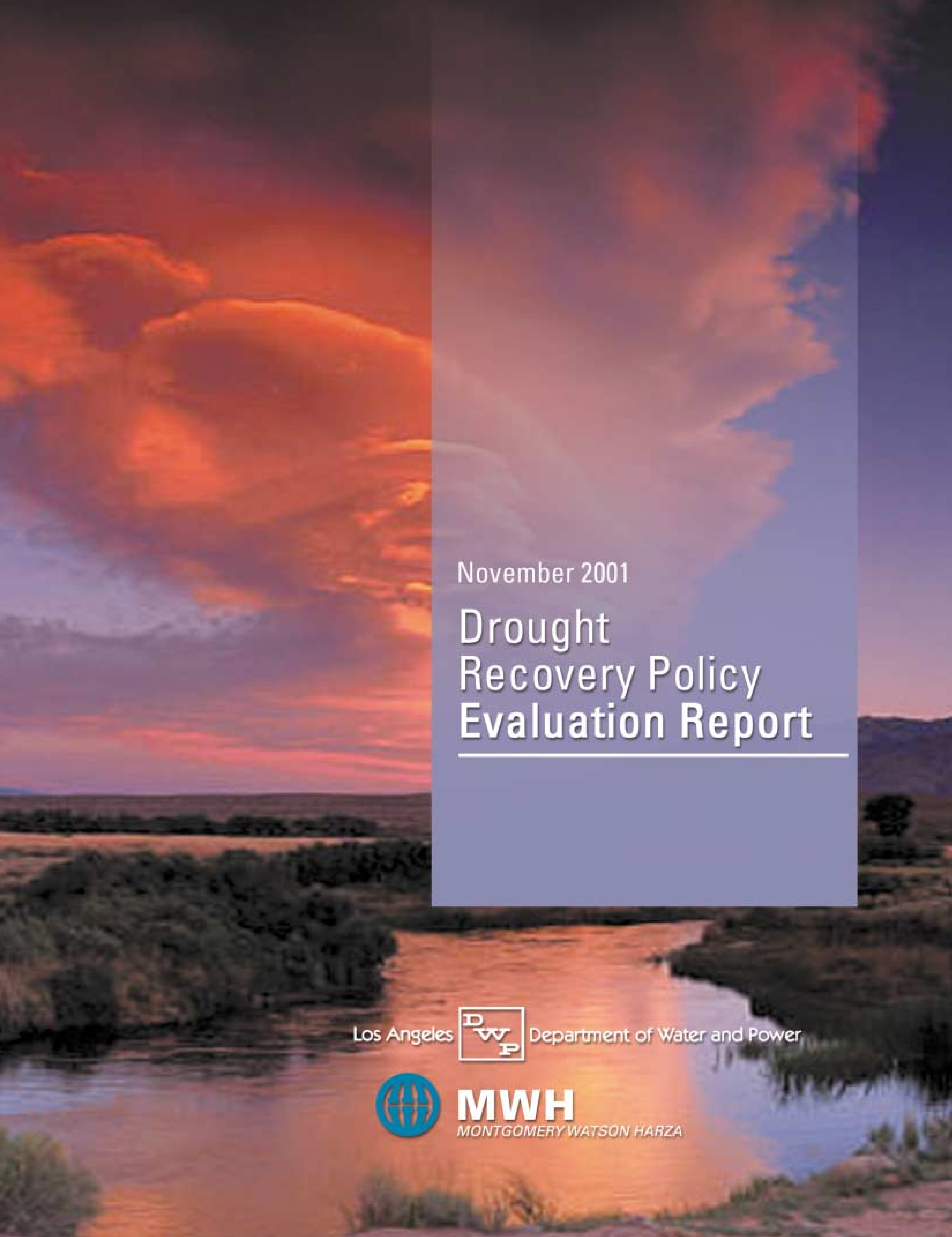

November 2001

Drought Recovery Policy Evaluation Report

Los Angeles Department of Water and Power

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Introduction

In response to the 1987 through 1992 drought, the Los Angeles Department of Water and Power (LADWP) increased its groundwater extraction in the Owens Valley during 1988 and 1989 to augment water supplies for Los Angeles. Drought conditions coupled with increased pumping were presumed to have caused adverse impacts on Owens Valley vegetation. To provide an environment for vegetation recovery, the Inyo County / Los Angeles Standing Committee developed the Drought Recovery Policy (DRP, 1992). The DRP is a one-page document that outlines management goals and provides general guidance for the development of annual pumping plans during the drought and the subsequent recovery period. The stated goal of this policy is that *"soil water within the rooting zone recover to a degree sufficient so that the vegetation protection goals of the Agreement are achieved."* The DRP established a more conservative management approach than that provided by the Agreement in the Green Book (October 1991), and was expected to result in *"reduced annual pumping programs as compared to annual pumping programs based solely on soil moisture conditions."*

The DRP does not specify a methodology for its termination. However, the policy states that *"It is intended that groundwater pumping will continue to be conducted in an environmentally conservative manner as was done during the 1990-91 and 1991-92 runoff years* ***until there has been a substantial recovery in soil moisture and water table conditions in areas of Types B, C and D vegetation that have been affected by groundwater pumping*** *(emphasis added)."* This clearly indicates that the management criteria for DRP termination are soil moisture and water table.

The purpose of this DRP termination report is to document soil moisture and water table conditions to determine whether sufficient recovery has occurred to allow termination of the DRP (1992) and return to the provisions of the Green Book (October 1991).

There are a total of nine wellfields in the Owens Valley, of which two (Bishop Cone and Lone Pine) are managed in a unique way from that in the Agreement (1991), and are therefore not considered by the DRP termination report. Wellfields considered as part of this report include:

- Laws
- Big Pine
- Taboose-Aberdeen
- Thibaut-Sawmill
- Independence-Oak
- Symmes-Shepherd
- Bairs-Georges.

The approach for evaluating the termination of the DRP (1992) is to evaluate termination of the DRP at the regional wellfield management area level. The Inyo/LA Water Agreement (1991) placed each wellfield within a unique management area with designated monitoring sites based on results of groundwater modeling by LADWP and Inyo County staff. These designations are regional with the intention of monitoring the cumulative conditions at each wellfield management area. Therefore, the evaluation of DRP termination was also done at this level by evaluating water level and soil moisture data specific to each area. Termination of the DRP at a wellfield is recommended when substantial recovery of the one of the two DRP termination factors, water level, has occurred. Substantial recovery of soil moisture data cannot be assessed because baseline data do not exist.

The step-by-step approach for evaluating termination of the DRP consists of three components presented below:

- Evaluation of depth to water data,
- Groundwater storage analysis, and
- Evaluation of soil moisture data.

Drought recovery is defined as having occurred when available monitoring data demonstrate that water levels have substantially recovered. The evaluation for DRP termination is presented at the wellfield level.

This approach evaluates all available wells in a wellfield's management area with sufficient record, in conjunction with groundwater balance data, and soil moisture data. If the vast majority of water table and soil moisture data within a wellfield exhibit substantial recovery, the entire wellfield is considered to have met the requirements for DRP termination.

The time period of Runoff Years 1985-1987 is used to represent baseline conditions because this period of time is when vegetation conditions in the valley were mapped. Although Montgomery Watson Harza uses Runoff Years 1985-1987 for baseline, this period is not truly representative of "baseline" as this period of time followed a period of significantly wetter than normal precipitation and runoff.

Findings

This section presents general findings of the DRP termination study. Detailed, wellfield-specific findings can be found in the individual wellfield chapters.

- Of the monitoring wells and associated depth to water data evaluated for each of the wellfields, evidence of substantial recovery, using techniques described in the Approach section of Chapter 1, is clearly demonstrated for each wellfield as summarized in **Table ES-1**.

Table ES-1
Summary of Water Level Recovery by Wellfield

Wellfield Management Area	Number of Shallow Wells Evaluated	Peak Year Percent of Shallow Wells with Evidence of Substantial Water Level Recovery	Year that Percent Recovery was Achieved	Percent of Shallow Wells with Evidence of Substantial Water Level Recovery since the DRP was instituted in 1992
Laws	13	100%	1999	100%
Big Pine	25	92%	1999	100%
Taboose-Aberdeen	11	82%	1996, 1998	100%
Thibaut-Sawmill	12	80%	1998, 1999, 2000	90%
Independence-Oak	12	100%	1999, 2000	100%
Symmes-Shepherd	17	94%	1999	94%
Bairs-Georges	5	100%	1998, 1999, 2000	100%
Total Owens Valley	95	92%		98%

Shallow wells are intended to represent the shallow aquifer and water table fluctuations in that shallow aquifer.

- From a hydrologic standpoint, the recent drought ended in Runoff Year 1992 as shown by precipitation records from Bishop Yard and Independence Yard.

- With regard to drought recovery and precipitation, the cumulative departure from average indicates that the precipitation deficit resulting from the drought since 1987 had been replaced by Runoff Year 1997. In other words, an analysis of the cumulative deficit of rainfall accumulated during the drought that began in 1987 was balanced by above-average rainfall by 1997.

- Evaluation of net recharge (recharge less pumping) in wellfield areas also documents drought recovery. Since 1992, pumping in individual wellfields has been managed conservatively which has resulted in significant gains since 1994. These storage gains have more than replaced the storage depletions of the late 1980s and early 1990s.

- The conceptual soil moisture model presented in Chapter 1 indicates that soil moisture is a function of much more than just groundwater levels, including: precipitation, as well as other surface activities that may provide water for percolation, evaporation, and transpiration (vegetation).

- Available soil moisture data analyzed in this report validate the conceptual soil moisture model.

- Although baseline data for soil moisture are unavailable, we conclude that based on the depth-to-groundwater/soil moisture relationships demonstrated by individual wellfield analysis and the conceptual model, and because water levels in all wellfields exhibit substantial recovery, it necessarily follows that soil moisture levels, to the extent that they are influenced by water levels, have also recovered.

- Soil moisture above the depth where groundwater is the dominant influence is controlled by numerous other factors such as precipitation, surface land use activities, evaporation, and transpiration. Of these, only precipitation shows a relation to drought conditions. Consequently, for this upper portion of the soil profile, only the consideration of precipitation is appropriate for evaluation of drought recovery.

Recommendations

Based on the findings presented in this report and the associated preponderance of evidence concerning depth to water data, groundwater balance, and soil moisture, substantial recovery as defined in the DRP has been achieved in each of the seven wellfields evaluated. In addition, two key hydrologic indicators, runoff and precipitation, both indicate that the drought has ended and substantial recovery with regard to these indicators has occurred. To summarize, the data clearly demonstrate that termination of the DRP is appropriate.

Chapter 1

Introduction

Chapter 1 Introduction

Introduction

In response to the 1987 through 1992 drought, the Los Angeles Department of Water and Power (LADWP) increased its groundwater extraction in the Owens Valley during 1988 and 1989 to augment water supplies for Los Angeles. Drought conditions coupled with increased pumping were presumed to have caused adverse impacts on Owens Valley vegetation. To provide an environment for vegetation recovery, the Inyo County/Los Angeles Standing Committee developed the Drought Recovery Policy (DRP, 1992). The DRP is a one-page document that outlines management goals and provides general guidance for the development of annual pumping plans during the drought and the subsequent recovery period. The stated goal of this policy is that *"soil water within the rooting zone recover to a degree sufficient so that the vegetation protection goals of the Agreement are achieved."* The DRP established a more conservative management approach than that provided by the Inyo/LA Water Agreement (1991) in the Green Book (October 1991), and was expected to result in *"reduced annual pumping programs as compared to annual pumping programs based solely on soil moisture conditions."*

The DRP does not specify a methodology for its termination. However, the policy states that *"It is intended that groundwater pumping will continue to be conducted in an environmentally conservative manner as was done during the 1990-91 and 1991-92 runoff years* ***until there has been a substantial recovery in soil moisture and water table conditions in areas of Types B, C and D vegetation that have been affected by groundwater pumping*** *(emphasis added)."* This clearly indicates that the management criteria for DRP termination are soil moisture and water table. The purpose of this DRP Evaluation Report is to document soil moisture and water table conditions to determine whether sufficient recovery has occurred to allow termination of the DRP (1992) and return to the provisions of the Green Book (October 1991). As shown on **Figure 1-1** nine wellfields occupy Owens Valley:

- Laws (DRP),
- Bishop,
- Big Pine (DRP),
- Taboose Aberdeen (DRP),
- Thibaut-Sawmill (DRP),
- Independence-Oak (DRP),
- Symmes-Shepherd (DRP),
- Bairs-Georges (DRP), and
- Lone Pine.

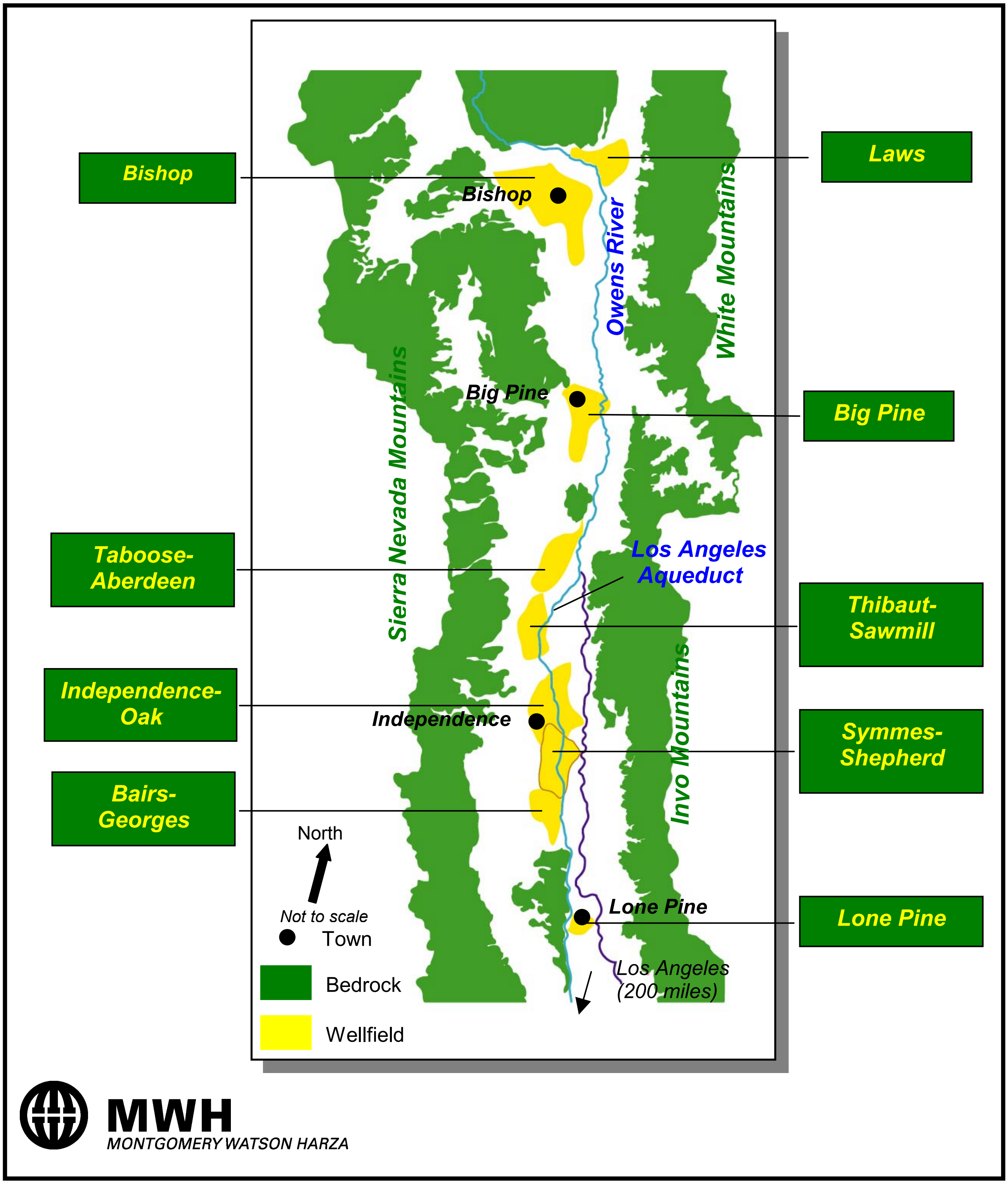

Figure 1-1
Vicinity Map Showing the Location of Owens Valley Wellfields

Two of these wellfields, Bishop and Lone Pine, are managed in a unique way from that in the Inyo/LA Water Agreement (1991). The Hillside Decree (August 1940) and Inyo/LA Water Agreement (1991) are used to manage the Bishop Wellfield. The Lone Pine Wellfield consists of one Enhancement Mitigation (E/M) well and two sole-source town-supply wells. These Lone Pine pumping wells are exempt from on/off procedures in the Inyo/LA Water Agreement (1991). Given the predominance of exempt-well pumping in these two wellfields coupled with governance by other management criteria, the DRP (1992) provisions do not affect management of these wellfields, and they are thus not evaluated as part of this report.

Hydrologic Conditions in the Owens Valley

Local precipitation and runoff for the Owens Valley watershed provide an indication of hydrologic conditions in the Valley. Although precipitation and runoff are not cited by the DRP (1992) as termination factors, they give a general indication of the hydrologic condition of the basin.

A drought by definition is temporary; therefore, documentation of the drought's end using hydrologic indicators is useful for evaluating whether or not DRP termination is appropriate. Documentation of hydrologic conditions was accomplished by computing and plotting the cumulative departure from average precipitation or runoff. The cumulative departure from average represents the running total of the difference between the precipitation in a given year and the average. A declining slope of the cumulative departure curve indicates a dry period (below-average precipitation) while an increasing slope indicates a wet period (above-average precipitation). The difference in the cumulative departure in a given time period indicates the variation from average precipitation. If the cumulative departure at the beginning and end of a period are the same, then precipitation in that period was close to the average conditions. Return of precipitation to average conditions are considered substantial when the cumulative departure from normal has recovered from the deficit that occurred during the drought.

Precipitation

Precipitation on the Owens Valley floor is highly variable and is substantially lower than precipitation on the surrounding mountains. Average valley-floor precipitation ranges from about 4 to 7 inches per year (in/yr). Precipitation gauges located at the Bishop Yard and the Independence Yard are presented as indicative of typical values while demonstrating the areal variability in precipitation.

During the period of Runoff Year 1970 to 1999, the average annual valley-floor precipitation measured at the LADWP Bishop Yard weather station was 6.54 inches/year (in/yr). This period was selected as it coincides with commencement of groundwater pumping for the Los Angeles Aqueduct. This value is 0.18 in/yr greater than the 69-year long-term average for this station of 6.36 in/yr, which indicates that the period of Runoff Years 1970 to 1999 was about 3 percent wetter than the long-term average (normal).

Figure 1-2 presents the annual valley-floor precipitation for the Bishop Yard weather station for this period along with the 69-year long-term average and the cumulative departure from average. This chart indicates that the baseline period of Runoff Years 1985-1987 was at the end of a nine-year wet period extending from Runoff Years 1977 through 1985 when valley-floor precipitation averaged 2.15 in/yr (34 percent) above normal. Runoff Year 1986 marked the beginning of a six-year dry period when valley-floor precipitation was about 2.3 in/yr (37 percent) below normal. From Runoff Years 1992 through 1997, valley-floor precipitation has averaged 1.5 in/yr (24 percent) above normal. Valley-floor precipitation has been below normal for the past two years.

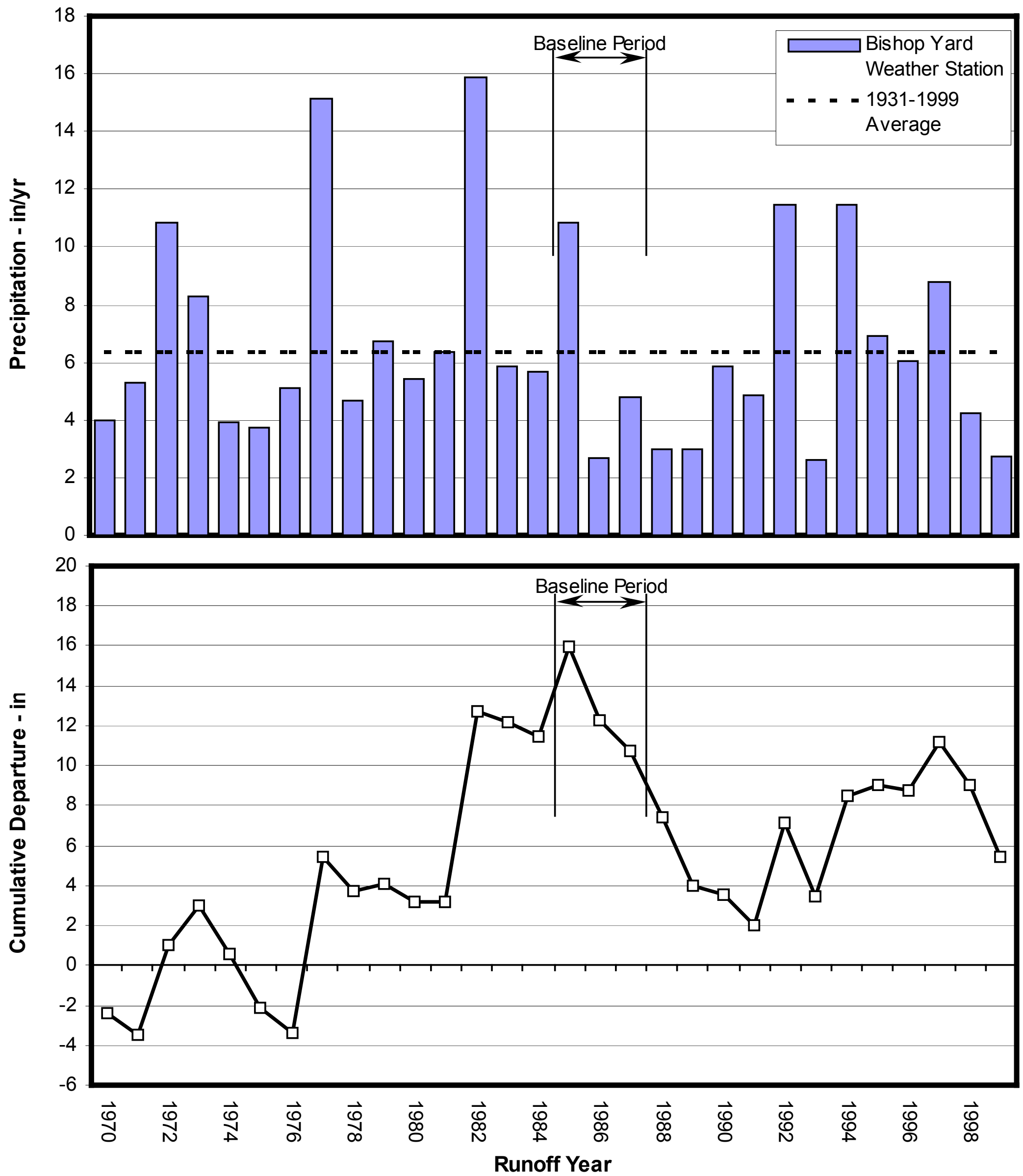

Figure 1-2
Bishop Yard Weather Station Precipitation (Runoff Years 1970–1999)

During this same period, the average annual valley-floor precipitation measured at the LADWP Independence Yard weather station was 5.4 inches/year (in/yr). **Figure 1-3** presents the annual valley-floor precipitation for the Independence Yard weather station for this period along with the 101-year long-term average and the cumulative departure from average. This chart indicates that the baseline period of Runoff Years 1985-1987 was at the end of a nine-year wet period extending from Runoff Years 1977 through 1985 when valley-floor precipitation about averaged 2.1 in/yr or 42 percent above normal. Runoff Year 1986 marked the beginning of a six-year dry period during which the precipitation was about 1.9 in/yr or 38 percent below normal. From Runoff Years 1992 through 1997, valley-floor precipitation has averaged 2.2 in/yr or 43 percent above normal. Valley-floor precipitation has been below normal for the past two years.

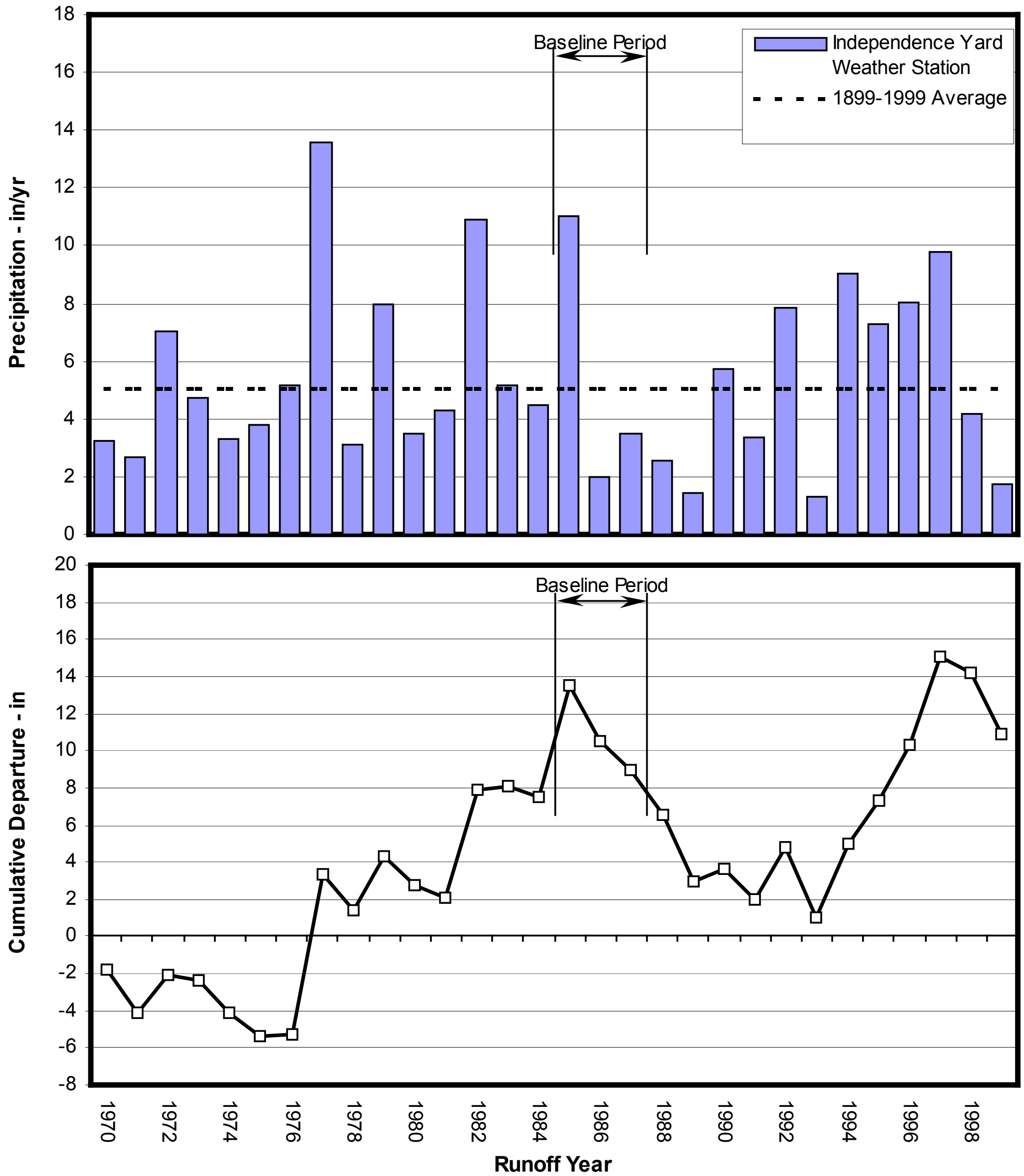

Figure 1-3
Independence Yard Weather Station Precipitation (Runoff Years 1970–1999)

The valley-floor precipitation data indicate that the recent drought that is the subject of the DRP ended in Runoff Year 1992 when the slope of the cumulative departure line began a general upward trend indicating above-normal precipitation until Runoff Year 1997. By Runoff Year 1997, the average precipitation for Runoff Years 1987 through 1997 had returned to within two percent of the long-term average indicating substantial recovery of precipitation at the Bishop Yard and to eight percent above of the long-term average at the Independence Yard indicating full recovery of precipitation.

Owens Valley Runoff

Another indicator of hydrologic conditions is Owens Valley runoff. Owens Valley runoff is determined from total measured runoff for streams flowing into the Owens River system. LADWP has maintained monthly runoff records for the Owens Valley since 1935. For this period, total annual runoff has averaged 426,400 acre-ft/yr (on a runoff year basis). Annual runoff ranges from a high of 885,800 acre-ft/yr to a low of 213,200 acre-ft/yr. Runoff is less than 393,400 acre-ft/yr about one half of the time. The total runoff for the period 1970-1990 is presented on **Figure 1-4** along with the cumulative departure from average runoff. Like that for precipitation, this chart indicates a significant dry period starting in Runoff Year 1987. However, the runoff data indicate below normal runoff extended until Runoff Year 1995. This additional two-year period of below-normal runoff, versus that for precipitation, may be due to the replacement of depleted soil moisture in the mountains that resulted from the drought. By Runoff Year 1998, the cumulative departure had not returned to its value at the end of the baseline (1987). This indicates that average runoff for Runoff Years 1987 through 1998 was about 10 percent below normal.

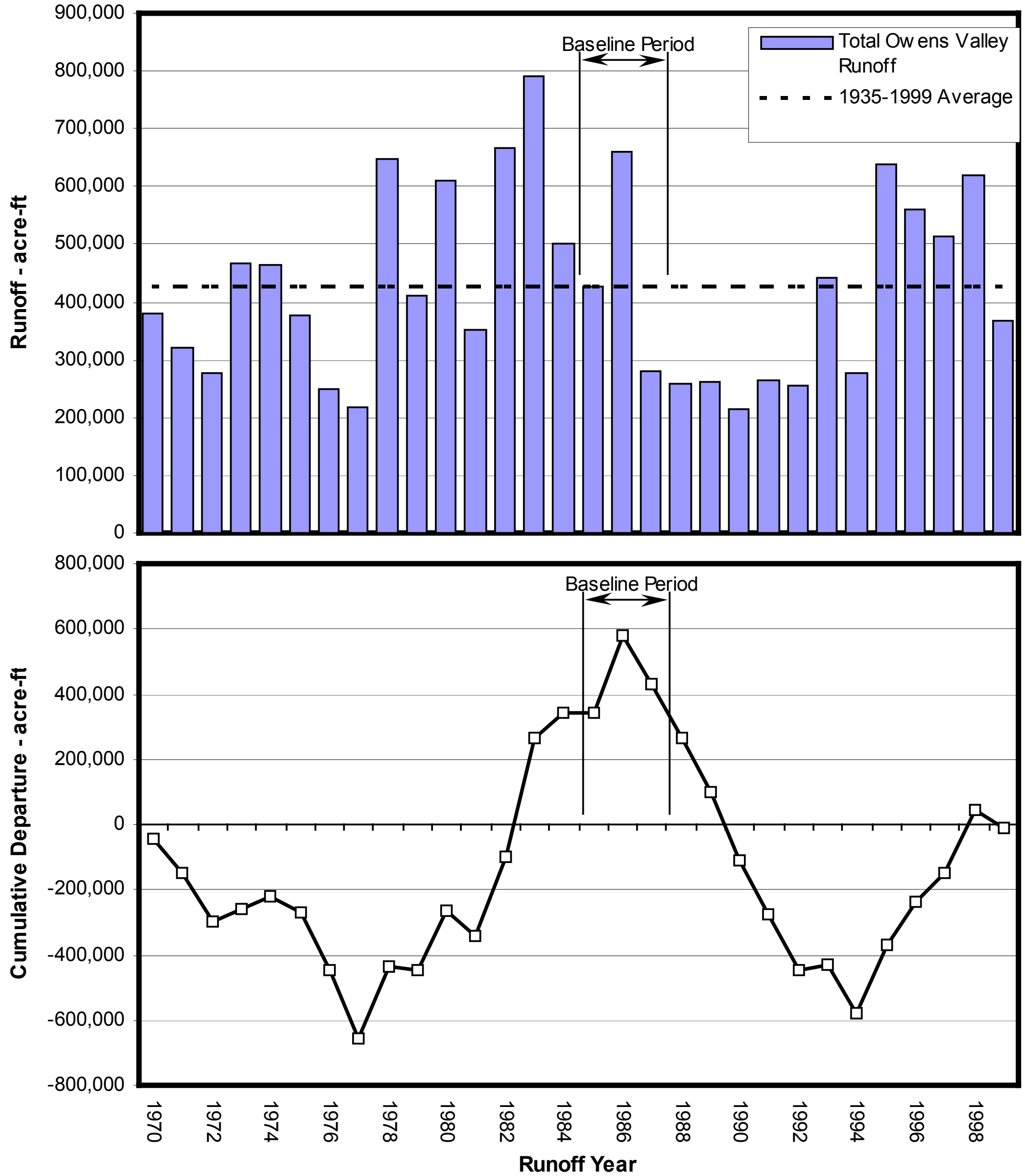

Figure 1-4
Owens Valley Runoff (Runoff Years 1970–1999)

Approach

The approach for evaluating the termination of the DRP (1992) is to evaluate termination of the DRP at the regional wellfield management area level. The Inyo/LA Water Agreement (1991) placed each wellfield within a unique management area with designated monitoring sites based on results of groundwater modeling by LADWP and ICWD staff. Per Section I.A of the Inyo/LA Agreement (1991) regarding management areas, *"Each wellfield area has been included in a designated management area. The boundaries of each management area have been established so as to contain all vegetation that could be impacted as a result of groundwater pumping from the wellfield area during 'worst case' conditions (multiple dry years along with heavy pumping).*

Each management area contains several monitoring sites. Each Department well in a management area is linked to a monitoring site for management purposes."

These management area designations are regional with the intention of monitoring the cumulative conditions at each wellfield management area. Therefore, the evaluation of DRP termination was also done at this level by evaluating water level and soil moisture data specific to each management area. Termination of the DRP at a wellfield is recommended when substantial recovery of the two DRP termination factors, water level and soil moisture, has occurred. Furthermore, it is recognized that individual wells may respond to small perturbations in the hydrologic system that are unrelated to the drought; however, the regional approach assists in smoothing data associated with isolated perturbations.

The step-by-step approach for evaluating termination of the DRP consists of three components presented below:

- Evaluation of depth to water data,
- Groundwater storage analysis, and
- Evaluation of soil moisture data.

In addition, for each monitoring site, the vegetation type is identified based on baseline (1985-1987) mapping. These data are presented for information purposes only. The DRP policy states that only sites with vegetation Types B, C, and D are subject to the DRP. However, in some cases, monitoring sites are located in areas of Type A vegetation. Nevertheless, an analysis of each wellfield's entire management area and all monitoring sites was performed.

Evaluation of Depth to Water Data

The DRP Evaluation Report evaluates all monitoring wells within each wellfield's management area boundary. Monitoring well identifications are proceeded by either a "T" or a "V" (i.e., Well T438 or Well V160). With occasional exception, "T" wells are generally shallow monitoring wells and "V" wells are generally deep wells that were largely used at one time as pumping wells. However, since the mid-1980's, deeper monitoring wells have been installed and given a "T" designation, and there are some shallow wells that have been assigned a "V" designation.

The only wells whose data can be used conclusively to evaluate termination of the DRP are the shallow wells. Shallow wells are intended to represent the shallow aquifer and water table fluctuations in that aquifer.

Analyses of shallow wells are separated from analysis of deep wells. Nevertheless, an analysis of deeper wells was performed because it yields a more complete picture of overall conditions in a management area; yet, as previously stated; deep wells do not necessarily reflect the shallow water table conditions.

The following three-step approach was used to evaluate depth to water data for wells contained within or falling on the boundaries of the management areas:

- Define baseline water table conditions at each well,
- Evaluate recovery at each well, and
- Determine if the wellfield has obtained substantial recovery.

Each of these steps is described in more detail below.

Define Baseline Water Table Conditions at Each Well

This DRP Evaluation Report uses a baseline determined from all available depth to water measurements in Runoff Years 1985-1987 (4/1/1985 - 3/31/1988) for wells within the management area boundaries. All depth to water measurements are expressed in feet below ground surface (fbgs). The use of all available measurements to define the baseline captures the natural hydrologic fluctuations that occur in an aquifer system throughout any given year; however, this is not representative of continuous water level conditions over the entire period. In some instances, data exist for only a portion of the baseline; therefore, the baseline is neither complete nor wholly accurate as it does not contain measurements from the entire baseline period. Measurements from Runoff Years 1985-1987 were selected for baseline conditions because this period of time is when vegetation conditions in the Owens Valley were mapped. Although Montgomery Watson Harza (MWH) uses Runoff Years 1985-1987 to represent baseline conditions, this period is not truly representative of "baseline" as this period of time was immediately preceded by significantly wetter than normal conditions.

In order for a monitoring well (those wells with a "T" or "V," respectively preceding the well number) to be evaluated, the well must meet the following criteria:

- A well must have a sufficient historical record from baseline (Runoff Years 1985-1987) to 2000,
- A well cannot have had any dry measurements during the baseline period, and
- A well cannot be a flowing well.

It is important to reiterate that data from shallow wells only is used to constitute DRP termination at a wellfield as these data represent water table conditions.

The mean of the baseline for each well was calculated and is presented with the 95 percent confidence interval for the data set. Confidence intervals were calculated using Equation 1 below.

$$\underline{\text{Equation 1}}: \quad CI = t_{0.975}(s/\sqrt{n})$$

Where:

CI = Confidence Interval

$t_{0.975}$ = Student t for 95% confidence (2-tailed)

s = Standard deviation

n = Number of samples (Davis, 1986; Remington and Schork, 1970).

Mean baseline values for those wells that had any dry measurements during the baseline could not be calculated. Nevertheless, hydrographs for these wells were constructed. Where sufficient data exist (i.e., a well's historical record has significant measurements that are not "dry"), these wells are discussed qualitatively within each wellfield chapter with a qualitative opinion on their recovery.

Evaluate Recovery at Each Well

Next, the baseline mean and lowest point in the drought were factored into Equation 2 to determine the depth to water that represents 80 percent recovery from the low point in the drought:

Equation 2: $80\ Percent\ Recovery = DTW_{Drought\ Low} - 0.80\ (DTW_{Drought\ Low} - DTW_{Baseline\ Mean})$

The DRP (1992) specifies that "*substantial recovery*" must occur for termination; however the term "*substantial*" does not have a quantitative value associated with it. This DRP report considers 80 percent recovery at a well to constitute substantial recovery. That is, if in a given runoff year at any one point in time, the water level in a well meets or exceeds the 80 percent recovery mark, that well exhibits substantial recovery.

Determine if the Wellfield has Obtained Substantial Recovery

Finally, the aggregate of the shallow wells that met the criteria for analysis in a wellfield management area (well must have a sufficient history, no dry measurements in baseline, and cannot be flowing) were used to determine if a wellfield exhibits substantial recovery, ultimately enabling the DRP to be terminated at the wellfield. Once again, the DRP (1992) does not identify quantitative factors for termination. This DRP Evaluation Report evaluates the percent of shallow wells in a management area that exhibit substantial recovery (per Equation 2) in a single runoff year following the drought. If substantial recovery at the wellfield level is met, then that wellfield exhibits substantial recovery and the criteria set forth in the DRP (1992) for DRP termination has been met.

Groundwater Storage Analysis

Groundwater storage in each wellfield management area was evaluated to demonstrate replacement of groundwater depletion following the drought. Although groundwater storage is not specified by the DRP as a termination factor, replacement of groundwater depletions following the drought provides valuable information on whether substantial recovery has occurred in a wellfield.

The Inyo/LA Water Agreement (1991) establishes a goal of avoiding long-term groundwater mining from the Owens Valley aquifers. This goal is to be met by managing annual groundwater pumping in each wellfield such that the total groundwater pumping over a 20-year period does not exceed the total recharge in the same 20-year period. Each year, LADWP and Inyo County evaluate hydrologic data for each wellfield to determine whether the proposed pumping program will cause groundwater mining.

Section IV.C of the Green Book (October 1991) defines the method to be used in evaluating recharge and a brief summary of this method is provided herein. As described in the Green Book, the calculation of annual recharge is "a detailed and rigorous exercise." To facilitate the annual calculations, empirical relationships derived from regression analysis between the percent of average Owens Valley runoff and wellfield recharge are used. The total annual recharge estimates for the current and previous 19 years are tabulated and totaled. The actual groundwater pumping for the previous 19½ years is subtracted from the 20-year recharge to arrive at the pumping limit for the next six months.

The data used to compute the mining limitations can be used to assess the general storage conditions of each wellfield. The annual change in groundwater storage is estimated from the difference between annual recharge estimates and the actual groundwater pumping. If recharge exceeds pumping, then water accumulates in storage. Conversely, if pumping exceeds recharge, then groundwater storage is being depleted. Totaling the annual change in storage values over a period of time provides a picture of the variation in total storage. The annual estimates of recharge and pumping were evaluated using this approach to determine if the storage depletions from the drought had been replaced and the current state of storage conditions in each wellfield.

One limitation of this storage analysis is that the net recharge values exclude evapotranspiration (ET). ET consumes a portion of the recharge water reducing the net recharge and the volume of water in storage. ET varies annually as a function of weather, vegetation conditions, and area of surface water. Data are not readily available to compute the ET of vegetation, and neither is this a consideration in the Green Book-defined method for the mining calculation. A second limitation of the storage analysis is that subsurface inflow and outflow are not considered.

Evaluation of Soil Moisture Data

Available soil moisture data collected in the Owens Valley from 1995 to present was compiled and evaluated. Because the neutron probe does not measure soil moisture directly, it is necessary to convert the neutron probe counts to soil moisture. This conversion assumes that there is a linear relationship between the neutron probe counts and soil water content. Neutron probe data were converted to soil moisture using the following Equation 3:

$$\underline{\textit{Equation 3}}\textit{: Soil moisture (volume \%)} = a\,\frac{\text{neutron probe counts}}{\text{neutron probe standard}} + b$$

Where a and b are field-determined constants which are largely dependent upon the soil type present at each of the soil probe sites.

Neutron probe data do not exist prior to May 1995; therefore, a soil moisture baseline cannot be defined. Soil psychrometer measurements prior to 1995 exist, but both LADWP and Inyo County consider these data invalid due to improper calibration and data collection. In addition, lithologic logs of the soil probes were not available. Consequently, potential influences of changes in soil type on field-determined constants cannot be evaluated.

Despite the absence of a baseline soil moisture data, it may still be possible to draw useful conclusion about soil moisture by means of a conceptual soil moisture model. Available data can then be compared to the conceptual model to validate it. To accomplish this, monthly soil moisture data for each monitoring site were combined into a single spreadsheet for analysis. Data were evaluated and compared to water level data from the designated monitoring site test well as well as the precipitation record from the nearest location. These comparisons are useful for developing an understanding of what processes are affecting which portions of the soil moisture profile.

Typical values of soil moisture at the wellfield monitoring sites range from 5% to 50%. Percent soil moisture indicates the percent of soil volume that is actually water; therefore, percent saturation represents the percent of pore spaces actually occupied by water. If all pore spaces were occupied by water, saturation would be 100%. However, a given volume of soil cannot have 100% moisture, otherwise it would be all water; rather, the maximum percent soil moisture is dependent upon soil type.

Conceptual Soil Moisture Model

Sources of moisture to the soil system come from the surface, from groundwater, or a combination of the two. If the amount of water applied at the surface exceeds evaporation, then water is available to percolate into the soil and increase the soil moisture. The soil moisture at the near-surface can increase up to the field capacity of the soil. If the field capacity of the soil is reached, then free water can move downward in the soil column. The leading edge of this free, downward-moving water is called the wetting front. If soil moisture does not exceed the field capacity, downward movement of water cannot occur and soil moisture cannot increase. The field capacity of a soil is generally less than the soil moisture at saturation.

Groundwater influences soil moisture from the bottom up. The portion of the soil column below the groundwater surface is necessarily saturated. A zone of saturated soil also exists above the groundwater surface. This is called the capillary fringe and the mechanism for this upward water movement is referred to as capillary rise. The height of the capillary fringe varies with soil type and also with plant transpiration, which lowers the height of the capillary fringe by removing moisture from the soil column. The capillary fringe is, by definition, saturated. There are no other mechanisms for moving appreciable amounts of water upward through the soil column.

Soil moisture can decrease through either evaporation or plant transpiration. Given the arid nature of the Owens Valley and the active vegetation across the valley, both of these mechanisms must be considered. Evaporation affects soil moisture near the surface. Root systems also remove moisture from the soil profile via plant transpiration. The influence of transpiration on soil moisture varies with plant type and community, root depth, amount of cover, and numerous other variables. It is transpiration that causes the decreasing soil moisture observed as one moves upward from the top of the capillary fringe. In fact, all other things being equal, the capillary fringe in a soil column would be higher absent transpiration. The conceptual model refers to this zone of decreasing soil moisture immediately above the capillary fringe as the intermediate zone.

Figure 1-5 depicts the soil moisture profile for probe BP1-3 and also depicts the various soil moisture zones described above. From this conceptual model, it is apparent that soil moisture in a given soil column is a function of precipitation, other surface activities that may provide water for percolation, evaporation, vegetation (transpiration), and groundwater.

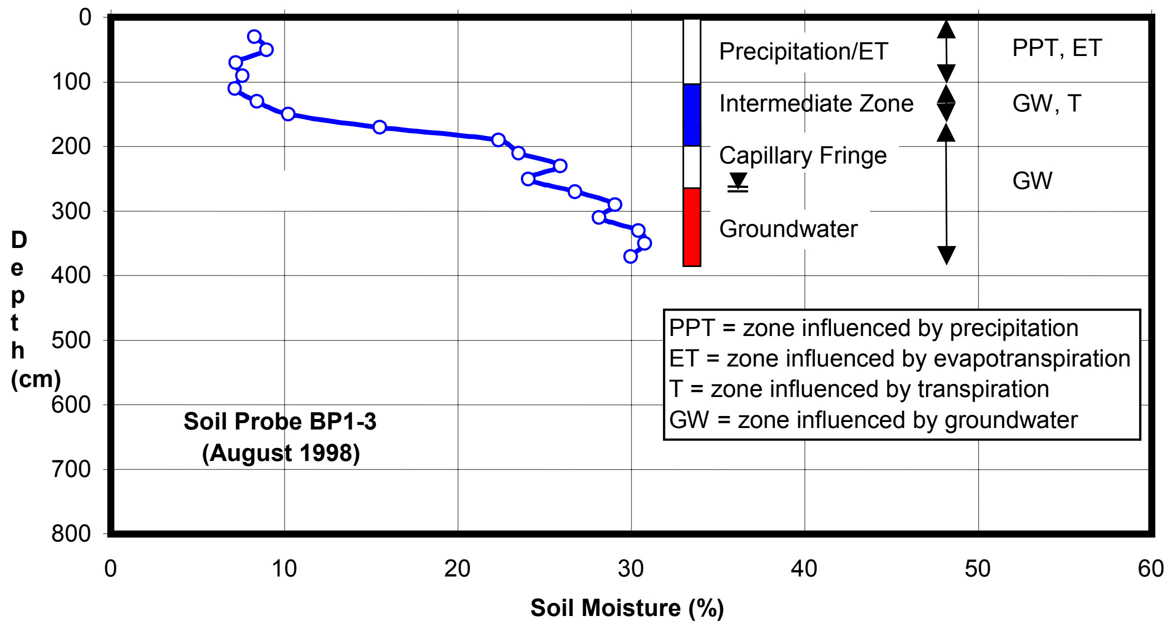

Figure 1-5
Conceptual Soil Moisture Model

Discussion

Drought recovery in a wellfield will be defined as having occurred when available monitoring data demonstrate that water level and soil moisture have substantially recovered, thereby meeting the criteria for DRP termination.

Figure 1-6 presents a conceptual cross-section depicting theoretical hydrologic conditions in the Laws Wellfield, the northernmost wellfield in the Owens Valley. This figure conceptualizes the numerous interrelationships operating at the wellfield and its corresponding monitoring sites, including precipitation and soil moisture, pumping and water levels, water level and soil moisture in the capillary fringe, and infiltration from the Owens River. This type of conceptual model is applicable to other wellfields in the Owens Valley, while recognizing that subsurface lithology, most notably the presence, absence, and character of the confining layer, varies throughout the Owens Valley.

To summarize, the evaluation for DRP termination is presented at the wellfield management area level. This approach evaluates the groundwater storage at a wellfield, all depth to water data for wells in a wellfield having sufficient record, as well as soil moisture data. However, it is only the shallow wells, which represent the shallow water table, that are the actual criteria and indicators for DRP termination. Wellfield definitions and management area boundaries are taken from the Inyo/LA Water Agreement (1991) and associated groundwater modeling by LADWP and Inyo County staff. If the vast majority (>80 percent) of depth to water data for the shallow wells within a wellfield exhibit substantial recovery per Equation 2, the entire wellfield is considered as meeting the requirements for DRP termination.

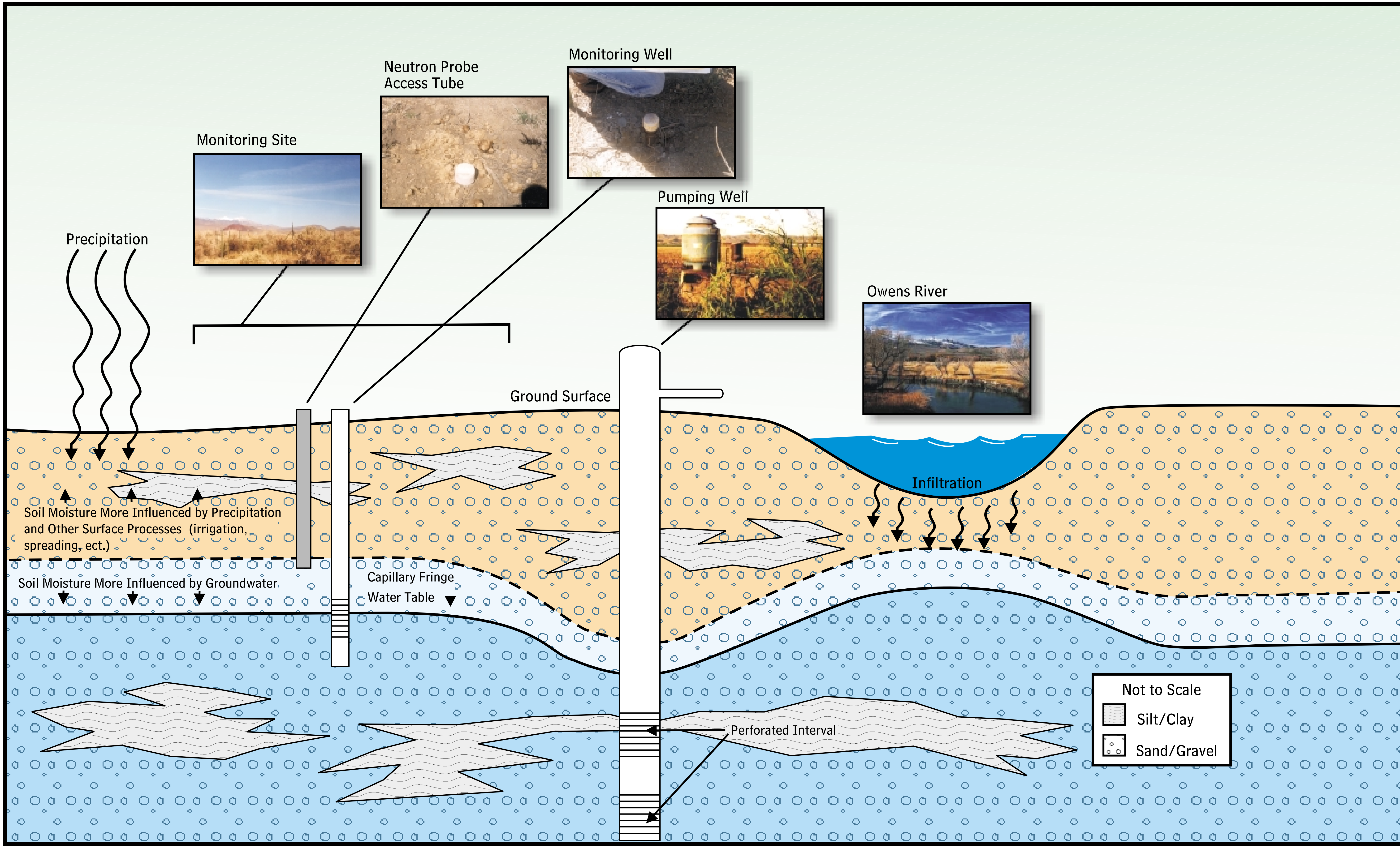

Figure 1-6
Conceptual Cross Section for Owens Valley Monitoring Sites

Chapter 2

Laws Wellfield

Chapter 2
Laws Wellfield

Wellfield Description

Located at the northern end of the Owens Valley in the immediate vicinity of the town of Laws and north of Bishop, the Laws Wellfield is one of seven wellfields operated by the LADWP where groundwater pumping and extraction have been governed by the DRP (1992). The provisions in the Green Book (October 1991) provide for five monitoring sites at this wellfield, L1 through L5, as summarized in **Table 2-1** and shown on **Figure 2-1**. However, monitoring sites L4 and L5 were never established.

Table 2-1
Summary of Laws Wellfield Monitoring Sites

Monitoring Site	Vegetation Type	Shallow Monitoring Well	Pumping Wells[1]	EM Wells
L1	A	T795[2]	W246AQ (replaced by W398AQ), W247AQ, W248AQ, W249AQ, W398AQ	
L2	C	V001G	W236AQ, W239AQ, W243AQ, W244AQ	
L3	C	T574[3]	W240AQ, W241AQ, W242AQ (replaced by W399AQ), W399AQ	W376EM, W377EM
L4 (site never established)				W385EM, W386EM
L5 (site never established)			W245AQ	W387EM, W388EM

[1] Wells W365AQ (sole source irrigation supply well) and W354DM (sole source town supply well) are located within the Laws Wellfield, but exempt from Green Book on/off provisions and DRP provisions.
[2] Well T795 was drilled in 1988 and has a depth to water history from May 1989 to present; therefore, no 1985-1987 baseline data exist for this well and monitoring site.
[3] T574 is located about 1/8 mile from the monitoring site. A new test well was recently installed right at the monitoring site.

Monitoring Site L1

Monitoring Site L1 is associated with pumping wells W247AQ, W248AQ, W249AQ, and W398AQ. The shallow monitoring well at this site is Well T795, which has a depth to water history from May 1989 to present and does not provide a 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (L1-1, L1-2, and L1-3). Representative vegetation at monitoring site L1 has been mapped as Type A, which does not fall under the DRP.

EXPLANATION

- Town
- Production Well
- Test "T" Well
- Monitoring "V" Well
- L2 Monitoring Site
- L2C Monitoring Control Site
- Streams and Rivers
- Highways
- Los Angeles Aqueduct
- Management Area

Figure 2-1

Laws Wellfield
Site Vicinity Map

N

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0 3000 6000 Feet

Monitoring Site L2

Monitoring Site L2 is associated with pumping wells W236AQ, W239AQ, W243AQ, and W244AQ. The shallow monitoring well at this site is Well V001G, also referred to as USGS 1. Well V001G has a depth to water history from September 1985 to present, thereby providing a portion of the 1985-1987 Runoff Year baseline. However, the well went dry for a portion of the baseline period and was not used for quantitative analysis. In addition, there are three soil moisture access tubes at this site (L2-1, L2-2, and L2-3). Representative vegetation at monitoring site L2 has been mapped Type C.

Monitoring Site L3

Monitoring Site L3 is associated with pumping wells W240AQ, W241AQ, and W399AQ, as well as EM Wells W376EM and W377EM. The shallow monitoring well at this site is Well T574. Well T574 has a depth to water history from August 1985 to present, thereby providing a portion of the 1985-1987 baseline. In addition, there are four soil moisture access tubes at this site (L3-1, L3-2, L3-3, and L3-4). Representative vegetation at monitoring site L3 has been mapped as Type C.

Management Area Monitoring Wells

There are a total of 38 shallow wells and nine deep wells, as shown on **Figure 2-1**, within the Laws management area. As summarized in **Table 2-2**, the following descriptive statistics apply to this data set of wells:

- Sixteen of the shallow wells and one of the deep wells do not have baseline data and no analysis was performed on these wells.
- Nine of the shallow wells and one of the deep wells were dry in the baseline allowing for a qualitative evaluation only.
- Thirteen of the shallow wells and seven of the deep wells have data suitable for the quantitative analysis described in Chapter 1.
- Although quantitative and qualitative evaluations are conducted on suitable shallow and deep wells, only the 13 shallow wells, whose data represent water table conditions suitable for quantitative analysis, are used to validate DRP termination.

Table 2-2
Summary of Wells in the Laws Wellfield Management Area

Descriptive Statistic	Quantity of Wells	
	Shallow	Deep
Wells in Management Area	38	9
Wells with No Baseline Data – No Analysis Performed	16	1
Wells that were Dry in Baseline - Qualitative Analysis Performed	9	1
Wells with Complete Data Sets - Quantitative Analysis Performed	13	7
Wells Used to Validate DRP Termination	13	0

Depth to Water

Methodology

As discussed previously, there are a total of 47 monitoring wells within the Laws Wellfield. Of these 47 monitoring wells, quantitative analyses were performed in accordance with **Table 2-2**. **Figure 2-1** shows the location of Laws management area wells and **Table 2-3** provides a listing of the 20 monitoring wells evaluated quantitatively.

Data Presentation

The quantitative methodology described in the Approach section of Chapter 1 was applied to the 13 shallow wells and seven deep wells. Baseline mean and 95 percent confidence intervals were calculated and are summarized in **Table 2-3**. Also shown in this table is the lowest depth to water recorded during the drought (DTW Drought Low), the water level that represents 80 percent recovery using Equation 2 (DTW 80 percent Recovery), runoff year during which drought low point occurred, and a column for each potential recovery year (Runoff Years 1995 – 2000).

Hydrographs for these 20 wells graphically depict the baseline and 80 percent recovery line and are provided **Appendix A**. In general, depth to water measurements were high during the baseline period and declined during the drought. Since the end of the drought, water levels have steadily climbed, typically achieving recovery in the late 1990s.

Table 2-3
Summary of Laws Wellfield Monitoring Wells Evaluated for DRP Termination

Well	Baseline			DTW Drought Low (fbgs)	DTW 80% Recovery (fbgs)	Runoff Year(s) During which Low Point Occurred	Substantial Recovery Achieved by Runoff Year						
	Mean[1] (fbgs)	Lower 95% CI	Upper 95% CI				1995	1996	1997	1998	1999	2000	Summary[3]
T434	8.4	9.9	6.9	18.8	10.5	1990	X	X	X	X	X	X	X
T435	8.4	9.9	6.8	22.2 [2]	11.1	1989-1990, 1991-1993					X	X	X
T436	8.5	9.2	7.7	18.0 [2]	10.4	1989-1992		X		X	X	X	X
T437	3.3	3.8	2.8	11.4	4.9	1990	X	X	X	X	X	X	X
T438	7.5	8.7	6.4	17.0 [2]	9.4	1989	X			X	X		X
T490	12.1	13.1	11.1	20.5	13.8	1992					X		X
T492	32.3	35.1	29.5	60.3 [2]	37.9	1989-1990	X	X	X	X	X	X	X
T493	15.5	17.7	13.4	49.5	22.3	1990	X			X	X	X	X
T503	12.4	14.2	10.7	29.3	15.8	1990	X	X	X	X	X	X	X
T574	14.2	15.6	12.8	20.6 [2]	15.5	1988-1993, 1994	X	X	X	X	X	X	X
T576	11.0	12.4	9.6	17.2 [2]	12.2	1988-1993, 1993-1995	X			X	X	X	X
T577	9.9	12.5	7.4	31.3 [2]	14.2	1989, 1990-1993	X	X	X	X	X		X
T606	24.9	27.9	21.9	38.2 [2]	27.6	1988-1993, 1995					X	X	X
Laws Wellfield Management Area Percent Recovery for Shallow Wells:							69%	54%	46%	78%	**100%**	78%	**100%**
V253	33.2	35.7	30.8	65.7	39.7	1991				X	X	X	X
V262	20.1	22.7	17.6	60.6	28.2	1990				X	X	X	X
V269	24.0	28.2	19.8	55.4	30.3	1989	X	X	X	X	X	X	X
V270	24.0	26.9	21.1	56.8	30.6	1990	X		X	X	X	X	X
V271	20.6	22.9	18.2	54.8	27.4	1990	X	X	X	X	X	X	X
V275	21.8	25.5	18.2	60.9	29.6	1990				X	X	X	X
V290	15.8	18.4	13.1	44.7	21.6	1989	X	X	X	X	X	X	X
Laws Wellfield Management Area Percent Recovery for Deep Wells:							57%	43%	57%	**100%**	**100%**	**100%**	**100%**

1 Baseline Mean is calculated from all available depth to water measurements collected during the baseline, on a Runoff Year basis (1985-1987).

2 DTW Drought Low represents the depth of the well as the well went dry at this point, precluding measurement of the actual water level. As a result, the actual DTW 80% recovery is lower than that presented in the table.

3 This "Summary" column indicates if substantial recovery has been achieved in a well at any time since the DRP was instituted in 1992.

Discussion

The data demonstrate that 100 percent of Laws Wellfield management area shallow wells exhibit substantial recovery in Runoff Year 1999; therefore the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met. In addition, all shallow wells show substantial recovery since the DRP was implemented in 1992.

Similarly, seven of the seven (100 percent) Laws deep wells exhibit substantial recovery in Runoff Years 1998, 1999, and 2000, lending additional support to termination of the DRP at the Laws Wellfield. In addition, all deep wells show substantial recovery since the DRP was implemented in 1992.

Furthermore, hydrographs for the nine shallow and one deep wells, as summarized in **Table 2-4**, that were dry in the baseline were constructed and are included in **Appendix A**. Of these wells, six wells express a pattern of recovery since the drought indicative of drought recovery. The other four wells are dominated by dry measurements from baseline to present such that it is not possible to draw any conclusions from the data for these wells.

Table 2-4
Summary of Laws Wellfield Monitoring Wells that were Dry During the Baseline

Shallow Wells	Deep Wells
T312A	V286
T313A	
T439	
T494	
T495	
T578	
T580	
T605	
V001G	

Summary

To summarize 100 percent of the Laws shallow wells exhibit substantial recovery in Runoff Year 1999 and since the DRP was implemented in 1992; therefore the entire wellfield exhibits substantial recovery and the water level DRP termination criteria have been met.

Hydrologic Indices

MWH reviewed groundwater balance data for the Laws area to determine the status of the hydrologic conditions. The results of this evaluation are presented below.

Groundwater Balance

For the Laws wellfield, the results of the groundwater balance evaluation are presented in **Figure 2-2**. This figure shows the annual recharge and pumping as bars with the differences between the bars representing the annual change in storage. This figure also shows the cumulative change in storage since 1969. The cumulative storage graph indicates an initial loss of about 40,000 acre-ft of storage between Water Year (WY) 1971 through 1973. From WY 1974 through 1977, groundwater storage was approximately balanced. Between WY 1977 and 1986, about 105,000 acre-ft of water accumulated in storage. From WY 1987 through 1994, approximately 65,000 acre-ft of water was pumped from storage to meet water demands during the drought. Since 1992, pumping in the Laws area has been managed conservatively resulting in a gain of almost 90,000 acre-ft since 1994, more than replacing the storage depletions in the late 1980s and early 1990s.

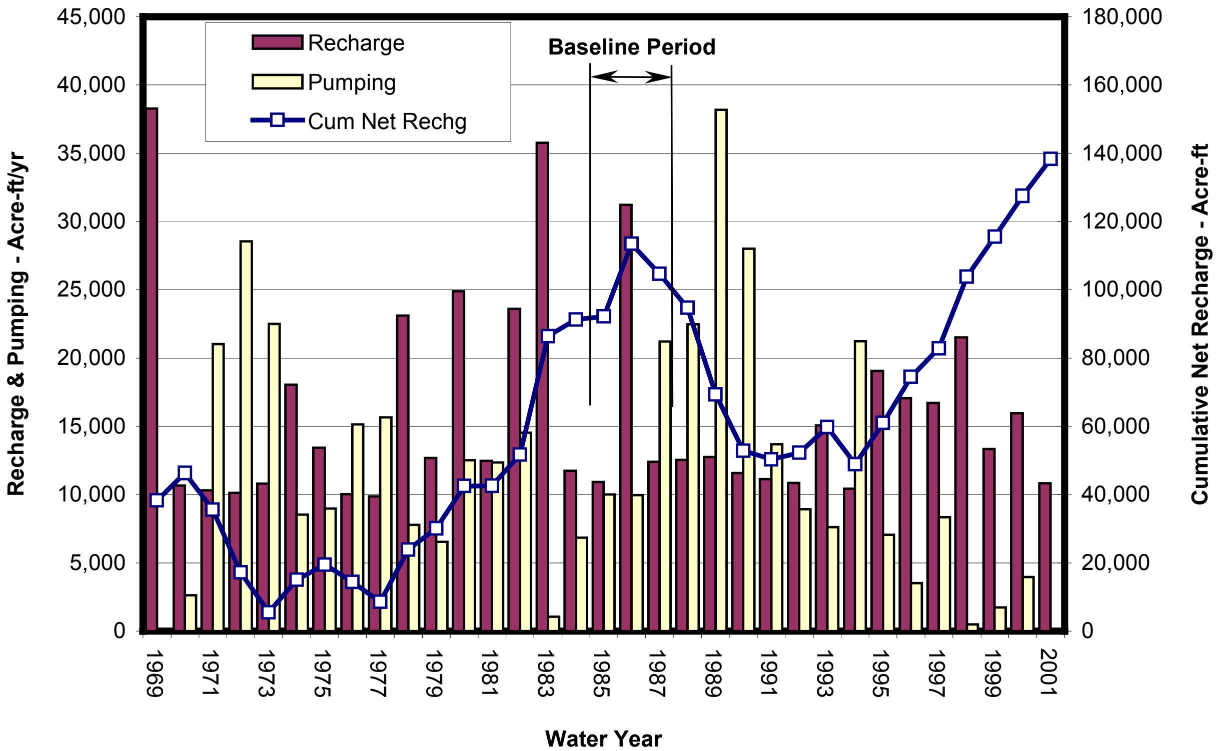


Figure 2-2
Laws Wellfield Groundwater Balance

Soil Moisture

Methodology

Neutron probe data have been collected on a monthly basis from 10 soil access tubes from the three monitoring sites (L1, L2, and L3) since June 1995. Neutron probe data were collected at 20-cm intervals from a depth of 30 cm to a depth of 390 cm to construct a soil moisture depth profiles. Soil moisture data were evaluated using the approach described in the Approach section of Chapter 1.

Data Presentation and Discussion

Precipitation and Soil Moisture

Figure 2-3 through **Figure 2-5** compare the average soil moisture at monitoring sites L1 (includes an average of soil access tubes L1-1, L1-2, and L1-3), L2 (includes an average of soil access tubes L2-1, L2-2, and L2-3), and L3 (includes an average of soil access tubes L3-1, L3-2, L3-3 and L3-4) at a depth of 30 cm to monthly precipitation at the LADWP Bishop Yard weather station. The uppermost depth measured, 30 cm, was selected to evaluate the correlation between the upper soil profile and precipitation. Subsequent analysis evaluates relationships at two additional depths, whereby the middle depth represents a point in the soil profile least influenced by both surface processes and water levels, and the lowermost depth represents the point most influenced by water levels only.

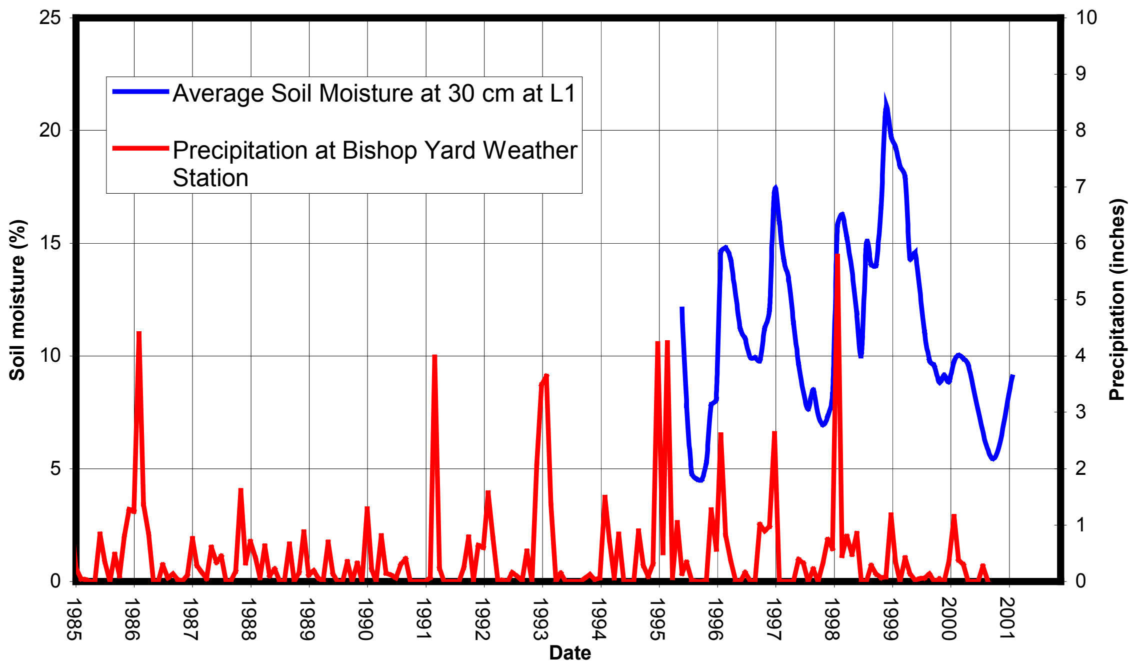


Figure 2-3
Average Soil Moisture at 30 cm for Monitoring Site L1 versus Precipitation

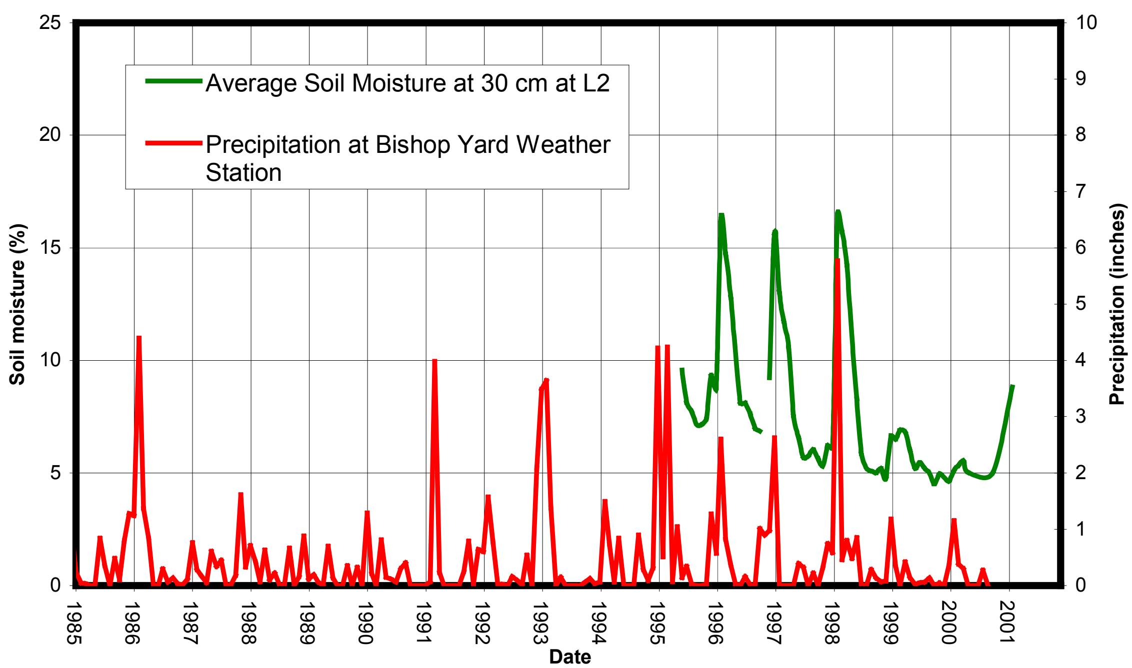


Figure 2-4
Average Soil Moisture at 30 cm for Monitoring Site L2 versus Precipitation

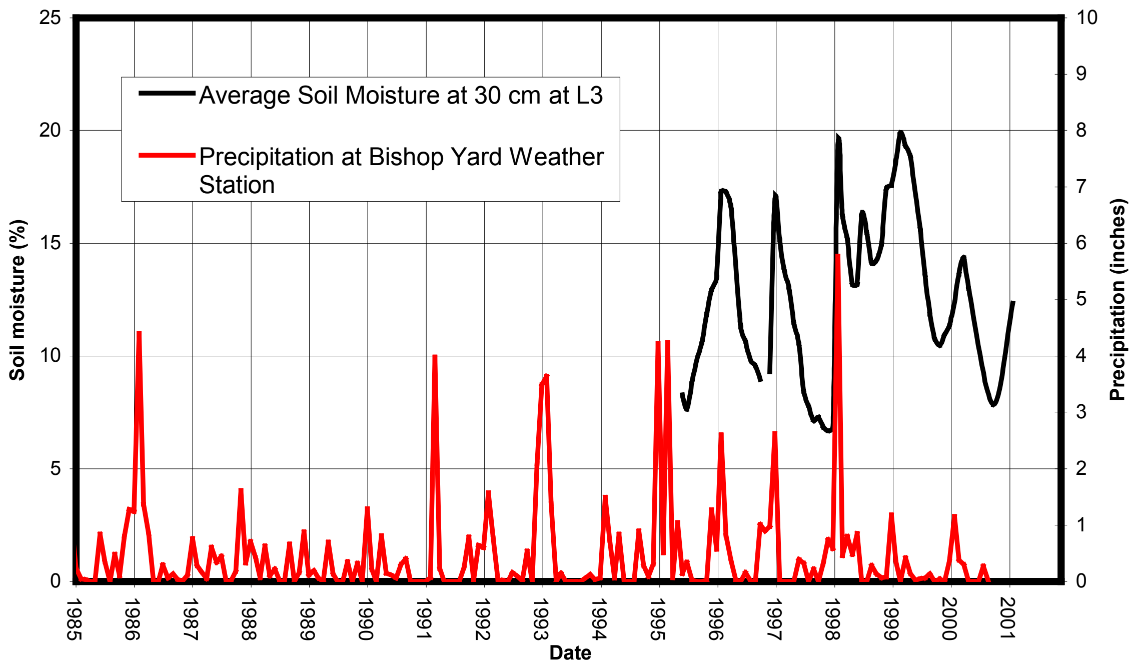


Figure 2-5
Average Soil Moisture at 30 cm for Monitoring Site L3 versus Precipitation

These curves indicate that the soil moisture at a depth of 30 cm has tracked parallel to monthly precipitation since 1995. Similarly, all three monitoring sites had nearly identical percent soil moisture until mid-1998. Monitoring sites L1 and L3 appear to have slightly higher soil moisture near the surface for a 2-year period from mid-1998 to mid-2000. These data suggest that the primary mechanism controlling soil moisture near the surface (30 cm) is precipitation, which is consistent with the conceptual soil moisture model.

Water Level and Soil Moisture

Figure 2-6 compares the average soil moisture at depths of 110 cm and 370 cm at monitoring site L1 to water levels in Well T795. As shown in this figure, soil moisture at both depths generally parallel water levels in Well T795 with maximum soil moisture content of approximately 40 percent. The maximum measurements correspond to times in which the water level in Well T795 is above the monitoring point of 370 cm and likely represents the saturation point for this soil.

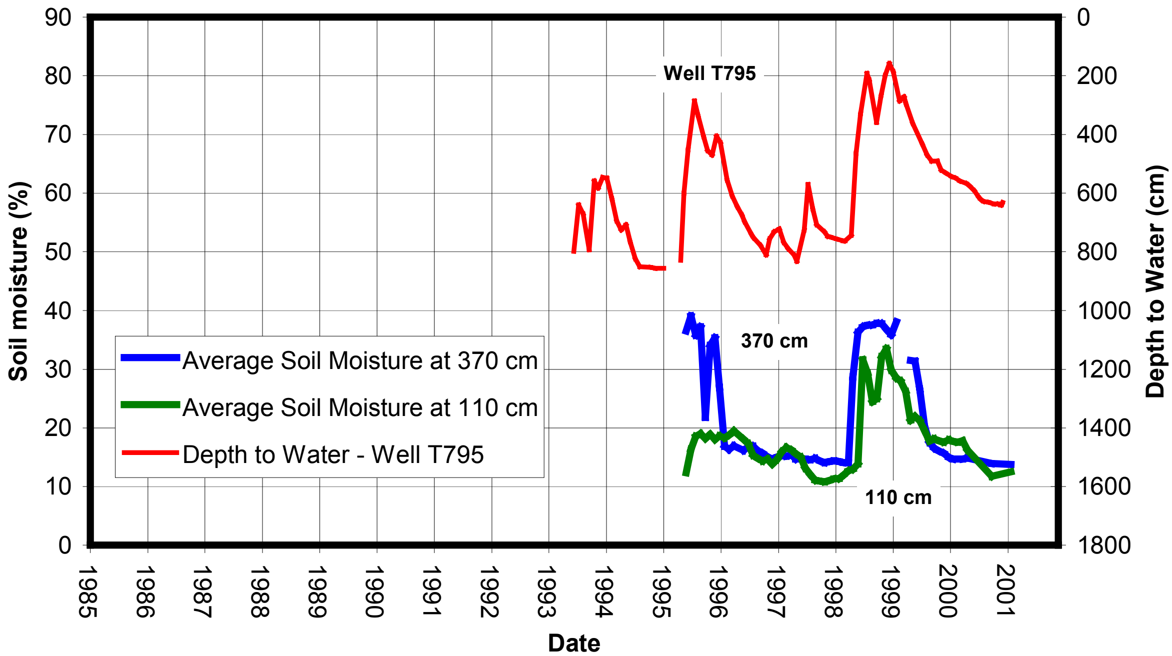


Figure 2-6
Average Soil Moisture for Monitoring Site L1 versus Water Level

Figure 2-7 compares the average soil moisture at depths of 110 cm and 370 cm at monitoring site L2 to water levels in Well V001G. As shown in this figure, soil moisture at 370 cm generally parallels water levels in Well V001G with a maximum percent soil moisture of approximately 20 percent. Soil moisture at 110 cm is initially higher than the soil moisture at 370 cm until mid-to late 1998 when soil moisture at 370 cm increases from less than 10 percent to more than 20 percent. The maximum measurements correspond to times in which the water level in Well V001G is at its highest. Soil moisture at site L2 is substantially lower than at L1 because water levels are more than 100 cm below the monitoring point.

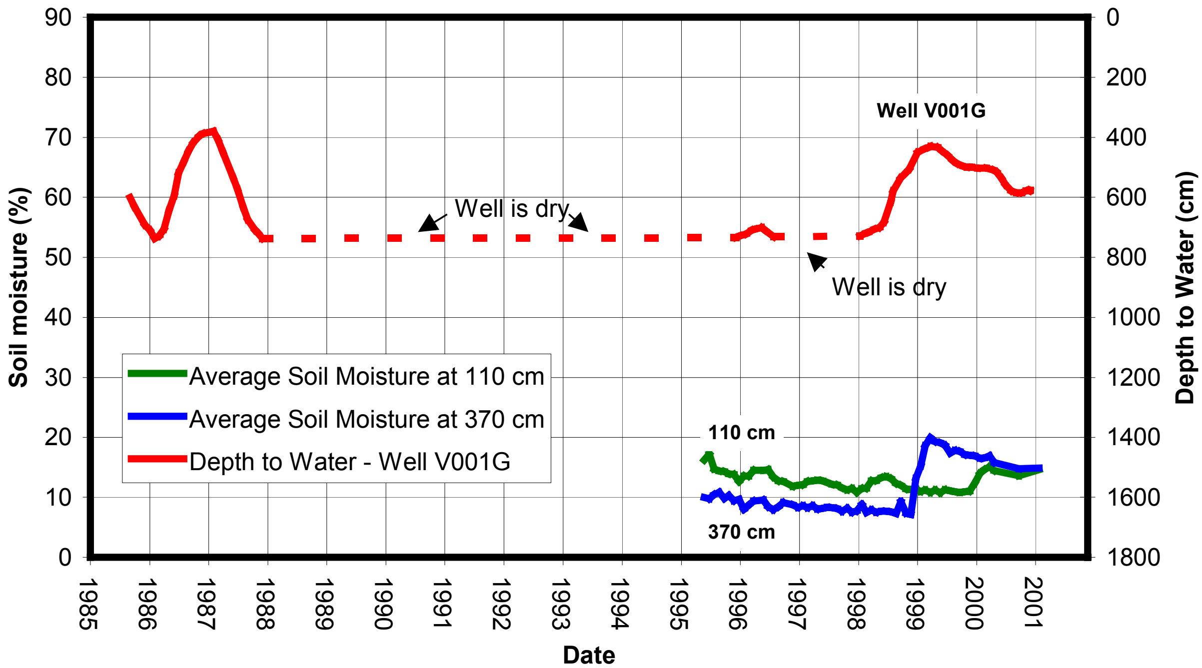


Figure 2-7
Average Soil Moisture for Monitoring Site L2 versus Water Level

Figure 2-8 compares the average soil moisture at 110 cm and 370 cm at monitoring site L3 to water levels in Well T574. As shown in this figure, soil moisture at both depths generally parallels water levels in Well T574 with a maximum soil moisture content of almost 60 percent at a depth of approximately 370 cm. Soil moisture at a depth of approximately 110 cm is below 30 percent. The maximum measurements correspond to times when the water level in Well T574 is near or above the monitoring point of 370 cm and likely represents soil saturation.

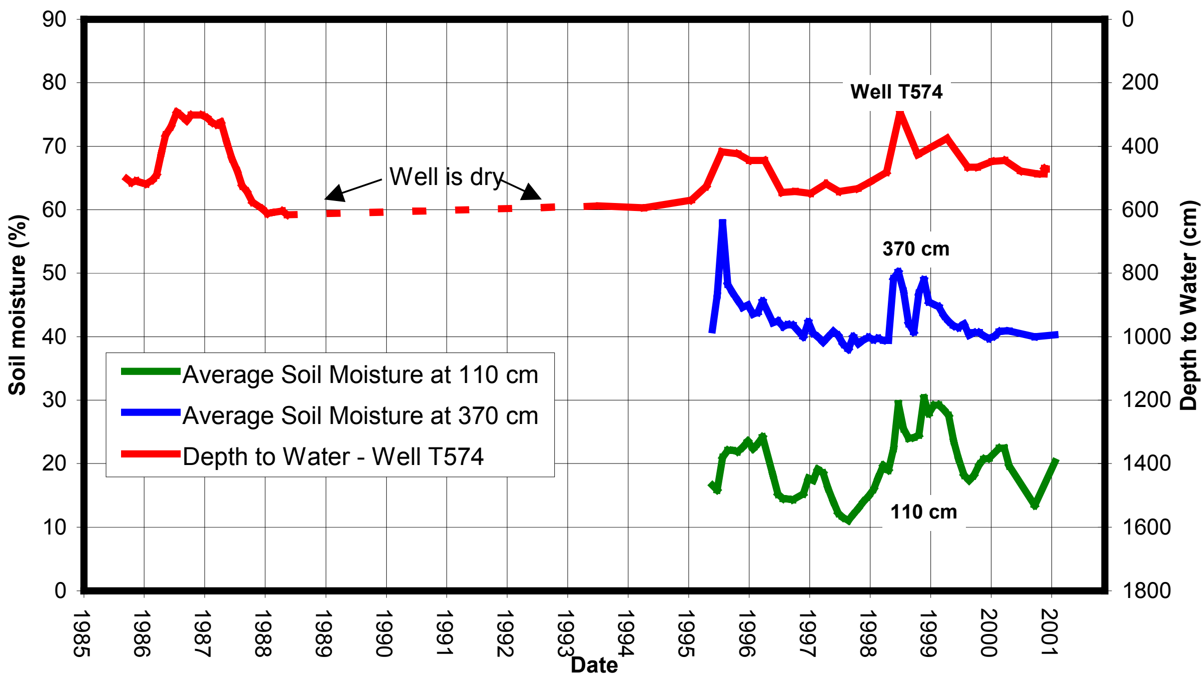


Figure 2-8
Average Soil Moisture for Monitoring Site L3 versus Water Level

Soil Moisture Profiles

As discussed in the conceptual soil moisture model, soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. Soil profiles for each location were compiled to evaluate the vertical relationship among water table, precipitation, and soil moisture. Vertical profiles were constructed for the maximum water level and the minimum water level during the time period from 1995 to 2000. Consequently, these data should represent the approximate range in soil moisture attributable to groundwater at each depth for this period.

Figure 2-9 presents soil moisture profiles in soil probe L1-2 during the time periods May 1997 and December 1998. As shown in this figure, soil moisture in May 1997 is below 20 percent. In addition, the percentage of soil moisture above a depth of approximately 100 cm remains below 25 percent in both time periods. As shown on **Figure 2-9**, water level depths ranged from nearly 800 cm in May 1997 to about 180 cm in December 1998. In December 1998, when water levels were at their highest, the soil moisture from 100 cm to 390 cm during this time period reached as high as 45 percent at a depth of about 210 cm, which is roughly coincident with the maximum height of the groundwater. The increases in soil moisture between 100 cm and 210 cm in this time period appear to be a result of a rising capillary fringe. On the other hand, water levels in May 1997 were below 780 cm, which results in an associated decrease in the soil moisture below 100 cm due to a lowering of the capillary fringe.

Because the soil moisture remains relatively low in 1997 (less than 25 percent) at a depth of approximately 100 cm, this appears to be the maximum extent of groundwater influence at this location during this time period. Above a depth of approximately 100 cm, soil moisture during the two time periods track similarly. These profile patterns do not correlate well with a change in water level. Therefore, for this analysis other factors such as precipitation appear to have more influence on soil moisture above 100 cm.

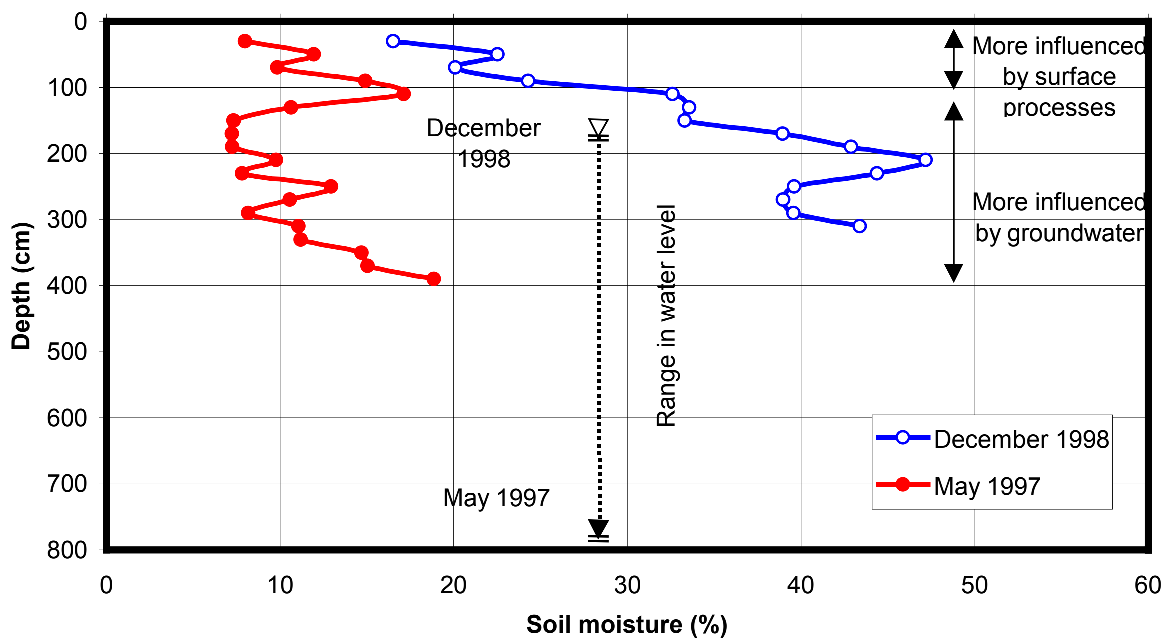


Figure 2-9
Soil Moisture Profile for Soil Probe L1-2

Figure 2-10 presents soil moisture profiles in soil probe L2-1 during the time periods December 1995 and April 1999. Soil moisture at this site above a depth of approximately 230 cm track nearly identically below 15 percent for each of the time periods shown. Below a depth of about 230 cm, the soil moisture in April 1999 gradually increases to about 35 percent by 390 cm. Soil moisture in December 1995 remains below 15 percent throughout the profile. The depth to water near soil probe L2-1 ranges from about 450 cm to 730 cm during this time period. Therefore, at this site, depth to groundwater appears to influence soil moisture below a depth of about 230 cm for the time period shown.

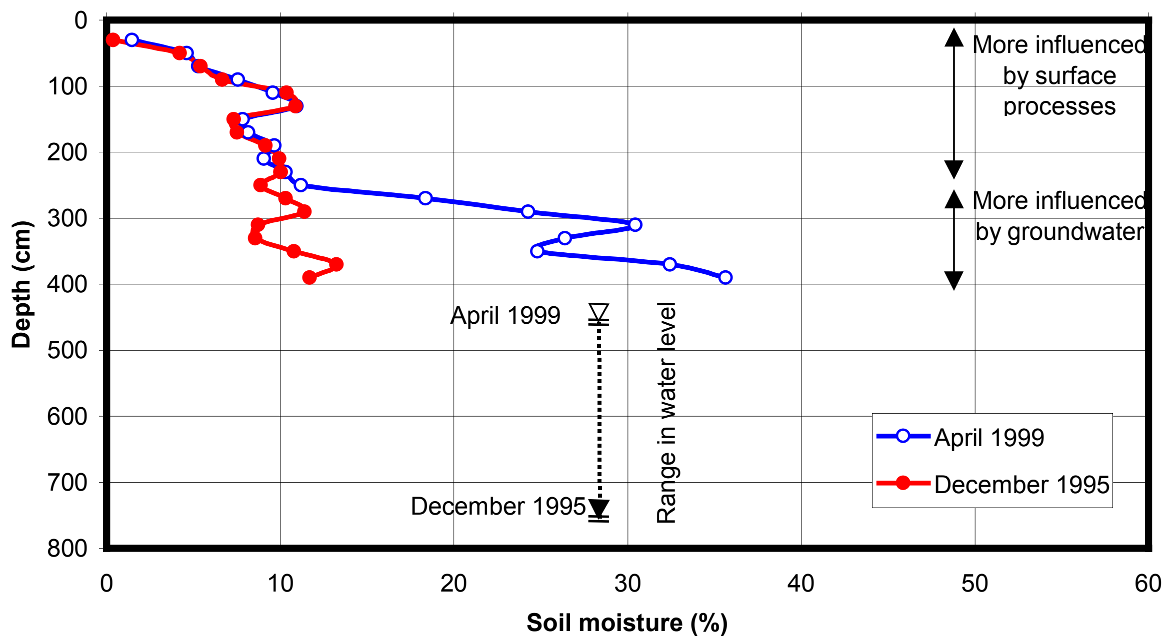


Figure 2-10
Soil Moisture Profile for Soil Probe L2-1

Figure 2-11 presents soil moisture profiles in soil probe L3-1 during the time periods January 1997 and July 1998. Soil moisture at this site generally increases from below 30 percent in the upper 100 cm to more than 45 percent below 300 cm during the time period shown. Water levels during this time period range from approximately 300 cm to nearly 600 cm. As might be expected, higher soil moisture content below a depth of about 130 cm are observed in this analysis when higher water levels are encountered. However, the existing data are not adequate to determine at what depth the influence of surface processes exceed the influence of groundwater levels on soil moisture.

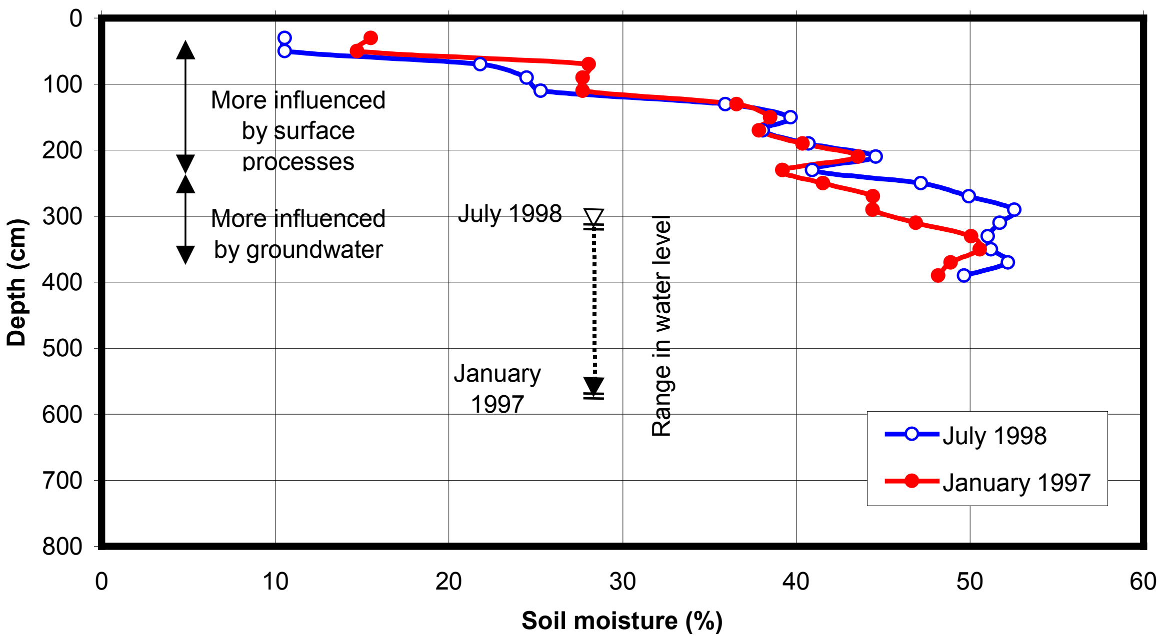


Figure 2-11
Soil Moisture Profile for Soil Probe L3-1

Summary

Soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. The data presented herein validate that the upper portion of the soil profile appears to be more strongly influenced by surface processes while the lower portion of the soil profile appears to be more strongly influenced by groundwater levels. This is clearly consistent with the conceptual model. Because soil moisture in the upper portion of the soil profile (the exact depth of this interface varies with time and location) is largely independent of groundwater levels, soil moisture in these portions of the soil profile should not be used to identify a return to baseline conditions nor the influence of groundwater pumping. Most significantly, from the strong correlation between water levels and the soil moisture associated with the capillary fringe, it can inferred that since water levels in the Laws management area have shown substantial recovery, then the portion of the soil moisture profile influenced by the water table also exhibits substantial recovery.

Findings

Based on the review of data pertinent to the issue of the Drought Recovery Policy, Montgomery Watson Harza presents the following findings:

1. The DRP states that "substantial recovery in soil moisture and water table conditions" are the criteria by which the DRP is terminated. Until then, it is intended for "environmentally conservative" groundwater pumping to be conducted. The DRP does not specify the consideration of any other criteria in determining the termination of DRP.

2. 100 percent of the Laws shallow wells exhibit substantial recovery in Runoff Year 1999 and since the DRP was implemented in 1992; therefore the entire wellfield exhibits substantial recovery and the water level DRP termination criteria have been met.

3. Evaluation of net recharge (recharge less pumping) in the Laws area also documents drought recovery. Since 1992, pumping in the Laws area has been managed conservatively resulting in a gain of almost 90,000 acre-ft since 1994, more than replacing the storage depletions in the late 1980s and early 1990s.

4. Neutron probe soil moisture data do not exist for the baseline period. Neutron probe data were not available prior to 1995. Despite the absence of baseline data, analysis of the available data yields information pertinent to the DRP.

5. Soil moisture data from the Laws monitoring sites show a direct correlation between the lower portion of the soil profile and groundwater levels. Soil moisture in the lower portion of the soil moisture profile is predominantly influenced by water levels. For the 1995 to 2000 time period, this depth is approximately 100 cm at monitoring site L1, about 230 cm at monitoring site L2, and undeterminable from available data at monitoring site L3.

6. Although baseline data for soil moisture are not available, we have been able to conclude that based on the depth-to-groundwater/soil moisture relationships demonstrated by the data described in Finding 5, and because groundwater levels in the Laws Wellfield have substantially recovered, it necessarily follows that soil moisture levels to the extent that they are influenced by groundwater levels, have also recovered.

7. Soil moisture above the depth where groundwater is the predominant influence is controlled by numerous other factors such as precipitation, surface land use activities, and evapotranspiration. Of these, only precipitation is a direct measure of drought conditions. Consequently, for this upper portion of the soil profile, only the consideration of precipitation is appropriate for evaluation of drought recovery.

Recommendations

Based on the findings above and associated preponderance of evidence concerning depth to water data, groundwater balance, and soil moisture, substantial recovery as defined in the DRP has been achieved. To summarize, the data clearly demonstrate that termination of the DRP is appropriate.

Chapter 3

Big Pine Wellfield

Chapter 3
Big Pine Wellfield

Wellfield Description

Located in the northern portion of the Owens Valley and in the immediate vicinity of the town of Big Pine, the Big Pine Wellfield is one of seven wellfields operated by the LADWP where groundwater pumping and extraction have been governed by the DRP. The provisions in the Green Book (October 1991) provide for four monitoring sites at this wellfield, BP1 through BP4, as summarized in **Table 3-1** and shown on **Figure 3-1**.

Table 3-1
Summary of Big Pine Wellfield Monitoring Sites

Monitoring Site	Vegetation Type	Shallow Monitoring Well	Pumping Wells[1]	EM Wells
BP1	C	T798	W210AQ	W378EM, W379EM, W389EM
BP2	B	T799	W220AQ, W229AQ, W374AQ	W375EM
BP3	A	T567	W222AQ, W223AQ, W231AQ, W232AQ	
BP4	A	T800	W331AQ	

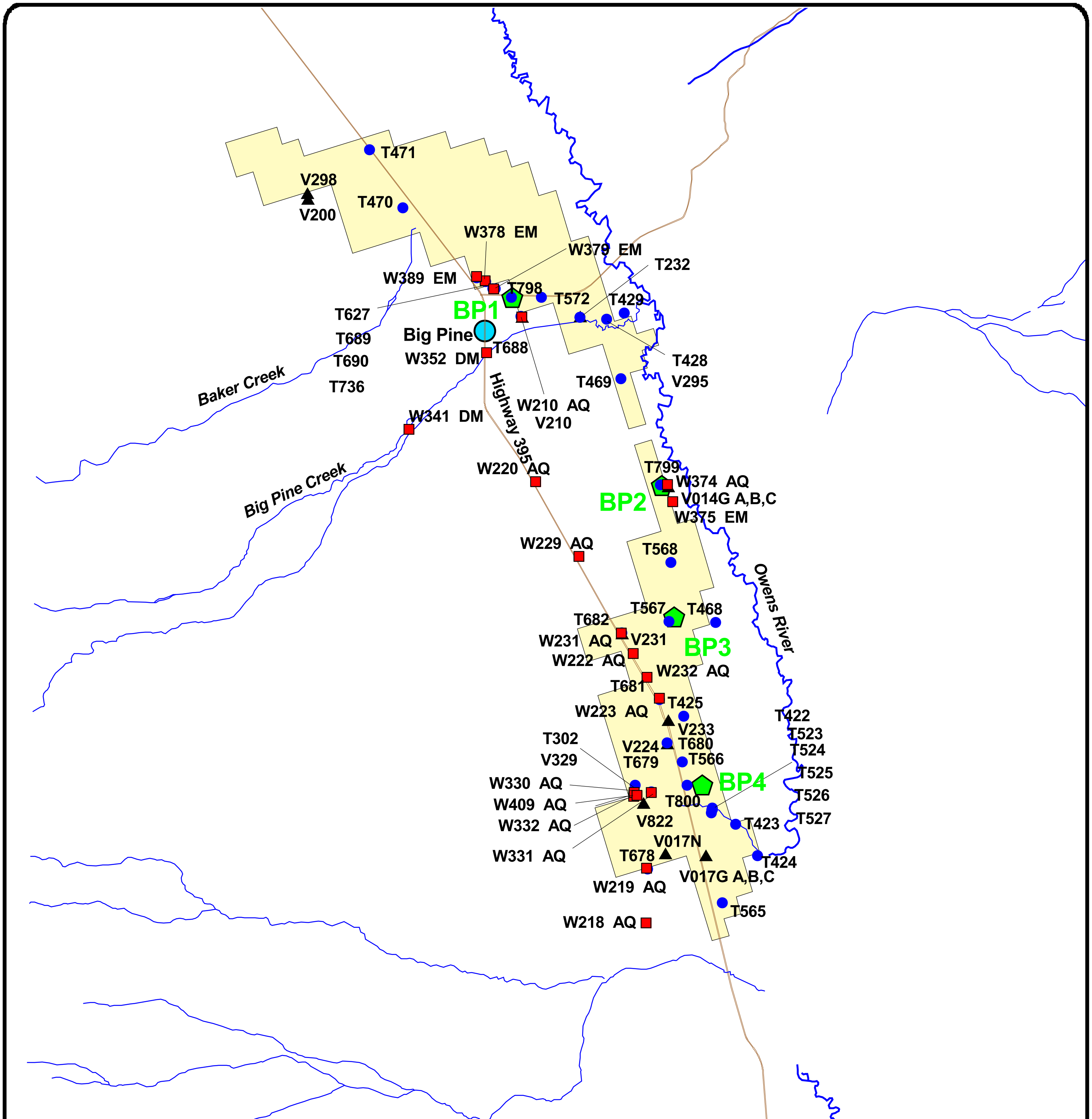
[1] Wells W218AQ, W219AQ (pumping wells with no impact on areas with groundwater dependent vegetation), W330AQ, W332AQ, and W409AQ (fish hatchery sole source supply) are located within the Big Pine Wellfield, but exempt from Green Book on/off provisions and DRP provisions.

Monitoring Site BP1

Monitoring Site BP1 is associated with pumping well W210AQ and EM wells W378EM, W379EM, and W389EM. The shallow monitoring well at this site is Well T798, which has a depth to water history from May 1989 to present and does not provide a 1985-1987 baseline. In addition, there are three soil moisture access tubes at this site (BP1-1, BP1-2, and BP1-3). Representative vegetation at monitoring site BP1 has been mapped as Type C.

Monitoring Site BP2

Monitoring Site BP2 is associated with pumping wells W220AQ, W229AQ, and W374AQ, as well as EM well W375EM. The shallow monitoring well at this site is Well T799. Well T799 has a depth to water history from May 1989 to present, and does not provide a 1985-1987 baseline. In addition, there are three soil moisture access tubes at this site (BP2-1, BP2-2, and BP2-3). Representative vegetation at monitoring site BP2 has been mapped as Type B.



EXPLANATION

- Town
- Production Well
- Test "T" Well
- Monitoring "V" Well
- L2 Monitoring Site
- L2C Monitoring Control Site
- Streams and Rivers
- Highways
- Los Angeles Aqueduct
- Management Area

Figure 3-1

Big Pine Wellfield
Site Vicinity Map

0 5000 10000 Feet

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Monitoring Site BP3

Monitoring Site BP3 is associated with pumping wells W222AQ, W223AQ, W231AQ, and, W232AQ. The shallow monitoring well at this site is Well T567. Well T574 has a depth to water history from August 1985 to present, thereby providing a portion of the 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (BP3-1, BP3-2, and BP3-3). Representative vegetation at monitoring site BP3 has been mapped as Type A, which is not subject to the provisions of the DRP.

Monitoring Site BP4

Monitoring Site BP4 is associated with pumping well W331AQ. The shallow monitoring well at this site is Well T800. Well T800 has a depth to water history from May 1989 to present, and does not provide a 1985-1987 baseline. There are three soil moisture access tubes at this site (BP4-1, BP4-2, and BP4-3). Representative vegetation at monitoring site BP4 has been mapped as Type A, which is not subject to the provisions of the DRP.

Management Area Monitoring Wells

There are a total of 36 shallow wells and 16 deep wells, as shown on **Figure 3-1**, within the Big Pine management area. As summarized in **Table 3-2**, the following descriptive statistics apply to this data set of wells:

- Nine of the shallow wells and five of the deep wells do not have baseline data and no analysis was performed on these wells.
- Two of the shallow wells and two of the deep wells were dry in the baseline allowing for a qualitative evaluation only.
- 25 of the shallow wells and nine of the deep wells have data suitable for the quantitative analysis described in Chapter 1.
- Although quantitative and qualitative evaluations are conducted on suitable shallow and deep wells, only the 25 shallow wells, whose data represent water table conditions suitable for quantitative analysis, are used to validate DRP termination.

Table 3-2
Summary of Wells in the Big Pine Wellfield Management Area

Descriptive Statistic	Quantity of Wells	
	Shallow	Deep
Wells in Management Area	36	16
Wells with No Baseline Data – No Analysis Performed	9	5
Wells that were Dry in Baseline - Qualitative Analysis Performed	2	2
Wells with Complete Data Sets - Quantitative Analysis Performed	25	9
Wells Used to Validate DRP Termination	**25**	0

Depth to Water

Methodology

As discussed previously, there are a total of 52 monitoring wells within the Big Pine Wellfield. Of these 52 monitoring wells, quantitative analyses were performed in accordance with **Table 3-2**. **Figure 3-1** shows the location of Big Pine management area wells and **Table 3-3** provides a listing of the 34 monitoring wells evaluated quantitatively.

Data Presentation

The quantitative methodology described in the Approach section of Chapter 1 was applied to the 25 shallow wells and nine deep wells listed in **Table 3-3**. Baseline mean and 95 percent confidence intervals were calculated and are summarized in. Also shown in this table is the lowest depth to water recorded during the drought (DTW Drought Low), the water level that represents 80 percent recovery using Equation 2 (DTW 80% Recovery), runoff year during which low point occurred, and a column for each potential recovery year (Runoff Years 1995 – 2000).

Hydrographs for these 34 wells graphically depict the baseline and 80 percent recovery line and are provided **Appendix B**. In general, depth to water measurements were high during the baseline period, yet declined during the drought, and since the drought's end, water levels have steadily climbed, typically achieving recovery in the late 1990's.

Table 3-3
Summary of Big Pine Wellfield Monitoring Wells Evaluated for DRP Termination

Well	Baseline			DTW Drought Low (fbgs)	DTW 80% Recovery (fbgs)	Runoff Year(s) During which Low Point Occurred	Substantial Recovery Achieved by Runoff Year						
	Mean[1] (fbgs)	Lower 95% CI	Upper 95% CI				1995	1996[2]	1997	1998	1999	2000	Summary [4]
T422	7.9	8.4	7.5	11.4	8.6	1990				X	X	X	X
T423	5.5	5.7	5.2	7.5	5.9	1999	X	X	X	X	X	X	X
T424	4.8	5.4	4.3	7.8	5.2	1987	X	X	X	X	X	X	X
T425	14.7	15.3	14.0	25.8	16.9	1990, 1991				X	X	X	X
T428	12.9	13.3	12.6	14.4	13.2	1988	X	X	X	X	X	X	X
T429	6.2	6.4	6.0	8.9	6.8	1988	X	X	X	X	X	X	X
T468	5.6	5.9	5.3	11.0	6.7	1992	X	X	X	X			X
T469	21.6	22.2	21.1	26.6	22.6	1989	X	X	X	X	X	X	X
T470	16.2	21.3	11.1	17.3	16.4	1988	X	X	X	X	X	X	X
T471	12.3	12.9	11.7	14.3	12.7	1989, 1990	X	X	X	X	X	X	X
T565	18.8	19.8	17.9	28.8	20.8	1992, 1993	X	X	X	X	X	X	X
T566	18.0	18.7	17.3	29.3	20.3	1990				X	X	X	X
T567	14.2	14.9	13.4	26.7	16.7	1991		X	X	X	X	X	X
T568	12.2	12.9	11.5	22.5	14.2	1991, 1992		X	X	X	X	X	X
T572	11.7	12.7	10.7	21.1	13.6	1989	X	X	X	X	X	X	X
T678	58.7	60.7	56.6	72.6 [3]	61.4	1993-1995					X	X	X
T679	8.0	8.4	7.5	11.0	8.6	1998							X
T680	21.2	22.8	19.6	33.3	23.6	1991-1992					X	X	X
T681	18.3	19.8	16.9	31.4 [3]	21.0	1989-1994					X		X
T682	14.8	15.5	14.2	34.1	18.7	1989	X	X	X	X	X	X	X
T688	22.5	23.0	22.0	24.6 [3]	22.9	1988-1993	X	X	X	X	X	X	X
T689	14.2	15.1	13.3	19.6	15.3	1989	X	X	X	X	X	X	X
T690	13.8	14.4	13.2	19.4	14.9	1989	X	X	X	X	X	X	X
V014GC	14.6	15.0	14.3	19.5	15.6	1990, 1991	X	X	X	X	X		X
V017GC	23.2	24.0	22.4	34.8	25.5	1990			X	X	X	X	X
Big Pine Wellfield Management Area Percent Recovery for Shallow Wells:							60%	68%	72%	**84%**	**92%**	**84%**	**100%**
T627	97.5	117.7	77.4	139.6	106.0	1988	X	No Data	X	X	X	X	X
T736	130.5	142.5	118.5	139.6	132.3	1988	X	X	X	X	X	X	X
V014GA	46.5	55.9	37.2	102.8	57.8	1987	X	X	X	X	X	X	X
V014GB	17.0	17.5	16.4	24.1	18.4	1989	X	X	X	X	X	X	X
V017GA	34.2	37.3	31.1	79.3	43.2	1990				X	X	X	X
V017GB	14.5	16.3	12.6	32.1	18.0	1992							
V224	38.9	43.1	34.7	79.5	47.0	1989	X	X	X	X	X	X	X
V233	39.7	45.6	33.8	80.1	47.8	1989			X	X	X	X	X
V298	6.6	7.1	6.0	9.1	7.1	1988	X	X	X	X	X	X	X
Big Pine Wellfield Management Area Percent Recovery for Deep Wells:							67%	63%	78%	**89%**	**89%**	**89%**	**89%**

[1] Baseline Mean is calculated from all available depth to water measurements collected during the baseline, on a Runoff Year basis (1985-1987).
[2] Wellfield management area percent recovery for deep wells for runoff year 1996 was calculated based on 6 wells rather than 7 because Well T627 had not data for this year and was not factored into the calculation.
[3] DTW Drought Low represents the depth of the well as the well went dry at this point, precluding measurement of the actual water level. As a result, the actual DTW 80% recovery is lower than that presented in the table.
[4] This "Summary" column indicates if substantial recovery has been achieved in a well at any time since the DRP was instituted in 1992.

Discussion

The data demonstrate that 84, 92, and 84 percent of Big Pine Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1998, 1999, and 2000, respectively. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met. In addition, 100 hundred percent of shallow wells show substantial recovery since the DRP was instituted in 1992.

Similarly, eight of the nine (89 percent) Big Pine deep wells exhibit substantial recovery in Runoff Years 1998, 1999, and 2000, which indicates substantial recovery since the DRP was implemented in 1992 and lends additional support to termination of the DRP at the Big Pine Wellfield.

Furthermore, hydrographs for the two shallow and two deep wells, as summarized in **Table 3-4**, that were dry in the baseline were constructed and are included in **Appendix B**. Of these wells, Well V295 expresses a pattern of recovery since the drought indicative of drought recovery, whereas Well V231 does not. The other two wells are dominated by dry measurements from baseline to present such that it is not possible to draw any conclusions from the data for these wells.

Table 3-4
Summary of Big Pine Wellfield Monitoring Wells that were Dry During the Baseline

Shallow Wells	Deep Wells
T232	V231
T302	V295

Summary

To summarize, 84, 92, and 84 percent of Big Pine Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1998, 1999, and 2000, respectively. All wells exhibit substantial recovery since implementation of the DRP in 1992. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

Hydrologic Indices

Montgomery Watson Harza reviewed groundwater balance data for the Big Pine area to determine the status of the hydrologic conditions. The results of this evaluation are presented below.

Groundwater Balance

For the Big Pine wellfield, the results of this evaluation are presented in **Figure 3-2**. This figure shows the annual recharge and pumping as bars with the differences between the bars representing the annual change in storage. This figure also shows the cumulative change in storage since 1969. The cumulative storage graph indicates several cycles of storage and draft between Water Year (WY) 1969 through 1977 when about 5,800 acre-ft of water was removed from storage. Between WY 1977 and 1986, about 100,000 acre-ft of water accumulated in storage. From WY 1987 through 1994, approximately 66,000 acre-ft of water was pumped from storage to meet water demands during the drought. Since WY 1992, pumping in the Big Pine area has been managed conservatively resulting in a gain of almost 88,000 acre-ft since 1992, more than replacing the storage depletions in the late 1980s and early 1990s.

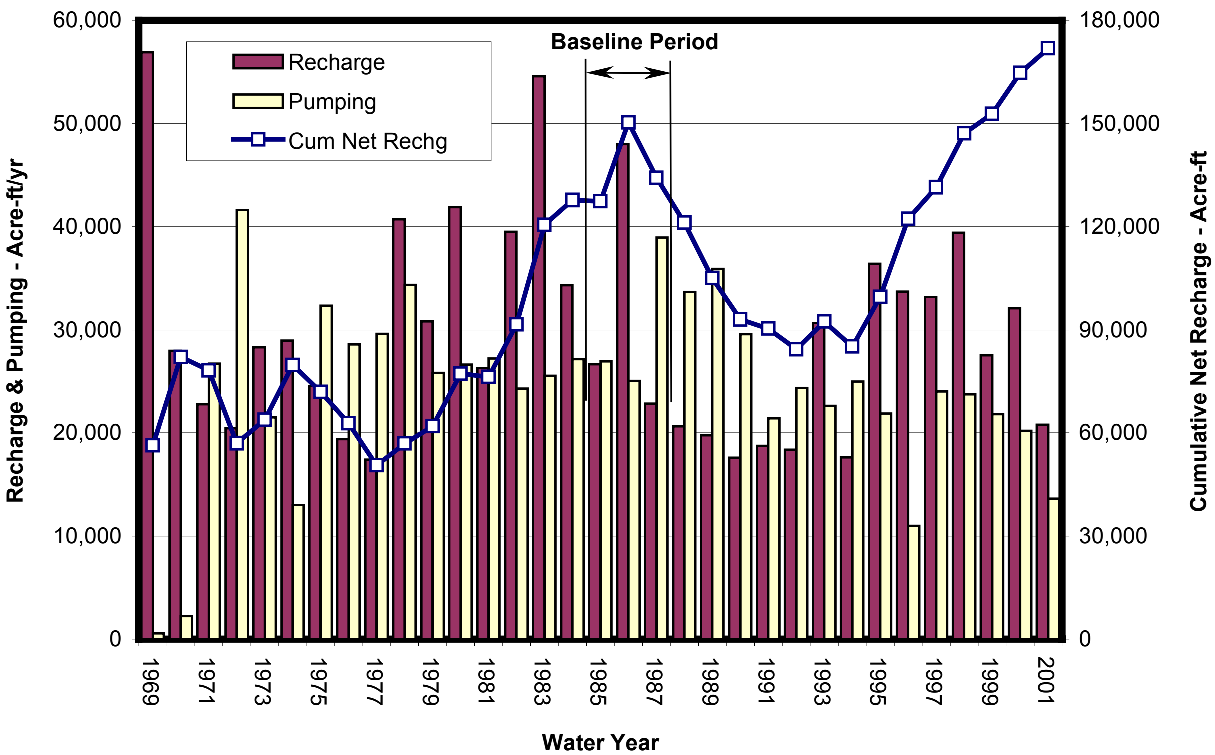


Figure 3-2
Big Pine Wellfield Groundwater Balance

Soil Moisture

Methodology

Neutron probe data have been collected on a monthly basis from 12 soil access tubes from the four monitoring sites (BP1, BP2, BP3, and BP4) since July 1995. Neutron probe data were collected at 20-cm intervals from a depth of 30 cm to a maximum depth of 530 cm at monitoring site BP2 to construct a soil moisture depth profile. Soil moisture data were evaluated using the approach described in the Approach section of Chapter 1.

Data Presentation and Discussion

Precipitation and Soil Moisture

Figure 3-3 through **Figure 3-6** compare the average soil moisture at monitoring sites BP1 (includes an average of soil access tubes BP1-1, BP1-2, and BP1-3), BP2 (includes an average of soil access tubes BP2-1, BP2-2, and BP2-3), BP3 (includes an average of soil access tubes BP3-1, BP3-2, and BP3-3) and BP4 (includes an average of soil access tubes BP4-1, BP4-2, and BP4) at a depth of 30 cm to monthly precipitation at the LADWP Big Pine weather station. The uppermost depth measured, 30 cm, was selected to evaluate the correlation between the upper soil profile and precipitation. Subsequent analysis evaluates relationships at two additional depths, whereby the middle depth represents a point in the soil profile least influenced by both surface processes and water levels, and the lowermost depth represents the point most influenced by water levels only.

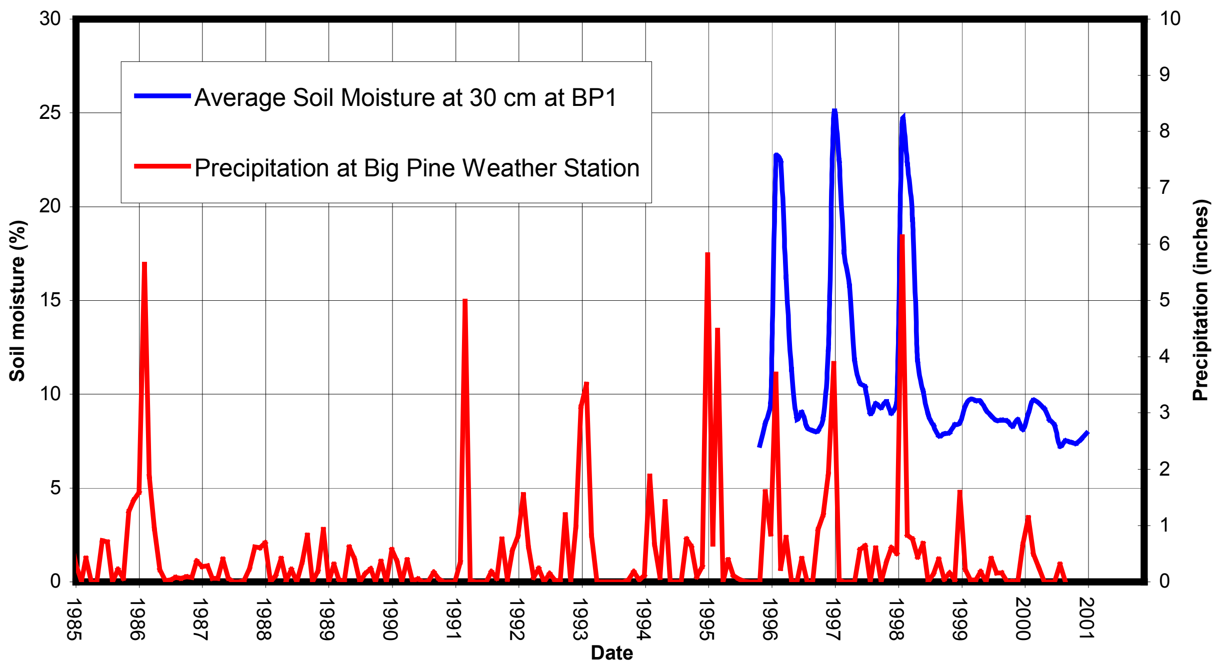


Figure 3-3
Average Soil Moisture at 30 cm for Monitoring Site BP1 versus Precipitation

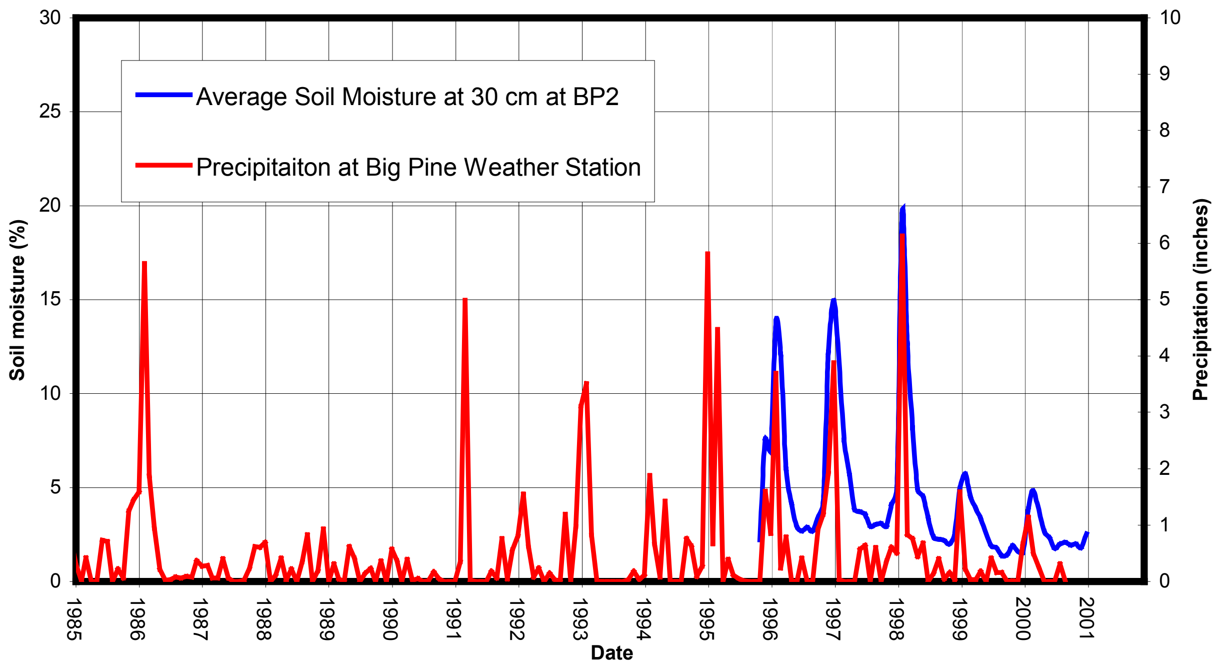


Figure 3-4
Average Soil Moisture at 30 cm for Monitoring Site BP2 versus Precipitation

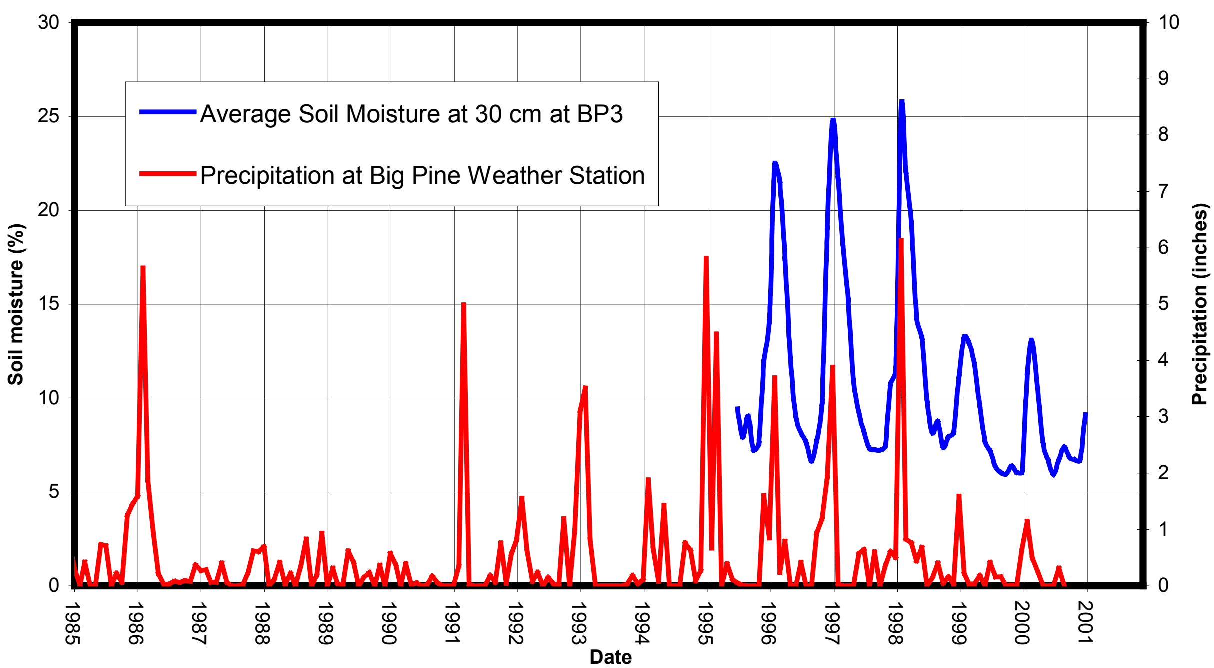


Figure 3-5
Average Soil Moisture at 30 cm for Monitoring Site BP3 versus Precipitation

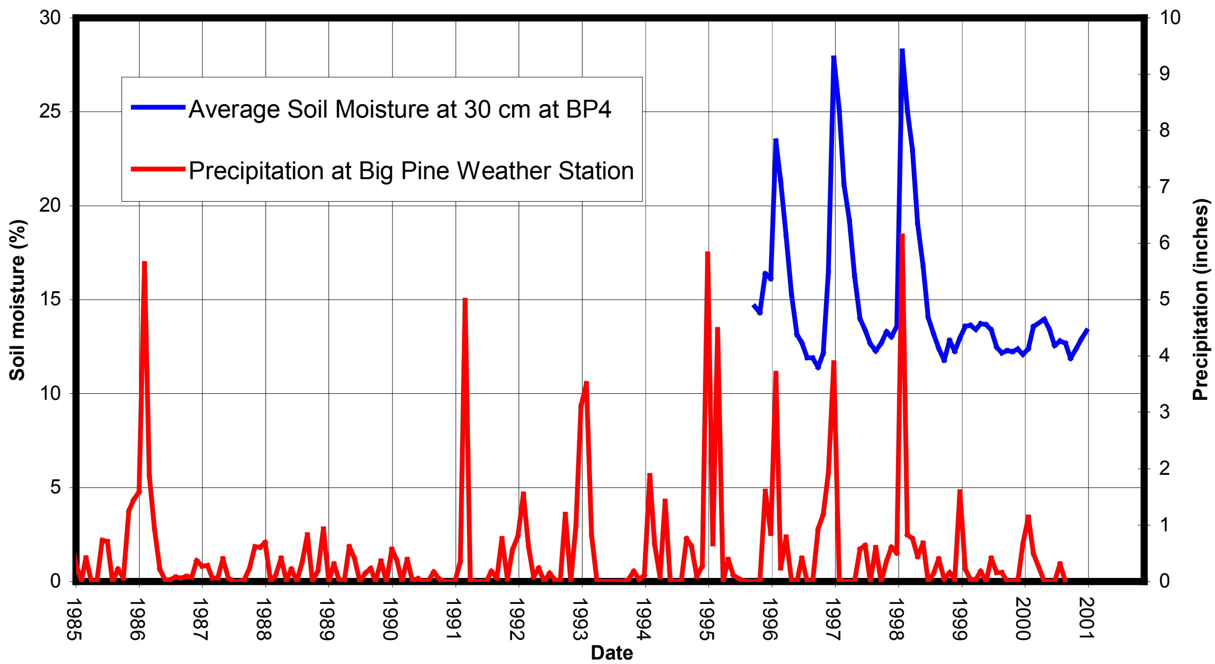


Figure 3-6
Average Soil Moisture at 30 cm for Monitoring Site BP4 versus Precipitation

These curves indicate that the soil moisture at a depth of 30 cm tracks parallel to monthly precipitation since 1995. Similarly, monitoring sites BP1, BP3 and BP4 have nearly identical soil moisture at 30 cm throughout the entire period. Monitoring site BP2 appears to have slightly lower percent soil moisture near the surface. These data suggest that the primary mechanism controlling soil moisture near the surface (30 cm) is precipitation, which is consistent with the conceptual soil moisture model.

Water Level and Soil Moisture

Figure 3-7 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site BP1 to water levels in Well T798. As shown in this figure, soil moisture at both depths generally parallels water levels in Well T798 with maximum soil moisture content of approximately 40 percent. The maximum measurements correspond to times in which the water level in Well T798 is above the monitoring point of 370 cm and likely represents the saturation point for this soil.

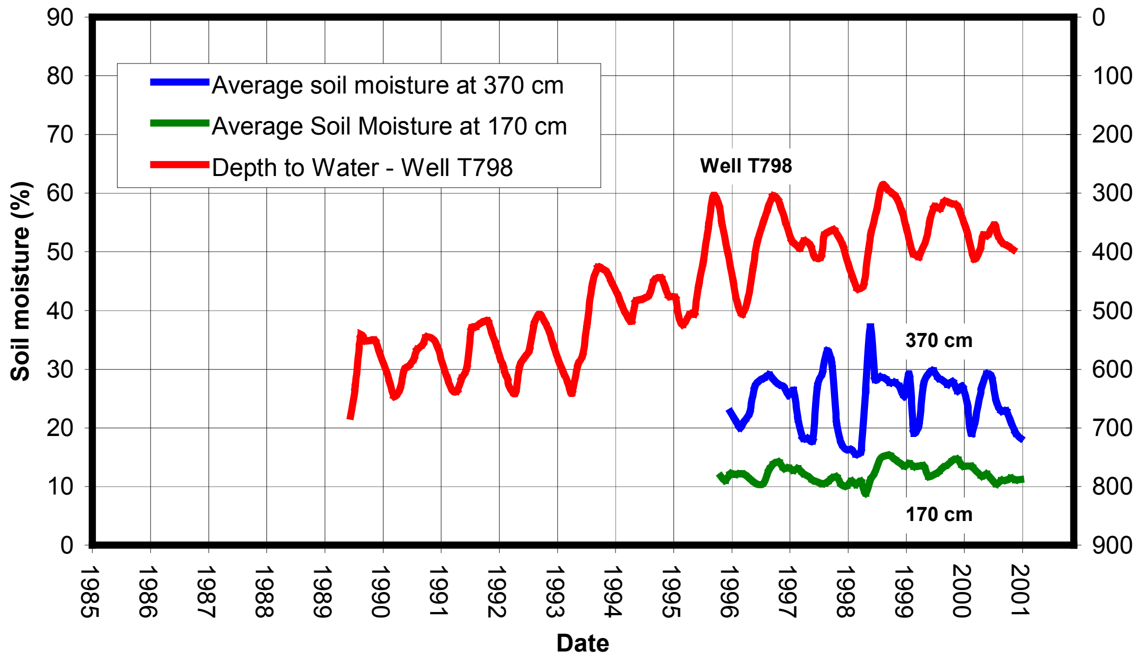


Figure 3-7
Average Soil Moisture for Monitoring Site BP1 versus Water Level

Figure 3-8 compares the average soil moisture at depths of 170 cm and 470 cm at monitoring site BP2 to water levels in Well T799. As shown in this figure, water levels in this well have remained relatively constant since 1995, between 500 and 600 cm. Likewise, soil moisture at 170 cm (about 5 percent) and 470 cm (about 20 percent) have also remained relatively constant. Soil moistures at site BP2 are lower than at BP1 likely because water levels are more than 50 cm below the soil moisture monitoring point of 470 cm.

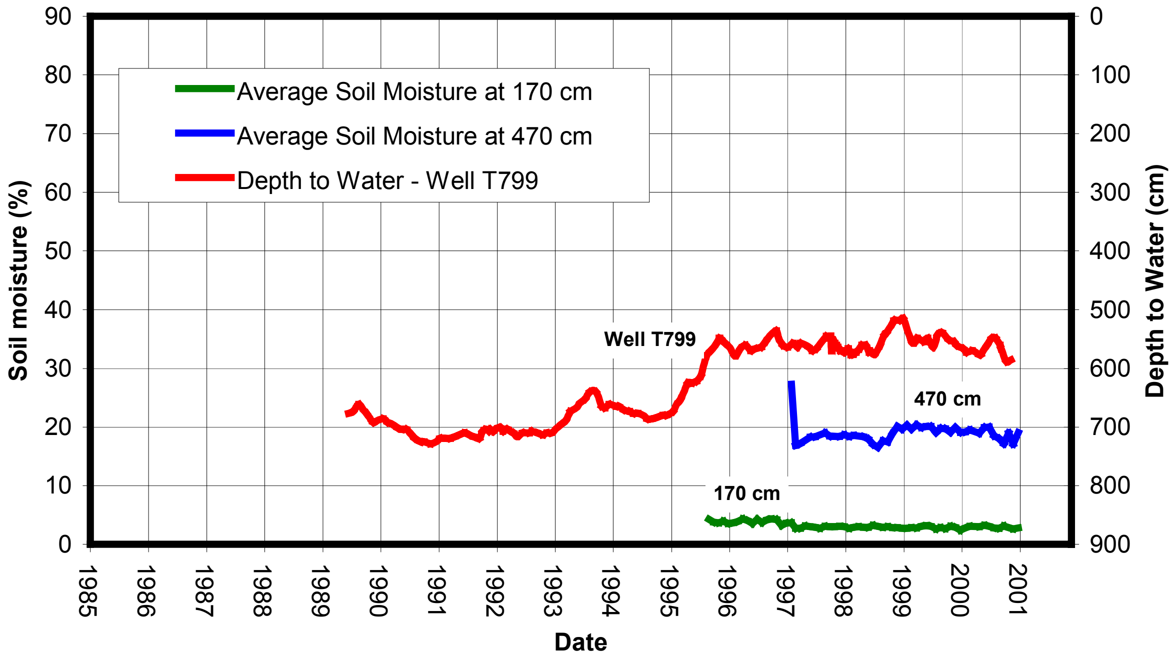


Figure 3-8
Average Soil Moisture for Monitoring Site BP2 versus Water Level

Figure 3-9 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site BP3 to water levels in Well T567. As shown in this figure, water levels in this well have steadily increased since 1995 to a maximum level of about 400 cm. Soil moisture at 170 cm has remained relatively constant with values below about 10 percent. Soil moisture percentages at 370 cm were about 10 percent until mid-1998 when they steadily increased to a maximum of about 30 percent. This increase corresponds with the point at which water levels rose above 400 cm. No change in soil moisture at 170 cm is observed during this time period.

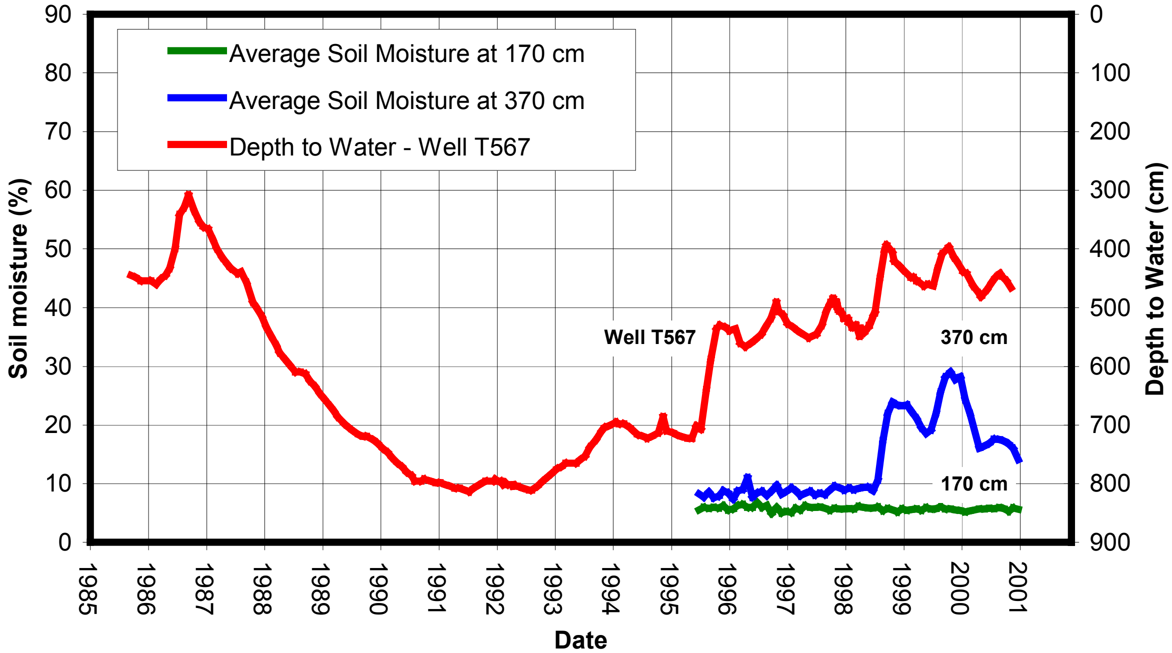


Figure 3-9
Average Soil Moisture for Monitoring Site BP3 versus Water Level

Figure 3-10 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site BP4 to water levels in Well T800. As shown in this figure, water levels in this well have steadily increased since 1995 to a maximum level of about 435 cm. Soil moisture percentages at 170 cm have remained relatively constant, with soil moisture percentages below about 10 percent. Soil moisture percentages at 370 cm were below about 20 percent until mid-1998 when they steadily increased to a maximum of about 35 percent. This increase corresponds with the point at which water levels rise above 500 cm. No change in soil moisture at 170 cm is observed during this time period.

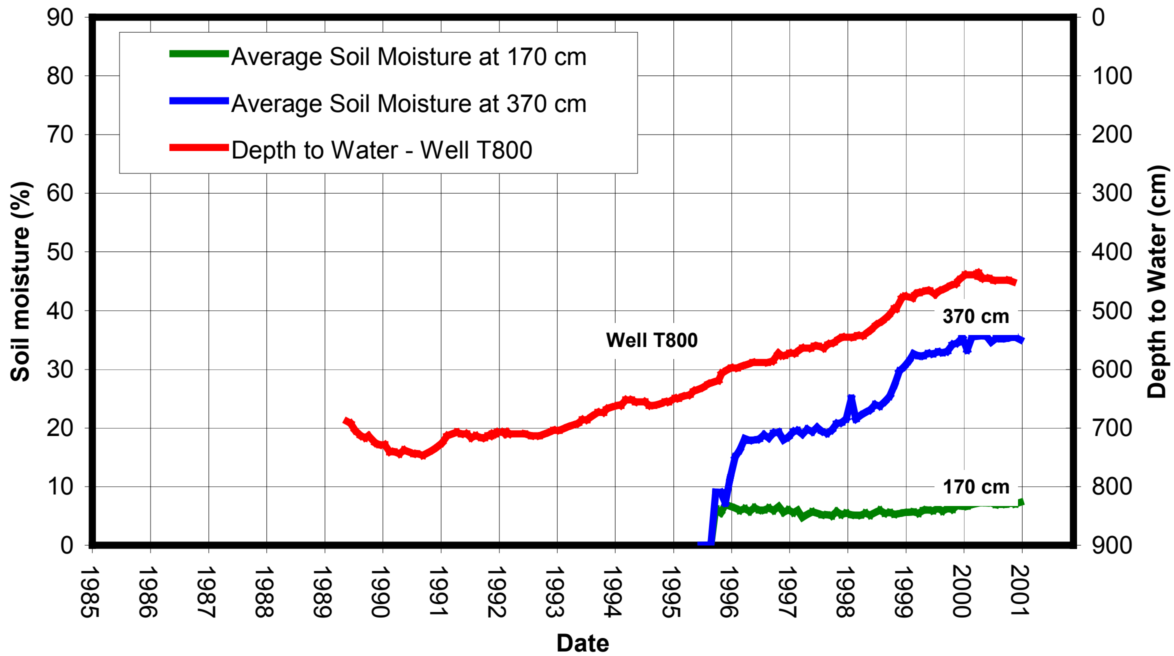


Figure 3-10
Average Soil Moisture for Monitoring Site BP4 versus Water Level

Soil Moisture Profiles

As discussed in the conceptual soil moisture model, soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. Soil moisture profiles for each location were compiled to evaluate the vertical relationship among water table, precipitation, and soil moisture. Vertical profiles were constructed for the maximum water level and the minimum water level during the time period from 1995 to 2000. Consequently, these data should represent the approximate range in soil moisture attributable to groundwater at each depth for this period.

Figure 3-11 presents soil moisture profiles in soil probe BP1-3 during the time periods March 1996 and August 1998. As shown in this figure, soil moisture in March 1996 is below about 25 percent. In addition, the percentage of soil moisture above a depth of approximately 200 cm remains below 25 percent in both time periods and tracks similarly. Water level depths ranged from nearly 500 cm in March 1996 to about 290 cm in August 1998. In August 1998, when water levels were at their highest, the soil moisture from 200 cm to 390 cm reached as high as about 30 percent at a depth of about 370 cm, which is below the maximum height of the groundwater and appears to represent soil saturation conditions. The increases in soil moisture between 200 cm and 390 cm in this time period appears to be a result of a rising capillary fringe. On the other hand, water levels in March 1996 were below 700 cm, which results in an associated decrease in the soil moisture below 200 cm due to a lowering of the capillary fringe.

Because the soil moisture remains relatively low (less than 20 percent) at a depth of approximately 200 cm in this analysis, this appears to be the maximum extent of groundwater influence at this location during this time period. Above a depth of approximately 200 cm, soil moisture during the two time periods track similarly. These profile patterns do not correlate completely with a change in water level. Above 50 cm, the soil moisture patterns again diverge, and this divergence appears to correlate with an increase in precipitation in March 1996 as opposed to August 1998. Therefore, other surface processes such as precipitation appear to have more influence on soil moisture above 50 cm.

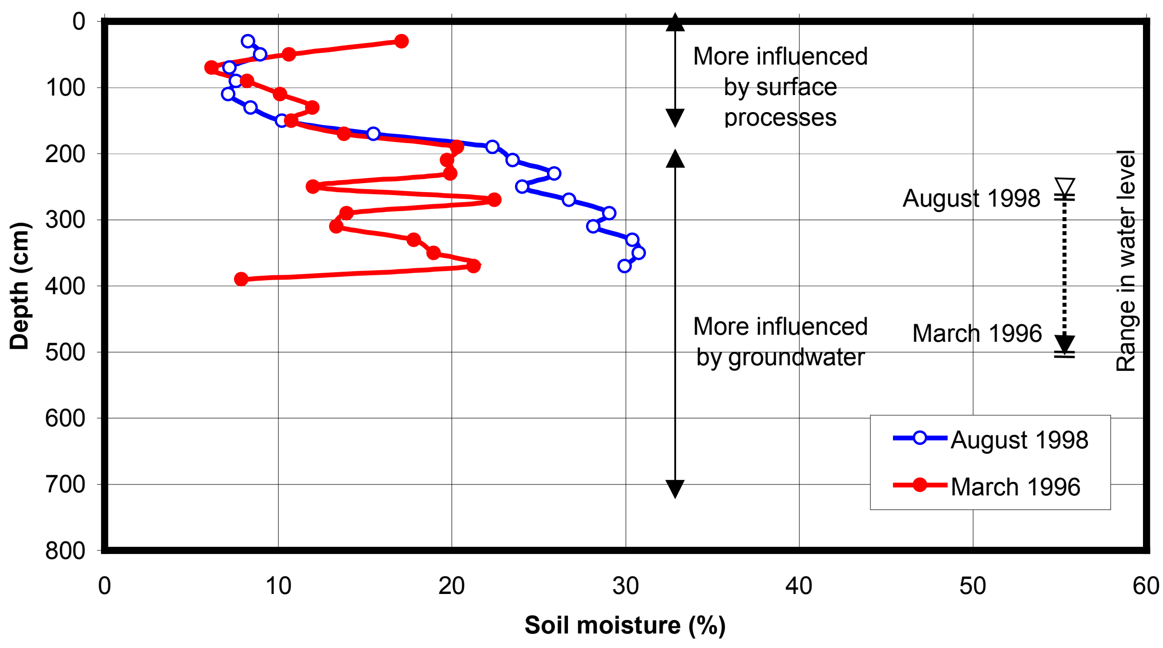


Figure 3-11
Soil Moisture Profile for Soil Probe BP1-3

Figure 3-12 presents soil moisture profiles in soil probe BP2-1 during the time periods September 1995 and January 1999, which represent the high and low water levels since 1995. The depth to water near soil probe BP2-1 ranges from about 515 cm to 620 cm during this time period. Soil moistures at this site above a depth of approximately 400 cm track nearly identically below 10 percent for each of the time periods shown. Below a depth of about 400 cm, the soil moisture in January 1999 gradually increases to about 35 percent by 510 cm. No data below 390 cm are available for September 1995. Based on these data and this analysis, depth to groundwater appears to influence soil moisture below a depth of about 400 cm for this time period.

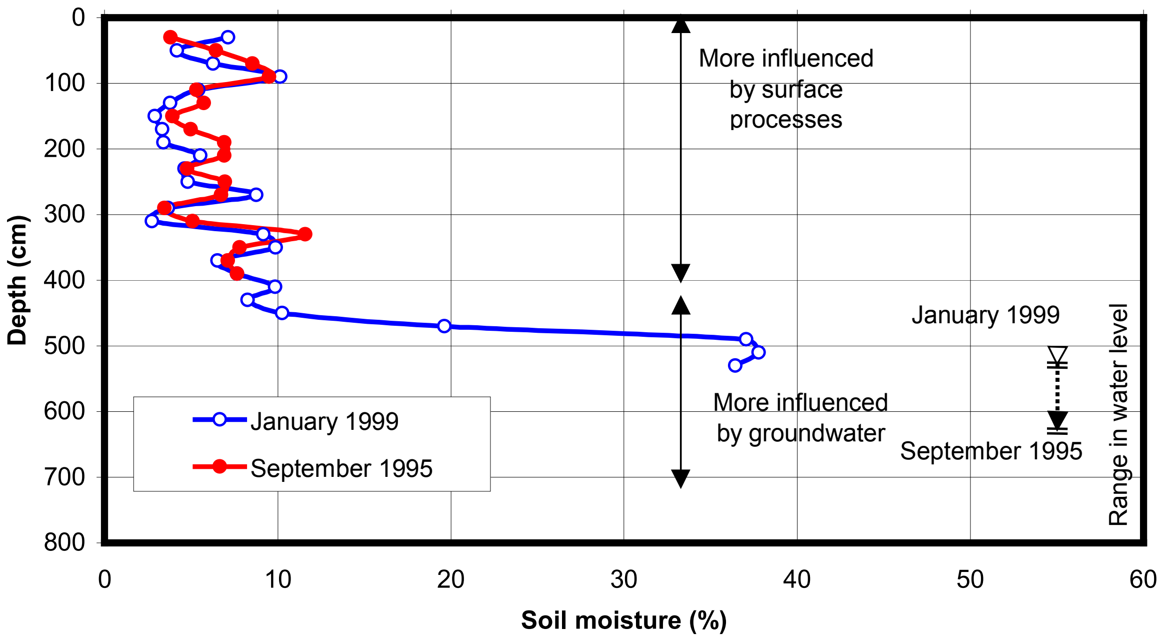


Figure 3-12
Soil Moisture Profile for Soil Probe BP2-1

Figure 3-13 presents soil moisture profiles in soil probe BP3-1 during the time periods July 1995 and September 1998, which represent the high and low water levels since 1995. The depth to water near soil probe BP3-1 ranges from about 400 cm to 700 cm during this time period. Soil moisture at this site between a depth of approximately 100 cm and 350 cm track nearly identically below 10 percent for each of the time periods shown. Below a depth of about 350 cm, the soil moisture in September 1998 gradually increases to about 25 percent by 390 cm. For September 1995, soil moisture remains below 10 percent. Therefore, at this site for this time period, depth to groundwater appears to influence soil moisture only below a depth of about 350 cm. In addition, above 100 cm, soil moisture curves for July 1995 and September 1998, like soil probe BP1-3, are divergent and likely represent precipitation effects.

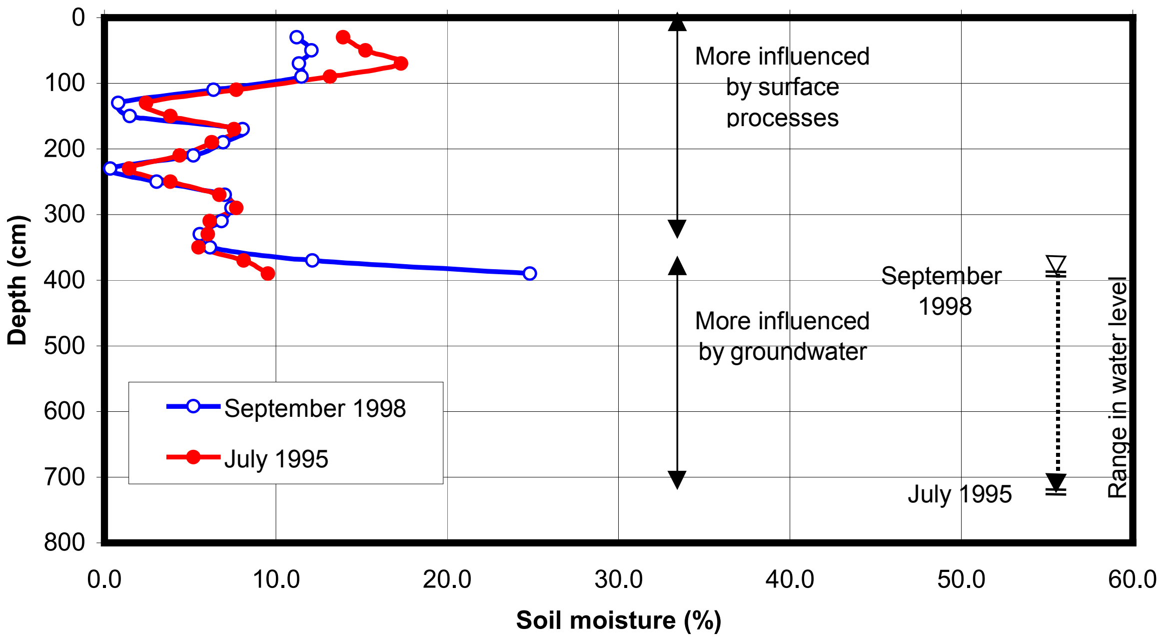


Figure 3-13
Soil Moisture Profile for Soil Probe BP3-1

Figure 3-14 presents soil moisture profiles in soil probe BP4-1 during the time periods December 1995 and April 2000, which represent the high and low water levels since 1995. The depth to water near soil probe BP4-1 ranges from about 435 cm to 600 cm during this time period. Soil moisture at this site above of depth of approximately 200 cm track nearly identically below 20 percent for each of the time periods shown. Below a depth of about 200 cm, the soil moisture in April 2000 gradually increases to about 35 percent by 370 cm. For December 1995, soil moisture remains below 20 percent. Therefore, at this site for this time period, depth to groundwater appears to influence soil moisture only below a depth of about 200 cm.

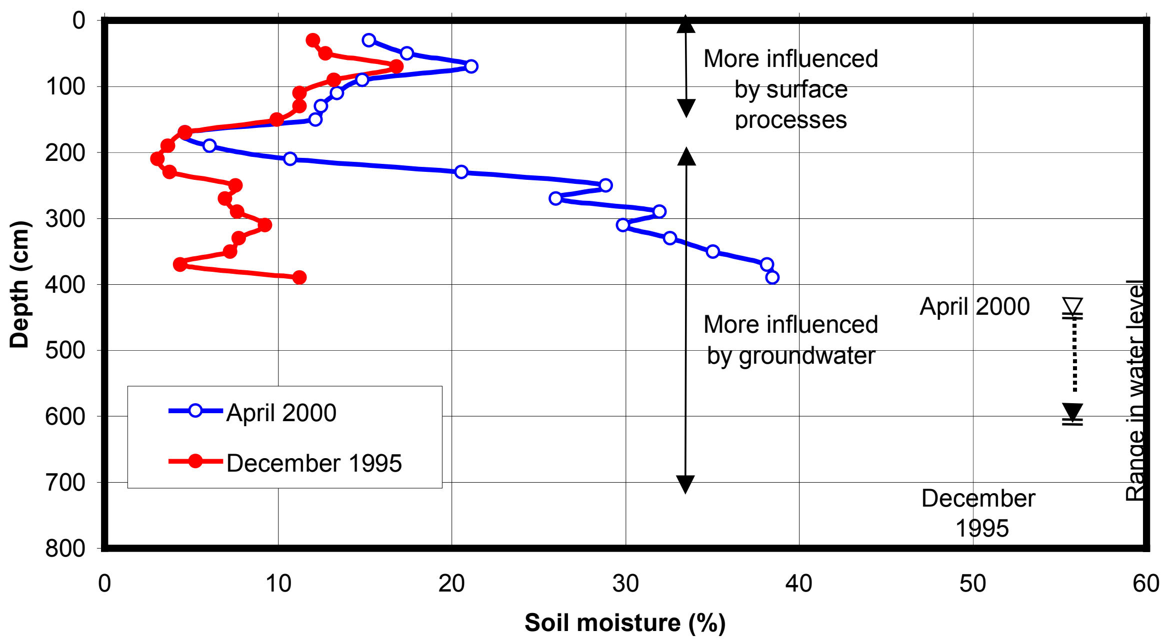


Figure 3-14
Soil Moisture Profile for Soil Probe BP4-1

Summary

Soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. The data presented herein validate that the upper portion of the soil profile appears to be more strongly influenced by surface water processes while the lower portion of the soil profile appears to be more strongly influenced by groundwater levels. This is clearly consistent with the conceptual model. Because soil moisture in the upper portion of the soil profile (the exact depth of this interface varies with time and location) is largely independent of groundwater levels, soil moisture in these portions of the soil profile should not be used to identify a return to baseline conditions nor the influence of groundwater pumping. Most significantly, from the strong correlation between water levels and the soil moisture associated with the capillary fringe, it can inferred that since water levels in the Big Pine management area have recovered then the portion of the soil moisture profile influenced by the water table also exhibits substantial recovery.

Findings

1. The DRP states that "substantial recovery in soil moisture and water table conditions" are the criteria by which the DRP is terminated. Until then, it is intended for "environmentally conservative" groundwater pumping to be conducted. The DRP does not specify the consideration of any other criteria in determining the termination of DRP.

2. Eighty-four percent of Big Pine Wellfield management area shallow wells exhibit substantial recovery in Runoff Year 1998 and 2000, and 92 percent of shallow wells exhibit substantial recovery in Runoff Years 1999. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met. Furthermore, 100 hundred percent of shallow wells exhibit substantial recovery since the DRP was instituted in 1992.

3. Evaluation of net recharge (recharge less pumping) in the Big Pine area also documents drought recovery. Since 1992, pumping in the Big Pine area has been managed conservatively resulting in a gain of almost 90,000 acre-ft since 1994, more than replacing the storage depletions in the late 1980s and early 1990s.

4. Neutron probe soil moisture data do not exist for the baseline period. Neutron probe data were not available prior to 1995. Despite the absence of baseline data, analysis of the available data yields information pertinent to the DRP.

5. Soil moisture data from the Big Pine monitoring sites show a direct correlation between the lower portion of the soil profile and groundwater levels. Soil moisture in the lower portion of the soil moisture profile is predominantly influenced by water levels. For the 1995 to 2000 time period, this depth is approximately 200 cm at monitoring site BP1, about 400 cm at monitoring site BP2, about 350 cm at monitoring site BP3, and about 200 at site BP4.

6. Although baseline data for soil moisture are not available, we have been able to conclude that based on the depth-to-groundwater/soil moisture relationships demonstrated by the data described above, and because groundwater levels in the Big Pine Wellfield have substantially recovered, it necessarily follows that soil moisture levels, to the extent that they are influenced by groundwater levels, have also recovered.

7. Soil moisture above the depth where groundwater is the predominant influence is controlled by numerous other factors such as precipitation, surface land use activities, and evapotranspiration. Of these, only precipitation is a direct measure of drought conditions. Consequently, for this upper portion of the soil profile, only the consideration of precipitation is appropriate for evaluation of drought recovery.

Recommendations

Based on the findings above and associated preponderance of evidence concerning depth to water data, groundwater balance, and soil moisture, substantial recovery as defined in the DRP has been achieved. To summarize, the data clearly demonstrate that termination of the DRP is appropriate.

Chapter 4

Taboose-Aberdeen Wellfield

Chapter 4
Taboose-Aberdeen Wellfield

Wellfield Description

Located in the Owens Valley, south of the community of Big Pine and on the north side of the Thibaut-Sawmill Wellfield, the Taboose-Aberdeen Wellfield is one of seven wellfields operated by the LADWP where groundwater pumping and extraction have been governed by the DRP. The provisions in the Green Book (October 1991) provide for six monitoring sites at this wellfield, TA1 through TA6, as summarized in **Table 4-1** and shown on **Figure 4-1**. However, TA1 and TA2 are not utilized.

Table 4-1
Summary of Taboose-Aberdeen Monitoring Sites

Monitoring Site	Vegetation Type	Shallow Monitoring Well	Pumping Wells[1]	EM Wells
TA1	Not utilized			
TA2	Not utilized			
TA3	C	T505	W106AQ, W110AQ, W111AQ, W114AQ	
TA4	C	T586	W342AQ, W347AQ	
TA5	A	T801	W349AQ	
TA6	C	T803	W109AQ, W370AQ	

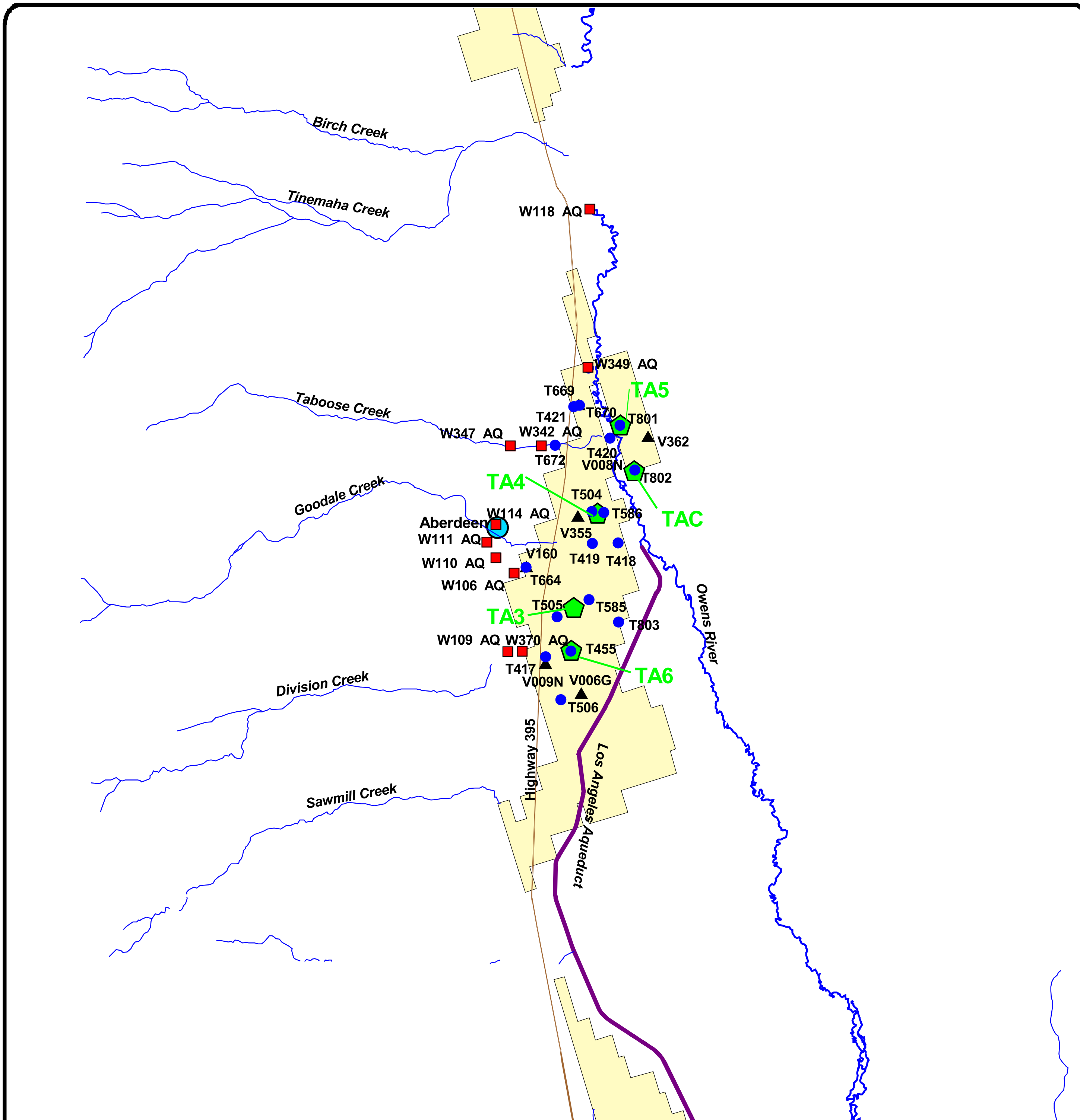
[1] Well W118AQ (no impact on areas with groundwater dependent vegetation) is located within the Taboose-Aberdeen Wellfield, but exempt from Green Book on/off provisions and DRP provisions.

Monitoring Site TA3

Monitoring Site TA3 is associated with pumping wells W106AQ, W110AQ, W111AQ, and W114AQ. The shallow monitoring well at this site is Well T505 located 0.3 miles from the monitoring site, which has a depth to water history from April 1978 to the present, thereby providing a 1985-1987 Runoff Year baseline. A new monitoring well was installed at the monitoring site in winter of 2000. In addition, there are three soil moisture access tubes at this site (TA3-1, TA3-2, and TA3-3). Representative vegetation at monitoring site TA3 has been mapped as Type C.

Monitoring Site TA4

Monitoring Site TA4 is associated with pumping wells W342AQ and W347AQ. The shallow monitoring well at this site is Well T586, which has a depth to water history from August 1985 to present, thereby providing a portion of the 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (TA4-1, TA4-2, and TA4-3). Representative vegetation at monitoring site TA4 has been mapped as Type C.



EXPLANATION

- Town
- Production Well
- Test "T" Well
- Monitoring "V" Well
- L2 Monitoring Site
- L2C Monitoring Control Site
- Streams and Rivers
- Highways
- Los Angeles Aqueduct
- Management Area

Figure 4-1

Taboose-Aberdeen Wellfield Site Vicinity Map

N

MWH MONTGOMERY WATSON HARZA

0 7000 14000 Feet

Monitoring Site TA5

Monitoring Site TA5 is associated with pumping well W349AQ. The shallow monitoring well at this site is Well T801, which has a depth to water history from May 1989 to present, and thereby does not provide a 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (TA5-1, TA5-2, and TA5-3). Representative vegetation at monitoring site TA5 has been mapped as Type A, which is not subject to the provisions of the DRP.

Monitoring Site TA6

Monitoring Site TA6 is associated with pumping wells W109AQ and W370AQ. The shallow monitoring well at this site is Well T803, which has a depth to water history from May 1989 to present, and thereby does not provide a 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (TA6-1, TA6-2, and TA6-3). Representative vegetation at monitoring site TA6 has been mapped as Type C.

Management Area Monitoring Wells

There are a total of 18 shallow wells and six deep wells, as shown on **Figure 4-1**, within the Taboose-Aberdeen wellfield management area. As summarized in **Table 4-2**, the following descriptive statistics apply to this data set of wells:

- Five of the shallow wells and two of the deep wells do not have baseline data and no analysis was performed on these wells.
- Two of the shallow wells and one of the deep wells were dry in the baseline allowing for a qualitative evaluation only.
- 11 of the shallow wells and three of the deep wells have data suitable for the quantitative analysis described in Chapter 1.
- Although quantitative and qualitative evaluations are conducted on suitable shallow and deep wells, only the 11 shallow wells, whose data represent water table conditions suitable for quantitative analysis, are used to validate DRP termination.

Table 4-2
Summary of Wells in the Taboose-Aberdeen Wellfield Management Area

Descriptive Statistic	Quantity of Wells	
	Shallow	Deep
Wells in Management Area	18	6
Wells with No Baseline Data – No Analysis Performed[1]	5	2
Wells that were Dry in Baseline - Qualitative Analysis Performed	2	1
Wells with Complete Data Sets - Quantitative Analysis Performed	11	3
Wells Used to Validate DRP Termination	**11**	0

Depth to Water

Methodology

As discussed previously, there are a total of 24 monitoring wells within the Taboose-Aberdeen Wellfield. Of these 24 monitoring wells, quantitative analyses were performed in accordance with **Table 4-2**. **Figure 4-1** shows the location of Taboose-Aberdeen management area wells and **Table 4-3** provides a listing of the 14 monitoring wells evaluated quantitatively.

Data Presentation

The quantitative methodology described in the Approach section of Chapter 1 was applied to the 11 shallow wells and three deep wells. Baseline mean and 95 percent confidence intervals were calculated and are summarized in **Table 4-3**. Also shown in this table is the lowest depth to water recorded during the drought (DTW Drought Low), the water level that represents 80 percent recovery using Equation 2 (DTW 80 percent Recovery) runoff year during which low point occurred, and a column for each potential recovery year (Runoff Years 1995 – 2000).

Table 4-3
Summary of Taboose-Aberdeen Wellfield Monitoring Wells Evaluated for DRP Termination

Well	Baseline			DTW Drought Low (fbgs)	DTW 80% Recovery (fbgs)	Runoff Year(s) During which Low Point Occurred	Substantial Recovery Achieved by Runoff Year						
	Mean[1] (fbgs)	Lower 95% CI	Upper 95% CI				1995	1996	1997	1998	1999	2000	Summary[3]
T417	26.0	27.6	24.4	51.3	31.1	1989	X	X	X	X	X	X	X
T418	8.9	9.4	8.4	19.0	10.9	1991			X	X	X	X	X
T419	8.1	9.3	6.9	24.9 [2]	11.5	1989-1990	X	X	X	X	X	X	X
T420	6.0	6.3	5.8	11.0	7.0	1992				X			X
T421	35.1	36.7	33.5	53.0	38.7	1989	X	X	X	X	X	X	X
T455	5.1	5.3	4.8	15.4	7.1	1991, 1992		X					X
T504	13.2	14.9	11.4	32.8	17.1	1989	X	X	X	X	X	X	X
T505	20.6	22.1	19.1	45.6	25.6	1989	X	X	X	X	X	X	X
T506	8.3	9.8	6.8	30.4	12.7	1989	X	X	X	X	X	X	X
T585	10.1	11.2	9.0	18.0 [2]	11.7	1988-1996		X					X
T586	10.1	10.9	9.2	24.2	12.9	1989	X	X	X	X	X	X	X
Taboose-Aberdeen Wellfield Management Area Percent Recovery for Shallow Wells:							64%	**82%**	73%	**82%**	73%	73%	**100%**
V006G	8.1	8.8	7.5	23.0	11.1	1991			X	X	X	X	X
V160	46.2	50.1	42.3	84.1	53.7	1988	X	X	X	X	X	X	X
V362	32.7	36.6	28.7	68.5	39.8	1988	X	X	X	X	X	X	X
Taboose-Aberdeen Wellfield Management Area Percent Recovery for Deep Wells:							67%	67%	**100%**	**100%**	**100%**	**100%**	**100%**

[1] Baseline Mean is calculated from all available depth to water measurements collected during the baseline, on a Runoff Year basis (1985-1987).
[2] DTW Drought Low represents the depth of the well as the well went dry at this point, precluding measurement of the actual water level. As a result, the actual DTW 80% recovery is lower than that presented in the table.
[3] This "Summary" column indicates if substantial recovery has been achieved in a well at any time since the DRP was instituted in 1992.

Hydrographs for these 14 wells graphically depict the baseline and 80 percent recovery line and are provided **Appendix C**. In general, depth to water measurements were high during the baseline period, yet declined during the drought, and since the drought's end, water levels have steadily climbed, typically achieving recovery in the late 1990s.

Discussion

The data demonstrate that 82 percent of Taboose-Aberdeen Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1996 and 1998. All shallow wells show substantial recovery since the DRP was instituted in 1992. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

Similarly, three of the three (100 percent) Taboose-Aberdeen deep wells exhibit substantial recovery in Runoff Years 1997, 1998, 1999, and 2000, which indicates substantial recovery since the DRP was implemented in 1992 and lends additional support to termination of the DRP at the Taboose-Aberdeen Wellfield.

Furthermore, hydrographs for the two shallow and one deep well, as summarized in **Table 4-4**, that were dry in the baseline were constructed and are included in **Appendix C**. Of these wells, Well T664 expresses a pattern of recovery since the drought indicative of drought recovery. The other two wells are dominated by dry measurements from baseline to present such that it is not possible to draw any conclusions from the data for these wells.

Table 4-4
Summary of Taboose-Aberdeen Wellfield Monitoring Wells that were Dry During the Baseline

Shallow Wells	Deep Wells
T664	V008N
T672	

Summary

To summarize, 82 percent of Taboose-Aberdeen Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1996 and 1998. In addition, all wells show substantial recovery since the DRP was instituted in 1992. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

Hydrologic Indices

Montgomery Watson Harza reviewed groundwater balance data for the Taboose-Aberdeen area to determine the status of the hydrologic conditions. The results of this evaluation are presented below.

Groundwater Balance

The Green Book and the mining calculations evaluate the combined recharge for the Taboose-Thibaut area, which includes the Taboose-Aberdeen and Thibaut-Sawmill wellfields. Since these wellfields are close together, have no natural hydrologic boundary separating them, and groundwater flow patterns between the wellfields change in response to high pumping, these wellfields are treated as one for purposes of calculating recharge. For the Taboose-Thibaut area, the results of this evaluation are presented in **Figure 4-2**. This figure shows the annual recharge and pumping as bars with the differences between the bars representing the annual change in storage. This figure also shows the cumulative change in storage since 1969. The cumulative storage graph indicates several cycles of storage and draft between Water Years (WY) 1969 through 1977, including 62,000 acre-ft of water that was removed from storage between 1975 and 1977 in response to a drought. Between WY 1977 and 1986, about 210,000 acre-ft of water accumulated in storage. From WY 1987 through 1992, approximately 107,000 acre-ft of water was pumped from storage to meet water demands during the drought. Since WY 1992, pumping in the Taboose-Thibaut area has been managed conservatively, resulting in a gain of 181,000 acre-ft since 1992, more than replacing the storage depletions in the late 1980s and early 1990s.

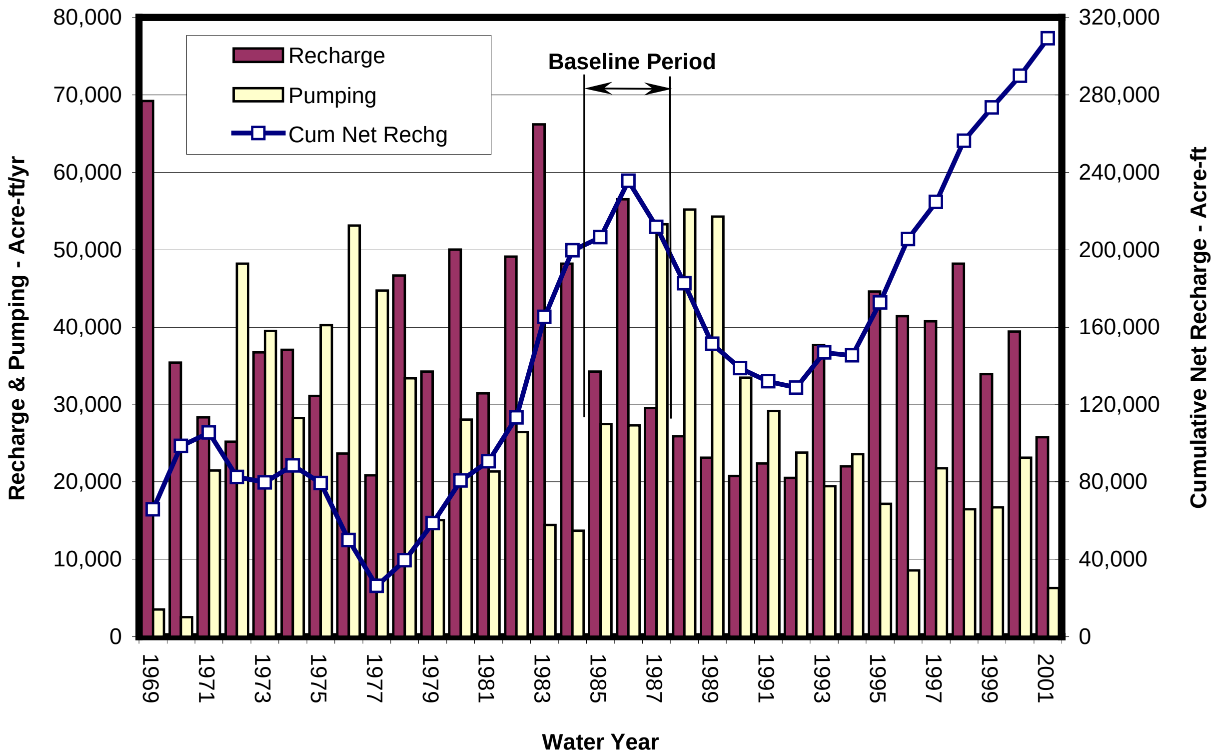


Figure 4-2
Taboose-Thibaut Wellfield Groundwater Balance

Soil Moisture

Methodology

Neutron probe data have been collected on a monthly basis from 14 soil access tubes from the four monitoring sites (TA3, TA4, TA5, and TA6) since July 1995. Neutron probe data were collected at 20-cm intervals from a depth of 30 cm to a depth of 390 cm to construct a soil moisture depth profile. Soil moisture data were evaluated using the approach described in the Approach section of Chapter 1.

Data Presentation and Discussion

Precipitation and Soil Moisture

Figure 4-3 through **Figure 4-6** compare the average soil moisture at monitoring sites TA3 (includes an average of soil access tubes TA3-1, TA3-2, and TA3-3), TA4 (includes an average of soil access tubes TA4-1, TA4-2, and TA4-3), TA5 (includes an average of soil access tubes TA5-1, TA5-2, and TA5-3) and TA6 (includes an average of soil access tubes TA6-1, TA6-2, and TA6-3) at a depth of 30 cm to monthly precipitation at the LADWP Tinemaha weather station. Subsequent analysis evaluates relationships at two additional depths, whereby the middle depth represents a point in the soil profile least influenced by both surface processes and water levels, and the lowermost depth represents the point most influenced by water levels only.

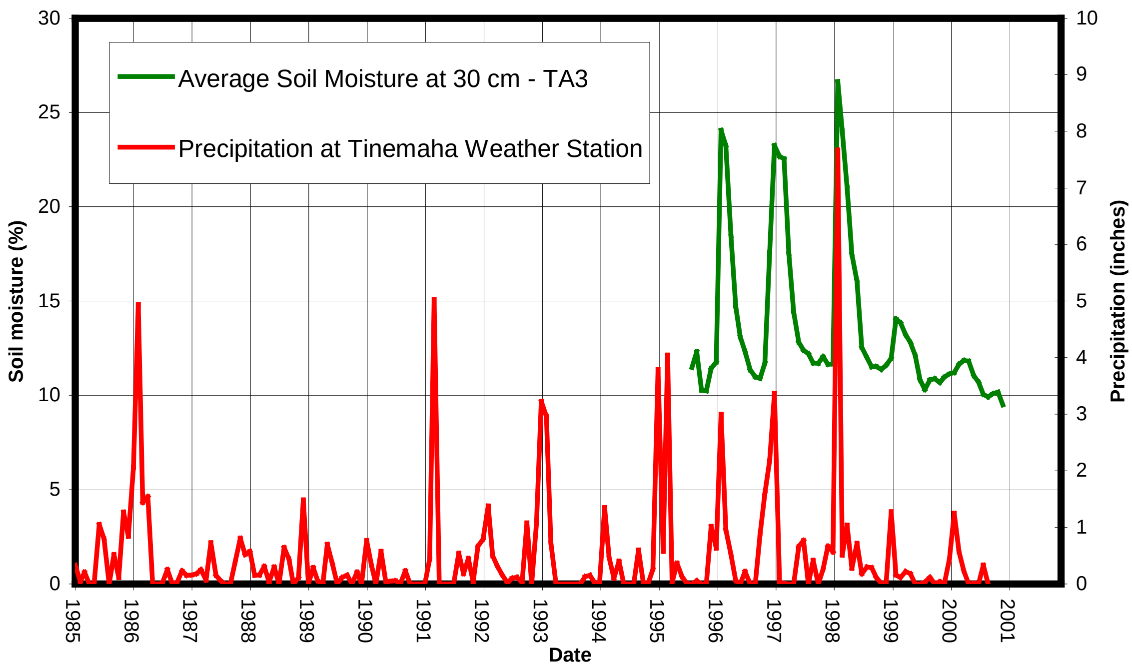


Figure 4-3
Average Soil Moisture at 30 cm for Monitoring Site TA3 versus Precipitation

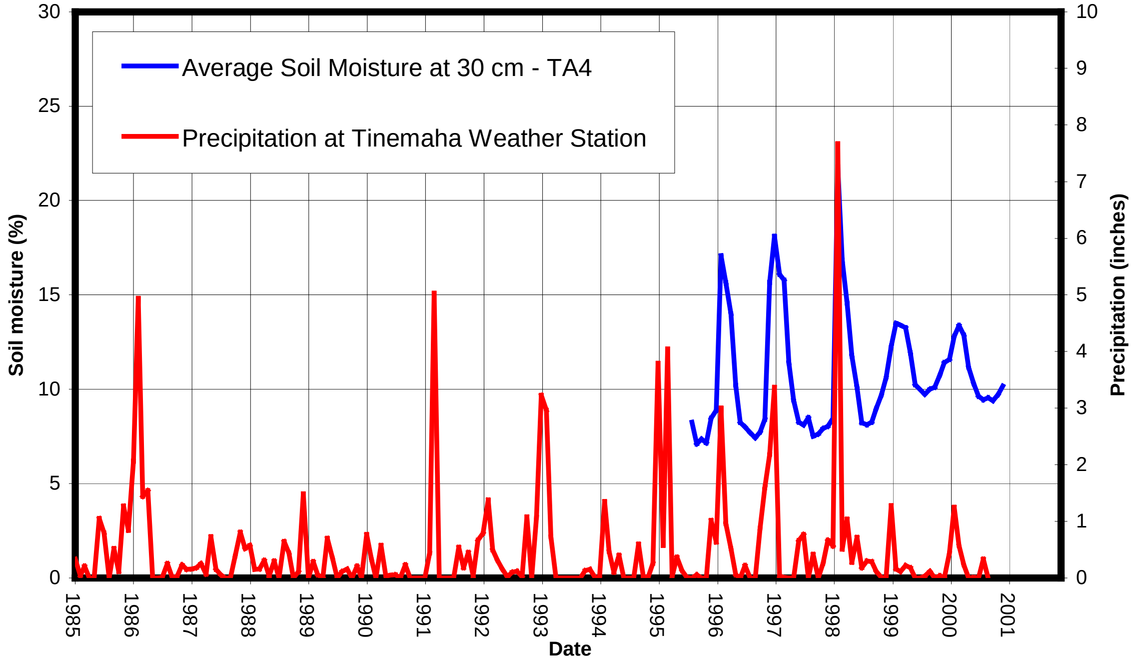


Figure 4-4
Average Soil Moisture at 30 cm for Monitoring Site TA4 versus Precipitation

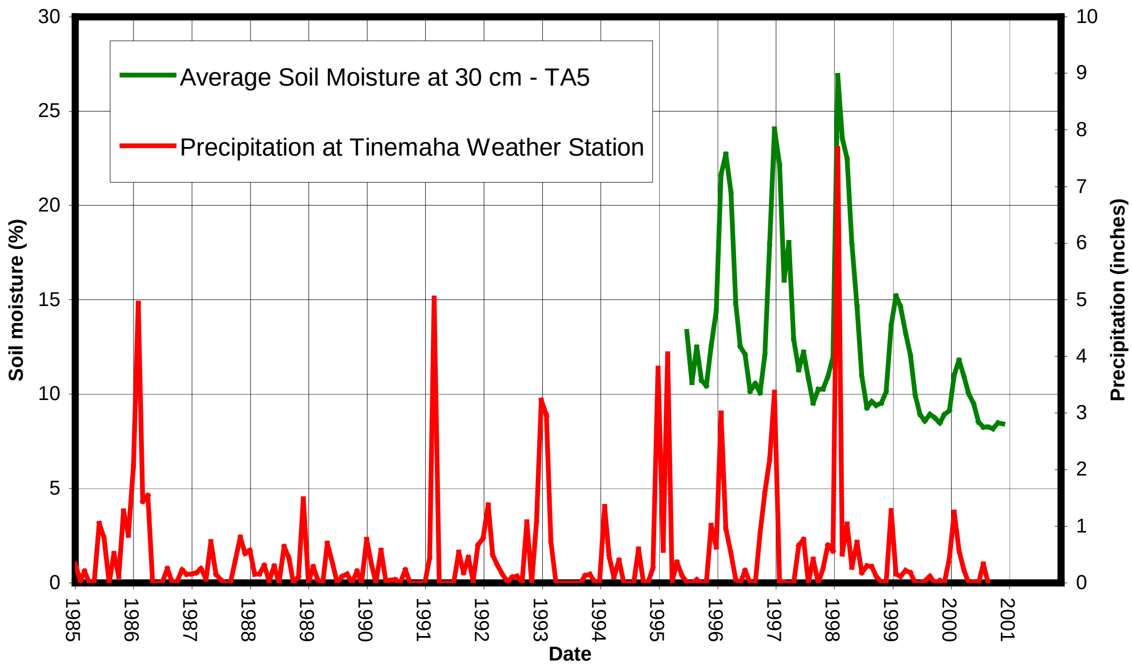


Figure 4-5
Average Soil Moisture at 30 cm for Monitoring Site TA5 versus Precipitation

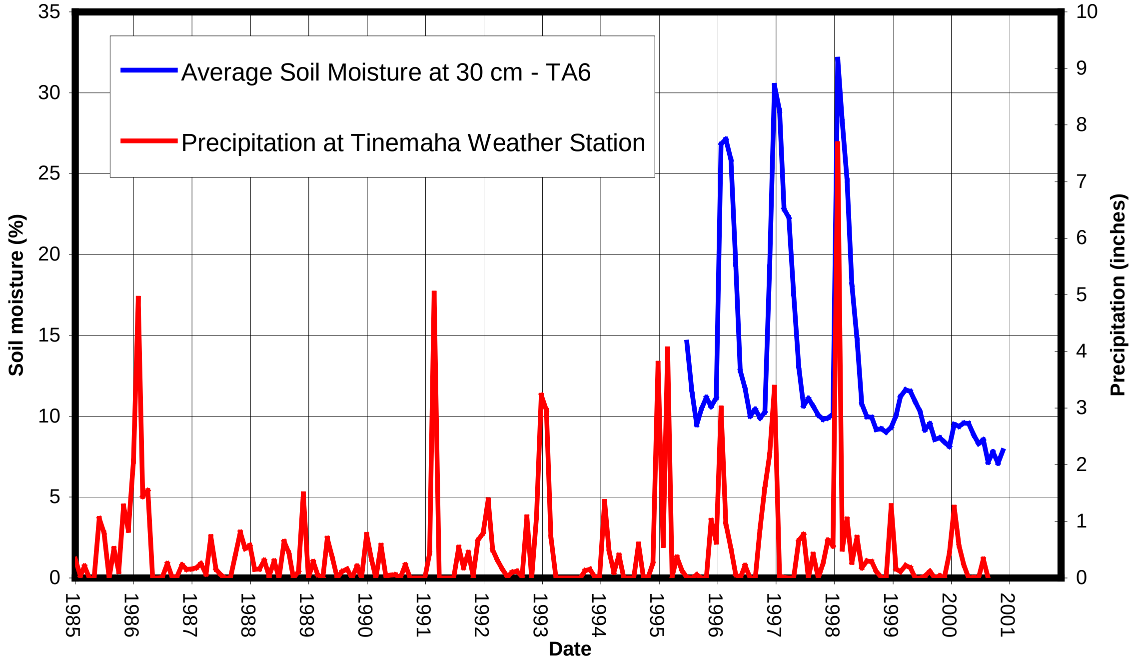


Figure 4-6
Average Soil Moisture at 30 cm for Monitoring Site TA6 versus Precipitation

The figures indicate that the soil moisture at a depth of 30 cm tracks generally parallel to monthly precipitation since 1995. Similarly, all four monitoring sites have similar percent soil moisture until mid-1998. After 1998, there appears to be a downward trend in soil moisture percentages at monitoring sites TA3, TA5, and TA6. On the other hand, the general trend in soil moisture percentages increases slightly at monitoring site TA4. These data suggest that the primary mechanism controlling soil moisture near the surface (30 cm) is precipitation, which is consistent with the conceptual soil moisture model.

Water Level and Soil Moisture

Figure 4-7 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site TA3 to water levels in Well T505, which is located 0.3 miles from the monitoring site. As shown in this figure, percent soil moisture is below about 15 percent in both zones. The maximum measurements at 370 cm correspond to times in which the water level in Well T505 is highest. In addition, measurements at the 170 cm depth are slightly higher than 370 cm until 1997, after which they track nearly identically. Water levels in Well T505 are more than 200 cm below the monitoring point and result in lower soil moisture. It is important to recognize that this well is located 0.3 miles from the monitoring site and may not represent actual water level conditions at the monitoring site.

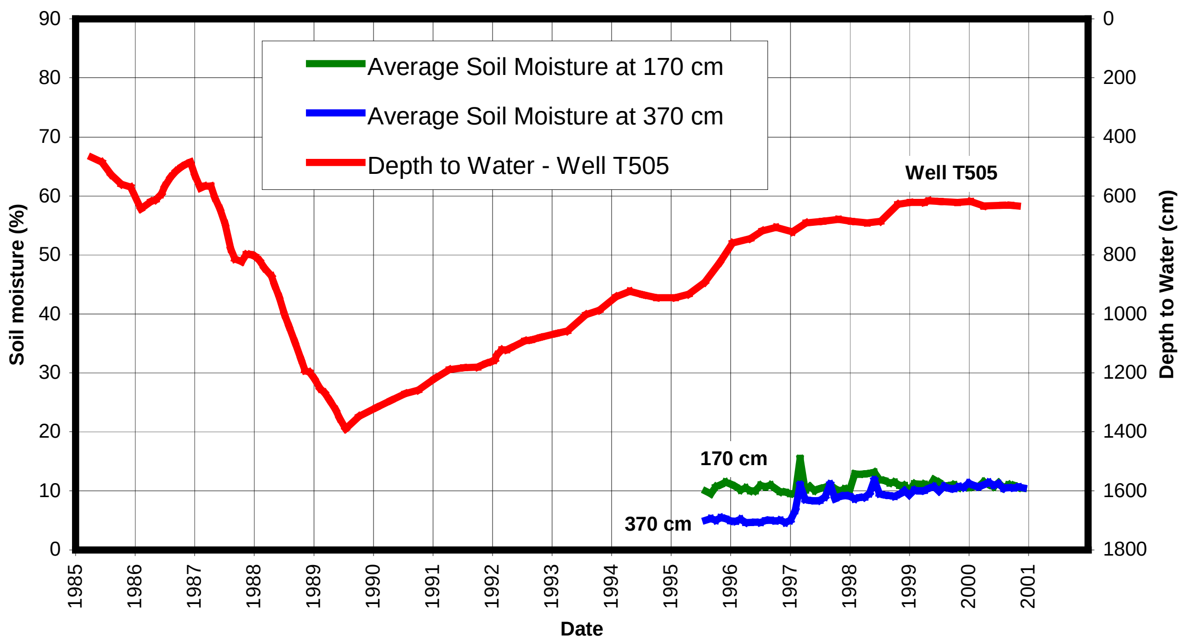


Figure 4-7
Average Soil Moisture for Monitoring Site TA3 versus Water Level

Figure 4-8 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site TA4 to water levels in Well T586. As shown in this figure, soil moisture at 370 cm generally parallels water levels in Well T586 with a maximum percent soil moisture of approximately 40 percent. Because water levels in Well T586 are above 370 cm, these soil moistures likely represent saturated conditions. Soil moisture at 170 cm also roughly parallels the water level but does not represent soil saturation. In summary, water table at this location recovered, allowing soil moisture to rise and plateau at 370 cm and 170 cm; therefore indicating that soil moisture has recovered.

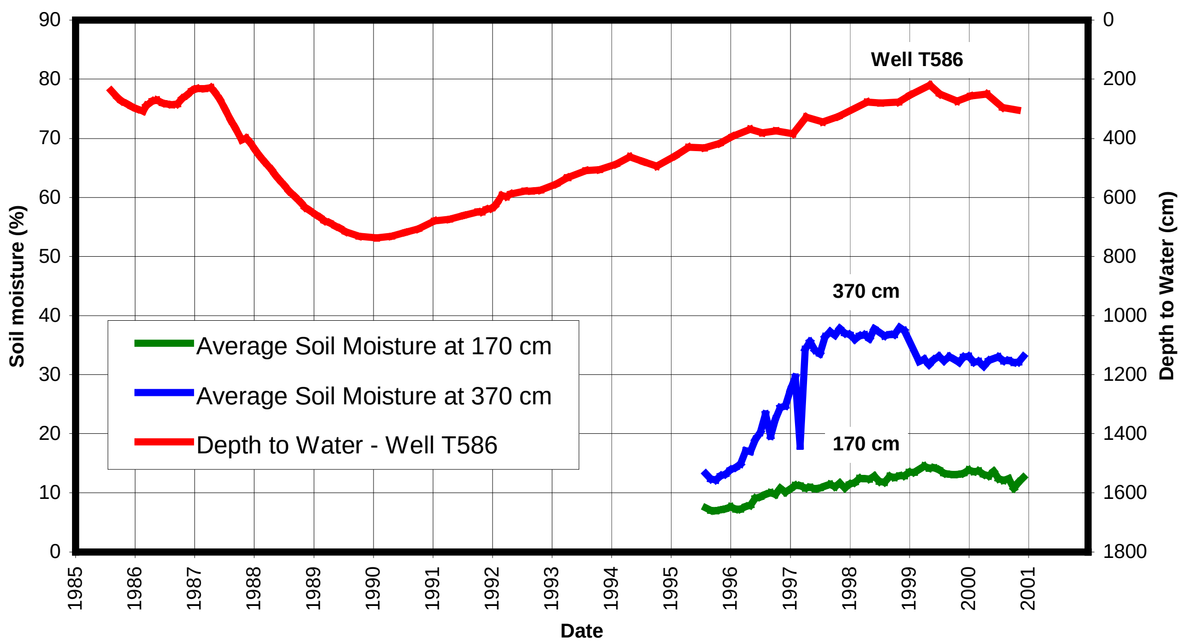


Figure 4-8
Average Soil Moisture for Monitoring Site TA4 versus Water Level

Figure 4-9 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site TA5 to water levels in Well T801. As shown in this figure, soil moisture at 370 cm and 170 cm generally parallel water levels in Well T801 with a maximum percent soil moisture of approximately 45 percent, and represents nearly saturated conditions. Because water levels do not change substantially at this monitoring site, the soil moisture does not change substantially either.

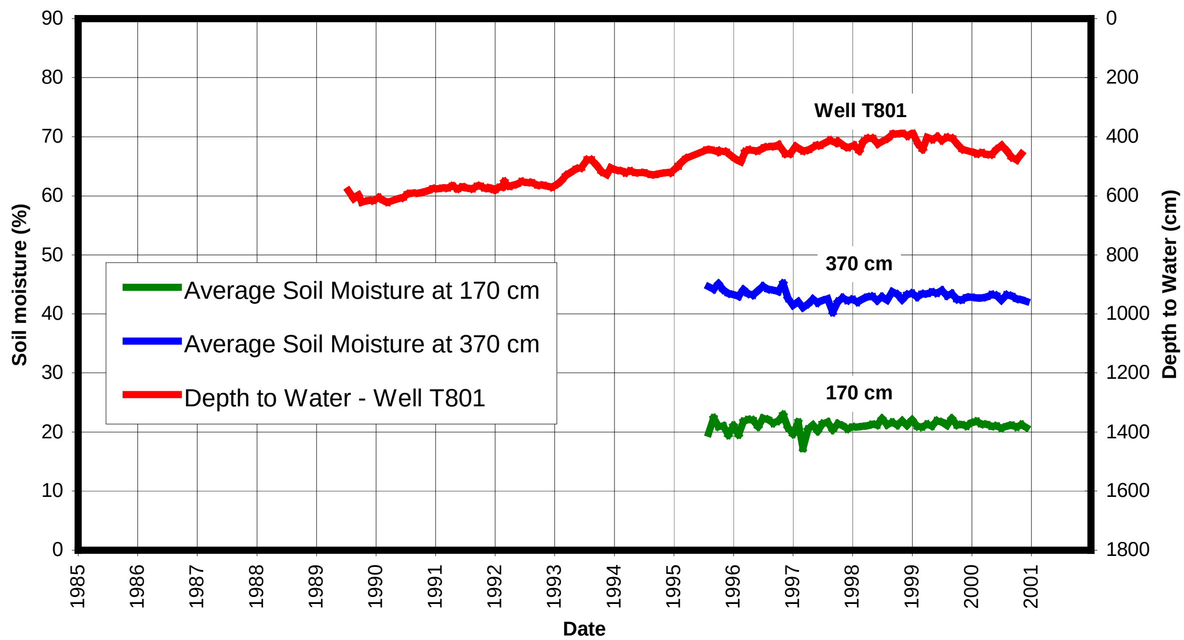


Figure 4-9
Average Soil Moisture for Monitoring Site TA5 versus Water Level

Figure 4-10 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site TA6 to water levels in Well T803. As shown in this figure, soil moisture at 370 cm generally parallels water levels in Well T803 with a maximum percent soil moisture of approximately 50 percent. Because water levels in well T803 are above 370 cm, this represents soil saturation. The trend in soil moisture at 170 cm does not appear to parallel water level and remains below about 15 percent.

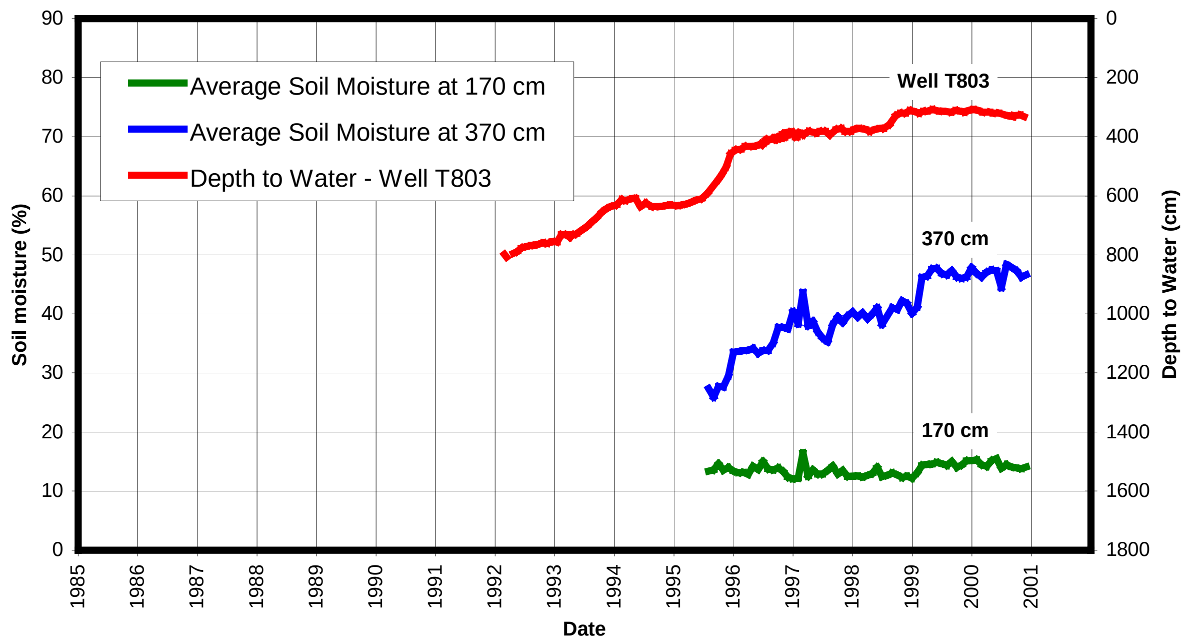


Figure 4-10
Average Soil Moisture for Monitoring Site TA6 versus Water Level

Soil Moisture Profiles

As discussed in the conceptual soil moisture model, soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. Soil profiles for each location were compiled to evaluate the vertical relationship among water table, precipitation, and soil moisture. Vertical profiles were constructed for the maximum water level and the minimum water level during the time period from 1995 to 2000. Consequently, these data should represent the approximate range in soil moisture attributable to groundwater at each depth for this period.

Figure 4-11 presents soil moisture profiles in soil probe TA3-1 during the time periods August 1995 and May 1999, which are correlative with the maximum and minimum water levels. As shown in this figure, soil moisture in each time period is below 15 percent. Water levels are well below the lowest monitoring point for the time period shown and do not appear to affect soil moisture in this analysis.

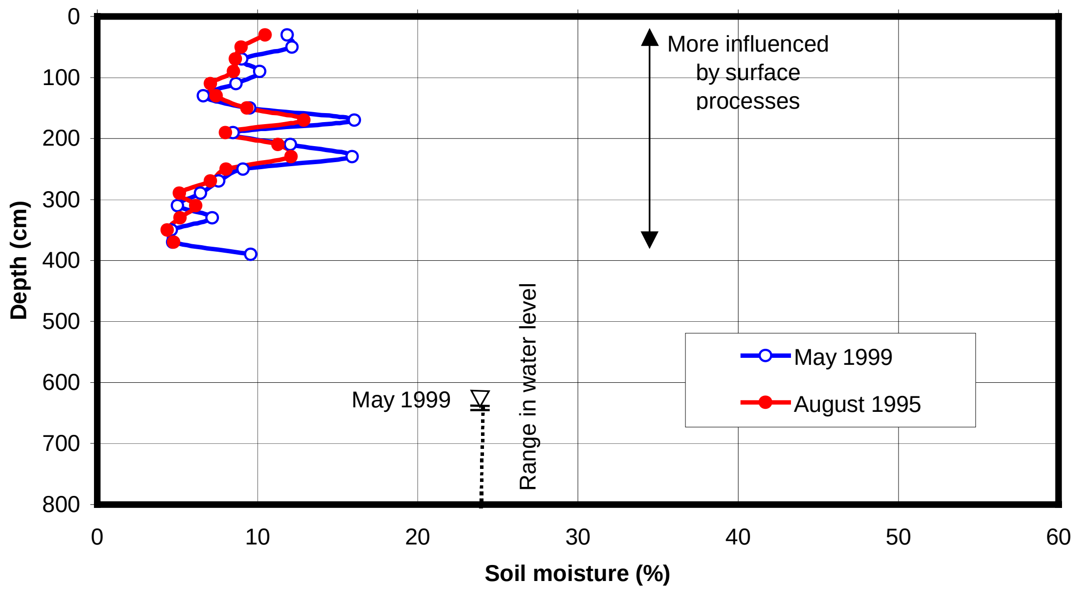


Figure 4-11
Soil Moisture Profile for Soil Probe TA3-1

Figure 4-12 presents soil moisture profiles in soil probe TA4-1 during the time periods August 1995 and May 1999, which are correlative with the maximum and minimum water levels. As shown in this figure, soil moisture in August 1995 is below 15 percent. In addition, the percentage of soil moisture above a depth of approximately 160 cm remains below 20 percent in both time periods. As shown on this figure, water level depths ranged from nearly 430 cm in August 1995 to about 220 cm in May 1999. In May 1999, when water levels were at their highest, the soil moisture during this time period reached as high as 45 percent at a depth of about 300 cm, which is below the maximum height of the groundwater. The increases in soil moisture between 160 cm and the groundwater table in this time period appears to be a result of a rising capillary fringe. Similarly, water levels in August 1995 were below 430 cm, which results in an associated decrease in the soil moisture below 160 cm due to a lowering of the capillary fringe.

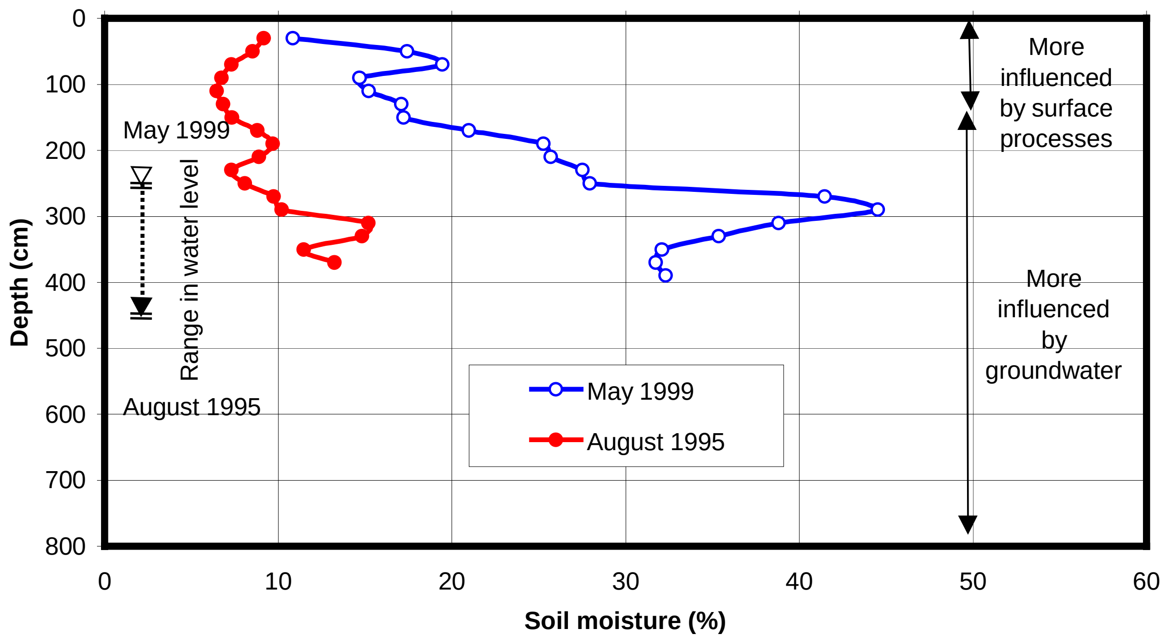


Figure 4-12
Soil Moisture Profile for Soil Probe TA4-1

Figure 4-13 presents soil moisture profiles in soil probe TA5-1 during the time periods February 1996 and November 1998, which are correlative with the maximum and minimum water levels. As shown in this figure, the soil moisture profiles for both time periods track nearly identically and appear to show increasing soil moisture with depth. The soil profiles do not appear to be change with water level, however.

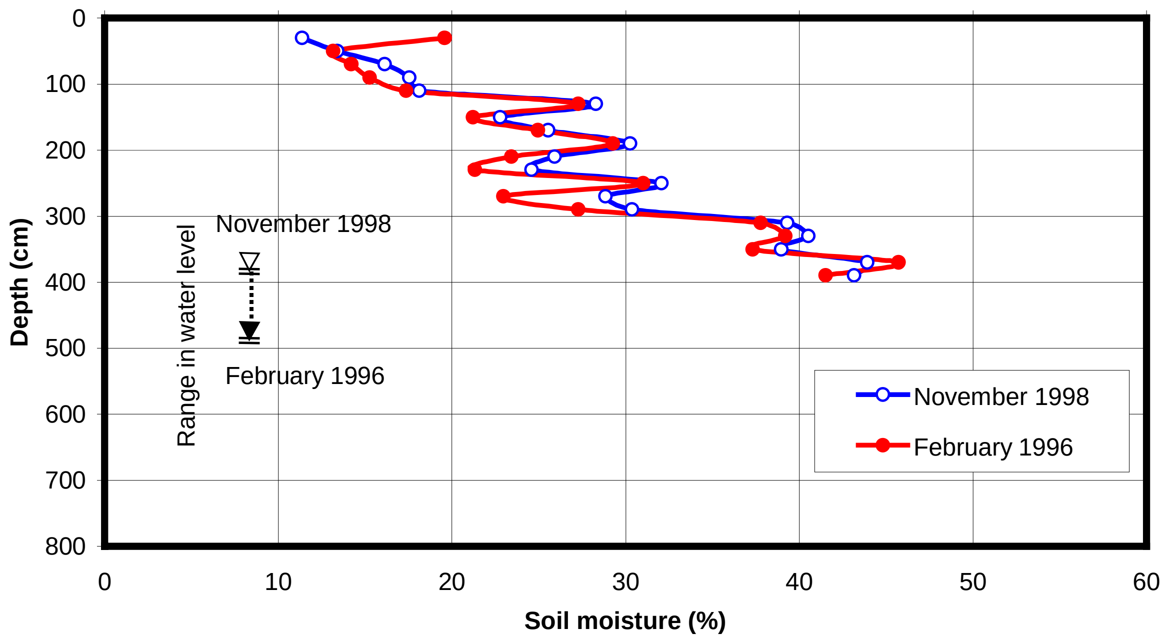


Figure 4-13
Soil Moisture Profile for Soil Probe TA5-1

Figure 4-14 presents soil moisture profiles in soil probe TA6-1 during the time periods July 1995 and May 1999, which are correlative with the maximum and minimum water levels. As shown in this figure, the soil moisture profiles for both time periods track nearly identically until a depth of approximately 200 cm. Below this depth, soil moisture in May 1999 increases to a maximum of nearly 50 percent at 390 cm. This corresponds to the point at which water levels are above the level of the probe. Soil moisture in July 1995 does not show this increase. Because the soil moisture remains relatively low (less than 20 percent) at a depth of approximately 250 cm, this appears to be the maximum extent of groundwater influence at this location during this time period.

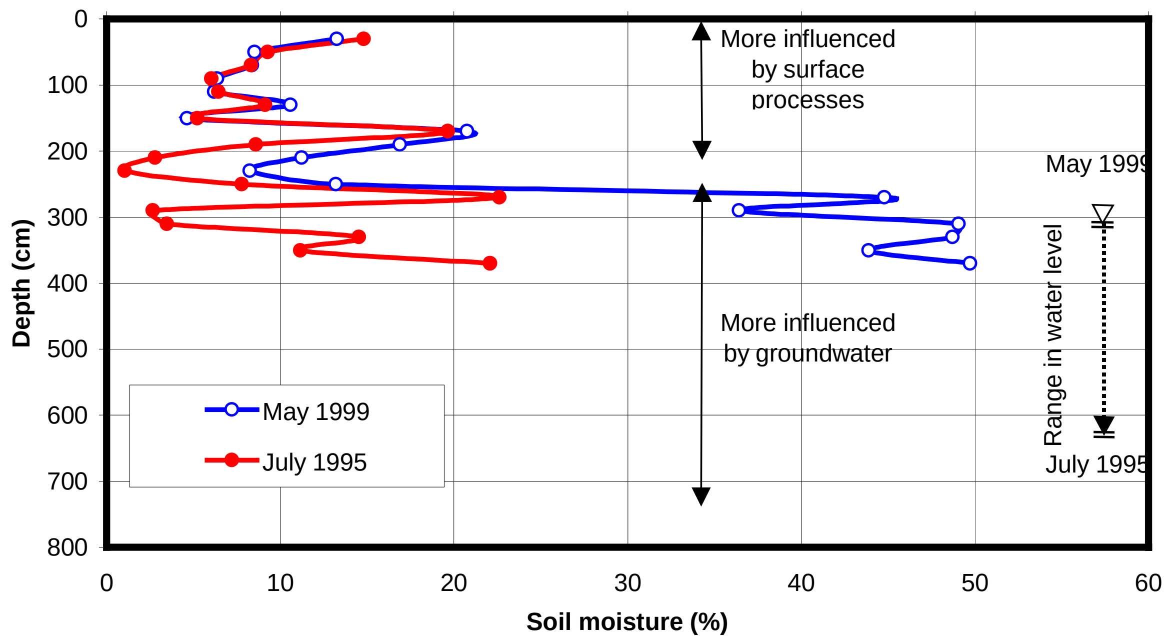


Figure 4-14
Soil Moisture Profile for Soil Probe TA6-1

Summary

Soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. The data presented herein validate that the upper portion of the soil profile appears to be more strongly influenced by surface water processes while the lower portion of the soil profile appears to be more strongly influenced by groundwater levels. This is clearly consistent with the conceptual model. Because soil moisture in the upper portion of the soil profile (the exact depth of this interface varies with time and location) is largely independent of groundwater levels, soil moisture in these portions of the soil profile should not be used to identify a return to baseline conditions nor the influence of groundwater pumping. Most significantly, from the strong correlation between water levels and the soil moisture associated with the capillary fringe, it can inferred that since water levels have recovered in the Taboose-Aberdeen management area then the portion of the soil moisture profile influenced by the water table also exhibits substantial recovery.

Findings

1. The DRP states that "substantial recovery in soil moisture and water table conditions" are the criteria by which the DRP is terminated. Until then, it is intended for "environmentally conservative" groundwater pumping to be conducted. The DRP does not specify the consideration of any other criteria in determining the termination of DRP.

2. Eighty-two percent of Taboose-Aberdeen Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1996 and 1998. All shallow wells show substantial recovery since the DRP was implemented in 1992. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

3. Evaluation of net recharge (recharge less pumping) in the Taboose-Thibaut area also documents drought recovery. Since 1992, pumping in the Taboose-Thibaut area has been managed conservatively resulting in a gain of almost 181,000 acre-ft since 1994, more than replacing the storage depletions in the late 1980s and early 1990s.

4. Neutron probe soil moisture data do not exist for the baseline period. Neutron probe data were not available prior to 1995. Despite the absence of baseline data, analysis of the available data yields information pertinent to the DRP.

5. Soil moisture data from the Taboose-Aberdeen monitoring sites show a direct correlation between the lower portion of the soil profile and groundwater levels. Soil moisture in the lower portion of the soil moisture profile is predominantly influenced by water levels. For the 1995 to 2000 time period, this depth is undeterminable from available data at monitoring site TA3, about 160 cm at monitoring site TA4, undeterminable from available data at monitoring site TA5 and about 250 cm at monitoring site TA6.

6. Although baseline data for soil moisture are not available, we have been able to conclude that based on the depth-to-groundwater/soil moisture relationships demonstrated by the data described above, and because groundwater levels in the Taboose-Aberdeen Wellfield have substantially recovered, it necessarily follows that soil moisture levels, to the extent that they are influenced by groundwater levels, have also substantially recovered.

7. Soil moisture above the depth where groundwater is the predominant influence is controlled by numerous other factors such as precipitation, surface land use activities, and evapotranspiration. Of these, only precipitation is a direct measure of drought conditions. Consequently, for this upper portion of the soil profile, only the consideration of precipitation is appropriate for evaluation of drought recovery.

Recommendations

Based on the findings above and associated preponderance of evidence concerning depth to water data, groundwater balance, and soil moisture, substantial recovery as defined in the DRP has been achieved. To summarize, the data clearly demonstrate that termination of the DRP is appropriate.

Chapter 5

Thibaut-Sawmill Wellfield

Chapter 5
Thibaut-Sawmill Wellfield

Wellfield Description

Located in the Owens Valley immediately to the north of the town of Independence, the Thibaut-Sawmill Wellfield is one of seven wellfields operated by the LADWP where groundwater pumping and extraction have been governed by the DRP. The provisions in the Green Book (October 1991) provide for five monitoring sites at this wellfield, TS1 through TS4 and TS6, as summarized in **Table 5-1** and shown on **Figure 5-1**. However, TS6 is not utilized.

Table 5-1
Summary of Thibaut-Sawmill Monitoring Sites

Monitoring Site	Vegetation Type	Shallow Monitoring Well	Pumping Wells[1]	EM Wells
TS1	C	T807	W159AQ	
TS2	C	T806	W155AQ	
TS3	C	T454	W103AQ, W104AQ,	W382EM
TS4	B	T804	W380AQ	W381EM
TS6	Not Utilized			

[1] Wells W351AQ and W356AQ (sole source fish hatchery supply) are located within the Thibaut-Sawmill Wellfield, but exempt from Green Book on/off provisions and DRP provisions.

Monitoring Site TS1

Monitoring Site TS1 is associated with pumping well W159AQ. The shallow monitoring well at this site is Well T807, which has a depth to water history from May 1989 to present and does not provide a 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (TS1-1, TS1-2, and TS1-3). Representative vegetation at monitoring site TS1 has been mapped as Type C.

Monitoring Site TS2

Monitoring Site TS2 is associated with pumping well W155AQ. The shallow monitoring well at this site is Well T806, which has a depth to water history from May 1989 to present and does not provide a 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (TS2-1, TS2-2, and TS2-3). Representative vegetation at monitoring site TS2 has been mapped as Type C.

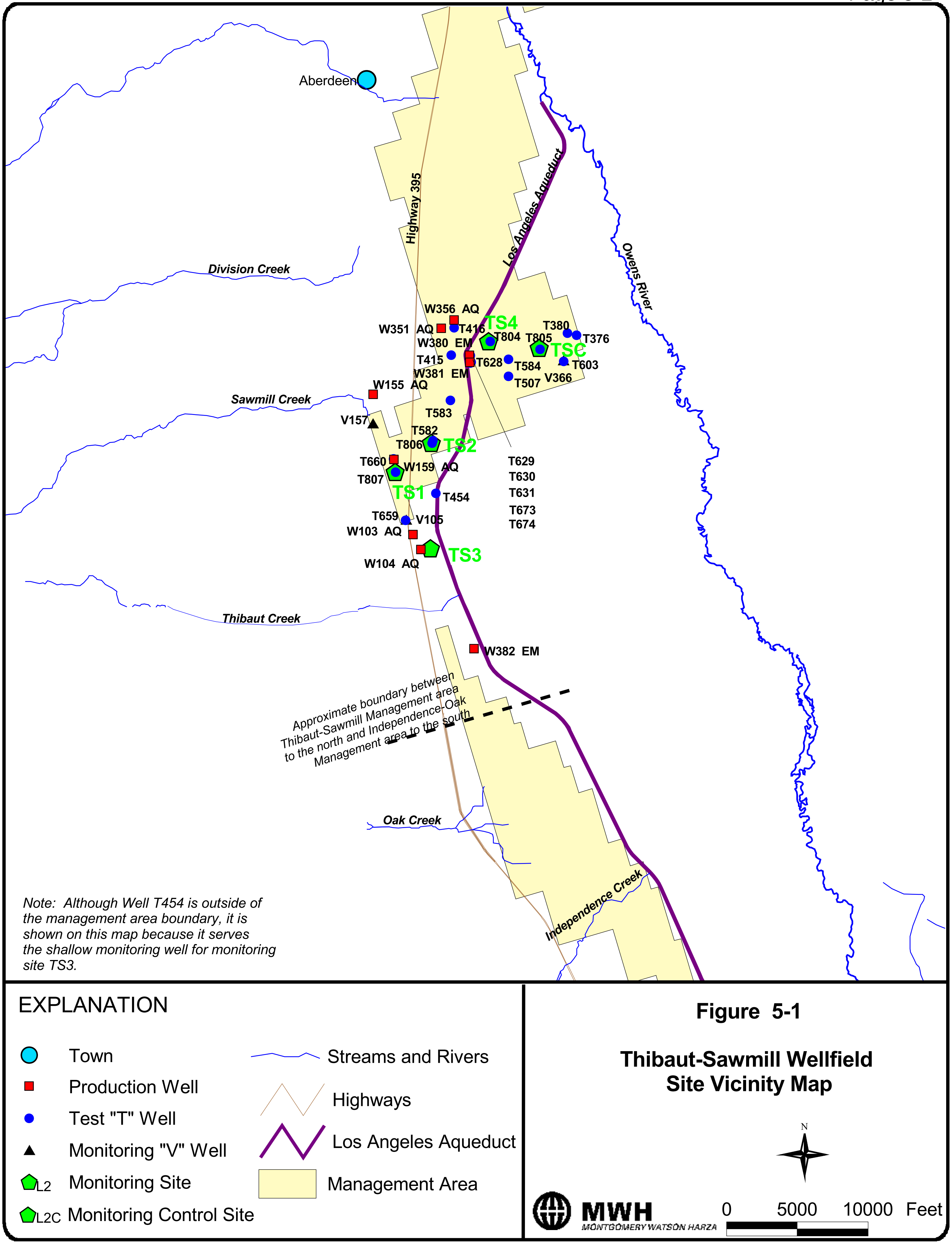


Figure 5-1

Thibaut-Sawmill Wellfield Site Vicinity Map

Monitoring Site TS3

Monitoring Site TS3 is associated with pumping wells W103AQ and W104AQ, as well as EM Well W382EM. The shallow monitoring well used for this site is Well T454 located 0.8 miles to the north of the monitoring site, which has a depth to water history from March 1974 to present, thereby providing a 1985-1987 Runoff Year baseline. A new monitoring well was installed at the monitoring site in the winter of 2000. In addition, there are four soil moisture access tubes at this site (TS3-1, TS3-2, TS3-3, and TS3-4). Representative vegetation at monitoring site TS3 has been mapped as Type C.

Monitoring Site TS4

Monitoring Site TS4 is associated with pumping well W380AQ and EM well W381EM. The shallow monitoring well at this site is Well T804, which has a depth to water history from May 1989 to present, and thereby does not provide a 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (TS4-1, TS4-2, and TS4-3). Representative vegetation at monitoring site TS4 has been mapped as Type B.

Management Area Monitoring Wells

There are a total of 19 shallow wells and five deep wells, as shown on **Figure 5-1**, within the Thibaut-Sawmill management area. As summarized in **Table 5-2**, the following descriptive statistics apply to this data set of wells:

- Six of the shallow wells and three of the deep wells do not have baseline data and no analysis was performed on these wells.
- Three of the shallow wells were dry in the baseline allowing for a qualitative evaluation only.
- Ten of the shallow wells and two of the deep wells have data suitable for the quantitative analysis described in Chapter 1.
- Although quantitative and qualitative evaluations are conducted on suitable shallow and deep wells, only the 10 shallow wells, whose data represent water table conditions suitable for quantitative analysis, are used to validate DRP termination.

Table 5-2
Summary of Wells in the Thibaut-Sawmill Wellfield Management Area

Descriptive Statistic	Quantity of Wells	
	Shallow	Deep
Wells in Management Area	19	5
Wells with No Baseline Data – No Analysis Performed	6	3
Wells that were Dry in Baseline - Qualitative Analysis Performed	3	0
Wells with Complete Data Sets - Quantitative Analysis Performed	10	2
Wells Used to Validate DRP Termination	**10**	2

Depth to Water

Methodology

As discussed previously, there are a total of 24 monitoring wells within the Thibaut-Sawmill Wellfield. Of these 24 monitoring wells, quantitative analyses were performed in accordance with **Table 5-2**. **Figure 5-1** shows the location of Thibaut-Sawmill management area wells and **Table 5-3** provides a listing of the 12 shallow and deep monitoring wells evaluated quantitatively.

Table 5-3
Summary of Thibaut-Sawmill Wellfield Monitoring Wells Evaluated for DRP Termination

Well	Baseline			DTW Drought Low (fbgs)	DTW 80% Recovery (fbgs)	Runoff Year(s) During which Low Point Occurred	Substantial Recovery Achieved by Runoff Year						
	Mean[1] (fbgs)	Lower 95% CI[2]	Upper 95% CI[2]				1995	1996	1997	1998	1999	2000[3]	Summary[5]
T376	6.4	6.7	6.1	9.8	7.1	1990, 1991, 1992			X	X	X	X	X
T380	8.1	8.3	7.9	12.0	8.9	1992					X	X	X
T416	5.5	6.1	4.9	18.2	8.0	1994		X	X	X	X	X	X
T507	5.0	5.8	4.3	9.6	6.0	1990			X	X	X	X	X
T584	6.0	6.3	5.7	10.1	6.8	1990, 1991, 1992				X	X	X	X
T603	4.7			8.2	5.4	1990, 1992				X			X
T659	14.5			18.6 [4]	15.3	1989-1997, 1999-2000							
T660	16.1	17.3	14.9	29.7 [4]	18.8	1990-1993		X	X	X	X	X	X
T673	4.9	5.3	4.4	6.6	5.2	1989	X	X	X	X	X	X	X
T674	5.7	6.2	5.3	7.9	6.2	1989, 1992	X	X	X	X	X	X	X
Thibaut-Sawmill Wellfield Management Area Percent Recovery for Shallow Wells							20%	40%	60%	**80%**	**80%**	**80%**	**90%**
T628	6.0			8.3	6.5	1989	X	X	X	X	X	No Data	X
T630	5.7			7.6	6.1	1989	X	X	X	X	X	X	X
Thibaut-Sawmill Wellfield Management Area Percent Recovery for Deep Wells:							**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

[1] Baseline Mean is calculated from all available depth to water measurements collected during the baseline, on a Runoff Year basis (1985-1987).
[2] In some instances, only one data point was available for the baseline mean, in which case confidence intervals could not be calculated.
[3] The wellfield management area percent recovery for deep wells for Runoff Year 2000 is based on one well rather than two because Well T628 had no data points for this year and was therefore not factored into the calculation.
[4] DTW Drought Low represents the depth of the well as the well went dry at this point, precluding measurement of the actual water level. As a result, the actual DTW 80% recovery is lower than that presented in the table.
[5] This "Summary" column indicates if substantial recovery has been achieved in a well at any time since the DRP was instituted in 1992.

Data Presentation

The quantitative methodology described in the Approach section of Chapter 1 was applied to the 10 shallow and two deep wells. Baseline mean and 95 percent confidence intervals were calculated and are summarized in **Table 5-3**. Also shown in this table is the lowest depth to water recorded during the drought (DTW Drought Low), the water level that represents 80 percent recovery using Equation 2 (DTW 80% Recovery), runoff year during which low point occurred, and a column for each potential recovery year (Runoff Years 1995 – 2000).

Hydrographs for these 12 wells graphically depict the baseline and 80 percent recovery line and are provided **Appendix D**. In general, depth to water measurements were high during the baseline period, yet declined during the drought, and since the drought's end, water levels have steadily climbed, typically achieving recovery in the late 1990s.

Discussion

The data demonstrate that 80 percent of Thibaut-Sawmill Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1998, 1999, and 2000. Furthermore, 90 percent of shallow wells exhibit substantial recovery since the DRP was instituted in 1992. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

In addition, two of the two (100 percent) Thibaut-Sawmill deep wells exhibit substantial recovery in Runoff Years 1995-2000, which indicates substantial recovery since the DRP was instituted in 1992 and lends additional support to termination of the DRP at the Thibaut-Sawmill wellfield.

Furthermore, hydrographs for the three shallow wells, as summarized in **Table 5-4**, that were dry in the baseline were constructed and are included in **Appendix D**. Of these wells, Wells T415 and T582 express a pattern of recovery since the drought indicative of drought recovery. Well T583 is dominated by dry measurements from baseline to present such that it is not possible to draw any conclusions from the data for this well.

Table 5-4
Summary of Thibaut-Sawmill Wellfield Monitoring Wells that were Dry During the Baseline

Shallow Wells	Deep Wells
T415	
T582	
T583	

Summary

To summarize, 80 percent of Thibaut-Sawmill Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1998, 1999, and 2000, respectively; therefore the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met. In addition, 90 percent of shallow wells exhibit substantial recovery since the DRP was instituted in 1992.

Hydrologic Indices

Montgomery Watson Harza reviewed groundwater balance data for the Thibaut-Sawmill area to determine the status of the hydrologic conditions. The results of this evaluation are presented below.

Groundwater Balance

As discussed in Chapter 4, the mining calculations for the Thibaut-Sawmill wellfield are not computed separately, but instead are combined with those for the Taboose-Aberdeen wellfield. The discussion in that chapter indicates that the Taboose-Thibaut area accumulated about 210,000 acre-ft of groundwater in storage in the wet period of the later 1970s through the mid-1980s. Increased groundwater pumping during the 1986-1991 drought extracted about 107,000 acre-ft of water from storage. Since the end of the drought, about 181,000 acre-ft of groundwater storage has been accrued, replacing the water removed during the drought.

Soil Moisture

Methodology

Neutron probe data have been collected on a monthly basis from 13 soil access tubes from the 4 monitoring sites (TS1, TS2, TS3, and TS4) since July 1995. Neutron probe data were collected at 20-cm intervals from a depth of 30 cm to a depth of 390 cm to construct a soil moisture depth profile. Soil moisture data were evaluated using the approach described in the Approach section of Chapter 1.

Data Presentation and Discussion

Precipitation and Soil Moisture

Figure 5-2 through **Figure 5-5** compare the average soil moisture at monitoring sites TS1 (includes an average of soil access tubes TS1-1, TS1-2, and TS1-3), TS2 (includes an average of soil access tubes TS2-1, TS2-2, and TS2-3), TS3 (includes an average of soil access tubes TS3-1, TS3-2, TS3-3 and TS3-4) and TS4 (includes an average of soil access tubes TS4-1, TS4-2, and TS4-3) at a depth of 30 cm to monthly precipitation at the LADWP Los Angeles Aqueduct Intake weather station. A depth of 30 cm was selected to evaluate the correlation between the upper soil profile and precipitation. Subsequent analysis evaluates relationships at two additional depths, whereby the middle depth represents a point in the soil profile least influenced by both surface processes and water levels, and the lowermost depth represents the point most influenced by water levels only.

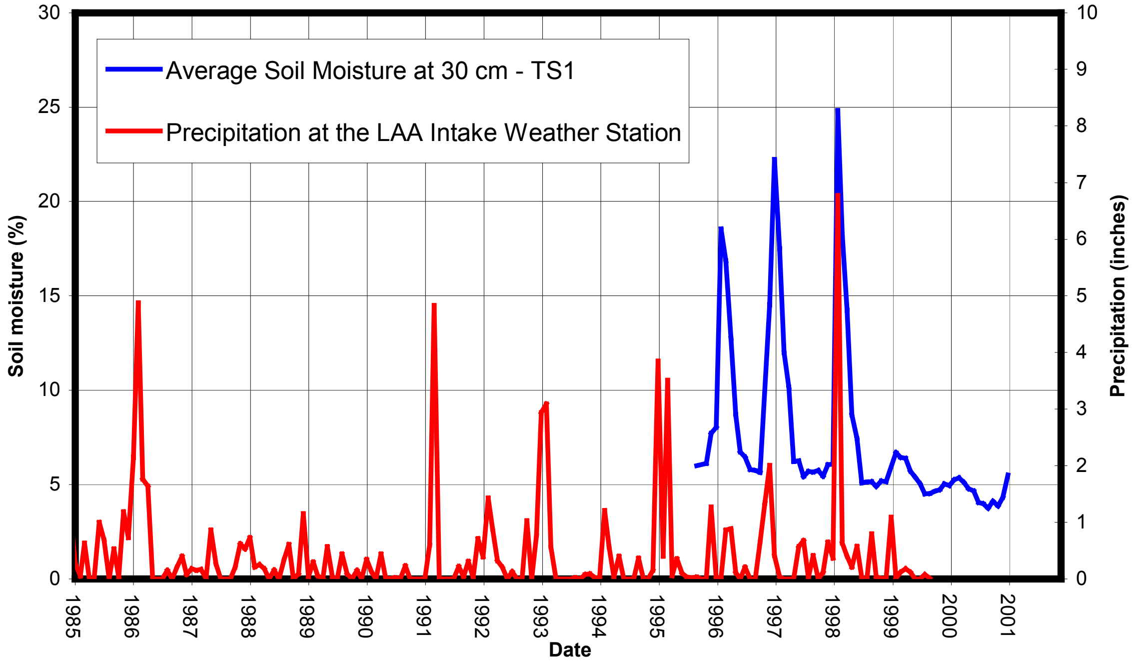


Figure 5-2
Average Soil Moisture at 30 cm for Monitoring Site TS1 versus Precipitation

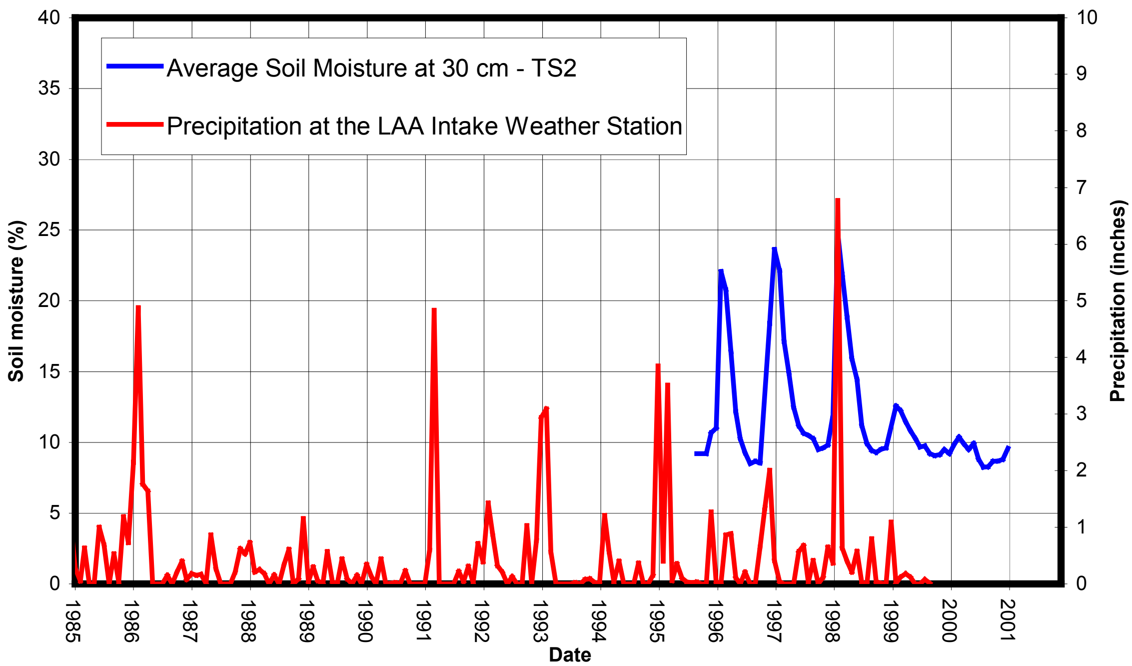


Figure 5-3
Average Soil Moisture at 30 cm for Monitoring Site TS2 versus Precipitation

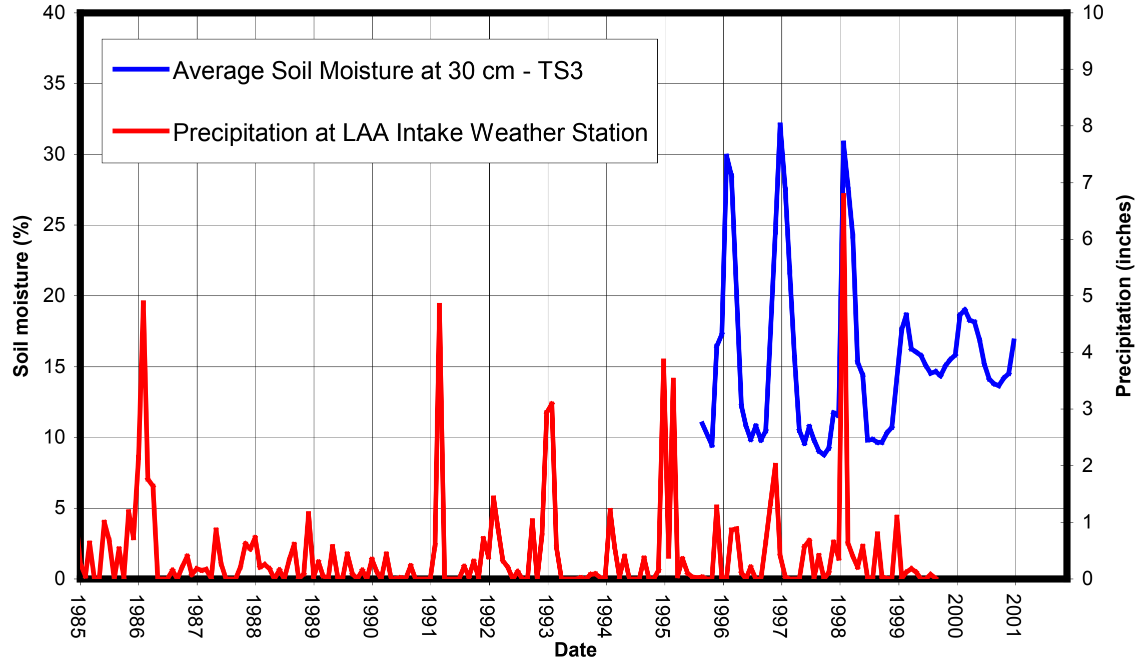


Figure 5-4
Average Soil Moisture at 30 cm for Monitoring Site TS3 versus Precipitation

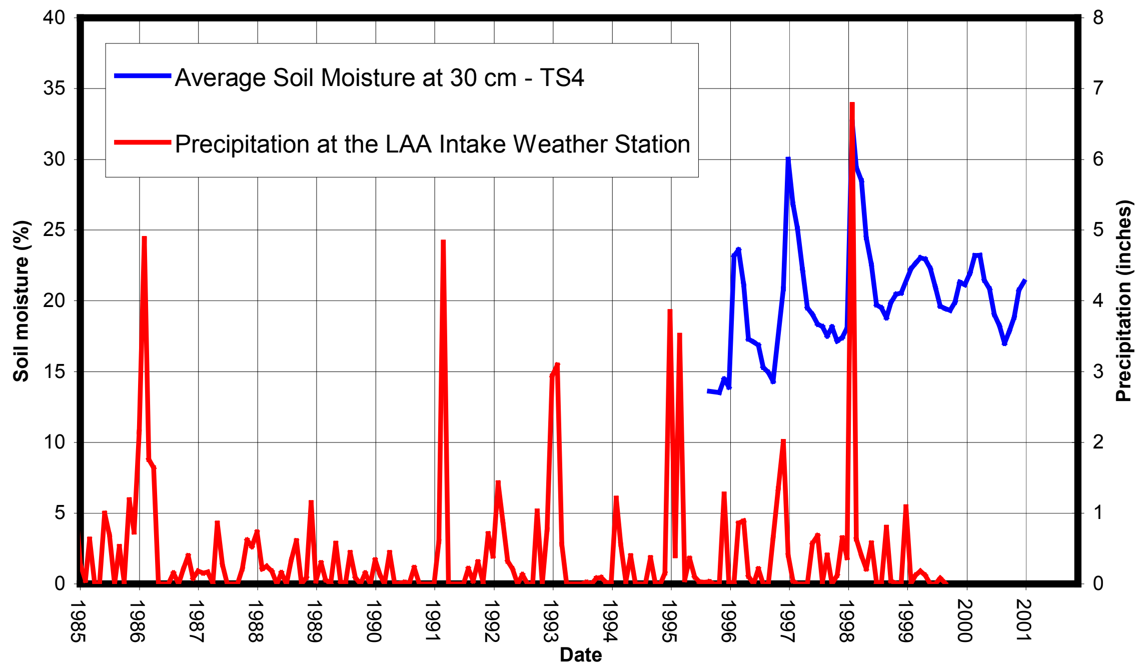


Figure 5-5
Average Soil Moisture at 30 cm for Monitoring Site TS4 versus Precipitation

The figures indicate that the soil moisture at a depth of 30 cm have generally tracked parallel to monthly precipitation since 1995. Similarly, all four monitoring sites have had similar percent soil moisture at 30 cm until mid-1998. After 1998, there appears to be a downward trend in the soil moisture percentages at monitoring sites TS1 and TS2. On the other hand, the general trend in soil moisture percentages increases slightly at monitoring sites TS3 and TS4. These data suggest that the primary mechanism controlling soil moisture near the surface (30 cm) is precipitation, which is consistent with the conceptual soil moisture model.

Water Level and Soil Moisture

Figure 5-6 compares the average soil moisture at depths of 110 cm and 370 cm at monitoring site TS1 to water levels in Well T807. As shown in this figure, percent soil moisture is slightly variable in both zones, but does appear to generally parallel water levels in Well T807. From 1995 to early 1997, percent soil moisture at 370 cm was typically higher than soil moisture at 110 cm. In June 1996, soil moisture in the 370 cm zone attained a maximum of 38 percent. This maximum measurement corresponds to the time during which the water level in Well T807 is above the monitoring point of 370 cm and likely represents the saturation point for the soil. Between early 1997 and late 1998, soil moisture at both levels were essentially the same. Since 1998, soil moisture at 370 cm has been higher than at 110 cm.

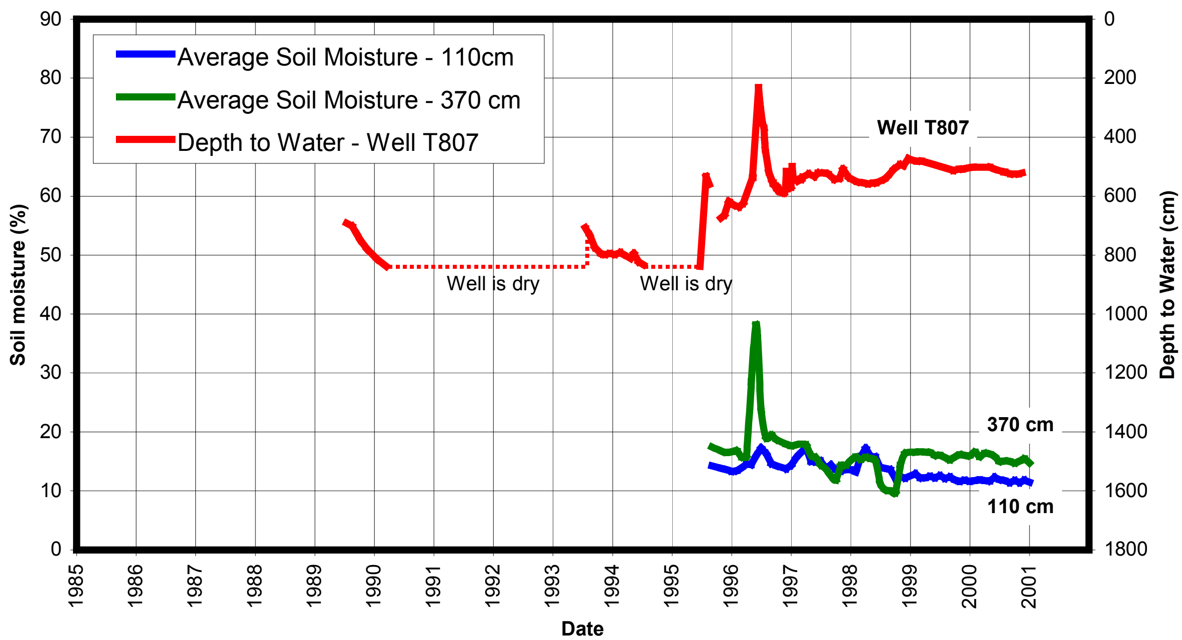


Figure 5-6
Average Soil Moisture for Monitoring Site TS1 versus Water Level

Figure 5-7 compares the average soil moisture at depths of 110 cm and 370 cm at monitoring site TS2 to water levels in Well T806. As shown in this figure, soil moisture at 370 cm generally parallels water levels in Well T806 with maximum percent soil moisture of nearly 35 percent. The maximum soil moisture occurs when water levels in Well T806 are also at about 370 cm, and likely represents soil saturation. The trend in soil moisture at 110 cm increases slightly from 1995 and reaches a maximum of about 10 percent.

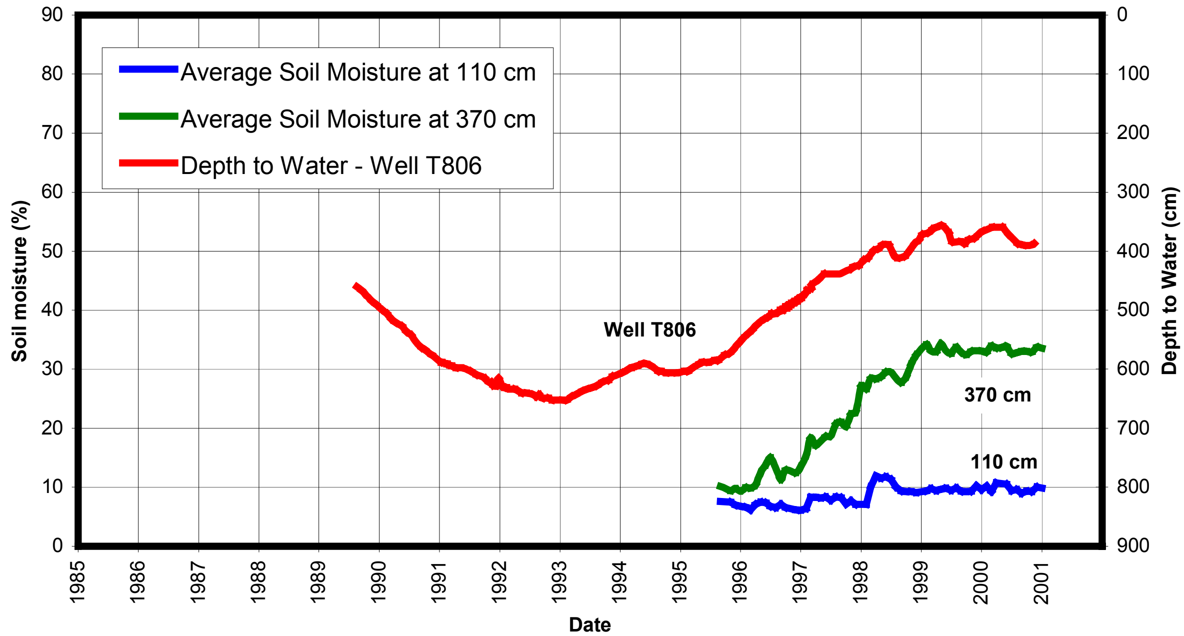


Figure 5-7
Average Soil Moisture for Monitoring Site TS2 versus Water Level

Figure 5-8 compares the average soil moisture at depths of 110 cm and 190 cm at monitoring site TS3 to water levels in Well T454, which is located 0.8 miles from the monitoring site. Because water levels are generally above 250 cm in Well T454, the maximum depth of the soil probe before it goes below the water table is about 250 cm. This conclusion, however, does not take into account the horizontal separation between the well and monitoring site. As shown in this figure, the trend in soil moisture at 190 cm and 110 cm increases slightly and generally parallels water levels in Well T454 with maximum percent soil moisture of approximately 50 percent. The maximum measurements correspond to times in which the water level in Well T454 is above the monitoring point of 190 cm and likely represents the saturation point for this soil. Soil moisture at 110 cm is generally lower than at 190cm, although the peaks observed at 190 cm are also observed at 110 cm.

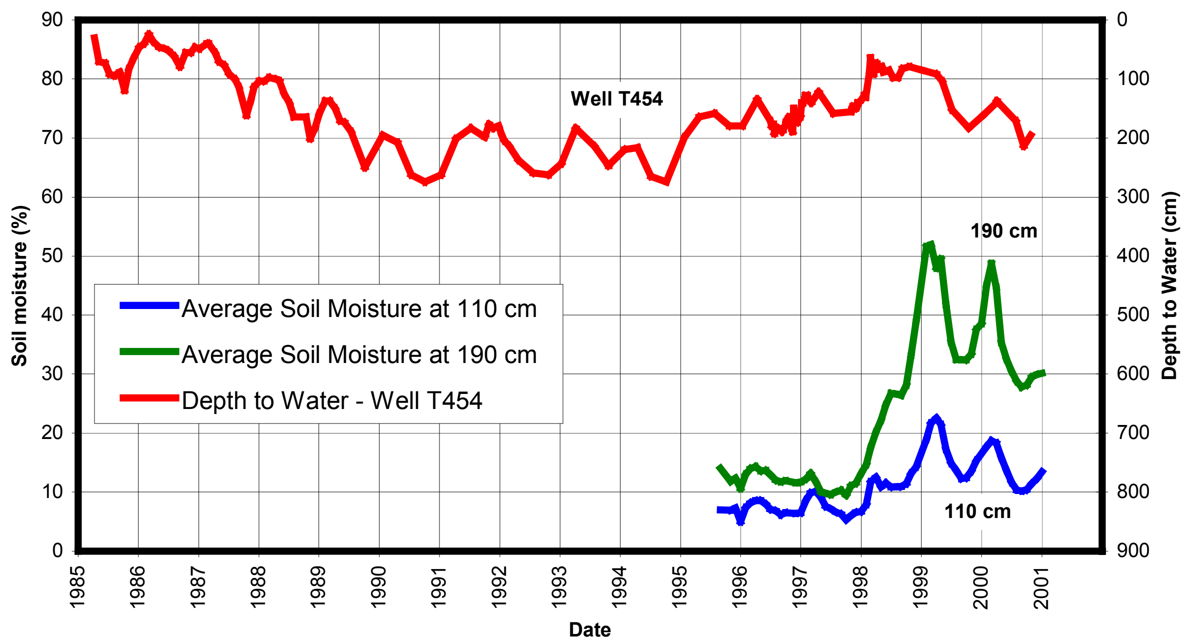


Figure 5-8
Average Soil Moisture for Monitoring Site TS3 versus Water Level

Figure 5-9 compares the average soil moisture at depths of 110 cm and 270 cm at monitoring site TS4 to water levels in Well T804. Because water levels have been generally above 290 cm at this location since 1995, the maximum depth of the soil probe before submersion beneath the water table is approximately 290 cm. As shown in this figure, water levels in Well T804 have gradually increased since 1995. Soil moisture at 270 cm generally follows the pattern of water levels with maximum soil moisture of more than 50 percent. This maximum is coincident with the higher water levels. Soil moisture at 110 cm roughly parallels water levels and reaches a maximum of only 30 percent.

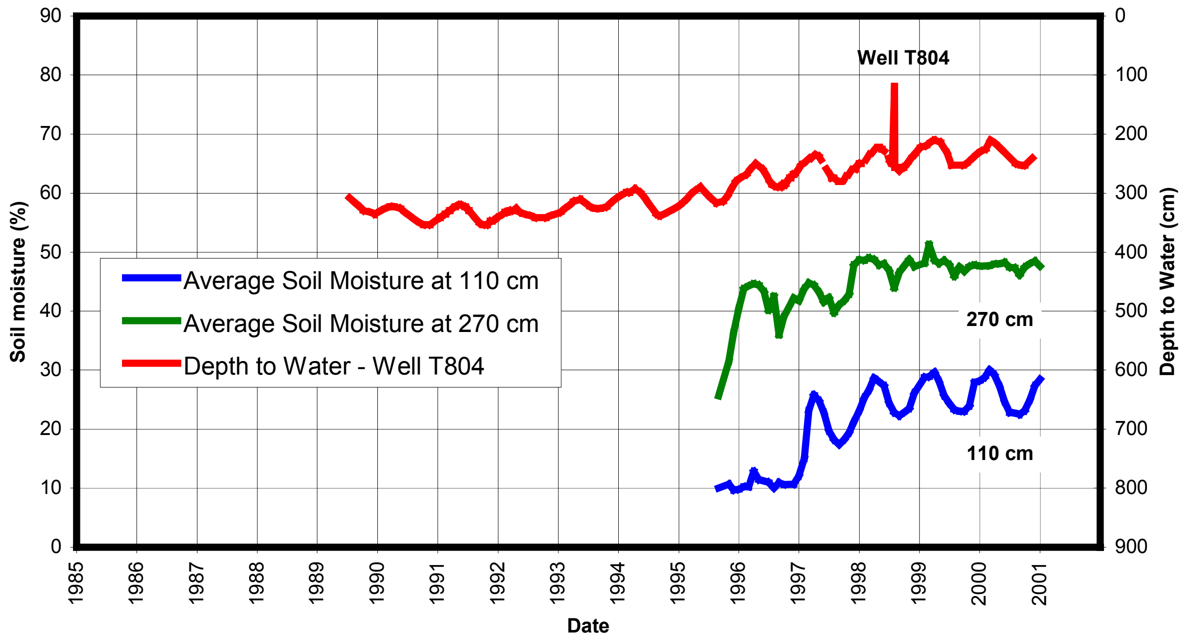


Figure 5-9
Average Soil Moisture for Monitoring Site TS4 versus Water Level

Soil Moisture Profiles

As discussed in the conceptual soil moisture model, soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. Soil profiles for each location were compiled to evaluate the vertical relationship among water table, precipitation, and soil moisture. Vertical profiles were constructed for the maximum water level and the minimum water level during the time period from 1995 to 2000. Consequently, these data should represent the approximate range in soil moisture attributable to groundwater at each depth for this period.

Figure 5-10 presents soil moisture profiles in soil probe TS1-2 during the time periods March 1996 and February 1998, which are correlative with the maximum and minimum water levels. As shown in this figure, soil moisture in February 1998 reaches a maximum of more than 30 percent at a depth of about 370 cm, which is lower than the water level at this time. In March 1996, when water levels are lower, the soil moisture at this level is about the same. In this analysis, soil moisture does not appear to correlate with water level during this time period.

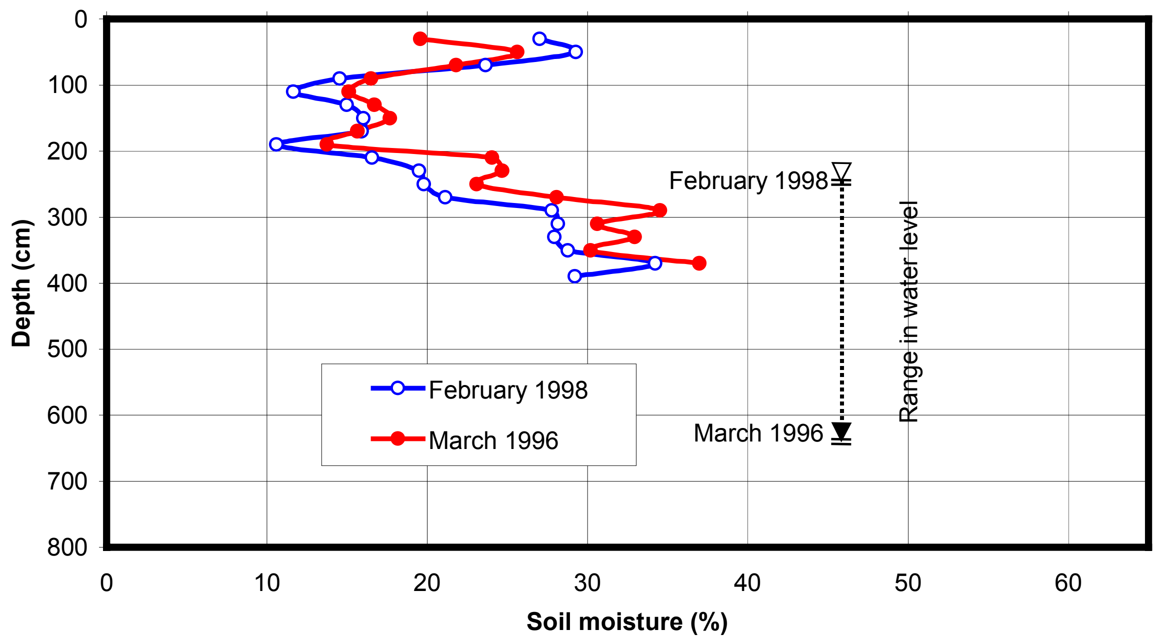


Figure 5-10
Soil Moisture Profile for Soil Probe TS1-2

Figure 5-11 presents soil moisture profiles in soil probe TS2-1 during the time periods August 1995 and May 1999, which are correlative with the maximum and minimum water levels. As shown in this figure, soil moisture in August 1995 is below 20 percent. In addition, the percentage of soil moisture above a depth of approximately 200 cm remains below 20 percent in both time periods. Water level depths ranged from nearly 585 cm in August 1995 to about 355 cm in May 1999. In May 1999, when water levels were at their highest, the soil moisture from 210 cm to 390 cm reached as high as 35 percent at a depth of about 390 cm, which is below the maximum height of the groundwater. The increases in soil moisture between 200 cm and the groundwater table in this time period appears to be a result of a rising capillary fringe. On the other hand, water levels in August 1995 were below 585 cm, which results in an associated decrease in the soil moisture below 200 cm due to a lowering of the capillary fringe. For this analysis, depth to groundwater and the associated capillary fringe appears to influence soil moisture below a depth of 200 cm during this period.

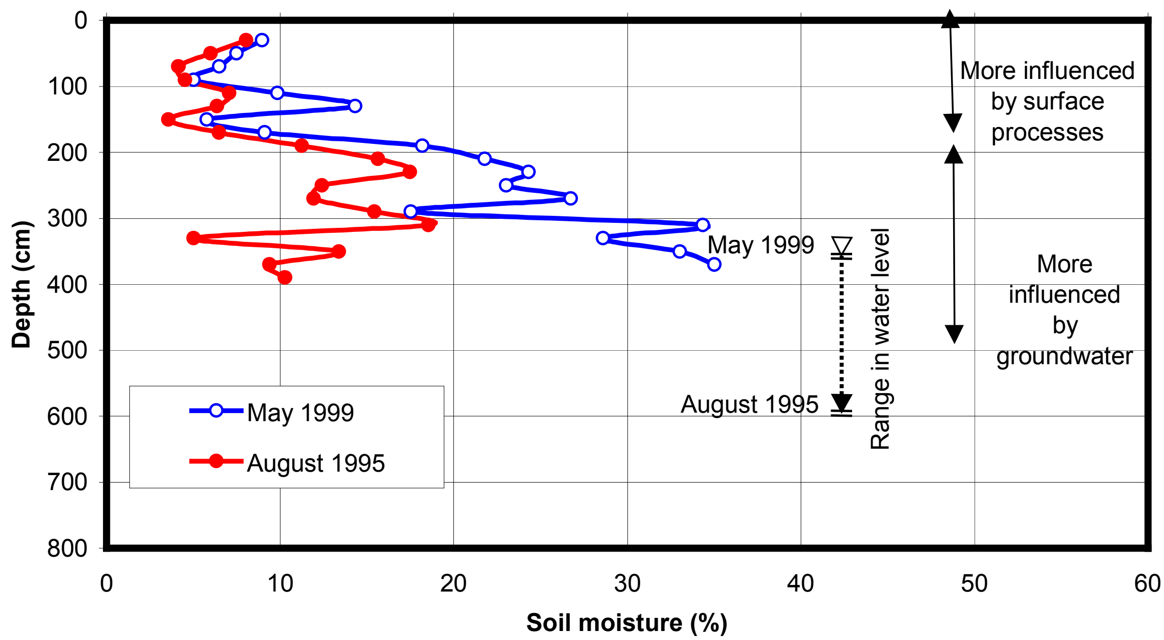


Figure 5-11
Soil Moisture Profile for Soil Probe TS2-1

Figure 5-12 presents soil moisture profiles in soil probe TS3-1 during the time period of February 1998 and September 2000, which are correlative with the maximum and minimum water levels. As shown in this figure, the soil moisture profiles for both time periods are parallel and appear to show increasing soil moisture with depth. Water levels at the well for this monitoring site, which is located 0.8 miles away from the monitoring site, are relatively high with minimum water depths of only 64 cm during this time period. Despite the high water levels, soil moisture at depths of 200 cm are still less than 30 percent, which is not consistent with a saturated condition, and the observed lack of correlation is likely attributable to the horizontal separation between the well and monitoring site.

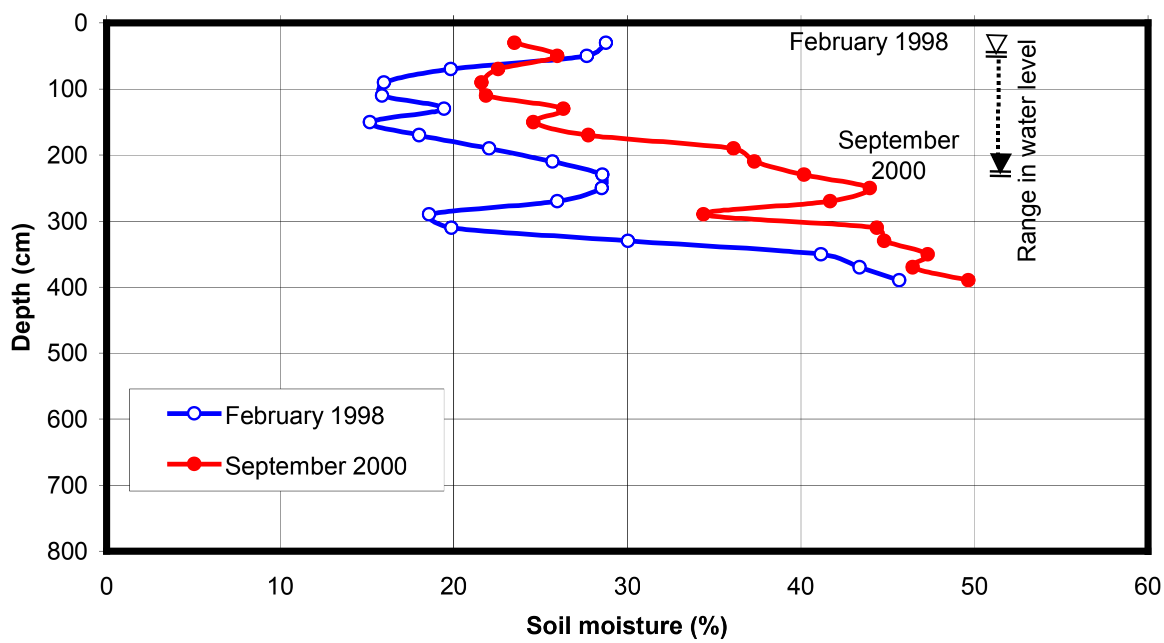


Figure 5-12
Soil Moisture Profile for Soil Probe TS3-1

Figure 5-13 presents soil moisture profiles in soil probe TS4-1 during the time periods August 1995 and August 1998, which are correlative with the maximum and minimum water levels. As shown in this figure, soil moisture in August 1995 ranges from 10 to 20 percent in the upper 100 cm of the soil profile. In the section between 100 and about 250 cm, the soil moisture is below 10 percent during this time period. Below a depth of about 250 cm, the soil moisture increases to more than 45 percent by 310 cm, where water is found in this analysis. In August 1998, soil moisture, like water levels is substantially higher with soil moisture ranging from 25 percent to above 50 percent, clearly a result of increasing groundwater levels. In this analysis, it is not possible to delineate the extent of the influence of groundwater and associated capillary fringe.

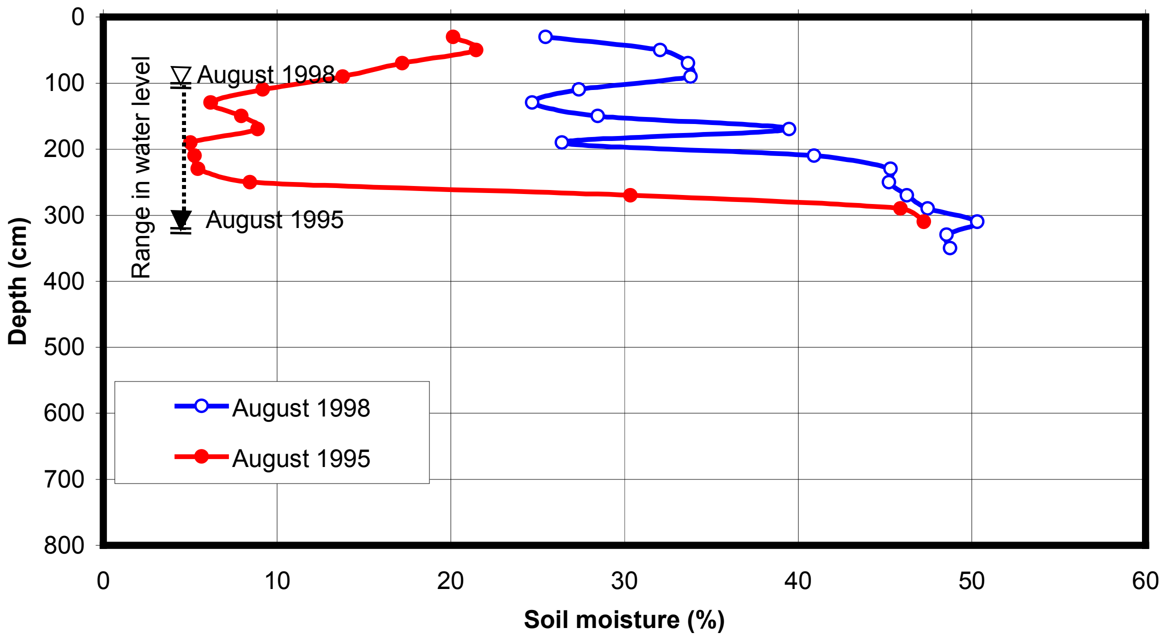


Figure 5-13
Soil Moisture Profile for Soil Probe TS4-1

Summary

Soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. The data presented herein validate that the upper portion of the soil profile appears to be more strongly influenced by surface water processes while the lower portion of the soil profile appears to be more strongly influenced by groundwater levels. This is clearly consistent with the conceptual model. Because soil moisture in the upper portion of the soil profile (the exact depth of this interface varies with time and location) is largely independent of groundwater levels, soil moisture in these portions of the soil profile should not be used to identify a return to baseline conditions nor the influence of groundwater pumping. Most significantly, from the strong correlation between water levels and the soil moisture associated with the capillary fringe, it can inferred that since water levels in the Thibaut-Sawmill management area have recovered then the portion of the soil moisture profile influenced by the water table also exhibits substantial recovery.

Findings

1. The DRP states that "substantial recovery in soil moisture and water table conditions" are the criteria by which the DRP is terminated. Until then, it is intended for "environmentally conservative" groundwater pumping to be conducted. The DRP does not specify the consideration of any other criteria in determining the termination of DRP.

2. Eighty percent of Thibaut-Sawmill Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1998, 1999, and 2000. Furthermore, 90 percent of shallow wells exhibit substantial recovery since the DRP was instituted in 1992. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

3. Evaluation of net recharge (recharge less pumping) in the Taboose-Thibaut area also documents drought recovery. Since 1992, pumping in the Taboose-Thibaut area has been managed conservatively resulting in a gain of almost 181,000 acre-ft since 1994, more than replacing the storage depletions in the late 1980s and early 1990s.

4. Neutron probe soil moisture data do not exist for the baseline period. Neutron probe data were not available prior to 1995. Despite the absence of baseline data, analysis of the available data yields information pertinent to the DRP.

5. Soil moisture data from the Thibaut-Sawmill monitoring sites show a direct correlation between the lower portion of the soil profile and groundwater levels. Soil moisture in the lower portion of the soil moisture profile is predominantly influenced by water levels. For the 1995 to 2000 time period, this depth is about 200 cm at monitoring site TS2, and undeterminable from available data at monitoring sites TS1, TS3 and TS4.

6. Although baseline data for soil moisture are not available, we have been able to conclude that based on the depth-to-groundwater/soil moisture relationships demonstrated by the data described above, and because groundwater levels in the Thibaut-Sawmill Wellfield have substantially recovered, it necessarily follows that soil moisture levels to the extent that they are influenced by groundwater levels, have also recovered.

7. Soil moisture above the depth where groundwater is the predominant influence is controlled by numerous other factors such as precipitation, surface land use activities, and evapotranspiration. Of these, only precipitation is a direct measure of drought conditions. Consequently, for this upper portion of the soil profile, only the consideration of precipitation is appropriate for evaluation of drought recovery.

Recommendations

Based on the findings above and associated preponderance of evidence concerning depth to water data, groundwater balance, and soil moisture, substantial recovery as defined in the DRP has been achieved. To summarize, the data clearly demonstrate that termination of the DRP is appropriate.

Chapter 6

Independence-Oak Wellfield

Chapter 6
Independence-Oak Wellfield

Wellfield Description

Located in the Owens Valley in the immediate vicinity of the town of Independence, the Independence-Oak Wellfield is one of seven wellfields operated by the LADWP where groundwater pumping and extraction have been governed by the DRP. The provisions in the Green Book (October 1991) provide for two monitoring sites at this wellfield, IO1 and IO2, as summarized in **Table 6-1** and shown on **Figure 6-1**.

Table 6-1
Summary of Independence-Oak Monitoring Sites

Monitoring Site	Vegetation Type	Shallow Monitoring Well	Pumping Wells[1]	EM Wells
IO1	C	T809	W391AQ, W400AQ	
IO2	A	T548	W63AQ	

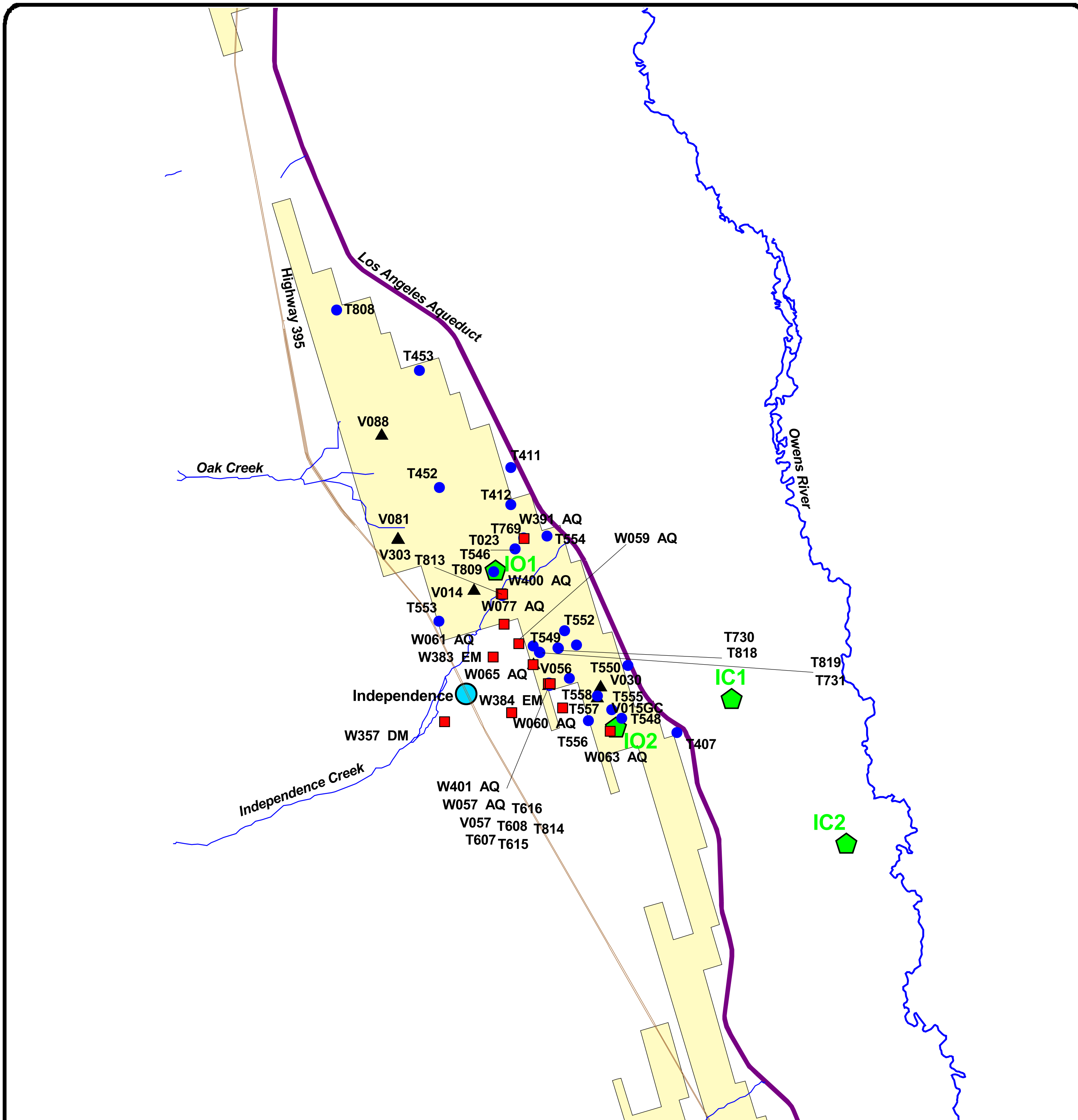
1. Wells W59AQ, W60AQ, WAQ61, W65AQ, W383EM, W384EM, W401AQ (pumping wells with no impact on areas with groundwater dependent vegetation), and W357AQ (sole source town supply) are located within the Independence-Oak Wellfield, but exempt from Green Book on/off provisions and DRP provisions. In addition, Well W401AQ is a replacement for Well W57AQ.

Monitoring Site IO1

Monitoring Site IO1 is associated with pumping wells W391AQ and W400AQ. The shallow monitoring well at this site is Well T809, which has a depth to water history from May 1989 to present, and thereby does not provide a 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (IO1-1, IO1-2, and IO1-3). Representative vegetation at monitoring site IO1 has been mapped as Type C.

Monitoring Site IO2

Monitoring Site IO2 is associated with pumping well W63AQ. The shallow monitoring well at this site is Well T548 located 0.1 miles from the monitoring site, which has a depth to water history from August 1985 to present, thereby providing a portion of the 1985-1987 Runoff Year baseline. This well is influenced by flows in a nearby ditch. A new monitoring well was installed at the monitoring site in winter of 2000. In addition, there are three soil moisture access tubes at this site (IO2-1, IO2-2, and IO2-3). Representative vegetation at monitoring site IO2 has been mapped as Type A, which is not subject to the provisions of the DRP.



EXPLANATION

- Town
- Production Well
- Test "T" Well
- Monitoring "V" Well
- L2 Monitoring Site
- L2C Monitoring Control Site
- Streams and Rivers
- Highways
- Los Angeles Aqueduct
- Management Area

Figure 6-1

Independence-Oak Wellfield Site Vicinity Map

N

MWH MONTGOMERY WATSON HARZA

0 4000 8000 Feet

Management Area Monitoring Wells

There are a total of 32 shallow wells and seven deep wells, as shown on **Figure 6-1**, within the Independence-Oak management area. As summarized in **Table 6-2**, the following descriptive statistics apply to this data set of wells:

- Twelve of the shallow wells and four of the deep wells do not have baseline data and no analysis was performed on these wells.
- Eight of the shallow wells and one of the deep wells were dry in the baseline allowing for a qualitative evaluation only.
- Twelve of the shallow wells and two of the deep wells have data suitable for the quantitative analysis described in Chapter 1.
- Although quantitative and qualitative evaluations are conducted on suitable shallow and deep wells, only the 12 shallow wells, whose data represent water table conditions suitable for quantitative analysis, are used to validate DRP termination.

Table 6-2
Summary of Wells in the Independence-Oak Wellfield Management Area

Descriptive Statistic	Quantity of Wells	
	Shallow	Deep
Wells in Management Area	32	7
Wells with No Baseline Data – No Analysis Performed	12	4
Wells that were Dry in Baseline - Qualitative Analysis Performed	8	1
Wells with Complete Data Sets - Quantitative Analysis Performed	12	2
Wells Used to Validate DRP Termination	12	0

Depth to Water

Methodology

As discussed previously, there are a total of 39 monitoring wells within the Independence-Oak Wellfield. Of these 39 monitoring wells, quantitative analyses were performed in accordance with **Table 6-2**. **Figure 6-1** shows the location of Independence-Oak management area wells and **Table 6-3** provides a listing of the 14 monitoring wells evaluated quantitatively.

Data Presentation

The quantitative methodology described in the Approach section of Chapter 1 was applied to the 12 shallow wells and two deep wells. Baseline mean and 95 percent confidence intervals were calculated and are summarized in **Table 6-3**. Also shown in this table is the lowest depth to water recorded during the drought (DTW Drought Low), the water level that represents 80 percent recovery using Equation 2 (DTW 80% Recovery), runoff year during which low point occurred, and a column for each potential recovery year (Runoff Years 1995 – 2000).

Table 6-3
Summary of Independence-Oak Wellfield Monitoring Wells Evaluated for DRP Termination

Well	Baseline			DTW Drought Low (fbgs)	DTW 80% Recovery (fbgs)	Runoff Year(s) During which Low Point Occurred	Substantial Recovery Achieved by Runoff Year						
	Mean[1] (fbgs)	Lower 95% CI	Upper 95% CI				1995	1996	1997	1998	1999	2000	Summary[3]
T023	6.1	6.7	5.5	14.5	7.8	1992	X	X	X	X	X	X	X
T407	7.9	8.5	7.2	18.6	10.0	1990				X	X	X	X
T411	5.2	5.7	4.8	10.6	6.3	1990	X	X	X	X	X	X	X
T412	5.0	5.7	4.2	12.1	6.4	1992		X	X	X	X	X	X
T452	5.1	6.0	4.1	14.2	6.9	1990	X	X	X	X	X	X	X
T453	6.6	7.9	5.4	20.1 [2]	9.3	1989	X	X	X	X	X	X	X
T546	4.9	5.4	4.4	13.4	6.6	1992	X	X	X	X	X	X	X
T550	3.2	3.6	2.7	5.8	3.7	1987, 1991	X	X	X	X	X	X	X
T552	5.7	6.8	4.5	19.2 [2]	8.4	1988-1989, 1990-1991, 1992, 1993	X	X	X	X	X	X	X
T554	4.5	4.9	4.1	9.7	5.5	1990	X	X	X	X	X	X	X
T555	7.2	8.3	6.1	16.9 [2]	9.1	1988-1992, 1992-1993, 1994-1995					X	X	X
V015GC	7.3	9.7	4.9	34.6	12.7	1990		X	X	X	X	X	X
Independence-Oak Wellfield Management Area Percent Recovery for Shallow Wells:							50%	**83%**	**83%**	**92%**	**100%**	**100%**	**100%**
V056	25.4	29.3	21.6	60.2	32.4	1990	X		X	X	X	X	X
V081	8.5	10.8	6.2	22.8	11.3 [2]	1988-1993, 1994-1995	X	X	X	X	X		X
Independence-Oak Wellfield Management Area Percent Recovery for Deep Wells:							**100%**	50%	**100%**	**100%**	**100%**	50%	**100%**

[1] Baseline Mean is calculated from all available depth to water measurements collected during the baseline, on a Runoff Year basis (1985-1987).
[2] DTW Drought Low represents the depth of the well as the well went dry at this point, precluding measurement of the actual water level. As a result, the actual DTW 80% recovery is lower than that presented in the table.
[3] This "Summary" column indicates if substantial recovery has been achieved in a well at any time since the DRP was instituted in 1992.

Hydrographs for these 14 wells graphically depict the baseline and 80 percent recovery line and are provided **Appendix E**. In general, depth to water measurements were high during the baseline period, yet declined during the drought, and since the drought's end, water levels have steadily climbed, typically achieving recovery in the late 1990s.

Discussion

The data demonstrate that 83, 83, 92, 100, and 100 percent of Independence-Oak Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1996, 1997, 1998, 1999, and 2000, respectively. In addition, 100 percent of the shallow wells show substantial recovery since the DRP was instituted in 1992. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

Similarly, two of the two (100 percent) Independence-Oak deep wells exhibit substantial recovery in Runoff Years 1995, 1997, 1998, and 1999 , which indicates substantial recovery since the DRP was instituted in 1992 and lends additional support to termination of the DRP at the Independence-Oak Wellfield.

Furthermore, hydrographs for the eight shallow and one deep well, as summarized in **Table 6-4**, that were dry in the baseline were constructed and are included in **Appendix E**. Of these wells, seven wells express a pattern of recovery since the drought indicative of drought recovery. The other two wells are dominated by dry measurements from baseline to present such that it is not possible to draw any conclusions from the data for these wells.

Table 6-4
Summary of Independence-Oak Wellfield Monitoring Wells that were Dry During the Baseline

Shallow Wells	Deep Wells
T548	V014
T549	
T556	
T557	
T558	
T608	
T615	
T616	

Summary

To summarize, the data demonstrate that 83, 83, 92, 100, and 100 percent of Independence-Oak Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1996, 1997, 1998, 1999, and 2000, respectively. Therefore, all wells show substantial recovery since the DRP was instituted in 1992, and the entire wellfield exhibits substantial recovery; therefore, the water level DRP termination criteria have been met.

Hydrologic Indices

Montgomery Watson Harza reviewed groundwater balance data for the Independence-Oak area to determine the status of the hydrologic conditions. The results of this evaluation are presented below.

Groundwater Balance

The Green Book and the mining calculations evaluate the combined recharge for the Independence-Oak, Symmes-Shepherd and Bairs-Georges wellfields. These wellfields are combined in the Green Book on the basis of groundwater flow patterns in the alluvial fan areas and the proximity of the wellfields to one another. For the Independence-Symmes-Bairs area, the results of this water balance evaluation are presented in **Figure 6-2**. This figure shows the annual recharge and pumping as bars with the differences between the bars representing the annual change in storage. This figure also shows the cumulative change in storage since 1969.

The cumulative storage graph indicates a steady increase in storage between Water Year (WY) 1969 through 1986 with about 444,000 acre-ft of water was accumulating in storage prior to the recent drought. From WY 1987 through 1989, approximately 23,000 acre-ft of water was pumped from storage to meet water demands during the drought. Since WY 1989, pumping in the Independence-Symmes-Bairs area has been managed conservatively resulting in a gain of 304,000 acre-ft, more than replacing the storage depletions in the late 1980s and early 1990s.

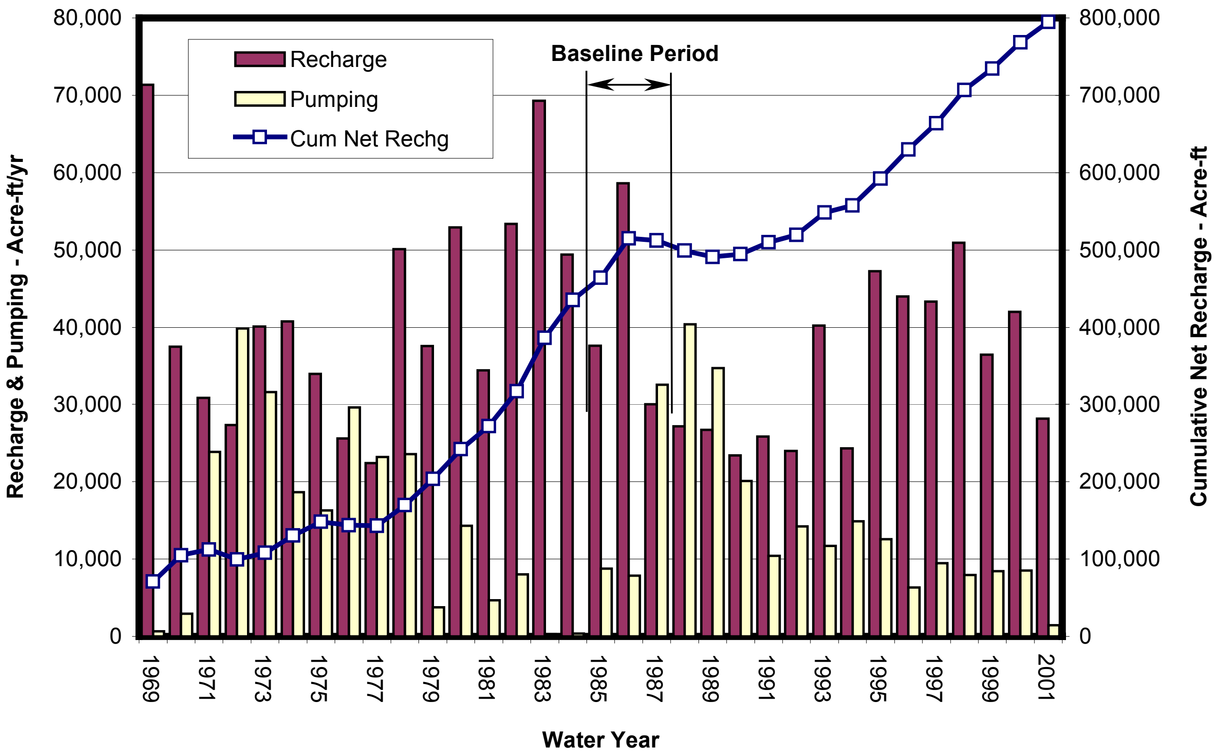


Figure 6-2
Independence-Symmes-Bairs Area Groundwater Balance

Soil Moisture

Methodology

Neutron probe data have been collected on a monthly basis from six soil access tubes from the two monitoring sites (IO1 and IO2) since September 1995. Neutron probe data were collected at 20-cm intervals from a depth of 30 cm to a depth of 550 cm to construct a soil moisture depth profile. Soil moisture data were evaluated using the approach described in the Approach section of Chapter 1.

Data Presentation and Discussion

Precipitation and Soil Moisture

Figure 6-3 and **Figure 6-4**compare the average soil moisture at monitoring sites IO1 (includes an average of soil access tubes IO1-1, IO1-2, and IO1-3) and IO2 (includes an average of soil access tubes IO2-1, IO2-2, and IO2-3) at a depth of 30 cm to monthly precipitation at the LADWP Independence Yard weather station. The uppermost depth measured, 30 cm, was selected to evaluate the correlation between the upper soil profile and precipitation. Subsequent analysis evaluates relationships at two additional depths, whereby the middle depth represents a point in the soil profile least influenced by both surface processes and water levels, and the lowermost depth represents the point most influenced by water levels only.

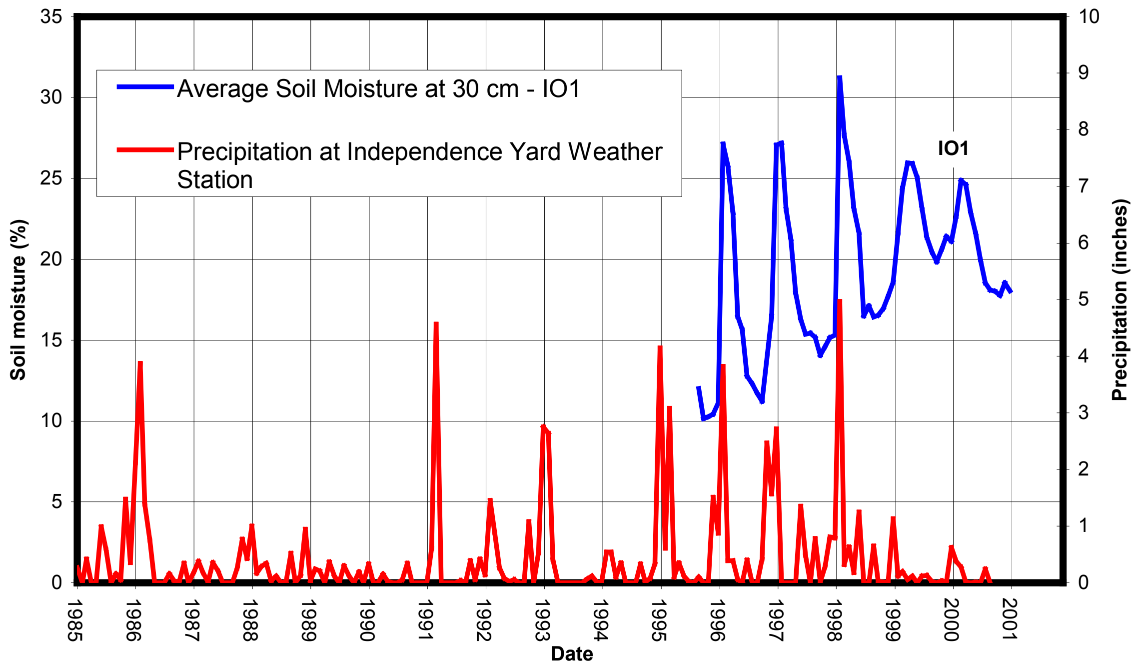


Figure 6-3
Average Soil Moisture at 30 cm for Monitoring Site IO1 versus Precipitation

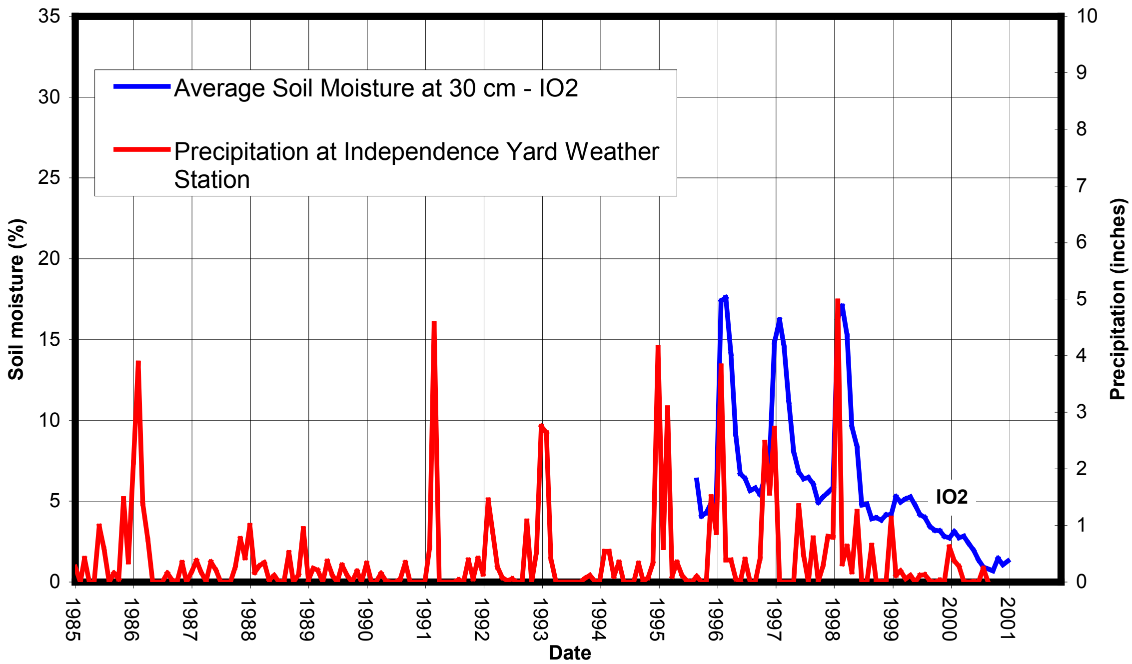


Figure 6-4
Average Soil Moisture at 30 cm for Monitoring Site IO2 versus Precipitation

As presented in these figures, soil moisture at a depth of 30 cm tracks generally parallel to monthly precipitation since 1995 at each monitoring site. Similarly, both monitoring sites have similar percent soil moisture until mid-1998. After 1998, there appears to be a generally downward trend in soil moisture percentages at monitoring site IO2. On the other hand, the general trend in soil moisture percentages increases slightly at monitoring site IO1. This diversion in the trend of each curve may represent changes in surface processes in the vicinity of each monitoring site. These data suggest that the primary mechanism controlling soil moisture near the surface (30 cm) is precipitation, which is consistent with the conceptual soil moisture model.

Water Level and Soil Moisture

Figure 6-5 compares the average soil moisture at depths of 90 cm and 270 cm at monitoring site IO1 to water levels in Well T809. As shown in this figure, percent soil moisture at the 90 cm and 270 cm zones generally parallels water levels in Well T809. Percent soil moisture in the 270 cm is generally higher than in the 90 cm and appears to reach a maximum in the early part of 1998 achieving a soil moisture content of approximately 36 percent. The maximum measurements of about 38 percent correspond to times in which the water level in Well T809 is above the monitoring point of 270 cm and likely represents the saturation point for this soil.

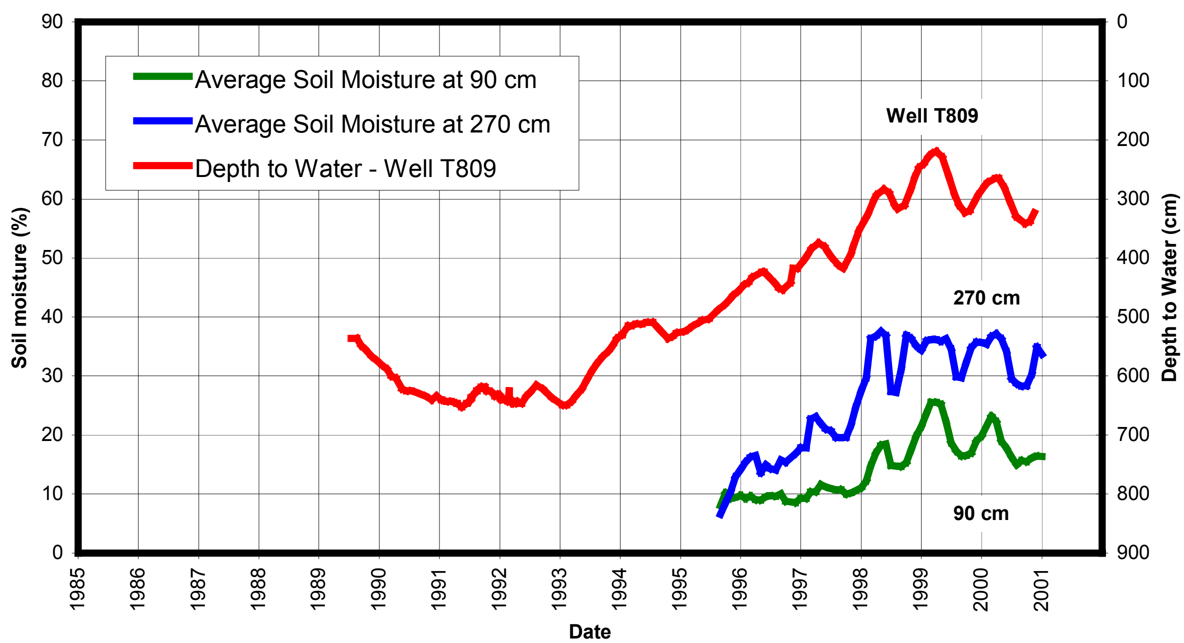


Figure 6-5
Average Soil Moisture for Monitoring Site IO1 versus Water Level

Figure 6-6 compares the average soil moisture at depths of 110 cm and 370 cm at monitoring site IO2 to water levels in Well T548. As shown in this figure, soil moisture remains relatively constant at both levels and does not appear to change with water levels even though water levels are above the 370 cm monitoring point during 1999 and 2000. This is likely attributable to the 0.1 mile horizontal separation between the monitoring site and well.

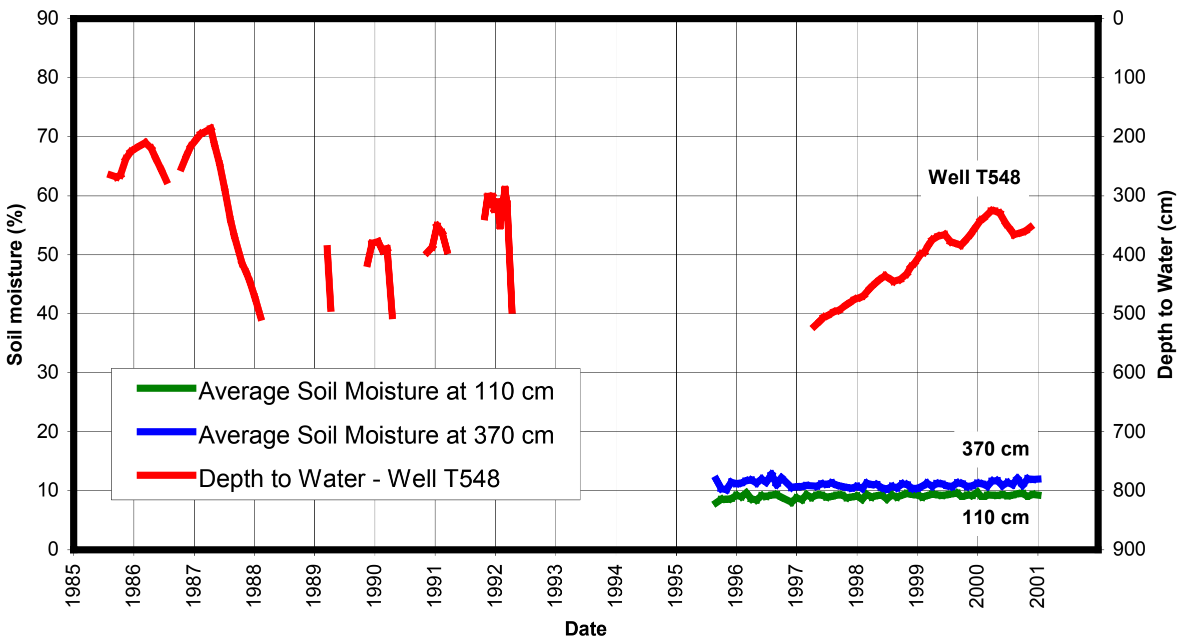


Figure 6-6
Average Soil Moisture for Monitoring Site IO2 versus Water Level

Soil Moisture Profiles

As discussed in the conceptual soil moisture model, soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. Soil profiles for each location were compiled to evaluate the vertical relationship among water table, precipitation, and soil moisture. Vertical profiles were constructed for the maximum water level and the minimum water level during the time period from 1995 to 2000. Consequently, these data should represent the approximate range in soil moisture attributable to groundwater at each depth for this period.

Figure 6-7 presents soil moisture profiles in soil probe IO1-3 during the time periods September 1995 and April 1999, which are correlative with the maximum and minimum water levels. As shown in this figure, soil moisture in April 1999 reaches a maximum of about 40 percent at a depth of about 210 cm, which is roughly coincident with water level. In this analysis, soil moisture throughout the profile is lower in September 1995 when water levels are lower. At this site, depth to groundwater and the associated capillary fringe appears to influence soil moisture below a depth of 100 cm during this time period.

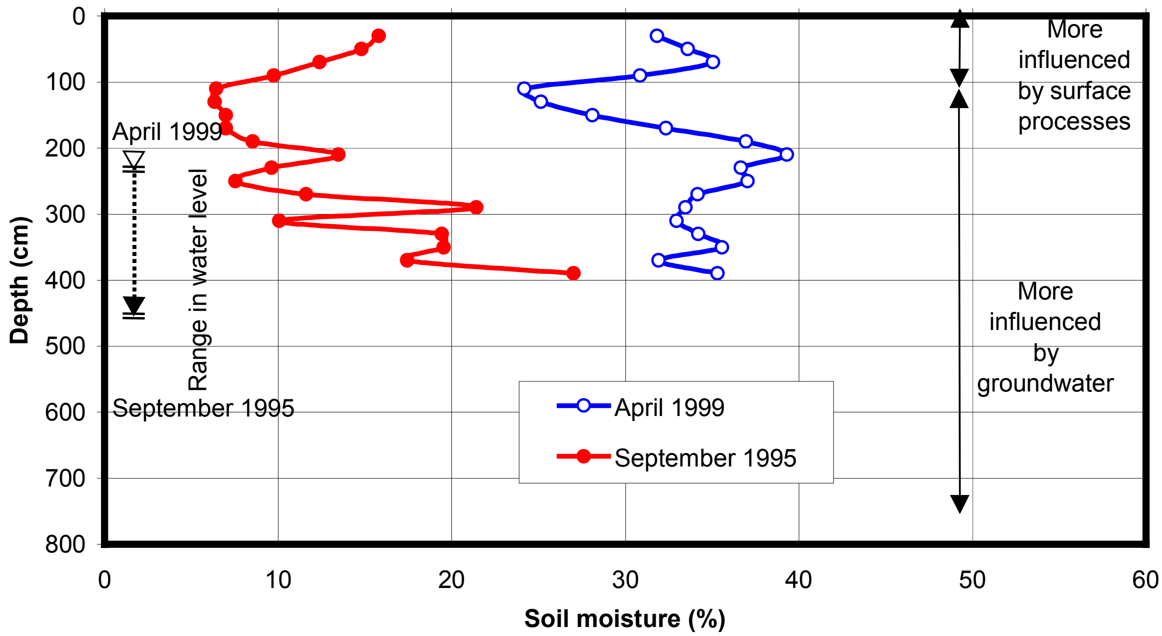


Figure 6-7
Soil Moisture Profile for Soil Probe IO1-3

Figure 6-8 presents soil moisture profiles in soil probe IO2-1 during the time periods April 1997 and March 2000, which are correlative with the maximum and minimum water levels. As shown in this figure, soil moisture in both profiles are nearly identical and do not appear to change with water level during this time period. In this analysis, the lack of a correlation is likely due to the horizontal separation between the monitoring site and well.

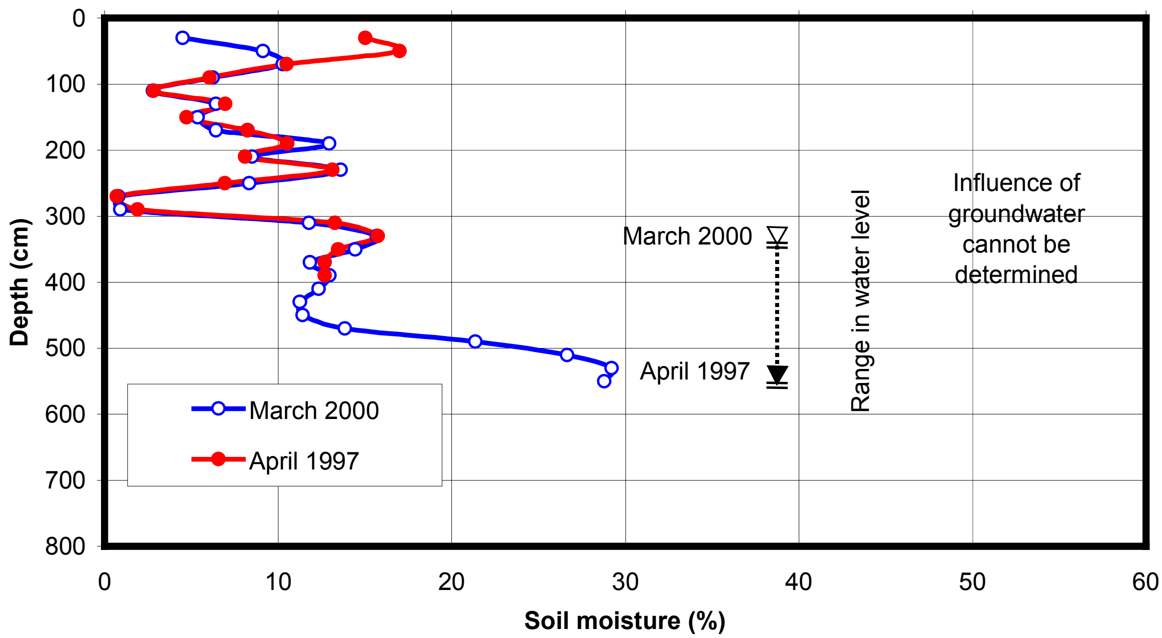


Figure 6-8
Soil Moisture Profile for Soil Probe IO2-1

Summary

Soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. The data presented herein validate that the upper portion of the soil profile appears to be more strongly influenced by surface water processes while the lower portion of the soil profile appears to be more strongly influenced by groundwater levels. This is clearly consistent with the conceptual model. Because soil moisture in the upper portion of the soil profile (the exact depth of this interface varies with time and location) is largely independent of groundwater levels, soil moisture in these portions of the soil profile should not be used to identify a return to baseline conditions nor the influence of groundwater pumping. Most significantly, from the strong correlation between water levels and the soil moisture associated with the capillary fringe, it can inferred that since water levels in the Independence-Oak management area have recovered then the portion of the soil moisture profile influenced by the water table also exhibits substantial recovery.

Findings

1. The DRP states that "substantial recovery in soil moisture and water table conditions" are the criteria by which the DRP is terminated. Until then, it is intended for "environmentally conservative" groundwater pumping to be conducted. The DRP does not specify the consideration of any other criteria in determining the termination of DRP.

2. Eighty-three, 83, 92, 100, and 100 percent of Independence-Oak Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1996, 1997, 1998, 1999, and 2000, respectively. All wells show substantial recovery since the DRP was instituted in 1992. Therefore the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

3. Evaluation of net recharge (recharge less pumping) in the Independence-Symmes-Bairs area also documents drought recovery. Since 1992, pumping in the Independence-Symmes-Bairs area has been managed conservatively resulting in a storage gain of 304,000 acre-ft since 1994, more than replacing the storage depletions in the late 1980s and early 1990s.

4. Neutron probe soil moisture data do not exist for the baseline period. Neutron probe data were not available prior to 1995. Despite the absence of baseline data, analysis of the available data yields information pertinent to the DRP.

5. Soil moisture data from the Independence-Oak monitoring sites show a direct correlation between the lower portion of the soil profile and groundwater levels. Soil moisture in the lower portion of the soil moisture profile is predominantly influenced by water levels. For the 1995 to 2000 time period, this depth is about 100 cm at site IO1, but undeterminable from available data at monitoring sites IO2.

6. Although baseline data for soil moisture are not available, we have been able to conclude that based on the depth-to-groundwater/soil moisture relationships demonstrated by the data described above, and because groundwater levels in the Independence-Oak Wellfield have substantially recovered, it necessarily follows that soil moisture levels to the extent that they are influenced by groundwater levels, have also recovered.

7. Soil moisture above the depth where groundwater is the predominant influence is controlled by numerous other factors such as precipitation, surface land use activities, and evapotranspiration. Of these, only precipitation is a direct measure of drought conditions. Consequently, for this upper portion of the soil profile, only the consideration of precipitation is appropriate for evaluation of drought recovery.

Recommendations

Based on the findings above and associated preponderance of evidence concerning depth to water data, groundwater balance, and soil moisture, substantial recovery as defined in the DRP has been achieved. To summarize, the data clearly demonstrate that termination of the DRP is appropriate.

Chapter 7

Symmes-Shepherd Wellfield

Chapter 7
Symmes-Shepherd Wellfield

Wellfield Description

Located in the Owens Valley immediately to the south of the town of Independence, the Symmes-Shepherd Wellfield is one of seven wellfields operated by the LADWP where groundwater pumping and extraction have been governed by the DRP. The provisions in the Green Book (October 1991) provide for four monitoring sites at this wellfield, SS1 through SS4, as summarized in **Table 7-1** and shown on **Figure 7-1**.

Table 7-1
Summary of Symmes-Shepherd Monitoring Sites

Monitoring Site	Vegetation Type	Shallow Monitoring Well	Pumping Wells[1]	EM Wells
SS1	B	V009G	W69AQ, W392AQ (replaced W68AQ), W393AQ (replaced W66AQ)	
SS2	B	T646	W74AQ, W394AQ (replaced W67AQ), W395AQ (replaced W73AQ)	
SS3	C	T561	W92AQ, W396AQ (replaced W96AQ)	W99EM
SS4	B	T811	W75AQ, W345AQ	

[1] Well W402EM ((sole source irrigation well) is located within the Symmes-Shepherd Wellfield, but exempt from Green Book on/off provisions and DRP provisions.

Monitoring Site SS1

Monitoring Site SS1 is associated with pumping wells W69AQ, W392AQ, and W393AQ. The shallow monitoring well at this site is Well V009G, which has a depth to water history from 1985 forward, and thereby provides a portion of the 1985-1987 Runoff Year baseline. There are three soil moisture access tubes at this site (SS1-1, SS1-2, and SS1-3). Representative vegetation at monitoring site SS1 has been mapped as Type B.

Monitoring Site SS2

Monitoring Site SS2 is associated with pumping wells W74AQ, W394AQ, and W395AQ. The shallow monitoring well at this site is Well T646, which has a depth to water history from October 1987 to present, thereby providing limited baseline data. In addition, there are three soil moisture access tubes at this site (SS2-1, SS2-2, and SS2-3). Representative vegetation at monitoring site SS2 has been mapped as Type B.

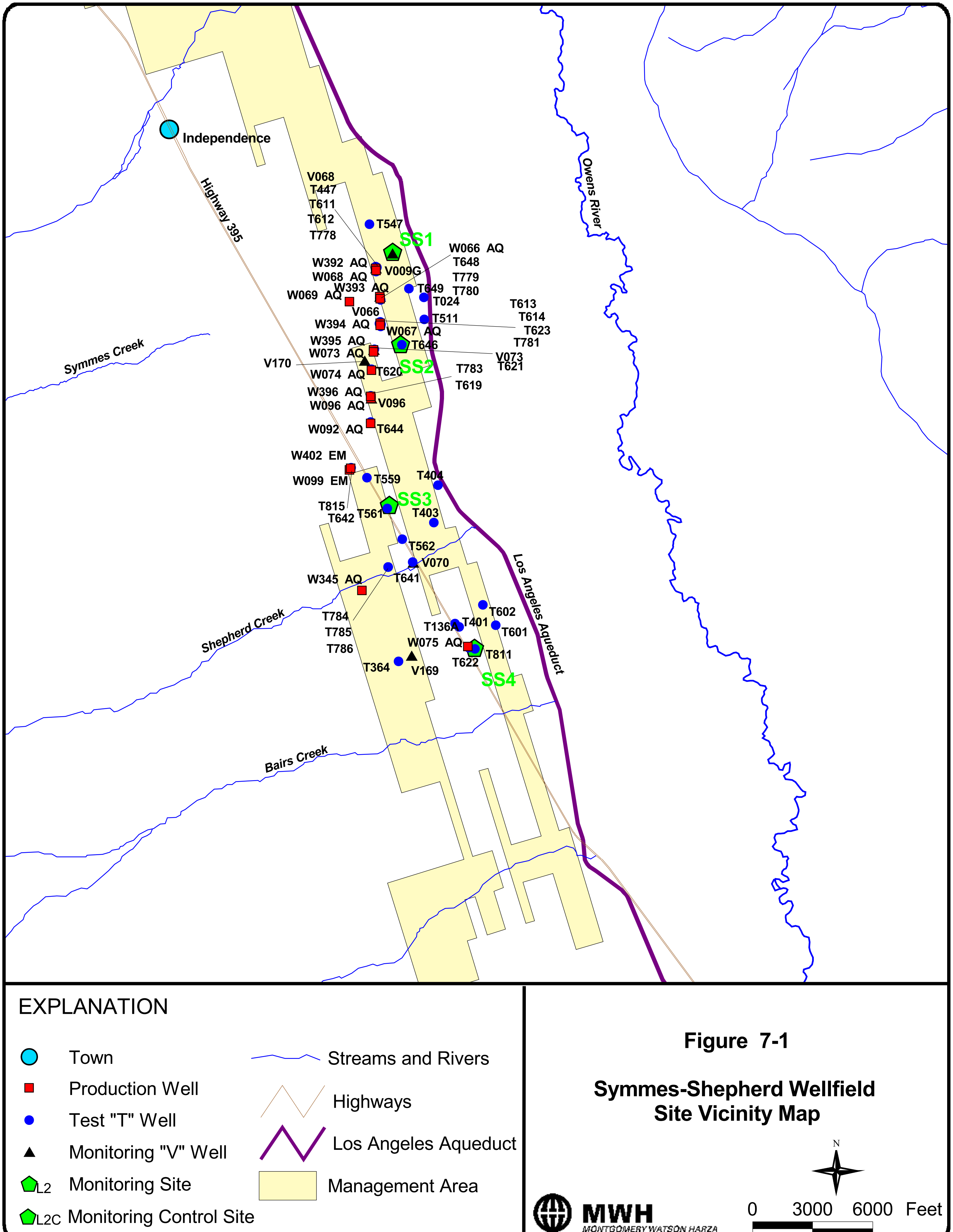


Figure 7-1

Symmes-Shepherd Wellfield Site Vicinity Map

Monitoring Site SS3

Monitoring Site SS3 is associated with pumping wells W92AQ and W396AQ, as well as EM well W99EM. The shallow monitoring well at this site is Well T561, which has a depth to water history from August 1985 to present, thereby providing a portion of the 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (SS3-1, SS3-2, and SS3-3). Representative vegetation at monitoring site SS3 has been mapped as Type C.

Monitoring Site SS4

Monitoring Site SS4 is associated with pumping wells W75AQ and W345AQ. The shallow monitoring well at this site is Well T811, which has a depth to water history from May 1989 to present, and thereby does not provide a 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (SS4-1, SS4-2, and SS4-3). Representative vegetation at monitoring site SS4 has been mapped as Type B.

Management Area Monitoring Wells

There are a total of 40 shallow wells and seven deep wells, as shown on **Figure 7-1**, within the Symmes-Shepherd management area. As summarized in **Table 7-2**, the following descriptive statistics apply to this data set of wells:

- Twelve of the shallow wells and four of the deep wells do not have baseline data and no analysis was performed on these wells.
- Eleven of the shallow wells were dry in the baseline allowing for a qualitative evaluation only.
- Seventeen of the shallow wells and three of the deep wells have data suitable for the quantitative analysis described in Chapter 1.
- Although quantitative and qualitative evaluations are conducted on suitable shallow and deep wells, only the 17 shallow wells, whose data represent water table conditions suitable for quantitative analysis, are used to validate DRP termination.

Table 7-2
Summary of Wells in the Symmes-Shepherd Wellfield Management Area

Descriptive Statistic	Quantity of Wells	
	Shallow	Deep
Wells in Management Area	40	7
Wells with No Baseline Data – No Analysis Performed	12	4
Wells that were Dry in Baseline - Qualitative Analysis Performed	11	0
Wells with Complete Data Sets - Quantitative Analysis Performed	17	3
Wells Used to Validate DRP Termination	**17**	0

Depth to Water

Methodology

As discussed previously, there are a total of 47 monitoring wells within the Symmes-Shepherd Wellfield. Of these 47 monitoring wells, quantitative analyses were performed in accordance with **Table 7-2**. **Figure 7-1** shows the location of Symmes-Shepherd management area wells and **Table 7-3** provides a listing of the 20 monitoring wells evaluated quantitatively.

Table 7-3
Summary of Symmes-Shepherd Wellfield Monitoring Wells Evaluated for DRP Termination

Well	Baseline			DTW Drought Low (fbgs)	DTW 80% Recovery (fbgs)	Runoff Year(s) During which Low Point Occurred	Substantial Recovery Achieved by Runoff Year						
	Mean[1] (fbgs)	Lower 95% CI[2]	Upper 95% CI[2]				1995	1996	1997	1998	1999	2000	Summary[4]
T024	6.4	6.7	6.1	13.5	7.8	1989				X	X	X	X
T364	12.4	13.8	11.1	25.8	15.1	1989					X		X
T401	20.8	23.0	18.6	36.0	23.9	1988	X	X	X	X	X	X	X
T403	7.1	7.9	6.3	16.6	9.0	1989		X	X	X	X	X	X
T404	4.4	4.8	4.1	9.7	5.5	1989	X	X	X	X	X	X	X
T447	25.2	27.6	22.9	56.0	31.4	1989					X	X	X
T511	5.0	5.4	4.6	10.4	6.1	1989				X	X	X	X
T547	23.5	25.1	21.8	40.1 [3]	26.8	1988-1996							
T562	11.1	12.0	10.3	17.1 [3]	12.3	1988-1990	X	X	X	X	X	X	X
T601	11.0	11.7	10.3	17.6	12.3	1988		X	X	X	X	X	X
T602	13.3	13.9	12.7	18.3 [3]	14.3	1988-1989, 1990		X	X	X	X	X	X
T612	33.1			41.3 [3]	34.7	1988-1998					X	X	X
T622	27.4			31.7	28.3	1988	X	X	X	X	X	X	X
T641	19.0			21.5	19.5	1989	X	X	X	X	X	X	X
T646	21.1	49.1	-6.9	28.4 [3]	22.6	1988-1996				X	X	X	X
T649	11.4			26.1	14.3	1990					X	X	X
V009G	6.9	8.5	5.4	12.1	12.1	1989					X	X	X
Symmes-Shepherd Wellfield Management Area Percent Recovery for Shallow Wells:							29%	47%	47%	69%	**94%**	**88%**	**94%**
V070	13.8	16.0	11.6	16.1	16.1	1988	X	X	X	X	X	X	X
V169	8.5	10.1	6.8	10.9	10.9	1988	X	X	X	X	X	X	X
V170	47.6	51.0	44.2	55.7 [3]	55.7	1988-1989			X	X	X	X	X
Symmes-Shepherd Wellfield Management Area Percent Recovery for Deep Wells:							67%	67%	**100%**	**100%**	**100%**	**100%**	**100%**

[1] Baseline Mean is calculated from all available depth to water measurements collected during the baseline, on a Runoff Year basis (1985-1987).
[2] In some instances, only one data point was available for the baseline mean, in which case confidence intervals could not be calculated. Also in some cases, the recovery mean upper CI is negative. We recognize that statistically this is correct, but physically, this number cannot be less than 0.
[3] DTW Drought Low represents the depth of the well as the well went dry at this point, precluding measurement of the actual water level. As a result, the actual DTW 80% recovery is lower than that presented in the table.
[4] This "Summary" column indicates if substantial recovery has been achieved in a well at any time since the DRP was instituted in 1992.

Data Presentation

The quantitative methodology described in the Approach section of Chapter 1 was applied to the 17 shallow wells and three deep wells. Baseline mean and 95 percent confidence intervals were calculated and are summarized in **Table 7-3**. Also shown in this table is the lowest depth to water recorded during the drought (DTW Drought Low), the water level that represents 80 percent recovery using Equation 2 (DTW 80% Recovery), runoff year during which low point occurred, and a column for each potential recovery year (Runoff Years 1995 – 2000).

Hydrographs for these 20 wells graphically depict the baseline and 80 percent recovery line and are provided **Appendix F**. In general, depth to water measurements were high during the baseline period, yet declined during the drought, and since the drought's end, water levels have steadily climbed, typically achieving recovery in the late 1990s.

Discussion

The data demonstrate that 94 percent and 88 percent of Symmes-Shepherd Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1999 and 2000, respectfully. In addition, 94 percent of shallow wells exhibit substantial recovery since the DRP was instituted in 1992. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

Similarly, three of the three (100 percent) Symmes-Shepherd deep wells exhibit substantial recovery in Runoff Years 1997 – 2000, which indicates substantial recovery since the DRP was instituted in 1992 and lends additional support to termination of the DRP at the Symmes-Shepherd Wellfield.

Furthermore, hydrographs for the 11 shallow wells, as summarized in **Table 7-4**, that were dry in the baseline were constructed and are included in **Appendix A**. Of these wells, three express a pattern of recovery since the drought indicative of drought recovery. The other eight wells are dominated by dry measurements from baseline to present such that it is not possible to draw any conclusions from the data for these wells.

Table 7-4
Summary of Symmes-Shepherd Wellfield Monitoring Wells that were Dry During the Baseline

Shallow Wells	Deep Wells
T316A	
T559	
T561	
T611	
T613	
T614	
T619	
T620	
T621	
T644	
T648	

Summary

To summarize, 94 percent and 88 percent of Symmes-Shepherd Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1999 and 2000, respectively. In addition, 94 percent of shallow wells exhibit substantial recovery since the DRP was instituted in 1992. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

Hydrologic Indices

Montgomery Watson Harza reviewed groundwater balance data for the Symmes-Shepherd area to determine the status of the hydrologic conditions. The results of this evaluation are presented below.

Groundwater Balance

As discussed in Chapter 6, the mining calculations for the Symmes-Shepherd wellfield are not computed separately, but instead are combined with those for the Independence-Symmes-Bairs area. The discussion in that chapter indicates that the Independence-Symmes-Bairs area accumulated about 444,000 acre-ft of groundwater in storage in the wet period of the later 1970s through the mid-1980s. Increased groundwater pumping during the 1986-1991 drought extracted about 23,000 acre-ft of water from storage. Since the end of the drought, about 304,000 acre-ft of groundwater storage has been accrued, more than replacing the water removed during the drought.

Soil Moisture

Methodology

Neutron probe data have been collected on a monthly basis from 12 soil access tubes from the four monitoring sites (SS1, SS2, SS3, and SS4) since July 1995. Neutron probe data were collected at 20-cm intervals from a depth of 30 cm to a depth of 550 cm to construct a soil moisture depth profile. Soil moisture data were evaluated using the approach described in the Approach section of Chapter 1.

Data Presentation and Discussion

Precipitation and Soil Moisture

Figure 7-2 through **Figure 7-5** compare the average soil moisture at monitoring sites SS1 (includes an average of SS1-1, SS-1-2, and SS-3), SS2 (includes an average of soil access tubes SS2-1, SS2-2, and SS2-3), SS3 (includes an average of soil access tubes SS3-1, SS3-2, and SS3-3), and SS4 (includes an average of soil access tubes SS4-1, SS4-2, and SS4-3) at a depth of 30 cm to monthly precipitation at the LADWP Independence Yard weather station. Subsequent analysis evaluates relationships at two additional depths, whereby the middle depth represents a point in the soil profile least influenced by both surface processes and water levels, and the lowermost depth represents the point most influenced by water levels only.

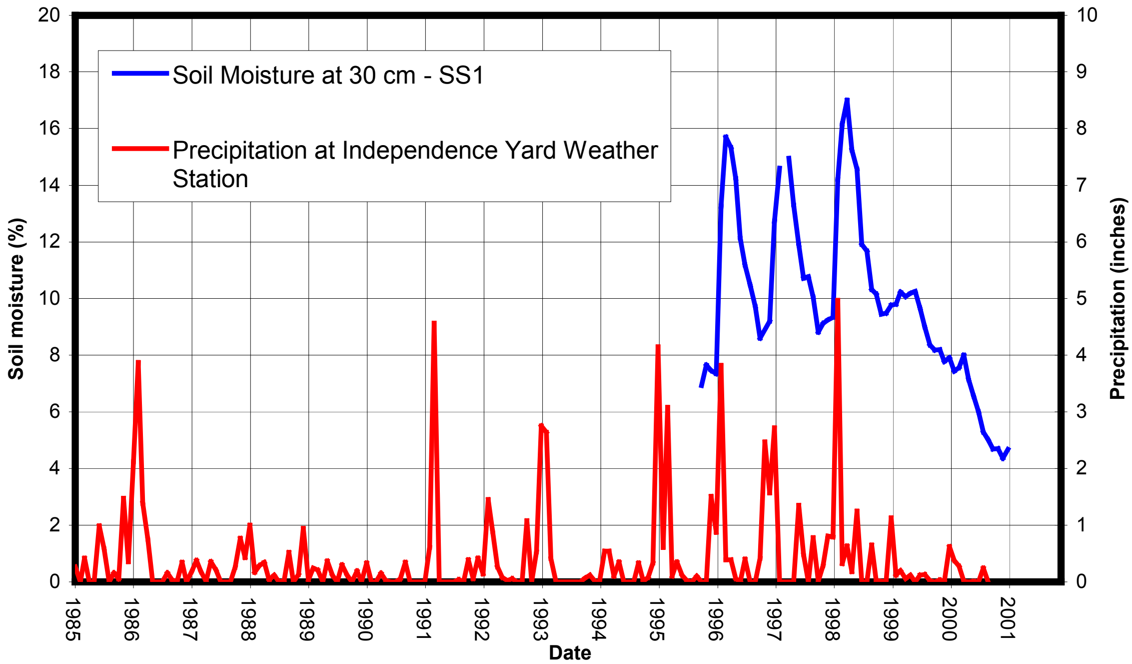


Figure 7-2
Average Soil Moisture at 30 cm for Monitoring Site SS1 versus Precipitation

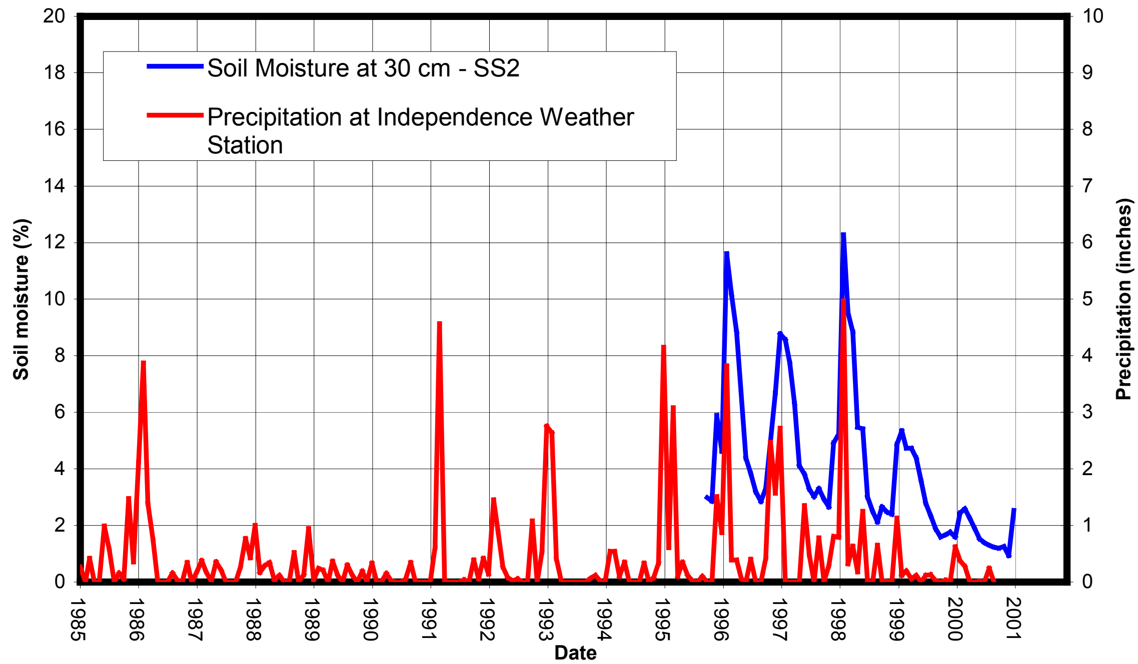


Figure 7-3
Average Soil Moisture at 30 cm for Monitoring Site SS2 versus Precipitation

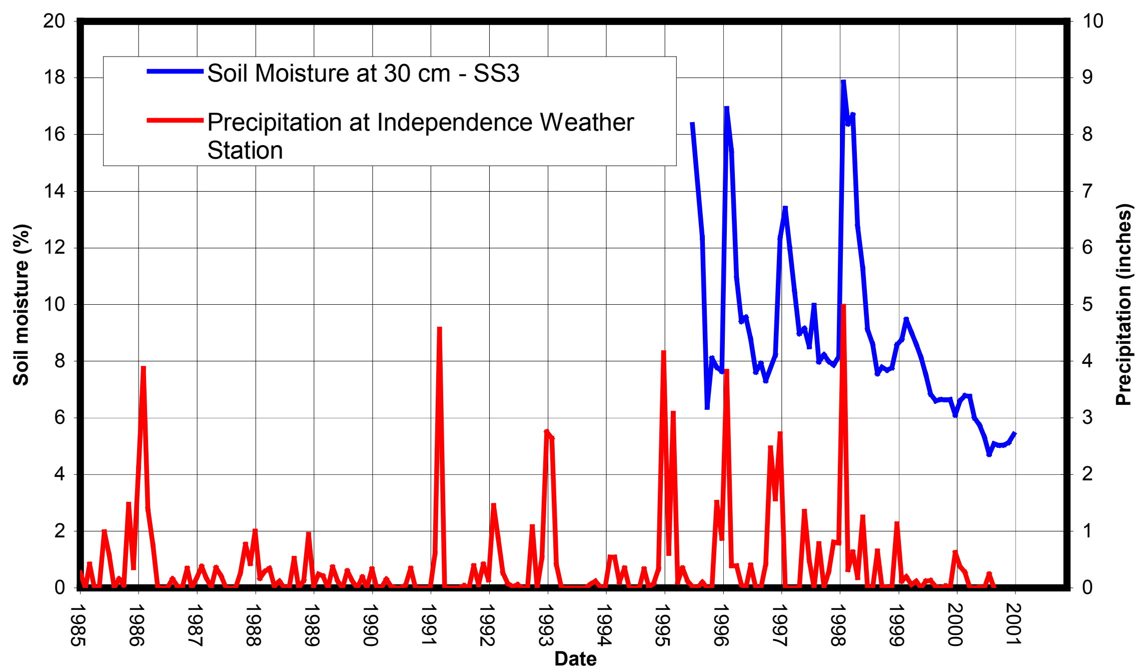


Figure 7-4
Average Soil Moisture at 30 cm for Monitoring Site SS3 versus Precipitation

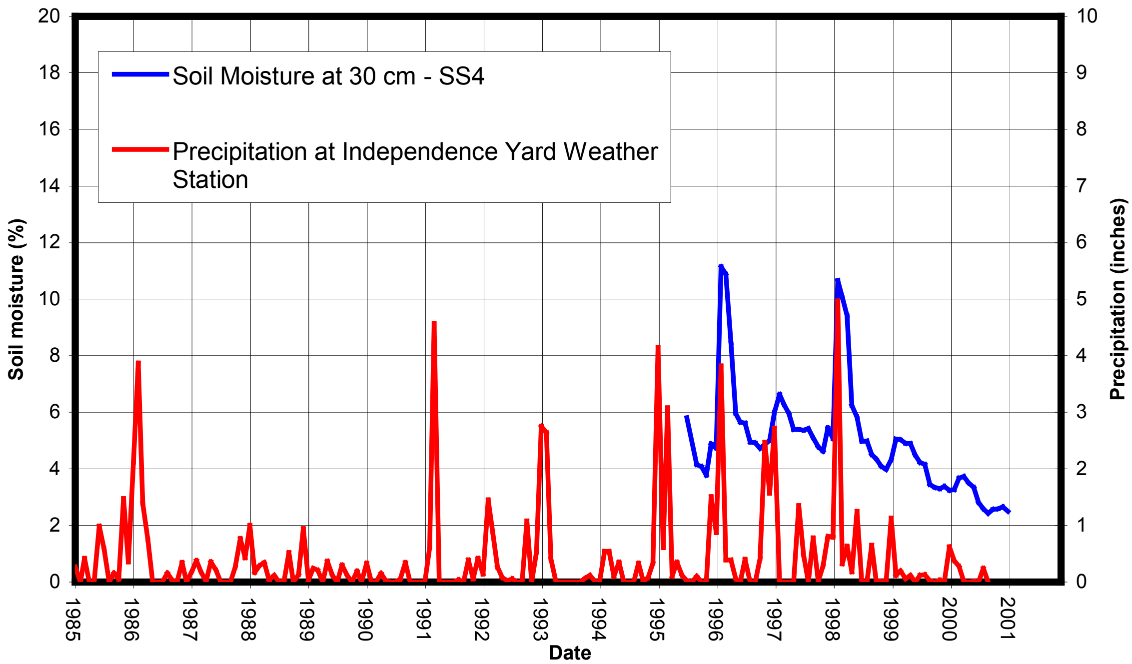


Figure 7-5
Average Soil Moisture at 30 cm for Monitoring Site SS4 versus Precipitation

The figures indicate that the soil moisture at a depth of 30 cm tracks generally parallel to monthly precipitation since 1995. Similarly, all three monitoring sites have similar percent soil moisture until mid-1998. After 1998, there appears to be a generally downward trend in soil moisture at all monitoring sites. These data suggest that the primary mechanism controlling soil moisture near the surface (30 cm) is precipitation, which is consistent with the conceptual soil moisture model.

Water Level and Soil Moisture

Figure 7-6 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site SS1 to water levels in Well V009G. As shown in this figure, soil moisture prior to 1998 at both levels is relatively low. In 1998, the soil moisture at 370 cm increases as water level increase attaining a maximum soil moisture of approximately 40 percent. The maximum measurements correspond to times in which the water level in Well V009G is roughly coincident with the monitoring point of 370 cm and likely represents the saturation point for this soil. Soil moisture at 170 cm remains below about 15 percent and does not appear to be influenced by the groundwater level.

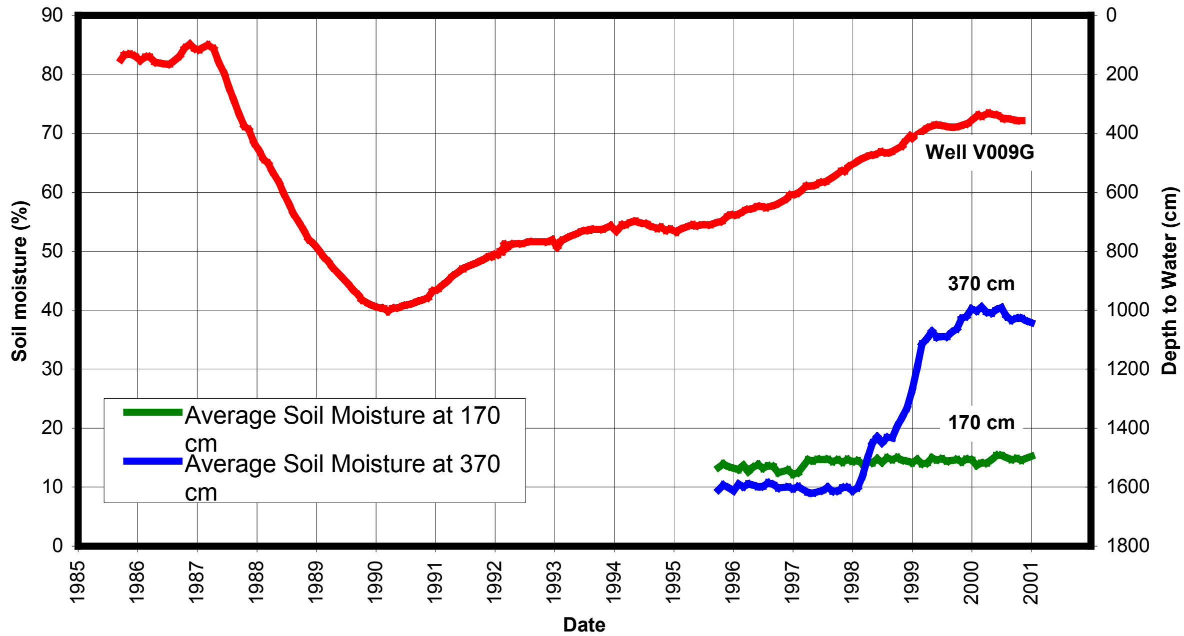


Figure 7-6
Average Soil Moisture for Monitoring Site SS1 versus Water Level

Figure 7-7 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site SS2 to water levels in Well T646. As shown in this figure, soil moisture at both levels do not change substantially, with soil moisture at approximately 15 percent at 370 cm and 5 percent at 170 cm, respectively. The absence of change in soil moisture suggests no influence from groundwater, which is significantly deeper.

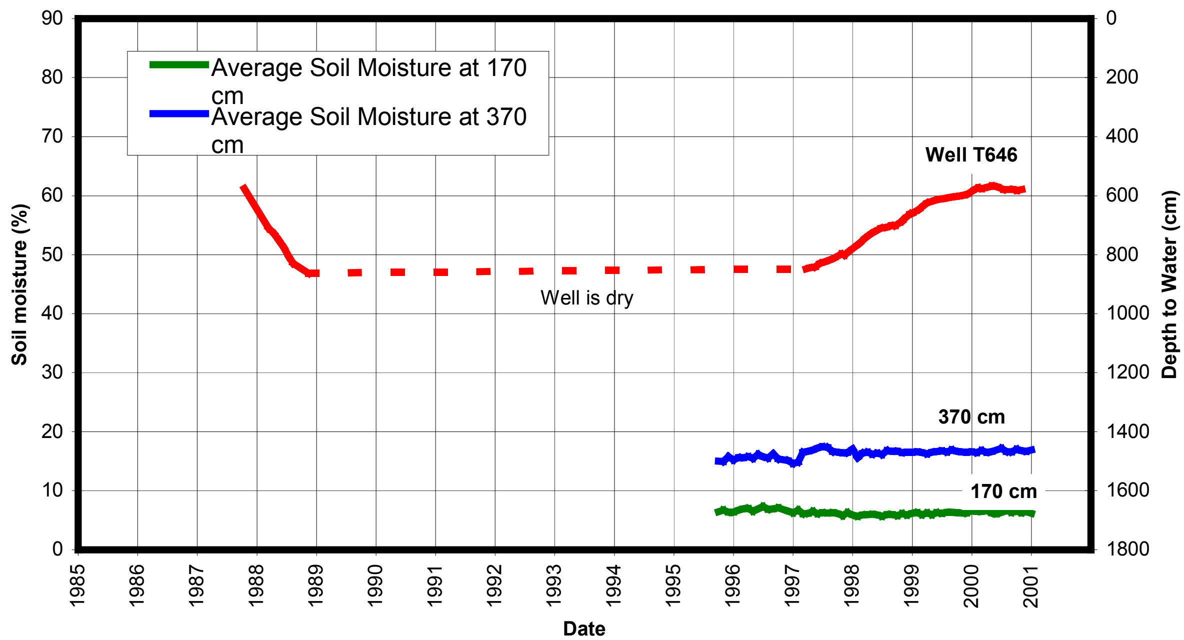


Figure 7-7
Average Soil Moisture for Monitoring Site SS2 versus Water Level

Figure 7-8 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site SS3 to water levels in Well T561. As shown in this figure, soil moisture is relatively constant at the 170 cm level, whereas the 370 cm level increases with water level to a maximum of about 40 percent. The maximum measurements correspond to times in which the water level in Well T561 is above the monitoring point of 370 cm and likely represents the saturation point for this soil. Prior to 1998, soil moisture in the 170 cm level was higher than the 370 cm level.

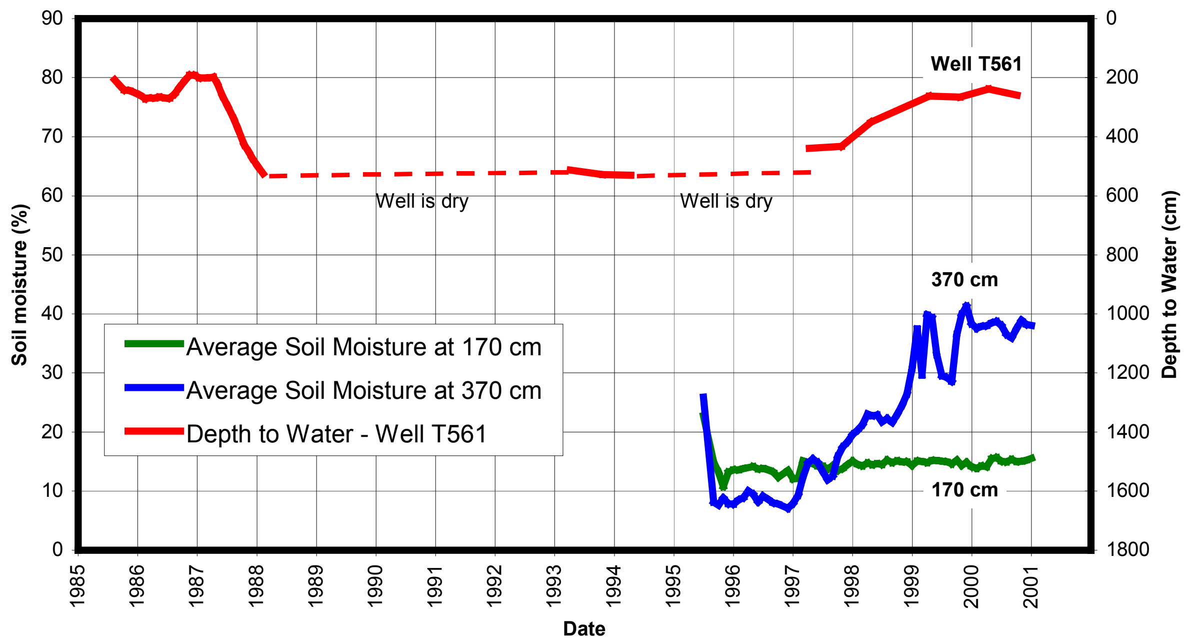


Figure 7-8
Average Soil Moisture for Monitoring Site SS3 versus Water Level

Figure 7-9 compares the average soil moisture at depths of 170 cm and 370 cm at monitoring site SS4 to water levels in Well T811. As shown in this figure, the trend in soil moisture at 370 cm generally parallels water level. Soil moisture at 170 cm does not change substantially.

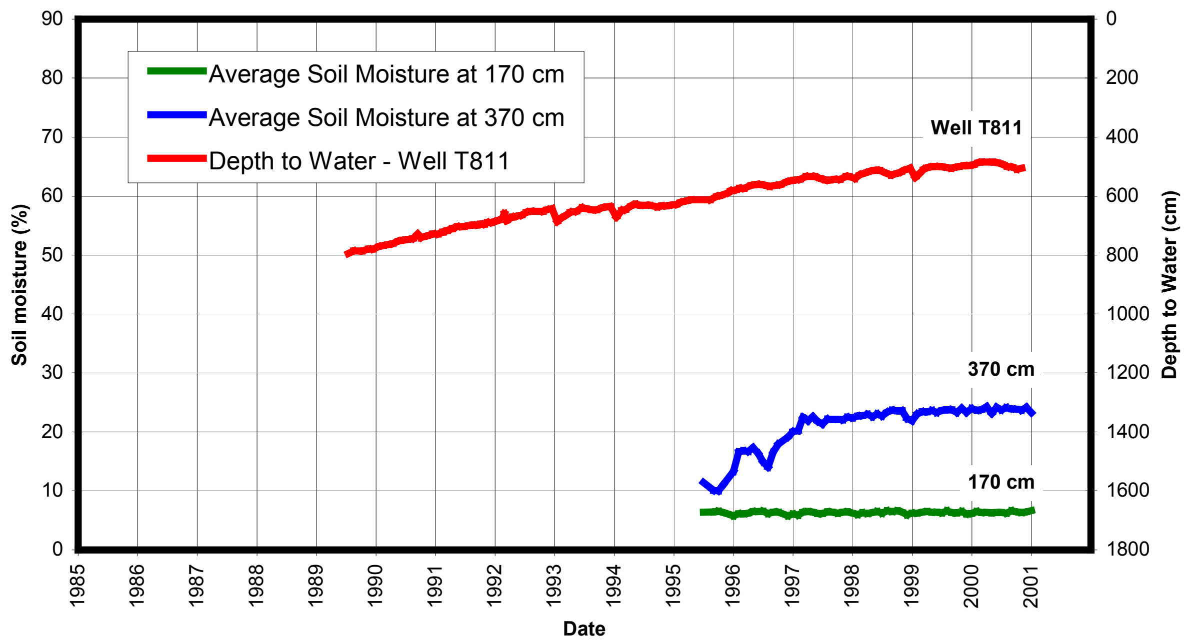


Figure 7-9
Average Soil Moisture for Monitoring Site SS4 versus Water Level

Soil Moisture Profiles

As discussed in the conceptual soil moisture model, soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. Soil profiles for each location were compiled to evaluate the vertical relationship among water table, precipitation, and soil moisture. Vertical profiles were constructed for the maximum water level and the minimum water level during the time period from 1995 to 2000. Consequently, these data should represent the approximate range in soil moisture attributable to groundwater at each depth for this period.

Figure 7-10 presents soil moisture profiles in soil probe SS1-1 during the time periods October 1995 and April 2000, which are correlative with the maximum and minimum water levels. As shown in this figure, the soil moisture in October 1995 is typically less than in April 2000 throughout the profile (although data for October 1995 are incomplete below 390 cm). This observation is consistent with the fact that water levels are substantially lower during this time period.

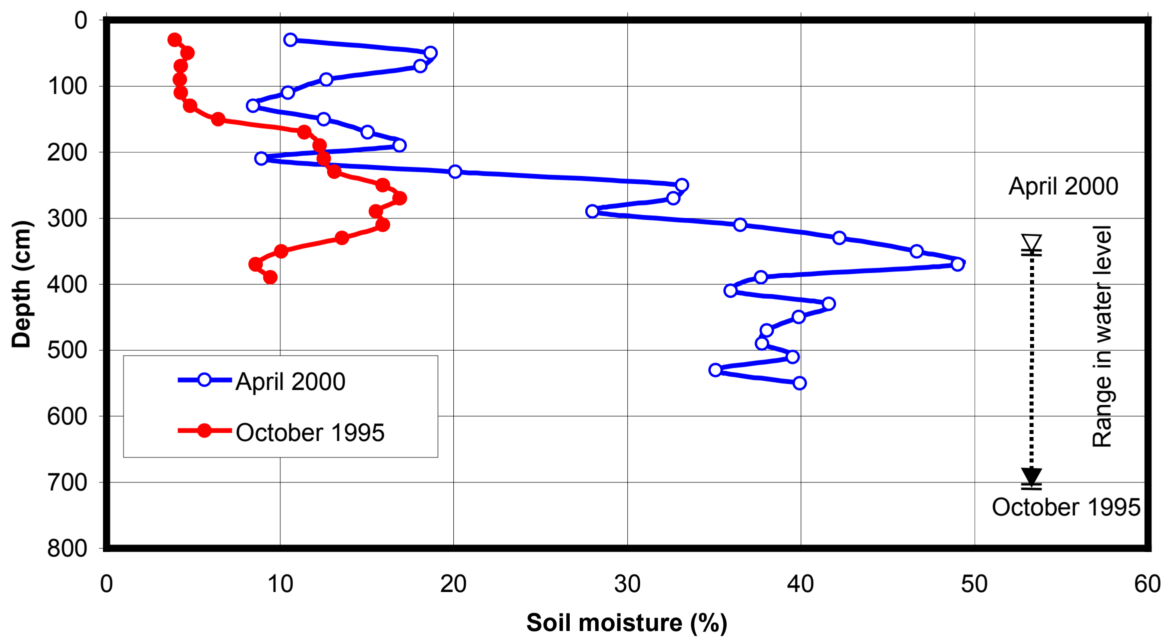


Figure 7-10
Soil Moisture Profile for Soil Probe SS1-1

Figure 7-11 presents soil moisture profiles in soil probe SS2-1 during the time periods April 1997 and April 2000, which are correlative with the maximum and minimum water levels. As shown in this figure, the two curves are relatively similar throughout the profile during this time period (although data for April 1997 are incomplete below 390 cm). In this analysis, the profile does not appear to be affected by changes in water levels.

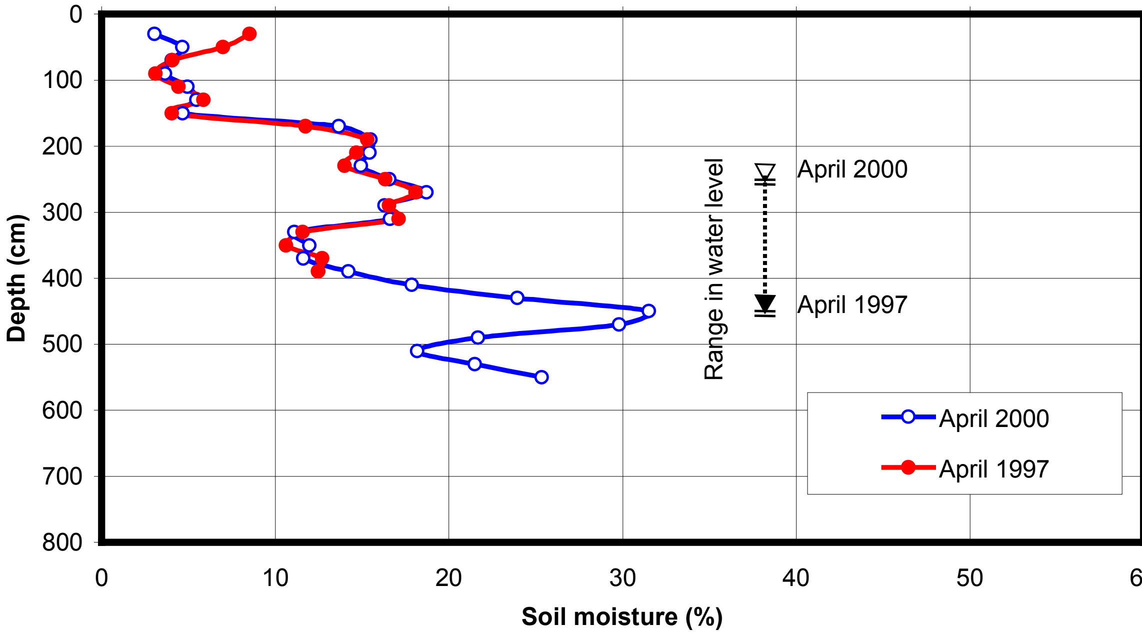


Figure 7-11
Soil Moisture Profile for Soil Probe SS2-1

Figure 7-12 presents soil moisture profiles in soil probe SS3-1 during the time periods April 1997 and April 2000, which are correlative with the maximum and minimum water levels. As shown in this figure, the soil moisture profiles for both time periods track nearly identically from 50 cm to 200 cm. Soil moisture in April 2000 exceeds 50 percent, where as soil moisture in April 1997 attains a maximum of 15 percent. In this analysis, these data indicate that the capillary fringe influences soil moisture up to about 220 cm during the time period shown.

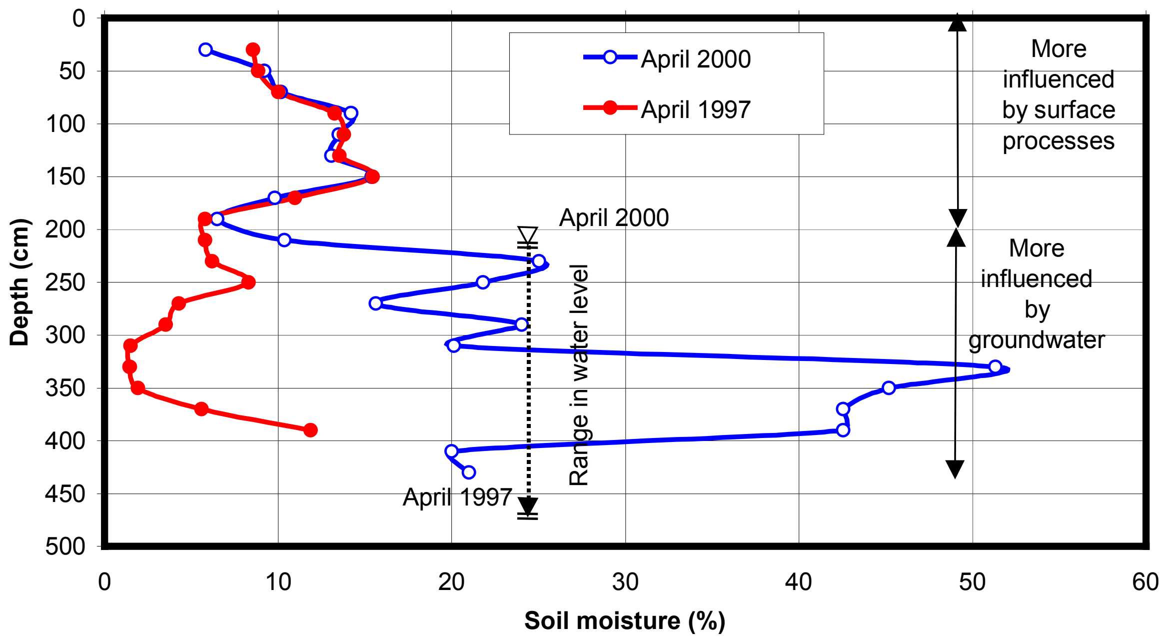


Figure 7-12
Soil Moisture Profile for Soil Probe SS3-1

Figure 7-13 presents soil moisture profiles in soil probe SS4-1 during the time periods July 1995 and March 2000, which are correlative with the maximum and minimum water levels. As shown in this figure, the soil moisture profiles for both time periods track nearly identically at and above 200 cm. Soil moisture in March 2000 exceeds 25 percent below 300 cm while in July 1995, the soil moisture is below 10 percent. In this analysis, the relationships indicate that the capillary fringe influences soil moisture up to about 220 cm during the time period shown.

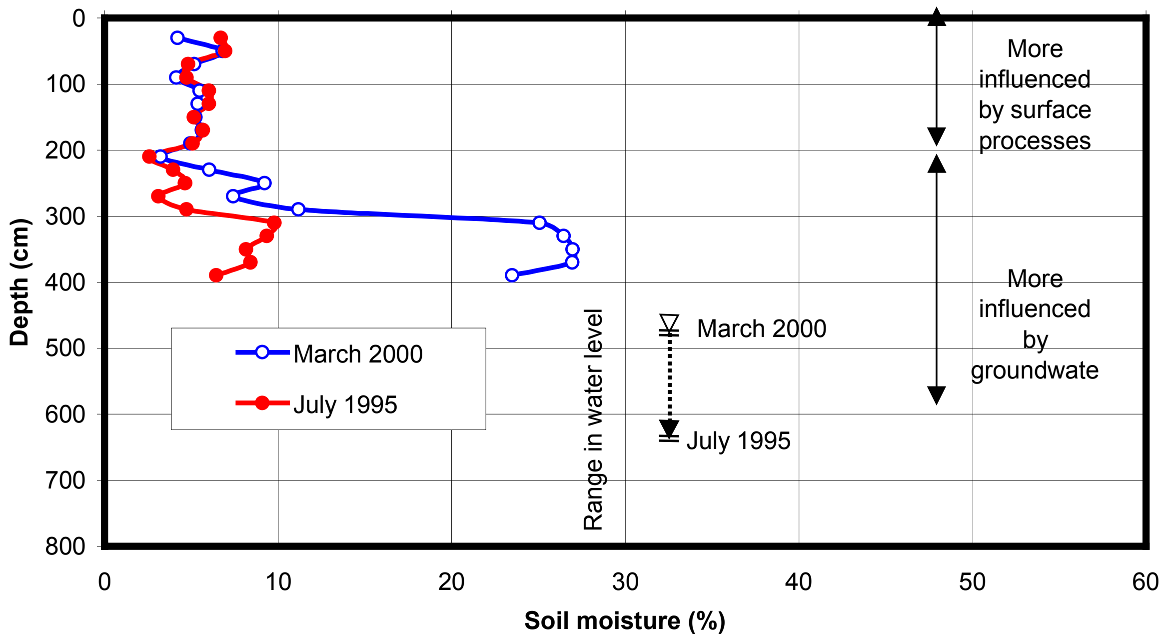


Figure 7-13
Soil Moisture Profile for Soil Probe SS4-1

Summary

Soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. The data presented herein validate that the upper portion of the soil profile appears to be more strongly influenced by surface water processes while the lower portion of the soil profile appears to be more strongly influenced by groundwater levels. This is clearly consistent with the conceptual model. Because soil moisture in the upper portion of the soil profile (the exact depth of this interface varies with time and location) is largely independent of groundwater levels, soil moisture in these portions of the soil profile should not be used to identify a return to baseline conditions nor the influence of groundwater pumping. Most significantly, from the strong correlation between water levels and the soil moisture associated with the capillary fringe, it can inferred that since water levels in the Symmes-Shepherd management area have recovered then the portion of the soil moisture profile influenced by the water table also exhibits substantial recovery.

Findings

1. The DRP states that "substantial recovery in soil moisture and water table conditions" are the criteria by which the DRP is terminated. Until then, it is intended for "environmentally conservative" groundwater pumping to be conducted. The DRP does not specify the consideration of any other criteria in determining the termination of DRP.

2. Ninety-four and 88 percent of Symmes-Shepherd Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1999 and 2000, respectfully. In addition, 94 percent of shallow wells exhibit substantial recovery since the DRP was instituted in 1992. Therefore, the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

3. Evaluation of net recharge (recharge less pumping) in the Independence-Symmes-Bairs area also documents drought recovery. Since 1992, pumping in the Independence-Symmes-Bairs area has been managed conservatively resulting in a storage gain of 304,000 acre-ft since 1994, more than replacing the storage depletions in the late 1980s and early 1990s.

4. Neutron probe soil moisture data do not exist for the baseline period. Neutron probe data were not available prior to 1995. Despite the absence of baseline data, analysis of the available data yields information pertinent to the DRP.

5. Soil moisture data from the Symmes-Shepherd monitoring sites show a direct correlation between the lower portion of the soil profile and groundwater levels. Soil moisture in the lower portion of the soil moisture profile is predominantly influenced by water levels. For the 1995 to 2000 time period, this depth is undeterminable from available data at monitoring site SS1 and SS2 and about 200 cm at sites SS3 and SS4.

6. Although baseline data for soil moisture are not available, we have been able to conclude that based on the depth-to-groundwater/soil moisture relationships demonstrated by the data described above, and because groundwater levels in the Symmes-Shepherd Wellfield have substantially recovered, it necessarily follows that soil moisture levels to the extent that they are influenced by groundwater levels, have also recovered.

7. Soil moisture above the depth where groundwater is the predominant influence is controlled by numerous other factors such as precipitation, surface land use activities, and evapotranspiration. Of these, only precipitation is a direct measure of drought conditions. Consequently, for this upper portion of the soil profile, only the consideration of precipitation is appropriate for evaluation of drought recovery.

Recommendations

Based on the findings above and associated preponderance of evidence concerning depth to water data, groundwater balance, and soil moisture, substantial recovery as defined in the DRP has been achieved. To summarize, the data clearly demonstrate that termination of the DRP is appropriate.

Chapter 8

Bairs-Georges Wellfield

Chapter 8
Bairs-Georges Wellfield

Wellfield Description

Located in the Owens Valley south of the town of Independence and north of the town of Lone Pine, the Bairs-Georges Wellfield is one of seven wellfields operated by the LADWP where groundwater pumping and extraction have been governed by the DRP. The provisions in the Green Book (October 1991) provide for one monitoring site at this wellfield, BG2, as summarized in **Table 8-1** and shown on **Figure 8-1**.

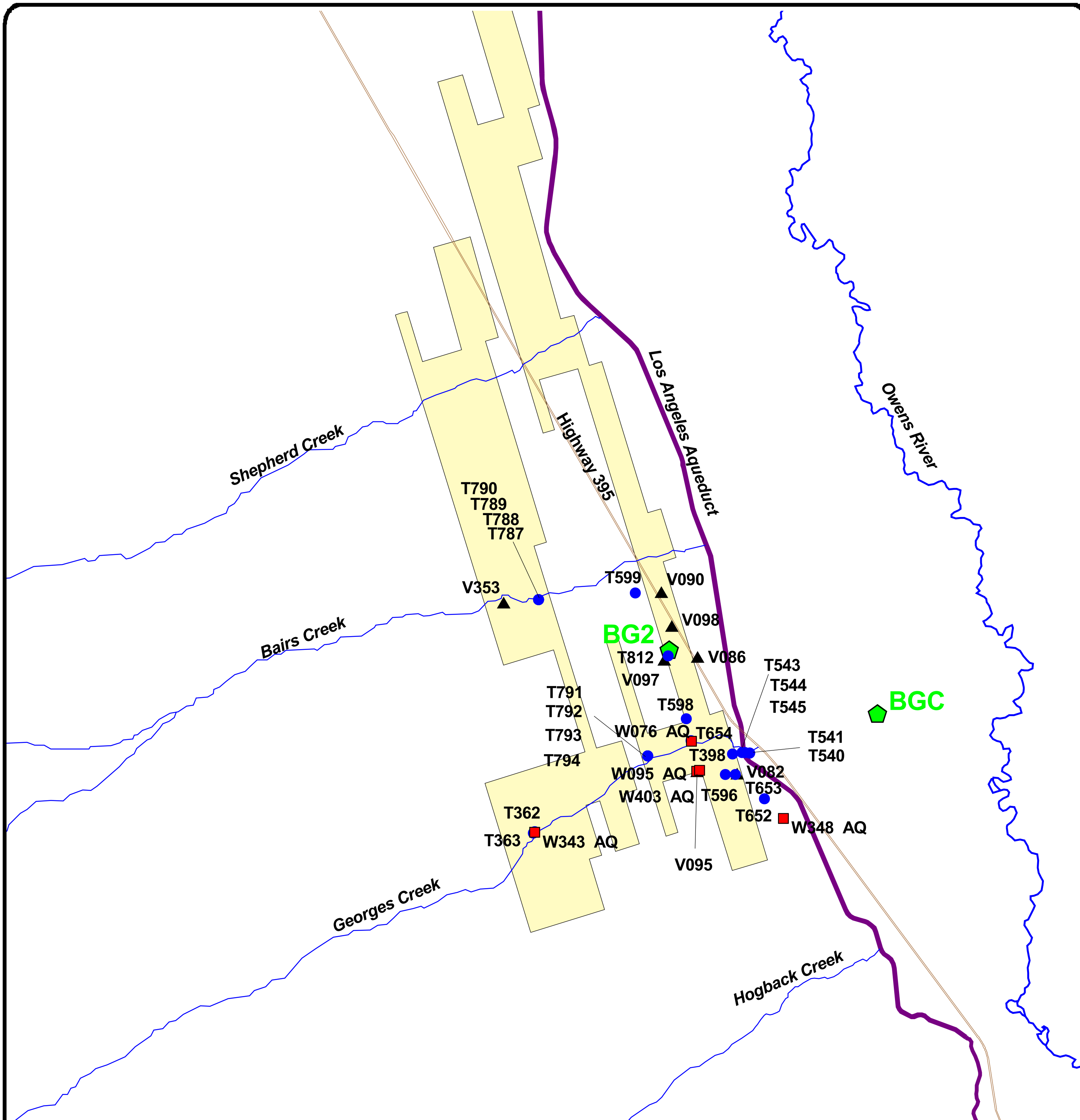
Table 8-1
Summary of Bairs-Georges Monitoring Sites

Monitoring Site	Vegetation Type	Shallow Monitoring Well	Pumping Wells[1]	EM Wells
BG2	B	T812	W76AQ, W348AQ, W403AQ (replacement for Well W95AQ)	

1. Wells W343AQ (sole source irrigation well in below average runoff years) is located within the Bairs-Georges Wellfield, but exempt from Green Book on/off provisions and DRP provisions.

Monitoring Site BG2

Monitoring Site BG2 is associated with pumping wells W76AQ, W348AQ, and W403AQ. The shallow monitoring well at this site is Well T812, which has a depth to water history from May 1989 to present, and thereby does not provide a 1985-1987 Runoff Year baseline. In addition, there are three soil moisture access tubes at this site (BG2-1, BG2-2, and BG2-3). Representative vegetation at monitoring site BG2 has been mapped as Type B.



EXPLANATION

Town

Production Well

Test "T" Well

Monitoring "V" Well

L2 Monitoring Site

L2C Monitoring Control Site

Streams and Rivers

Highways

Los Angeles Aqueduct

Management Area

Figure 8-1

Bairs-Georges Wellfield
Site Vicinity Map

MWH MONTGOMERY WATSON HARZA

N

0 3000 6000 Feet

Management Area Monitoring Wells

There are a total of 23 shallow wells and seven deep wells, as shown on **Figure 8-1**, within the Bairs-Georges management area. As summarized in **Table 8-2**, the following descriptive statistics apply to this data set of wells:

- Fourteen of the shallow wells and four of the deep wells do not have baseline data and no analysis was performed on these wells.
- Four of the shallow wells were dry in the baseline allowing for a qualitative evaluation only.
- Five of the shallow wells and three of the deep wells have data suitable for the quantitative analysis described in Chapter 1.
- Although quantitative and qualitative evaluations are conducted on suitable shallow and deep wells, only the five shallow wells, whose data represent water table conditions suitable for quantitative analysis, are used to validate DRP termination.

Table 8-2
Summary of Wells in the Bairs-Georges Wellfield Management Area

Descriptive Statistic	Quantity of Wells	
	Shallow	Deep
Wells in Management Area	23	7
Wells with No Baseline Data – No Analysis Performed	14	4
Wells that were Dry in Baseline - Qualitative Analysis Performed	4	0
Wells with Complete Data Sets - Quantitative Analysis Performed	5	3
Wells Used to Validate DRP Termination	**5**	0

Depth to Water

Methodology

As discussed previously, there are a total of 30 monitoring wells within the Bairs-Georges Wellfield. Of these 30 monitoring wells, quantitative analyses were performed in accordance with **Table 8-2**. **Figure 8-1** shows the location of Bairs-Georges management area wells and

Table 8-3
Summary of Bairs-Georges Wellfield Monitoring Wells Evaluated for DRP Termination

Well	Baseline			DTW Drought Low (fbgs)	DTW 80% Recovery (fbgs)	Runoff Year(s) During which Low Point Occurred	Substantial Recovery Achieved by Runoff Year						
	Mean[1] (fbgs)	Lower 95% CI[2]	Upper 95% CI[2]				1995	1996	1997	1998	1999	2000	Summary[3]
T362	20.4	22.1	18.8	38.7	24.1	1989	X	X	X	X	X	X	X
T363	14.6	15.7	13.5	31.7	18.0	1990				X	X	X	X
T398	6.1	7.2	5.0	13.2	7.5	1988	X	X	X	X	X	X	X
T652	17.5			19.1	17.8	1989	X	X	X	X	X	X	X
T654	19.5			20.5	19.7	1988	X	X	X	X	X	X	X
Bairs-Georges Wellfield Management Area Percent Recovery for Shallow Wells:							80%	80%	80%	100%	100%	100%	100%
V086	9.3	13.0	5.7	25.2	12.5	1988	X	X	X	X	X	X	X
V097	13.6	17.1	10.1	30.0	16.9	1988	X	X	X	X	X	X	X
V098	9.8	11.7	8.0	23.2	12.5	1988	X	X	X	X	X	X	X
Bairs-Georges Wellfield Management Area Percent Recovery for Deep Wells:							100%	100%	100%	100%	100%	100%	100%

[1] Baseline Mean is calculated from all available depth to water measurements collected during the baseline, on a Runoff Year basis (1985-1987).
[2] In some instances, only one data point was available for the baseline mean, in which case confidence intervals could not be calculated.
[3] This "Summary" column indicates if substantial recovery has been achieved in a well at any time since the DRP was instituted in 1992.

Data Presentation

The quantitative methodology described in the Approach section of Chapter 1 was applied to the five shallow wells and three deep wells. Baseline mean and 95 percent confidence intervals were calculated and are summarized **Table 8-3**. Also shown in this table is the lowest depth to water recorded during the drought (DTW Drought Low), the water level that represents 80 percent recovery using Equation 2 (DTW 80% Recovery), runoff year during which low point occurred, and a column for each potential recovery year (Runoff Years 1995 – 2000).

Hydrographs for these eight wells graphically depict the baseline and 80 percent recovery line and are provided **Appendix G**. In general, depth to water measurements were high during the baseline period, yet declined during the drought, and since the drought's end, water levels have steadily climbed, typically achieving recovery in the late 1990s.

Discussion

The data demonstrate that four of the five (80 percent) and five of the five (100 percent) Bairs-Georges Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1995-1997 and 1998-2000, respectively. Therefore the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met. One hundred percent of the shallow wells exhibit substantial recovery since the DRP was instituted in 1992.

Similarly, three of the three (100 percent) Bairs-Georges deep wells exhibit substantial recovery in Runoff Years 1995-2000, lending additional support to termination of the DRP at the Bairs-

Georges Wellfield. One hundred percent of the deep wells exhibit substantial recovery since the DRP was instituted in 1992.

Furthermore, hydrographs for the four shallow wells, as summarized in **Table 8-4**, that were dry in the baseline were constructed and are included in **Appendix G**. Of these wells, all four wells express a pattern of recovery since the drought indicative of drought recovery.

Table 8-4
Summary of Bairs-Georges Wellfield Monitoring Wells that were Dry During the Baseline

Shallow Wells	Deep Wells
T596	
T598	
T599	
T653	

Summary

To summarize, 80 and 100 percent of Bairs-Georges Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1995-1997 and 1998-2000, respectively. All shallow wells exhibit substantial recovery since the DRP was instituted in 1992. Therefore the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

Hydrologic Indices

Montgomery Watson Harza reviewed groundwater balance data for the Bairs-Georges area to determine the status of the hydrologic conditions. The results of this evaluation are presented below.

Groundwater Balance

As discussed in Chapter 6, the mining calculations for the Bairs-Georges wellfield are not computed separately, but instead are combined with those for the Independence-Symmes-Bairs area. The discussion in that chapter indicates that the Independence-Symmes-Bars area accumulated about 444,000 acre-ft of groundwater in storage in the wet period of the later 1970s through the mid-1980s. Increased groundwater pumping during the 1986-1991 drought extracted about 23,000 acre-ft of water from storage. Since the end of the drought, about 304,000 acre-ft of groundwater storage has been accrued, more than replacing the water removed during the drought.

Soil Moisture

Methodology

Neutron probe data have been collected on a monthly basis from three soil access tubes from the one monitoring site (BG2) since May 1995. Neutron probe data were collected at 20-cm intervals from a depth of 30 cm to a depth of 390 cm to construct a soil moisture depth profile. Soil moisture data were evaluated using the approach described in Chapter 1's Approach section.

Data Presentation and Discussion

Precipitation and Soil Moisture

Figure 8-2 compare the average soil moisture at monitoring site BG2 (includes an average of soil access tubes BG2-1, BG2-2, and BG2-3) at a depth of 30 cm to monthly precipitation at the LADWP Alabama Gates weather station. The uppermost depth measured, 30 cm, was selected to evaluate the correlation between the upper soil profile and precipitation. Subsequent analysis evaluates relationships at two additional depths, whereby the middle depth represents a point in the soil profile least influenced by both surface processes and water levels, and the lowermost depth represents the point most influenced by water levels only.

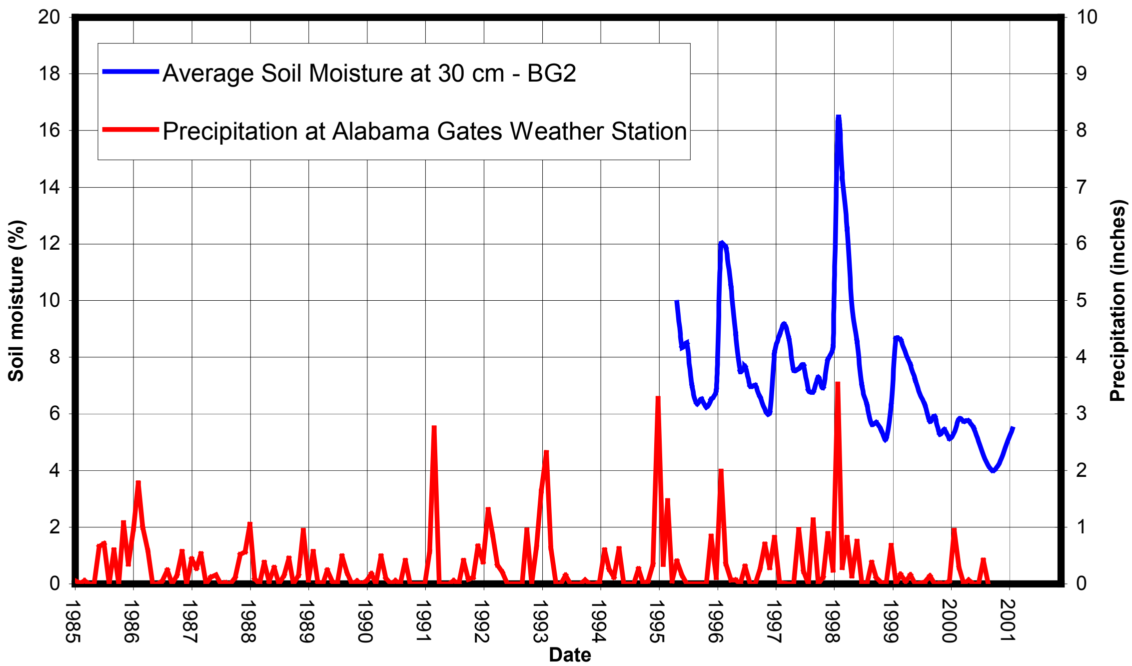


Figure 8-2
Average Soil Moisture at 30 cm for Monitoring Site BG2 versus Precipitation

This analysis indicates that the soil moisture at a depth of 30 cm tracks generally parallel to monthly precipitation since 1995. After 1998, there appears to be a downward trend in soil moisture at monitoring site BG2. This diversion in the trend of each curve may represent changes in surface processes in the vicinity of each monitoring site. These data suggest that the primary mechanism controlling soil moisture near the surface (30 cm) is precipitation, which is consistent with the conceptual soil moisture model.

Water Level and Soil Moisture

Figure 8-3 compares the average soil moisture at depths of 110 cm and 290 cm at monitoring site BG2 to water levels in monitoring Well T812. As shown in this figure, percent soil moisture at the 110 cm zone has remained relatively constant since 1995 and does not reflect changes in water levels. Percent soil moisture at 290 cm is generally higher than at 110 cm and parallels changes in water level, appearing to reach a maximum of about 30 percent in the early part of 1999. The maximum is coincident with the approximate time in which water levels average approximately 290 cm in well, indicating soil saturation.

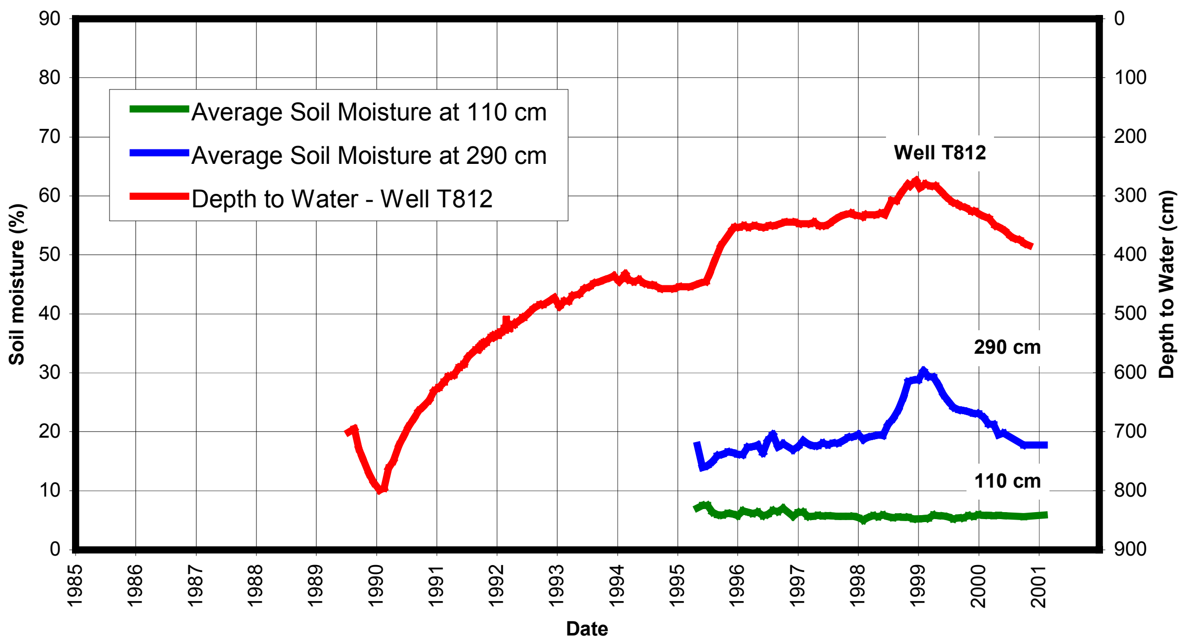


Figure 8-3
Average Soil Moisture for Monitoring Site BG-2 versus Water Level

Soil Moisture Profiles

As discussed in the conceptual soil moisture model, soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. Soil profiles for each location were compiled to evaluate the vertical relationship among water table, precipitation, and soil moisture. Vertical profiles were constructed for the maximum water level and the minimum water level during the time period from 1995 to 2000. Consequently, these data should represent the approximate range in soil moisture attributable to groundwater at each depth for this period.

Figure 8-4 presents soil moisture profiles in soil probe BG2-1 during the time periods June 1995 and December 1999, which are correlative with the maximum and minimum water levels. As shown in this figure, soil moisture in December 1999 reaches a maximum of about 35 percent at a depth of about 350 cm (which is below the water level). In this analysis, soil moisture in the profile below 150 cm is lower in June 1995 when water levels were lower. In December 1999, when water levels were high, the soil moisture from approximately 300 cm to 400 cm during this time period reached a maximum of 35 percent at a depth of about 350 cm, which is deeper than the maximum height of the groundwater and indicates soil saturation. In this analysis, the increases in soil moisture between 200 cm and 350 cm in this time period appear to be a result of a rising capillary fringe and groundwater level. Soil moisture remains relatively low in June 1995 (less than 10 percent) to a depth of approximately 300 cm. Therefore, below this depth of approximately 300 cm, soil moisture during the two time periods track similarly and do not vary substantially with a change in water level. In this analysis, other factors such as precipitation appear to have more influence on soil moisture above 270 cm during the time period shown.

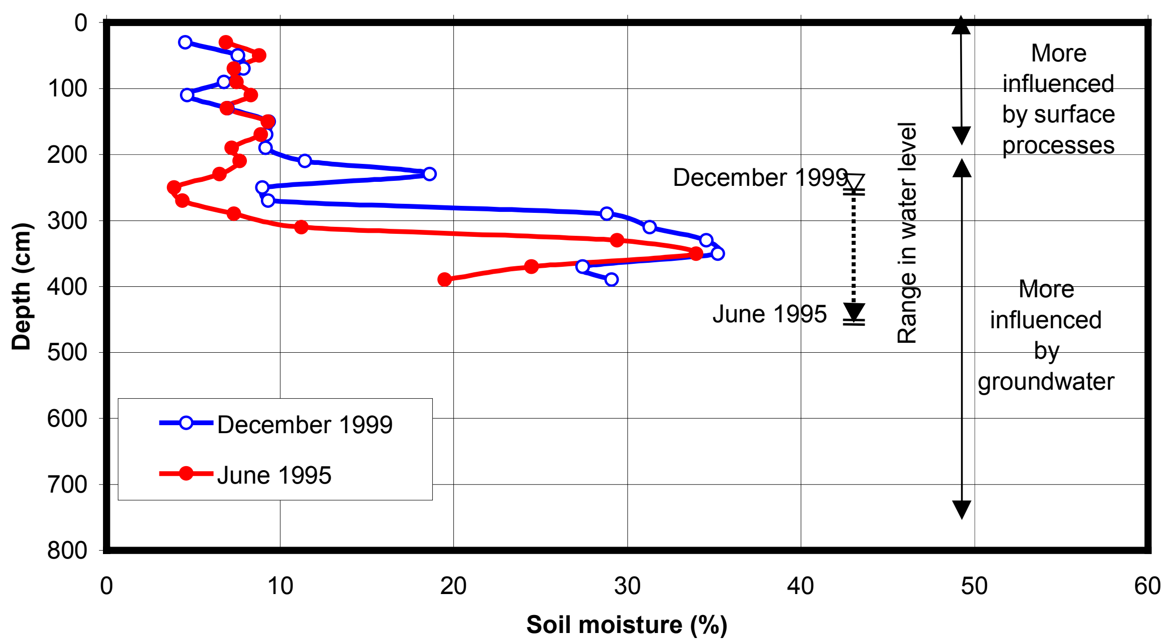


Figure 8-4
Soil Moisture Profile for Soil Probe BG2-1

Summary

Soil moisture is a function of precipitation, other surface activities that may provide water for percolation, evaporation, transpiration, and groundwater. The data presented herein validate that the upper portion of the soil profile appears to be more strongly influenced by surface water processes while the lower portion of the soil profile appears to be more strongly influenced by groundwater levels. This is clearly consistent with the conceptual model. Because soil moisture in the upper portion of the soil profile (the exact depth of this interface varies with time and location) is largely independent of groundwater levels, soil moisture in these portions of the soil profile should not be used to identify a return to baseline conditions nor the influence of groundwater pumping. Most significantly, from the strong correlation between water levels and the soil moisture associated with the capillary fringe, it can inferred that since water levels in the Bairs-Georges management area have recovered then the portion of the soil moisture profile influenced by the water table also exhibits substantial recovery.

Findings

1. The DRP states that "substantial recovery in soil moisture and water table conditions" are the criteria by which the DRP is terminated. Until then, it is intended for "environmentally conservative" groundwater pumping to be conducted. The DRP does not specify the consideration of any other criteria in determining the termination of DRP.

2. Eighty and 100 percent of Bairs-Georges Wellfield management area shallow wells exhibit substantial recovery in Runoff Years 1995-1997 and 1998-2000, respectively. All shallow wells exhibit substantial recovery since the DRP was instituted in 1992. Therefore the entire wellfield exhibits substantial recovery, and the water level DRP termination criteria have been met.

3. Evaluation of net recharge (recharge less pumping) in the Independence-Symmes-Bairs area also documents drought recovery. Since 1992, pumping in the Independence-Symmes-Bairs area has been managed conservatively resulting in a storage gain of 304,000 acre-ft since 1994, more than replacing the storage depletions in the late 1980s and early 1990s.

4. Neutron probe soil moisture data do not exist for the baseline period. Neutron probe data were not available prior to 1995. Despite the absence of baseline data, analysis of the available data yields information pertinent to the DRP.

5. Soil moisture data from the Bairs-Georges monitoring site show a direct correlation between the lower portion of the soil profile and groundwater levels. Soil moisture in the lower portion of the soil moisture profile is predominantly influenced by water levels. Data indicate that for the 1995 to 2000 time period, this depth is about 270 cm at site BG2.

6. Although baseline data for soil moisture are not available, we have been able to conclude that based on the depth-to-groundwater/soil moisture relationships demonstrated by the data described above, and because groundwater levels in the Bairs-Georges Wellfield have substantially recovered, it necessarily follows that soil moisture levels to the extent that they are influenced by groundwater levels, have also recovered.

7. Soil moisture above the depth where groundwater is the predominant influence is controlled by numerous other factors such as precipitation, surface land use activities, and evapotranspiration. Of these, only precipitation is a direct measure of drought conditions. Consequently, for this upper portion of the soil profile, only the consideration of precipitation is appropriate for evaluation of drought recovery.

Recommendations

Based on the findings above and associated preponderance of evidence concerning depth to water data, groundwater balance, and soil moisture, substantial recovery as defined in the DRP has been achieved. To summarize, the data clearly demonstrate that termination of the DRP is appropriate.

Chapter 9

References

Chapter 9
References

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