jul-07	76.5	75.2	79.3	84.9	68.8	71.6	59.8	68.8	74.8	75.4
11-Jul-07	74.2	72.9	76.1	75.7	68.8	71.5	61.8	66.9	73.1	73
12-Jul-07	74	73.7	76.7	77.9	70	71.9	62.4	67.3	72.6	73.6
13-Jul-07	75.4	75.4	77.5	79.3	72.4	73.6	65	69.8	75	75.1
14-Jul-07	76.9	77	80.7	82.2	72.1	73.6	64.9	72.4	75.7	76.9
15-Jul-07	77.6	77.7	80.7	83.1	74	76	69.4	71	78.4	77.7
16-Jul-07	77.3	76.1	79.7	82	69.6	72.8	65.2	67.6	72.7	75.9
17-Jul-07	73.6	72.8	74.4	74.1	69.7	71.4	64.6	67	73.6	72.6
18-Jul-07	71.4	71.2	72	70.7	70.5	71.6	67	67.1	71.2	71.1
19-Jul-07	72.3	71.9	72.9	74.5	70.2	71.4	67.1	66.4	73.1	71.8
20-Jul-07	75.4	75	77.4	77.1	71.2	73.4	66.5	68.2	75.4	74.8
21-Jul-07	77.5	77.5	79.9	80.3	73.6	76	68.4	71.7	77.8	77.3
22-Jul-07	79.2	79.3	81.3	84.4	75.8	77.5	70.6	75	78.4	79.1
23-Jul-07	82.8	81.8	85	87	77.8	80.1	76.3	76.1	81.5	82.2
24-Jul-07	81.4	79.5	84.3	86.5	74	76.5	66.8	75.3	78	80
25-Jul-07	75.6	74.2	78.9	82.6	69.8	71.3	61.6	72.7	71.8	74.8
26-Jul-07	74.7	73.5	76.5	80.9	70.3	70.2	63	73.3	71.4	73.8
27-Jul-07	77.3	75.9	79	82.3	72.2	73.2	62.7	75.4	74.8	76.2
Max	90.7	89.1	92.1	93.6	86.2	87.9	76.3	84.4	88.5	89.2
Min	71.4	71.2	72	70.7	68.2	70.2	59.8	66.4	70.6	71.1
Mean	77.7	76.8	80.0	82.0	72.5	74.5	65.4	72.2	75.9	76.9

Daily Maximum Temperatures (F)

Date	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
5-Jul-07	105.8	107.6	107.6	109.4	105.8	105.8	95	105.8	107.6	106.3
6-Jul-07	104	104	107.6	109.4	96.8	100.4	75.2	100.4	100.4	102.2
7-Jul-07	93.2	93.2	96.8	98.6	84.2	87.8	78.8	93.2	86	92.2
8-Jul-07	95	96.8	96.8	105.8	93.2	93.2	80.6	100.4	96.8	95.3
9-Jul-07	95	95	96.8	98.6	91.4	93.2	73.4	87.8	93.2	93.7
10-Jul-07	89.6	89.6	89.6	105.8	80.6	86	71.6	86	91.4	88.6
11-Jul-07	86	87.8	87.8	84.2	80.6	82.4	71.6	80.6	82.4	84.9
12-Jul-07	87.8	89.6	91.4	93.2	84.2	87.8	75.2	84.2	86	88.2
13-Jul-07	91.4	91.4	93.2	96.8	89.6	91.4	84.2	89.6	91.4	91.1
14-Jul-07	96.8	96.8	96.8	98.6	91.4	93.2	82.4	89.6	91.4	95
15-Jul-07	95	96.8	98.6	98.6	93.2	95	91.4	87.8	96.8	95.6
16-Jul-07	93.2	93.2	95	96.8	82.4	87.8	82.4	84.2	89.6	91.3
17-Jul-07	87.8	87.8	87.8	84.2	84.2	86	78.8	78.8	87.8	85.9
18-Jul-07	82.4	84.2	82.4	80.6	80.6	82.4	77	75.2	80.6	81.9
19-Jul-07	87.8	87.8	87.8	89.6	86	87.8	82.4	80.6	89.6	86.9
20-Jul-07	89.6	89.6	91.4	89.6	87.8	89.6	80.6	82.4	89.6	88.8
21-Jul-07	93.2	93.2	95	93.2	89.6	91.4	82.4	86	93.2	91.9
22-Jul-07	95	96.8	96.8	98.6	93.2	95	89.6	91.4	95	95.4
23-Jul-07	98.6	100.4	98.6	102.2	95	98.6	100.4	93.2	98.6	98.6
24-Jul-07	93.2	91.4	96.8	100.4	91.4	93.2	86	93.2	91.4	93
25-Jul-07	93.2	93.2	96.8	98.6	86	89.6	78.8	91.4	89.6	91.8
26-Jul-07	93.2	93.2	95	100.4	89.6	91.4	78.8	95	89.6	92.4
27-Jul-07	96.8	96.8	96.8	100.4	93.2	96.8	82.4	98.6	96.8	95.7
Max	105.8	107.6	107.6	109.4	105.8	105.8	100.4	105.8	107.6	106.3
Min	82.4	84.2	82.4	80.6	80.6	82.4	71.6	75.2	80.6	81.9
Mean	93.2	93.7	94.9	97.1	89.1	91.6	81.7	89.4	91.9	92.5

Daily Minimum Temperature (F)

Date	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
5-Jul-07	71.6	69.8	73.4	71.6	68	68	53.6	62.6	66.2	69.9
6-Jul-07	75.2	69.8	77	77	62.6	66.2	53.6	62.6	62.6	72.1
7-Jul-07	59	57.2	64.4	68	55.4	55.4	53.6	57.2	57.2	59.8
8-Jul-07	60.8	59	66.2	66.2	55.4	55.4	51.8	59	59	60.7
9-Jul-07	64.4	64.4	69.8	73.4	59	60.8	53.6	55.4	62.6	64.7
10-Jul-07	64.4	59	64.4	66.2	57.2	60.8	50	53.6	57.2	61
11-Jul-07	64.4	62.6	69.8	68	60.8	62.6	55.4	59	66.2	65.6
12-Jul-07	59	57.2	62.6	64.4	57.2	59	48.2	53.6	60.8	59.3
13-Jul-07	57.2	59	62.6	62.6	57.2	59	48.2	53.6	55.4	59.5
14-Jul-07	60.8	57.2	64.4	62.6	57.2	60.8	53.6	55.4	57.2	59.9
15-Jul-07	59	60.8	62.6	66.2	59	60.8	53.6	53.6	59	60.4
16-Jul-07	64.4	64.4	66.2	68	60.8	62.6	53.6	55.4	62.6	63.8
17-Jul-07	60.8	60.8	60.8	60.8	59	59	51.8	53.6	60.8	60.1
18-Jul-07	66.2	64.4	64.4	64.4	60.8	64.4	55.4	60.8	64.4	65.5
19-Jul-07	57.2	55.4	59	62.6	57.2	57.2	51.8	53.6	57.2	57.3
20-Jul-07	60.8	59	62.6	64.4	59	60.8	50	53.6	60.8	60.4
21-Jul-07	62.6	62.6	66.2	68	62.6	62.6	55.4	59	64.4	63.4
22-Jul-07	62.6	62.6	66.2	69.8	62.6	64.4	57.2	59	64.4	63.8
23-Jul-07	66.2	64.4	69.8	69.8	64.4	64.4	57.2	62.6	66.2	66
24-Jul-07	71.6	69.8	73.4	75.2	62.6	64.4	55.4	60.8	64.4	70.6
25-Jul-07	59	57.2	64.4	68	59	57.2	53.6	57.2	59	59.8
26-Jul-07	57.2	55.4	59	62.6	55.4	55.4	53.6	55.4	55.4	56.9
27-Jul-07	59	57.2	62.6	60.8	55.4	55.4	53.6	55.4	57.2	58.6
Max	75.2	69.8	77	77	68	68	57.2	62.6	66.2	72.1
Min	57.2	55.4	59	60.8	55.4	55.4	48.2	53.6	55.4	56.9
Mean	62.8	61.3	65.7	67.0	59.5	60.7	53.2	57.0	60.9	62.6

Appendix B: Winds

Daily Mean Winds (mph)

Date	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
5-Jul-07	5.4	4	4.5	5.8	3.8	6	4.2	3.1	4.2	4.6
6-Jul-07	8.5	7.9	5.9	8.4	9	10.2	7.4	3.2	9.2	7.6
7-Jul-07	8.8	8.4	5.8	7.1	10.1	11.1	4.7	3.7	10.8	7.9
8-Jul-07	6.4	6.8	6.8	7.4	6.5	9.6	5.8	3.5	8.1	6.9
9-Jul-07	5.6	7.6	4.7	6.9	9.5	10.2	4.5	8.3	9.2	6.9
10-Jul-07	6.1	5.9	5	7.7	7.6	9.3	5.4	7	7.5	6.3
11-Jul-07	11.9	10.7	8.2	7.5	11.5	11.5	4.9	9	12.1	10.1
12-Jul-07	7.7	8	6.6	6.7	8.7	10.2	4.9	4.4	7.6	7.5
13-Jul-07	5.9	5.9	4.5	4.6	6.3	8.3	4.2	2.2	6.3	5.5
14-Jul-07	4.7	5	5.8	6.3	7.7	8.9	5.1	4.7	6.5	5.8
15-Jul-07	5.9	6.6	5.1	6.3	7	9.4	5	4.9	7	6.3
16-Jul-07	12.1	11.8	11.5	11.1	9.9	14	4.7	6.3	13.3	11.4
17-Jul-07	12.2	10.3	8.5	7.9	8.1	10.3	5.1	2.9	9	9.4
18-Jul-07	11.8	10.3	11	11.4	9.7	11.2	6.8	4.5	10.7	10.5
19-Jul-07	5.5	5	2.6	2.8	6.6	7.6	4.6	5.5	6.7	4.8
20-Jul-07	9.2	10	7.2	6.7	8.3	10.5	5	5	7.7	8.5
21-Jul-07	7.5	8.2	6.1	5.8	7.5	10	4.3	4.3	8.8	7.3
22-Jul-07	4.4	4.6	3.4	3.2	6.4	7.4	4.5	4.6	7	4.7
23-Jul-07	6.6	6	4.3	4.7	6.4	8.3	6	6.7	6.9	5.9
24-Jul-07	8.4	7.6	7.2	6.8	8.1	9.9	7.3	4.2	8.8	7.7
25-Jul-07	7.2	7.2	5.6	6.8	9.7	11.3	5	3.5	10.4	7.2
26-Jul-07	5	5.2	4.2	3.8	7.6	8.4	4.8	2.7	7.5	5.3
27-Jul-07	5.5	4.1	3.9	4.9	5.8	7.2	4.8	2.8	5.8	4.8
Max	12.2	11.8	11.5	11.4	11.5	14	7.4	9	13.3	11.4
Min	4.4	4	2.6	2.8	3.8	6	4.2	2.2	4.2	4.6
Mean	7.5	7.3	6.0	6.5	7.9	9.6	5.2	4.7	8.3	7.1

Daily Maximum Winds (mph)

Date	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
5-Jul-07	9.2	12.7	8.1	12.7	9.2	9.2	11.5	11.5	11.5	8
6-Jul-07	17.3	16.1	15	15	17.3	17.3	15	8.1	21.9	13.5
7-Jul-07	19.6	11.5	12.7	11.5	15	15	11.5	11.5	15	12.7
8-Jul-07	12.7	13.8	16.1	17.3	11.5	16.1	15	10.4	11.5	12.9
9-Jul-07	11.5	12.7	8.1	13.8	13.8	13.8	11.5	15	13.8	8.4
10-Jul-07	16.1	13.8	18.4	24.2	13.8	17.3	10.4	18.4	15	14.4
11-Jul-07	20.7	16.1	18.4	16.1	17.3	17.3	10.4	17.3	17.3	14.6
12-Jul-07	11.5	10.4	11.5	15	17.3	15	12.7	12.7	15	10.6
13-Jul-07	11.5	10.4	10.4	12.7	10.4	12.7	12.7	8.1	12.7	9.1
14-Jul-07	11.5	11.5	13.8	16.1	15	15	11.5	13.8	13.8	11.1
15-Jul-07	10.4	11.5	10.4	13.8	13.8	15	15	15	13.8	9.5
16-Jul-07	19.6	19.6	20.7	19.6	17.3	19.6	12.7	12.7	19.6	16.6
17-Jul-07	19.6	16.1	16.1	15	13.8	16.1	13.8	11.5	13.8	13.7
18-Jul-07	18.4	16.1	15	17.3	16.1	16.1	17.3	12.7	20.7	13.9
19-Jul-07	9.2	10.4	8.1	6.9	15	13.8	11.5	12.7	13.8	7.5
20-Jul-07	12.7	11.5	11.5	15	15	15	16.1	13.8	17.3	11.2
21-Jul-07	10.4	11.5	10.4	12.7	13.8	13.8	10.4	9.2	16.1	9.4
22-Jul-07	8.1	10.4	6.9	8.1	13.8	15	13.8	13.8	13.8	7.8
23-Jul-07	11.5	13.8	8.1	12.7	13.8	13.8	16.1	13.8	11.5	10.7
24-Jul-07	12.7	13.8	15	15	17.3	16.1	16.1	12.7	15	13.9
25-Jul-07	11.5	12.7	10.4	13.8	13.8	16.1	12.7	11.5	16.1	10.4
26-Jul-07	10.4	11.5	9.2	10.4	11.5	16.1	11.5	10.4	13.8	8.6
27-Jul-07	9.2	9.2	8.1	10.4	11.5	12.7	12.7	11.5	11.5	9
Max	20.7	19.6	20.7	24.2	17.3	19.6	17.3	18.4	21.9	16.6
Min	8.1	9.2	6.9	6.9	9.2	9.2	10.4	8.1	11.5	7.5
Mean	13.3	12.9	12.3	14.1	14.2	15.1	13.1	12.5	15.0	11.2

Appendix C: Precipitation

Daily Total Precipitation (inches)

Date	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
5-Jul-07	0	0	0	0	0	0	0	0	0	0
6-Jul-07	0	0	0	0	0	0	0	0	0	0
7-Jul-07	0	0	0	0	0	0	0	0	0	0
8-Jul-07	0	0	0	0	0	0	0	0	0	0
9-Jul-07	0	0	0	0	0	0	0	0	0	0
10-Jul-07	0.81	0	0	0	0	0	0	0	0	0.14
11-Jul-07	0	0.01	0	0	0.01	0	0.03	0.01	0	0
12-Jul-07	0	0	0	0	0	0	0.01	0	0	0
13-Jul-07	0	0	0	0	0	0	0	0	0	0
14-Jul-07	0	0	0	0	0	0	0	0	0	0
15-Jul-07	0	0	0	0	0	0	0	0	0	0
16-Jul-07	0	0	0	0	0	0	0	0	0	0
17-Jul-07	0	0	0	0	0	0	0.01	0.01	0	0
18-Jul-07	0.01	0.03	0.43	0.79	0	0	0.06	0.1	0.09	0.16
19-Jul-07	0	0	0	0	0	0	0	0	0	0
20-Jul-07	0	0	0	0	0	0	0	0	0	0
21-Jul-07	0	0	0	0	0	0	0	0	0	0
22-Jul-07	0	0	0	0	0	0	0	0	0	0
23-Jul-07	0	0	0	0	0	0	0	0	0	0
24-Jul-07	0	0	0	0	0	0	0	0	0	0
25-Jul-07	0	0	0	0	0	0	0	0	0	0
26-Jul-07	0	0	0	0	0	0	0	0	0	0
27-Jul-07	0	0	0	0	0	0	0	0	0	0
Total	0.82	0.04	0.43	0.79	0.01	0.00	0.11	0.12	0.09	0.30
Max	0.81	0.03	0.43	0.79	0.01	0.00	0.06	0.10	0.09	0.16
Mean	0.04	0.00	0.02	0.03	0.00	0.00	0.00	0.01	0.00	0.01

Maximum Hourly Precipitation Totals (inches)

Date	KBAB	KMYV	KOVE	KRBL	KSAC	KSMF	KSTS	KUKI	KVCB	Site
5-Jul-07	0	0	0	0	0	0	0	0	0	0
6-Jul-07	0	0	0	0	0	0	0	0	0	0
7-Jul-07	0	0	0	0	0	0	0	0	0	0
8-Jul-07	0	0	0	0	0	0	0	0	0	0
9-Jul-07	0	0	0	0	0	0	0	0	0	0
10-Jul-07	0.54	0	0	0	0	0	0	0	0	0.09
11-Jul-07	0	0.01	0	0	0.01	0	0.03	0.01	0	0
12-Jul-07	0	0	0	0	0	0	0.01	0	0	0
13-Jul-07	0	0	0	0	0	0	0	0	0	0
14-Jul-07	0	0	0	0	0	0	0	0	0	0
15-Jul-07	0	0	0	0	0	0	0	0	0	0
16-Jul-07	0	0	0	0	0	0	0	0	0	0
17-Jul-07	0	0	0	0	0	0	0.01	0.01	0	0
18-Jul-07	0.01	0.02	0.14	0.17	0	0	0.03	0.04	0.05	0.04
19-Jul-07	0	0	0	0	0	0	0	0	0	0
20-Jul-07	0	0	0	0	0	0	0	0	0	0
21-Jul-07	0	0	0	0	0	0	0	0	0	0
22-Jul-07	0	0	0	0	0	0	0	0	0	0
23-Jul-07	0	0	0	0	0	0	0	0	0	0
24-Jul-07	0	0	0	0	0	0	0	0	0	0
25-Jul-07	0	0	0	0	0	0	0	0	0	0
26-Jul-07	0	0	0	0	0	0	0	0	0	0
27-Jul-07	0	0	0	0	0	0	0	0	0	0
Max	0.54	0.02	0.14	0.17	0.01	0.00	0.03	0.04	0.05	0.09
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01

Appendix D: Sacramento Climate Summary

Monthly Climate Data Summary

Country: United States

Station: Sacramento, California

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Average Temp (F)	46.3	51.2	54.5	58.9	65.5	71.5	75.4	74.8	71.7	64.4	53.3	45.8	61.1
Average High Temp (F)	53.8	60.5	64.7	71.4	80.0	87.4	92.4	91.4	87.5	78.2	63.7	53.9	73.7
Average Low Temp (F)	38.8	41.9	44.2	46.3	50.9	55.5	58.3	58.1	55.8	50.6	42.8	37.7	48.4
Extreme High Temp (F)	70.0	76.0	88.0	95.0	105.0	115.0	114.0	110.0	108.0	104.0	87.0	72.0	115.0
Extreme Low Temp (F)	23.0	23.0	26.0	31.0	36.0	41.0	48.0	49.0	43.0	36.0	26.0	18.0	18.0
No. Days Temp >= 90 F	0	0	0	0	5	12	22	19	13	3	0	0	74
No. Days Temp <= 32 F	6	2	0	0	0	0	0	0	0	0	1	6	16
Average Heating Degree Days	580	387	335	208	97	10	0	0	11	84	359	595	2666
Average Cooling Degree Days	0	0	6	24	110	204	320	303	210	66	5	0	1248
AM Relative Humidity (%)	91	89	86	83	82	78	77	78	77	79	87	88	83
PM Relative Humidity (%)	70	61	53	44	38	32	30	29	31	37	57	67	46
Average Precipitation (in)	3.84	3.54	2.80	1.02	0.53	0.20	0.05	0.06	0.36	0.89	2.19	2.45	17.93
Average Snowfall (in)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No. Days Precipitation >= 0.01 in	10	9	9	5	3	1	0	0	1	3	7	9	58
Avg Wind Speed (mph)	7.1	7.3	8.4	8.6	9.0	9.6	8.9	8.4	7.4	6.4	6.0	6.4	7.8
Max Wind Speed (mph)	60	51	66	45	74	47	36	38	42	68	70	70	74
Max Wind Direction	SE	SE	S	SW	SW	SW	SW	SW	NW	SE	SE	SE	SW
Avg No. Clear Days	7	8	10	12	17	22	27	26	24	19	10	8	188
Avg No. Partly Cloudy Days	6	7	9	10	9	6	3	4	4	6	8	6	77
Avg No. Cloudy Days	19	13	12	8	5	2	1	1	2	6	12	17	100