BEFORE THE STATE WATER RESOURCES CONTROL BOARD

In the Matter of the State Water Resources Control Board (State Water Board) Hearing to Determine whether to Adopt a Draft Cease & Desist Order against California American Water Regarding its Diversion of Water from the Carmel River in Monterey County under Order WR 95-10	))))))))	Hearing Date: July 23 - 25, 2008 Carmel River in Monterey County

EXHIBIT MPWMD-TC15

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

RIPARIAN CORRIDOR MONITORING REPORT
CARMEL RIVER
2004

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I. INTRODUCTION

The mission of the Monterey Peninsula Water Management District (MPWMD) is to manage, augment, and protect water resources for the benefit of the community and the environment. MPWMD is an independent Special District created by an act of the California State legislature in 1977. Its boundaries include the Monterey Peninsula and much of the Carmel River watershed. Although not a water supplier, MPWMD has the power to regulate water production and distribution within its boundaries. The Monterey Peninsula relies entirely on local water resources, primarily surface and groundwater from the Carmel River, to meet its water supply needs.

Since the early 1980s, MPWMD has integrated water supply management with an active program to mitigate for the impacts from water extraction including restoration of degraded natural resources in the Carmel River. Some of the unique functions of MPWMD include Carmel River mitigation programs in fisheries, riparian restoration, and erosion protection. The 1990 Water Allocation Program Environmental Impact Report (EIR) documented environmental degradation associated with water extraction. In 1995, the State Water Resources Control Board (SWRCB) found that the California-American Water Company (Cal-Am) had valid rights to 3,376 acre-feet of water per year, but had been illegally diverting 10,730 acre-feet per year from the Carmel River and its alluvial aquifer.

Over the last century, the Carmel River has undergone a transformation from a wide, meandering, shallow watercourse to a moderately incised channel. Major alterations in the hydrologic regime began in 1921 with the construction of the San Clemente Dam and Reservoir (1,425 acre-feet of capacity) at River Mile 18.6. In 1948, the Los Padres Dam and Reservoir (3,030 acre-feet of capacity) was built at River Mile 25. A combination of floodplain development in the 15.5-mile alluvial section, trapping of sediment load behind the dams, and gravel mining in the channel bottom downstream of the dams, has led to channel incision. Today, 98 percent of the San Clemente Reservoir's original storage capacity and over one half of Los Padres Reservoir's capacity have been displaced by sediment.

An absence of major flood damage between the 1911 flood (estimated to be 20,000 cubic feet per second) and the 1958 flood allowed for encroachment of development into the floodplain. Increased demands on groundwater beginning in the 1960's in conjunction with a severe two-year drought in1976 and 1977 put an enormous amount of pressure on the limited water resources in Carmel Valley. Groundwater levels declined to unprecedented lows causing widespread mortality to riparian vegetation. Between 1978 and 1983, high flows destabilized the alluvial portion of the. The degradation of the river corridor and decline of the wildlife habitat galvanized efforts within the community to find solutions to the environmental problems. Currently the California red-legged frog

(Rana aurora draytonii) and steelhead trout *(Oncorhynchus mykiss)* are listed as threatened under the Federal Endangered Species Act in the Carmel River watershed. In 1983, after 83 percent of riverfront property owners approved a benefit assessment zone along the river to help fund projects, MPWMD began a restoration program.

In studies contracted by the MPWMD, a negative correlation was demonstrated between groundwater pumping and the health of the riparian vegetation. This means that with increased groundwater pumping, the health of the riparian vegetation would decrease, and vice-versa: less groundwater pumping will increase the health of the riparian vegetation, of which is essential to channel stability (McNiesh, 1986, '88, '99, '91a, '91b). It was determined that plant stress was directly related to soil water availability and depth to groundwater. It was recommended that mitigation was necessary in the form of irrigation if all four of the following criteria were met (McNiesh, 1986):

1. Dry river channel

2. Drop in the water table by greater than 2 feet per week or seasonally, 8 feet or more below the elevation of the river channel

3. Unacceptable soil moisture levels

4. Unacceptable vegetation stress

To determine these conditions MPWMD developed a monitoring system, currently in use, to measures plant stress, soil moisture, and depth to groundwater. When necessary, supplemental irrigation is applied to help mitigate the effects of unacceptable vegetation stress.

This report summarizes 2004 monitoring methods and results.

II. SITE DESCRIPTIONS

The 36-mile-long Carmel River drains 255 square miles of the central coast of California. The watershed includes the Santa Lucia Mountains to the south and the Sierra del Salinas Range to the north. Bedrock in the basin consists mainly of Sur Series crystalline rock (granite, gneiss, schist), Monterey Shale and sandstone (Page and Matthews, 1984). Mean annual rainfall varies from about 14 inches along the northeast perimeter of the basin to over 40 inches in the high peaks (up to approximately 5,000 feet in elevation) of the southern portion (James, 1999). Upper reaches on the Carmel River flow through steep-sided canyons, while the lower 16 miles is a relatively flat alluvial valley to the ocean. The average annual runoff at the San Clemente Dam site is 69,000 acre-feet (James, 2003). Bankfull flow is 2,200 cubic feet per second (cfs) near the mouth. On March 10, 1995, the river discharge peaked at 16,000 cfs, which is the largest event ever recorded on the Carmel River. The MPWMD has maintained four vegetation monitoring sites: Rancho Cañada, San Carlos, Valley Hills, and Schulte (Figure 1).

Location of Monitoring Sites and Carmel River Watershed

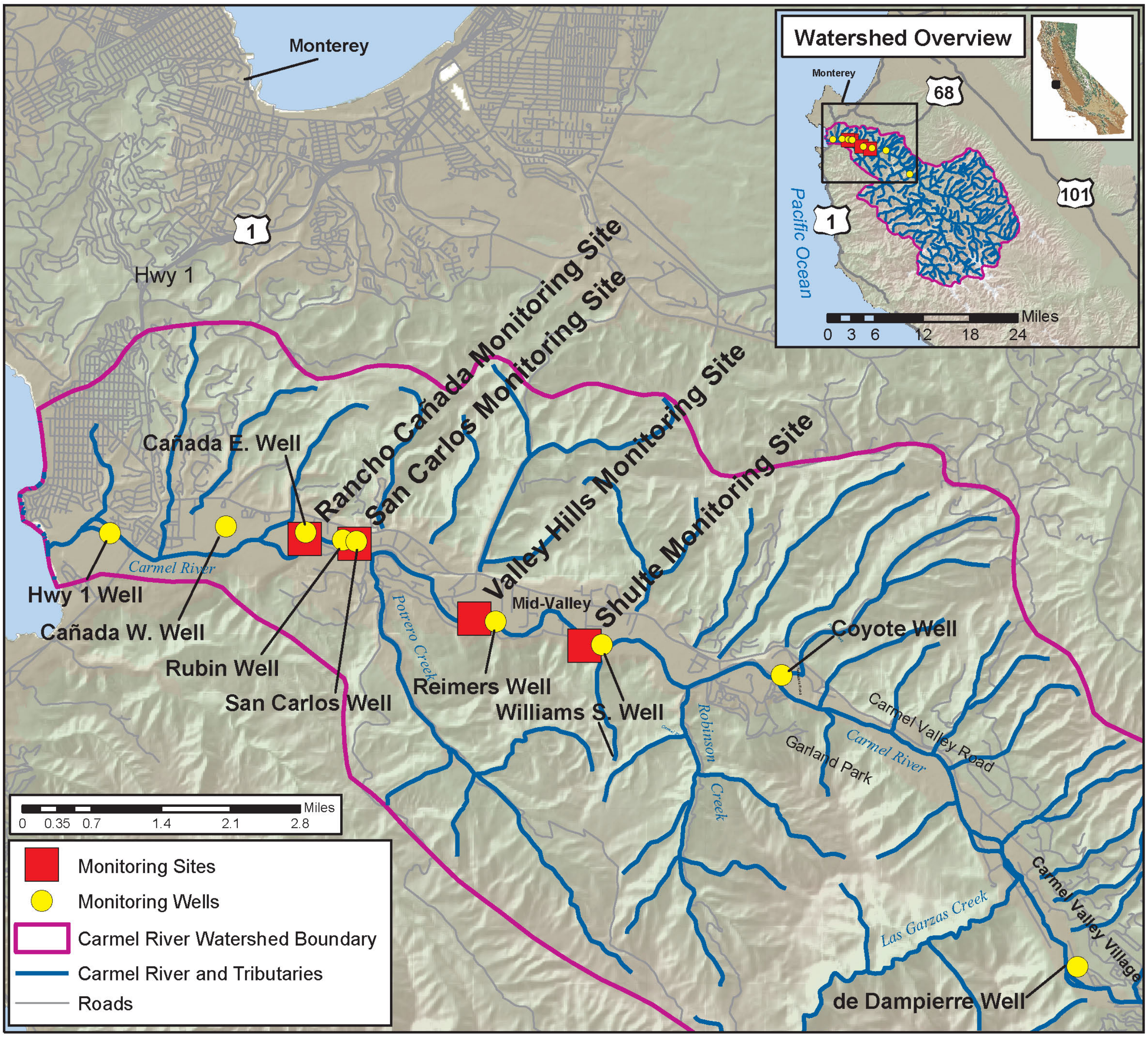

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Figure 1. The four vegetation monitoring sites and the Carmel River watershed

The Rancho Cañada monitoring site is located 3.24 miles upstream of the Carmel River mouth in the vicinity of Cal-Am's Cañada production well. This well has the capacity to pump up to 5 cubic feet per second and can negatively effect riparian vegetation. The north bank is comprised of relatively young riparian vegetation that is part of restoration efforts by the Rancho Cañada Golf course. The south bank is a more mature stand of willows and cottonwoods. Both banks are steep with high terraces. Pre-dawn leaf moisture stress samples taken at this site include three willows, and three cottonwoods. This site has a monitoring well but no tensiometers.

The San Carlos monitoring site is located 3.60 miles upstream of the Carmel river mouth. This site encompasses one of the largest mature riparian areas remaining in the lower Carmel Valley. It consists of a high terrace with large black cottonwoods and relatively steep banks consisting mostly of red and arroyo willows. Cal-Am has a production well at the site that is capable of pumping 2.45 cubic feet/second but has not been in production since November 8th, 2002, since the Monterey County Environmental Health Department determined it to be under the influence of surface water. This prevented Cal-Am from using this well until they can provide surface water treatment. This well could be put back into production as Cal-Am has investigated treatment of the water. Irrigation at this site began in 1989 to offset impacts to riparian vegetation. The San Carlos site includes two tensiometer stations and a monitoring well. Pre-dawn leaf moisture stress samples include three willows and three cottonwoods.

The Valley Hills monitoring site is located 5.60 miles upstream of the Carmel River mouth. This restoration site, installed in 1992, is 1,500 linear feet along the river channel and is located adjacent to agricultural lands. The Cypress production well is adjacent to the site and can negatively effect riparian vegetation. The Valley Hills monitoring site includes two tensiometer stations and pre-dawn leaf moisture stress samples that include three cottonwoods and four willows.

The Schulte river monitoring site is located 6.70 miles upstream of the Carmel River mouth. This restoration project was completed in January of 1988 and consisted of 3,200 lineal feet of channel realignment and floodplain modification. The Schulte production well is adjacent to the monitoring site and can negatively effect riparian vegetation. The Schulte project includes three tensiometer stations and a monitoring well. Pre-dawn leaf moisture stress samples include four willows and three cottonwoods.

III. METHODS

Groundwater Monitoring

For this report, eight wells are monitored for depth to groundwater (Table 1) with an Olympic Well Probe model 150. Five monitoring wells are used to characterize the depth to groundwater within the lower portion of the Carmel River alluvial aquifer. The most downstream monitoring well is the State Parks/Highway 1 monitoring well followed by the Cañada West, Cañada East, Rubin, and San Carlos wells, respectively. Three 'upstream' monitoring wells are used to characterize depth to groundwater values in the upper alluvial portion of the Carmel River alluvial aquifer, from downstream to upstream, the Reimers, Coyote and deDampierre monitoring wells.

For this report, depth to groundwater data is collected every two weeks from May through October, but other MPWMD personnel monitor some of these wells in addition to many other wells year round on a monthly interval. Data from one of these wells 'Williams South' was chosen for use in this report to show depth to groundwater near the Valley Hills monitoring site, bringing the number of wells referred to in this report to a total of nine.

For the 2004 season, depth to groundwater monitoring began on May 7, 2004. The monitoring alternated bi-monthly between downstream well stations (San Carlos, Rubin, Cañada East, Cañada West, and Highway 1) and well stations further upstream (de Dampierre, Coyote, and Reimers).

Table 1. Attributes of the Carmel River Alluvial Aquifer Monitoring Wells Selected for Study

Name Used[1]	Other Common Name	Year Drilled	State Well No.	River Mile[2]	Distance from River (feet)	Well Depth (feet)	Screened Interval (feet)	Reference Point Elevation (feet AMSL)[3]	Date of Maximum Depth to Groundwater Measured	Maximum Measured Depth to Groundwater 2004 (feet)
Highway 1	Odello West - near CAWD (E)	1989	T16S/R1W-13Lb	0.72	65	65	55-64	15.00 (e)	09/24/04	8.44
Cañada West	Rancho Cañada West	1993	T16S/R1E-18Ka	2.13	1230	100	40-90	38.00 (e)	10/22/04	21.45
Cañada East	Rancho Cañada North Deep	1978	T16S/R1E-17Lb	3.13	360	100	60-80	49.69 (s)	10/22/04	43.80
Rubin	Rubin	1984	T16S/R1E-17Jd	3.56	80	95	5-95	48.59 (s)	10/22/04	23.76
San Carlos	San Carlos Deep (#2)	1983	T16S/R1E-17Jc	3.65	170	68	48-68	51.32 (s)	10/22/04	23.08
Williams South	Williams Monitor	1984	T16S/R1E-22Fc	5.57	90	100	5-100	87.08 (s)	08/30/04	44.38
Reimers	Reimers #1	1988	T16S/R1E-23La	6.72	150	122	50-122	102.10 (s)	10/15/04	22.80
Coyote	Coyote Upstream/ Scarlett #1	Pre-1973	T16S/R2E-19Nx	8.86	340	47	20-41	142.32 (s)	09/17/04	21.66
de Dampierre	Little League #1	1988	T17S/R2E-03La	13.65	580	50	30-50	251.00 (s)	09/03/04	8.04

NOTES:
1. Name used in this project
2. River Mile designations are calculated in distance from the mouth of the Carmel River at Carmel Bay
3. (s) = surveyed elevation, (h) = hand-leveled elevation, (a) = altimeter elevation, (e) = estimated elevation from topographic map

Soil Moisture Measurement

Tensiometers (Figure 2) are used at three vegetation monitoring sites (San Carlos, Valley Hills, and Schulte) to determine soil moisture. The tensiometers consist of a sealed tube, a porous tip (at the bottom of the tube), a vacuum gauge, and a reservoir pump. The tube is buried with the porous tip at the bottom and water is hand-pumped into the tube from the reservoir. Once the column of water in the tube is filled, the device is left alone. Over time, the soil pulls the water out of the tube though a porous tip. A vacuum gauge then measures the attractive forces of the surrounding soil on the water filled column. Tensiometers work on the principle that the drier the soil is; harder it pulls on the water filled in the column. Eventually, the pull of the soil will reach equilibrium with the vacuum inside the tube and an accurate measure of soil tension can be read from the vacuum gauge. Soil tension is inversely proportional to available moisture and gives an indication of how much moisture is available for plant health.

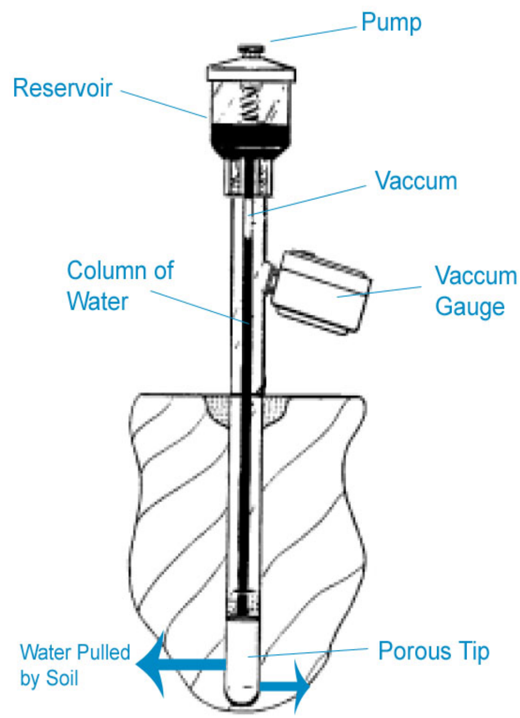

Figure 2. Tensiometer

The tensiometers used have two different lengths (18” & 36” below the surface), and are buried in pairs (one station contains one pair of each; 18” and 36”) so that the perforated ends are placed at 18 inches and 36 inches below the surface. These stations are located at different elevations above the river in order to measure soil moisture at that elevation.

Maintenance of tensiometers includes pumping of algaecide treated water into the column and refilling the reservoirs at least once every two weeks, generally done after readings are taken.

Plant Moisture Stress Testing (Pre-Dawn Leaf Water Potential)

Selected trees at the four monitoring sites are monitored bi-monthly through the dry season, which typically extends from May through October, for moisture stress. A total of 14 red willows (*Salix laevigata)* and 13 black cottonwoods (*Populus trichocarpa balsamifera*) are sampled every two weeks. The selected trees have been removed from surrounding irrigation systems, except for four 'control' trees; one of each cottonwood and willow at both the Schulte and Valley Hills restoration sites. The data collected from trees shows the water stress of specific sample trees, giving an indication of moisture stress in the surrounding area.

The trees' moisture stress is quantified through the use of a PMS Instruments Model 670 pressure bomb (plant water status console) using the following methods: First, newer-growth leaves are collected from specified trees in the pre-dawn hours for a single monitoring site. Next, for each leaf, a clean cross-sectional slice is made across the petiole of the leaf. The leaf petiole is fit tightly, cut side up, into a rubber stopper and then sealed with 'silly' putty. Then, the leaf is placed within the model 670's nitrogen pressure chamber with the petiole sticking out of the pressure chamber within view of the operator. The operator slowly increases the pressure in the chamber while simultaneously observing the tip of the petiole with a hand-lens. When the operator observes water being forced out of the petiole (leaf), the operator immediately stops increasing the pressure and records the pressure in the chamber as it reads on the model 670's dial gauge (bars). The above method is then performed for all leaves within several minutes of their collection.

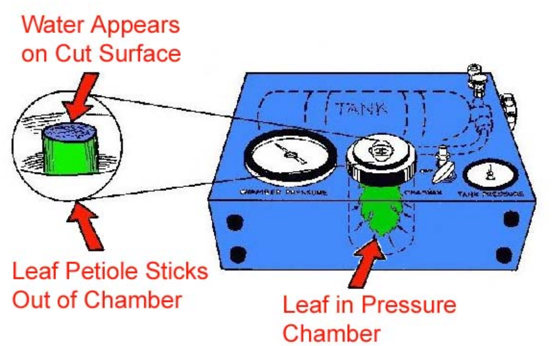

Figure 3. Pressure Bomb Instrument

Illustration Courtesy of PMS Instrument Co.

The above is performed before dawn when stomata are closed and water in the leaf is a function of available soil moisture (McNiesh, 1988). The greater the pressure required to force moisture from the tree leaf, the more stress the tree is experiencing; the amount of pressure it takes to force the free water from the petiole is a measure of the amount of water available within the plant for life processes. The established laboratory stress index stated in the Woodhouse study shows that "severe" stress is recognized when the results for willows rise above 7.5 bars and when readings for cottonwoods rise above 10.0 bars (Woodhouse, 1983). Woodhouse recommends, "Irrigation should begin when pre-dawn water potential falls to within two bars of these critical values."

In order to show the effects of irrigation on the trees, two ‘control’ monitoring trees, one each of cottonwood and willow, at both the Valley Hills and Schulte sites, were irrigated and tested for plant moisture stress. The results of plant moisture stress testing for irrigated versus non-irrigated trees will be compared to show the affects of irrigation.

IV. RESULTS

2004 Depth to Groundwater Monitoring:

The following monitoring wells; Cañada, Rubin, San Carlos, and Williams South show an increase in depth to groundwater over time especially as the river dried up in early June (Figure 4). Within a period of seven months (May through October) the aquifer level dropped 16.35 feet overall at the Williams South well and 22.28 feet overall at the Rancho Cañada well. Reasons for this steady drop in groundwater values are attributed to constant pumping of Cal-Am's production wells resulting in the lack of recharging river flow within this reach. The streambed remained dry due to the pumping and lack of rainfall until the first significant storms established streamflow al the way to the Carmel River Lagoon on December 27, 2004.

In contrast to these above-mentioned monitoring wells, the 'upstream' monitoring wells (at DeDampierre, Coyote, and Reimers) show little overall change in depth to groundwater values (Figure 5). The consistent values at these upstream groundwater level monitoring sites are a function of perennial flow, and reduced pumping of the nearby production wells.

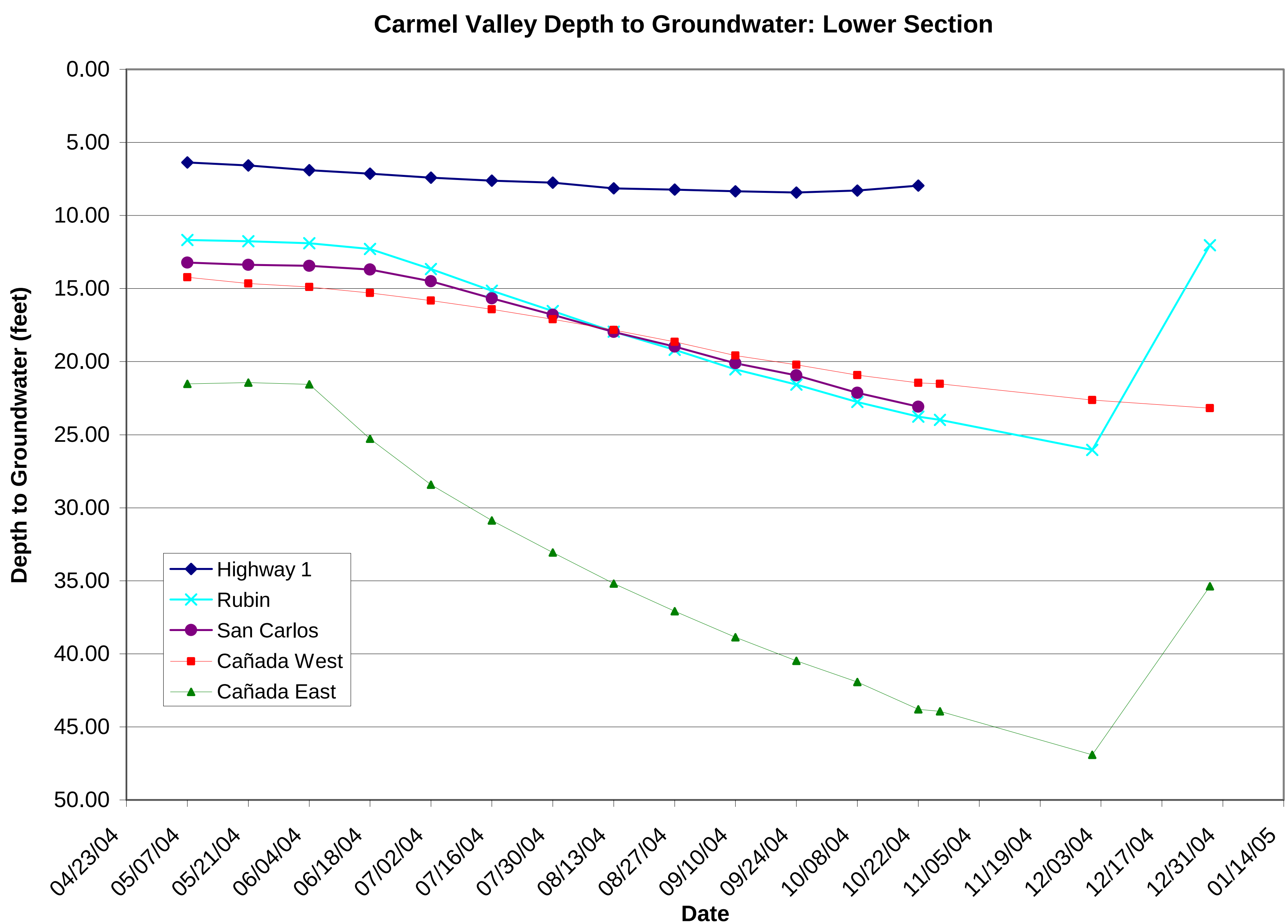

Figure 4. Carmel Valley Alluvial Aquifer Depth to Groundwater: Lower Section

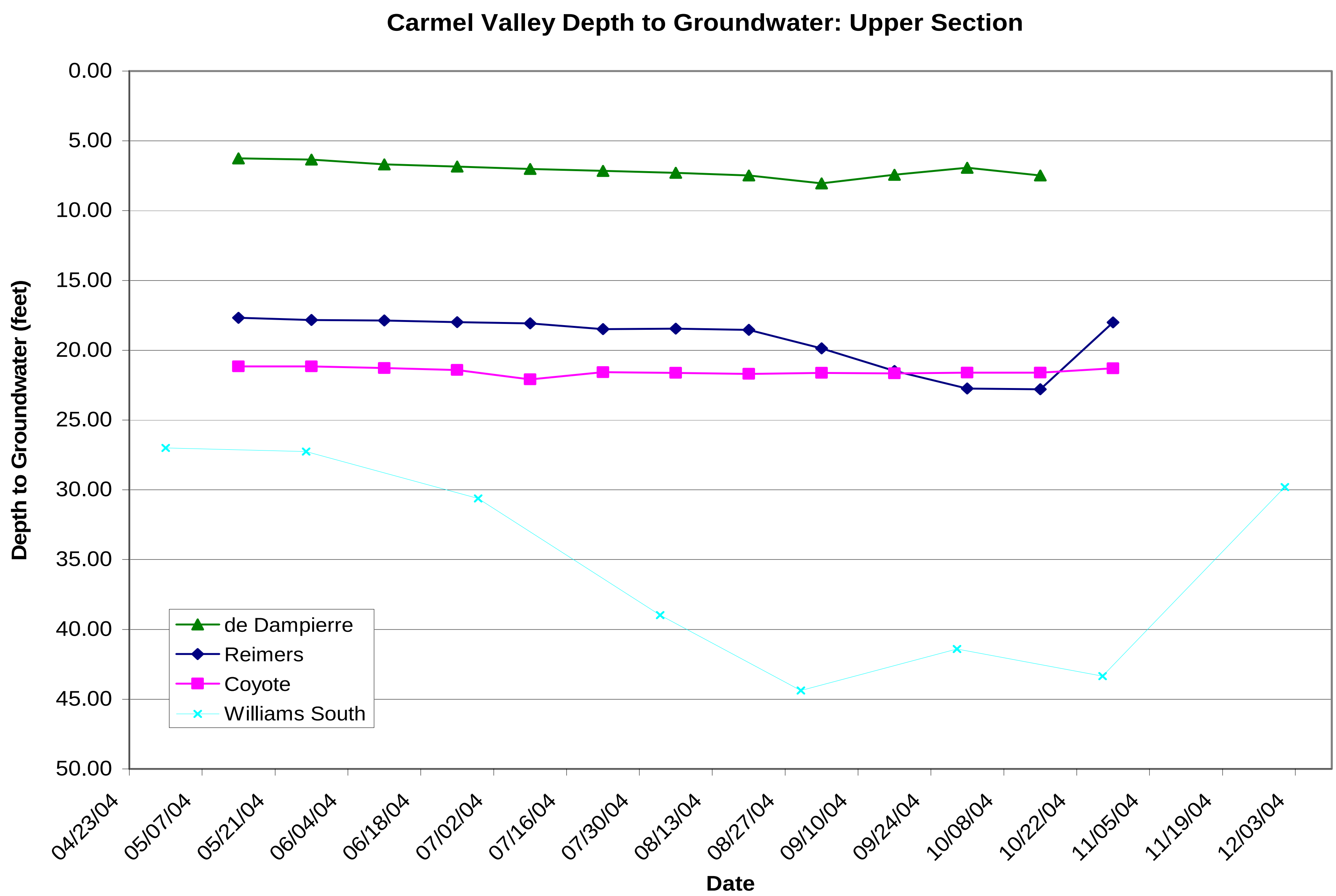

Figure 5. Carmel Valley Alluvial Aquifer Depth to Groundwater: Upper Section

2004 Pumping Regime

The plot of Cal-Am's Rancho Cañada production well verses the depth to groundwater values at the adjacent Rubin, San Carlos, and Rancho Cañada monitoring wells (Figure 6) shows the drop in depth to groundwater is proportional to the pumping of municipal production wells. The general trend shows as production remained consistent during the heavy demand period of May through October, the depth to groundwater continuously dropped after the river dried up in early June at the nearby Via Mallorca Bridge.

Figure 6 also shows the 'cone of depression'; a regional drop in the water table that increases in depth as it approaches the production well. The San Carlos and Rubin monitoring wells are further from the Rancho Cañada production well than the Cañada East Monitoring well, of which shows a much greater drop in depth to groundwater.

Figure 7 shows a steady drop in depth to groundwater at the Williams South monitoring well, located adjacent to the cypress well. Groundwater levels dropped to over 40 feet below the wooded terrace, and remained there throughout the remainder of the summer.

A direct relationship between municipal pumping and depth to groundwater is illustrated in Figure 8; Shulte Well Production Vs. Depth to Groundwater at Reimer's well. Depth to groundwater dropped more than 4.5 feet after the river dried up through the Shulte area in July, due to pumping at Cal Am's Shulte production well. However, in October, production was, for some reason or another, halved then reduced to fractions of what it had been for the previous months. Without this extraction, the cone of depression quickly disappeared and by the end of the month, the water table rose to levels seen previous to the river drying.

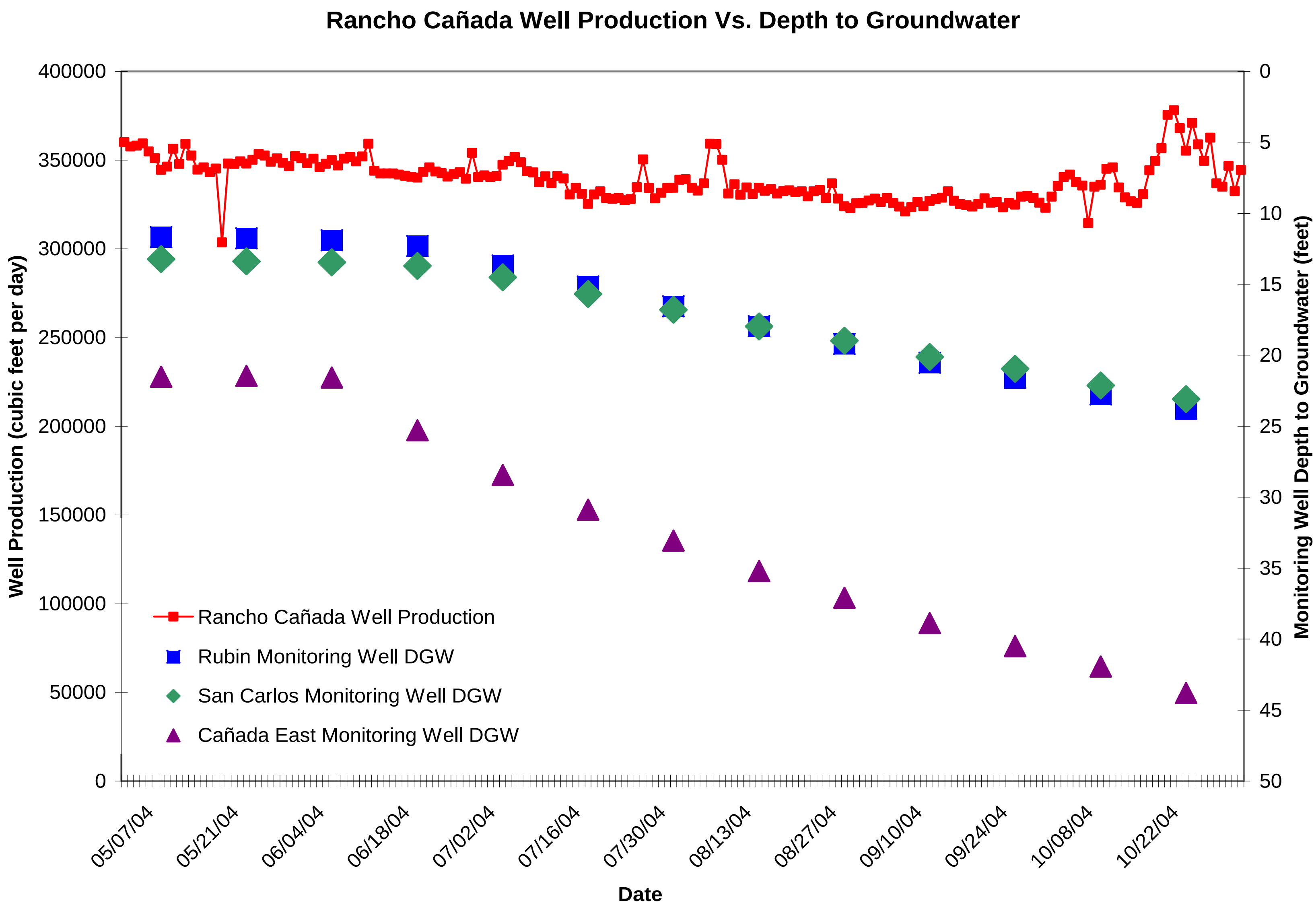

Figure 6. Rancho Cañada Well Production Correlated with Nearby Depth to Groundwater

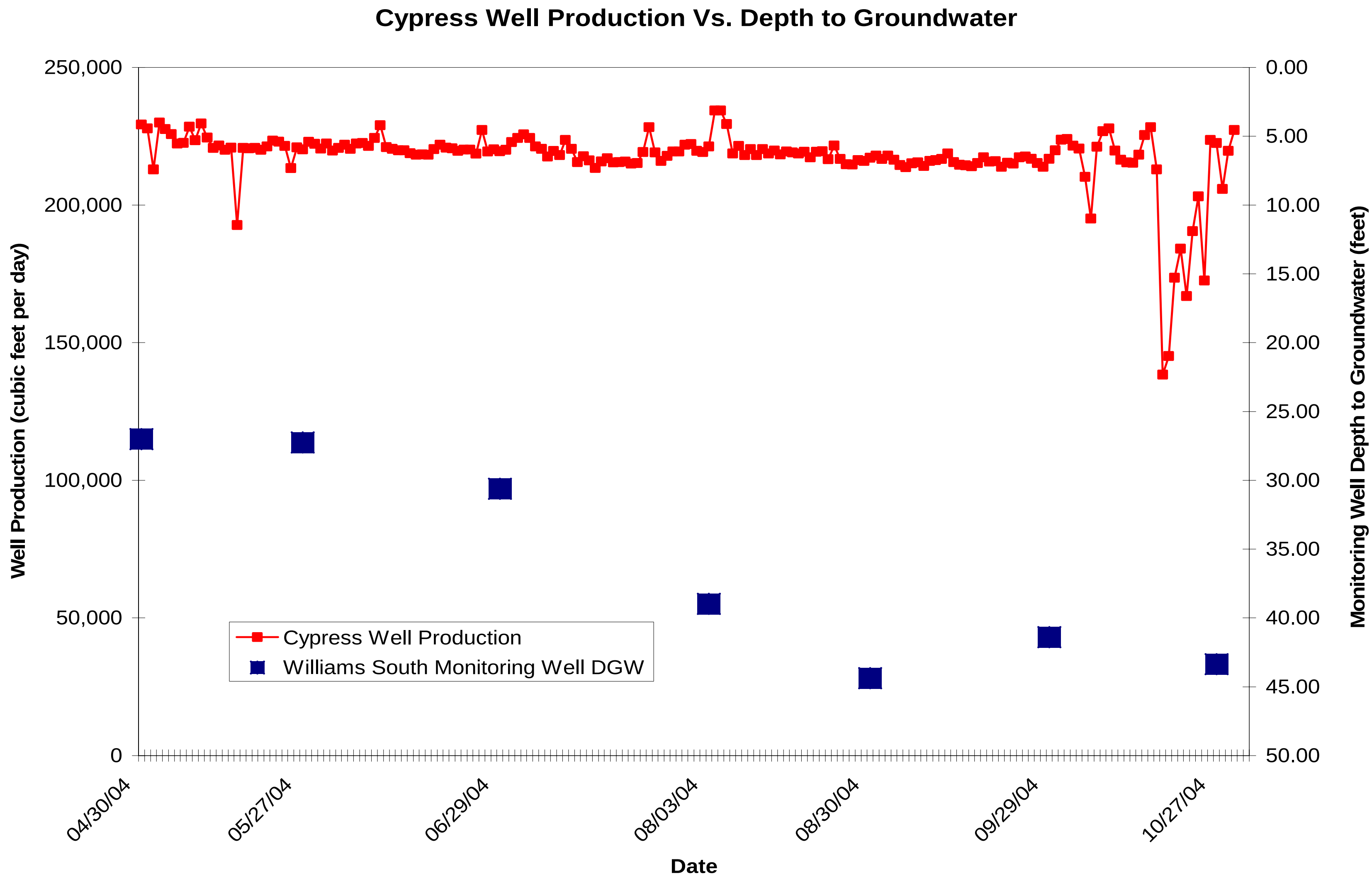

Figure 7. Cypress Well Production Correlated with Nearby Depth to Groundwater

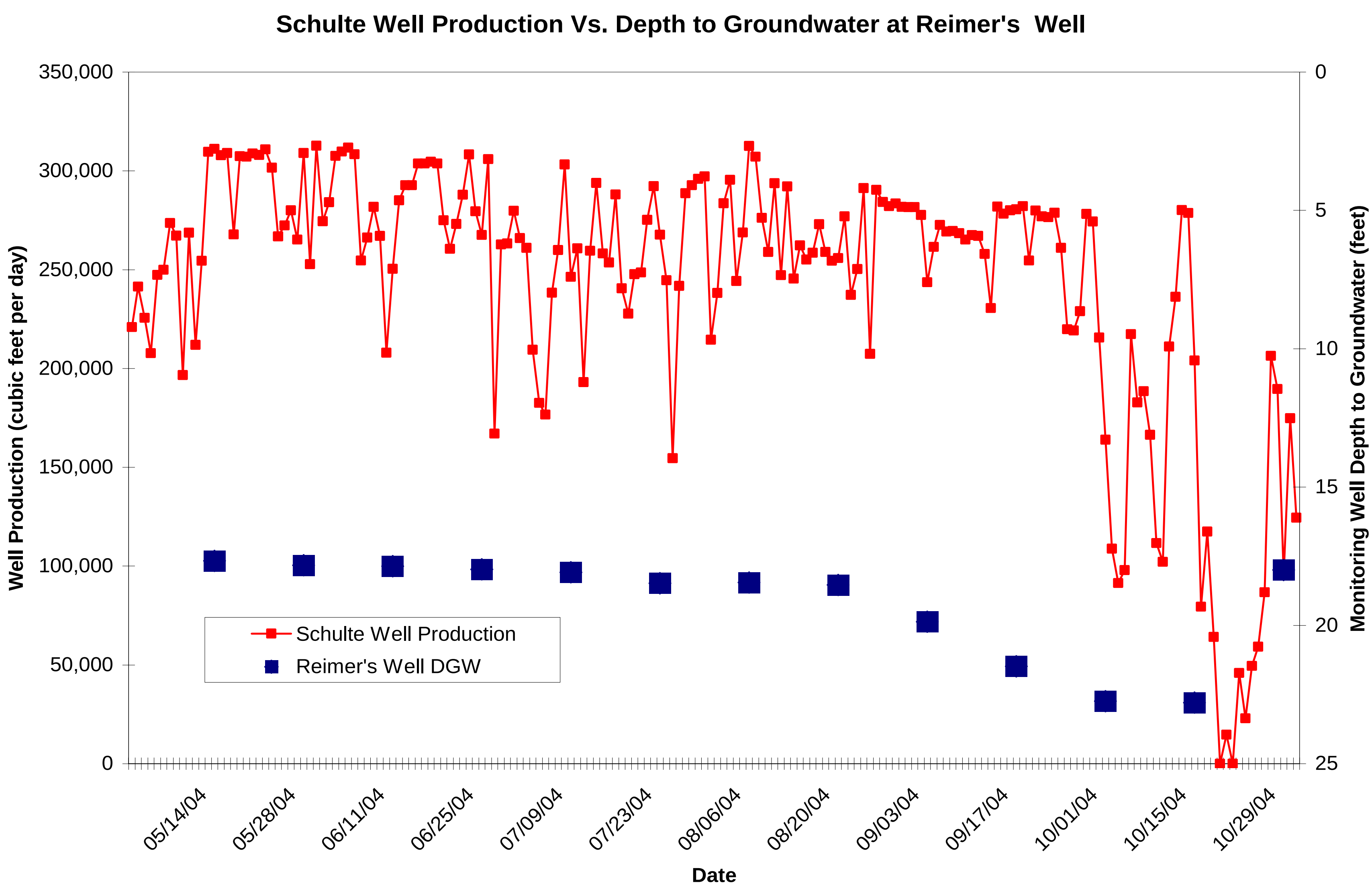

Figure 8. Schulte Well Production Correlated with Nearby Depth to Groundwater

Soil Moisture:

Tensiometer values at San Carlos begin at approximately 0.08 bars (toe station, close to river channel) and 0.50 bars (terrace station) in early May and rose steeply to 0.75 bars by August (Figure 9. San Carlos Site Tensiometer Soil Dryness Values). Analyses of these graphs (Figures 9-11) are useful in determining the duration of specific moisture conditions. For example at the San Carlos site the tensiometer readings remained in a steady pattern for the terrace station while the toe station showed a rapid change in soil moisture which is related to the river channel drying up at the site. Station low is located near the river while station high is located up on the terraces. This explains the large variations between the two stations form the start. In comparison, soil moisture at the Valley Hills site demonstrated the same pattern. Each station shows a general pattern (Figure 10. Soil Tension at the Valley Hills Site).

The relationship between river flow and soil moisture is demonstrated in Figure 10. Soil tension remained low (soil was moist) throughout May and early June when there was river flow and a healthy water table associated with that flow. In late June, heavy groundwater pumping by Cal Am drew down the water table in the area, river flow subsequently ceased, and the soil dried out (see Figure 7). Soil tension at the toe tensiometer stations (near the river) rose abruptly from ≈0.10 bars to ≈0.80 bars- the wilting point for most plants. Dryness values remained high until late October when it finally rained.

Values for terrace tensiometers at the Valley Hills Monitoring site (Figure 10) do not reflect the actual dryness experienced by nearby monitoring trees. These tensiometers would not hold a vacuum at all from mid-August until the late October rains. This could be attributed to extreme tension of which would be powerful enough to break seals on the tensiometers, air spaces around the shaft of the tensiometer, or that conditions were drier than these tensiometers are designed to operate in. Tensiometers can also fail when all of the liquid is completely sucked out of the vacuum shaft and it can no longer hold a vacuum. Tensiometer failures can be seen in discontinuous data in the plots of Figures 9 & 11 as well. These failures all have been on terrace tensiometers where the soil is drier.

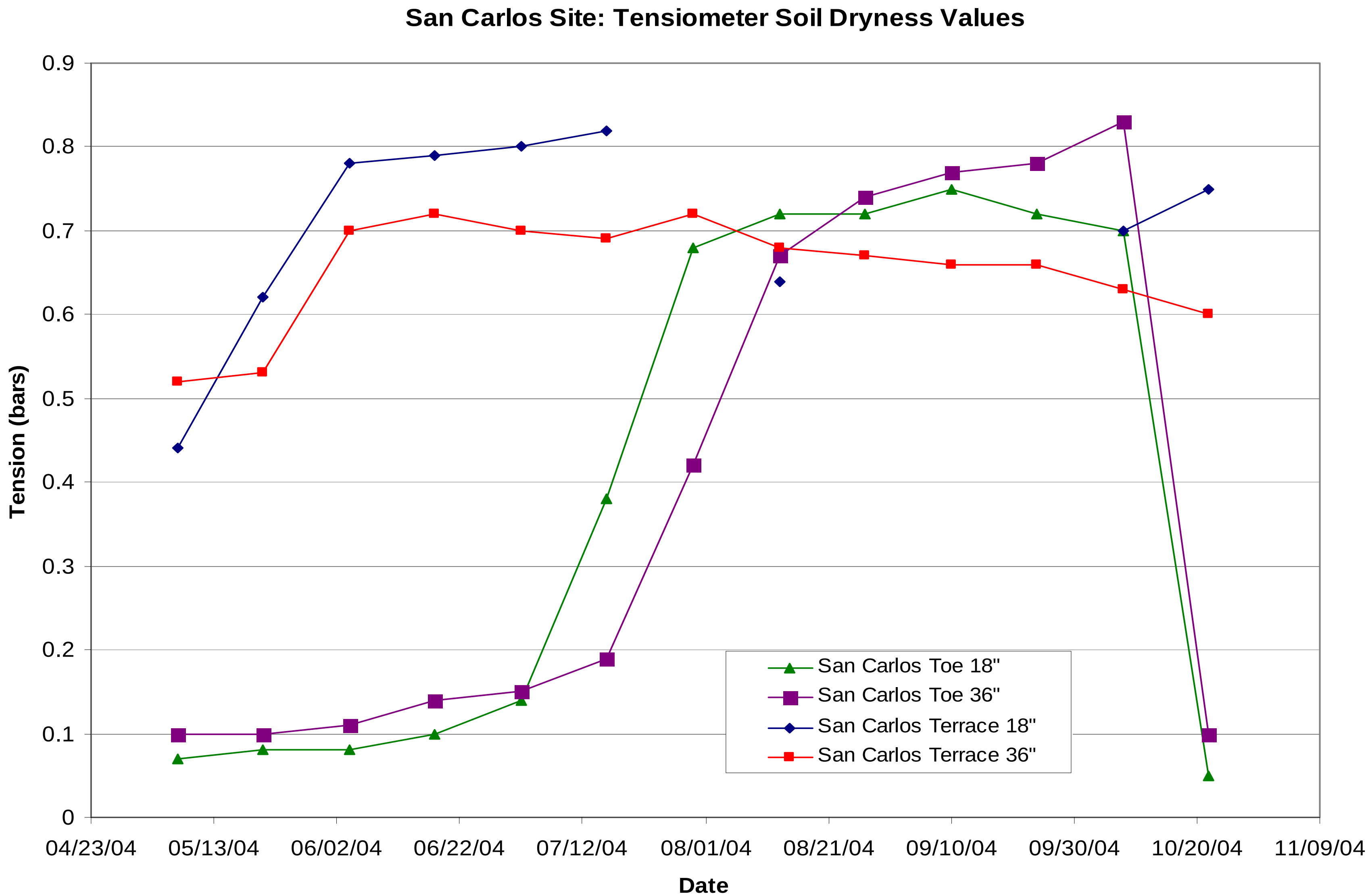

Figure 9. Soil tension at the San Carlos Site

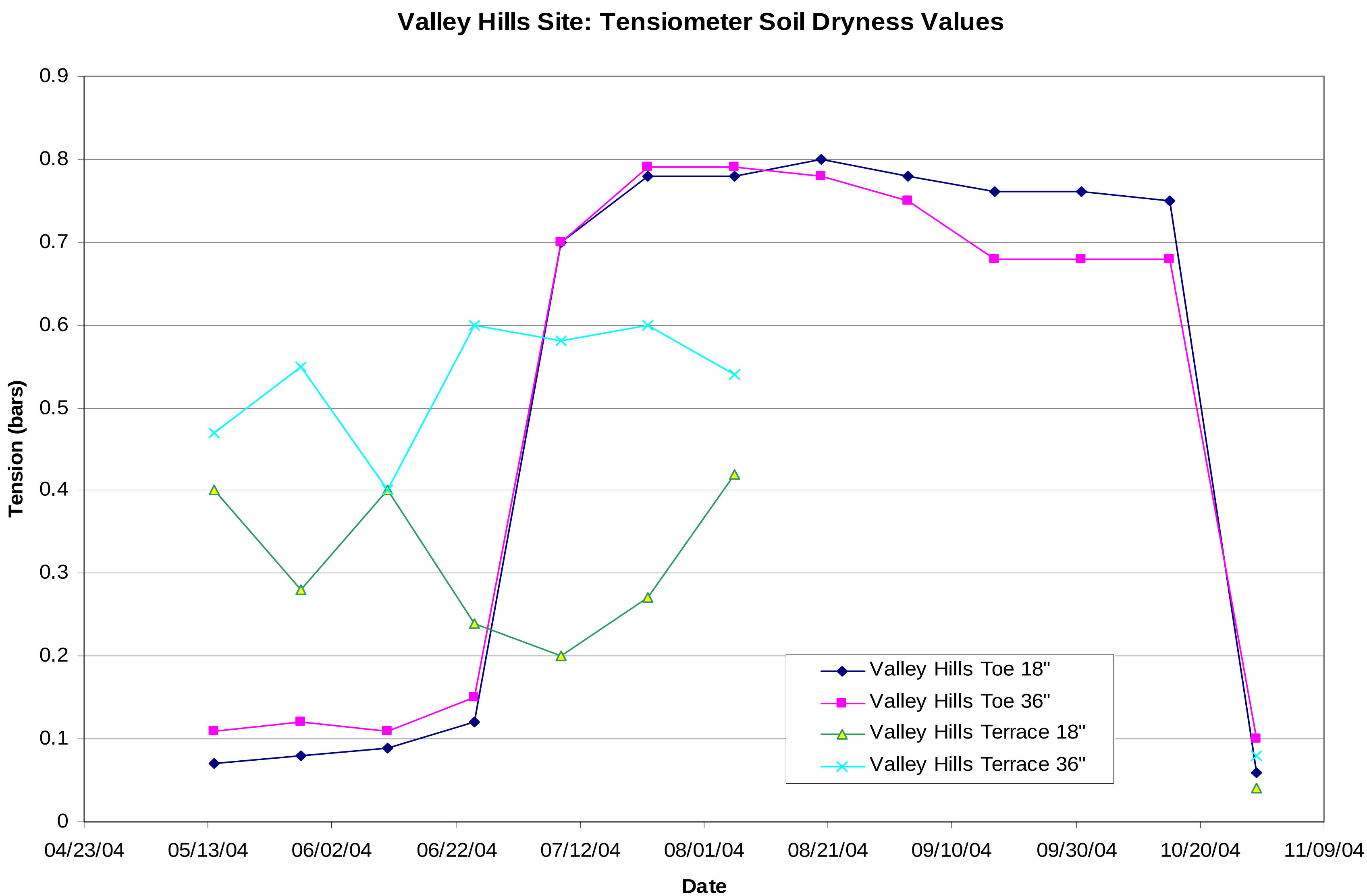

Figure 10. Soil tension at the Valley Hills Site

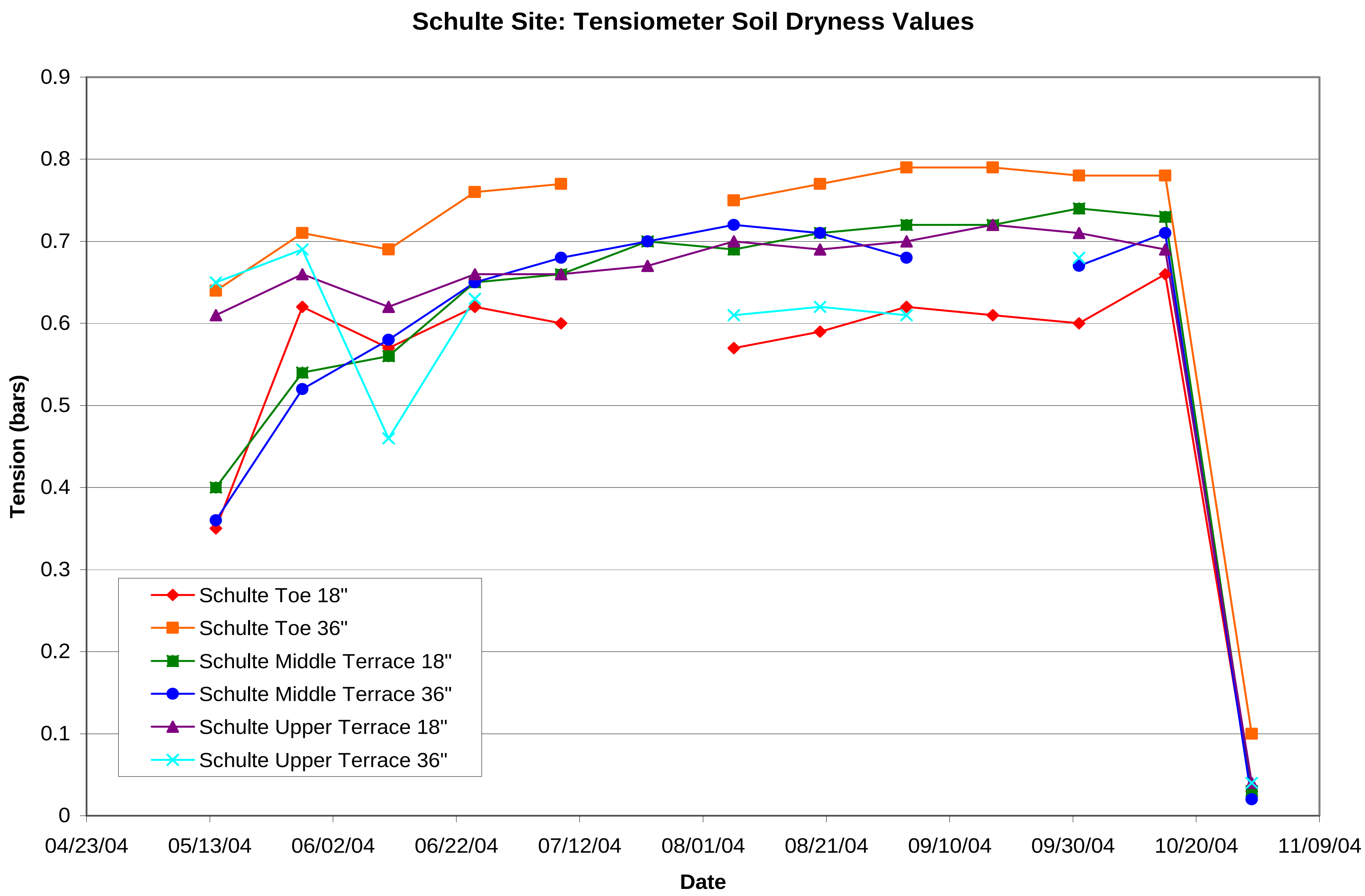

Figure 11. Soil tension at the Schulte Site

Plant Moisture Stress

Table 2 is a summary of pre-dawn moisture potential readings for all four sites. The average annual reading for willows and cottonwoods as well as the highest reading for each tree at each site is given.

Table 2. Average Pre-Dawn Leaf Water Potential Summary 2004

Monitoring Site	Cottonwood		Willow	
	Maximum (bars)	Average (bars)	Maximum (bars)	Average (bars)
Rancho Cañada	9.00	5.36	5.58	3.93
San Carlos	6.08	3.61	4.07	2.60
Valley Hills	12.63	7.98	14.00	7.92
Schulte	6.00	4.21	7.58	3.89

Depth to Groundwater Values vs. Average Pre-Dawn Leaf Water Potential Values

Pre-dawn leaf water potential monitoring is a valuable tool in monitoring vegetation stress within the riparian corridor. Pre-dawn leaf water potential readings of 7.5 bars or greater indicate water stress in willows and values of 10.0 bars or greater indicate water stress in cottonwoods (McNiesh, 1988).

Pre-dawn leaf water potential values fluctuate naturally due to weather. For example, values tend to drop during periods of heavy fog. Because the vegetation monitoring sites are all located within several miles of the coast, periods of heavy fog in lower Carmel Valley can precipitate around trees, providing them with much needed water in the form of fog drip. Variations in available sunlight can also affect Pre-dawn water potential values; with more sunlight, the tree has more potential for photosynthesis- a process in which water is pulled form the tree. These two processes together can have an additive affect. For example, sunny days with no fog, versus foggy days with less sunlight, can create large fluctuations in Pre-dawn leaf water potential. These fluctuations are distinctive in Figures 12-14. Because of these natural fluctuations, pre-dawn moisture potential is discussed in terms of averages over time.

The San Carlos graph illustrates that average pre-dawn leaf water potential values rise as depth to groundwater values fell (Figure 13). By July, river flow ceased within the San Carlos reach, which led to an overall rise in pre-dawn leaf water potential values (bars) starting from mid-July and continuing through October, when the first storm systems returned ample water to the trees monitored.

Similar patterns are shown in Figures 12 and 14, pre-dawn leaf water potential rises sharply as the depth to groundwater falls subsequent to the river drying. Note that the river dries from downstream to upstream as the groundwater, which provides the support for the surface flow, is diverted by production wells. In order from lowest to highest the river dries (and groundwater falls) first at the Cañada site, then at San Carlos, Valley Hills and finally Schulte. This pattern is reflected in Figures 12 through 14 as average pre-dawn leaf water potential rises and depth to groundwater drops.

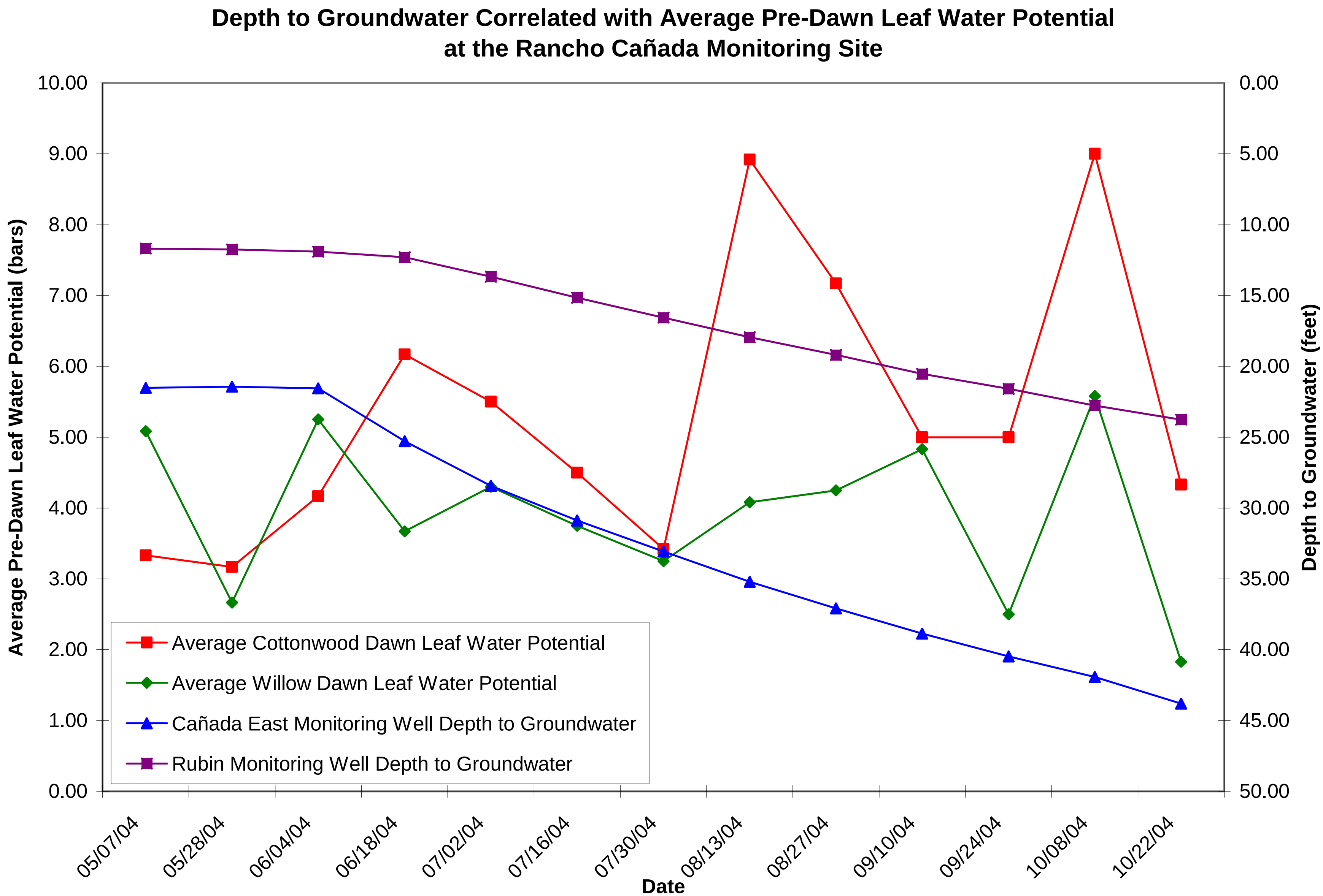

Figure 12. Plant Stress Correlated with Groundwater Availability at the Rancho Cañada Site

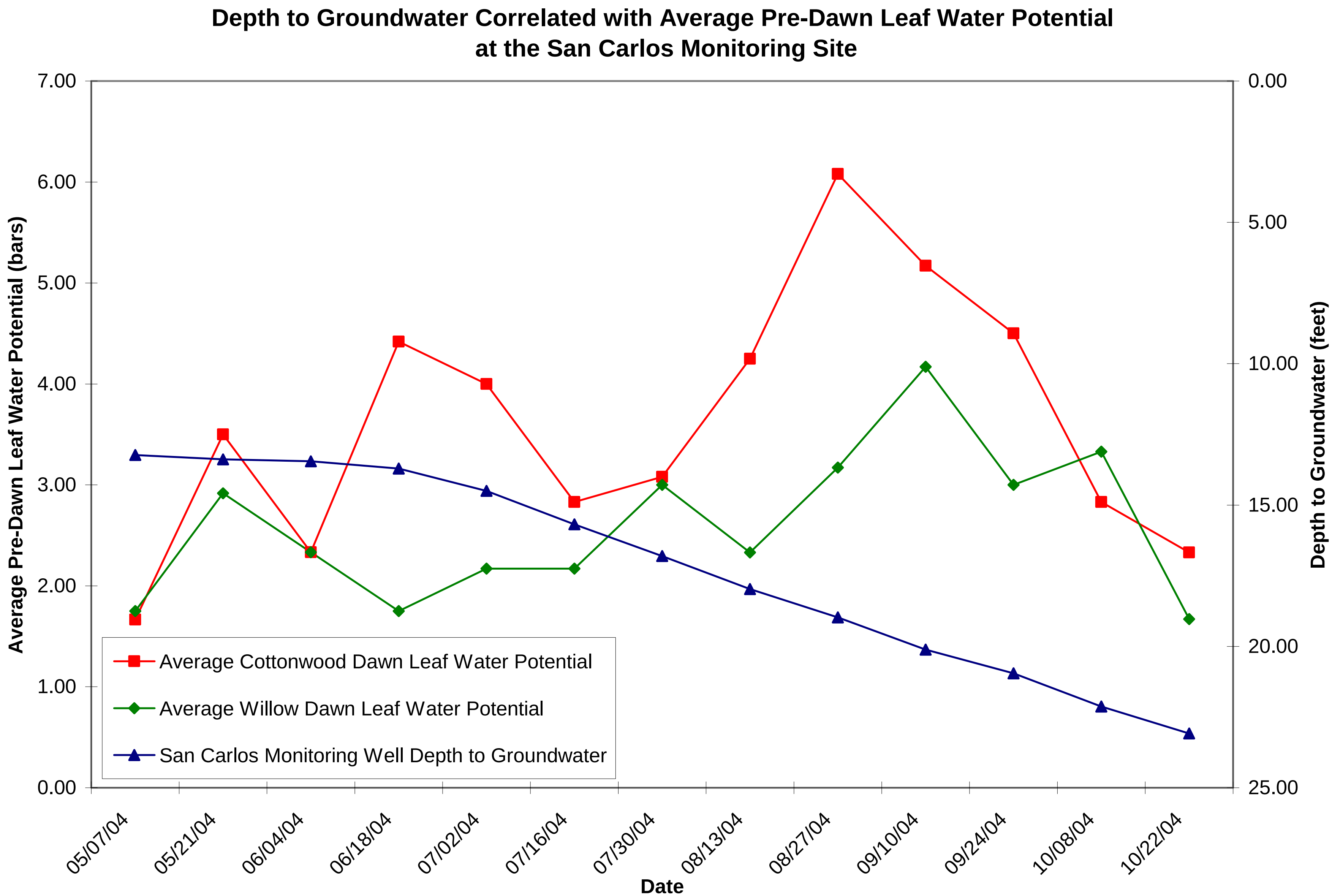

Figure 13. Plant Stress Correlated with Groundwater Availability at the San Carlos Site

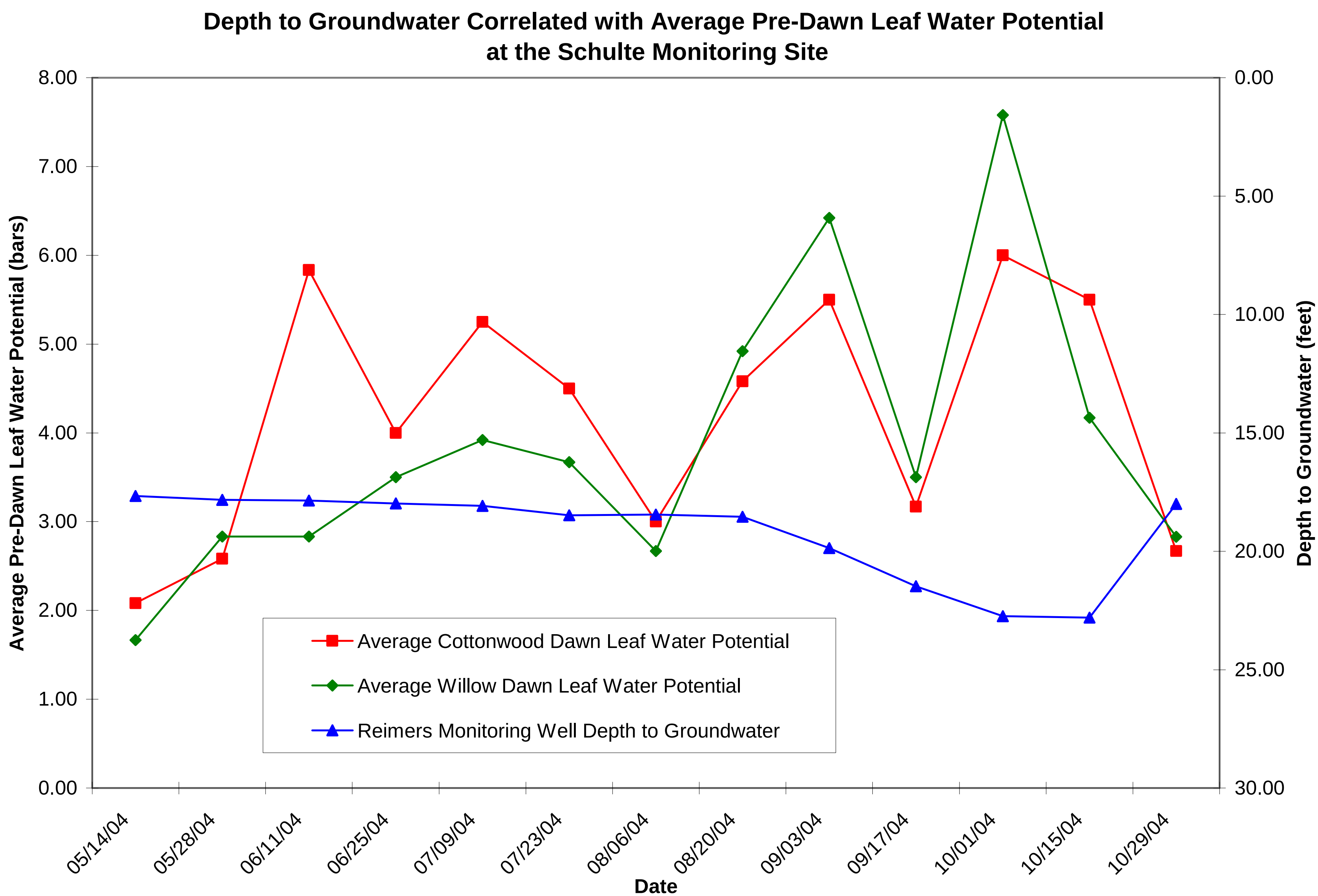

Figure 14. Plant Stress Correlated with Groundwater Availability at the Schulte Site

Historic Depth to Groundwater

Historic depth to groundwater values from 1988 through 2004 were plotted for six monitoring well sites; de Dampierre, Coyote, Reimers, San Carlos, Rubin, and Highway 1. These plots provide baseline data for each monitoring site, indicating minimum and maximum groundwater depths from 1988 through 2004 (See Appendix A for historic depth to groundwater plots). The annual variation in depth to groundwater is mostly a function of annual precipitation, stream flow, and municipal pumping regimes. Extreme groundwater levels that are observed to exceed historic maximum depth can justify the application of irrigation to mitigate stress on riparian vegetation.

Irrigation

With the exception of the irrigated 'control' trees, all monitoring trees (those that are analyzed for plant moisture stress) are removed from irrigation, though may be under the influence of irrigation from neighboring trees. These trees are removed from irrigation for two reasons; to measure how the trees respond to drops in the water table without the irrigation, and to gauge how the trees will respond to weaning them off irrigation.

In drier years, monitoring trees have suffered moisture stress to the point of fatality, either directly from desiccation or indirectly from disease resulting from lack of water. In several instances another tree was chosen to study so that the dying tree could be removed from the monitoring program and returned to the irrigation regime. Overall, mortality rates are higher for trees planted at the higher elevations above the river channel (also referred to as the terrace).

As shown in Figures 15 & 16, trees irrigated weekly ('control' trees) show less stress than unirrigated trees. At the Schulte site average irrigated cottonwood stress was 2.69 bars versus 4.21 bars for the average unirrigated cottonwood; this shows 36% less plant moisture stress.

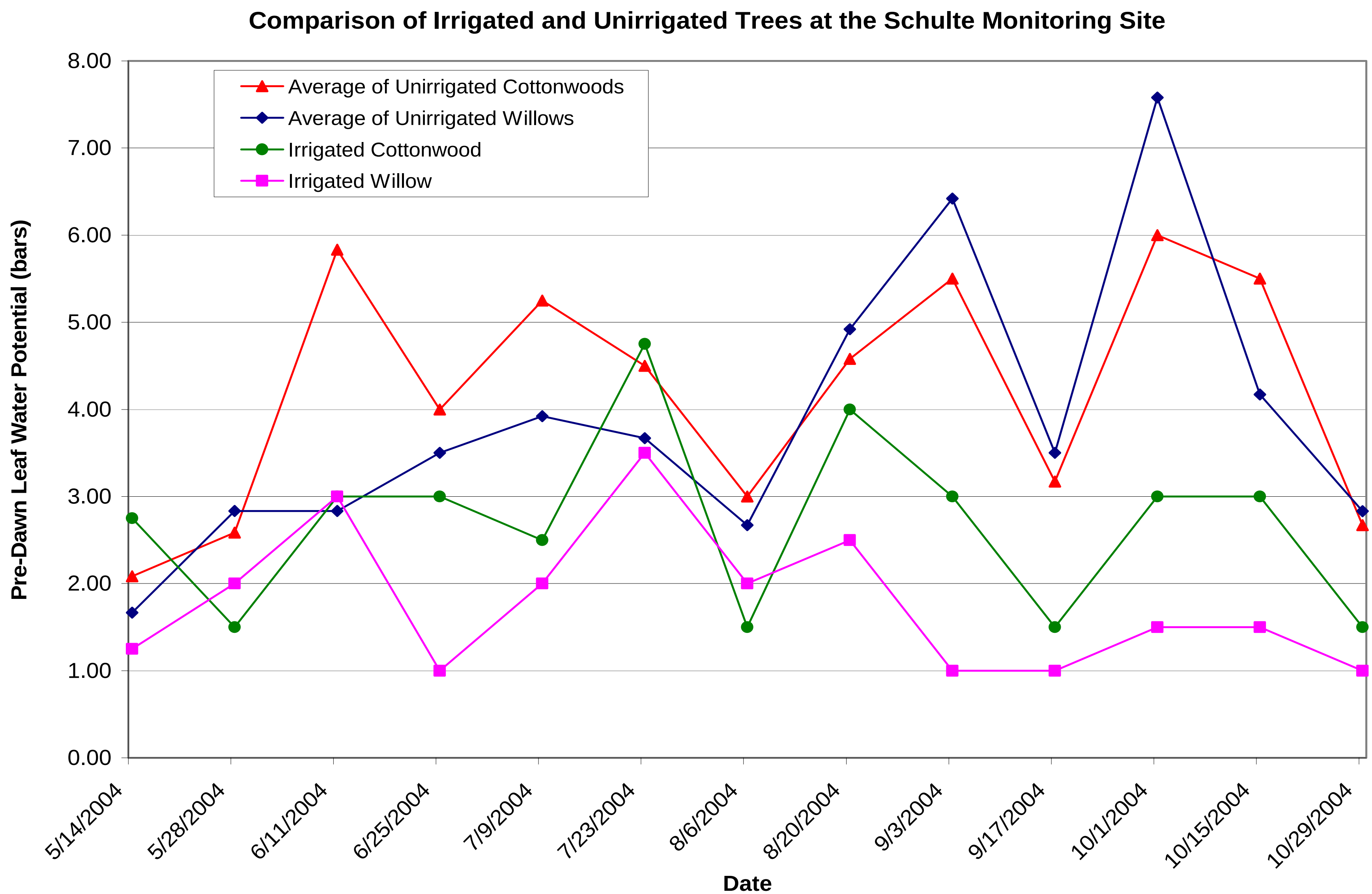

Figure 15. Effects of Irrigation on Monitored Trees at the Schulte Monitoring Site

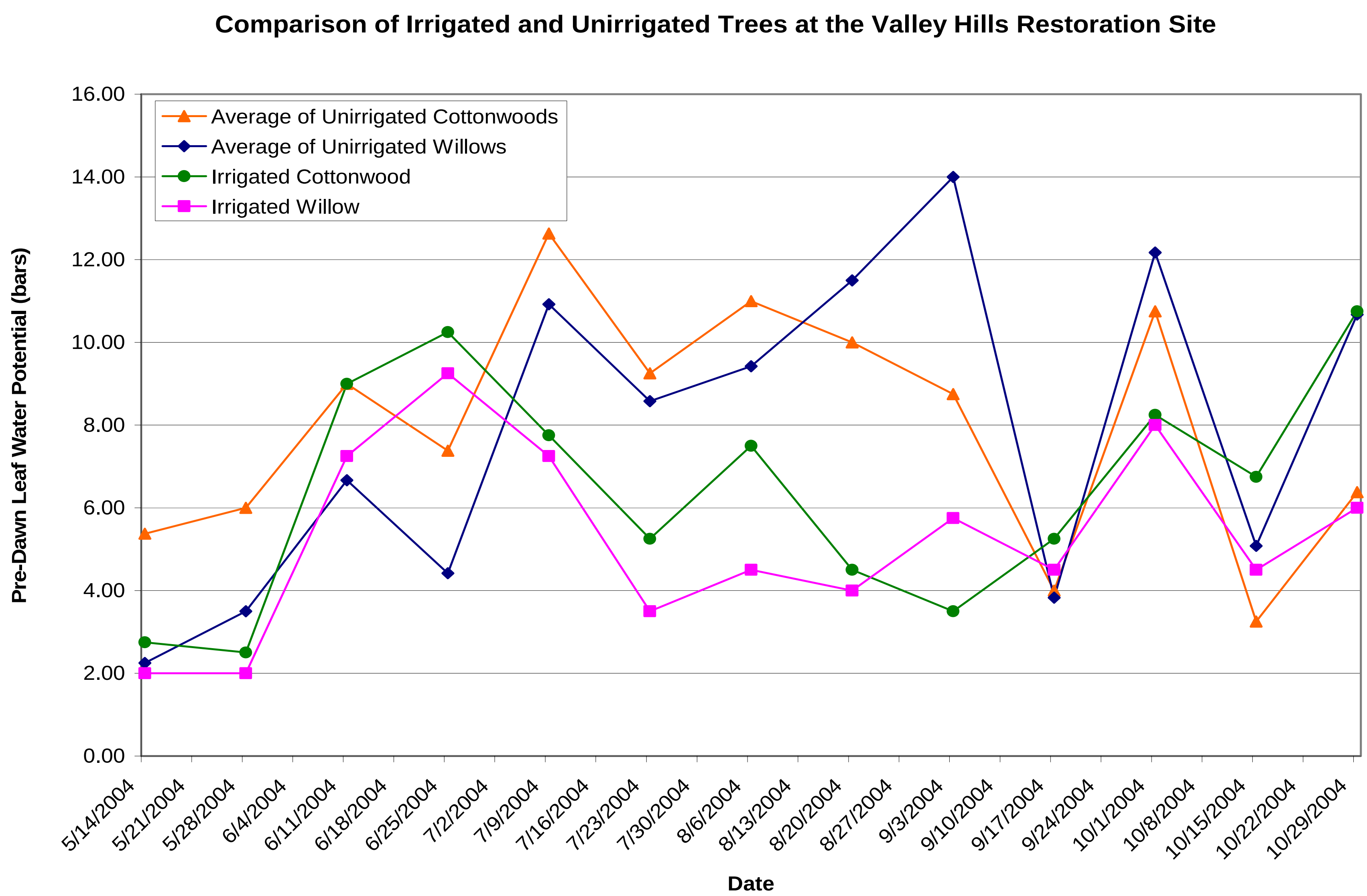

Figure 16. Effects of Irrigation on Monitored Trees at the Valley Hills Monitoring Site

V. DISCUSSION

Many complex interacting factors influence the moisture stress experienced by riparian vegetation. Factors that impact riparian monitoring results include depth to groundwater, which is influenced by weather, precipitation, river flow, and groundwater pumping. This in turn impacts soil moisture. To complicate things further, different soils have different water holding capacities. Finer textured soils (clay) hold more water than coarse textured soils (sand). Therefore, directly measuring plant stress helps integrate the various driving forces. However, it is important to note that there is a lag time associated with a change in depth to groundwater and moisture stress in individual plants. Plant available moisture is a function of matric potential (capillary and surface binding forces), osmotic potential produced by solutes in the soil water, gravitational forces, and external pressure (Kramer, 1995). As the water table drops, residual moisture in the soil still provides water for a limited time to plants.

Production wells in Carmel Valley influence overall flow in the Carmel River. However, the most notable impacts to riparian vegetation occur near higher volume production wells (Cañada, Cypress, and Pearce). The results show that riparian vegetation experiences an increase in moisture stress in relation to a reduction in stream flow and a drop in the water table elevation. Initial studies on the Carmel River done by McNiesh state that severe water stress is defined by a draw down rate of two or more feet per seven days; mild water stress is defined by a draw down rate of one to two feet per seven days or a total draw down of eight feet below the elevation of the adjacent river channel; and no effect is defined as draw down of less than one foot per week throughout summer and autumn and a total draw down of less than four feet below the adjacent river channel (McNiesh, 1986).

Draw down on the Carmel River peaked at the Cañada Well with a 1.86 foot drop in the water table (3.72 ft drop for a two week period June 4-18, 2004). Other studies show that on coarse substrates in dry regions, early establishment and growth of *Populus* spp. seedlings may require water tables within 3.3-6.6 feet of the established surface (McBride and Strahan, 1984, Mahoney and Rood, 1992, Stromberg et. al, 1996). Root growth of established trees allows survival during gradual water table decline. Mature trees are more suited to withstand channel incision and flood plain isolation (Everitt, 1968). Cottonwoods typically grow where the depth to the water table is 11.5 feet (Busch et. al. 1995, Scott et. al. 1997, Stromberg et. al. 1997), although cottonwoods have been observed to exist in areas where the water table is 23 to 30 feet deep. The San Carlos results show that the depth to groundwater dropped to almost 19 feet below the wooded terrace in August and continued to drop to a maximum low of 23.08 feet below the riverbed on October 22, 2004. Mature black cottonwoods have also been found 31 feet above the water table on a historic floodplain in the San Carlos area. These values appear to be close to the limit of what black cottonwoods on the Carmel River can withstand. Mortality may have been avoided simply because these are mature black cottonwoods, with extensive root structures, growing in a soil with higher organic content than some of the sandy areas with riparian vegetation. Fine textured soils have a greater holding capacity for moisture and buffer some groundwater-dependent plants against rapid water table declines. The higher organic content in the San Carlos soil would enable a greater degree of water retention and capillary rise from the root zone toward the soil surface.

Obtaining an accurate characterization of soil moisture can be difficult in alluvial areas. In the past MPWMD used a neutron probe to test soil moisture in riparian areas. This system was complicated because it depended on radioactive equipment and a special license. Currently MPWMD uses tensiometers that are limited in that they are difficult to install deeper than 3 feet and are designed for homogenous agricultural soils. Working with tensiometers in gravel and sandy areas give a relative indication of soil drying and wetting. The ideal tensiometer range is 0.0 to 0.5 bars with a peak of 0.8 bars. Highly stressed vegetation exceeds the potential of this tool. Pre-dawn leaf moisture potential laboratory testing results indicate that the vegetation wilting point is reached at 15 bars and 0.3 bars indicates field capacity or total soil saturation. This range varies according to soil type and plant type (Kramer and Boyer, 1995). As a result, the plant moisture stress methodology can provide information concerning riparian vegetation stress.

VI. CONCLUSION

During the 2004 water year, the total annual rainfall was 18.16 inches at the San Clemente Dam, located mid-watershed. Precipitation for this season was 85 percent of normal (21.37 inches is the average annual rainfall at San Clemente from 1922 to the 2004). Monitoring stream flow, depth to groundwater, soil moisture, and pre-dawn leaf water potential help determine when supplemental irrigation should be applied to riparian vegetation. During the 2004 monitoring season an overall trend towards higher stress during the summer was observed. In addition, monitoring results show that pumping does impact depth to groundwater at specific sites thus impacting soil moisture and riparian vegetation.

In 2004 MPWMD irrigated ten project areas (de Dampierre, Trail and Saddle Club, Scarlett, Begonia, Schulte South, Shulte Bridge, Schulte, All Saints, Valley Hills, and San Carlos) with a total of 9.46 acre-feet of supplemental water to offset stress associated with water diversions from the Carmel River. Mitigation in the form of irrigation can be used to prevent plant mortality along the riparian corridor thus contributing to stable riverbanks and habitat for wildlife.

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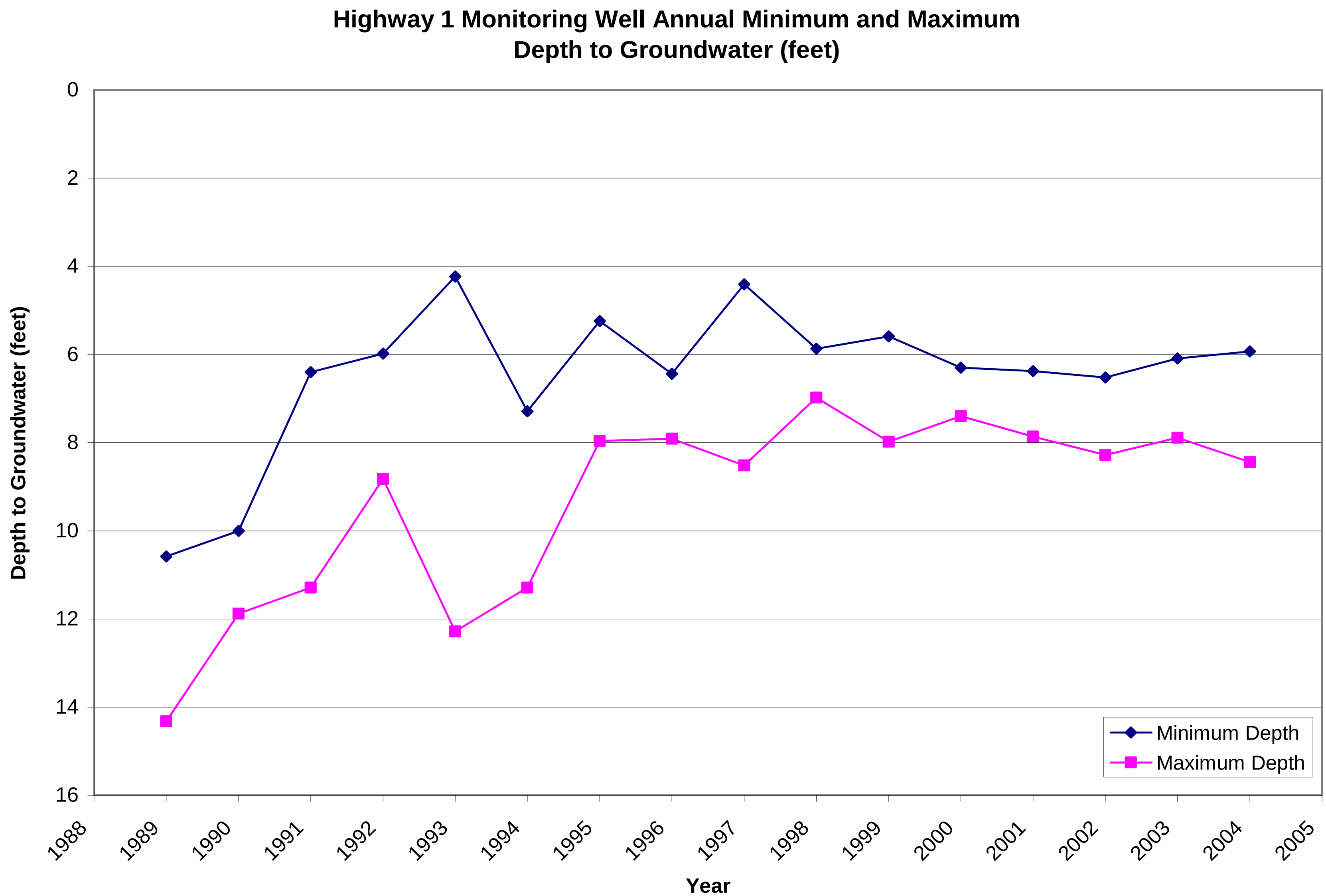
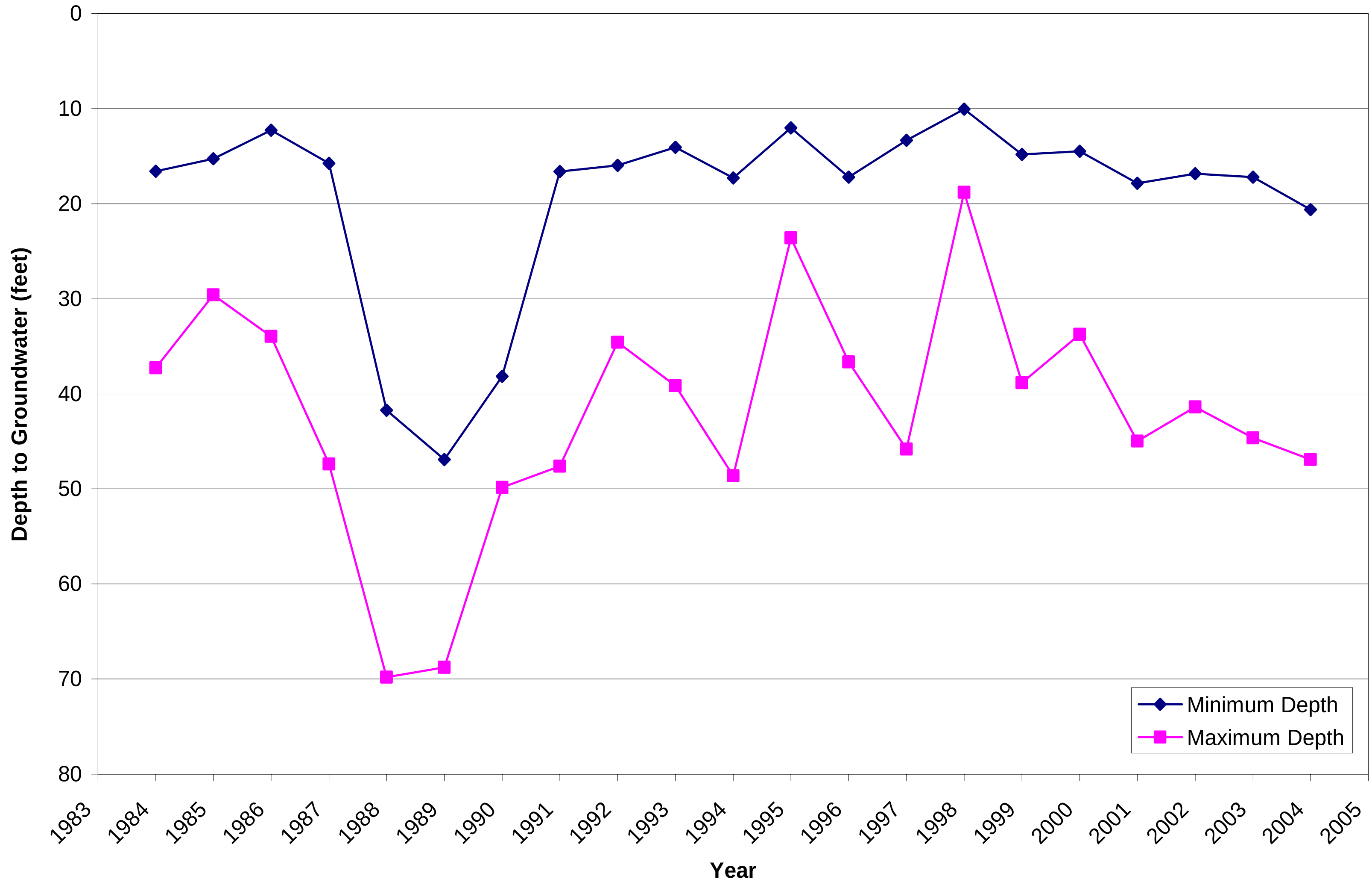
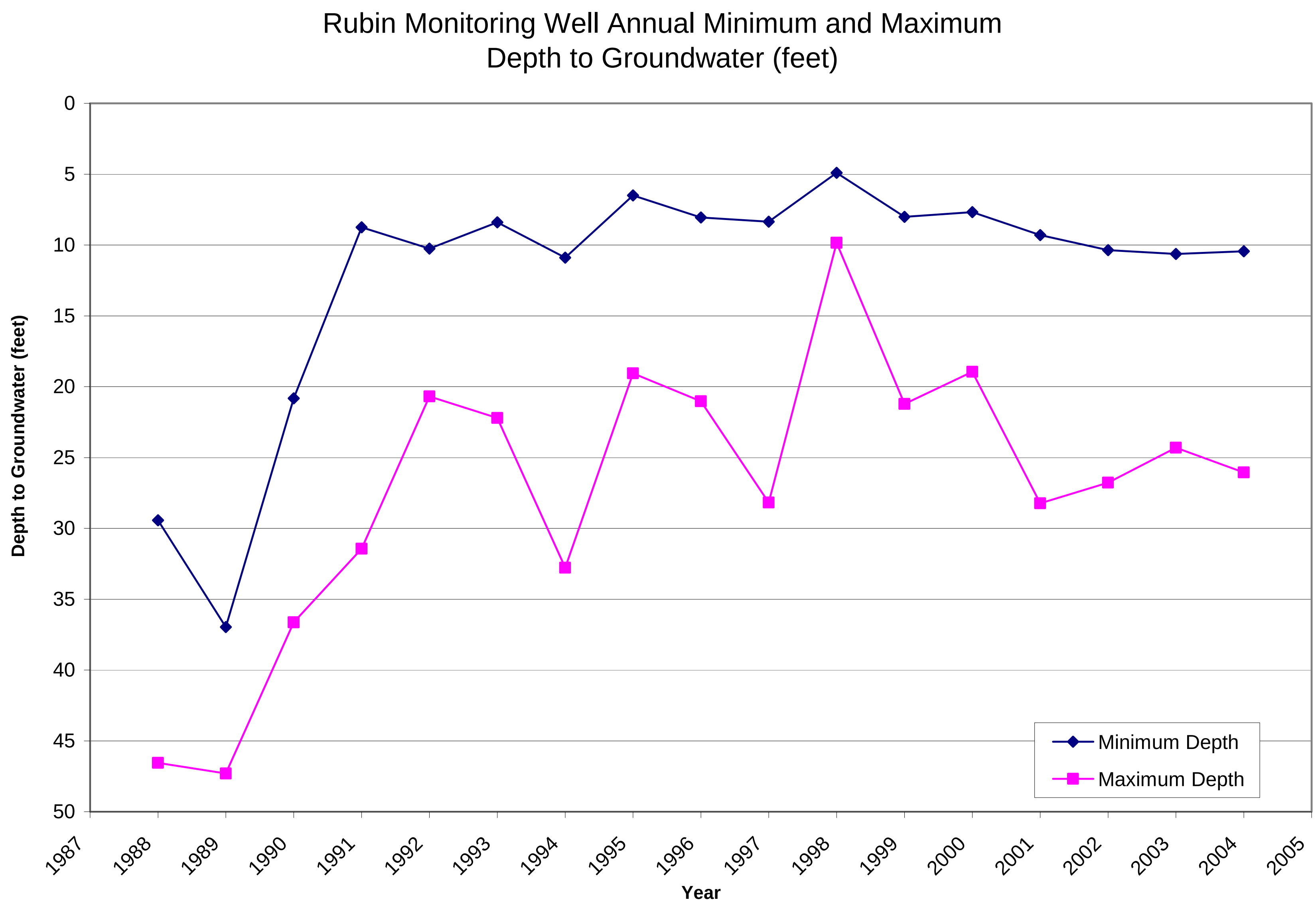
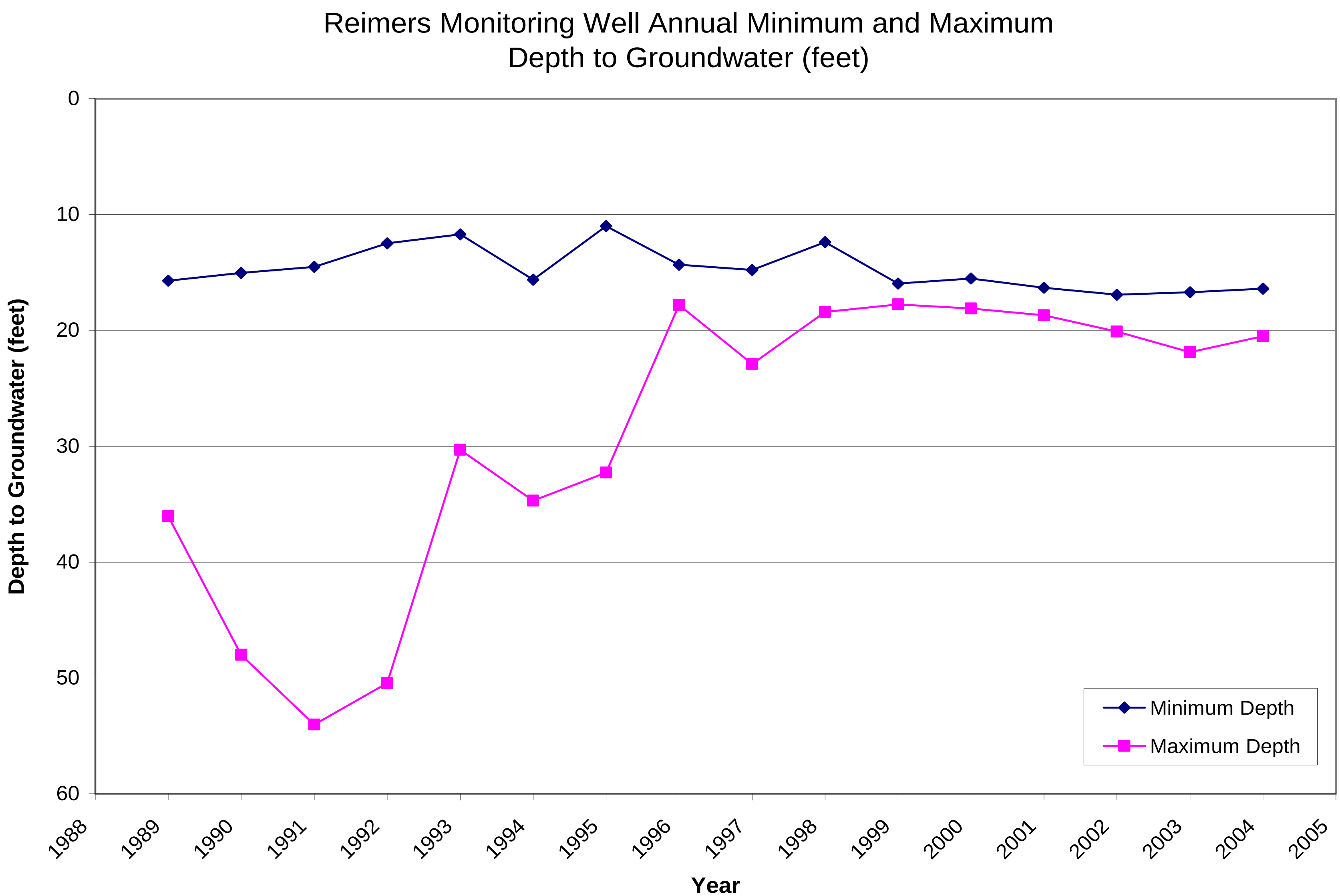
APPENDIX A: Historical Depth to Groundwater for Selected Monitoring Wells


Highway 1 Monitoring Well Annual Minimum and Maximum
Depth to Groundwater (feet)
Depth to Groundwater (feet)
0
2
4
6
8
10
12
14
16
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year
Minimum Depth
Maximum Depth

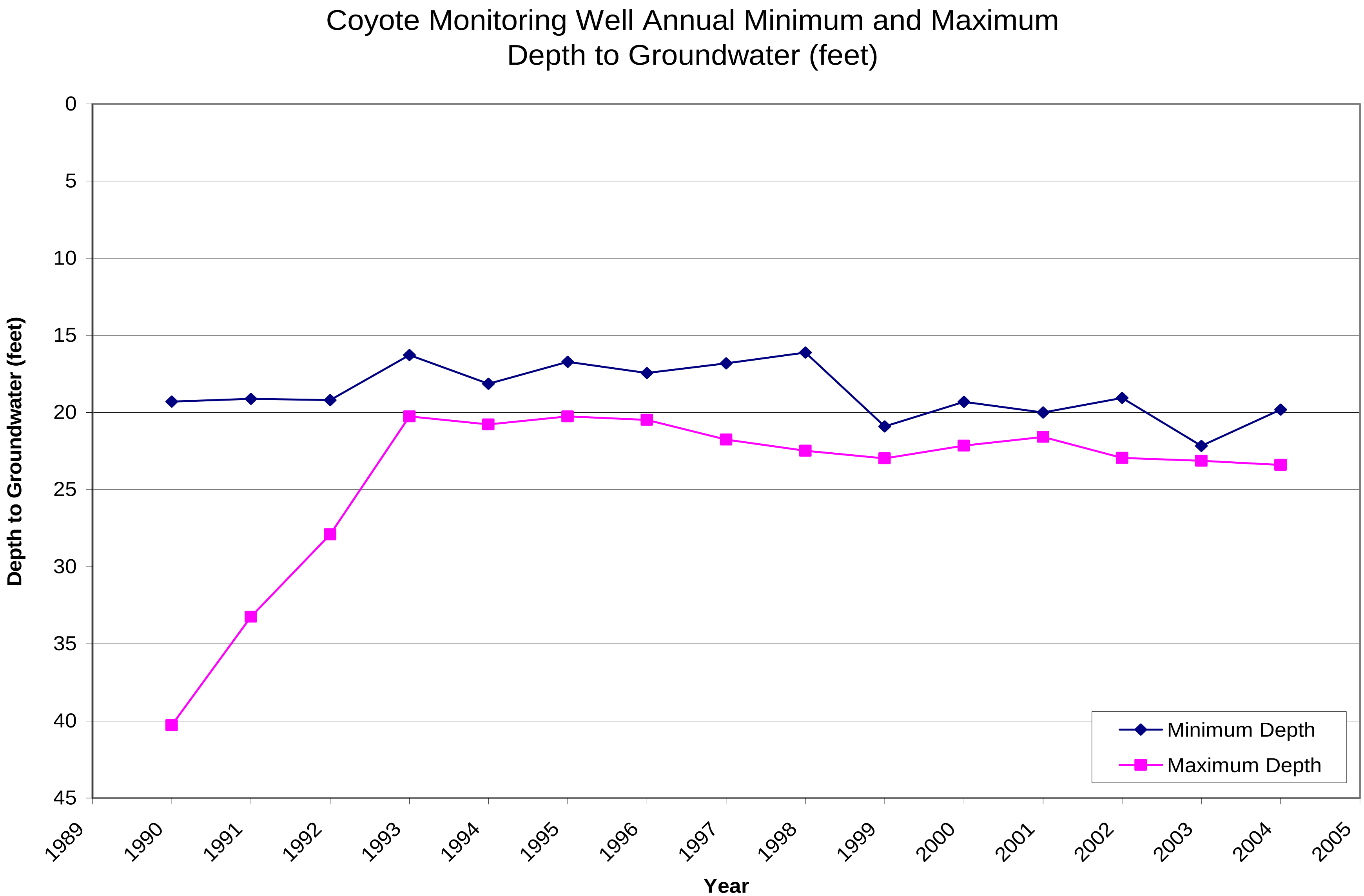
Cañada East Monitoring Well Annual Minimum and Maximum Depth to Groundwater (feet)



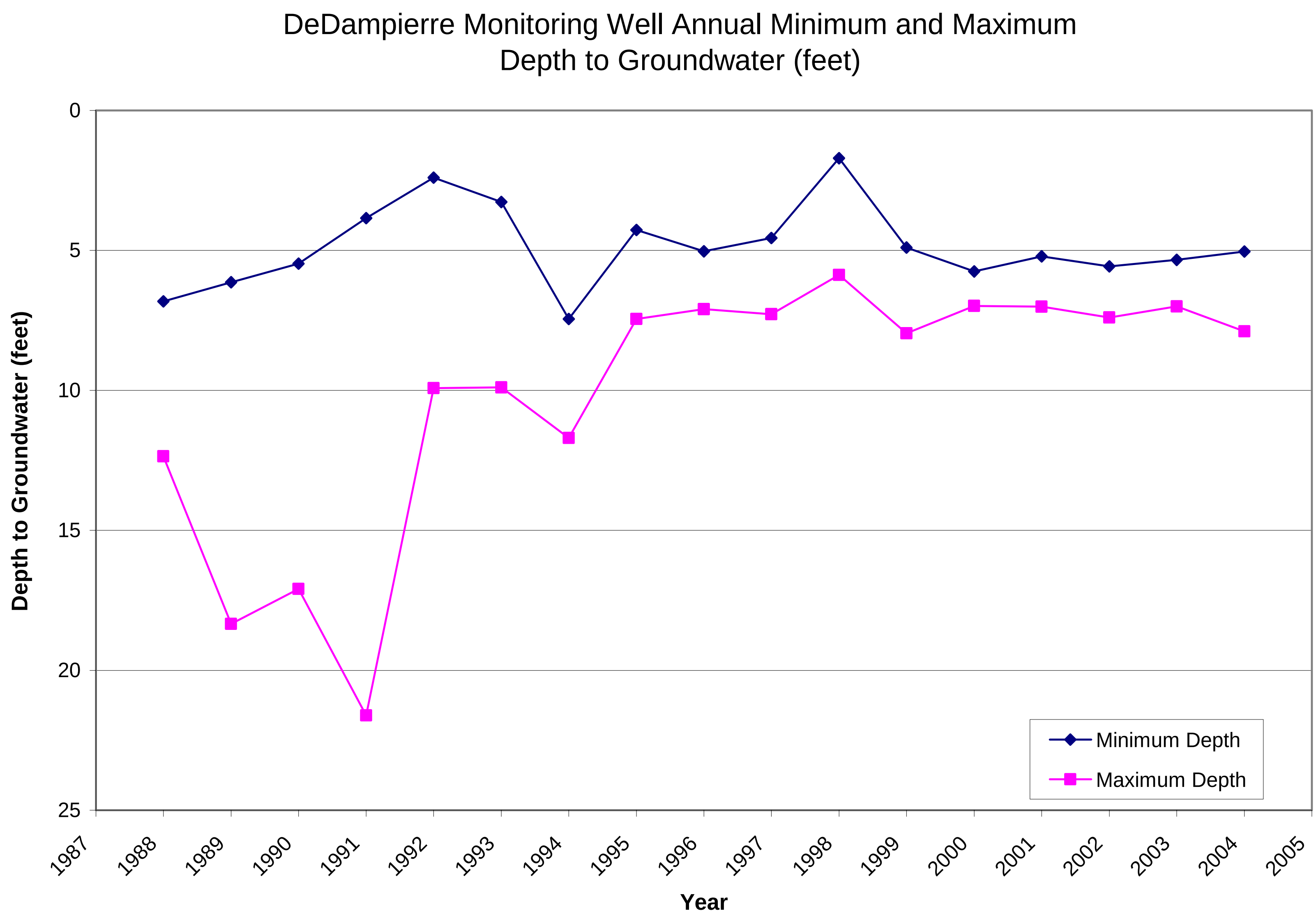

Rubin Monitoring Well Annual Minimum and Maximum
Depth to Groundwater (feet)
Depth to Groundwater (feet)
0
5
10
15
20
25
30
35
40
45
50
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year
Minimum Depth
Maximum Depth



Reimers Monitoring Well Annual Minimum and Maximum
Depth to Groundwater (feet)
Depth to Groundwater (feet)
0
10
20
30
40
50
60
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year
Minimum Depth
Maximum Depth



Coyote Monitoring Well Annual Minimum and Maximum
Depth to Groundwater (feet)
Depth to Groundwater (feet)
0
5
10
15
20
25
30
35
40
45
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year
Minimum Depth
Maximum Depth


DeDampierre Monitoring Well Annual Minimum and Maximum
Depth to Groundwater (feet)
Depth to Groundwater (feet)
0
5
10
15
20
25
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year
Minimum Depth
Maximum Depth