APPENDIX B: GROUNDWATER HYDROLOGY

SANTA ANA RIVER WATER RIGHT APPLICATIONS
FOR SUPPLEMENTAL WATER SUPPLY
DRAFT ENVIRONMENTAL IMPACT REPORT

October 2004

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT
• 1954 •

WESTERN
MUNICIPAL
WATER
DISTRICT

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1.0 INTRODUCTION

This appendix presents detailed information and provides supportive documentation and analysis of the existing conditions and impacts of the Project on groundwater resources. The overall goal of Appendix B is to describe the groundwater modeling methods and results that were used to evaluate the potential impacts associated with implementation of the Project. The results are included in sections 3.2, 3.4, and 3.12 of the EIR.

The first five chapters in Appendix B address the following topics: groundwater basin descriptions; spreading facilities; water quality issues; and groundwater levels. These sections provide the environmental setting and act as a basis for discussion of the groundwater modeling results. Chapter 6 discusses the methodology used for the groundwater modeling, a description of the models, assumptions used and the modeling results. Applicable results are presented as part of the environmental impact discussions in sections 3.2, 3.4, and 3.12. However Appendix B and its addendum contain complete groundwater model results.

The groundwater model integrates with surface water hydrology model components. These and other surface water information are described in detail in Appendix A, the Surface Water Hydrology Appendix. A number of terms and definitions are specific to groundwater modeling and groundwater studies and are given at the end of this appendix.

Chapter 2 provides a summary of physical characteristics of the groundwater basins in the Muni/Western service area that have the potential to be impacted by the Project. These groundwater basins are: San Bernardino Basin Area (SBBA); Yucaipa; Rialto–Colton; Riverside, and San Timoteo Basins. Water bearing formations, subsurface flow, basin boundaries, and groundwater storage are discussed for the SBBA. Many of the physical characteristics described in Chapter 2 become an important part of the input for the groundwater model.

Chapter 3 provides a summary description of the recharge facilities that overlie the SBBA and surrounding basins. The facilities used for the Project are contained mainly within the SBBA and others remain within the Muni/Western service area but lie outside of the SBBA.

One of the most important aspects related to the Project is the understanding of recharge rates of each basin. This is determined by the size of the active spreading area and the expected percolation rates and therefore these basin attributes are described for each basin in Chapter 3. As with the physical characteristics of the basins described previously, information on the recharge basins also is a critical part of the input for the groundwater model.

Chapter 4 provides additional documentation and analysis of water quality topics relative to the SBBA, since implementation of the Project would modify groundwater conditions. Chapter 4 discussions include constituents of concern; water quality objectives (WQOs); imported water quality; and groundwater quality in specific basins. Constituents of concern in the region are total dissolved solids (TDS), perchlorate, arsenic, radon, methyl tertiary butyl ether (MTBE), trichloroethylene (TCE), tetrachloroethylene (PCE) and nitrate (NO_3). They are described in the context of water quality standards including the National Primary and Secondary Drinking Water Regulations. In addition, the Santa Ana Regional Water Quality Control Board

(SARWQCB) has developed WQOs for sub-areas within the SBBA. These objectives are discussed in Chapter 4.

Chapter 5, Liquefaction and Subsidence, describes the relationship between groundwater levels and the potential for liquefaction and subsidence. This is an important consideration due to the proximity of the SBBA in relation to the San Andreas and other active fault systems and the historically high groundwater levels found there.

Liquefaction can occur when groundwater is close to the surface (<50 feet below ground surface). With the occurrence of a seismic event, the soil structure shifts and 'liquefies' due to the high groundwater. Ground subsidence also may occur as a result of a seismic event or lowering of the groundwater. This is especially true for alluvial valleys similar to that within the SBBA.

A description of the groundwater model and methodology and assumptions for the model are discussed in Chapter 6. The chapter provides an overview of the various groundwater models used including MODFLOW, MODPATH, MT3DMS, PRESS, and the Hantush Equation. MODFLOW (MODular three-dimensional finite-difference ground-water FLOW model) was developed by the U.S. Geological Survey (USGS) and is one of the most widely used models in the world for groundwater flow simulation. MODFLOW was used in this case to describe groundwater flow for the SBBA and its overlying recharge basins. For analysis of spreading facilities outside of the SBBA (in Yucaipa and Rialto-Colton), the Hantush Equation was used. This Equation calculates the vertical recharge of the spreading basin. Groundwater levels underneath the spreading basin can then be assessed.

MODPATH is an associated program of MODFLOW and is used to estimate groundwater flow paths and travel times of groundwater in a basin. Another associated program of MODFLOW is MT3DMS (Modular 3-D Multi-Species Transport Model) that simulates groundwater contaminant transport such as TCE and PCE.

Apart from the groundwater flow model, PRESS was used to analyze subsidence in the SBBA. The PRESS model simulates subsidence by taking into account changes in groundwater levels. In this case, changes of water levels due to implementation of the Project were modeled with PRESS.

Chapter 7 contains the references cited in the document, while acronyms are defined in Chapter 8. Chapter 9 identifies terms and definitions.

An Addendum contains the complete set of hydrographs (illustrating groundwater levels) and graphs showing TDS and NO_3 concentrations and other groundwater model results which were used for the impact analysis.

1.1 SUMMARY OF GROUNDWATER MODELING RESULTS

Extensive groundwater modeling was completed to predict potential changes in groundwater levels, subsurface flow patterns, and water quality given the implementation of the Project. This section provides a summary of these results from the groundwater model analyses, including those from the groundwater flow model (MODFLOW), particle tracking

(MODPATH), and solute transport model (MTD3MS) of the SBBA. Also the PRESS model results are briefly discussed and water level changes due to spreading in Yucaipa and Rialto-Colton (outside of the SBBA) are also summarized.

Groundwater flow directions have remained similar in the past and under current (No Project) conditions with groundwater flowing west from the SAR and Mill Creek Spreading Grounds, and southeast from the Lytle Creek and Cajon Creek. Flow direction is towards the Pressure Zone, the area of historical high groundwater levels. This also remains the same under the Project.

Groundwater levels, however, change under the Project as compared to No Project. Levels are higher in the northwestern portion of the SBBA and lower in the central and eastern portions, including in the Pressure Zone. This is primarily due to the increase of artificial recharge under the Project at several spreading basins in the northern and western portions of the SBBA, including Waterman, East Twin Creek, Devil Canyon/Sweetwater and Lytle Creek. This diversion of water to the spreading grounds also results in lower groundwater levels in the Pressure Zone. Diversion to the basins means that less groundwater is percolating in the Santa Ana River (SAR) channel, and therefore less groundwater enters the Pressure Zone. As a consequence of higher groundwater levels (and steeper hydraulic gradients) in the northwestern portion of the SBBA, the rate of groundwater flow is generally faster for the Project than for No Project condition. Because of the reduced levels in the southeastern portion and in the Pressure Zone, groundwater flow in this part of the SBBA is generally slower under the Project.

The change in groundwater levels relates to a change in the area of potential liquefaction in the Pressure Zone. With the Project there is a reduction in the total area of potential liquefaction within the Pressure Zone, when compared to No Project. This is during the period of 2001 to 2039. Potential liquefaction total area under the Project decreases over this period by as much as 77 percent compared to No Project. With the Project, the Pressure Zone has no potential liquefaction in up to 26 years (of the 39-year base period). This is a 66 percent reduction from the 13 years in No Project in which the Pressure Zone has no potential liquefaction.

Groundwater levels in the spreading areas outside of the SBBA, including Cactus Spreading and Flood Control Basins (Rialto-Colton Basin), Wilson (Yucaipa Basin) and Garden Air Creek (San Timoteo Basin) were also analyzed. With the Project diversions to these spreading grounds, groundwater levels do not rise to within 50 feet of the land surface and therefore are outside of the potential liquefaction zone.

With the change of groundwater levels, subsidence may also occur. An analysis with the PRESS model (described briefly earlier) was done for the location with the highest decrease in groundwater levels (Well Raub #8). The average subsidence increased by 0.27 feet in the worst case due to the Project, compared to subsidence during No Project. The subsidence rate also increased slightly.

When discussing changes in groundwater levels it is also important to consider the groundwater storage in the SBBA. Normally, under No Project, the basin groundwater storage declines on average 3,324 acre-feet/yr (afy). The Project would reduce groundwater storage levels in the SBBA by only 82 afy. This is small compared to the groundwater storage capacity of the basin; 5,976,000 af. The change is due to the reduced streamflow recharge in the SAR. As discussed previously, the Project diverts this water and spreads it at several spreading basins within the SBBA.

As discussed above, the Project causes some minor increases in the rate of groundwater flow, but not in flow direction in the northwestern portion of the SBBA. As will be discussed in more detail in Chapter 3, there currently are contaminant plumes in this area. However, because the Project changes occur mainly upgradient of contaminant plumes, the changes are not expected to interfere with the existing remediation systems. Increasing the rate of groundwater flow upgradient of the contaminant plumes may aid the remediation efforts. This is the case for the PCE and TCE plume, which moves faster towards the U.S. Environmental Protection Agency (US EPA) remediation extraction wells with the Project.

The Project only minimally changes (by less than 1 milligram per liter [mg/L]) the average TDS and NO_3 concentrations for the SBBA.

2.0 GROUNDWATER BASINS

This chapter describes the groundwater basins that could be affected by the Project. The basin within which most Project-related activities would take place is the SBBA that is comprised of the Bunker Hill and Lytle Creek basins. Other groundwater basins where fewer or no Project-related activities are anticipated include the Rialto–Colton, Riverside, Yucaipa, and San Timoteo basins. The SAR, through which groundwater recharge occurs, and the majority of the proposed spreading facilities that are part of the Project are located within the SBBA.

2.1 SAN BERNARDINO BASIN AREA

The SBBA plays a central role in the water supply for communities within the Muni/Western service areas. The SBBA has a surface area extent of approximately 90,000 acres. It is bordered on the northwest by the San Gabriel Mountains; on the northeast by the San Bernardino Mountains; on the south by the Banning Fault and Crafton Hills; and on the southwest by a low, east-facing escarpment of the San Jacinto Fault (Figure 2.1-1). Alluvial fans extend from the base of the mountains and hills that surround the valley and coalesce to form a broad, sloping alluvial plain in the central part of the valley. Most of this area is known as the Bunker Hill Basin, which is further divided into minor sub-areas, including the Pressure Zone, Cajon, Lytle Canyon, Devil Canyon, City Creek, Redlands, Mill Creek, Reservoir, and Divide sub-areas (Figure 2.1-2).

A relatively small northwest-trending portion of the SBBA along Lytle Creek, which is hydraulically separated from the Bunker Hill Basin by a system of faults, is known as the Lytle Creek Basin. The Loma Linda Fault is the primary boundary between the Lytle Creek and Bunker Hill basins (Figure 2.1-3); however, this fault does not appear to act as a groundwater barrier along most of its course. Therefore, the two basins are considered as one basin (Dutcher and Garret 1963, Hardt and Hutchinson 1980, Danskin et al. N.D.).

2.1.1 Water-Bearing Formations

The primary water-bearing formations of the SBBA are the unconsolidated sediments of older and younger alluvium and river channel material deposited and reworked by the SAR and tributaries such as Lytle Creek and Cajon Creek (Figure 2.1-1) (Dutcher and Garrett 1963). Near the mountain front, the unconsolidated deposits tend to be coarse-grained and poorly sorted, becoming finer-grained and better sorted downstream. The older alluvium consists of continental, fluvial deposits, ranging in thickness from some tens of feet to more than 800 feet. The younger alluvium is about 100 feet thick, composed mainly of floodplain deposits. The relatively recent river channel deposits are less than 100 feet thick but are among the most permeable sediments in the SBBA and contribute to large seepage losses from streams (Danskin et al. N.D.).

Dutcher and Garrett (1963) divided the SBBA alluvial sediments into upper, middle, and lower confining members and upper, middle, and lower water-bearing members. However, the aquifer system of the SBBA is generally unconfined to semi-confined with water moving vertically between the multiple water-bearing layers. The confining and semi-continuous members are more accurately described as very "leaky" aquitards (i.e., finer grained sediments which may transmit water due to vertical gradients caused by differences in hydraulic heads at the top and bottom of the aquitards).

These three separate water-bearing zones are not identifiable in the southwestern part of the basin, between the San Jacinto and Loma Linda faults, i.e., Lytle Creek Basin, but are generally recognizable from the Loma Linda Fault eastward for approximately 4 miles. In addition, thin Holocene river channel deposits present in creek bottoms are highly permeable and water-bearing Quaternary to Tertiary sedimentary deposits along the southeastern and northwestern margins of the basin are also locally water bearing (Dutcher and Garrett 1963).

The eastern portion of the basin and part of a former marshland in the south part of the basin is an exception to the general presence of the stratified system described above. In the area between Warm Creek and the SAR, thick clay sequences in the Holocene younger alluvium result in semi-confined aquifer conditions in the upper 50 to 100 feet of saturated materials. This area containing the upper confining member is referred to as the "Pressure Zone" (Figure 2.1-2). The upper confining member aquitard is also absent adjacent to the San Bernardino Mountains, (i.e., the "forebay area") allowing groundwater recharge into the basin from mountain stream runoff. This area adjacent to the mountains is considered the forebay of the SBBA and includes the Devil Canyon Sub-area (Figure 2.1-2).

The greatest thickness (over 1,200 feet) of water-bearing, unconsolidated and partly consolidated deposits in the SBBA is adjacent to the northeast side of the San Jacinto fault, between the City of San Bernardino and the SAR (Fife et al. 1976). This area coincides with a former marshland, which was present until the 1880s. As significant groundwater pumping was initiated, shallow groundwater levels fell, resulting in disappearance of the marsh. Upslope from the former marshland, the valley-fill deposits become progressively thinner as one moves northwest toward the San Gabriel Mountains; north toward the San Bernardino Mountains; and east toward the Crafton Hills (Hardt and Hutchinson 1980).

The upper and middle water-bearing zones provide most of the water to municipal and agricultural wells. In the central part of the SBBA, these zones are separated by as much as 300 feet of interbedded silt, clay, and sand (the middle confining member). This middle confining member produces confined conditions over the central part of the basin, but thins and becomes less effective toward the margins of the basin (Dutcher and Garrett 1963). In the area where the middle confining member is effective, it is referred to locally as the "confined area" (Mendenhall 1905, Dutcher and Garrett 1963, Danskin et al. N.D.). The areal extent of the confined area is approximately the same as the areal extent of flowing wells recorded by Mendenhall (1905) and also about the same as the areal extent of the upper confining member (i.e., the Pressure Zone aquitard). Although the middle confining member is not as permeable as the adjacent water bearing zones, water production from this zone still occurs in many wells (Danskin et al. N.D.).

Although both the upper and middle water-bearing zones are locally tapped for groundwater production, the lower confining member and lower water-bearing zone are not penetrated by most production wells and play a smaller role in the valley-fill aquifer, mainly because the lower water-bearing zone is much slower to drill through than the overlying deposits. This zone may be composed of poorly consolidated or partly cemented older Pleistocene alluvium, or may be composed solely of even older Plio-Pleistocene continental deposits. In either case, the top of the lower water-bearing zone forms the effective bottom of the groundwater flow system within the valley-fill aquifer (Danskin et al. N.D.).

As illustrated in Figure 2.1-4, depth to groundwater within the SBBA is historically low in the Pressure Zone (i.e., close to the surface) and along major surface streams and rivers, especially the SAR, Lytle Creek, and Cajon Creek. Depth to groundwater is deeper immediately southwest of the SBBA across the San Jacinto Fault in the Rialto–Colton Basin and to the east in the Yucaipa Basin.

Changes in groundwater level are evident from information developed by the USGS and portrayed in Figures 2.1-5, 2.1-6, and 2.1-7. The information on water levels referenced in these maps is based on heads (calculated from well pressure and elevations), water tables, and composite heads. Groundwater levels are a function primarily due to differences in recharge and discharge. Recent conditions (1994) are illustrated in Figure 2.1-5. During a period of less than average rainfall, extractions exceed recharge and groundwater levels tend to fall as can be seen in the case of 1966 (Figure 2.1-6). When recharge is plentiful and extractions are reduced, water levels rise closer to the surface as shown for conditions in 1945 (Figure 2.1-7). In all cases, the direction of groundwater flow remains essentially the same, flowing both southeast and southwest where the SAR exits the SBBA (Figures 2.1-5 through 2.1-7).

Pressure Zone Sub-Area within the SBBA

As previously discussed, in the vicinity of the confluence of Warm Creek and the SAR (Figure 2.1-1), the upper confining member acts to restrict vertical flow causing semi-confined conditions in the upper 50 to 100 feet of saturated materials (the Pressure Zone) (Dutcher and Garrett 1963). In the past, groundwater levels in the Pressure Zone rose high enough under these semi-confined conditions to cause artesian conditions and flooding. High groundwater levels in this area have damaged building foundations, flooded basements and utility structures, and increased the potential for liquefaction in this seismically active region. The Pressure Zone is located wholly within the City of San Bernardino. Several wells in the Pressure Zone were selected to present a long-term view of groundwater levels in the form of hydrographs. The well locations are shown in Figure 2.1-8; the hydrograph is shown in Figure 2.1-9. The numeric data on which the hydrographs are based is contained in Table 2.1-1. The data illustrates that groundwater levels (recorded in selected wells) have ranged from over 200 feet below ground surface during dry periods (in the 1960s and 1970s), to artesian and near-artesian conditions during wet periods (mid 1940s and early 1980s). The long-term trend is marked by dropping water levels (Figure 2.1-9).

High groundwater in the Pressure Zone is further exacerbated in part by the direction of groundwater movement in the Bunker Hill Basin, which generally flows in a southwesterly direction from the San Bernardino Mountains towards the San Jacinto Fault (Figures 2.1-5, 2.1-6, and 2.1-7). The fault zone generally runs sub-parallel to perpendicular to the groundwater flow and acts for the most part as a partial barrier, or underground dam, causing the groundwater to "pool" behind the fault and rise toward the land surface in the form of high groundwater.

In places, the upper confining member appears to have been eroded by stream flow and replaced with coarse sand and gravel. Boreholes drilled to a depth of about 50 feet below ground surface in the vicinity of the SAR and the San Jacinto Fault indicate a predominance of coarse sand and gravel, not fine-grained silt and clay. In these locations, the coarse material is essentially part of the upper water-bearing unit, vertical flow is less restricted, and unconfined conditions are likely to be present throughout the upper 100 to 200 feet of valley-fill sediment (Danskin et al. N.D.).

Lytle Creek Basin

The Bunker Hill and Lytle Creek basins are generally considered as one groundwater basin, the SBBA. However, the three separate water-bearing zones and intervening confining zones of the Bunker Hill Basin are not recognized in the Lytle Creek Basin. Sediments within the Lytle Creek Basin are highly permeable and unconfined, resulting in significant fluctuations in water levels. Water levels in many wells have fluctuated in excess of 200 feet over relatively short periods and, in select wells (e.g., Fontana Union's Well FU 8), have fluctuated over 400 feet. Figure 2.1-10 displays the generalized areal extent of the basin and location of wells selected for hydrographs (in Figure 2.1-11). Numeric information describing changes in groundwater levels in the well is contained in Table 2.1-2. Though groundwater is close to the surface, there are no artesian conditions reflected in the hydrographs for the Lytle Creek Basin. However, groundwater levels decrease over the late 1940s through the mid 1950s (as with the Pressure Zone wells in Figure 2.1-9), increase markedly in the late 1960s, and follow a pattern with sharp peaks and drops through until 2002. Comparing Figures 2.1-9 and 2.1-11, the Pressure Zone has a more gradual response to wet and dry periods over the time period 1934 to 2002 than Lytle Creek.

2.1.2 Subsurface Flow and Basin Boundaries

The areal pattern of groundwater flow, from areas of recharge along the base of the mountains, to areas of discharge where the SAR crosses the San Jacinto Fault, has historically remained relatively unchanged (Figures 2.1-5, 2.1-6, and 2.1-7). However, vertical movement has changed through historical times due to groundwater pumping and artificial recharge. Groundwater pumping has occurred from deeper and deeper depths, altering the natural vertical movement of groundwater (Danskin et al. N.D.).

The barrier effect of aquifers within the younger alluvium is not as pronounced because faulting is generally absent. However, faulting in the deeper aquifers of older alluvium generally impedes groundwater flow due to low permeability effects in and near the vicinity of barriers due to 'fault gouge' and offsetting at permeable and impermeable beds. This leads to a difference in hydraulic gradients across the barriers and results in offsets of groundwater levels. The barrier effect of the faults on groundwater movement is believed to be due to the presence of highly cemented zones, clayey fault gouge, and sharp folds in the deposits at and near the faults. These faulted, older alluvium aquifers store more water than others and therefore are considered the principal water bearing units of the area. Groundwater in these aquifers generally flows southwesterly and southeasterly towards the Colton Narrows (Figure 2.1-1) (Dutcher and Garrett 1963).

Table 2.1-1. Summary of Groundwater Levels
Pressure Zone Sub-Basin, 1934 - 2002

	Depth to Water (ft.)						Change in Water Level (ft.)					
	21	51 - 1	ANTIL WELL NO 3	34	23RD STREET	MILL & D ST	21	51 - 1	ANTIL WELL NO 3	34	23RD STREET	MILL & D ST
	01S04W13L02S	01S04W23A05S	1S4W02K01S	1S4W24K01S	1N4W27N01S	1S4W10N06S	01S04W13L02S	01S04W23A05S	1S4W02K01S	1S4W24K01S	1N4W27N01S	1S4W10N06S
Year	Source	Source	Source	Source	Source	Source	Source	Source	Source	Source	Source	Source
1934	-47.00	-29.00	12.00	-41.00	-96.00	9.00	n/a	n/a	n/a	n/a	n/a	n/a
1935	-49.00	-30.00	2.00	-43.00	-98.00	6.00	-2.00	-1.00	-10.00	-2.00	-2.00	-3.00
1936	-55.00	-26.00	5.00	-35.00	-100.00	4.00	-6.00	4.00	3.00	8.00	-2.00	-2.00
1937	-48.00	-21.00	14.00	-27.00	-90.00	10.00	7.00	5.00	9.00	8.00	10.00	6.00
1938	-42.00	-17.00	30.00	-14.00	-78.00	14.00	6.00	4.00	16.00	13.00	12.00	4.00
1939	-36.00	-13.00	34.00	-22.00	-79.00	16.00	6.00	4.00	4.00	-8.00	-1.00	2.00
1940	-30.00	-15.00	38.00	-20.00	-75.00	14.00	6.00	-2.00	4.00	2.00	4.00	-2.00
1941	-15.00	-19.00	42.00	-17.00	-59.00	23.00	15.00	-4.00	4.00	3.00	16.00	9.00
1942	-18.00	-15.00	23.00	-14.00	-57.00	20.00	-3.00	4.00	-19.00	3.00	2.00	-3.00
1943	-16.00	-21.00	34.00	-19.00	-55.00	21.00	2.00	-6.00	11.00	-5.00	2.00	1.00
1944	-13.00	-24.00	44.00	-3.00	-54.00	27.00	3.00	-3.00	10.00	16.00	1.00	6.00
1945	-16.00	-19.00	18.00	-7.00	-55.00	21.00	-3.00	5.00	-26.00	-4.00	-1.00	-6.00
1946	-13.00	-29.00	40.00	-4.00	-59.00	23.00	3.00	-10.00	22.00	3.00	-4.00	2.00
1947	-19.00	-27.00	10.00	-24.00	-65.00	19.00	-6.00	2.00	-30.00	-20.00	-6.00	-4.00
1948	-22.00	-37.00	6.00	-31.00	-75.00	17.00	-3.00	-10.00	-4.00	-7.00	-10.00	-2.00
1949	-29.00	-43.00	22.00	-27.00	-79.00	16.00	-7.00	-6.00	16.00	4.00	-4.00	-1.00
1950	-33.00	-37.00	-5.00	-46.00	-94.00	11.00	-4.00	6.00	-27.00	-19.00	-15.00	-5.00
1951	-35.00	-46.00	-11.00	-60.00	-106.00	6.00	-2.00	-9.00	-6.00	-14.00	-12.00	-5.00
1952	-39.00	-57.00	-20.00	-62.00	-106.00	2.00	-4.00	-11.00	-9.00	-2.00	0.00	-4.00
1953	-58.00	-63.00	-28.00	-70.00	-117.00	2.00	-19.00	-6.00	-8.00	-8.00	-11.00	0.00
1954	-55.00	-71.00	-14.00	-75.00	-119.00	6.00	3.00	-8.00	14.00	-5.00	-2.00	4.00
1955	-63.00	-68.00	-39.00	-84.00	-133.00	-3.00	-8.00	3.00	-25.00	-9.00	-14.00	-9.00
1956	-68.00	-82.00	-44.00	-90.00	-142.00	-8.00	-5.00	-14.00	-5.00	-6.00	-9.00	-5.00
1957	-72.00	-76.00	-37.00	-87.00	-151.00	-8.00	-4.00	6.00	7.00	3.00	-9.00	0.00
1958	-66.00	-75.00	-58.00	-94.00	-154.00	-11.00	6.00	1.00	-21.00	-7.00	-3.00	-3.00
1959	-80.00	-87.00	-63.00	-100.00	-161.00	-17.00	-14.00	-12.00	-5.00	-6.00	-7.00	-6.00
1960	-75.00	-84.00	-58.00	-103.00	-169.00	-19.00	5.00	3.00	5.00	-3.00	-8.00	-2.00
1961	-95.00	-96.00	-96.00	-117.00	-186.00	-29.00	-20.00	-12.00	-38.00	-14.00	-17.00	-10.00
1962	-120.00	-112.00	-104.00	-137.00	-196.00	-35.00	-25.00	-16.00	-8.00	-20.00	-10.00	-6.00
1963	-116.00	-119.00	-93.00	-132.00	-212.00	-40.00	4.00	-7.00	11.00	5.00	-16.00	-5.00
1964	-135.00	-111.00	-125.00	-145.00	-222.00	-47.00	-19.00	8.00	-32.00	-13.00	-10.00	-7.00
1965	-141.00	-135.00	-123.00	-145.00	-233.00	-51.00	-6.00	-24.00	2.00	0.00	-11.00	-4.00
1966	-137.00	-135.00	-139.00	-154.00	-240.00	-59.00	4.00	0.00	-16.00	-9.00	-7.00	-8.00
1967	-134.00	-143.00	-143.00	-145.00	-245.00	-63.00	3.00	-8.00	-4.00	9.00	-5.00	-4.00
1968	-141.00	-149.00	-142.00	-148.00	-247.00	-69.00	-7.00	-6.00	1.00	-3.00	-2.00	-6.00
1969	-97.00	-152.00	-120.00	-130.00	-228.00	-57.00	44.00	-3.00	22.00	18.00	19.00	12.00
1970	-105.00	-140.00	-101.00	-120.00	-214.00	-52.00	-8.00	12.00	19.00	10.00	14.00	5.00
1971	-108.00	-113.00	-129.00	-141.00	-209.00	-45.00	-3.00	27.00	-28.00	-21.00	5.00	7.00
1972	-111.00	-123.00	-100.00	-122.00	-207.00	-41.00	-3.00	-10.00	29.00	19.00	2.00	4.00
1973	-111.00	-108.00	-107.00	-132.00	-199.00	-37.00	0.00	15.00	-7.00	-10.00	8.00	4.00
1974	-114.00	-115.00	-99.00	-125.00	-181.00	-34.00	-3.00	-7.00	8.00	7.00	18.00	3.00
1975	-119.00	-99.00	-110.00	-132.00	-189.00	-35.00	-5.00	16.00	-11.00	-7.00	-8.00	-1.00
1976	-117.00	-101.00	-88.00	-128.00	-192.00	-35.00	2.00	-2.00	22.00	4.00	-3.00	0.00
1977	-128.00	-104.00	-95.00	-148.00	-200.00	-37.00	-11.00	-3.00	-7.00	-20.00	-8.00	-2.00
1978	-110.00	-96.00	-59.00	-111.00	-173.00	-31.00	18.00	8.00	36.00	37.00	27.00	6.00
1979	-102.00	-101.00	-58.00	-110.00	-169.00	-18.00	8.00	-5.00	1.00	1.00	4.00	13.00

Table 2.1-1. Summary of Groundwater Levels (continued)
Pressure Zone Sub-Basin, 1934 - 2002

	Depth to Water (ft.)						Change in Water Level (ft.)					
	21	51 - 1	ANTIL WELL NO 3	34	23RD STREET	MILL & D ST	21	51 - 1	ANTIL WELL NO 3	34	23RD STREET	MILL & D ST
	01S04W13L02S	01S04W23A05S	1S4W02K01S	1S4W24K01S	1N4W27N01S	1S4W10N06S	01S04W13L02S	01S04W23A05S	1S4W02K01S	1S4W24K01S	1N4W27N01S	1S4W10N06S
Year	Source	Source	Source	Source	Source	Source	Source	Source	Source	Source	Source	Source
1980	-70.00	-66.00	-31.00	-80.00	-141.00	-2.00	32.00	35.00	27.00	30.00	28.00	16.00
1981	-67.00	-23.00	-21.00	-60.00	-130.00	7.00	3.00	43.00	10.00	20.00	11.00	9.00
1982	-61.00	-20.00	-17.00	-61.00	-115.00	5.00	6.00	3.00	4.00	-1.00	15.00	-2.00
1983	-20.00	-13.00	-10.00	-40.00	-103.00	7.00	41.00	7.00	7.00	21.00	12.00	2.00
1984	-14.00	-9.00	-4.00	-47.00	-98.00	-6.00	6.00	4.00	6.00	-7.00	5.00	-13.00
1985	-34.00	-28.00	-34.00	-55.00	-119.00	-5.00	-20.00	-19.00	-30.00	-8.00	-21.00	1.00
1986	-41.00	-34.00	-39.00	-76.00	-124.00	-5.00	-7.00	-6.00	-5.00	-21.00	-5.00	0.00
1987	-36.00	-44.00	-49.00	-67.00	-140.00	-25.00	5.00	-10.00	-10.00	9.00	-16.00	-20.00
1988	-50.00	-41.00	-59.00	-96.00	-155.00	-17.00	-14.00	3.00	-10.00	-29.00	-15.00	8.00
1989	-53.00	-62.00	-78.00	-104.00	-170.00	-8.00	-3.00	-21.00	-19.00	-8.00	-15.00	9.00
1990	-67.00	-65.00	-96.00	-112.00	-192.00	-17.00	-14.00	-3.00	-18.00	-8.00	-22.00	-9.00
1991	-77.00	-78.00	-113.00	-132.00	-214.00	-26.00	-10.00	-13.00	-17.00	-20.00	-22.00	-9.00
1992	-86.00	-90.00	-107.00	-125.00	-217.00	-27.00	-9.00	-12.00	6.00	7.00	-3.00	-1.00
1993	-84.00	-107.00	-101.00	-125.00	-205.00	-28.00	2.00	-17.00	6.00	0.00	12.00	-1.00
1994		-91.00		-132.00	-214.00	-30.00	n/a	16.00	n/a	-7.00	-9.00	-2.00
1995		-79.00		-120.00	-205.00	-28.00	n/a	12.00	n/a	12.00	9.00	2.00
1996		-68.00		-134.00	-205.00	-25.00	n/a	11.00	n/a	-14.00	0.00	3.00
1997		-58.00		-129.00	-192.00	-25.00	n/a	10.00	n/a	5.00	13.00	0.00
1998		-72.00		-98.00	-184.00	-20.00	n/a	-14.00	n/a	31.00	8.00	5.00
1999		-82.90		-109.00	-196.60	-23.00	n/a	-10.90	n/a	-11.00	-12.60	-3.00
2000		-88.50		-120.00	-206.50	-23.30	n/a	-5.60	n/a	-11.00	-9.90	-0.30
2001		-88.15		-118.00	-216.30	-25.90	n/a	0.35	n/a	2.00	-9.80	-2.60
2002		-87.80		-143.00	-251.00	-37.00	n/a	0.35	n/a	-25.00	-34.70	-11.10

Shaded cells with no values represent no depth available.
Shaded cells with values represent interpolated depths.
Source: Muni, 2003.

Table 2.1-2. Summary of Groundwater Levels
Lytle Creek Sub-Basin, 1934 - 2002

	Depth to Water (ft.)				**Change in Water Level (ft.)**					
	WELL NO 05	**WELL NO 07**	**FU 3**	**WELL NO 02**	**FU 8**	**WELL NO 05**	**WELL NO 07**	**FU 3**	**WELL NO 02**	**FU 8**
	1N5W25E01S	**1N5W36H04S**	**1N5W22F02S**	**1N5W23Q00S**	**1N5W15Q02S**	**1N5W25E01S**	**1N5W36H04S**	**1N5W22F02S**	**1N5W23Q00S**	**1N5W15Q02S**
Year	Source	Source	Source	Source	Source	Source	Source	Source	Source	Source
1934	-227.00	-279.00	-135.00	-227.00	-350.00	n/a	n/a	n/a	n/a	n/a
1935	-210.00	-265.00	-125.00	-208.00	-313.00	17.00	14.00	10.00	19.00	37.00
1936	-216.00	-262.00	-130.00	-212.00	-259.00	-6.00	3.00	-5.00	-4.00	54.00
1937	-173.00	-246.00	-120.00	-148.00	-205.00	43.00	16.00	10.00	64.00	54.00
1938	-67.00	-150.00	-85.00	-60.00	-151.00	106.00	96.00	35.00	88.00	54.00
1939	-35.00	-89.00	-115.00	-51.00	-167.00	32.00	61.00	-30.00	9.00	-16.00
1940	-82.00	-85.00	-146.00	-69.00	-184.00	-47.00	4.00	-31.00	-18.00	-17.00
1941	-11.00	-32.00	-70.00	-8.00	-117.00	71.00	53.00	76.00	61.00	67.00
1942	-32.00	-59.00	-140.00	-35.00	-161.00	-21.00	-27.00	-70.00	-27.00	-44.00
1943	-23.00	-49.00	-110.00	-28.00	-131.00	9.00	10.00	30.00	7.00	30.00
1944	-27.00	-45.00	-102.00	-20.00	-137.00	-4.00	4.00	8.00	8.00	-6.00
1945	-47.00	-62.00	-153.00	-55.00	-174.00	-20.00	-17.00	-51.00	-35.00	-37.00
1946	-82.00	-95.00	-205.00	-86.00	-207.00	-35.00	-33.00	-52.00	-31.00	-33.00
1947	-118.00	-122.00	-240.00	-175.00	-237.00	-36.00	-27.00	-35.00	-89.00	-30.00
1948	-177.00	-189.00	-294.00	-230.00	-290.00	-59.00	-67.00	-54.00	-55.00	-53.00
1949	-232.00	-231.00	-320.00	-189.00	-336.00	-55.00	-42.00	-26.00	41.00	-46.00
1950	-264.00	-268.00	-347.00	-233.00	-345.00	-32.00	-37.00	-27.00	-44.00	-9.00
1951	-315.00	-267.00	-366.00	-270.00	-354.00	-51.00	1.00	-19.00	-37.00	-9.00
1952	-262.00	-311.00	-228.00	-229.00	-360.00	53.00	-44.00	138.00	41.00	-6.00
1953	-217.00	-326.00	-300.00	-208.00	-347.00	45.00	-15.00	-72.00	21.00	13.00
1954	-270.00	-287.00	-288.00	-226.00	-357.00	-53.00	39.00	12.00	-18.00	-10.00
1955	-304.00	-282.00	-322.00	-242.00	-371.00	-34.00	5.00	-34.00	-16.00	-14.00
1956	-297.00	-314.00	-355.00	-260.00	-419.00	7.00	-32.00	-33.00	-18.00	-48.00
1957	-288.00	-317.00	-349.00	-276.00	-421.00	9.00	-3.00	6.00	-16.00	-2.00
1958	-190.00	-298.00	-172.00	-186.00	-323.00	98.00	19.00	177.00	90.00	98.00
1959	-246.00	-333.00	-232.00	-210.00	-328.00	-56.00	-35.00	-60.00	-24.00	-5.00
1960	-300.00	-370.00	-287.00	-214.00	-358.00	-54.00	-37.00	-55.00	-4.00	-30.00
1961	-314.00	-377.00	-371.00	-281.00	-417.00	-14.00	-7.00	-84.00	-67.00	-59.00
1962	-299.00	-370.00	-351.00	-283.00	-426.00	15.00	7.00	20.00	-2.00	-9.00
1963	-282.00	-365.00	-348.00	-296.00	-444.00	17.00	5.00	3.00	-13.00	-18.00
1964	-357.00	-379.00	-332.00	-322.00	-472.00	-75.00	-14.00	16.00	-26.00	-28.00
1965	-370.00	-392.00	-378.00	-350.00	-503.00	-13.00	-13.00	-46.00	-28.00	-31.00
1966	-363.00	-385.00	-338.00	-343.00	-472.00	7.00	7.00	40.00	7.00	31.00
1967	-312.00	-333.00	-231.00	-299.00	-402.00	51.00	52.00	107.00	44.00	70.00
1968	-305.00	-322.00	-180.00	-262.00	-372.00	7.00	11.00	51.00	37.00	30.00
1969	-110.00	-130.00	-168.00	-22.00	-87.00	195.00	192.00	12.00	240.00	285.00
1970	-59.00	-65.00	-160.00	-46.00	-108.00	51.00	65.00	8.00	-24.00	-21.00
1971	-57.00	-80.00	-154.00	-74.00	-207.00	2.00	-15.00	6.00	-28.00	-99.00
1972	-83.00	-100.00	-213.00	-113.00	-252.00	-26.00	-20.00	-59.00	-39.00	-45.00
1973	-110.00	-130.00	-261.00	-131.00	-271.00	-27.00	-30.00	-48.00	-18.00	-19.00
1974	-126.00	-147.00	-224.00	-148.00	-279.00	-16.00	-17.00	37.00	-17.00	-8.00
1975	-124.00	-159.00	-268.00	-162.00	-300.00	2.00	-12.00	-44.00	-14.00	-21.00
1976	-146.00	-182.00	-362.00	-179.00	-320.00	-22.00	-23.00	-94.00	-17.00	-20.00
1977	-173.00	-201.00	-386.00	-210.00	-338.00	-27.00	-19.00	-24.00	-31.00	-18.00
1978	-48.00	-52.00	-158.00	-53.00	-349.00	125.00	149.00	228.00	157.00	-11.00
1979	-30.00	-54.00	-162.00	-30.00	-328.00	18.00	-2.00	-4.00	23.00	21.00

Table 2.1-2. Summary of Groundwater Levels (continued)
Lytle Creek Sub-Basin, 1934 - 2002

	Depth to Water (ft.)				**Change in Water Level (ft.)**					
	WELL NO 05	**WELL NO 07**	**FU 3**	**WELL NO 02**	**FU 8**	**WELL NO 05**	**WELL NO 07**	**FU 3**	**WELL NO 02**	**FU 8**
	1N5W25E01S	**1N5W36H04S**	**1N5W22F02S**	**1N5W23Q00S**	**1N5W15Q02S**	**1N5W25E01S**	**1N5W36H04S**	**1N5W22F02S**	**1N5W23Q00S**	**1N5W15Q02S**
Year	Source	Source	Source	Source	Source	Source	Source	Source	Source	Source
1980	-15.00	-13.00	-182.00	-29.00	-360.00	15.00	41.00	-20.00	1.00	-32.00
1981	-26.00	-47.00	-175.00	-63.00	-356.00	-11.00	-34.00	7.00	-34.00	4.00
1982	-49.00	-74.00	-158.00	-38.00	-353.00	-23.00	-27.00	17.00	25.00	3.00
1983	-20.00	-14.00	-141.00	-26.00	-88.00	29.00	60.00	17.00	12.00	265.00
1984	-30.00	-38.00	-124.00	-13.00	-152.00	-10.00	-24.00	17.00	13.00	-64.00
1985	-53.00	-95.00	-186.00	-47.00	-203.00	-23.00	-57.00	-62.00	-34.00	-51.00
1986	-73.00	-129.00	-189.00	-70.00	-232.00	-20.00	-34.00	-3.00	-23.00	-29.00
1987	-97.00	-180.00	-248.00	-116.00	-279.00	-24.00	-51.00	-59.00	-46.00	-47.00
1988	-172.00	-224.00	-308.00	-172.00	-336.00	-75.00	-44.00	-60.00	-56.00	-57.00
1989	-211.00	-279.00	-367.00	-226.00	-370.00	-39.00	-55.00	-59.00	-54.00	-34.00
1990	-242.00	-350.00	-416.00	-281.00	-392.00	-31.00	-71.00	-49.00	-55.00	-22.00
1991	-268.00	-367.00	-380.00	-301.00	-311.00	-26.00	-17.00	36.00	-20.00	81.00
1992	-292.00	-352.00	-230.00	-304.00	-229.00	-24.00	15.00	150.00	-3.00	82.00
1993	-43.00	-200.00	-79.00	-39.00	-148.00	249.00	152.00	151.00	265.00	81.00
1994	-55.00	-176.00	-172.00	-63.00	-188.00	-12.00	24.00	-93.00	-24.00	-40.00
1995	-40.00	-158.00	-96.00	-12.00	-208.00	15.00	18.00	76.00	51.00	-20.00
1996	-54.00	-158.00	-151.00	-45.00	-198.00	-14.00	0.00	-55.00	-33.00	10.00
1997	-72.00	-188.00	-196.00	-79.00	-230.00	-18.00	-30.00	-45.00	-34.00	-32.00
1998	-51.00	-177.00	-114.00	-65.00	-190.00	21.00	11.00	82.00	14.00	40.00
1999	-73.00	-203.00	-188.00	-95.00	-239.00	-22.00	-26.00	-74.00	-30.00	-49.00
2000	-144.00	-225.00	-315.00	-172.00	-316.00	-71.00	-22.00	-127.00	-77.00	-77.00
2001	-195.00	-275.00	-358.00	-217.00	-383.00	-51.00	-50.00	-43.00	-45.00	-67.00
2002	-275.00	-334.00	-378.00	-317.00	-431.00	-80.00	-59.00	-20.00	-100.00	-48.00

Shaded cells with no values represent no depth available.
Shaded cells with values represent interpolated depths.
Source: Muni, 2003.

The foothills of the San Bernardino Mountains define the northeastern boundary of the SBBA. At the base of the mountains is the northwest-trending, strike-slip, San Andreas Fault, which acts as a leaky barrier. This fault juxtaposes Quaternary age, water-bearing alluvium of the basin with the Precambrian/Cambrian basement complex (minimally fractured consolidated igneous and metamorphic rock) of the San Bernardino Mountains. The basement complex is essentially non-water bearing and inflow from the east is predominantly surface water.

The southeastern boundary of the valley fill alluvium is the Crafton Fault and the associated Crafton Hills and San Timoteo Badlands area (Figure 2.1-3). Early reports (Gleason 1947) and recent groundwater modeling (Danskin et al. N.D.) indicate that groundwater flows northwest at the southern part of the basin and is fed by underflow from the west and east of the Crafton Hills, including underflow from the Badlands area. The Crafton Fault does not act as a groundwater barrier in this area. To the south of the Crafton Fault, consolidated rock makes up the Crafton Hills and the surrounding area (Dutcher and Garrett 1963).

The southwestern side of the SBBA is defined by the northwest-trending San Jacinto and Loma Linda faults (Figure 2.1-3). The San Jacinto Fault is the boundary, from the Colton Narrows northwest to Lytle Creek Basin, between the valley-fill older alluvium that comprises the aquifer system and the basement complex rock to the southwest. The most obvious evidence that the San Jacinto Fault is a partial barrier to groundwater flow is the abrupt boundary of the area of historically artesian wells along the northeast side of the fault (Dutcher and Garrett 1963).

The near-surface younger alluvium is not offset by the San Jacinto Fault. Most of the groundwater outflow from the basin is through this un-faulted younger alluvium that underlies the floodplain of the SAR at the Colton Narrows, near the confluence with Lytle Creek (Figure 2.1-1). An approximately 1.1-mile wide swath of underflow-bearing alluvium occurs across the San Jacinto Fault at this location through the shallow alluvial sediments. In addition, less southwest-trending basin outflow occurs along the San Jacinto Fault through the older alluvium of Lytle Creek Canyon, located northwest of the Colton Narrows.

Lytle Creek Basin

Lytle Creek Basin is bordered on the west by the Rialto-Colton Basin along the Lytle Creek fault (also known as Barrier E shown in Figure 2.1-3), and on the east and southeast by the Bunker Hill Basin along the Loma Linda Fault and Barrier G (Figure 2.1-3). The northwestern border of the basin is delineated by the San Gabriel Mountains (Figure 2.1-3) and runoff from the mountains flows south/southeast through Lytle and Cajon creeks into the basin. Numerous groundwater barriers are present within Lytle Creek Basin, resulting in six compartments within the basin. The upper (i.e., northwestern) basin is divided into five compartments and the lower (i.e., southeastern) basin comprises the sixth compartment. Barrier F divides the upper and lower basins and Barriers A through D divide the upper basin. The amount of pumping in the compartments in large part controls the movement of groundwater across the groundwater barriers. Of the five compartments in upper Lytle Creek Basin, the most westerly is the first to receive recharge from both seepage from Lytle Creek and underflow across Barrier J. Barrier J appears to be an effective barrier to groundwater movement within the older alluvium but not the younger alluvium (Dutcher and Garrett 1963).

The Loma Linda Fault and Barrier G together form the common border between Lytle Creek and Bunker Hill basins (Figure 2.1-3). Geologic evidence for the Loma Linda Fault is limited in extent and character in the basement complex in the San Gabriel Mountains and hydrologic evidence showing the effectiveness of the Loma Linda Fault as a barrier to underflow is also limited. Based on differences in water level fluctuations on either side of the Loma Linda fault and parallel Barrier A, the rate of recharge to this compartment is probably relatively constant; is primarily by subsurface flow from Bunker Hill Basin and/or from the area of upper Lytle Creek Basin west of Barrier A; and is not appreciably changed by the relative changes in head recorded on opposite sides of the Loma Linda Fault and/or Barrier A.

For that part of the Loma Linda Fault bordering the lower Lytle Creek Basin, from Barrier F southeast to Barrier G and including Barrier G (Figure 2.1-3), there is a similar lack of evidence on the effectiveness of the barriers to completely inhibit groundwater movement. However, relatively large disparities in groundwater levels (over 100 feet locally) indicate that the Loma Linda Fault and Barrier G are reasonably effective as barriers to groundwater movement. In addition, rising groundwater levels in Lytle Creek Basin with corresponding lowering groundwater levels in Bunker Hill Basin have been observed during a number of periods, thus providing further evidence that this groundwater barrier is somewhat effective.

The common boundary between the Lytle Creek and Rialto–Colton basins is considered to be the San Jacinto Fault and Barrier E (also known as the Lytle Creek Fault), which is probably a branch of the San Jacinto Fault (Figure 2.1-3). Water level contours based on data from existing wells on both sides of the fault suggest no movement of water from Lytle Creek Basin to Rialto–Colton Basin, where the groundwater levels may be several hundred feet lower.

2.1.3 Basin Groundwater Storage

Deep percolation from channel beds is the primary source of recharge and well pumpage is the primary source of extraction in the basin. Recharge of the basin occurs from a number of sources, the most important of which are:

- Streams emanating from the San Bernardino and San Gabriel mountains which border the basin to the north. The major such streams are the SAR, Lytle Creek, Cajon Creek, Devil Canyon Creek, East Twin Creek, Warm Creek, City Creek, Plunge Creek, and Mill Creek (Figure 2.1-1);
- Underflow (subsurface inflow) through bedrock of the San Bernardino Mountains, along the northern boundary of the basin;
- Direct infiltration of precipitation;
- Artificial recharge through the use of spreading basins, most of which are located in the forebay section of the basin along the southern edge of the San Bernardino Mountains;
- Ungaged mountain front runoff; and
- Return flow.

Recharge

Seepage from gaged streams is the major source of recharge in the SBBA. Recharge occurs both in the stream channels and in nearby artificial recharge basins. As a result of the highly permeable river-channel deposits and the artificial recharge operations, nearly all of the flow in the smaller gaged streams (Devil Canyon, Waterman, East Twin, Plunge, and San Timoteo Creeks*)* is recharged to the aquifer close to the mountain front. During floods, the major streams (SAR, Mill Creek, and Lytle Creek) transmit large volumes of water during a short period, resulting in some water exiting the basin. Recharge from all gaged stream flow is calculated by subtracting total gaged surface water outflow from total gaged surface water inflow (Danskin et al. N.D.).

Seepage from ungaged runoff (i.e., runoff from areas between gaged watersheds) is of less importance since the total quantity is about one-tenth that of gaged runoff. Nearly all the ungaged runoff that flows into the basin is assumed to recharge the valley fill aquifer. The majority of recharge is due to runoff from the surrounding mountains and hills, localized rock outcrops within the basin, and impermeable urban surfaces within the basin.

With the exception of unusually wet years, recharge from direct precipitation on the basin is minimal with an average annual precipitation in the basin of 16.4 inches (in) (see Figure 2.1-12). A long-term average recharge from precipitation of 8,400 afy was estimated by the California Department of Water Resources (DWR) (1986), which is equal to an average infiltration rate of about 0.11 feet/year (ft/yr), or about 8 percent of the average precipitation rate. However, the USGS believes that this value is too high as an average because during many years essentially no infiltration of direct precipitation occurs (Danskin et al. N.D.). Citing numerous other studies (Eychaner 1983, Danskin 1988, Hollett et al. 1991, Hanson et al. 1994), the USGS (Danskin et al. N.D.) indicates the infiltration rate of direct precipitation in other semi-arid basins ranges from zero to about 0.05 ft/yr. The USGS believes the 8,400 afy value includes recharge, not only from direct precipitation, but also from local runoff resulting from precipitation (i.e., impermeable urban surfaces and rock outcrops within the basin).

Artificial recharge of imported water began in 1972. Because of the extremely permeable sand and gravel deposits, maximum instantaneous recharge rates are high. Based on a recharge efficiency rate of 95 percent, the total quantity of imported, artificial recharge in the basin averaged about 7,400 afy from 1972 to 1992. In 1973, total recharge was 30,000 afy. An even greater quantity of water could be imported and recharged along the base of the San Bernardino Mountains if necessary because of the size of several of the recharge basins and exceptionally permeable material. An additional source of recharge is that derived from return flow of water pumped from and used locally within the SBBA. Hardt and Hutchinson (1980) estimated return flow to be 30 percent of total pumpage, except for wells that export groundwater directly out of the San Bernardino area.

Underflow into the SBBA occurs (1) across the Crafton fault and through the low permeability materials comprising the San Timoteo Badlands; (2) across a small section of unconsolidated deposits north of the Crafton Hills; and (3) through materials beneath the Cajon Creek and Lytle Creek channels. Underflow across the Crafton Fault and through the Badlands was defined by Dutcher and Fenzel (1972) to be approximately 6,000 afy for the period 1945 to 1965. Underflow beneath the creek channels was estimated by the DWR (1970) to be approximately 3,300 afy for the period 1935 to 1960.

Discharge

Groundwater discharge from the SBBA primarily occurs into the lower reaches of Warm Creek, when nearby groundwater rises above the level of the channel bottom. The quantity of discharge into the creek for the period 1945 to 1992 was determined to be highly variable, with a maximum discharge exceeding 40,000 afy and a minimum discharge of zero for 16 consecutive years, from 1963 to 1978 (Danskin et al. N.D.).

In addition, underflow out of the basin occurs across the San Jacinto Fault and Barrier E in two locations, including in the vicinity of the SAR at the Colton Narrows and where Lytle Creek emerges from the San Gabriel Mountains, north of Barrier J (Figure 2.1-1). Underflow near the SAR occurs in the younger alluvium, which is about 100 feet thick. The river has eroded and re-deposited these materials, removing most of the restriction to groundwater flow caused by movement of the San Jacinto Fault. In the older, deeper deposits, fault gouge and offset of permeable zones restrict groundwater flow. For the period 1936 to 1949, underflow was estimated to range from 14,300 to 23,700 afy (Dutcher and Garrett 1963).

The underflow estimate for the Colton Narrows was derived on the basis of data obtained approximately 1,300 feet downstream of the San Jacinto Fault. These data include the coefficient of transmissivity and cross-sectional area of the saturated younger alluvium. This cross-sectional area of younger alluvium, in the vicinity where the underflow was calculated (110 feet thick by 1.1 miles wide), was approximately the same as where the river crosses the fault. The river maintained a fairly constant width and the base of the alluvium was generally flat. However, the younger alluvium recharges the older alluvium with increasing distance from the fault, thus decreasing the saturated thickness of the younger alluvium downstream from the fault. This indicates that the annual loss of underflow from the younger alluvium to the older alluvium exceeds the annual recharge from Warm Creek and the SAR.

Underflow out of the basin north of Barrier J (Figure 2.1-3) was estimated to be approximately 4,000 afy by Dutcher and Garrett (1963) on the basis of 1951 water level data and pump test data, using methods similar to calculations at Colton Narrows (described above). Similarly, underflow in this area was estimated by DWR (1970) to be 2,700 to 4,200 afy during water years 1935 to 1960.

While stream flow and underflow contribute to basin discharge, groundwater pumpage is the primary discharge from groundwater storage. The extracted water is used for agricultural, municipal, and industrial purposes. Most pumpage is located near major streams, including the SAR, Lytle Creek, Warm Creek, and East Twin Creek (Figure 2.1-1). This areal distribution of pumpage reflects the exceptionally permeable deposits that underlie the stream channels and the abundant nearby recharge (Danskin et al. N.D.).

As the area has become urbanized, the quantity of agricultural pumpage has declined considerably, presently accounting for less than 20 percent of the gross pumpage. However, overall pumpage has increased in the basin. Prior to 1940, gross pumpage in the basin was less than 110,000 afy, while currently pumping has reached as high as about 200,000 afy (Western–San Bernardino Watermaster 2002).

Change in Storage

Estimates are made annually of the change in groundwater volume, or storage, in the SBBA by Muni from which a cumulative change in basin storage is calculated. The approach employed by Muni calculates the change in storage for nine sub-areas: Cajon, Devil Canyon, Lytle Creek, Pressure Zone, City Creek, Redlands, Mill Creek, Reservoir, and Divide (see Table 2.1-3 and Figure 2.1-2). Calculating the change in storage for the SBBA is done by summing the individual values for each of the sub-areas.

The first change in storage calculation was completed for the years 1934 to 1960 by DWR and the results were summarized in *Bulletin 104-5, Meeting Water Demands in the Bunker Hill-San Timoteo Area, Geology, Hydrology, and Operation-Economics Studies, Text and Plates* (DWR 1970). The DWR change in storage values were calculated using the Specific Yield Method and a mathematical model developed by TRW, Incorporated (Muni 2004). In 1980, Muni updated the change in storage calculation to include the years 1961 to 1980. In the early 1990s, Muni created a new change in storage model using software developed by Environmental Systems Research Institute (ESRI). In years of low precipitation, infiltration (direct from precipitation and from surface streams) decreases while groundwater extractions increase, thereby causing the cumulative storage to decrease. The trend in cumulative change in storage over the period 1934 to 2002 is displayed in Figure 2.1-13. The cumulative change in storage is cyclical based upon weather conditions e.g., 1934 through 1949 and 1979 through 1987 were wet periods, which produced increases in storage, while 1950 through 1978 was a dry period, resulting in decreased storage.

Table 2.1-3. Change in Storage for Sub-Areas within the San Bernardino Basin for 2003

Sub-Area	*No. of Wells Used to Calculate Change in Storage*	*Annual Change in Storage (af)*
Cajon	47	2,929
Devil Canyon	8	-5,877
Lytle Creek	8	-13,804
Pressure Zone	11	-6,744
City Creek	13	12,454
Redlands	7	-1,631
Mill Creek	2	4,171
Reservoir	1	-168
Divide	1	1,720

Source: Muni 2004.

The Lytle Creek Sub-Area contains Lytle Creek with extensive headwaters in the adjacent mountain areas and a river channel comprised of deep, porous alluvial deposits. Due to the presence of Lytle Creek and its relatively small size, this sub-area exhibits far greater and more extreme changes in storage than any other sub-area. In 40 of the 68 years, the annual average change in depth to groundwater exceeds 20 feet, with 8 years showing changes greater than 50 feet and 3 years exceeding 100 feet.

2.2 RIALTO–COLTON GROUNDWATER BASIN

The approximately 30,100-acre Rialto–Colton Basin lies to the west of the SBBA. The basin is bounded on the northwest by the San Gabriel Mountains; on the southwest by the Rialto–Colton Fault; on the southeast by the Badlands; on the northeast by the San Jacinto Fault and Barrier E (Figure 2.1-1).

Except in the southeastern part of the basin, the San Jacinto and Rialto–Colton faults act as barriers that impede flow into and out of the basin (Danskin et al. N.D.). See section 2.1.2 for additional detail on the boundary with the SBBA.

The basin consists of four water-bearing units: the river channel; upper; middle; and lower. Groundwater generally moves from east to west in the river channel and upper water bearing units. In the middle and lower water bearing units, water moves from northwest to southeast. Groundwater movement is affected by two internal faults, Barrier J and an unnamed fault (Figures 2.2-1 and 2.1-3). Water moves across Barrier J into the un-faulted part of the groundwater system. The unnamed fault may be a partial barrier to groundwater movement in the middle water-bearing unit and a more effective barrier in the lower water-bearing unit. Generally, imported water flows laterally across the unnamed fault above the saturation zone (Danskin et al. N.D.).

Sources of recharge to the Rialto–Colton Basin are underflow, precipitation, imported water, seepage from the SAR and Warm Creek, and irrigation return flow (Danskin et al. N.D.). Since 1971, pumping from the basin has varied from a low of approximately 5,000 af (in 1983) to a high of approximately 17,600 af (in 1990). In 2000, pumping was approximately 13,000 af (Western–San Bernardino Watermaster 2002). The basin has an estimated total storage capacity of about 2,517,000 af.

Water levels vary across the basin due to the presence of internal faults. For example, in the northern part of the basin, water levels rise quickly following rainfall. In the northern portion of the basin, in the 1990s, it was typical for well water levels to vary by 50 feet in a given year (DWR 2003). In the southern part of the basin, however, groundwater levels are more static, as evidenced by water level variations of only 5 to 10 feet per year in the 1990s (DWR 2003).

MODFLOW and MODPATH were used to simulate groundwater flows in the Rialto-Colton Basin with particular attention placed on the effects of artificial recharge at the Cactus Basins and Linden Ponds (Woolfenden and Koczot 1999). Three recharge patterns were modeled over a simulated period of 1982 to 2027; (i) artificial recharge at Linden Ponds; (ii) no artificial recharge in the basin; and (iii) artificial recharge at Cactus Basin. The latter is described here, since it involves a spreading facility proposed for use in the Project.

Simulated flow patterns based on historical artificial recharge activities that occurred between 1982 and 1996 are illustrated in Figure 2.2-2. Flow patterns associated with artificial recharge of 10,000 af per year are shown in Figure 2.2-3. Movement of recharged water in a southeasterly direction away from Cactus Basin can be seen in both Figure 2.2-2 and Figure 2.2-3. Some of the particle tracks are captured by down-gradient production wells under both sets of circumstances. Some mounding is also evident in Figure 2.2-3 with lateral particle traces. In terms of particle distance traveled, with average historical artificial recharge, a distance of 2 miles resulted from the model. The average particle velocity was 240 ft/yr. With 10,000 afy recharge to Cactus Basin, the particle distance traveled was 2.75 miles with an average velocity of 320 ft/yr (Woolfenden and Koczot 1999).

2.3 RIVERSIDE GROUNDWATER BASIN

The 58,600-acre Riverside Basin (also known as the Riverside–Arlington Sub-basin) lies to the southwest of the Rialto–Colton Basin. Mount Rubidoux and the Chino Basin form the northwest boundary; the north of the basin is defined by the Jurupa Mountains; the eastern boundary is formed by the Rialto–Colton Fault and Box Springs Mountains;; and the south is defined by the Arlington Mountains (Figure 2.1-1) (DWR 2003).

The Rialto–Colton fault, which separates the Riverside and Rialto–Colton basins, is a known barrier to groundwater flow along much of its length (DWR 2003). The basin is recharged by SAR flow, limited underflow through the Rialto–Colton fault, limited underflow from the Chino Basin, return irrigation flow, and percolation of precipitation (DWR 2003). Pumping in the Riverside basin varies, but over time there has been a general increase in pumping. In 1971, pumping from the Riverside Basin was approximately 29,000 af, whereas in 2000, pumping was approximately 35,800 af (Western–San Bernardino Watermaster 2002). Groundwater storage capacity is estimated to be 243,000 af (DWR 2003).

In the northeastern part of the basin, groundwater levels near the SAR fluctuated about 20 feet from 1985 to 2001 and declined about 10 feet from 1995 to 2000. However, in the central part of the basin near Riverside, groundwater levels are generally static, fluctuating only about 4 feet in 20 years, from 1965 to 1985 (DWR 2003).

2.4 YUCAIPA GROUNDWATER BASIN

The 25,300-acre Yucaipa Basin lies to the east-southeast of the SBBA and is bounded on the north by the San Andreas fault; on the east by the Yucaipa Hills; on the south by the Banning Fault; and on the west by the Redlands Fault and Crafton Hills (Figure 2.1-1). The basin is drained by Wilson Creek, Oak Glen Creek, and Yucaipa Creek, which converge to form San Timoteo Creek.

Groundwater movement in the Yucaipa Basin is generally from the mountains and hills located to the north and east, in southward and westward directions. However, there are a number of faults that influence the direction of flow on a local level. The northeasterly-trending Chicken Hill Fault, Yucaipa Barrier, Casa Blanca Fault and Gateway Barrier all restrict groundwater movement in the basin. These structures displace water levels by as much as 160 feet. In the western part of the basin, northeast dipping beds of the San Timoteo Formation form barriers that cause artesian conditions (DWR 2003).

Groundwater storage capacity in the Yucaipa Basin is estimated to be 807,517 af and pumping from the basin for domestic and irrigation use is estimated at 13,800 afy. Recharge to the basin is from percolation, infiltration from local overlying streams, underflow, and artificial recharge at spreading grounds. Groundwater levels have declined historically in the Yucaipa Basin. The decline was gradual from the 1930s until increased development and associated pumping (beginning after World War II) caused more rapid declines (DWR 2003).

2.5 SAN TIMOTEO GROUNDWATER BASIN

The 71,300-acre San Timoteo Basin is located southeast of the SBBA and south of the Yucaipa Basin (Figure 2.2-1). The Banning Fault marks the boundary between the Yucaipa and San Timoteo basins and the San Jacinto Fault marks the southern boundary of the groundwater basin (DWR 2003). The western part of the basin is bounded by the San Jacinto Mountains and the eastern boundary is a topographic drainage divide with the Colorado River system (DWR 2003). Alluvium is the principal water-bearing unit of the San Timoteo Basin. The alluvium is thickest near the City of Beaumont and thins to the southwest, but is not present in the central portion of the basin. The San Timoteo Formation, folded and eroded alluvial deposits, comprises the other water-bearing unit in the basin. The total thickness of the San Timoteo Formation is estimated to be between 1,500 and 2,000 feet, but water levels in the central part of the basin indicate water-bearing gravels to depths of only 700 to 1,000 feet (DWR 2003).

Groundwater flow, which is generally from east to west toward the SBBA, is affected by local faulting. Water levels across the Banning Fault drop 100 to 200 feet to the south. In the western part of the basin, water levels drop to the south about 75 feet across the Loma Linda Fault and about 50 feet across the San Timoteo Barrier. In the northeastern part of the basin, water levels drop to the south across two unnamed faults (DWR 2003).

Recharge to the San Timoteo Basin is from the percolation of runoff carried in streams, groundwater inflow from adjacent areas, percolation of direct precipitation, and percolation of water imported for domestic or irrigation use. A study of change in water levels, between 1933 and 1960, revealed distinctive hydrograph characteristics for wells in alluvial deposits in different parts of the basin. Hydrographs for wells in centrally located San Timoteo Canyon illustrated low yearly fluctuations; wells in the northeast portion of the basin showed high yearly fluctuations; and other areas showed a continual downward trend (DWR 2003).

The total storage capacity of alluvial deposits in the basin is estimated to be about 2,010,000 af, which is an increase from estimated 1960 groundwater storage levels of approximately 1,570,000 af. Groundwater is replenished by subsurface inflow and percolation of precipitation, runoff, and imported water. Runoff and imported water are delivered to streambeds and spreading grounds for percolation and groundwater recharge (DWR 2003).

2.6 GROUNDWATER STORAGE CAPACITY SUMMARY

Table 2.6-1 summarizes the storage capacity information for the basins presented in this section.

Table 2.6-1. Summary of Groundwater Storage Capacities and Basin Surface Area

Basin	*Storage Capacity (af)*[1]	*Surface Area (acres)*
SBBA	5,976,000	90,000
Rialto–Colton	2,517,000	30,100
Riverside	243,000	58,600
Yucaipa	807,517	25,300
San Timoteo	2,010,000	73,100

Source: DWR 2003.

[1] Based on most recent available reference for storage capacity estimate.

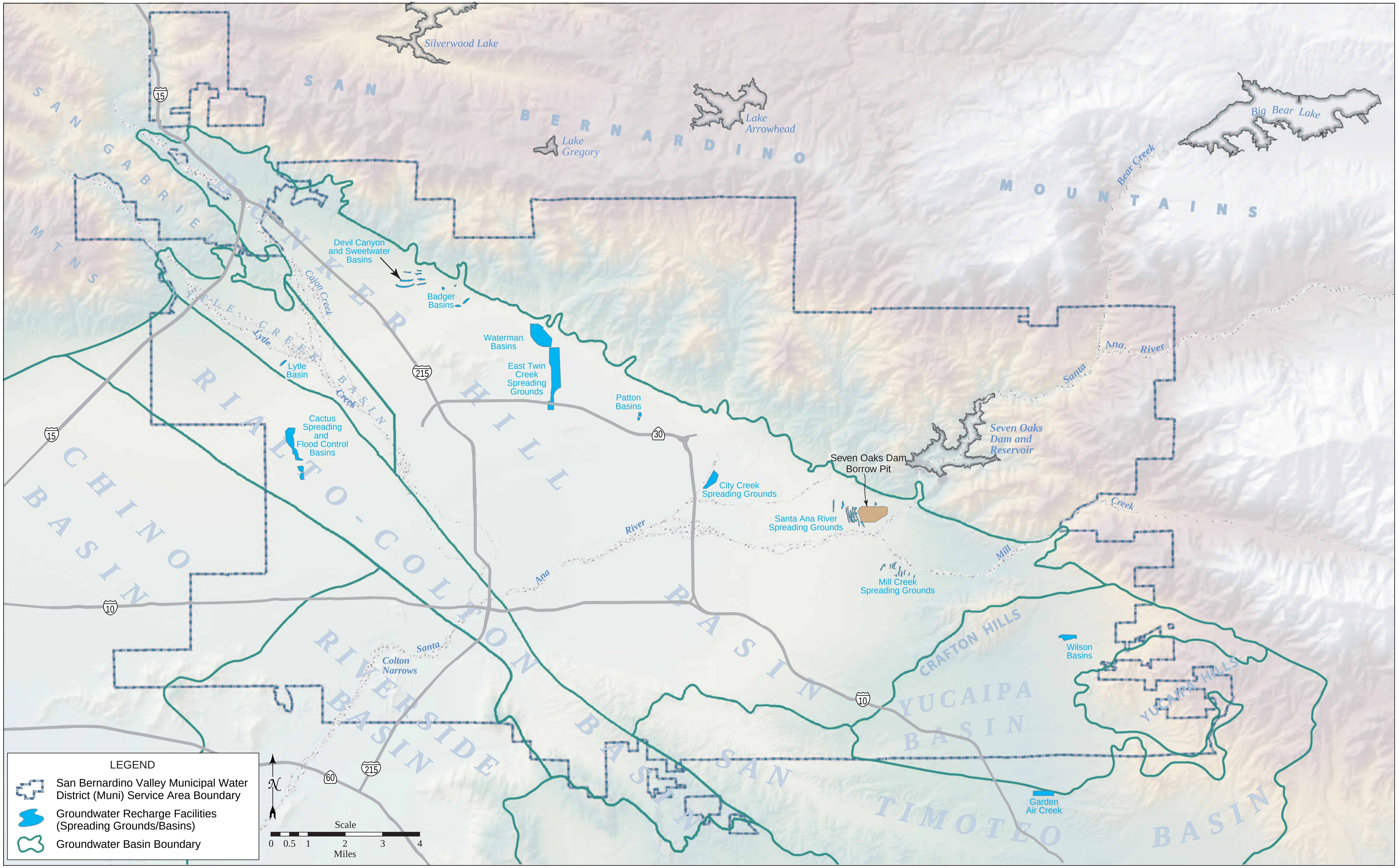
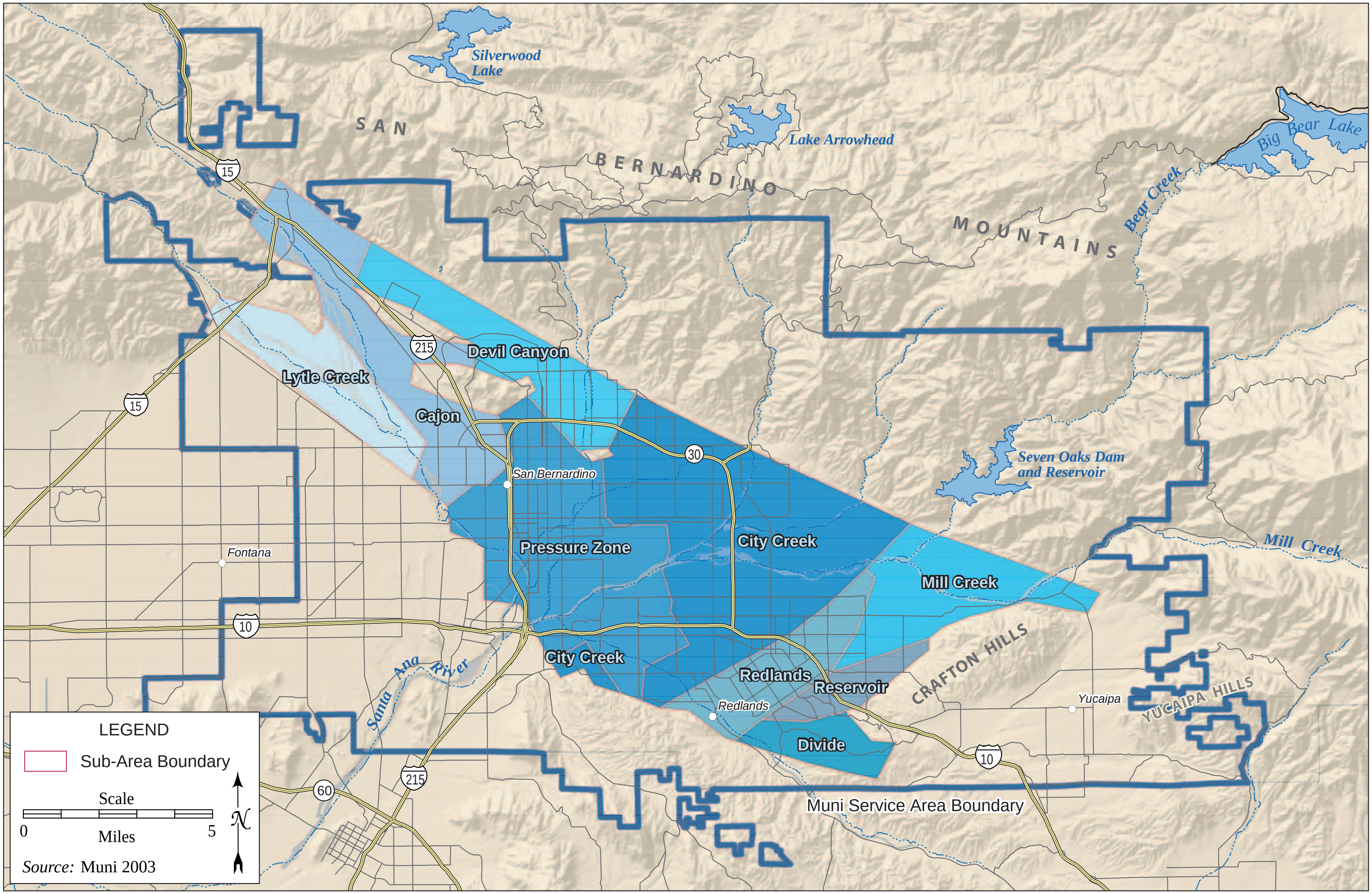


Figure 2.1-1. Groundwater Basins and Recharge Facilities



Source: Muni 2003

Figure 2.1-2. San Bernardino Basin Area (SBBA): Sub-Areas

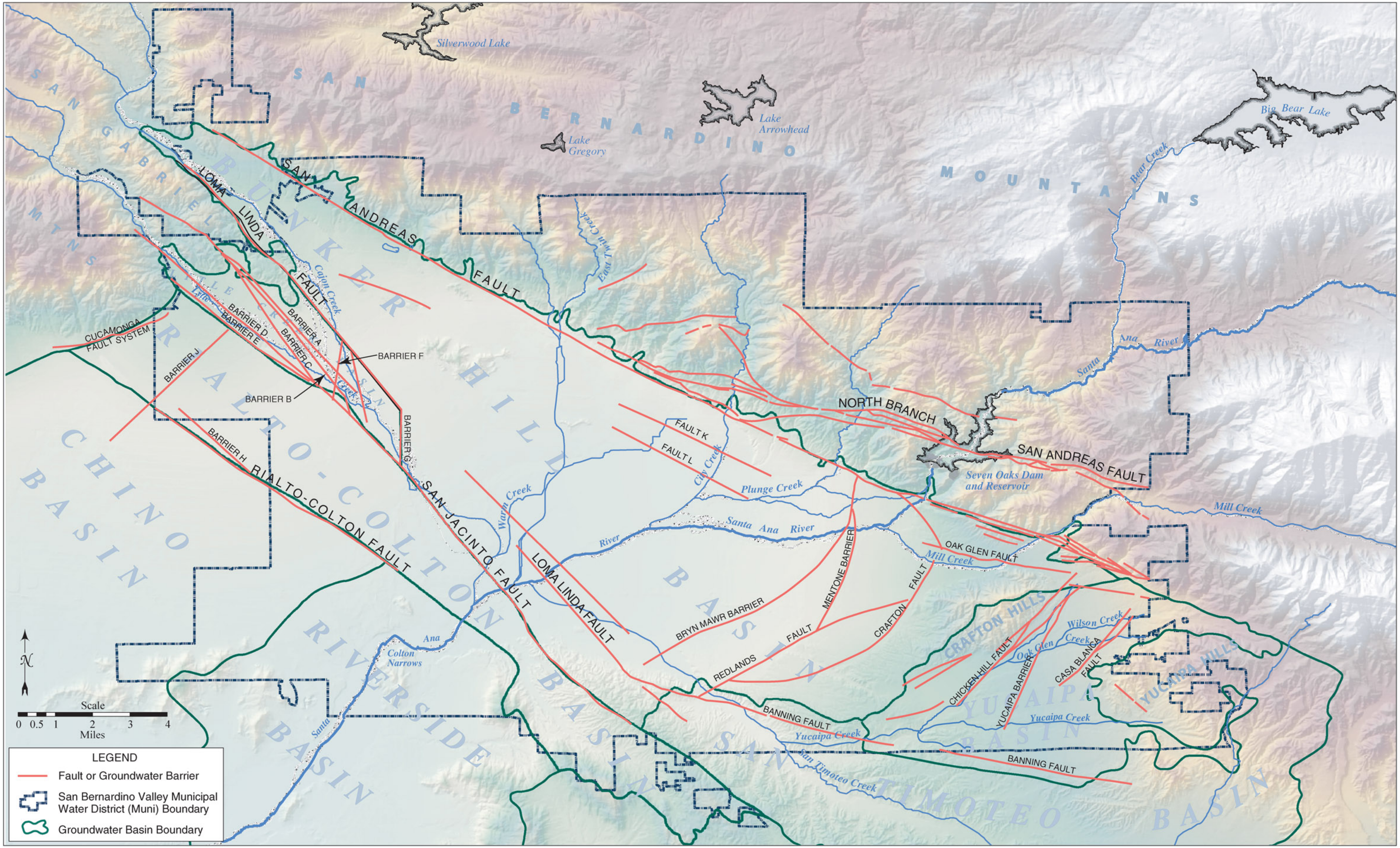
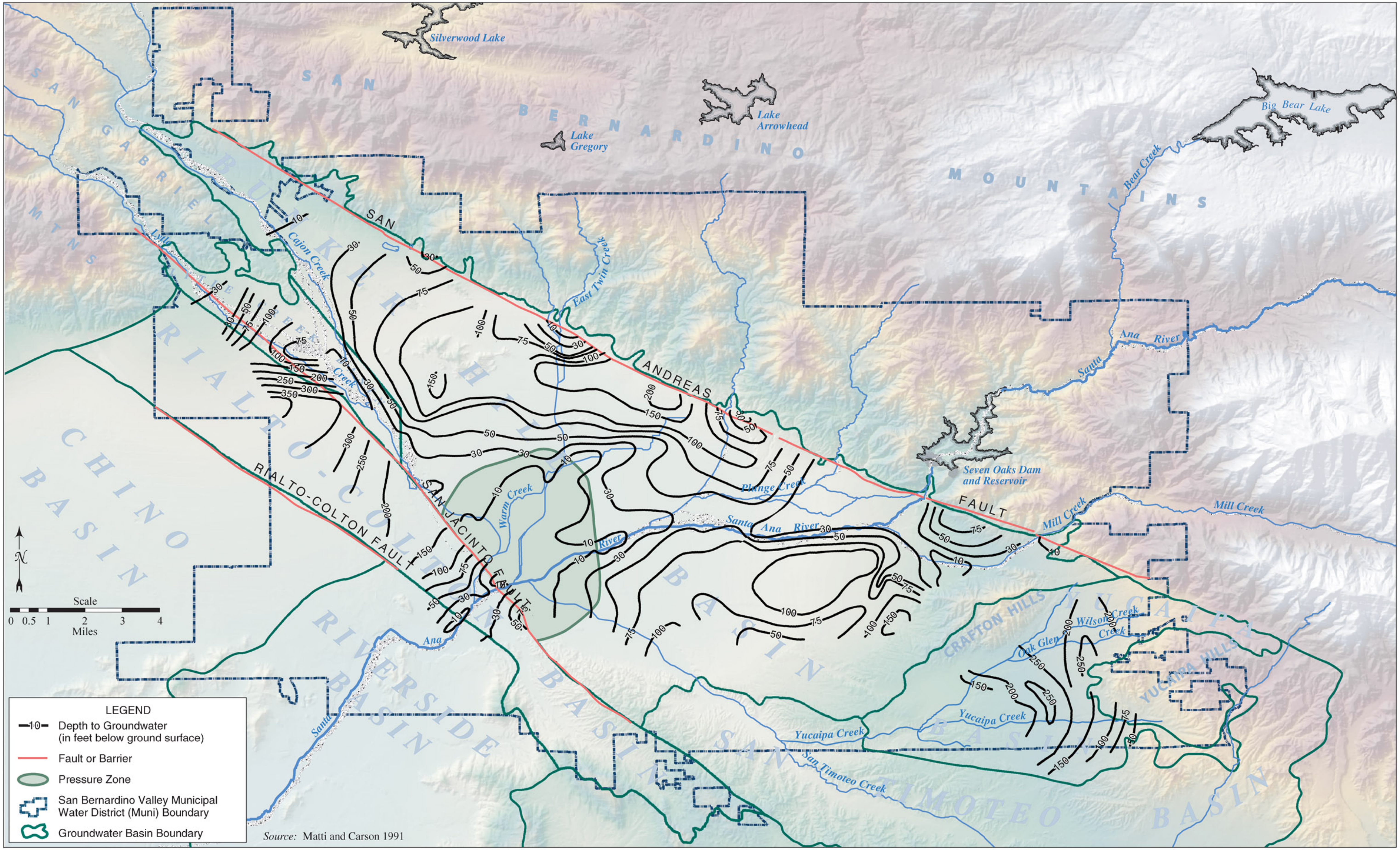
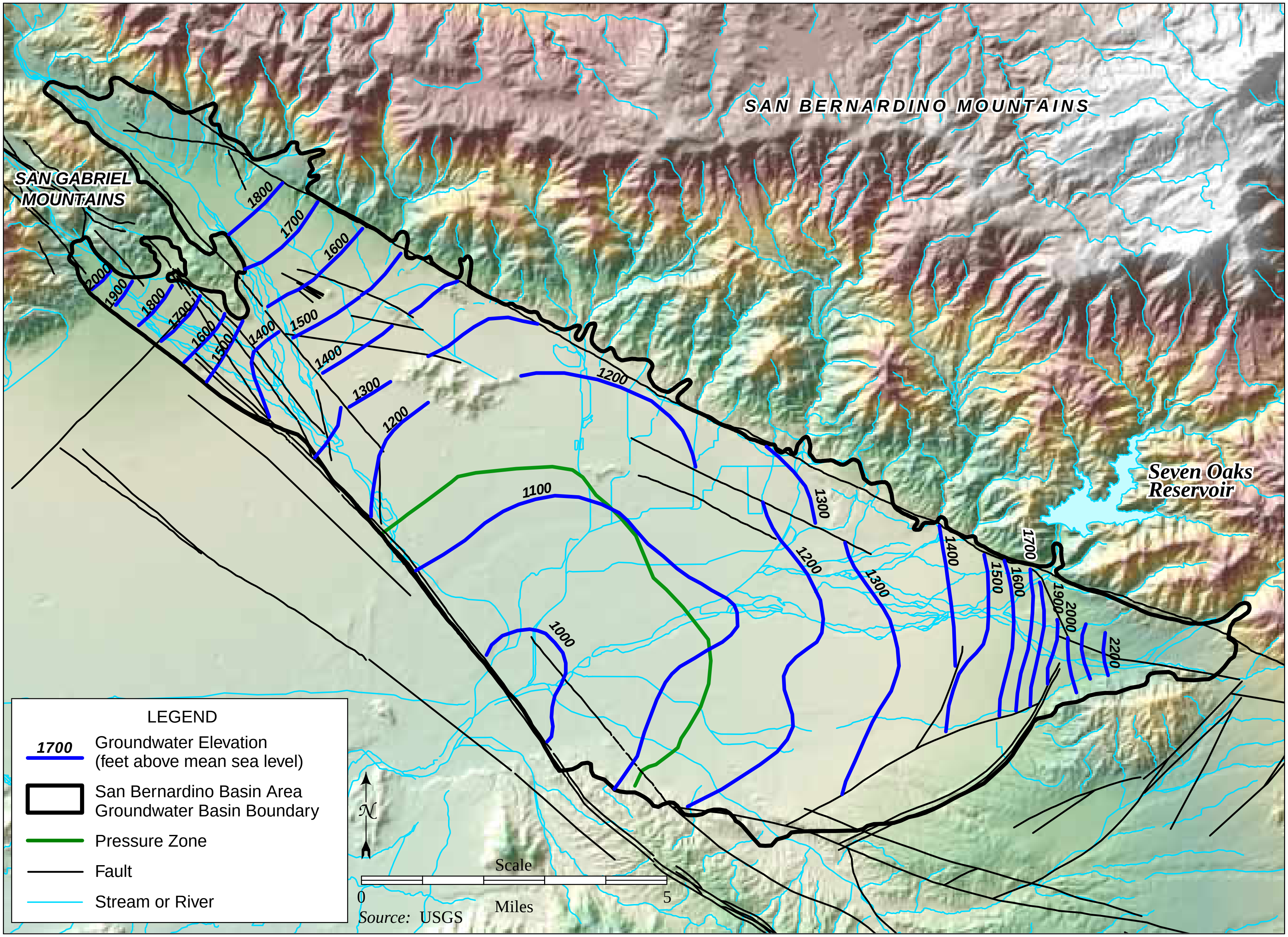


Figure 2.1-3. Faults and Groundwater Barriers in the Vicinity of the San Bernardino Basin Area (SBBA)



Source: Matti and Carson 1991

Figure 2.1-4. San Bernardino Basin Area (SBBA) Depth to Groundwater in 1991



Source: USGS

Figure 2.1-5. San Bernardino Basin Area (SBBA) Groundwater Elevation Contours - 1994

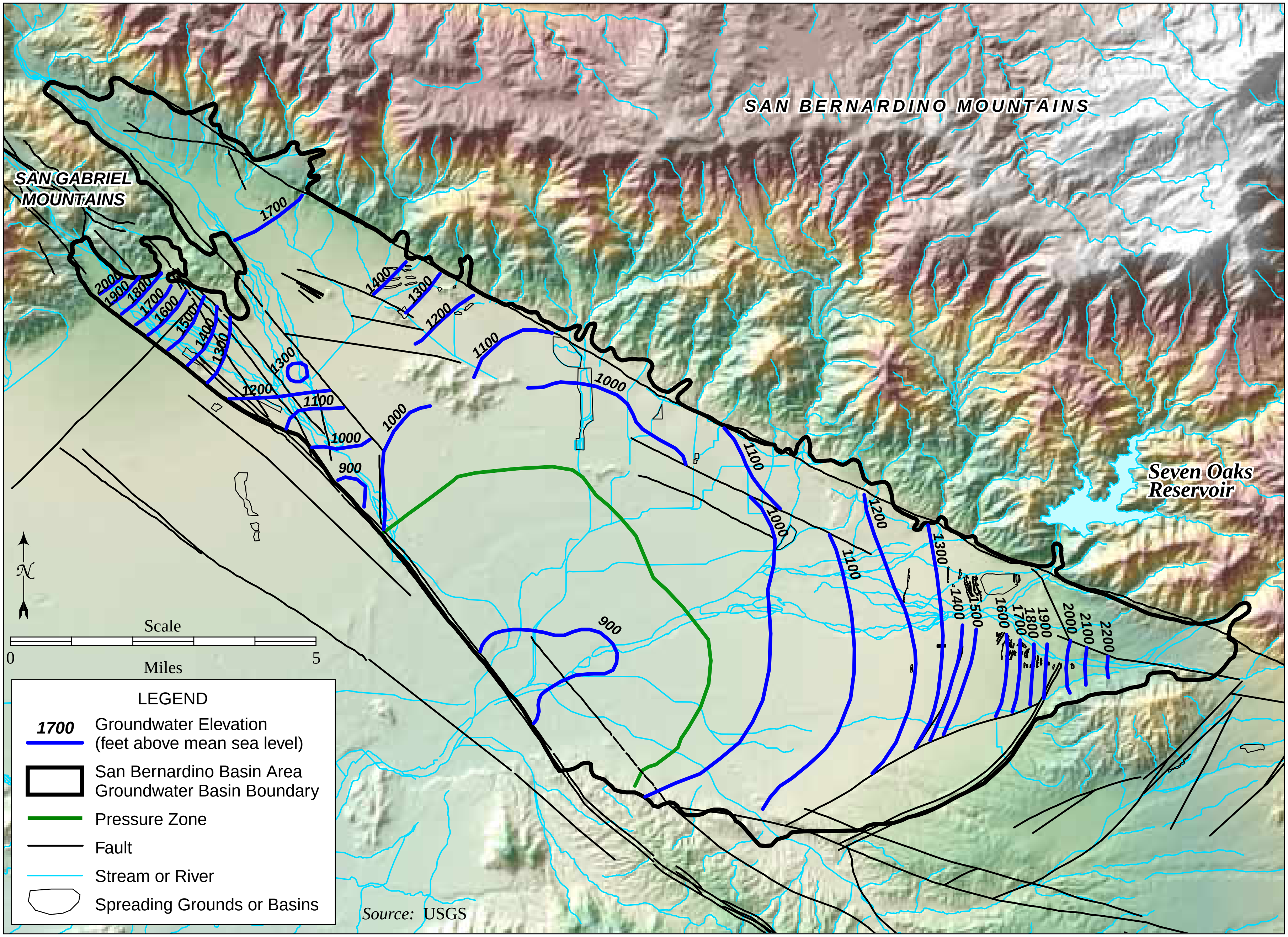
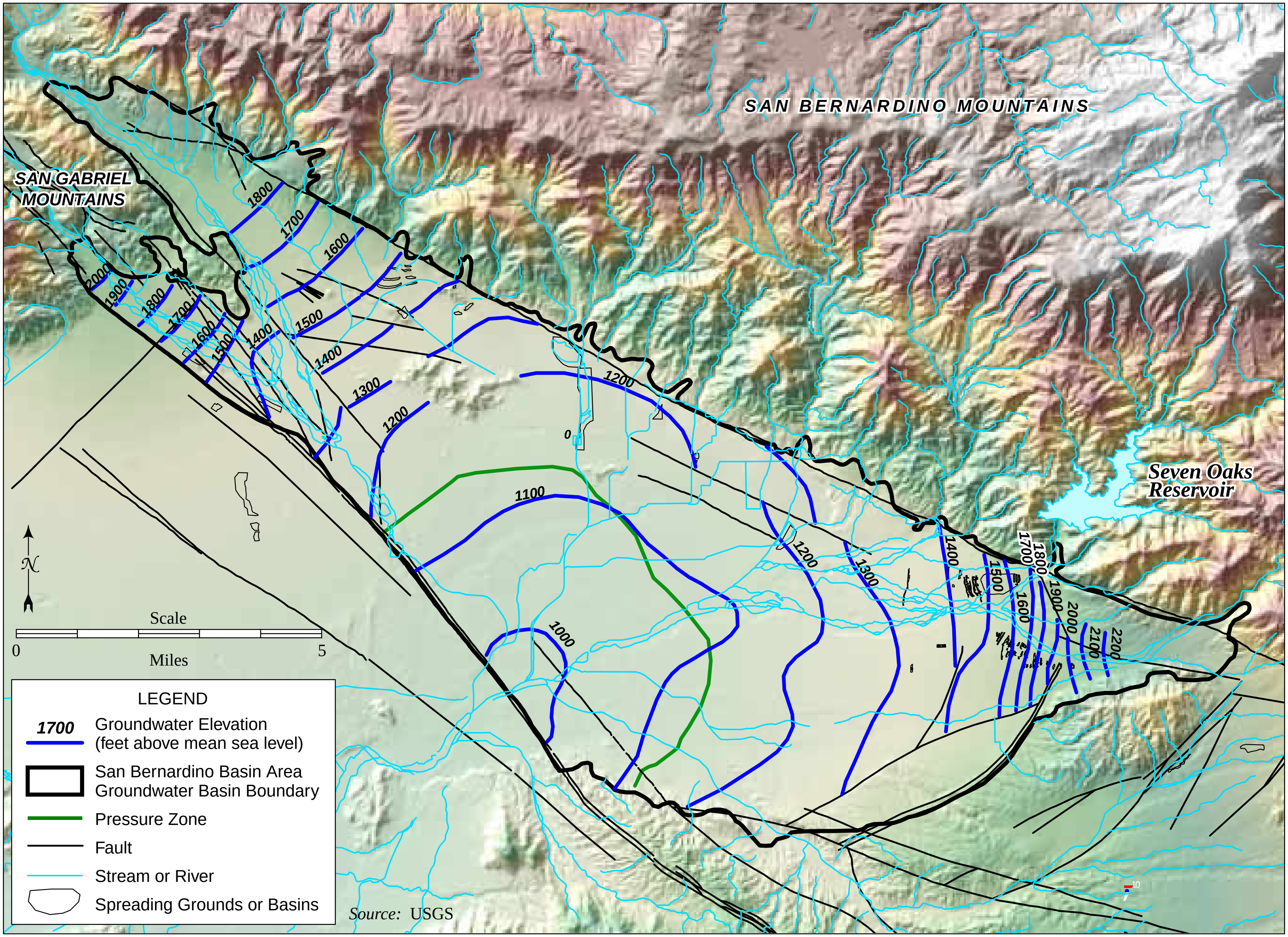


Figure 2.1-6. San Bernardino Basin Area (SBBA) Groundwater Elevation Contours - 1966



Source: USGS

Figure 2.1-7. San Bernardino Basin Area (SBBA) Groundwater Elevation Contours - 1945

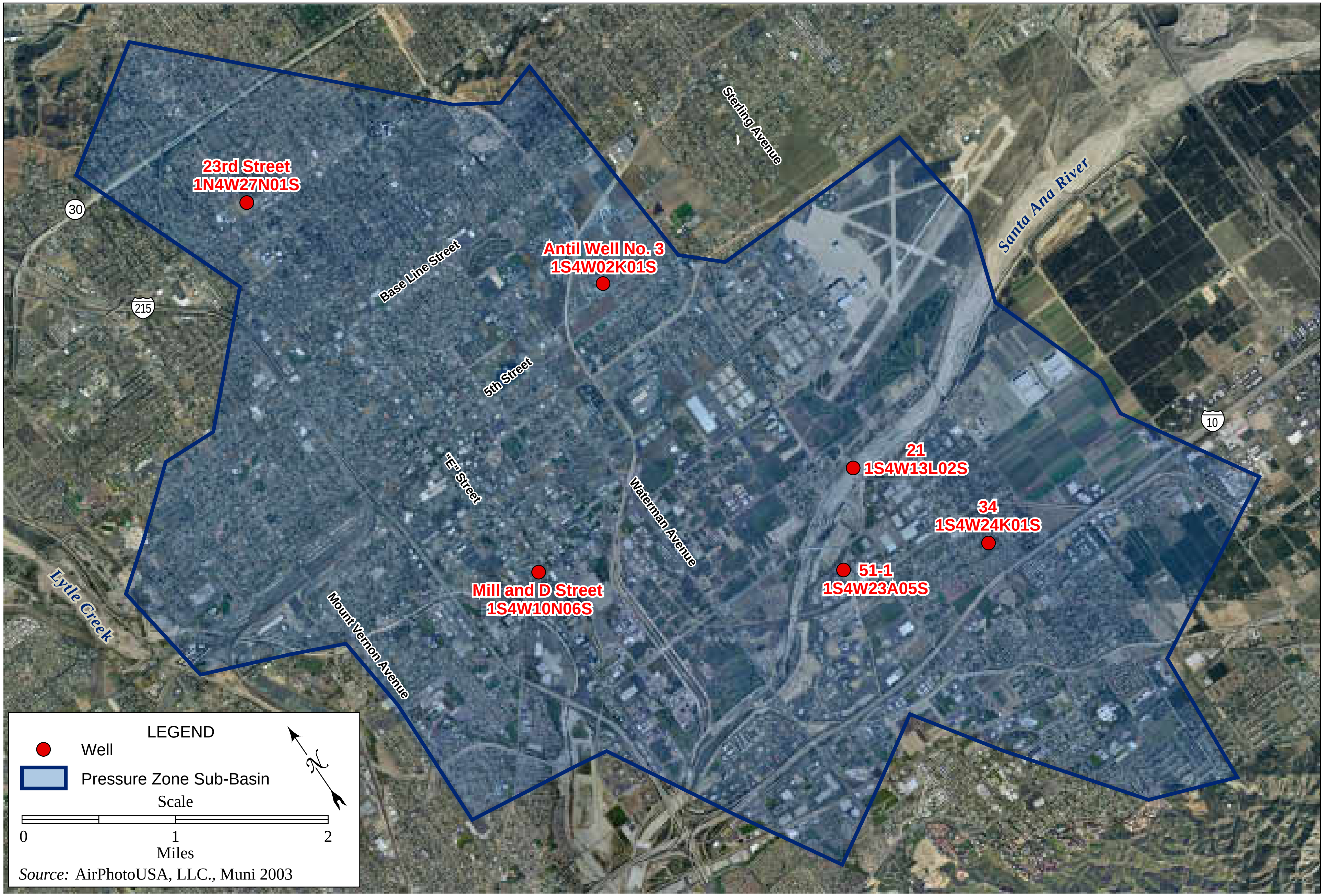
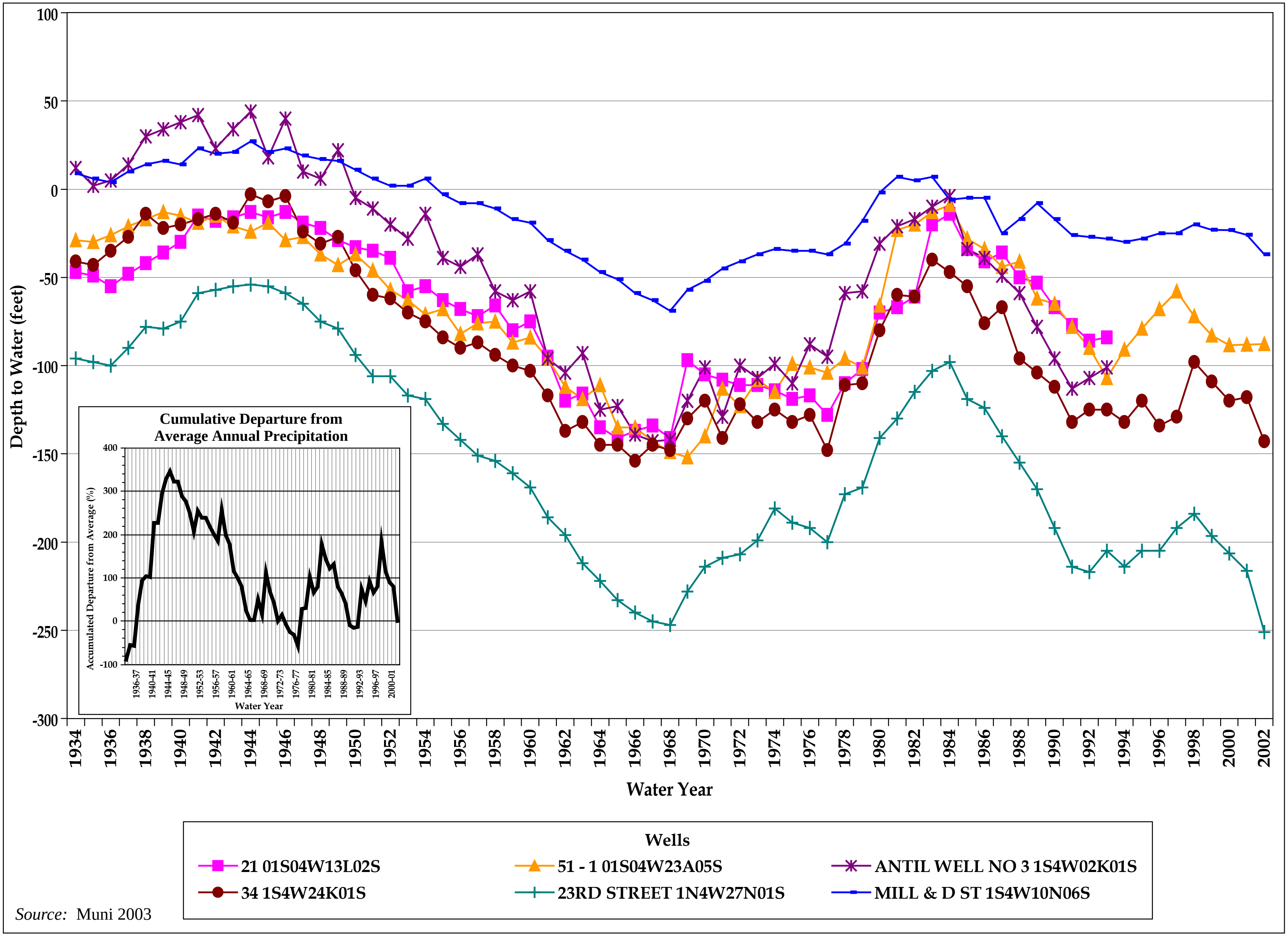
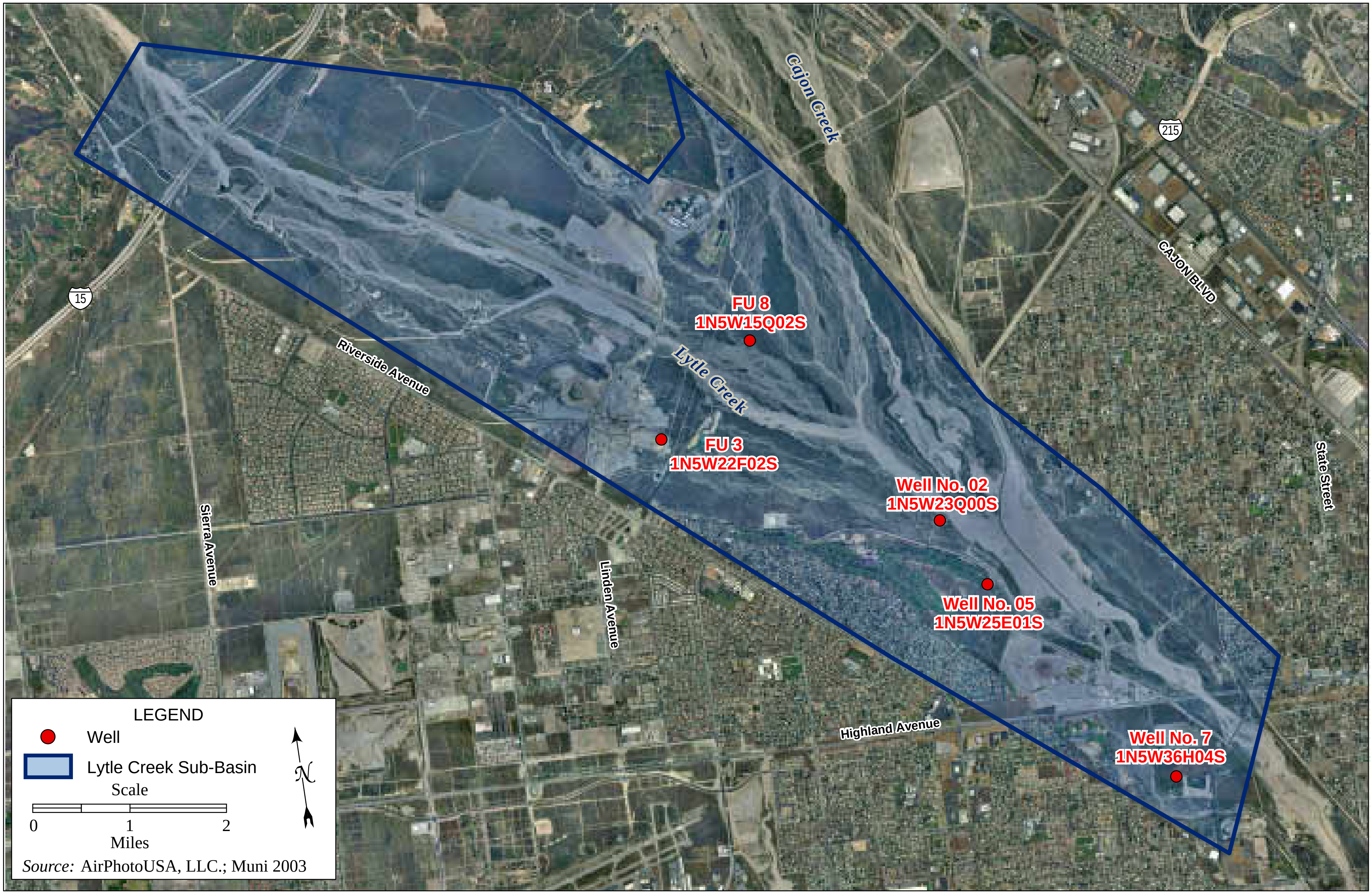


Figure 2.1-8. San Bernardino Basin Area (SBBA): Pressure Zone Sub-Basin and Well Locations



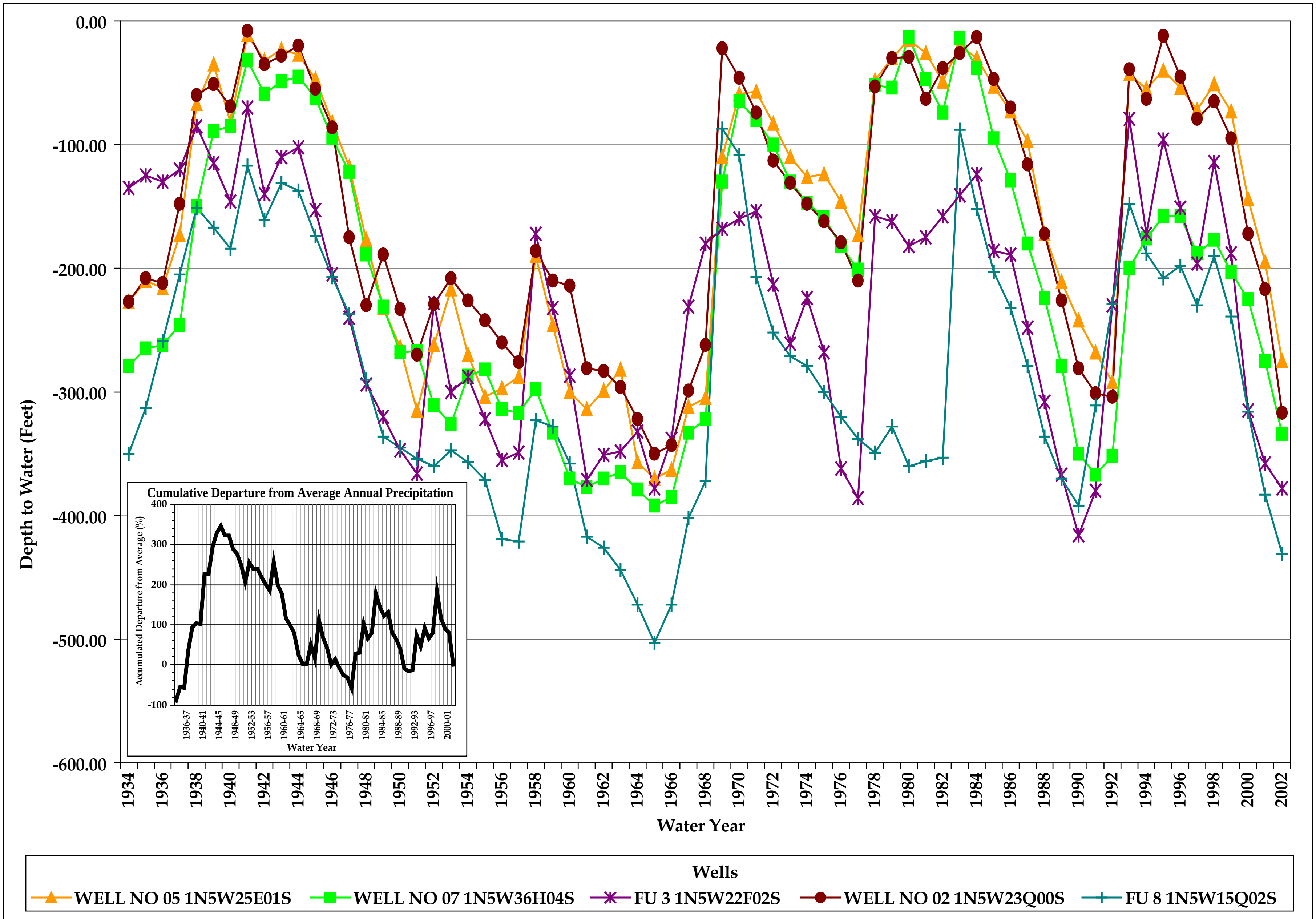
Source: Muni 2003

Figure 2.1-9. Groundwater Level Hydrographs for Selected Wells in the Pressure Zone Sub-Basin, WY 1934-35 to WY 2001-02



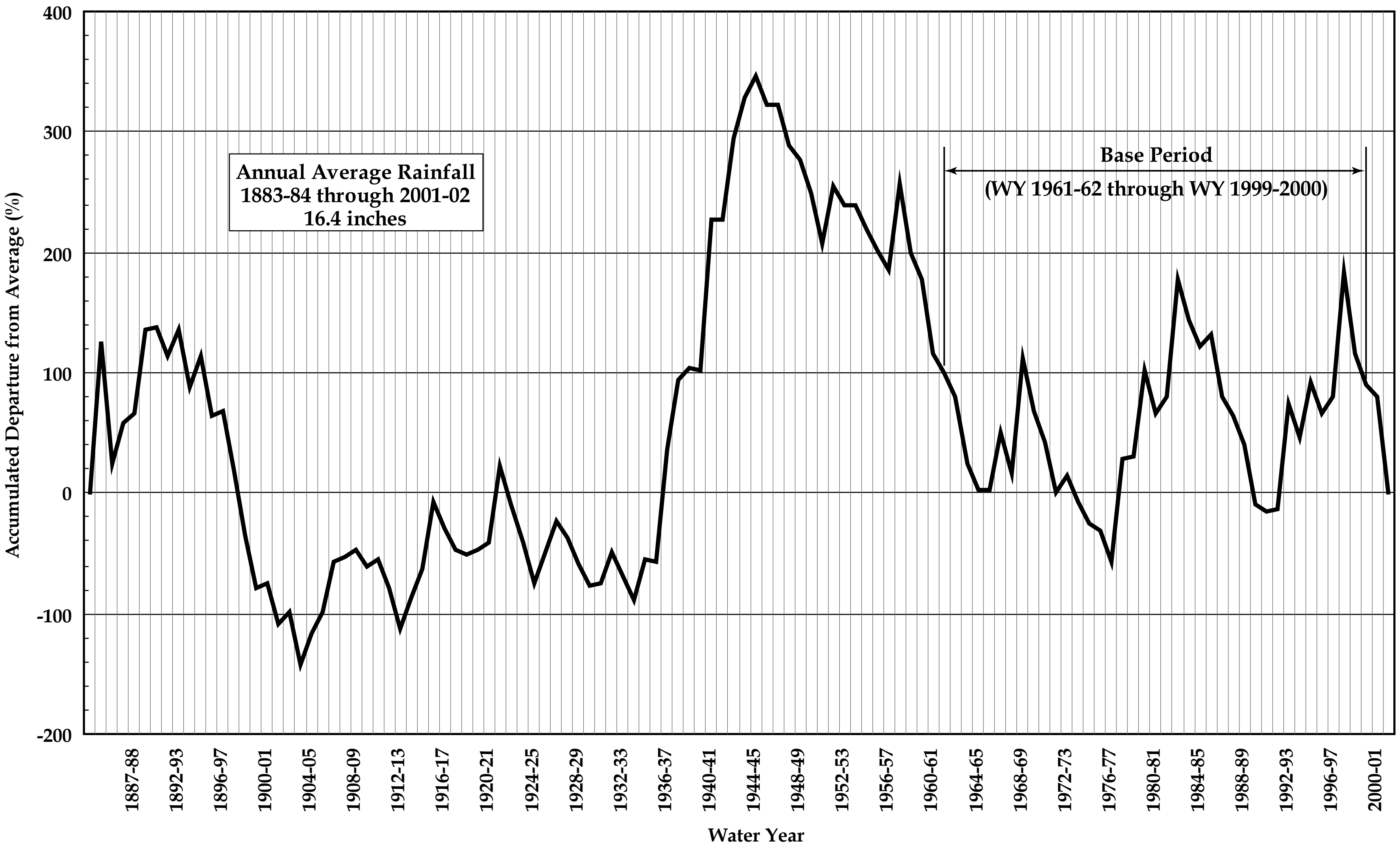
Source: AirPhotoUSA, LLC.; Muni 2003

Figure 2.1-10. San Bernardino Basin Area (SBBA): Lytle Creek Sub-Basin and Well Locations



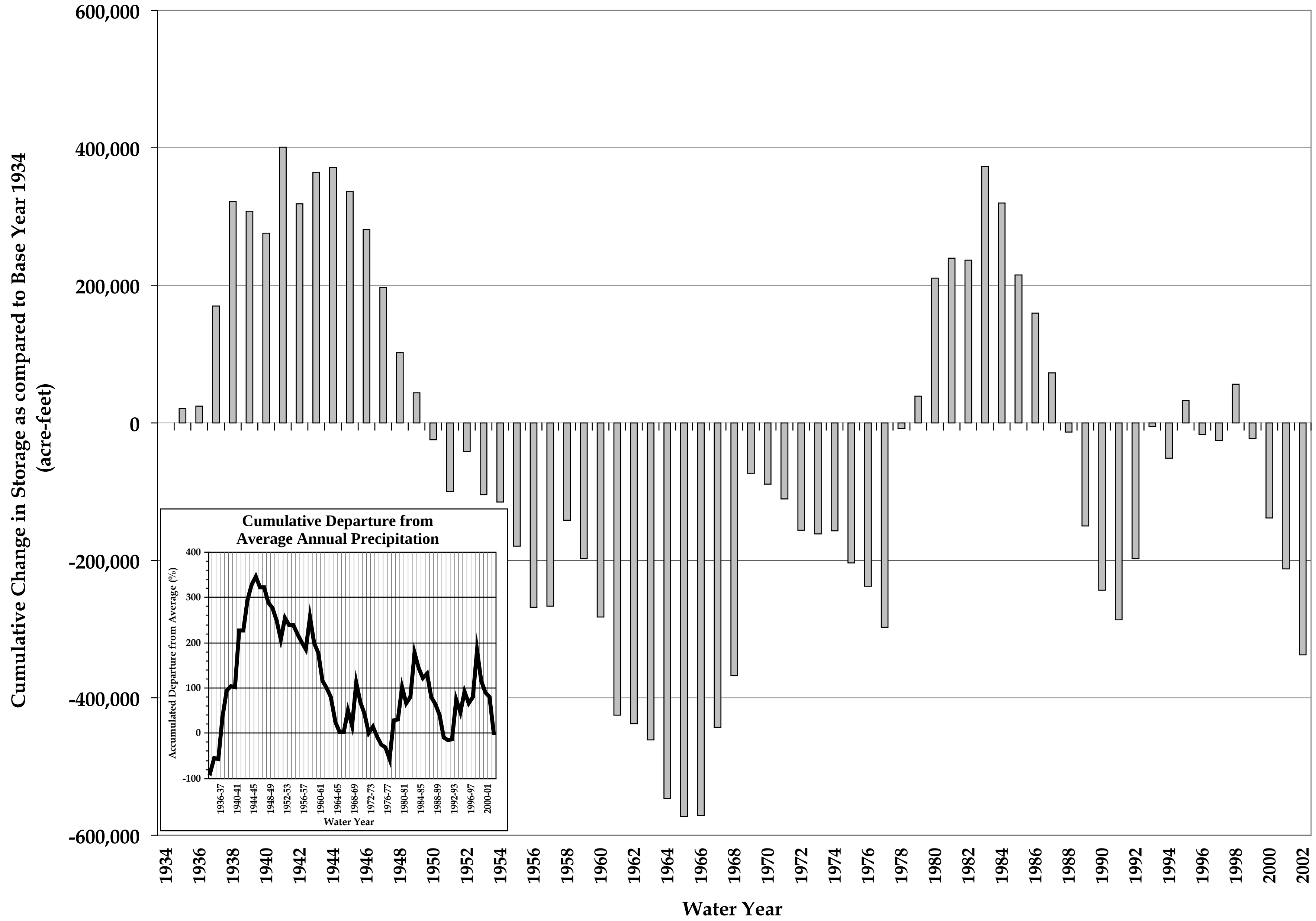
Source: Muni 2003

Figure 2.1-11. Groundwater Level Hydrographs for Selected Wells in the Lytle Creek Sub-Basin, WY-1934-35 to WY-2001-02



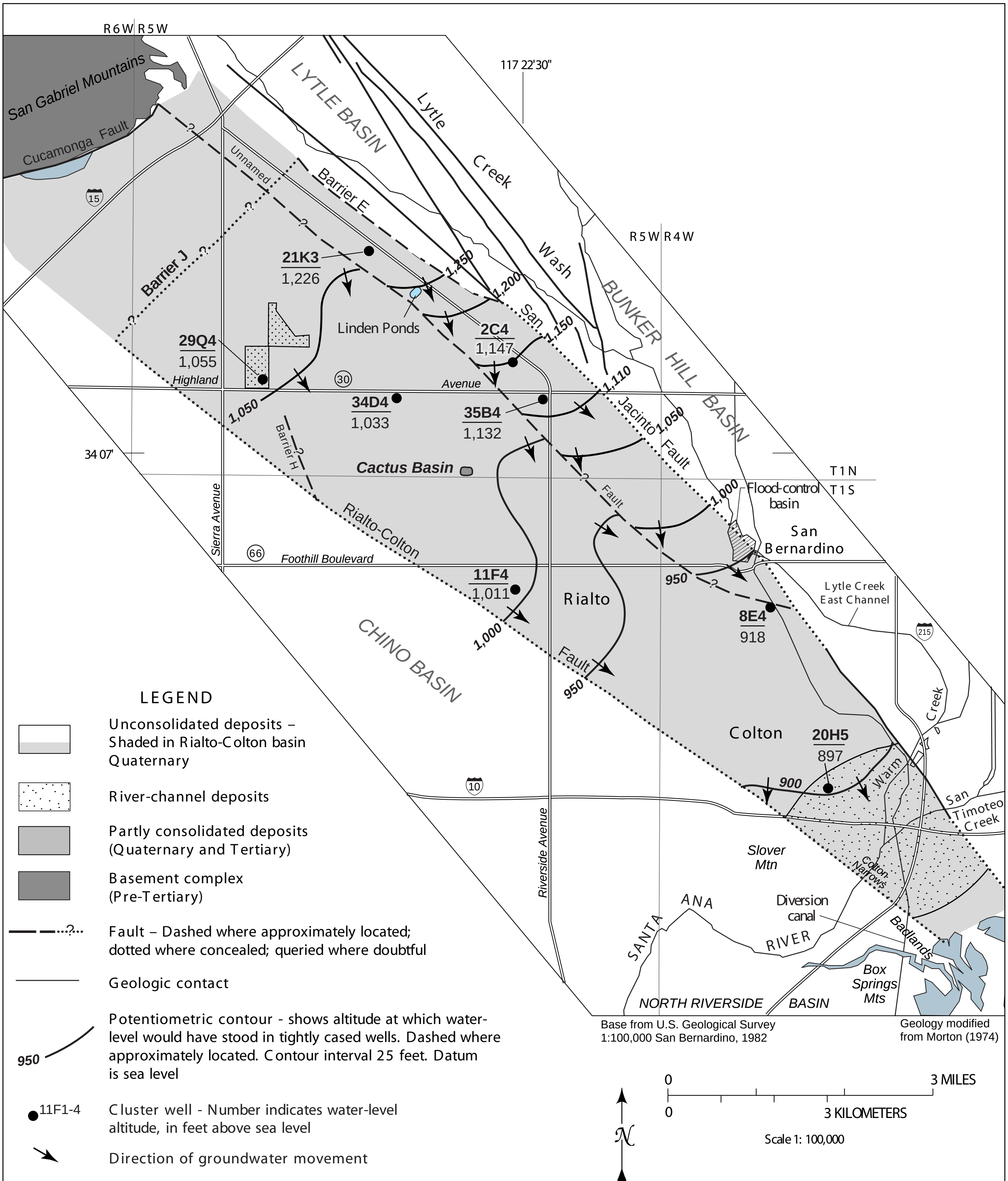
Source: San Bernardino County Flood Control District

Figure 2.1-12. Accumulated Departure from Average Annual Precipitation at San Bernardino County Hospital Recording Station, WY 1883-84 through WY 2001-02



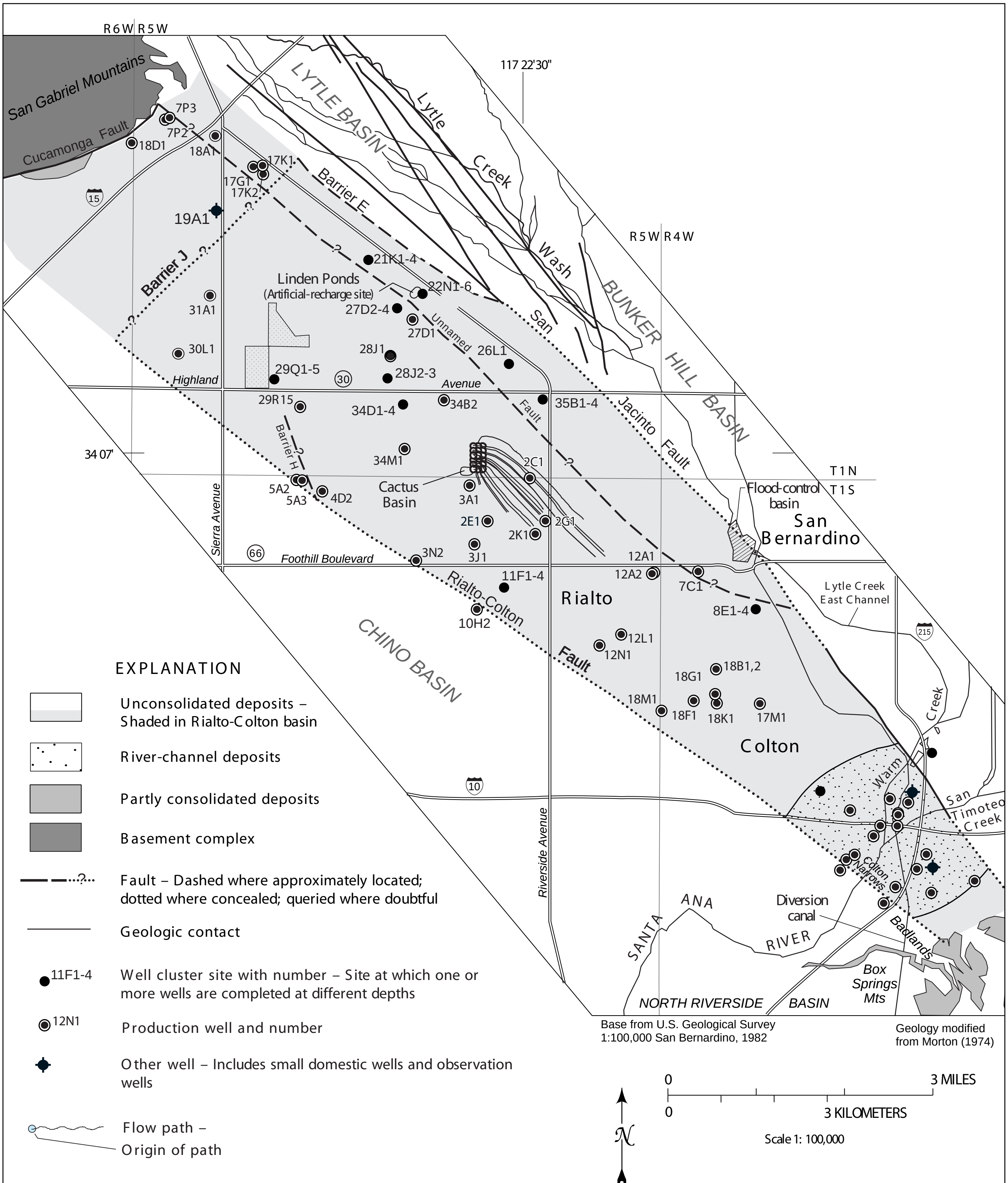
Source: Muni 2003

Figure 2.1-13. Cumulative Change in Groundwater Storage for the SBBA, WY 1934-35 to WY 2001-02



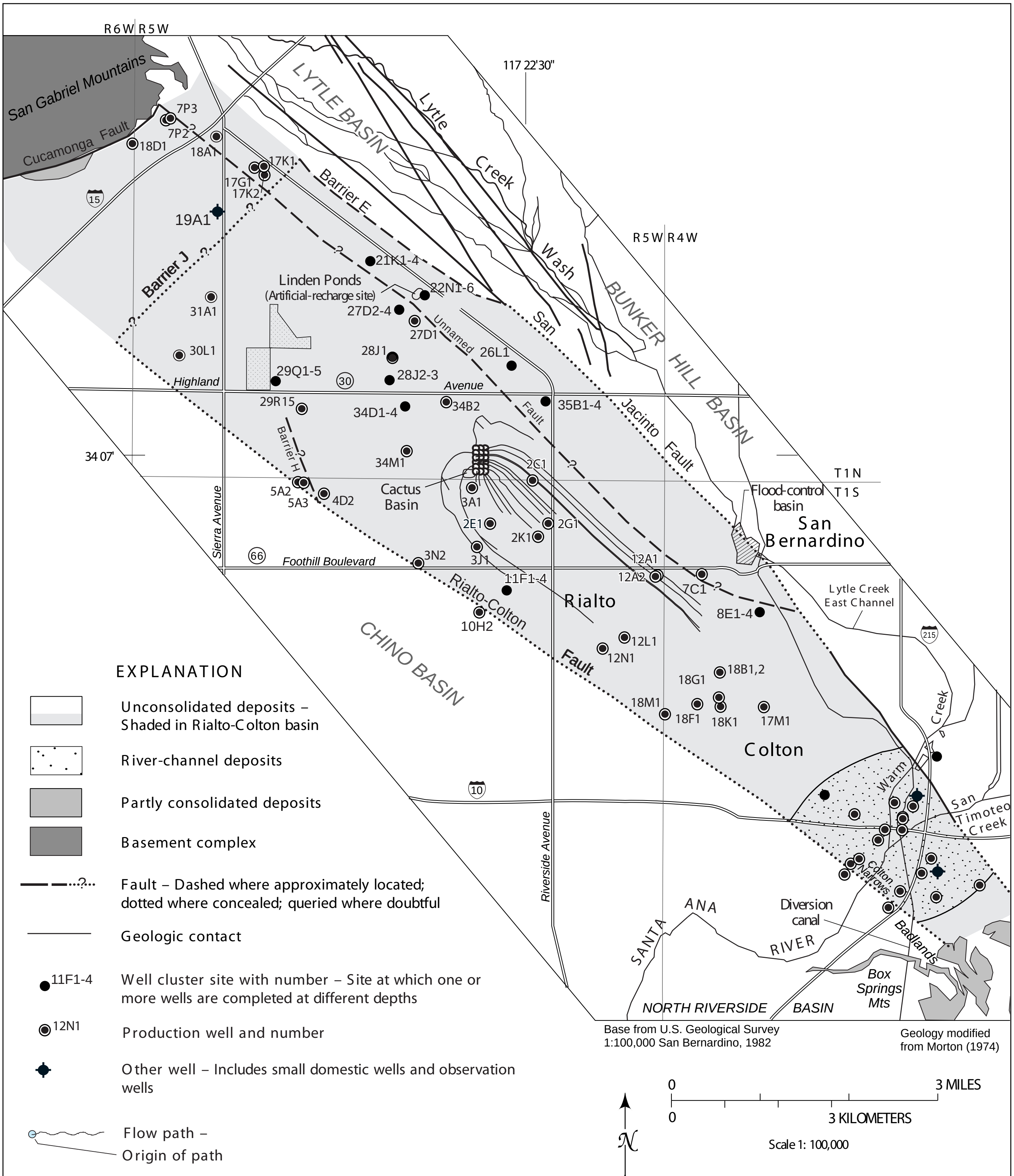
Source: Woolfenden and Koczot 1999

Figure 2.2-1. Potentiometric Contours and Direction of Groundwater Movement in the Middle Water-Bearing Unit in the Rialto-Colton Basin, San Bernardino County, California, Spring 1996



Source: Woolfenden and Koczot 1999

Figure 2.2-2. Simulated Flow Pattern (1982-2027) with Historical Recharge in Cactus Basin



Source: Woolfenden and Koczot 1999

Figure 2.2-3. Simulated Flow Pattern (1982-2027) with 10,000 AF per Year Recharge in Cactus Basin

3.0 GROUNDWATER SPREADING FACILITIES

The Project includes the utilization of numerous existing groundwater recharge facilities (spreading grounds) located in the SBBA, Rialto–Colton, and Yucaipa groundwater basins (Table 3.1-1 and Figure 2.1-1). Existing turn-outs serve these recharge facilities, with the exception of the Cactus Basins. Construction of the Lower Lytle Creek and Cactus Basins pipelines would accommodate deliveries to the Cactus Basins. In the following sections, each of the individual recharge facilities are described.

Table 3.1-1 indicates that the percolation rates in the spreading grounds range between 0.3 and 1.5 feet/day. Estimated recharge varies from 0.5 to 56.7 cfs. The total acreage of the spreading grounds is approximately 285 acres.

Table 3.1-1. Groundwater Recharge Facilities

		Conveyance Used to Serve Facility	*Recharge Facility Characteristics* [a]				
Facility Name	*Owner or Operator*	*Turnout Name & Capacity (cfs)*	*Active Recharge Facility Area* [b] *(acres)*	*Percolation Rate* [c] *(ft/day)*	*Monthly Capacity (af)*	*Absorptive Capacity used in Allocation Analysis* [d] *(cfs)*	*Groundwater Basin (and sub-basin) Recharged* [e]
Santa Ana River Spreading Grounds	Conservation District	Foothill Pipeline Santa Ana Low Flow (288)	60 [g]	1.5	3,060	50[h]	SBBA (Bunker Hill)
Devil Canyon Basins & Sweetwater Basins	San Bernardino County Flood Control District (SBCFCD)[f]	Foothill Pipeline Sweetwater (37)	30	1.5	1,350	23	SBBA (Bunker Hill)
Lytle Basins	Lytle Creek Water Conservation Association	Fontana Power Plant Constructed drainage channel	Variable	1.5	Variable	30[i]	SBBA (Lytle)
City Creek Spreading Grounds	SBCFCD	Foothill Pipeline City Creek (60)	75	1.5	3,375	57	SBBA (Bunker Hill)
Patton Basin	SBCFCD	Foothill Pipeline Patton (12)	3	0.3	27	1	SBBA (Bunker Hill)
Waterman Basin	SBCFCD	Foothill Pipeline Waterman (135)	120	0.5	810	30[j]	SBBA (Bunker Hill)
East Twin Creek Spreading Grounds	SBCFCD	Foothill Pipeline Waterman (135)	32	1.5	225	24[k]	SBBA (Bunker Hill)

Table 3.1-1. Groundwater Recharge Facilities (continued)

		Conveyance Used to Serve Facility	*Recharge Facility Characteristics* [a]				
Facility Name	*Owner or Operator*	*Turnout Name & Capacity (cfs)*	*Active Recharge Facility Area* [b] *(acres)*	*Percolation Rate* [c] *(ft/day)*	*Monthly Capacity (af)*	*Absorptive Capacity used in Allocation Analysis* [d] *(cfs)*	*Groundwater Basin (and sub-basin) Recharged* [e]
Badger Basins	SBCFCD	Foothill Pipeline	15	0.5	225	4	SBBA (Bunker Hill)
		Sweetwater (22)					
Mill Creek Spreading Grounds	SBVWCD	Greenspot Pipeline	26	1.5	1,170	20	SBBA (Bunker Hill)
		Mill Creek Spreading (50)					
Cactus Spreading and Flood Control Basin	SBCFCD	Lower Lytle Creek Pipeline	46	1.5	2,070	35	Rialto-Colton
		Lower Lytle Creek (55)					
Wilson Basins	SBCFCD	East Branch Extension	12	1	360	6	Yucaipa Basin
		Wilson Basins (30)					
Garden Air Creek	Muni	East Branch Extension	n/a	n/a	n/a	16	San Timoteo Basin
		Garden Air Creek (16)					

Notes:

a. Values are from tabulation on map contained in Water Right Application by Muni/Western to appropriate water from the SAR or by engineering evaluation of spreading grounds.

b. Recharge facility area is the geographical extent of each basin that can be inundated for recharge.

c. Estimated percolation rate. This is the estimated rate at which water can percolate into the ground through the basin, expressed in feet per day. The values used have generally been computed from the annual recharge capacity tabulated on the application map. Those rates are typically about one-half of the percolation rates presented in USGS (1972). The use of the lower percolation rates is reasonable in that this Project would involve longer-term percolation rates that are typically lower than short-term rates.

d. The estimated absorptive capacity for each site is computed by multiplying the basin area by the estimated percolation rate. Results are expressed in cubic feet per second (cfs) and used in the Allocation Model in acre-feet per month.

e. Note that there may be flow out of the sub-basin or basin identified. For example, a report by Geoscience (1992) estimated that only 36 percent of the water recharged in the upper Lytle Creek area remains in the Lytle Creek Sub-basin, while most of it flows to the Rialto–Colton Basin.

f. San Bernardino Flood Control District

g. Recharge facility area of 60 acres used, based on analysis of 1995 aerial photographs. However, the application map shows an area of 448 acres, which includes the borrow area for Seven Oaks Dam, possibly usable for recharge.

h. Santa Ana River Spreading Grounds was assigned 50 cfs because of shared use of this facility.

i. Available absorptive capacity of Lytle Basins is assigned 30 cfs per month for use in the Allocation Model because of groundwater recharge targets; however, it has a higher estimated absorptive capacity of 97 cfs.

j. Available absorptive capacity for the Waterman Spreading Ground was assigned 30 cfs per month in the Allocation Model based on historical recharge rates. This would require use of 54 acres of the total site of 165 acres.

k. Available absorptive capacity for the East Twin Creek Spreading Ground was assigned 24 cfs per month in the Allocation Model based on historical recharge rates. This would require use of 32 acres of the total site of 144 acres.

3.1 SANTA ANA RIVER SPREADING GROUNDS

The SAR Spreading Grounds (SG), located downstream of Seven Oaks Dam on the alluvial fan of the SAR (Figure 2.1-1), are operated by the San Bernardino Valley Water Conservation District (Conservation District). The water right application filed by the WCD with the State Water Resources Control Board (SWRCB) indicated that these spreading grounds have an area of about 448 acres. However, smaller estimated areas are presented in other documents (e.g., 60 acres in USGS 2000). Also, this site includes the borrow pit, which was a source of materials used in the construction of Seven Oaks Dam. The potential for recharge activities and facilities in the borrow pit is currently under investigation by the Conservation District.

Information contained in the Muni/Western applications to the SWRCB indicates that the percolation rate for the SAR SG is approximately 1.5 feet/day. The resulting recharge rate (based on 448 acres) would be about 22,800 af per month, or about 384 cfs. Use of some of the smaller acreages would result in smaller estimates of the recharge rate. For example, use of a more limited 60 acres would result in an estimated recharge rate of about 3,060 af per month, or about 51 cfs. Water delivered to the SAR SG recharges the Bunker Hill sub-area of the SBBA.

3.2 SANTA ANA RIVER CHANNEL

While not a formal spreading facility, significant groundwater recharge occurs in the channel of the SAR. However, evaluating recharge potential can be more complicated for recharge in a natural channel than in a spreading facility dedicated to recharge. For example, the recharge rate depends on the wetted area, and this can vary substantially in a natural channel depending on flow conditions. The area of the "active" channel of the SAR (defined by the area on aerial photographs with limited vegetation) has been estimated to be about 79 acres, while the area from the mouth of the canyon to Sterling Avenue (i.e., to about the San Bernardino International Airport or former Norton Air Force Base), including overflow lands, is about 2,110 acres (Danskin et al. N.D.).

In Danskin et al. (N.D.), the potential percolation rate was estimated to be about 4 feet/day. Consistent with the percolation rates for spreading grounds included in the applications, a percolation rate of 2 feet/day is used here as the long-term percolation rate that might be achieved in the channel. This indicates that the recharge rate may be about 4,740 af per month (or about 80 cfs) for the active channel, from the mouth of the canyon to Sterling Avenue, and about 126,600 af per month (or about 2,128 cfs) if the overflow lands are included. Percolation in the river could recharge the Bunker Hill sub-area of the SBBA and the Rialto–Colton Basin (Figure 2.1-1). In a similar analysis, the U.S. Army Corps of Engineers (USACE) (1997) estimated that recharge in the active channel to Sterling Avenue would be approximately 1 cfs per wetted acre, which approximates to 79 cfs.

The maximum area (including overflow lands) for reaches from Sterling Avenue to Lower Warm Creek and from Lower Warm Creek to the San Bernardino/Riverside county line is given in Danskin et al. (N.D.). However, no recharge rate is provided, as those reaches overlie an artesian area where the upward flow of groundwater into the channel is greater than the downward recharge of stream flows. It was estimated that there was a net recharge of approximately 95 cfs from Sterling Avenue to Prado Dam (USACE 1997).

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4.0 WATER QUALITY

This section describes the water quality of the following groundwater basins: SBBA, Rialto–Colton, Riverside, Yucaipa, and San Timoteo. For the SBBA, information is presented for specific sub-areas.

4.1 WATER QUALITY OBJECTIVES

Several factors affect groundwater quality including the following:

1. Recharge from adjacent mountains (San Bernardino Mountains and San Gabriel Mountains);
2. Imported waters from the SWP and Colorado River Aqueduct (CRA);
3. High evaporation rates;
4. Use of recycled wastewater;
5. Local geology and faulting;
6. Historical land uses and salinization; and
7. Contaminants introduced through human activities.

Regional and state authorities have implemented plans to manage the groundwater quality in the basins. The Groundwater Management Plan contained in the SAR Basin Plan, developed by the SARWQCB (1995), balances natural recharge, artificial recharge, groundwater pumping, surface water use, imported water use, and wastewater reclamation to optimize water quality and quantity. The RWQCB identifies beneficial uses of groundwater in the SAR Basin Plan. Beneficial use refers to the manner in which water is used for the benefit of one or more activities or purposes. Examples of beneficial uses are: drinking water, irrigation water applied to croplands, recreation, and environmental resources such as fresh and saline aquatic species and their habitats. For all sub-basins in the Upper SAR basin, including the SBBA and Rialto-Colton, Riverside, Yucaipa, and San Timoteo, beneficial uses fall into the following categories: agricultural, industrial service and process, municipal, and domestic supplies.

WQOs as stated in the Basin Plan relevant to the Project are presented in Table 4.1-1.

WQOs differ among the groundwater basins due to the varying local groundwater conditions and local water resource management goals. For example, the highest acceptable TDS objectives are in Riverside Basin, while the lowest are in the Lytle Creek and Rialto–Colton basins. Similarly, the other constituents listed are also higher for Riverside Basin.

In the future, however, the WQOs and basin delineations may be changing. Using newly available information and analytical tools, different sub-areas of the SBBA are proposed as a change to the 1995 Basin Plan. The original areas and sub-areas presented in the 1995 Basin Plan for the SAR Basin are illustrated in Figure 4.1-1. The proposed area and sub-area names and boundaries are illustrated in Figure 4.1-2. Table 4.1-2 lists the proposed TDS and nitrate-nitrogen WQOs for the groundwater management zones.

Table 4.1-1. Water Quality Objectives - Santa Ana River Groundwater Sub-Basins

Upper Santa Ana River Groundwater Basin	WQO (MILLIGRAMS/LITER [mg/L])					
	Total Dissolved Solids (TDS)	*Hardness*	*Sodium (Na)*	*Chloride (Cl)*	*Nitrate-nitrogen (NO_3-N)*	*Sulphate (SO_4)*
Bunker Hill I	260	190	15	10	1	45
Bunker Hill II	290	190	30	20	5	62
Bunker Hill Pressure Zone	300	160	30	20	1	62
Lytle Creek	225	175	15	10	1	30
Rialto	200	95	35	35	2	40
Colton	400	240	35	35	3	64
Riverside I	490	270	50	50	4	85
Riverside II	650	360	70	85	10	100
Riverside III	990	500	125	170	20	135
Arlington	1,050	500	125	180	20	160
San Timoteo/Yucaipa	240	170	45	25	6	35

Source: SARWQCB 1995.

The National Water Quality Assessment program of the USGS has also issued a report on groundwater quality of the Inland Basin (synonymous with the groundwater basins from Prado Reservoir area to the Bunker Hill Basin) (USGS 2002). The tri-linear diagram (or piper plot) presented as Figure 4.1-3 describes the basic chemical signature of water. Figure 4.1-3 shows the groundwater composition of samples derived from a number of wells in the basin in terms of its major ions, such as calcium, sodium, magnesium, chloride, sulfate, and bicarbonate. In general, the waters are primarily calcium-bicarbonate types. The location of the wells from which the samples were derived is shown in Figure 4.1-4.

Since the 1970s there has been an ongoing effort to move once-used water in the SAR Basin downstream rather than recycling it back to the local groundwater basins. Management in this way reduces the problem of salinity increasing in the groundwater. In accordance with the Groundwater Management Plan, most municipal wastewater is exported directly from the upper basin, minimizing groundwater quality degradation and the localized high groundwater problems. The Groundwater Management Plan also includes goals for adequate recharge of groundwater basins with good water quality.

4.2 CONSTITUENTS OF CONCERN

Constituents of concern are substances in water that potentially pose a threat to the environment or human health. Several major categories of pollutants occur in groundwater basins within the SAR region. This section identifies those pollutants and describes their primary sources and relevant water quality standards. This is followed by a discussion of the

Table 4.1-2. Proposed Groundwater Quality Objectives for Groundwater Management Zones

Groundwater Management Zone	*Total Dissolved Solids (TDS) mg/L*	*Nitrate-nitrogen (NO_3-N) mg/L*
UPPER SANTA ANA RIVER BASIN		
Bunker Hill A	310	2.7
Bunker Hill B	330	7.3
Lytle	260	1.5
Rialto	230	2.0
Colton	410	2.7
San Timoteo “maximum benefit”[a]	400	5.0
San Timoteo “anti-degradation” [b]	300	2.7
Yucaipa “maximum benefit”	370	5.0
Yucaipa “anti-degradation”	320	4.2
MIDDLE SANTA ANA RIVER BASIN		
Riverside A	560	6.2
Riverside B	290	7.6
Riverside C	680	8.3
Riverside D	810	10.0
Riverside E	720	10.0
Riverside F	660	9.5

a. Maximum benefit means that the objectives for the management zones assure protection of beneficial uses and are of maximum benefit to the people of the state. If the Regional Board finds that the maximum benefit is not demonstrated, then the anti-degradation objectives for these waters will apply.

b. Anti-degradation objectives are the historical ambient quality TDS and nitrate-nitrogen objectives. These objectives were based partly on consideration of anti-degradation requirements (State Board Resolution No. 68-16) and factors specified in Water Code Section 13241.

Source: SARWQCB 2003a, Table 4-1, Attachments to Resolution No. R8-2004-0001.

TDS, nitrates, and pollutant levels that occur in each of the groundwater basins located in the Project area.

In the upper SAR Basin, there are several man-made substances that are monitored in the drinking water supplies. These include TDS, nitrates, perchlorate, arsenic, and volatile organic compounds (VOCs). The highest levels of these substances are found in the plumes located particularly in the SBBA. These plumes are described in more detail in section 4.3.

There are two types of drinking water standards. Primary standards are National Primary Drinking Water Regulations that are legally enforceable and public water systems are responsible for their maintenance. Secondary standards are for certain contaminants that cause cosmetic or aesthetic effects in drinking water. They may cause skin or tooth discoloration or may add undesirable odors, colors, or tastes. There are also recommended, but not enforceable, standards for these contaminants, which are called National Secondary Drinking Water Regulations.

The California Department of Health Services (DHS) regulates public drinking water suppliers and establishes California's regulatory drinking water standards, officially known as maximum contaminant levels (MCLs). State law requires the DHS to set each MCL as close to the corresponding public health goal (PHG) as is economically and technically feasible, placing primary emphasis on the protection of public health. Although not a regulatory requirement, the PHG is a goal for drinking water that California's public water suppliers and regulators should strive to meet if it is feasible to do so. The Office of Environmental Health Hazard Assessment (OEHHA) defines a PHG as a level of contaminant in drinking water that does not pose a significant short-term or long-term health risk (OEHHA 2004). The DHS can set the MCL above the level of the PHG if it determines that the economic impact on water suppliers or consumers of reducing a contaminant to the PHG level would be excessive compared to the reduction in estimated health risk, or if current testing or treatment technologies are not adequate to ensure drinking water contamination levels would be at or below the PHG. State law prohibits OEHHA from considering economic issues when it develops a PHG. Once the MCL is established, water systems exceeding the MCL are required to notify the DHS and the public to take steps to immediately return to compliance. If the MCL is exceeded by 10 times, the water system is required to remove the source from the service.

4.2.1 Total Dissolved Solids

Concentrations of total dissolved solids in groundwater are a function of the recharge of water originating from storm flows, urban runoff, imported water, and incidental recharge. Concentrations are also attributed in part to salt contamination from past agricultural and land uses. The primary drinking water standard for TDS is 1,000 mg/L, whereas the secondary drinking water standard for TDS is 500 mg/L (EPA 2002).

4.2.2 Nitrates

Nitrates are particularly mobile in groundwater. The federal drinking water quality standard for nitrate (reported as nitrogen) is set at 10 mg/L. Water containing nitrate concentrations higher than 10 mg/L must either be treated or blended with other water sources in order to reduce nitrate levels (EPA 2002). Similar to TDS, areas with significant irrigated land use or dairy waste disposal histories typically overlie groundwater with elevated nitrate concentrations (SA RWQCB 1995). In humans, nitrate turns into nitrite in the body and interferes with oxygen carrying capacity. With long-term exposure, nitrates may cause diuresis, starchy deposits, and spleen hemorrhaging (EPA 2002).

4.2.3 Perchlorate

Perchlorate is a chemical associated with many industrial applications, but primarily with the manufacture of rocket fuel and other explosives. It is mobile in soil and groundwater environments but can persist for many decades under typical groundwater and surface water conditions, because of its resistance to reaction with other available constituents. At very high levels, perchlorate interferes with the function of the thyroid gland and the production of hormones necessary for normal human development. In extreme cases, it can cause brain damage in fetuses and a potentially fatal form of anemia in adults. However, effects of chronic exposures to lower levels currently detected in groundwater are not known (Borkovich 2002).

There are neither federal nor state regulatory requirements for perchlorate in drinking water. However, in March 2004, the OEHHA released a final PHG for perchlorate of 6 parts per billion (ppb).

4.2.4 Arsenic

The current drinking water MCL for arsenic is 0.05 mg/L, but this standard will be lowered in the year 2006 to 0.01 mg/L (EPA 2002). In September 2001, a subcommittee of the National Research Council (NRC) released their review of the toxicological basis for the new drinking water standard. That report confirmed the finding that recent studies of arsenic in humans, taken together with earlier studies, "provide a sound and sufficient database showing an association between bladder and lung cancers and chronic arsenic exposure in drinking water, and they provide a basis for quantitative risk assessment." In addition, recent studies increase the weight of evidence for an association between internal cancers and arsenic exposure through drinking water. The report also cited increasing evidence that chronic exposure to arsenic in drinking water may be associated with health effects other than cancer (NRC 2001).

4.2.5 Volatile Organic Compounds

VOCs are synthetic chemicals that readily vaporize at room temperature. VOCs present in water can be ingested or absorbed through the skin during bathing. Degreasing agents, glues, dyes, paint thinners, and some pesticides are VOCs. Methyl tertiary butyl ether (MTBE), benzene, trichloroethylene (TCE), tetrachloroethylene (PCE), and vinyl chloride are all considered VOCs and all are thought to increase the risk of cancer (Spellman and Drinan 2000).

MTBE is a gasoline additive used to improve air quality by reducing emissions and increasing octane ratings. There is statewide concern regarding groundwater contamination due to the widespread use of MTBE in gasoline. Lawrence Livermore National Laboratory's June 1998 report *An Evaluation of MTBE Impacts to California Groundwater Resources* found MTBE detected in groundwater at 78 percent of the leaking underground fuel tank (LUFT) sites (Santa Ana Watershed Project Authority [SAWPA] 2002). The DHS considers MTBE a carcinogen. Effective May 2000, DHS adopted a primary drinking water standard MCL of 13 micrograms per liter (µg/L) (DHS 2002).

TCE and PCE are widely used as industrial solvents. TCE was commonly used for metal degreasing and was also used as a food extractant. PCE is commonly used in the dry-cleaning industry. About 80 percent of all dry cleaners used PCE as their primary cleaning agent. The MCL for both PCE and TCE is 5 µg/L (California Code of Regulations [CCR] 2003).

4.2.6 Radon

Radon was not found recently in groundwater taken from two well locations in the SBBA (data provided by Muni). However, it was found in 79 percent of the sites sampled in the Inland Basin, with concentrations exceeding the proposed MCL (USGS 2002). Many of these locations had wells screened within granitic deposits that naturally have a higher radon concentration than other weathered deposits.

4.3 GROUNDWATER QUALITY IN SPECIFIC BASINS

Groundwater quality varies among the sub-basins of the upper SAR, naturally due to geology and faulting patterns and recharge points, and from anthropogenic sources of contamination.

4.3.1 San Bernardino Basin Area

Groundwater in the SBBA is generally a calcium-bicarbonate type, containing equal amounts (on an equivalent basis) of sodium and calcium in water near the land surface and an increasing predominance of sodium in water from deeper parts of the valley-fill aquifer. A TDS range of 150 to 550 mg/L, with an average of 324 mg/L, is found in public supply wells (DWR 2003). Electrical conductivity (EC) is a measure of total dissolved ionic constituents. EC has been measured within a range of 95 to 2920 microMhos (µMhos) with an average of 523 µMhos.

The inorganic composition of the groundwater may be affected by geothermal water emanating from faults and fractures in the bedrock surface underlying the aquifer. For example, concentrations of fluoride that exceed the public drinking water standard have limited the use of groundwater extracted near some faults and from deeper parts of the aquifer.

In some public supply well locations in the SBBA, some inorganics (primary and secondary), radiological constituents, nitrates, pesticides, and VOCs and Synthetic Organic Chemicals (SOCs) were found above the MCL (Table 4.3-1).

Table 4.3-1. Prevalence of Contaminants in SBBA Wells

Constituent	*No. Wells Sampled*	*No. Wells with a Concentration Above MCL*
Inorganics (primary)	212	13
Radiological	207	34
Nitrates	214	34
Pesticides	211	20
VOCs and SOCs	211	32
Inorganics (secondary)	212	25

Source: DWR 2003.

The SBBA is affected by five major groundwater contaminant plumes as illustrated in Figure 4.3-1. Plumes in the Basin include (1) the Redlands-Crafton plume, with TCE and lower levels of PCE and dibromochloropropane (DBCP); (2) the Norton Air Force Base TCE and PCE plume, stretching 2.5 miles from its source and contaminating 100,000 af of groundwater; (3 and 4) the Muscoy and Newmark plumes near the Shandon Hills, which are Superfund sites with TCE and PCE; and (5) the Santa Fe plume with PCE, TCE and 1,2-DCE contamination.

Within the City of San Bernardino, the Newmark plume and the Muscoy plume consist primarily of PCE. The plumes have impacted City of San Bernardino water supply wells. Under the federal Superfund Program, the US EPA has implemented cleanup of these plumes, including use of groundwater extraction and treatment using granulated activated carbon. The treated water is then used to supplement the City of San Bernardino's potable water supply. It appears that cleanup efforts will be adequate to protect 32 down-gradient water supply wells (SAWPA 2002).

The Norton Air Force Base plume, located just to the southwest of the former installation in the City of San Bernardino, is a major contaminant plume, consisting primarily of TCE and PCE (Figure 4.3-1). The plume has impaired 10 wells owned by the City of Riverside and the City of San Bernardino. Cleanup efforts by the Air Force, consisting of soil removal, soil gas extraction, and groundwater treatment, have significantly reduced this plume. The treatment plants now operate in a stand-by mode (SAWPA 2002).

Two commingled plumes, comprising the Redlands-Crafton plume, have impacted water supply wells for the cities of Riverside, Redlands, and Loma Linda, including Loma Linda University wells. One plume contains TCE and the other perchlorate; both are in the upper 300 to 400 feet of groundwater. TCE has been measured in water supply wells at over 100 ppb, over 20 times the MCL of 5 ppb. Currently, however, water supply well concentrations are around 7 ppb. Perchlorate is present in water supply wells at concentrations up to 77 ppb.

As required by the SA RWQCB, Lockheed has prepared contingency plans to address impacts of the plume on water supply wells. These include blending, treatment, and/or providing alternative water supply sources. The plumes are currently being captured by the City of Riverside's Gage well-field. Lockheed has installed granulated activated carbon treatment units at some of the Gage wells to remove TCE, and has installed ion exchange units on some of these wells for the removal of perchlorate (SAWPA 2002).

The Santa Fe groundwater plume consists primarily of 1,2 Dichloroethylene (1,2-DCE), TCE, and PCE; this plume is currently being monitored (ERM 2001).

4.3.2 Rialto-Colton Groundwater Basin

In public supply well samples in the Rialto–Colton Basin, the average TDS is 264 mg/L with a range of 163 to 634 mg/L (DWR 2003). Other source samples show an average TDS of 230 mg/L with a range of 201 to 291 mg/L. This is a lower TDS range than the groundwater in the Bunker Hill Basin, where TDS levels from 1995 through 1997 ranged as high as 1,000 mg/L along the SAR.

The San Jacinto Fault markedly affects the groundwater chemistry in the basin. The TDS in groundwater downstream from the San Jacinto Fault is greater than that in the surface water found in the Bunker Hill outflow area. It is also higher in dissolved solids than well water just upstream from the fault.

Of 38 public supply wells sampled, two were over the MCL for nitrates, and in three wells secondary inorganics, VOCs, and SOCs exceeded the MCL (Table 4.3-2). Most reported NO_3 concentrations are less than 22.5 mg/L, with a few samples ranging from 45 to 90 mg/L. Table 4.3-2 shows that most of the wells sampled did not contain constituents over the MCL concentration.

More than 143 water source wells in Riverside and San Bernardino counties alone now exceed 4 ppb of perchlorate contamination (DHS 2003a). In the Muni service area, the City of Rialto, City of Colton, West Valley Water District, and the Fontana Water Company have shut down or restricted the use of 20 wells due to perchlorate contamination in the Rialto–Colton Basin, where concentrations reach above 4 ppb (SA RWQCB 2003b).

Table 4.3-2. Prevalence of Contaminants in Rialto–Colton Basin Wells

Constituent	*No. Wells Sampled*	*No. Wells with a Concentration Above an MCL*
Inorganics (primary)	38	0
Radiological	40	0
Nitrates	38	2
Pesticides	40	0
VOCs and SOCs	40	3
Inorganics (secondary)	38	3

Source: DWR 2003.

4.3.3 Riverside Groundwater Basin

The Riverside Basin contains groundwater that is predominantly calcium or sodium bicarbonate. Of water sampled from 46 wells, TDS ranged from 210 to 889 mg/L, with an average of 463 mg/L (DWR 2003). From other sources, TDS has been found to range from 320 to 756 mg/L. This is a higher TDS range than in the Rialto–Colton and Bunker Hill basins.

In some of the sampled public supply well locations, MCLs were exceeded for inorganics (primary and secondary), radiological constituents, nitrates, pesticides, VOCs, and SOCs (Table 4.3-3). Nitrate (as NO_3) concentrations of greater than 20 mg/L were detected as early as the 1940s, probably due to historical land use, including citrus production. NO_3 was the constituent found most frequently in the sampled wells, followed by pesticides (Table 4.3-3). Only a few wells were found to have concentrations of primary and secondary inorganics (Table 4.3-3).

Table 4.3-3. Prevalence of Contaminants in Riverside Basin Wells

Constituent	*No. Wells Sampled*	*No. Wells with a Concentration Above an MCL*
Inorganics (primary)	48	2
Radiological	48	11
Nitrates	51	21
Pesticides	50	19
VOCs and SOCs	50	8
Inorganics (secondary)	38	3
Source: DWR 2003		

4.3.4 Yucaipa Groundwater Basin

Most of the recent groundwater samples from the Yucaipa Basin indicate a calcium bicarbonate type groundwater, generally meeting U.S. EPA drinking water standards, with little variation across the basin. Groundwater has higher mineral concentrations, but otherwise is similar to the surface water in the area. The average TDS from public supply wells is 322 mg/L with a range of 200 to 630 mg/L. This is similar to average TDS values estimated from other sources: 343 mg/L and 334 mg/L (DWR 2003). The TDS estimates in the Yucaipa Basin are lower than the Riverside Basin and slightly higher than the Rialto–Colton and Bunker Hill basins.

Table 4.3-4 contains data from wells sampled for various pollutants (DWR 2003). Some samples contained concentrations above the MCL. This was true for one sample with primary inorganics, VOCs, and SOCs; four samples with pesticides and secondary inorganics; and 12 samples with nitrates (Table 4.3-4). As in the Riverside Basin, nitrates were found more than any other constituent in the sample well set (Table 4.3-4).

Table 4.3-4. Prevalence of Contaminants in Yucaipa Basin Wells

Constituent	*No. Wells Sampled*	*No. Wells with a Concentration Above an MCL*
Inorganics (primary)	43	1
Radiological	44	1
Nitrates	46	12
Pesticides	43	4
VOCs and SOCs	44	1
Inorganics (secondary)	43	4
Source: DWR 2003.		

4.3.5 San Timoteo Groundwater Basin

The mineral character of groundwater beneath San Timoteo Canyon is sodium bicarbonate; calcium bicarbonate in the alluvium of Little San Gorgonio Creek; calcium bicarbonate in younger alluvium near Beaumont; and sodium bicarbonate in older deposits. Water samples from 24 public supply wells have an average TDS content of approximately 253 mg/L, with a range of 170 to 340 mg/L. The TDS range is lower than in the Riverside, Bunker Hill, and Yucaipa basins and comparable to the Rialto–Colton Basin. Out of 27 sampled wells, one well contained secondary inorganics above the MCL (Table 4.3-5). Otherwise, no contaminants were found (DWR 2003).

Table 4.3-5. Prevalence of Contaminants in San Timoteo Basin Wells

Constituent	*No. Wells Sampled*	*No. Wells with a Concentration Above an MCL*
Inorganics (primary)	27	0
Radiological	26	0
Nitrates	28	0
Pesticides	27	0
VOCs and SOCs	27	0
Inorganics (secondary)	27	1

Source: DWR 2003.

4.4 IMPORTED WATER QUALITY

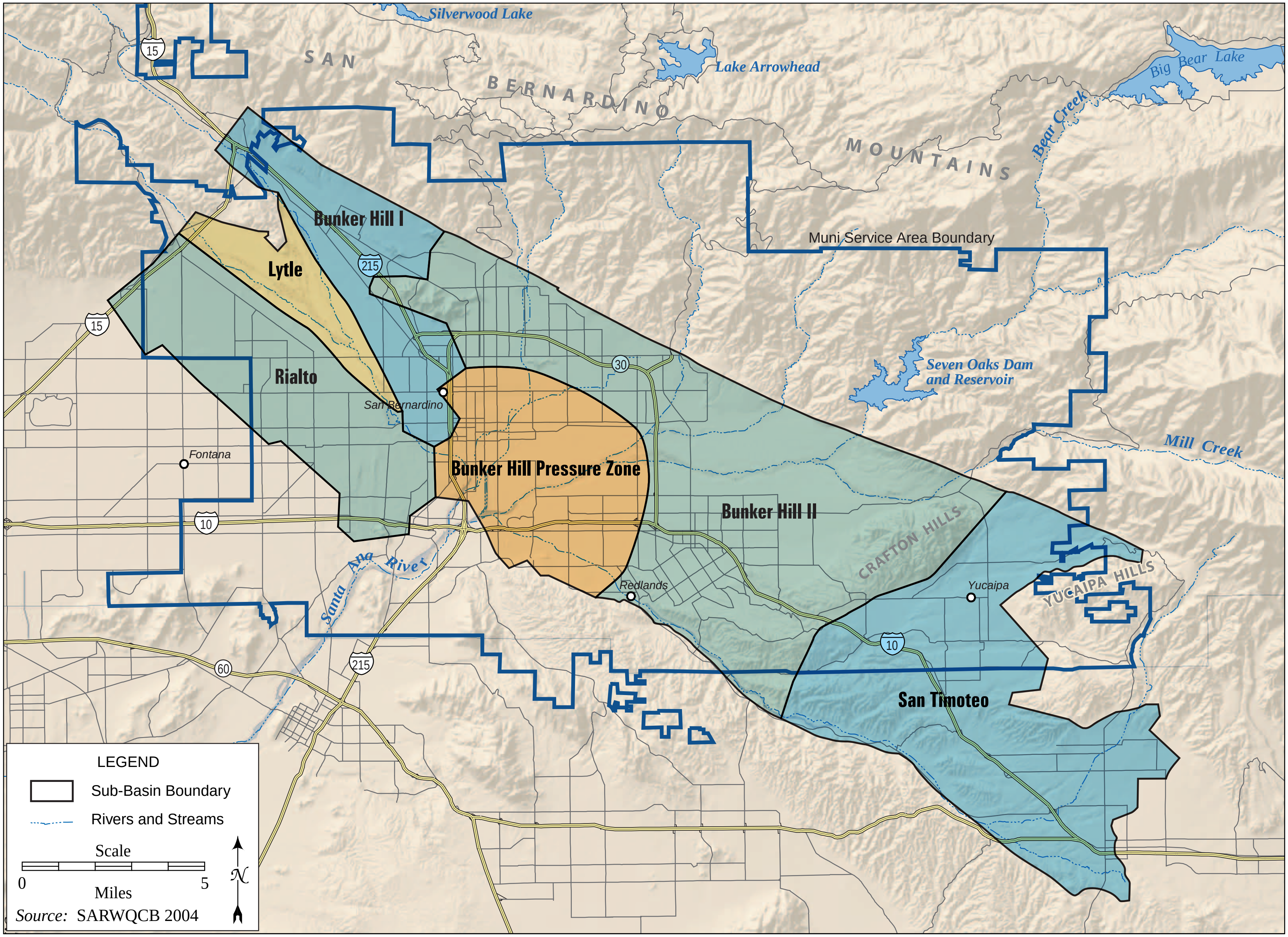
Water imported into the Muni service area is diverted from the Sacramento/San Joaquin River Delta and transported by the California SWP facilities. Water is imported into the Western service area via SWP facilities and from the Colorado River via the CRA, owned and operated by The Metropolitan Water District of Southern California (Metropolitan). These two water sources contain different levels of constituents, briefly described in the following sections. When these water sources mix with groundwater, the groundwater composition can be altered.

4.4.1 State Water Project (SWP)

SWP water is suitable for most beneficial uses due to its low TDS of 200 to 300 mg/L at delivery. This is variable due to drought conditions, flood events, reservoir management practices, and salt input from local streams. In drought years, the TDS can be 400 mg/L (SA RWQCB 1995).

4.4.2 Colorado River

The TDS level in CRA water averages approximately 700 mg/L and during drought years can increase to above 900 mg/L, according to the 1999 Metropolitan/U.S. Bureau of Reclamation (USBR) Salinity Management Report. The salinity (TDS) of the water in the Colorado River Aqueduct through the year 2015 is expected to be above 800 mg/L under dry year conditions. Salinity projections for wet year conditions show TDS values between 650 and 800 mg/L.



Source: SARWQCB 2004

Figure 4.1-1. Current SARWQCB Sub-Basin Boundaries

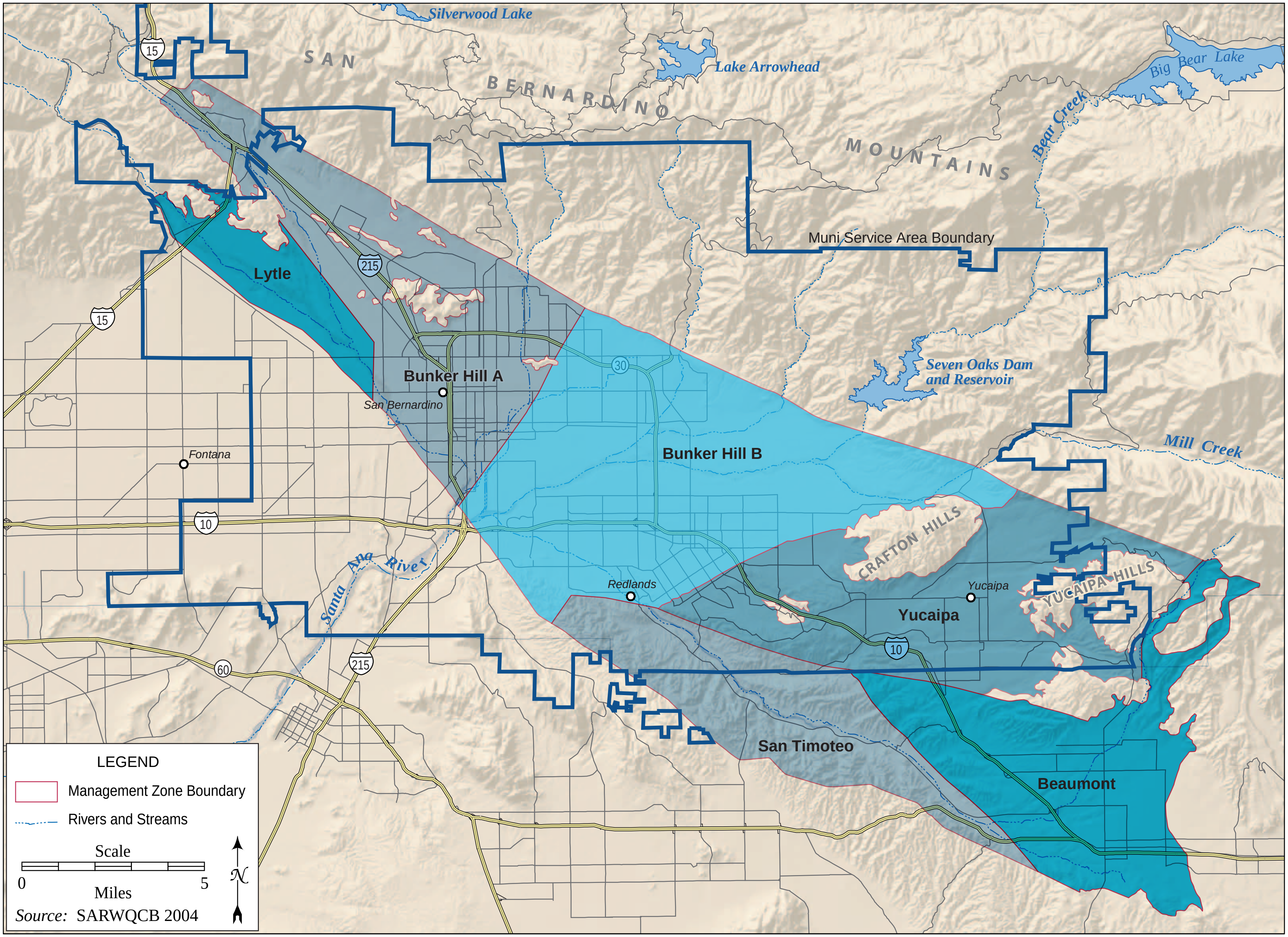
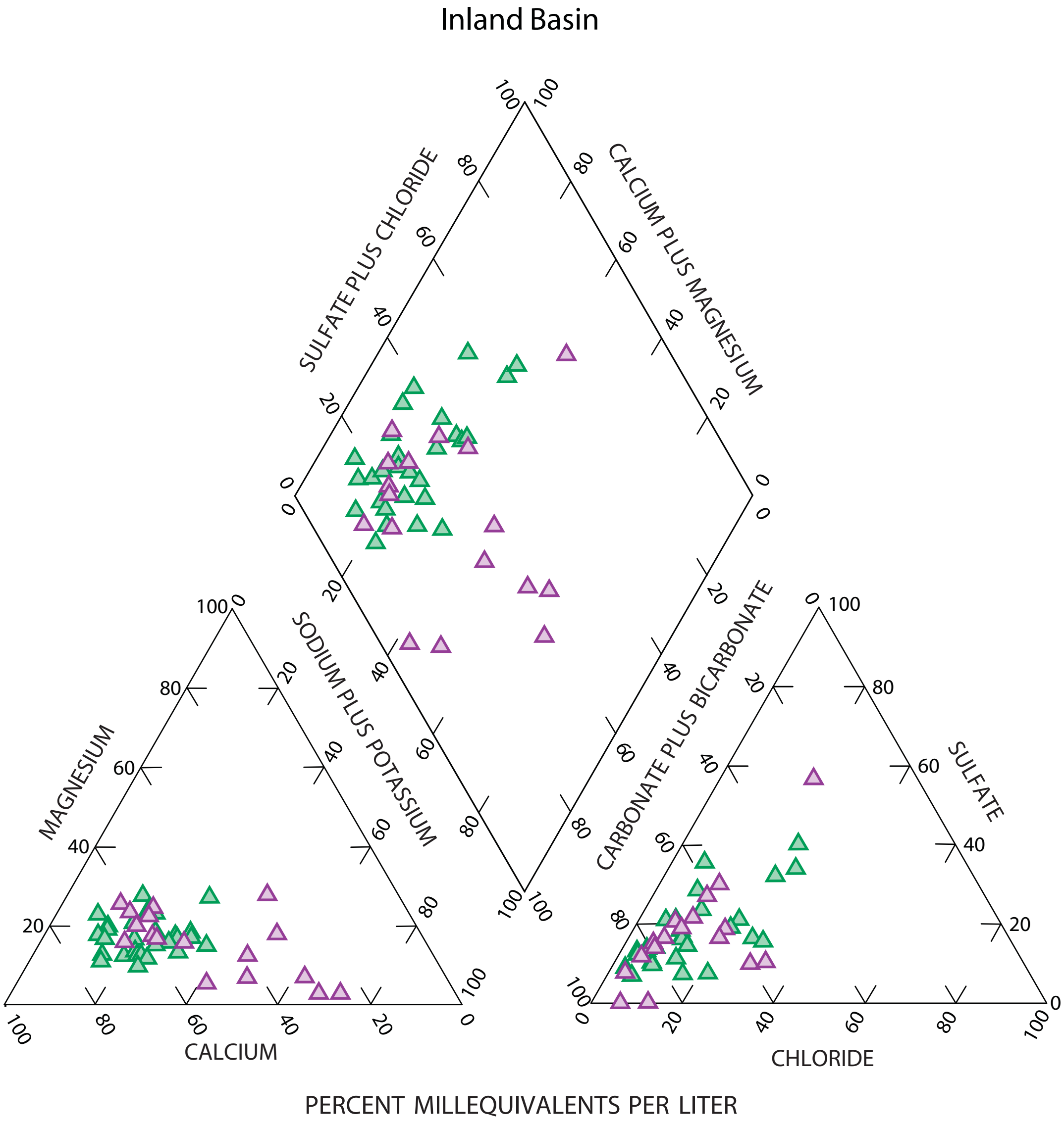


Figure 4.1-2. Proposed SARWQCB Management Zone Boundaries

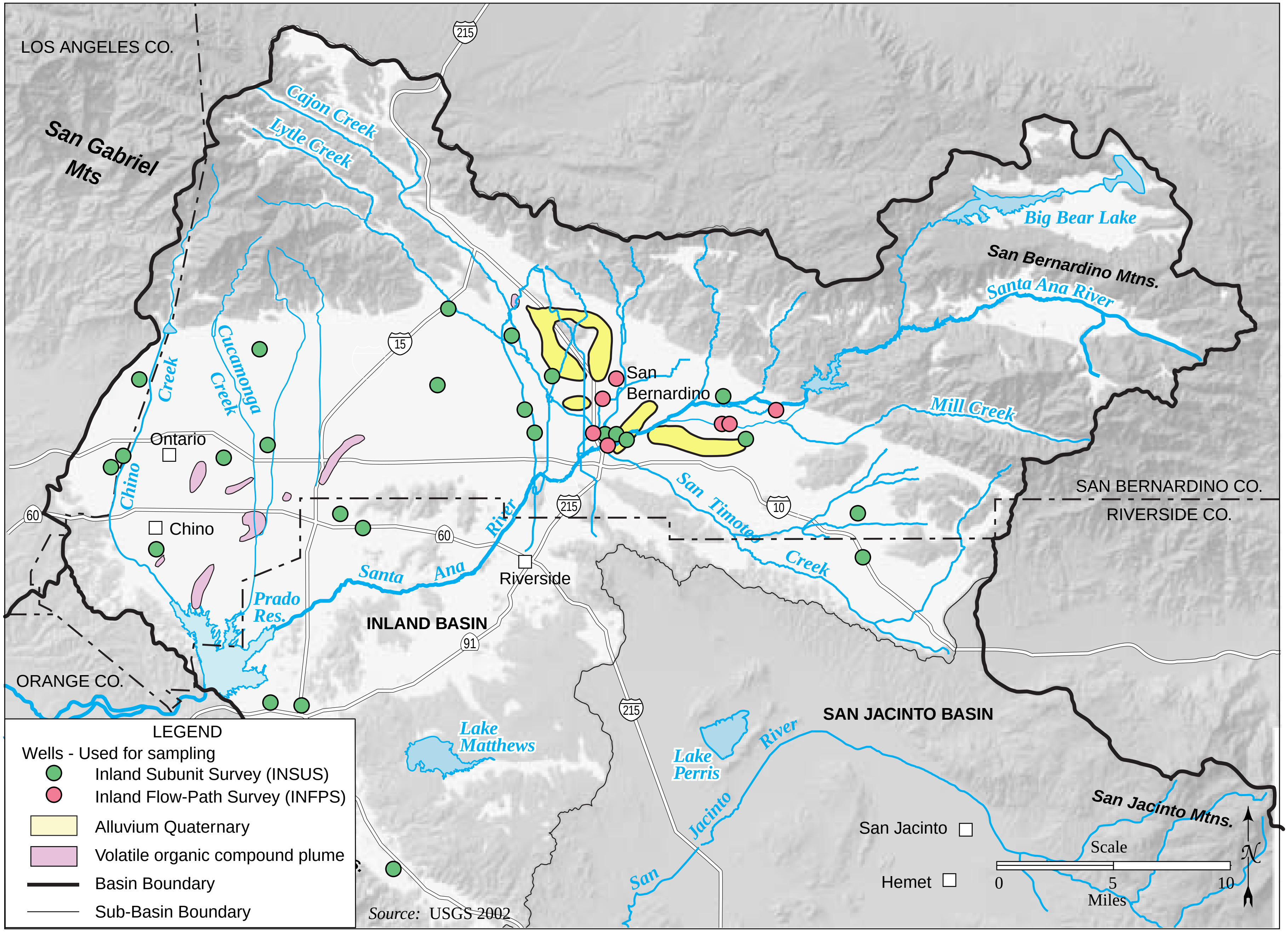


EXPLANATION

- △ Inland Subunit Survey Well (INSUS)
- △ Inland Flow-Path Survey Well (INFPS)

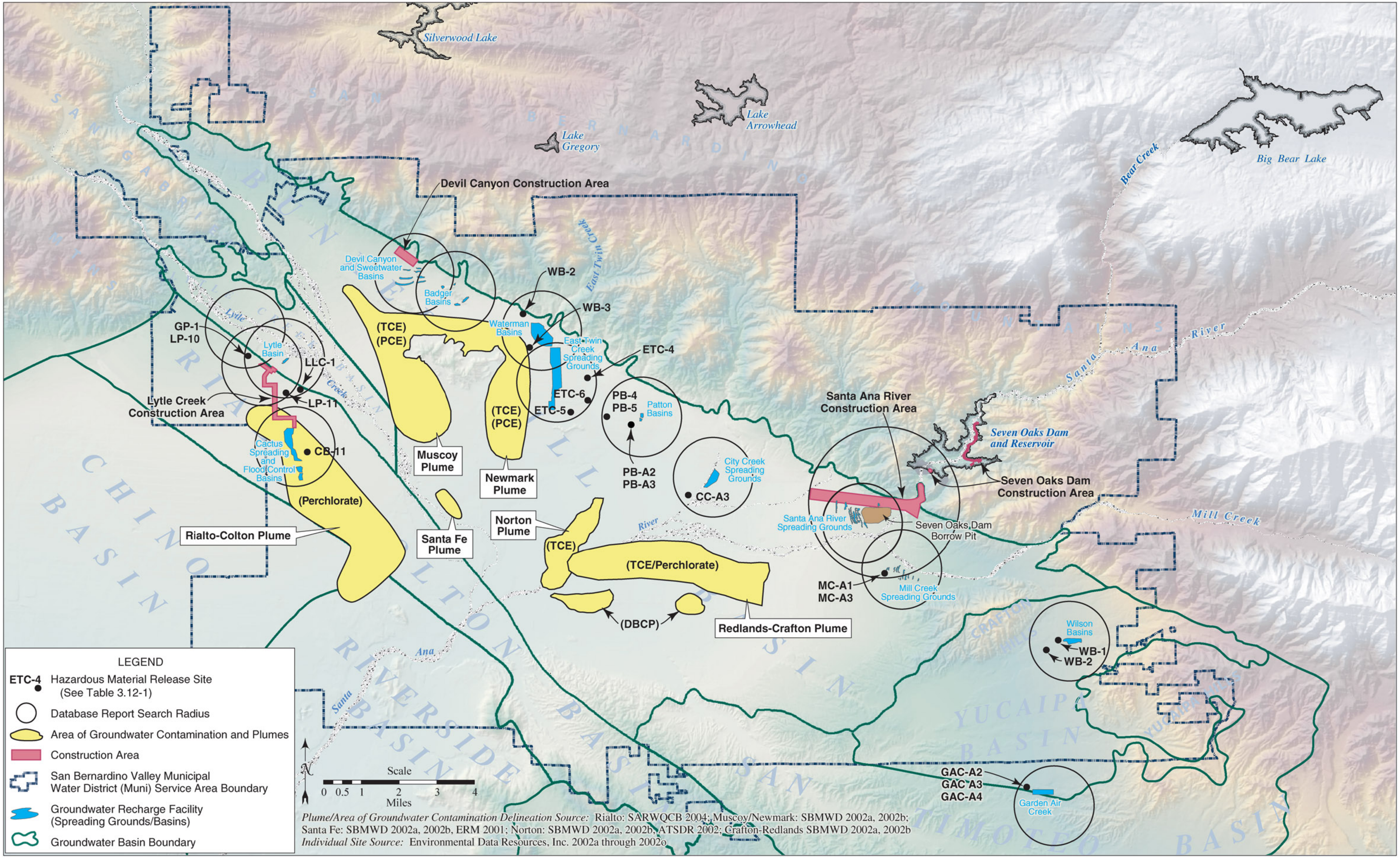
Source: USGS 2002

Figure 4.1-3. Inland Basin Groundwater, Major Ion Composition of Groundwater Samples



Source: USGS 2002

Figure 4.1-4. Inland Basin Study Area and Locations of Sampled Wells



Plume/Area of Groundwater Contamination Delineation Source: Rialto: SARWQCB 2004; Muscoy/Newmark: SBMWD 2002a, 2002b; Santa Fe: SBMWD 2002a, 2002b, ERM 2001; Norton: SBMWD 2002a, 2002b, ATSDR 2002; Crafton-Redlands SBMWD 2002a, 2002b
Individual Site Source: Environmental Data Resources, Inc. 2002a through 2002o

Figure 4.3-1. Known Contamination Plumes and Sites

5.0 LIQUEFACTION AND SUBSIDENCE

Groundwater levels are a critical factor in determining the potential for liquefaction and subsidence. Project-related recharge may influence the depth to groundwater and the associated potential for liquefaction and subsidence, most notably in the Pressure Zone of the SBBA. This chapter describes the relationship between depth to groundwater, subsidence, and liquefaction.

5.1 LIQUEFACTION

Liquefaction is a form of seismically-induced ground failure. In cohesionless, granular material having low relative density, such as loose sandy sediment, seismically induced vibrations can disturb the particle framework, leading to increased compaction of the material and reduction of pore space between the grains. If the sediment is saturated, water occupying the pore spaces resists this compaction and exerts pore pressure that reduces the contact stress between the sediment grains. With continued shaking, transfer of intergranular stress to pore water can generate pore pressures great enough to cause the sediment to lose its strength and change from a solid state to a liquid state. This mechanical transformation can cause various kinds of ground failure at or near the surface (Matti and Carson 1991).

The type of ground failure caused by liquefaction depends on slope conditions and the geologic and hydrologic settings. Four common types of ground failure are (1) lateral spreads (landslides having limited displacement); (2) flow failures (flow landslides); (3) ground oscillation; and (4) loss of bearing strength (quick conditions). Sand boils (injections of fluidized sediment) commonly accompany these different types of ground failure and form sand volcanoes at the ground surface or convolute layering and sand dikes in subsurface sediment layers (Seed 1968, Ambraseys and Sarma 1969, Matti and Carson 1991).

Damaging ground failure resulting from earthquake-induced liquefaction has occurred throughout the world. For example, during the Guatemala earthquake of February 4, 1976, differential lateral displacements and settlements resulting from lateral spreading destroyed or damaged 90 percent of the houses in the La Playa area of Lake Amatitlan (Hoose et al. 1978). The Niigata, Japan, earthquake of June 16, 1964, generated widespread damage resulting from liquefaction (Seed and Idriss 1967). That earthquake resulted in extensive areas being covered by water and sand that were ejected from sand boils and from cracks in the earth. In addition, loss of bearing strength resulted in differential settlement that caused extensive damage. Many overlying structures settled 3 feet or more or suffered severe tilting and buoyant subgrade structures, such as sewage treatment tanks, floated to the surface. Sand boils that were generated during the Imperial Valley, California, earthquake of May 18, 1940 ejected large quantities of sand in the nearby Yuma Valley, creating extensive damage to irrigation systems by covering fields and choking canals and ditches (Richter 1958, Matti and Carson 1991).

The factors that determine whether sedimentary materials are susceptible to earthquake-induced liquefaction can be grouped into three categories: (1) the geotechnical properties of the sediments; (2) the depth to groundwater; and (3) the intensity and duration of ground shaking. By using a variety of techniques, it is possible to determine each of these factors at an individual site to evaluate whether liquefaction is likely to occur during an earthquake of specified magnitude. By using additional analytical methods and statistical analysis, site-specific results can be extrapolated regionally to assign generalized liquefaction-susceptibility ratings to large areas (Matti and Carson 1991).

In evaluating liquefaction hazards, the standard references are California Division of Mines and Geology (CDMG) Special Publication 117 (CDMG 1997) and *Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Liquefaction in California* (CDMG 1999). These publications are based on original research by Seed and Idriss (1971, 1982), with subsequent refinements by Seed et al. (1983), Seed and De Alba (1986), and Seed and Harder (1990). Based on these publications, the vast majority of liquefaction hazards are associated with sandy soils and silty soils of low plasticity (the ability of the soil to be molded). Cohesive soils are generally not considered susceptible to soil liquefaction, although they can be under certain conditions. In addition, some gravelly soils are potentially susceptible to liquefaction. Most gravelly soils drain relatively well, but these soils may be vulnerable to liquefaction when the voids are filled with finer particles or the gravels are surrounded by less pervious soils that impeded drainage. In general, pre-Holocene gravels (older than about 11,000 years) are generally not considered susceptible to liquefaction due to their higher density.

To be susceptible to liquefaction, potentially liquefiable soils must be saturated or nearly saturated. In general, liquefaction hazards are most severe in the upper 50 feet of the surface, but on a slope near a free face or where deep foundations go beyond that depth, liquefaction potential should be considered at greater depth. If it can be demonstrated that any potentially liquefiable materials present at a site: (i) are currently unsaturated (e.g., are above the water table), (ii) have not previously been saturated (e.g., are above the historic-high water table), (iii) are highly unlikely to become saturated (given foreseeable changes in the hydrologic regime), then such soils generally do not constitute a liquefaction hazard that would require mitigation (CDMG 1997). The most susceptible zone occurs at depths shallower than 50 feet. Diminished susceptibility as depth increases is due to the increased firmness of deeper sedimentary materials. Much of the SBBA is located in an area of moderate to high liquefaction susceptibility (Matti and Carson 1991).

5.2 SUBSIDENCE

Subsidence is the phenomenon where soils and other earth materials underlying a site settle or compress, resulting in a lower ground surface elevation. The two types of subsidence of major concern in San Bernardino County are (1) tectonic subsidence, and (2) subsidence due to groundwater withdrawal. Tectonic subsidence is primarily of concern during very large earthquakes when subsidence could occur instantaneously and may total many feet. Subsidence due to groundwater withdrawal can be superimposed on tectonic subsidence in large sedimentary basins in tectonically active regions, such as the SBBA (Fife et al. 1976).

Subsidence due to groundwater withdrawal has been, and still remains, a concern in the alluvial valleys of San Bernardino County. Thick, poorly consolidated alluvial deposits, such as those found in the SBBA, may be subjected to subsidence if a large quantity of water is removed. Even relatively small percentages of montmorillonite clay, micaceous minerals, or organic debris, if present, will increase the possibility of subsidence. One of the greatest potential subsidence problems involves aquifers with artesian areas. The amount of subsidence that a confined aquifer system will experience is a function of soil particle size, shape, and mineralogy; geochemistry of pore water and of pore water in contiguous aquifers; and compression. The area located within the City of San Bernardino, immediately northeast of the San Jacinto Fault (i.e., the Pressure Zone) (Figure 2.2-3), is a former artesian area due to semi-confined groundwater conditions (Fife et al. 1976).

The entire alluvial valley area in southwestern San Bernardino County has experienced subsidence from groundwater withdrawal. The USGS estimates that a maximum of approximately 1.3 feet of subsidence occurred from about 1943 to 1969, immediately east of the San Jacinto Fault, near Loma Linda (DWR 1970, Fife et al. 1976). An additional 0.8 to 5.8 feet of subsidence is reportedly possible in this area located northeast of the fault.

In general, the type of subsidence that occurs as a result of groundwater pumping is uniform in nature, rather than differential, and generally does not cause damage to individual small structures (DWR 1970, Fife et al. 1976, Diaz Yourman & Associates 2003). However, subsidence does affect structures sensitive to slight changes in elevation, such as highways, canals, pipelines, drains, sewers, and particularly hydraulic structures subject to high pressures (Fife et al. 1976). Nationwide, subsidence (due to various causes) has resulted in approximately $125 million in structural damage and flood damage. It is estimated that cumulatively, an additional $400 million has been spent nationwide in attempts to control subsidence. Overdrafting of aquifers is the major cause of areally extensive land subsidence (Prince 1995).

Earth fissures and surface faulting sometimes occur in association with subsidence due to groundwater withdrawal, resulting in damage to overlying structures and infrastructure. Such ground failure occurs as a result of localized differential compaction and/or ground extension, in association with down-warping of the sediments. Earth fissures and surface faulting associated with land subsidence induced by human activity have been reported in at least 18 alluvial basins in 12 areas in the United States; the SBBA is not one of these 12 areas (Holzer 1984). However, in the San Bernardino area, large cracks have formed in the ground surface in the Yucaipa area in the years following heavy withdrawal of water for irrigation. These cracks may be the result of groundwater withdrawal or possibly hydro-compaction. About 600 acres are underlain by artesian aquifers in Yucaipa (Fife et al. 1976). The closest area (outside the Muni/Western service area) displaying ground fissures due to groundwater withdrawal is the San Jacinto Basin, a deep sedimentary basin located between the Casa Loma and Claremont faults, approximately 20 miles southeast of the City of San Bernardino (Morton 1995).

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6.0 GROUNDWATER MODELS: METHODOLOGY AND RESULTS

6.1 OVERVIEW

This section describes the tools, methodology, and results used in the evaluation of potential impacts associated with implementation of the Project. As discussed in section 1, various models are used to describe groundwater flow, groundwater quality and subsidence. Results pertain to the SBBA and three artificial recharge basins that are used in the Project but are outside of the SBBA. The models are briefly described in section 1 and listed here.

MODFLOW Groundwater Flow Model

The MODFLOW groundwater flow model of the SBBA developed by the USGS was adapted and used to evaluate water level changes for the Project. MODFLOW is a block-centered, three-dimensional, finite difference groundwater flow model that accounts for the interaction between surface streams and groundwater. It is one of the most widely used models in the evaluation of groundwater flow.

MODPATH

Using output from MODFLOW, an associated program, MODPATH, is a particle-tracking technique that is used here to compute artificial recharge, groundwater pathlines, and travel distances of plumes in the SBBA.

MT3DMS Groundwater Solute Transport Model

A groundwater transport model was developed using MT3DMS to simulate the groundwater quality for PCE, TCE, TDS, NO_3, and perchlorate in the SBBA. These water quality parameters are constituents of concern in the SBBA and are described in section 4.

Hantush Equation

An analytical expression was used to simulate the growth and decay of the groundwater mounds in response to the artificial recharge at the three spreading grounds outside of the SBBA. These are: Cactus Spreading Grounds in the Rialto-Colton Groundwater Basin, the Wilson Spreading Grounds in the Yucaipa Groundwater Basin, and Garden Air Creek in the San Timoteo Groundwater Basin. The equation used was developed by Hantush (1967) and is applicable to the growth and decay of groundwater mounds in response to uniform percolation beneath rectangular spreading basins.

PRESS Model

The PRESS model is a one-dimensional simulation of aquifer system compaction. The model computes ground surface disturbance resulting from a given change in potentiometric head within an aquifer system. This is used to compare disturbance under No Project and Project implementation.

This section first discusses the structure of the groundwater flow model and the model assumptions including the hydrologic base period. The groundwater flow model results are tabulated. Discussion follows of the other models and corresponding results. Several figures and tables referenced in this section are included as an addendum to this Appendix B.

6.2 MODFLOW GROUNDWATER FLOW MODEL

6.2.1 General Description and Purpose of Model

The purpose of the groundwater flow model is to support the evaluation of potential impacts of the Project on groundwater levels and groundwater quality in the SBBA. As mentioned previously, the Allocation Model described in Appendix A and the groundwater models had substantial interaction. Any rejected recharge in the spreading basins as shown by the groundwater modeling results were used as guidelines to modify the Allocation Model's water delivery scenarios. The groundwater model was then run again. This iterative process was continued until water allocated to particular recharge facilities was completely accommodated in that facility.

6.2.2 Use of the USGS Flow Model

The electronic files of the USGS SBBA groundwater flow model were made available through Muni, an agency which cooperated with the USGS in developing the model. The pre-processing software "Groundwater Vistas", version 3 (Environmental Simulations, Inc. 2001) was used to construct the MODFLOW groundwater flow model based on USGS groundwater model files. The transient model (time dependent model) was calibrated by the USGS. This calibration was then rerun for the period from 1945 to 1998, and cumulative inflow and outflow terms compared to the USGS results. To ensure the model data were appropriately transferred from USGS model data, a peer review was conducted with the model's author (Wes Danskin of USGS).

The following sections describe the construction of the USGS groundwater flow model including the conceptual model, model grid and layers, model boundary conditions, aquifer parameters, recharge, and discharge.

6.2.2.1 Conceptual Model

The USGS SBBA groundwater flow model is an integrated streamflow and groundwater model developed for streams and the valley-fill aquifer of the SBBA including Bunker Hill and Lytle Creek basins. The groundwater model consists of two model layers: Layer 1 contains the upper confining member and upper water-bearing zone, while Layer 2 consists of the middle and lower confining members and middle and lower water-bearing zone. Groundwater flow between the two layers is restricted by numerous fine-grained deposits in the middle confining member. Near the mountain front, the fine-grained deposits thin until they no longer exist, and the two layers act as one. The streams crossing the model area in the aquifers can be both influent (losing water to the aquifer) and effluent (gaining water from the aquifer). The streamflow inflow components are generated from surface runoff originating from rain events as well as water gained from aquifers. The streamflow outflow components include deep percolation to underlying leakage aquifers and flow out of the basin. The primary sources of recharge to the model area include seepage from gaged streams, seepage from ungaged runoff, direct infiltration of precipitation, recharge from local runoff (i.e., runoff originating from precipitation), artificial recharge of imported water, return flow from groundwater pumping, and underflow from adjacent groundwater areas. The primary discharge terms are groundwater extraction, evapotranspiration, and subsurface outflow.

6.2.2.2 Model Cells, Layers and Time Step

The two-layered model covers approximately 524 square miles and consists of 118 nodes[1] in the north-to-south direction (i-direction) and 184 nodes in the west-to-east direction (j-direction), for a total of 43,424 nodes (see Figure 6.2-1). Each model cell represents an area of approximately 15 acres (820 feet by 820 feet). The time length used to change model parameters such as pumping, streamflow, etc. was annual. This is also referred to as annual "stress periods". Each annual stress period was subdivided into 100 time steps which were used to progress the model forward in time. The purpose of the small time steps was to obtain as accurate a solution as possible.

6.2.2.3 Boundary Conditions

The SBBA is bordered on the northwest by the San Gabriel Mountains, on the northeast by the San Bernardino Mountains, on the southeast by the Crafton Fault, and on the southwest by the San Jacinto Fault (see Figure 6.2-1).

The mountainous areas to the northwest and northeast represent impermeable boundaries and were assigned as "no-flow" or "inactive" cells. Groundwater recharge along the mountain front was simulated using MODFLOW's Well Package (see also 6.2.2.5.3). Surface inflow from streams was simulated using MODFLOW's Streamflow-Routing Package (described further in 6.2.2.5.1). Unconsolidated or poorly consolidated sediments southeast of the Crafton Fault (Yucaipa Basin and San Timoteo Basin), and southwest of the San Jacinto Fault (Rialto-Colton Basin and Riverside Basin), were also assigned as "no-flow" or "inactive" cells. The underflow recharge or discharge across these faults was simulated using MODFLOW's Well Package.

6.2.2.4 Aquifer Parameters

6.2.2.4.1 Transmissivity

The initial transmissivity values used by the USGS model were based on values from Hardt and Hutchinson (1980). Hardt and Hutchinson used transmissivity values calculated from specific capacity tests performed by the California DWR (1970) and modified the values based on model calibration. The final transmissivity values used by the USGS model are shown in Figure 6.2-2. The values differ between the model layers. For Model Layer 1, the transmissivity ranges from approximately 200 to 1,000 feet [ft]^2/day (1,500 to 7,500 gallons per day [gpd]/ft) in the Cajon Canyon area, to 23,000 ft^2/day (172,000 gpd/ft) near the center of the SBBA. For Model Layer 2, the transmissivity ranges from approximately 200 to 1,000 ft^2/day (1,500 to 7,500 gpd/ft) in the Cajon Canyon area to 43,000 ft^2/day (321,600 gpd/ft) near the center of the SBBA.

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[1] A model "node" is the center of a model "cell." The model cells are square with a side of 820 ft. The network of model cells forms a "grid" or "mesh" covering the entire model area.

6.2.2.4.2 Storativity

The initial storativity values for Model Layer 1 (conceptualized as an unconfined aquifer), were assigned the specific yield[2] values based on Eckis (1934). For the Model Layer 2, a storativity for a confined aquifer (0.0001) was assigned (see Figure 6.2-3). The highest storativity for Layer 1 is in the middle of the basin including part of the Pressure Zone.

6.2.2.4.3 Vertical Leakance Between Layer 1 and Layer 2

Model Layers 1 and 2 are in hydraulic continuity with flow across the layer boundary dependent upon the hydraulic head difference between the layers as well as the leakance[3]. The initial leakance values used by the USGS model were based on Hardt and Hutchinson (1980) data that were refined by model calibration. The final leakance values range from approximately 0.0001 day^{-1} in the pressure zone, to 0.03 day^{-1} near the base of the San Gabriel and San Bernardino Mountains (see Figure 6.2-4). This distribution reflects the variations of aquitard thickness and aquitard material grain size.

6.2.2.4.4 Conductance for Groundwater Barriers

The USGS model considers several faults and groundwater barriers to be "partial" barriers to groundwater flow within the aquifer systems of the SBBA. The locations of these faults and groundwater barriers were delineated from Matti and Carson (1991) and Dutcher and Garrett (1963). The groundwater barriers were simulated in the model using the Horizontal-Flow-Barrier Package and assigning a lower hydraulic characteristic value (the barrier transmissivity divided by the width of the horizontal-flow barrier) to the boundary of the barrier. The values were derived primarily by trial-and-error during the model calibration. Figure 6.2-5 shows the model cells and final hydraulic characteristic values used for the Horizontal-Flow-Barrier Package. The smaller the hydraulic characteristic value, the greater the effectiveness of the groundwater barrier. For Model Layer 1, the hydraulic characteristic value ranges from 0.0315 ft/day for the northwest segment of Loma Linda Fault, to 24.19 ft/day for the southeast segment. For Model Layer 2, the values range from 0.0315 ft/day for the northwest segment of Loma Linda Fault to 11.66 ft/day for Barrier G (see Figure 6.2-5 for barrier location).

6.2.2.5 Recharge and Discharge

Recharge and discharge terms (i.e., "flux" terms) in the SBBA were simulated using MODFLOW's Streamflow-Routing Package, Recharge Package, Well Package and Evapotranspiration Package. Table 6.2-1 lists recharge and discharge terms and the associated MODFLOW package used by the USGS model.

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[2] Equivalent to effective porosity or "drainable" porosity.

[3] "Leakance" as defined by Hantush (1964) is the rate of flow that crosses a unit area of the interface between the main aquifer and the semi-pervious layer (i.e., "leaky layer") if the difference between the heads at the top and bottom of the semi-pervious layer is unity.

Table 6.2-1. Recharge and Discharge Terms and Associated MODFLOW Package Used

Recharge and Discharge Flux Used in the Model		*MODFLOW Package*
Recharge	Gaged Streamflow	Streamflow-Routing
	Recharge from Ungaged Mountain Front Runoff	Well
	Imported Water	Well
	Return Flow from Groundwater Pumping	Well
	Underflow	Well
	Infiltration from Direct Precipitation	Recharge
	Recharge from Local Runoff Generated from Precipitation	Recharge
Discharge	Groundwater Pumping	Well
	Evapotranspiration	Evapotranspiration
	Gaged Streamflow	Streamflow-Routing
	Underflow	Well

6.2.2.5.1 Streamflow-Routing Package

The Streamflow-Routing Package was used to simulate the recharge and discharge of the gaged mountain front runoff through interaction between major streams and aquifers of the SBBA.

Streamflow was routed down the stream channels, through Spreading Grounds and past the outflow gages near the San Jacinto Fault. A total of 56 “segments” were identified (see Figure 6.2-6). A stream segment is defined as the longest portion of a surface watercourse having no tributaries.

Segments 1, 2, 5, 17, 19, 30, 33, 35, 42 and 53 receive surface runoff from the drainage area tributary to each segment. The surface runoff inflow for these segments was based on the annual discharge of each segment’s mountain front gage. These gages include Lytle Creek near Fontana (Segment 1), Cajon Creek below Lone Pine Creek near Keenbrook (Segment 2), Devil Canyon Creek near San Bernardino (Segment 5), Waterman Canyon Creek near Arrowhead Springs (Segment 17), East Twin Creek near Arrowhead Springs (Segment 19), City Creek near Highland (Segment 30), Plunge Creek near East Highlands (Segment 33), Santa Ana River near Mentone (Segment 35), Mill Creek near Yucaipa (Segment 42), and San Timoteo Creek near Redlands (Segment 53).

Inflow from surface runoff during the period 1945-1998 for each gage is shown in the Addendum as Figures B 1 through B 10. Figure 6.2-7 shows the total inflow from surface runoff to the SBBA. As shown, during the model calibration period from 1945 to 1998, the total surface water inflow from these gages ranges from 35,900 af in 1961, to 674,000 af in 1969 with an annual average of 146,700 afy.

A stream "reach" is defined as the portion of a stream segment that transects a single model grid cell. Model cells containing a portion of a stream across a corner or along an edge were generally included as reaches. Reaches were identified by their "i, j" coordinates (node coordinates) and were numbered (by segment) from their upstream to downstream. The top streambed elevation for each reach was determined based on the average surface elevation along the edge of the stream within the reach. The stream stage and the bottom elevation of the streambed were assumed to be 5 feet above and 5 feet below the top elevation of the streambed, respectively.

The initial streambed conductance used by the USGS model was calculated using the following equation:

$$\mathrm{CSTR} = \frac{\mathrm{KLW}}{\mathrm{M}}$$

where:

CSTR = streambed conductance [ft^2/day],

K = vertical hydraulic conductivity of the streambed [ft/day],

L = length of stream reach [ft],

W = width of stream [ft], and

M = thickness of streambed [ft].

During model calibration, streambed conductance was adjusted using trial-and-error until final calibration was achieved (see section 6.2.3). Figure 6.2-8 shows the streambed conductance values used for the final model calibration. During wet years (with higher precipitation and therefore higher streamflow), an increase in the width of the stream usually occurs due to amounts of streamflow overflowing the stream channels (i.e., historical flow). In addition, the vertical hydraulic conductivity of the streambed increases due to the removal of fine-grained sediments by the high energy of the streamflow. Both of these result in an increase in streambed conductance. In order to account for variation of streambed conductance with time, considering the wet and dry cycles, an adjustment factor was applied to the values (shown in Figure 6.2-8) for wet years, specifically 1958, 1967, 1969, 1978, 1979, 1980, 1983, 1993, 1995 and 1998. The adjustment factor ranges from one (unchanged) to five (higher conductance).

6.2.2.5.2 Recharge Package

The Recharge Package simulates regionally distributed recharge to the groundwater system as a result of precipitation. This includes infiltration from direct precipitation and recharge from local runoff generated from precipitation. The infiltration from precipitation was assumed to be approximately 1 percent of the long-term mean annual precipitation and to be constant from year to year. This assumption results in approximately 1,100 afy of infiltration originating from precipitation for the SBBA. Recharge from local runoff generated from precipitation varies each year and was assumed to be 5 percent of the annual precipitation. During the model calibration period from 1945 to 1998, the recharge from local runoff generated from precipitation in the SBBA ranged from 2,000 af in 1947, to 11,800 af in 1983 with an annual average of 5,500 afy (see Figure 6.2-9).

The recharge values were areally distributed to each model cell based on the isohyetal map (see Figure 6.2-10) representing the spatial variation of long-term average annual precipitation. The most precipitation occurs in the upper Cajon Wash and Lytle Creek sub-basins. The least precipitation occurs along the southwestern boundary of the SBBA.

6.2.2.5.3 Well Package

Input data for the Well Package included the following:

- Recharge from Ungaged Mountain Front Runoff;
- Artificial Recharge of Imported Water;
- Groundwater Pumping (extractions);
- Return Flow from Application of Groundwater Pumping; and
- Underflow Recharge and Underflow Discharge.

Recharge from ungaged mountain front runoff from the adjacent mountains and small outcrops within the SBBA was estimated based on drainage areas, streamflow in nearby basins, and measured flow in the SAR. Figure 6.2-11 shows the model cells used to simulate recharge of ungaged mountain front runoff in the USGS model. During the model calibration period (1945 to 1998), the recharge from mountain front runoff for the SBBA ranges from 4,000 af in 1990 to 67,700 af in 1980 with an annual average of 16,200 afy (see Figure 6.2-12).

Artificial recharge of imported water was based on the historically measured imported water used for each of the spreading grounds. A recharge rate of 95 percent of the imported water was used by the USGS model to simulate water that actually recharged the groundwater systems (Figure 6.2-13 shows model cells used to simulate artificial recharge of imported water). During the period from 1945 to 1998, artificial recharge of imported water for the SBBA ranged from 0 afy (artificial recharge began in 1972) to 30,400 afy with an annual average of 2,900 afy (see Figure 6.2-14).

Groundwater extraction quantities used by the USGS model were based on measured data obtained from the Muni/Western watermaster. The amount of groundwater pumped from each well was distributed to Model Layers 1 and 2 based on the perforated interval in the well and the hydraulic conductivity of adjacent deposits. The proportion of pumping from each well from each layer is a function of the length of the well screen in that layer and the hydraulic conductivity of the layer.

Wells are located throughout the SBBA. Figure 6.2-15 shows the distribution of 762 production wells. Figure 6.2-16 shows annual groundwater pumping for the period 1945 to 1998. Annual groundwater pumping ranges from 122,900 af in 1945 to 214,000 af in 1961 with an annual average of 175,100 afy.

For the purposes of the model, return flow from groundwater pumping was assumed to be the quantity of groundwater pumped that returns to the groundwater system as a result of agricultural, domestic and municipal uses. Return flow was assumed to be 30 percent of total groundwater pumping except for wells that export groundwater directly out of the SBBA. Previous reports (Hardt and Hutchinson 1980) estimated that return flow from these sources was equivalent to 30 percent of the applied water, considering the permeability of the soil and volume of applied water. Wells used for export were assumed to have 0 to 3 percent (pipe losses) return flow. This is a common engineering estimate of expected leakage from pipes. The return flow was assumed to recharge Model Layer 1 in the same cell as the pumping wells. In other words, it was assumed that groundwater was applied in the nearby vicinity of the pumping well. As shown in Figure 6.2-17, the annual return flow from groundwater pumping ranges from 20,100 af in 1945 to 37,000 af in 1961 with an annual average of 28,300 afy for the period from 1945 to 1998.

Recharge from underflow to the SBBA occurs across the Crafton Fault. Figure 6.2-18 shows the model cells used to simulate this recharge. The amount of annual recharge from underflow used by the USGS model ranged from 3,800 af to 6,800 af with an annual average of 5,100 afy for the period from 1945 to 1998 (see Figure 6.2-19). Groundwater outflow from the SBBA occurs across the San Jacinto Fault and Barrier E. Figure 6.2-18 also shows the model cells used to simulate the groundwater outflow. The amount of subsurface outflow in the USGS model ranges from 2,900 af to 14,100 af with an annual average of 6,100 afy for the period from 1945 to 1998 (see Figure 6.2-20).

6.2.2.5.4 Evapotranspiration Package

The Evapotranspiration Package simulates the effects of plant transpiration and direct evaporation in removing water from the saturated zone. Data on maximum evapotranspiration rate, evapotranspiration surface, and extinction depth are required inputs to the model.

A maximum evapotranspiration rate of 38 in./yr was used in the USGS model based on Hardt and Hutchinson (1980). Extinction depth was estimated to be 15 feet (Lee 1912, Robinson 1958, and Sorenson et. al. 1991). Based on the depth to water, the evapotranspiration rate linearly decreased from 100 percent at the surface to 0 percent at the extinction depth of 15 feet. Evapotranspiration is assumed to occur whenever the water level is above the extinction depth.

6.2.3 Model Calibration

The method of calibration used by the USGS model was the standard "history matching" technique. In this method, a steady-state calibration of 1945 was chosen, along with a transient calibration period of 1945 to 1998. Model-generated groundwater levels were compared with measured levels for wells in the SBBA. Adjustments in hydrogeologic parameters were then made within tolerable limits until a satisfactory match was obtained. Model-calculated recharge and discharge terms were also compared to the estimated and measured recharge and discharge terms.

For the model calibration, historical groundwater level data for 43 wells within the SBBA were obtained from the USGS website and compared with model-generated groundwater levels. In general, the pattern of the model-generated and measured levels are similar in that the model appears to capture the long- and short-term temporal trends in groundwater levels in most parts of the basin (see Figure 6.2-21). Figure 6.2-22 is an "x-y" plot showing comparisons of measured and model-generated groundwater levels. The relative error (the standard deviation of the water level residuals[4] divided by the observed head range; Zheng and Bennett, 2002) of the model-generated groundwater levels between 1945 and 1998 is approximately 5 percent. Common modeling practice is to consider a good fit between historical and model-predicted data if the relative error is below 10 percent (Spitz and Moreno 1996 and Environmental Simulations, Inc. 1999). The USGS model also provided a good match with the gaged surface runoff within the SBBA (see Figure 6.2-23).

6.2.4 Model Verification

In addition to re-running the USGS model calibration, a verification run was simulated by adding the years 1999 and 2000 to the 1945-1998 calibration run[5]. The year 2000 is the most recent year for which verified groundwater production data were available at the time of the work. The purpose of this verification model run was to validate the USGS flow model. In addition, the most recent model-generated groundwater elevations (i.e., 2000) were used as initial elevations for future model scenarios in order to avoid the errors that may be introduced from hand contouring (i.e., constructing initial groundwater elevations for the start of model runs).

Annual values of recharge and discharge were based on measured data or estimated for the two years (1999-2000) using the same methods as described in section 6.2.2.5. In general, the model verification run validates the model calibration for groundwater levels. During the model verification period (1999-2000), the relative error of the model-generated groundwater levels is 6 percent (see Figure 6.2-24).

6.2.5 Model Scenarios

6.2.5.1 Hydrologic Base Period

A hydrologic base period is the period of time over which elements of the equation of hydrologic equilibrium[6] are evaluated. The time period selected should:

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[4] "Residual" = measured – modeled

[5] The USGS model was only calibrated between 1945-1998. Verification consisted of extending the calibration through the year 2000.

[6] The equation of hydrologic equilibrium is a quantitative statement of the conservation of mass. In groundwater hydrology, it is simply Inflow = Outflow ± Change in Storage. Also known as a water balance or hydrologic budget.

- Be representative of long-term hydrologic conditions,
- Include wet, dry, and average years of precipitation,
- Span a 20- to 30-year period (Mann 1968),
- Have its start and end years preceded by comparatively similar rainfall quantities (DWR 2002),
- Preferably start and end in a dry period (Mann 1968). This minimizes any water draining (in transit) through the vadose zone, and
- Include recent cultural conditions (DWR 2002).

Based on analyses of historical precipitation and streamflow, the 39-year period from October 1961 through September 2000 (water years October 1961 - September 1962 through October 1999 - September 2000) was selected as the hydrologic base period. This base period covers both wet and dry hydrologic cycles, and the average precipitation is approximately the same as the long-term average. For model prediction runs, the hydrologic base period was assumed to represent future conditions for the 39-year period October 2000 through September 2039 (water years October 2000 - September 2001 through October 2038 - September 2039). The annual time step of the model, i.e., the annual stress periods, for the predictive scenarios duplicated historical hydrologic conditions of the base period.

6.2.5.2 *Assumptions and Sources of Data*

Table 6.2-2 summarizes assumptions and sources of model input data that were used for the various model scenarios.

6.2.5.3 *Description of Model Scenarios*

Five model scenarios were run:

1) No Project,
2) Scenario A,
3) Scenario B,
4) Scenario C, and
5) Scenario D.

Table 6.2-3 presents the allocation assumptions used for each scenario.

Results from the OPMODEL and Allocation Model provided the following groundwater model recharge and discharge values, for the various model scenarios:

- Releases to SAR from the Seven Oaks Dam,
- Artificial recharge in the spreading grounds, and
- Groundwater pumping and return flow from groundwater pumping.

All other model input values remained the same for each of the five model scenarios. Table 6.2-4 summarizes the key recharge and discharge values used for these scenarios.

Table 6.2-2. Summary of Model Assumptions and Sources of Data

Description of Model Input Data		*Assumptions and Sources of Data*
Gaged Mountain Front Runoff	Release to SAR from the Seven Oaks Dam	OPMODEL
	Other Gaged Inflow	Historical Data (1962-2000)*
Artificial Recharge at Spreading Grounds		Allocation Model
Recharge from Underflow		Extension of Historical Trend*
Return Flow from Groundwater Pumping		Allocation Model
Recharge from Ungaged Mountain Front Runoff		Historical Data 1962-2000*
Infiltration from Direct Precipitation		Historical Data 1962-2000*
Recharge from Local Runoff Generated by Precipitation		Historical Data 1962-2000*
Groundwater Pumping		Allocation Model
Groundwater Outflow (Underflow Discharge)	Across San Jacinto Fault near SAR area	Model-Calculated
	Across Barrier E	Extension of Historical Trend*

* From flow model calibration (1945-1998) and verification (1999-2000) runs.

Table 6.2-3. Assumptions for Model Scenarios

	WCD[1] Spreading		*Senior Water Right Diversion*		*Habitat Release*		*Muni/Western Diversion*		
Model Scenario	*Historical*	*Licensed*	*Historical*	*88 cfs*	*Habitat Release*	*Other Habitat Treatment[2]*	*Plunge Pool 1500 cfs Diversion Rate*	*Cuttle Weir 500 cfs Diversion Rate*	*No*
No Project Condition	x		x		x				x
Scenario A		x	x			x	x		
Scenario B		x	x			x		x	
Scenario C	x			x	x		x		
Scenario D	x			x	x			x	

[1] San Bernardino Valley Water Conservation District

[2] Less than 100 af in the 39-year period.

Source: See Appendix A: (Surface Water Hydrology) of the EIR for details. Also see sections 6.2.5.3.1 through 6.2.5.3.3 of this appendix for clarification of this table.

6.2.5.3.1 *Releases to SAR from the Seven Oaks Dam*

Releases to the SAR from the Seven Oaks Dam were based on the results from OPMODEL. As listed in Table 6.2-4, for the No Project condition, the Seven Oaks Dam releases included, on average, 20,704 afy of undiverted SAR water, 915 afy of habitat release and zero turnback to SAR for an average annual total of 21,619 afy during the period 2001-2039.

For scenarios A and C, both undiverted SAR water and turnback to SAR were computed to be zero. However, the amount of undiverted SAR water is 734 afy for Scenario D and 1,317 afy for Scenario B. The amount of turnback to SAR water is 426 afy for Scenario D and 536 afy for Scenario B.

Table 6.2-4. Summary of Key Recharge and Discharge Values
(units in afy)

Average Annual Recharge and Discharge		*No Project*	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*
Seven Oaks Dam Releases	Undiverted SAR	20,704	0	1,317	0	734
	Habitat Release	915	0	0	712	712
	Turnback to SAR	0	0	536	0	426
	Total	**21,619**	**0**	**1,853**	**712**	**1,872**
Artificial Recharge	SAR Spreading Grounds	10,384	4,961	5,411	16,691	16,976
	Other Spreading Grounds	21,932	39,172	37,119	27,242	27,006
	Total	**32,316**	**44,133**	**42,530**	**43,933**	**43,982**
Groundwater Pumping	Non-Plaintiffs	169,140	169,140	169,140	166,439	166,439
	Plaintiffs	64,348	67,442	66,960	67,216	66,981
	Total	**233,488**	**236,582**	**236,100**	**233,655**	**233,420**

Source: See Appendix A: (Surface Water Hydrology) of the EIR for details. Also see sections 6.2.5.3.1 through 6.2.5.3.3 of this appendix for clarification of this table.

In terms of habitat release, this was determined to be zero for both Scenarios A and B (less than 100 af in 39 years from other habitat treatment), and averaged 712 afy for both Scenarios C and D. Table B 1 (in the Addendum to this appendix) summarizes the annual Seven Oaks Dam releases for each scenario.

6.2.5.3.2 *Artificial Recharge at Spreading Grounds*

The amount of artificial recharge from spreading grounds was based on results from the Allocation Model. During the development of water delivery scenarios, the Allocation Model and the groundwater model worked iteratively to determine reasonable deliveries to spreading grounds. The iterative process was necessary since deliveries of water to spreading grounds are limited by several factors. One factor is delivery constraints. For example, the available conveyance route capacities and absorptive capacities of spreading facilities need to be considered. Other factors are groundwater levels and the effect of water deliveries on groundwater contamination plumes. Water delivery scenarios in the Allocation Model were modified by a series of iterations that considered high groundwater levels in the Pressure Zone and interference with remediation efforts in the contaminant plume areas (determined using the groundwater model).

Annual artificial recharge at each spreading ground for the period 2001-2039 for each model scenario is shown in Tables B 2 through B 6 (in the addendum to this appendix). Table 6.2-5 summarizes (by scenarios) average annual artificial recharge applied at each spreading ground during the period 2001-2039.

Table 6.2-5. Summary of Average Annual Artificial Recharge, 2001-2039 (units in afy)

Spreading Grounds	*No Project*	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*
SAR	10,384	4,961	5,411	16,691	16,976
Mill Creek	0	468	718	406	499
City Creek	0	3,956	2,116	45	254
Patton	372	484	482	361	357
Waterman	7,813	12,320	13,551	9,474	8,671
East Twin Creek	6,332	10,274	11,108	7,971	7,533
Badger	1,403	2,200	1,990	1,503	1,806
Devil Canyon/ Sweetwater	3,227	4,622	3,514	3,657	3,821
Lytle Creek	2,785	4,848	3,640	3,825	4,065
Total	32,316	44,133	42,530	43,933	43,982

Source: See Appendix A: (Surface Water Hydrology) of the EIR for details.

Artificial recharge at the SAR spreading grounds for No Project was estimated to be 10,384 afy based on historical spreading by the Conservation District. This amount increased to 16,691 and 16,976 afy for Scenarios C and D, respectively. This is because artificial recharge for Scenarios C and D included spreading by the Conservation District and by senior water rights claimants (refer to section 2.4.3.1 in Appendix A for more information on senior water rights claimants). Artificial recharge decreased to 4,961 and 5,411 afy for Scenarios A and B. Artificial recharge for Scenarios A and B was largely comprised of spreading by the Conservation District, which was estimated based on the Conservation District's license application (as opposed to the Conservation District's historical spreading used in the other scenarios and No Project).

For both Scenarios A and B, artificial recharge increased at spreading grounds other than the SAR compared to No Project. For Scenario B, these increases ranged from 110 af (at the Patton Spreading Grounds) to 5,738 af (at the Waterman Spreading Grounds). For Scenario A, the increases ranged from 112 af at the Patton Spreading Grounds, to 4,507 af at the Waterman Spreading Grounds. With Scenarios C and D, artificial recharge varied at spreading grounds other than the SAR compared to No Project. For Scenario C, the changes in spreading ranged from a decrease of 11 af (at the Patton Spreading Grounds) to an increase of 1,661 af (at the Waterman Spreading Grounds). For Scenario D, the changes in spreading ranged from a decrease of 15 af at the Patton Spreading Grounds, to an increase of 1,280 af at the Lytle Basins.

6.2.5.3.3 Groundwater Pumping and Return Flow from Groundwater Pumping

Within the *Western* Judgment, Plaintiffs and Non-Plaintiffs are identified (refer to 2.4.1.2 in Appendix A for more information). The same designation is used in the Allocation Model and also in the groundwater model to describe the groundwater pumping. Table 6.2-6 lists the estimated annual groundwater pumping for the Non-Plaintiffs and Plaintiffs for each model scenario during the period 2001-2039. The pumping value assigned to each well in a particular year was based on the amount pumped in the year 2000 multiplied by the ratio of the total projected pumping for that particular year[7]. The total projected groundwater pumping for each of the model scenarios was based on results from the Allocation Model.

Table 6.2-6. Average Annual Groundwater Pumping, 2001 to 2039 (units in af)

Type of Groundwater Pumping	*No Project Condition*	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*
Non-Plaintiffs	169,140	169,140	169,140	166,439	166,439
Plaintiffs	64,348	67,442	66,960	67,216	66,981
Total	233,488	236,582	236,100	233,655	233,420
Source: See Appendix A: (Surface Water Hydrology) of the EIR for details.					

Table 6.2-7 summarizes the average annual groundwater pumping used for the model scenarios.

The groundwater pumping for Non-Plaintiffs for No Project and Scenarios A and B was estimated to be 169,140 af. For both Scenarios C and D the Non-Plaintiffs' groundwater pumping was estimated to be approximately 2,701 afy less than that for No Project. This was due to the additional diversion of senior water rights claimants. For all four Project scenarios, modeled increases in groundwater pumping by Plaintiffs ranged from 2,612 afy to 3,094 afy relative to No Project. This estimate was based on the Plaintiffs' existing right to export from the SBBA. The right to export for the Plaintiffs was adjusted based on three items:

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[7] For example, for a well pumped 1,000 gpm in 2000, the ratio of the total projected pumping for 2020 to the total pumping in 2000 is 1.11 (an increase of 11 percent). Pumping for this well in 2020 would be 1,110 gpm (1110 = 1.11 x 1000)..

Annual Groundwater Pumping for Model Scenarios - 2001 to 2039 (Units in acre-ft)

Water Years	No Project Condition			Scenario A			Scenario B			Scenario C			Scenario D		
	Non-Plaintiffs	Plaintiffs	Total	Non-Plaintiffs	Plaintiffs	Total	Non-Plaintiffs	Plaintiffs	Total	Non-Plaintiffs	Plaintiffs	Total	Non-Plaintiffs	Plaintiffs	Total
2001	150,176	63,401	213,577	150,176	63,441	213,617	150,176	63,441	213,617	150,176	63,342	213,518	150,176	63,342	213,518
2002	162,949	63,249	226,198	162,949	63,275	226,224	162,949	63,275	226,224	161,964	63,121	225,085	161,964	63,121	225,085
2003	160,444	63,097	223,541	160,444	63,110	223,554	160,444	63,110	223,554	159,926	62,926	222,853	159,926	62,926	222,853
2004	156,257	62,990	219,247	156,257	62,944	219,201	156,257	62,944	219,201	154,213	62,651	216,864	154,213	62,651	216,864
2005	143,328	63,018	206,346	143,328	63,283	206,612	143,328	63,283	206,612	134,397	62,756	197,153	134,397	62,756	197,153
2006	156,172	63,202	219,373	156,172	62,530	218,702	156,172	62,882	219,054	142,091	62,808	204,899	142,091	62,808	204,899
2007	153,738	63,330	217,068	153,738	63,728	217,466	153,738	63,710	217,448	153,738	63,049	216,787	153,738	63,049	216,787
2008	153,128	64,365	217,493	153,128	66,861	219,990	153,128	67,047	220,176	131,287	67,055	198,342	131,287	67,359	198,646
2009	157,592	64,652	222,244	157,592	67,299	224,891	157,592	67,487	225,079	144,640	70,267	214,906	144,640	70,536	215,175
2010	168,946	64,646	233,592	168,946	67,371	236,317	168,946	67,557	236,503	156,072	70,501	226,573	156,072	69,690	225,762
2011	172,055	64,404	236,459	172,055	69,603	241,657	172,055	69,437	241,491	164,655	70,041	234,696	164,655	69,231	233,886
2012	156,903	64,872	221,775	156,903	68,939	225,842	156,903	69,144	226,047	149,719	70,277	219,996	149,719	69,466	219,185
2013	164,284	64,001	228,285	164,284	67,481	231,764	164,284	67,481	231,764	164,284	66,501	230,784	164,284	65,385	229,669
2014	169,657	63,783	233,440	169,657	68,676	238,333	169,657	68,676	238,333	169,657	63,553	233,210	169,657	62,472	232,129
2015	173,381	63,722	237,104	173,381	70,497	243,878	173,381	69,525	242,906	173,381	63,043	236,425	173,381	63,042	236,424
2016	179,649	63,713	243,362	179,649	69,467	249,116	179,649	67,881	247,529	177,083	63,239	240,322	177,083	63,236	240,319
2017	172,577	64,719	237,296	172,577	69,501	242,079	172,577	68,043	240,621	172,577	65,218	237,796	172,577	65,210	237,787
2018	160,551	65,702	226,252	160,551	68,020	228,571	160,551	66,563	227,113	160,551	67,083	227,634	160,551	67,068	227,619
2019	163,379	66,690	230,070	163,379	70,001	233,380	163,379	69,152	232,531	163,379	71,087	234,466	163,379	72,140	235,519
2020	171,026	66,779	237,805	171,026	69,459	240,485	171,026	69,571	240,596	171,026	75,199	246,224	171,026	74,160	245,185
2021	168,673	67,049	235,723	168,673	69,587	238,261	168,673	70,326	238,999	168,673	76,161	244,834	168,673	74,801	243,474
2022	165,902	65,820	231,722	165,902	71,395	237,297	165,902	72,062	237,964	165,902	77,319	243,221	165,902	76,313	242,215
2023	166,437	64,874	231,310	166,437	73,109	239,545	166,437	73,882	240,318	166,437	77,088	243,525	166,437	75,877	242,314
2024	174,109	63,763	237,872	174,109	72,513	246,623	174,109	71,926	246,035	174,109	72,866	246,976	174,109	70,599	244,709
2025	161,230	63,774	225,004	161,230	71,343	232,573	161,230	70,374	231,604	161,230	69,175	230,405	161,230	69,000	230,230
2026	180,137	63,439	243,576	180,137	72,395	252,531	180,137	69,609	249,745	180,137	68,265	248,401	180,137	68,426	248,563
2027	178,662	63,100	241,762	178,662	70,023	248,684	178,662	67,183	245,844	176,978	64,630	241,607	176,978	64,431	241,408
2028	187,764	62,957	250,721	187,764	68,113	255,877	187,764	65,168	252,932	184,660	62,616	247,276	184,660	62,628	247,289
2029	196,976	62,962	259,938	196,976	65,101	262,077	196,976	62,907	259,883	196,630	62,666	259,296	196,630	62,667	259,297
2030	184,343	62,914	247,257	184,343	64,498	248,841	184,343	62,686	247,029	179,760	62,065	241,824	179,760	62,065	241,825
2031	174,341	63,180	237,522	174,341	62,865	237,207	174,341	62,871	237,213	174,341	62,405	236,746	174,341	62,405	236,746
2032	171,384	64,437	235,822	171,384	64,109	235,493	171,384	64,207	235,592	171,384	66,387	237,771	171,384	66,707	238,091
2033	172,663	64,551	237,214	172,663	66,594	239,257	172,663	66,373	239,035	172,663	66,946	239,609	172,663	67,068	239,730
2034	171,257	65,122	236,378	171,257	66,618	237,874	171,257	66,910	238,166	171,257	68,390	239,646	171,257	68,743	239,999
2035	178,698	65,221	243,919	178,698	68,336	247,034	178,698	68,033	246,732	178,698	69,156	247,854	178,698	69,285	247,984
2036	178,984	65,258	244,242	178,984	68,444	247,428	178,984	68,132	247,116	178,984	69,272	248,256	178,984	69,390	248,374
2037	171,677	65,140	236,816	171,677	67,503	239,180	171,677	67,247	238,924	171,677	67,604	239,280	171,677	67,460	239,137
2038	182,251	65,081	247,332	182,251	65,575	247,826	182,251	65,482	247,734	182,251	67,166	249,417	182,251	67,225	249,476
2039	184,788	66,587	251,375	184,788	66,613	251,401	184,788	65,848	250,636	180,552	67,538	248,090	180,552	67,534	248,086
Average	**169,140**	**64,348**	**233,488**	**169,140**	**67,442**	**236,582**	**169,140**	**66,960**	**236,100**	**166,439**	**67,216**	**233,655**	**166,439**	**66,981**	**233,420**

Source: SAIC (2004)

1) the Plaintiffs' share of the newly conserved water[8],
2) the Plaintiffs' share of the sub-basin exchange water (captured SAR water that is delivered outside of the SBBA but within Muni's service area), and
3) the Conservation District adjustment[9].

Return flow from groundwater pumping was assumed to be 30 percent of the total amount of groundwater extracted except for wells that export groundwater directly out of the SBBA. Wells used for export were assumed to have a 0 percent to 3 percent return flow. The return flow was assumed to recharge Model Layer 1 in the vicinity of the wells. These assumptions are the same as the assumptions used by the USGS for the model calibration period from 1945-1998.

6.2.6 Groundwater Flow Model Results

6.2.6.1 Groundwater Elevations

Groundwater elevation contours for No Project are shown in the addendum as Figure B 11 for Model Layer 1 and Figure B 12 for Model Layer 2. This is shown for the year 2000, which represents the model initial conditions and every 5 years through 2015. Year 2016 (the year with the lowest levels of groundwater), 2020, 2022 (the year with the highest groundwater levels), and 2025, 2030, 2035, and 2039 (end of model simulation) are also given.

In general, model-generated groundwater flow is similar to historical directions with groundwater flowing west from the SAR and Mill Creek Spreading Grounds, and southeast from the Lytle Creek and Cajon Creek. Water is flowing towards the Pressure Zone. Water level fluctuations reflect hydrological wet and dry cycles. For example, a change in water level of 50 feet to 100 feet occurs in the Pressure Zone between model years 2016 (equivalent to 1977 – end of a dry year cycle) and 2022 (end of a wet cycle, historical year 1983; also see Figure B 11). Groundwater flow directions and general patterns of fluctuations for the four Project scenarios are similar to No Project (see Addendum, Figures B 13 through B 20).

Differences in groundwater levels between No Project and Scenario C in selected years are shown in Figure B 21 (Model Layer 1) and Figure B 22 (Model Layer 2). In general, groundwater levels for Scenario C are higher in the northwestern portion of the SBBA, reflecting an increase in artificial recharge at Waterman, East Twin Creek, Devil Canyon/Sweetwater and Lytle Basins. Meanwhile, groundwater levels are lower in the central (Pressure Zone) and eastern portions of the SBBA, as the diversion of SAR water results in a reduction of groundwater percolation in the SAR channel.

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[8] New conservation as defined in the *Western* Judgment is any increase in replenishment from natural precipitation which results from operation of works and facilities that did not exist in 1969. The portion for the Plaintiff is always 27.95 percent of the new conservation.

[9] The Conservation District adjustment representing the difference between the average annual diversions made by the Conservation District, based on diversion records, and their average annual diversions based on the conditions set for each Project scenario. The first value is determined using data from the Watermaster's 26-year base period of water years 1935 to 1960 and the second value is determined using OPMODEL for the 39-year base period as part of the analysis of the Project.

Differences in groundwater levels between No Project and Scenario D in selected years are shown in Figure B 23 (Model Layer 1) and Figure B 24 (Model Layer 2). The distribution and magnitude of water level differences are similar to the differences in groundwater levels between No Project Condition and Scenario C.

Differences in groundwater levels between No Project and Scenario A are shown in Figure B 25 (Model Layer 1) and Figure B 26 (Model Layer 2). Model-generated groundwater levels for Scenario A are higher in the northwestern portion of the SBBA and the northwestern portion of the Pressure Zone, reflecting the increase in artificial recharge at the Waterman, East Twin Creek, Badger, Devil Canyon/Sweetwater, and Lytle Basins. Groundwater levels are lower in most portions of the Pressure Zone and the eastern portion of the SBBA due to the diversion of SAR water. The diversion prevents deep percolation in a portion of the SAR channel reach.

Differences in groundwater levels between No Project and Scenario B are shown in Figure B 27 (Model Layer 1) and Figure B 28 (Model Layer 2). Model-generated groundwater levels for Scenario B are higher in the northwestern portion of the SBBA and the northwestern portion of the Pressure Zone. Groundwater levels for Scenario B are lower in most portions of the Pressure Zone and the eastern portion of the SBBA.

Hydrographs at selected wells and spreading grounds for No Project and all four Project scenarios are shown in the addendum as Figures B 29 (a) through B 29 (y). These hydrographs show the temporal variations in the water levels reflecting the hydrologic conditions, artificial recharge and groundwater pumping assumed for these scenarios. For location of these wells refer to Figure 3.2-15 in section 3.2 of the EIR.

6.2.6.2 Depth to Water Less Than or Equal to 50 feet from Land Surface

Areas where depth to groundwater less than or equal to 50 feet below the land surface were delineated using the groundwater model. These areas are shown in Figures B 11, B 13, B 15, B 17, and B 19 in the addendum for selected years. The estimated acreages for each year are also shown in these figures for the entire SBBA as well as the Pressure Zone (not including the river channels). Yearly acreages for all scenarios are shown on Figures 6.2-25 and 6.2-26. Differences in areas of potential liquefaction between each of the modeled Project scenarios and No Project are shown on Figures B 30 through B 33 for future year 2016 (hydrologic year 1977 – lowest water level) and future year 2022 (hydrologic year 1983 – highest water level).

Liquefaction typically occurs in recent (Holocene to late Pleistocene) deposits of silt, sand, and gravel. Most liquefaction occurs where the depth to groundwater is less than 50 feet; this depth is traditionally considered adequate for most investigations of liquefaction potential (Martin and Lew 1999). Soil liquefaction is a major cause of damage during earthquakes. For purposes of this report, areas with depth to groundwater of less than 50 feet in the Pressure Zone were evaluated for each model scenario (see also section 5 [Liquefaction and Subsidence]).

Results from all modeled scenarios with Project implementation produce a general reduction in the total area of potential liquefaction within the Pressure Zone area (not including river channels) when compared to No Project.

Differences from No Project are very similar for both Scenarios C and D. In both cases, the area of potential liquefaction in the Pressure Zone is reduced during wet years (see Figures B 30 through B 33 in the addendum). The cumulative total area of potential liquefaction in the Pressure Zone during the period 2001 through 2039 is approximately 32,184 acres. The area reduced to 17,196 acres for Scenario C and 16,825 acres for Scenario D. These amounted to a reduction (cumulative total area) of 14,988 acres and 15,359 acres for Scenario C and Scenario D, respectively (or a reduction of areas subjected to potential liquefaction of 47 percent and 48 percent respectively).

For Scenario A, the area of potential liquefaction in the Pressure Zone is substantially reduced during the wettest years of the hydrologic cycle compared to No Project. The cumulative total area reduces to 7,533 acres for Scenario A with a total cumulative reduction in potential liquefaction area of 24,651 acres (77 percent).

For Scenario B, the area of potential liquefaction in the Pressure Zone during the wettest years of the hydrologic cycle is also smaller than for No Project. It reduces cumulative total area to 10,188 acres with a total cumulative reduction of 21,996 acres (68 percent).

Results from all modeled scenarios with Project implementation show more years where no potential liquefaction area occurs within the Pressure Zone as compared to No Project. For the No Project condition, no potential liquefaction area occurs in 13 years of the 39-year model period (approximately 33 percent of the time; see Figure 6.2-26 and Table 6.2-8). The number of years when no potential liquefaction area occurs increases to 18 years (46 percent of the time) for both Scenarios C and D. The number of years when no potential liquefaction area occurs increases to 26 years (67 percent of the time) and 24 years (62 percent of the time) for Scenario A and B, respectively. The Project scenario that reduces the potential liquefaction area in the Pressure Zone the most compared to No Project is Scenario A.

6.2.6.3 Groundwater Budgets

The overall water budgets for each of the model runs were compiled to evaluate the SBBA groundwater model. The inflow terms for the model include recharge to groundwater from gaged streamflow, artificial recharge, local runoff generated by precipitation, infiltration from direct precipitation, return flow from groundwater pumping, ungaged mountain front runoff and underflow. The outflow terms consist of evapotranspiration, groundwater pumping, and underflow. The difference between the total inflow and total outflow is the change in groundwater storage. Annual groundwater budgets for each scenario are shown in Tables B 7 through B 11 in the addendum. Table 6.2-9 summarizes the average annual groundwater budgets for the period 2001-2039.

Groundwater storage in the SBBA declines 3,324 afy during the period 2001 through 2039 under No Project. Groundwater storage declines for all four Project scenarios are similar to No Project ranging from decline of 3,326 afy for Scenario C to decline of 3,406 afy for Scenario A.

In Table 6.2-9, the primary change in groundwater budgets between No Project and the Project scenarios is recharge from gaged streamflow. For No Project, the average annual recharge from gaged streamflow is 139,517 afy. For Scenarios C and D, the groundwater recharge from streamflow would be reduced by approximately 10,959 afy and 11,264 afy respectively. This is due to the diversion of the SAR water. For No Project, a portion of the 20,704 afy undiverted SAR water would recharge the groundwater basin. For Scenarios A and B, groundwater recharge from streamflow would be reduced by approximately 8,495 afy and 7,418 afy, respectively.

Table 6.2-8. No Potential Liquefaction Area Occurrence, 2001-2039

Project Scenarios	*Number of Years with No Potential Liquefaction Area Occurrence*	*Percent of Time for the 39-Year Period*
No Project Condition	13	33%
Scenario A	26	67%
Scenario B	24	62%
Scenario C	18	46%
Scenario D	18	46%

Table 6.2-9. Average Annual Groundwater Budgets, 2001-2039 (units in af)

Flux Terms		*No Project*	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*
Inflow	Recharge from Gaged Streamflow	139,517	131,022	132,099	128,558	128,253
	Artificial Recharge at SAR Spreading Grounds	10,384	4,961	5,411	16,691	16,976
	Artificial Recharge at Other Spreading Grounds	21,932	39,172	37,119	27,242	27,006
	Recharge from Local Runoff Generated by Precipitation	5,627	5,627	5,627	5,627	5,627
	Infiltration from Direct Precipitation	1,137	1,137	1,137	1,137	1,137
	Return Flow from Groundwater Pumping	39,575	39,614	39,608	39,040	39,037
	Recharge from Ungaged Mountain Front Runoff	17,820	17,820	17,820	17,820	17,820
	Underflow Recharge	2,997	2,997	2,997	2,997	2,997
	Total Inflow	**238,989**	**242,350**	**241,818**	**239,112**	**238,853**
Outflow	Evapotranspiration	5,822	6,314	6,180	5,864	5,903
	Groundwater Pumping	233,488	236,582	236,100	233,655	233,420
	Underflow Discharge	3,003	2,860	2,929	2,919	2,904
	Total Outflow	**242,313**	**245,756**	**245,209**	**242,438**	**242,227**
Change in Groundwater Storage (Total Inflow – Total Outflow)		**-3,324**	**-3,406**	**-3,391**	**-3,326**	**-3,374**
Source: Groundwater flow model for various scenarios.						

Addendum Figures B 34 through B 37 show the inflow and outflow terms as a percentage of the total groundwater budget and average annual change in groundwater storage for each of the Project scenarios as compared to No Project.

6.3 MODPATH MODEL

6.3.1 General Description and Purpose of Model

The purpose of the MODPATH model is to evaluate potential effects of the Project on remediation efforts by evaluating groundwater the seepage velocities of the flow paths, and travel times. MODPATH is a post-processing package, i.e., it uses output from MODFLOW to compute three-dimensional flow paths (particle tracks). MODPATH develops a particle's[10] flow path for each finite-difference grid cell of the model. Particle paths are computed by tracking particles from one cell to the next until the particle reaches a boundary, an internal sink or source, or satisfies some other termination criterion.

MODPATH does not take into account dispersion, retardation, or half-life decay; other factors in solute transport. The results of MODPATH simply provide an indication of the direction and rate of groundwater flow.

6.3.2 Development of the MODPATH Model

In addition to model input data used by MODFLOW, MODPATH requires data on model layer elevations and effective porosity[11]. Elevations at the bottom of Model Layer 1 and Layer 2 were defined by geophysical borehole logs and lithologic logs as well as the following documents:

- Dutcher & Garrett, USGS WRI 1419 (1963);
- Morton, California Division of Mines and Geology (1976);
- Geoscience (1993);
- Hardt & Hutchinson, USGS WRI 80-576 (1980);
- Camp Dresser & McKee, Inc. (CDM 1996);
- Danskin et al. N.D.
- HSI GeoTrans (1998);
- URS Greiner (1997 and 1999); and
- Wildermuth Environmental, Inc. (2000)

Elevations at the bottom of Model Layer 1 and Layer 2 are shown in Figures 6.3-1 and 6.3-2, respectively. Model layer thicknesses are presented in Figures 6.3-3 and 6.3-4.

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[10] A "particle track" represents the flow path taken by groundwater through the "model time" and influenced by any relevant recharge or discharge component such as pumping or spreading of water.

[11] Also equivalent to specific yield.

Effective porosity values in Model Layer 1 were assumed to be the same as the specific yields in Model Layer 1 (see Figure 6.2-3). Effective porosity values for Model Layer 2 were assumed to be 80 percent of the values for Model Layer 1 (personal communication with Wes Danskin of USGS).

6.3.3 MODPATH Model Scenarios

Results from the MODFLOW simulations for each Project scenario were used in conjunction with MODPATH. Particle-tracking was simulated by using particles released at spreading grounds and at the leading edges of the Muscoy/Newmark PCE plume and the Redlands-Crafton TCE plume at the beginning of model year 2001 (see section 4.3.1 for more detailed plume descriptions).

6.3.4 Particle Tracking Results

Paths traveled by particles in the four Project scenarios were compared to paths traveled for particles under No Project. Figures B 38 through B 40 represent Scenario C, Figures B 41 through B 43, Scenario D, Figures B 44 through B 46, Scenario A, and Figures B 47 through B 49 represent Scenario B. In general, groundwater flow directions are similar under the four Project scenarios and No Project, but the rate of groundwater flow differs. The differences are due primarily to increased hydraulic gradients as the result of artificial recharge.

For Scenario A, groundwater flows slightly faster in the northwestern portion of the SBBA than it does for No Project. The particles travel greater distances in the same amount of time (see Table 6.3-1). This reflects increased artificial recharge at Waterman, East Twin Creek, Badger, Devil Canyon/Sweetwater and Lytle Basins. Increased artificial recharge steepens local hydraulic gradients and therefore increases rates of flow. In the southeastern portion of the SBBA, groundwater flow is slightly slower for Scenario A than for No Project, due to the diversion of SAR water.

For Scenarios C and D, groundwater flow rates are also slightly faster in the northwestern portion of the SBBA and slower in the southeastern portion of the SBBA in comparison to the No Project, reflecting the diversion of SAR water. The magnitude of these differences is less than that observed between Scenario A and No Project. Groundwater flow rates were the least different from No Project for Scenario B. For Scenario B, groundwater flow rates in the northwestern portion of the SBBA were higher than the No Project, but less than the other three Project scenarios. Groundwater flow rates for Scenario B were the same as the No Project in the southeastern portion of the SBBA.

In all four Project scenarios, groundwater flow from the fronts of plumes in the Pressure Zone is similar to flow for No Project Condition and its direction is similar. Because the increases in seepage velocity occur mainly upgradient of contaminant plumes, they are not expected to interfere with the operation of existing remediation systems. In fact, increasing the rate of groundwater flow upgradient of the contaminant plumes may actually aid in the remediation efforts, as the upgradient portion of the plume would be "pushed" by the increased flow velocities resulting from steeper hydraulic gradients in the vicinity of the spreading grounds.

Table 6.3-1. Seepage Velocity (ft/day) Determined by MODPATH Model under Different Model Scenarios

Area	*No Project*	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*
Northwest area encompassing Devil Canyon/Sweetwater, Badger, Waterman, East Twin Creek Spreading Grounds (Model Layer 1)	2.7	3.5	3.2	3.4	3.4
Southeast area encompassing SAR, Mill Creek, and Patton Spreading Grounds (Model Layer 1)	5.1	4.8	5.1	5.0	5.0
PCE Plume Front (Muscoy/Newmark) (Model Layer 2*)	1.9	1.9	1.9	1.9	1.9
TCE Plume Front (Redlands-Crafton) (Model Layer 1)	1.8	1.8	1.8	1.8	1.8
* Major plume is in Model Layer 2.					

6.4 SOLUTE TRANSPORT MODELS

6.4.1 General Description and Purpose of Model

The purpose of the solute transport models was to evaluate the potential effect of the Project on existing plumes and chemical constituents of concern such as PCE, TCE, TDS, NO_3, and perchlorate. Solute transport modeling was carried out using MT3DMS (USACE 1999), a modular 3-dimensional multi-species transport model. The solute transport model requires data from the groundwater flow model (e.g., seepage velocities and flow directions). The flow in and out of each model cell is read by MT3DMS and used to track concentrations of PCE, TCE, TDS, NO_3, and perchlorate advectively[12] and dispersively, applying retardation to the species if needed. For purpose of this study, the PCE transport model was used to simulate the migration of the Muscoy and Newmark plumes and the TCE transport model was used to simulate the movement of the Norton and Redlands-Crafton plumes.

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[12] Advection refers to the bulk movement of groundwater. Solute concentrations may have different densities and viscosity than the groundwater and this can affect the mass transport in the aquifer system. Dispersion occurs when the contaminant does not move at the same rate as the average linear velocity. Retardation or retardation factor is a solute transport term used to describe the adsorption of the contaminant in the groundwater.

For PCE and TCE, a linear isotherm equation was used to model the equilibrium-controlled linear sorption processes that occur in the aquifers. The retardation factor is a function of aquifer parameters and the sorption distribution coefficient, which may be written as:

$$R = 1 + \frac{\rho_b}{\theta} Kd$$

where:

R = Retardation Factor,

ρ_b = Bulk Density of Aquifer Materials [g/cm^3],

θ = Effective Porosity,

Kd = Sorption Distribution Coefficient [cm^3/g],

For TDS, NO_3, and perchlorate, the linear isotherm was not used, as the retardation factor for these constituents was assumed to be one. A retardation factor of 1 means that a solute is conservative and is not retarded and will travel at the same speed as the groundwater, whereas a retardation factor greater than 1 means that a solute is retarded by chemical adsorption to the aquifer materials and travels slower than the groundwater. Longitudinal dispersivity is an aquifer property that describes the amount that a solute plume will spread in the direction of flow and is greater than transverse (or lateral) dispersivity, which describes the amount of spreading perpendicular to flow.

Although other chemicals are present in the contaminant plumes within the SBBA, PCE and TCE are the principal contaminants in the Muscoy/Newmark and Norton AFB plumes, respectively. Most of the other chemicals are either below their respective MCL or are reaction by-products of either PCE or TCE. For the purpose of this model, it was assumed that neither PCE nor TCE degrades significantly in groundwater. If significant degradation does occur, this assumption would result in an overestimation of PCE and TCE contamination.

6.4.2 Development of Transport Models

In addition to the aquifer parameters used for the MODFLOW and MODPATH models, the solute transport model requires the following data to simulate transport of chemical constituents: longitudinal, transverse, and vertical dispersivities, bulk density of the aquifer material, and the sorption distribution coefficient of each chemical constituent.

These parameters were determined during model calibration for both PCE and TCE. Table 6.4-1 summarizes the final values.

Using an average effective porosity of 0.09, which approximates the average porosity in the region of the PCE and TCE plumes (see Figure 6.2-3), the retardation factors for PCE and TCE were calculated as 3.0 and 2.1, respectively.

Table 6.4-1. Summary of Solute Transport Model Parameters

Model Parameters		*Units*	*PCE*	*TCE*	*TDS*	*Nitrate*	*Perchlorate*
Dispersivity	Longitudinal	[ft]	300	300	300	300	300
	Transverse	[ft]	100	100	100	100	100
	Vertical	[ft]	1	1	1	1	1
Bulk Density		[g/cm^3]	1.9	1.9	-	-	-
Sorption Distribution Coefficient		[cm^3/g]	0.0947	0.054	-	-	-

6.4.3 Transport Model Calibration

Solute transport model calibration was performed for PCE and TCE for the period from 1986 to 2000. This time period was chosen based on the amount of data available for these years. The solute transport models were initially calibrated using PEST (Watermark Numerical Computing and Waterloo Hydrogeologic 2000) in which dispersivities, sorption distribution coefficients, and mass loading of continued sources were varied within acceptable limits. In addition, calibration also consisted of conventional trial-and-error history matching techniques to best fit the model-generated plumes to observed concentrations at wells. Sources of water quality data used for transport model calibration include CDM, 1996; HSI GeoTrans, 1998; URS, 1997-1999; Wildermuth Environmental, Inc., 2000; California DHS, 2003b; and USGS NWISWeb, 2003.

6.4.3.1 Initial Conditions

The initial concentrations used to calibrate the PCE and TCE transport models were derived from 1986 measured concentrations (see Figures 6.4-1 and 6.4-2). Due to the limited quantity of measured PCE and TCE data available for 1986, PCE and TCE concentrations measured between 1987 to 1996 were also used.

6.4.3.2 Sinks and Sources

The MT3DMS transport model required concentrations to be specified for each of the sinks and sources used in the flow model. The PCE and TCE models required inputs of dissolved contaminants to simulate point sources where the dissolution of adsorbed contaminants continues in source areas. All other sources of recharge identified in the flow model were considered to contribute no PCE or TCE. All sinks (areas of discharge) were considered to have the same PCE and TCE concentration as that occurring in the same model cell (equal to the aquifer concentration).

The amount of contaminant introduced to the model was varied iteratively to match observed concentrations. The PCE input was simulated using mass-loading of dissolved PCE located at the Muscoy Source and the Newmark Source areas. PCE mass-loading began at a rate of 4 grams/day (g/day) for the Muscoy Source and the Newmark Source in 1986. It decreased linearly to a rate of 3.5 g/day and 2 g/day in 2000 for the Muscoy and the Newmark Source areas respectively (see Figure 6.4-3). The TCE input was located in the northeastern part of the Norton plume. The concentration of the TCE input was estimated initially based on the observed data in the Norton plume area. The amount of TCE introduced into the model is shown in Figure 6.4-4.

6.4.3.3 Transport Model Calibration Results

The model-generated PCE MCL plume boundary for selected years is shown in Figure B 50 (Model Layer 1) and Figure B 51 (Model Layer 2). In general, the model-generated MCL plume boundary closely matches the MCL plume boundary contoured from observed data. The model-generated TCE MCL plume boundary is shown in Figure B 52 (Model Layer 1) and Figure B 53 (Model Layer 2). The model-generated migration rate of the TCE plume agrees with the rate estimated from observed data as can be seen by comparing the observed TCE measurements over time with movement of the MCL plume boundary.

In order to evaluate the accuracy of the transport model calibration, PCE and TCE concentrations from the final calibration run were compared to measured data at selected wells (see Figures B 54 and B 55). In most of the wells, measured and model-generated PCE and TCE concentrations display similar trends.

Histograms of PCE and TCE residual concentrations (measured concentrations less model-generated concentrations) are shown in Figures B 56 and B 57, respectively. The histograms show a bell shape with most of the residual concentrations in the range of +/- 5 µg/L, indicating an acceptable model calibration. The model relative error[13] is 8 percent and 9 percent for PCE and TCE concentrations, respectively. It is common modeling practice to consider a relative error of less than 10 percent to be a good fit (Spitz and Moreno 1996; Environmental Simulations, Inc. 1999). Therefore, these results are considered reasonable.

6.4.4 Transport Model Scenarios

After calibrating the PCE and TCE transport models, the predictive flow models described in section 6.2.5 were used to provide input to the predictive transport models. The transport model prediction runs consisted of 39 annual stress periods from October 2000 through September 2039. The transport model was run for each of the predictive flow model scenarios:

1) No Project,
2) Scenario A,
3) Scenario B,
4) Scenario C, and
5) Scenario D.

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[13] Relative error is the standard deviation of the water quality residuals divided by the observed range.

6.4.4.1 Initial Conditions

Concentrations obtained from PCE and TCE model calibration results were used as initial concentrations for the predictive transport model scenarios and are shown in Figures 6.4-5 and 6.4-6.

As the distributions of TDS and NO_3 concentrations were strongly heterogeneous, a different approach was used to establish initial conditions for these constituents. The model area was divided into several equal concentration zones and each zone assigned the average of concentrations observed in the year 2000 within the zone. These zones are shown in Figures 6.4-7 and 6.4-8. The transport model was then run using the same groundwater flow model used in the PCE and TCE calibration, but with initial conditions determined by the equal concentration zones and source-sink concentrations assigned as described in the following section. The purpose of these model runs was to generate "smooth" initial TDS and NO_3 concentrations for the predictive transport models from the equal concentration zones (see Figures 6.4-9 and 6.4-10).

Initial concentrations for the perchlorate transport model were derived from observed concentrations in the year 2000, and are shown in Figure 6.4-11.

6.4.4.2 Source and Sink[14] Concentrations

PCE and TCE

In the PCE model, the amount of mass-loading in the source area was assumed to decrease linearly by extending the trend of 1986-2000 (see Figure 6.4-3) until all sources were exhausted. In the PCE calibration model, the mass-loading of solute simulated the mobilization of PCE adsorbed to aquifer materials at the source area of PCE contamination and was necessary to match observed data. The linear trend of mass-loading was continued into the future to continue the simulation of PCE desorbing from aquifer materials. The TCE model, however, did not contain any additional sources of TCE other than the initial concentrations, and concentrations at all TCE sources dropped to zero by the end of the model calibration period[15]. Based on available historical data, it was assumed that no potential future sources of TCE would exist. All sinks used concentrations found in the aquifer at the cell in which the sinks are located.

TDS and Nitrate

The sources for TDS and NO_3 input concentrations were specified according to the flow input source defined in the flow model. The sources of flow into the model are described in section 6.2.2.5, and a summary of the source type and the TDS and NO_3 concentrations used is shown in Table 6.4-2. Source concentrations were specified either based on SAR and SWP water concentrations, or based on the equal concentration zones described above in the Initial Conditions section.

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[14] A source is a recharge flux term (e.g., injection well or spreading basin). A sink is a discharge flux term (e.g., well).

[15] Concentrations of PCE and TCE at other sources in the model were considered to be zero.

Table 6.4-2. Assumptions for TDS and Nitrate Concentrations

Flow Source	*Source Type*	*Concentration Used*
Direct Infiltration from Precipitation	Recharge	Same as equal concentration zones
Recharge from Local Runoff Generated by Precipitation	Recharge	Same as equal concentration zones
Artificial Recharge	Recharge	Flow-weighted average of recharge water source concentrations (SAR or SWP)
Recharge from Ungaged Mountain Front Runoff	Well	Same as equal concentration zones
Return Flow from Groundwater Pumping	Well	Same as equal concentration zones
Underflow Recharge	Well	Same as equal concentration zones
Streamflow	Stream	Gaged streamflow and flow-weighted average

The concentrations of TDS and NO_3 used to represent SAR and SWP water were determined from an average of all available sampling data from those sources (Table 6.4-3).

Perchlorate

It was assumed that there were no additional sources of perchlorate other than the initial concentrations. Little information is available regarding the perchlorate plume source; therefore, only reported perchlorate concentrations were used to delineate the plume. All sinks used concentrations found in the aquifer in the cell in which they were located.

Table 6.4-3. TDS and Nitrate Concentrations for SAR and SWP Water (mg/L)

Constituent	*Artificial Recharge Water*	
	SANTA ANA RIVER[1]	STATE WATER PROJECT[2]
TDS	232	282
Nitrate (as NO_3)	5.7	3.1

[1] Determined from USGS Water Quality database.
[2] Determined from historical State Water Project water quality records.

6.4.5 Transport Model Results

6.4.5.1 PCE

Results for the PCE transport model are shown in Figures B 58 through B 65 in the addendum. These figures show the modeled MCL (5 µg/L) plume boundary of the Newmark and Muscoy PCE plumes for each of the Project scenarios compared to that of No Project. In each of the Project scenarios, the PCE plume boundary dissipates more quickly as a result of increased artificial recharge at spreading basins upgradient of the plumes. These spreading grounds include Lytle Creek, Devil Canyon/Sweetwater, East Twin, and Waterman Spreading Grounds in the northwestern portion of the SBBA.

The plume sizes for Scenarios C and D are smaller than the plume sizes of No Project (see model years 2030, 2035 and 2039 in Figures B 59 and B 61). Scenarios C and D have 24 percent and 20 percent more artificial recharge, respectively, at these spreading grounds than No Project.

The plume sizes in Scenarios A and B are also smaller than the plume sizes of No Project (see model years 2030, 2035 and 2039 in Figures B 63 and B 65). Scenario A and B show greater reduction in plume sizes than Scenarios C and D. At the Lytle Creek, Devil Canyon/Sweetwater, East Twin, and Waterman Spreading Grounds, there is a 59 percent and 58 percent increase in artificial recharge at Scenarios A and B, respectively, compared to No Project.

6.4.5.2 TCE

Results for the TCE transport model are shown in Figures B 66 through B 73. These figures show the modeled MCL (5 µg/L) plume boundary of the Norton and Redlands-Crafton TCE plumes for each of the Project scenarios compared to that of No Project. In each of the Project scenarios, the TCE plume boundary dissipates more quickly as a result of increased artificial recharge at spreading basins upgradient of the Norton plume and increased pumping from the Pressure Zone by Plaintiffs.

The TCE plume disappears earliest in the higher diversion and spreading Scenarios A and B as shown where the plume boundary has disappeared entirely by 2035 (see Figures B 70 through B 73). There is a 58 percent increase in artificial recharge at the spreading grounds at the northwestern part of the SBBA over that of No Project for Scenario A. In addition, there is an increase in pumping from Plaintiffs by 3,094 afy for Scenario A relative to No Project. There is a 56 percent increase in artificial recharge at the spreading grounds at the northwestern part of the SBBA and 2,612 afy increase in pumping by Plaintiffs over that of No Project for Scenario B.

The plume sizes for the lower diversion and spreading Scenario C and D are smaller than the plume sizes of No Project (see model years 2035 and 2039 in Figures B 66 and B 68). The reduction of plume sizes for Scenarios C and D is less than the reduction for Scenarios A and B. The Scenarios C and D have 22 percent and 20 percent more artificial recharge at these spreading grounds than No Project condition.

6.4.5.3 TDS

TDS concentrations from the solute transport model were examined for No Project and each of the four Project scenarios. The average TDS concentration for the SBBA compared to No Project was calculated by determining the differences in cell-by-cell model concentration at the end of model simulation between the Project scenarios and No Project. A weighted average of the differences was then calculated based on the aquifer thickness and specific yield. Table 6.4-4 is a weighted average of the difference in TDS concentration for the SBBA between No Project and each of the Project scenarios.

Table 6.4-4. Average for the SBBA of the Difference in TDS Concentration from No Project - 2039

Project Scenario	*Weighted Average of Difference from No Project [mg/L]*
Scenario A	+0.75
Scenario B	+0.59
Scenario C	-0.15
Scenario D	-0.21

The differences in TDS concentration from No Project for the four Project scenarios resulted from the amounts of SWP spreading, SAR spreading, SAR channel percolation, and groundwater pumping.

Model-generated TDS concentration at the 25 index wells and nine spreading grounds for Project scenarios were compared to No Project and are shown in Figures B 74(a – ah). Most of these wells are deep and show TDS concentrations from Model Layer 2. These deep wells are isolated and buffered from the TDS changes in Layer 1 and therefore show infrequent variation and little difference between scenarios. TDS at index well IW14 decreases the most in response to high volumes of low TDS SAR water applied to spreading grounds at Devil Canyon/Sweetwater, Waterman, and East Twin Creek Spreading Grounds for Scenarios A and B (see Figure B 74[n]). Deep wells near the upper reaches of the SAR region, including IW17 (see Figure B 74[q]) maintain fairly constant, low TDS concentrations as a result of recharge from the SAR or high quality, low TDS artificial recharge at the SAR or Mill Creek Spreading Grounds for No Project and all Project scenarios. Deep wells in the Pressure Zone, such as IW11 (see Figure B 74[k]) and IW12 (Figure B 74[l]), show less change with time than wells in the central basin area, but outside the Pressure Zone.

Model-generated TDS concentration at the spreading grounds for the Project scenarios compared to the No Project is also shown in Figure B 74 (z-ah). TDS concentrations at Patton, East Twin Creek, and Waterman Spreading Grounds change most frequently in response to annual fluctuations of low TDS recharge water from either the SWP or SAR. The ambient, groundwater TDS concentration in these areas is generally high and the applied high quality recharge water dilutes the existing conditions during periods of high recharge. TDS concentrations at the SAR and Mill Creek Spreading Grounds are generally constant since recharge water is generally the same concentration as the ambient conditions. Differences in TDS concentrations between Project scenarios at spreading grounds are principally a result of the frequency and amount of low TDS recharge water allocated to each scenario.

6.4.5.4 Nitrate

NO_3 concentrations from the solute transport model were examined for No Project and each of the four Project scenarios. The average NO_3 concentration for the SBBA compared to No Project was calculated using the same method described in section 6.4.5.3. Table 6.4-5 is a weighted average of the difference in NO_3 concentration for the SBBA between No Project and each of the Project scenarios.

The minor difference in NO_3 concentration from No Project and the Project scenarios resulted from SWP spreading, SAR spreading, SAR channel percolation, and groundwater pumping.

Model-generated NO_3 concentrations at the 25 index wells and nine spreading grounds for the Project scenarios compared to No Project are shown in Figure B 75 (a-ah). As with the TDS concentrations, the deep wells show infrequent variation and little difference between scenarios and deep wells near the upper reaches of the SAR region maintain fairly constant, low NO_3 concentrations as a result of recharge. Deep wells in the Pressure Zone, such as IW11 and IW12 show a steady decline in NO_3 concentrations as high quality groundwater recharged at the spreading grounds gradually migrates to the Pressure Zone. The largest difference among deep wells between scenarios was observed at IW16, which shows a decline in NO_3 concentration at the end of the model period under the No Project scenario, while in Scenario A and B, it resumes its initial high concentration after a brief decline (see Figure B 75p). This occurs as a result of increased recharge of high-quality, low NO_3 SAR or SWP water at the Waterman, East Twin Creek, and Patton Spreading Grounds that push high NO_3 groundwater from the Warm Creek region towards IW18 (B75r).

Table 6.4-5. Average for the SBBA of the Difference in NO_3 Concentration from No Project – 2039

Project Scenario	*Weighted Average of Difference from No Project [mg/L]*
Scenario A	-0.49
Scenario B	-0.51
Scenario C	-0.25
Scenario D	-0.19

Model-generated NO_3 concentrations at spreading grounds for the four Project scenarios to No Project are shown in Figure B 75(z–ah). As with TDS concentrations, frequent fluctuations at Waterman, Devil Canyon/Sweetwater, and Patton Spreading Grounds occurred in response to applied recharge water. Differences in NO_3 concentrations between model scenarios at spreading grounds are principally a result of the frequency and amount of low NO_3 recharge water allocated to each scenario.

6.4.5.5 *Perchlorate*

Results for the Perchlorate transport model are shown in Figure B 76 – B 83. These figures compare the modeled 6 µg/L plume boundary of the Redlands-Crafton plume for each of the

Project scenarios to that of No Project. The plume advances and disappears fastest in No Project and Scenarios C and D, but takes slightly longer to disappear in Scenarios A and B (see model year 2020 in Figures B 81 and B 83). This is because more recharge occurs in the SAR in No Project or in the SAR and Mill Creek Spreading Grounds in Scenarios C and D as compared to Scenarios A and B.

6.5 ANALYTICAL METHOD USED TO EVALUATE IMPACTS OF SPREADING OUTSIDE OF MODEL AREA

6.5.1 Description of Analytical Method (Hantush Equation)

Three artificial recharge areas designated by the Allocation Model lie outside of the groundwater model domain for the SBBA, specifically:

- Cactus Spreading and Flood Control Basins (in Rialto-Colton Basin),
- Wilson (in Yucaipa Basin), and
- Garden Air Creek (in San Timoteo Basin).

To evaluate effects of artificial recharge in these areas due to surface spreading, an analytical method was used. The growth and decay of groundwater mounds in response to uniform percolation has been described by Hantush (1967).

Hantush (1967) presents an analytical expression for changes in groundwater elevation at any distance from the center of a rectangular spreading basin subject to uniform percolation. Assumptions used to derive the analytical expression assume that the underlying aquifer is homogeneous, isotropic, and effectively of infinite areal extent, the formation parameters are constant, and the constant rate of deep percolation relative to the horizontal hydraulic conductivity is so small that vertically downward percolation is almost entirely refracted in the direction of the slope of the water table. The Hantush equation requires the following inputs:

- The approximate length and width of the spreading ground areas,
- The uniform percolation rate,
- The time required for recharge,
- The depth to groundwater and effective saturated thickness of the underlying aquifer, and
- The horizontal hydraulic conductivity and effective porosity of the underlying aquifer.

For each spreading ground area, estimates of the above parameters were obtained from the following sources:

- Matusak, 1979. Preliminary Evaluation of State Water Project Groundwater Storage Program, Bunker Hill – San Timoteo – Yucaipa Basins.
- Moreland, 1972. Artificial Recharge in the Upper Santa Ana Valley, Southern California. U.S. Geological Survey Open-File Report.

- Total Inorganic Nitrogen (TIN)/TDS Study – Phase 2A of the Santa Ana Watershed Development of Groundwater Management Zones – Final Technical Memorandum. Prepared for TIN/TDS Task Force. Dated July 2000.
- Woolfenden and Koczot, 1999. Numerical Simulation of Ground-Water Flow and Assessment of the Effects of Artificial Recharge in the Rialto-Colton Basin, San Bernardino County, California. U.S. Geological Survey Water-Resources Investigations Report.

6.5.2 Results

6.5.2.1 Rialto-Colton Groundwater Basin (Cactus Spreading and Flood Control Basin)

Results from the analytical Hantush Equation are shown as groundwater mound height contours for each Project scenario (Figures B 84 – B 87). The maximum groundwater mound height was estimated to be 48 feet, near the center of the Cactus Spreading Grounds. Areas with a rise in groundwater level greater than 10 feet are approximately 2,400 acres for Scenarios C and D and 3,400 acres for Scenarios A and B. These recharge amounts did not cause the groundwater levels to rise to within 50 feet of the land surface.

6.5.2.2 Yucaipa Groundwater Basin (Wilson Spreading Grounds)

The Wilson Spreading Grounds are located in the center of the Yucaipa Basin. The maximum amount of water allocated to the Wilson Spreading Grounds by the Allocation Model is zero for No Project and 2,154 af for all four Project scenarios (see Table B 12). The following table (Table 6.5-2) summarizes the parameters for the calculations of the groundwater mound height using the Hantush Equation.

Results from the analytical Hantush Equation are shown as groundwater mound height contours for each Project scenario (see Figures B 84 – B 87). The maximum groundwater mound height was estimated to be 76 feet, near the center of the Wilson Spreading Grounds. Areas with a rise in groundwater level greater than 10 feet are approximately 400 acres for all the four Project scenarios. These recharge amounts did not cause the groundwater levels to rise to within 50 feet of the land surface.

6.5.2.3 San Timoteo Groundwater Basin

Garden Air Creek is located in the San Timoteo Groundwater Basin. The maximum amount of water allocated to Garden Air Creek by the Allocation Model is zero for No Project and 5,745 af for all the four Project scenarios (see Table B 12). The following table (Table 6.5-3) summarizes the parameters for the calculations of the groundwater mound height using the Hantush Equation.

Results from the analytical Hantush Equation are shown as groundwater mound height contours for each Project scenario (see Figures B 84 – B 87). The maximum groundwater mound height was estimated to be 38 feet, near the center of Garden Air Creek. Areas with a rise in groundwater level greater than 10 feet are approximately 930 acres for all four Project scenarios. These recharge amounts did not cause the groundwater levels to rise to within 50 feet of the land surface.

Table 6.5-1. Parameters Used to Estimate Changes in Groundwater Elevation in Hantush Equation
Cactus Spreading Grounds

Parameter	*Value*
Total Basin Area	46 acres
Rectangular Basin Width[1]	500 ft
Rectangular Basin Length	4,000 ft
Land Surface Elevation	1,400 ft amsl[2]
Initial Groundwater Elevation	1,200 ft amsl
Bedrock Elevation	550 ft amsl
Saturated Thickness	650 ft
Hydraulic Conductivity	374 gpd/ft^2
Effective Porosity	0.15
Total Recharge Volume	13,217 af (Scenarios C and D) 18,953 af (Scenarios A and B)
Duration of Recharge	144 days (Scenarios C and D) 206 days (Scenarios A and B)
Recharge Rate	2 ft/day
Maximum Recharge Mound Height	144 days (Scenarios C and D) – 45 ft 206 days (Scenarios A and B) – 48 ft

[1] For purposes of the groundwater mound height calculation, it was assumed that the total spreading basin area was approximated by a rectangle having the same area.

[2] above mean sea level

1

Table 6.5-2. Parameters used in Hantush Equation
Wilson Spreading Grounds

Parameter	*Value*
Total Basin Area	34 acres
Rectangular Basin Width	650 ft
Rectangular Basin Length	2,275 ft
Land Surface Elevation	2,850 ft amsl
Initial Groundwater Elevation	2,700 ft amsl
Bedrock Elevation	2,250 ft amsl
Saturated Thickness	450 ft
Hydraulic Conductivity	66 gpd/ft^2
Effective Porosity	0.15
Total Recharge Volume	2,154 af
Duration of Recharge	63 days
Recharge Rate	1 ft/day
Maximum Recharge Mound Height	76 ft

Table 6.5-3. Parameters used in Hantush Equation for Garden Air Creek

Parameter	*Value*
Total Basin Area	26 acres
Rectangular Basin Width	566 ft
Rectangular Basin Length	2,000 ft
Land Surface Elevation	2,360 ft amsl
Initial Groundwater Elevation	2,200 ft amsl
Bedrock Elevation	1,800 ft amsl
Saturated Thickness	400 ft
Hydraulic Conductivity	224 gpd/ft^2
Effective Porosity	0.15
Total Recharge Volume	5,745 af
Duration of Recharge	221 days
Recharge Rate	1 ft/day
Maximum Recharge Mound Height	38 ft

6.6 PRESS MODEL

6.6.1 Description of the PRESS Model

Subsidence modeling has been completed in association with No Project and the four Project scenarios (A through D), using the groundwater flow model and the PRESS subsidence model. The PRESS model is a modified version of a program initially developed by Helm for one-dimensional simulation of aquifer system compaction (Helm 1975). Revisions were made in 1979-1980 by the Harris-Galveston Coastal Subsidence District (Espey, Huston & Associates, Inc. 1979), which included changes in format, plotting and input/output routines. Specifically, the modifications allow for multiple aquifers and simplification of input preparation.

The PRESS model computes ground surface subsidence resulting from a given change in potentiometric head within a system of aquifers. Both the virgin (non-elastic) and rebound (elastic) compressibilities of the clay layers (aquitards) are taken into account when estimating total subsidence.

The program uses the one-dimensional Terzaghi consolidation theory[16] with some simplification of parameters to relate a time history of potentiometric head changes to a time history of subsidence. The total ground surface subsidence, as a function of time, is computed by summing up the individual subsidence occurring in each clay layer. Calibration of the model to historically measured subsidence using observed changes in potentiometric head for a given lithology allows prediction of future subsidence.

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[16] A simple one-dimensional consolidation model consists of a rectilinear element of soil subject to vertical changes in loading and through which only vertical seepage flow is taking place.

6.6.2 Model Input Parameters

Water level impacts were simulated at City of Riverside well Raub #8, located on the southeast corner of Waterman and Orange Show Road. This well was selected from a collection of SBBA wells with recorded geophysical logs, because it is located in the Pressure Zone nearest to the area of maximum historical subsidence (Fife et al. 1976) and had the largest cumulative thickness of clay layers. An idealized lithologic log for Raub #8 was constructed from the short normal resistivity geophysical log[17] (see Figure B 88). Clay layers and their thicknesses were identified and six compacting intervals were approximated. The virgin compressibility, elastic compressibility, and pre-compaction stress were determined during the calibration process. Vertical hydraulic conductivity was chosen from calibrated values from wells similar in lithology, but located in the Chino Groundwater Basin.

The PRESS model is able to simulate two controlling aquifers by specifying potentiometric head at three places in the total alluvial thickness. The change in potentiometric surface over time (drawdown) is specified for the upper and lower aquifers and for the bottom of the alluvial thickness. This drawdown over time is the PRESS loading function. The loading function used was the drawdown generated in layers 1 and 2 of the MODFLOW model at the Raub #8 well for model calibration and verification period (1945-2000) and each of the MODFLOW Project implementation scenarios (2001-2039). The drawdown loading functions for the MODFLOW model Layers 1 and 2 are illustrated in Figures B 89 and B 90.

6.6.3 Model Calibration

The properties of the compaction intervals including virgin compressibility, elastic compressibility, and pre-compaction stress were determined by a trial-and-error parameter estimation procedure. The model was calibrated to measured subsidence of 1.3 feet occurring from the period from 1943 to 1968-1969 at a location immediately east of the San Jacinto fault near Loma Linda, as measured by the Coast and Geodetic Survey (Lofgren 1971). Figure B 91 shows that the modeled subsidence in 1969 matches the measured subsidence of 1.3 feet.

6.6.4 Results

With the compaction interval properties calibrated, the PRESS model was run using the drawdown loading functions generated from the calibrated MODFLOW model run (from 1945 to 2000) and each of the future Scenarios (from 2001 to 2039). The modeled subsidence for all scenarios is shown in Figure B 91. During the period from 2001 through 2039, the No Project condition had 0.35 feet of subsidence at the location of Well Raub #8 with an average subsidence rate of 0.0083 ft/yr. Scenario A had 0.62 feet of subsidence at the same location with an average subsidence rate of 0.0158 ft/yr. There was a difference of 0.27 feet of subsidence between No Project and Scenario A. During the same period of time, the total subsidence was estimated to be 0.61 feet, 0.45 feet, and 0.43 feet for Scenarios B through D, respectively. The average subsidence rate was approximately 0.0155 ft/yr, 0.0112 ft/yr and 0.0108 ft/yr for Scenarios B through D, respectively. The following table (Table 6.6-1) summarizes the total

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[17] Resulting from a resistivity tool placed within the Raub # 8 well.

subsidence and average subsidence rate at the location of Well Raub #8 during the period 2001 through 2039 for each Project scenario.

Table 6.6-1. Total Subsidence and Average Subsidence Rate at the Location of Well Raub #8, 2001-2039

Scenario	*Total Subsidence [ft]*	*Average Subsidence Rate [ft/yr]*
No Project	0.35	0.0083
Scenario A	0.62	0.0158
Scenario B	0.61	0.0155
Scenario C	0.45	0.0112
Scenario D	0.43	0.0108

It is important to note that the model-predicted subsidence was based on limited data on measured historical subsidence and parameters related to subsidence calculations (e.g., virgin and elastic compressibilities). Installation of an extensometer to monitor the aquifer systems responding to the water level changes can significantly enhance the ability of subsidence prediction.

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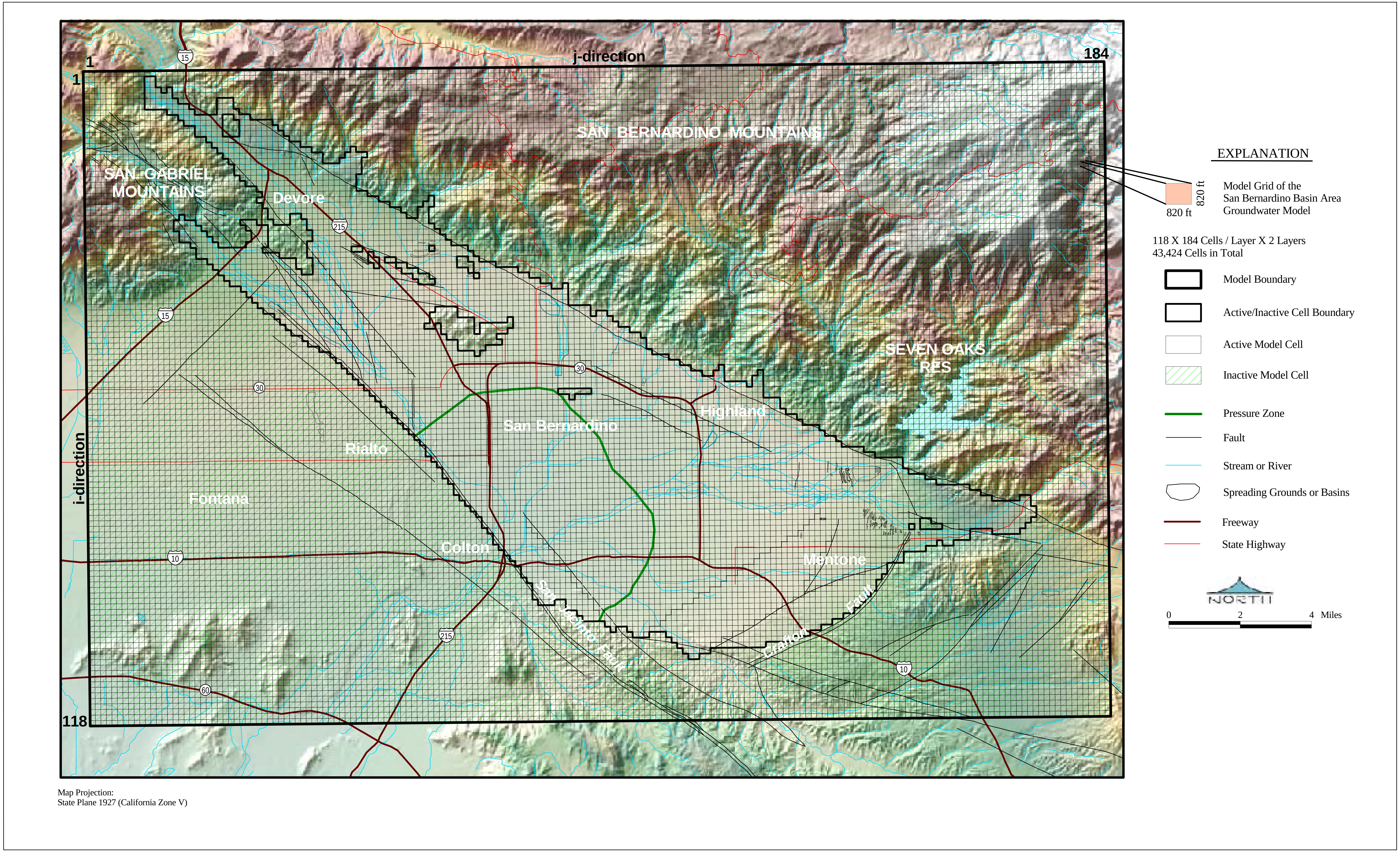
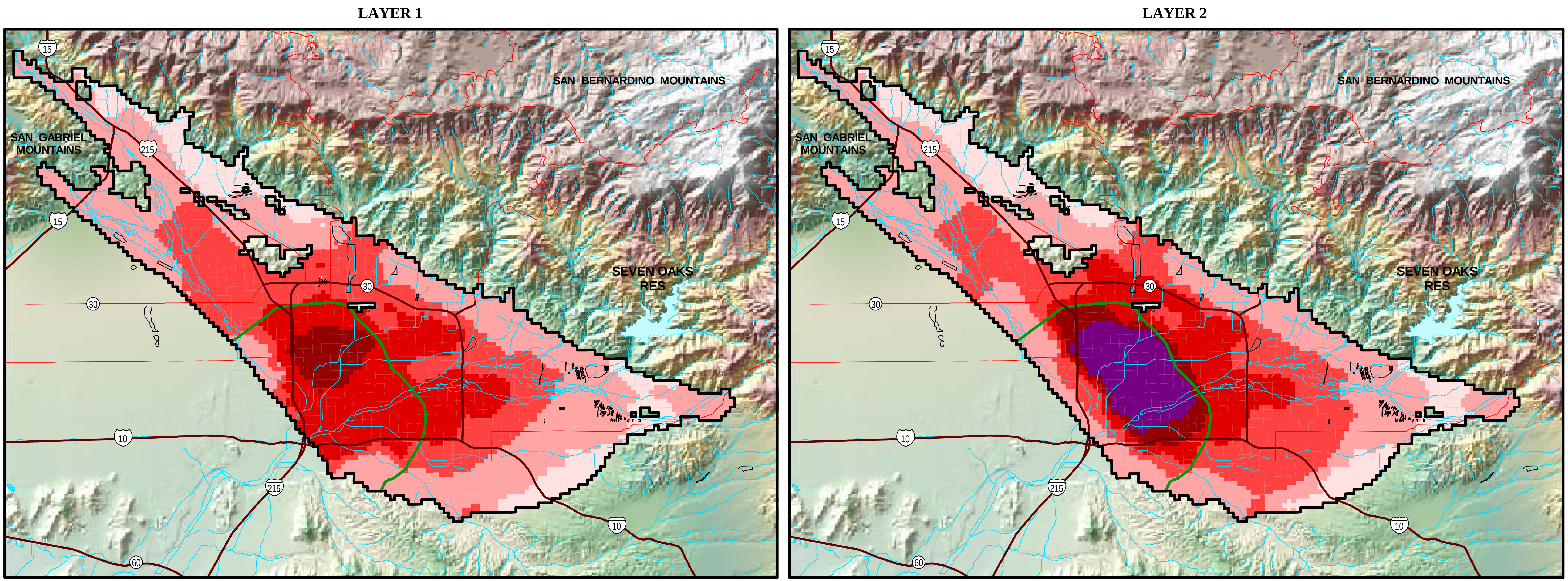


Figure 6.2-1. Model Grid of the San Bernardino Basin Area Groundwater Model



EXPLANATION

Transmissivity (ft^2 / day)	
🟥	200 - 1,000
🟥	1,000 - 5,000
🟥	5,000 - 10,000
🟥	10,000 - 20,000
🟥	20,000 - 30,000
🟪	30,000 - 45,000

▭	Active/Inactive Cell Boundary
—	Pressure Zone
—	Stream or River
⬭	Spreading Grounds or Basins
—	Freeway
—	State Highway

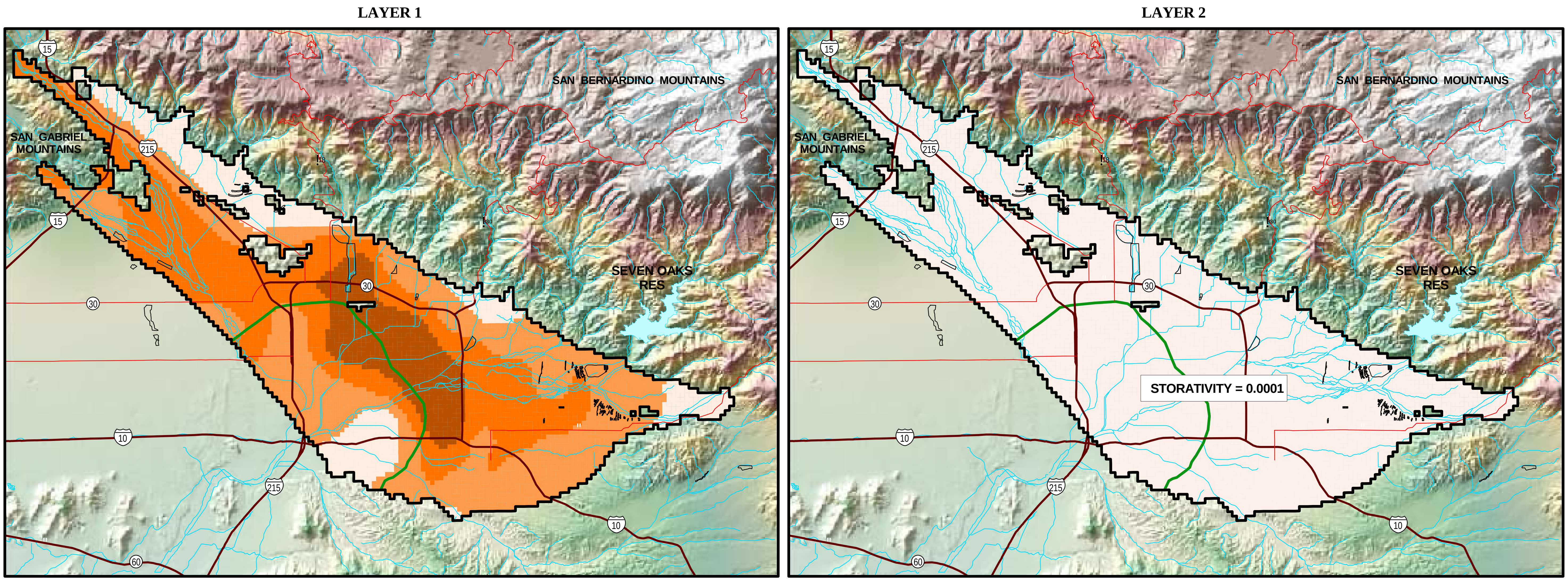
Map Projection:
State Plane 1927 (California Zone V)

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R.,
"Hydrology, description of computer models, and evaluation of
selected water-management alternatives in the San Bernardino area, California"
US. Geological Survey, draft in preparation.

NORTH

0 3 6 Miles

Figure 6.2-2. Transmissivity of Model Layers



EXPLANATION

Storativity *

▨	0.04 - 0.07
▨	0.07 - 0.10
▨	0.10 - 0.13
▨	0.13 - 0.17

* = equivalent to specific yield
or effective porosity

▭	Active/Inactive Cell Boundary
—	Pressure Zone
—	Stream or River
⬭	Spreading Grounds or Basins
—	Freeway
—	State Highway

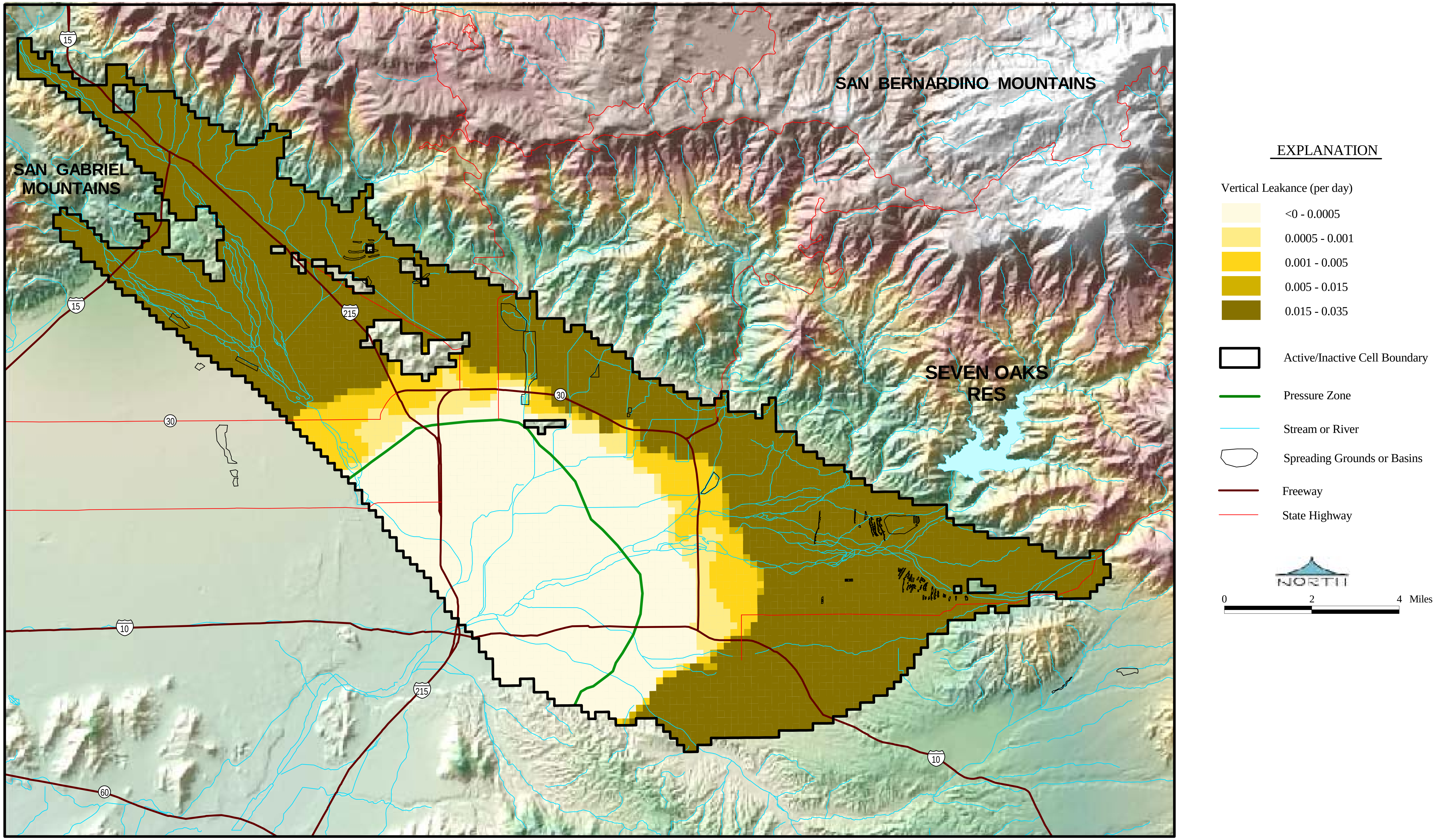
Map Projection:
State Plane 1927 (California Zone V)

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R.,
"Hydrology, description of computer models, and evaluation of
selected water-management alternatives in the San Bernardino area, California"
US. Geological Survey, draft in preparation.

NORTH

0 3 6 Miles

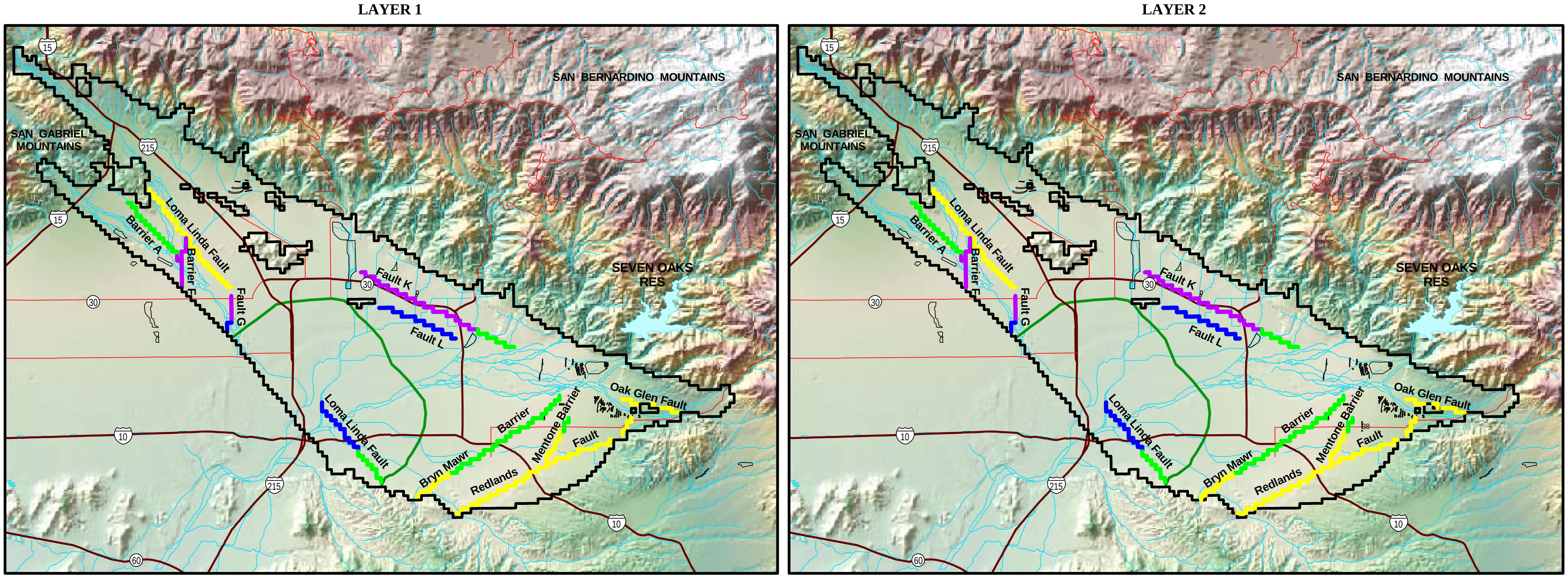
Figure 6.2-3. Storativity of Model Layers



Map Projection:
State Plane 1927 (California Zone V)

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R., "Hydrology, description of computer models, and evaluation of selected water-management alternatives in the San Bernardino area, California" US. Geological Survey, draft in preparation.

Figure 6.2-4. Vertical Leakance Values Between Model Layer 1 and Model Layer 2



EXPLANATION

Hydraulic Characteristic of Groundwater Barrier (ft/day)

- 🟨 <1
- 🟩 1 - 5
- 🟪 5 - 10
- 🟦 10 - 25

- ▭ Active/Inactive Cell Boundary
- ― Pressure Zone
- ― Stream or River
- ⬭ Spreading Grounds or Basins
- ― Freeway
- ― State Highway

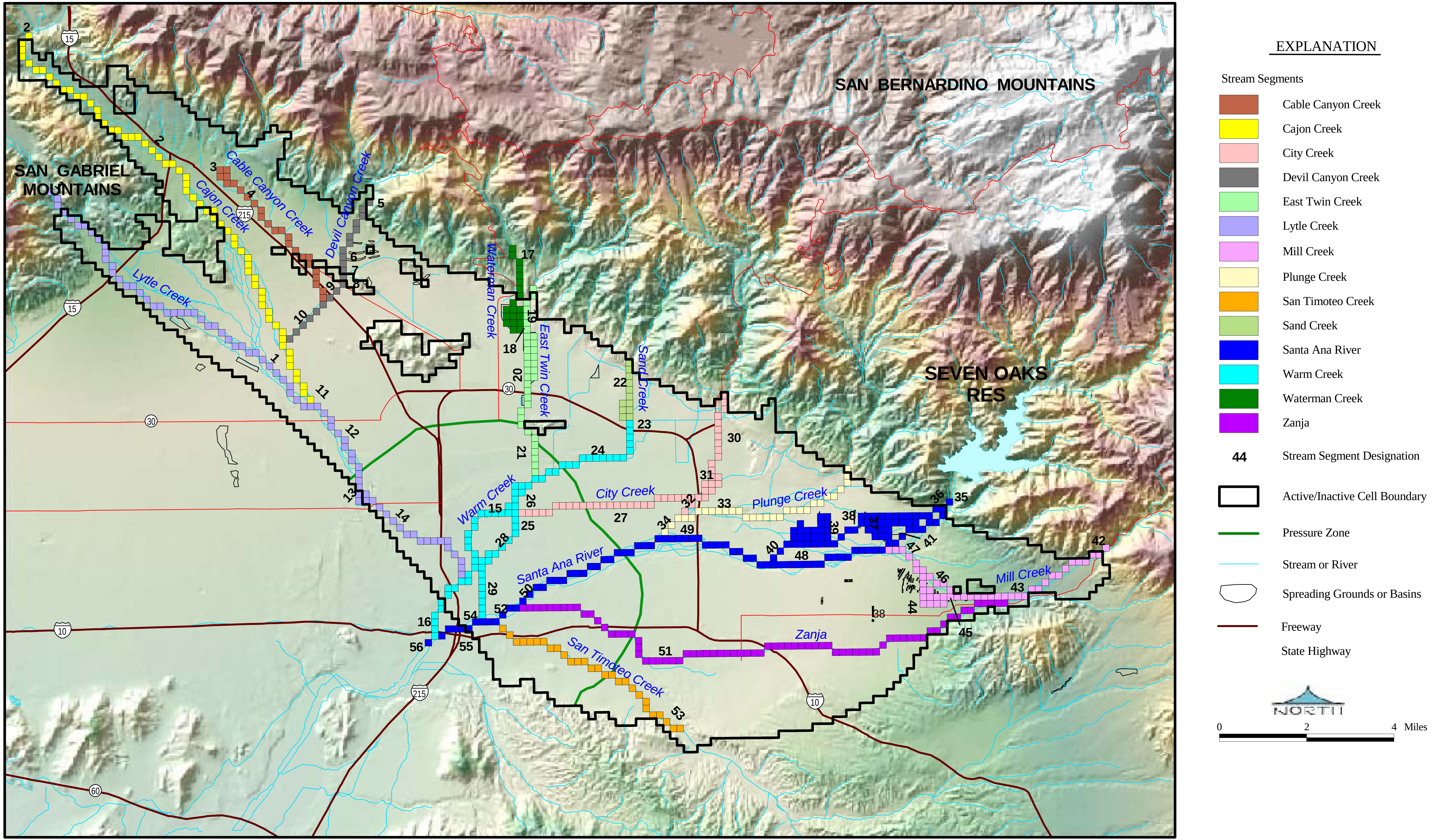
Map Projection:
State Plane 1927 (California Zone V)

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R.,
"Hydrology, description of computer models, and evaluation of
selected water-management alternatives in the San Bernardino area, California"
US. Geological Survey, draft in preparation.

NORTH

0 3 6 Miles

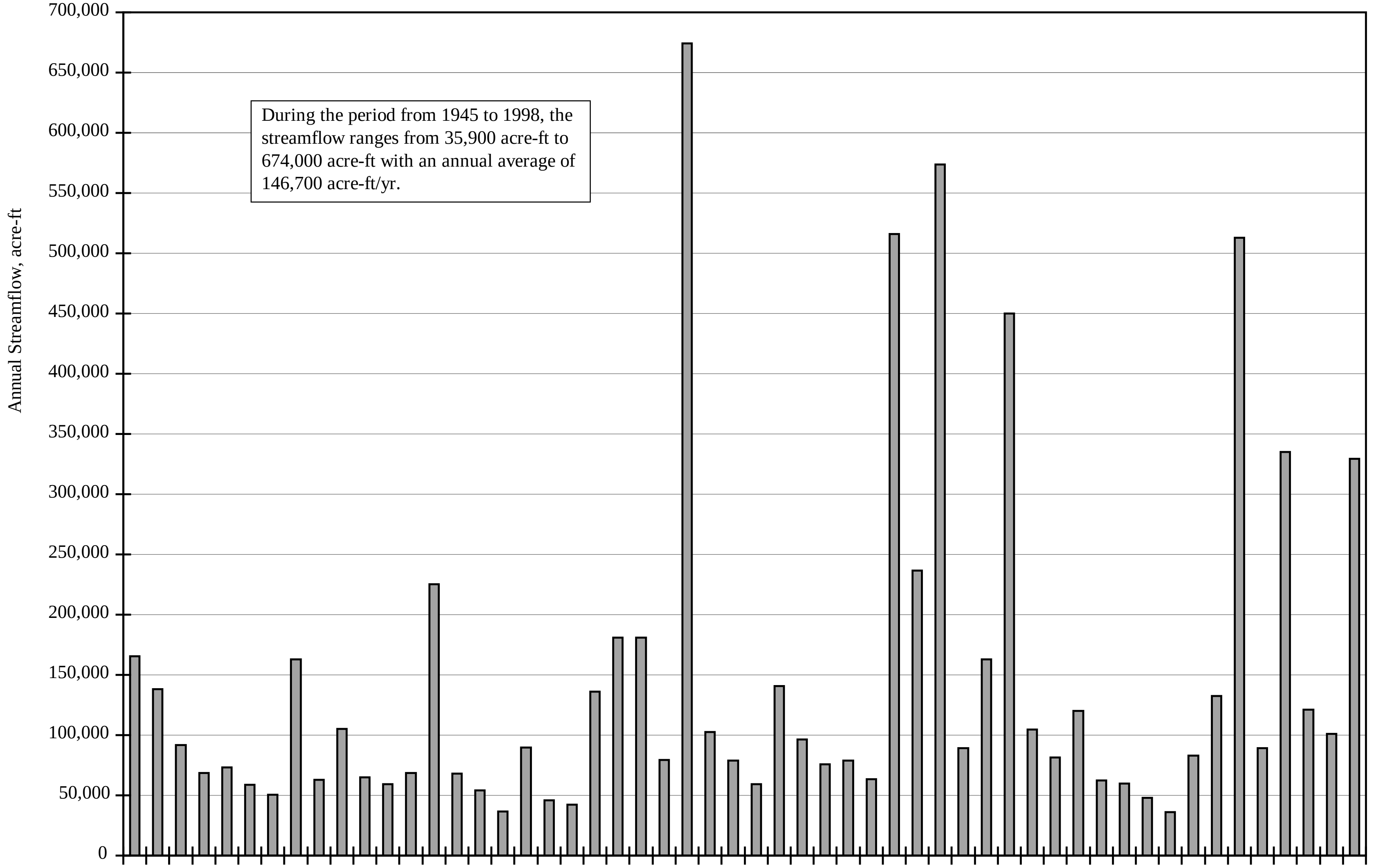
Figure 6.2-5. Hydraulic Characteristics of Groundwater Barriers (Horizontal-Flow Barrier Values Package)



Map Projection:
State Plane 1927 (California Zone V)

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R.,
"Hydrology, description of computer models, and evaluation of
selected water-management alternatives in the San Bernardino area,
California" US. Geological Survey, draft in preparation.

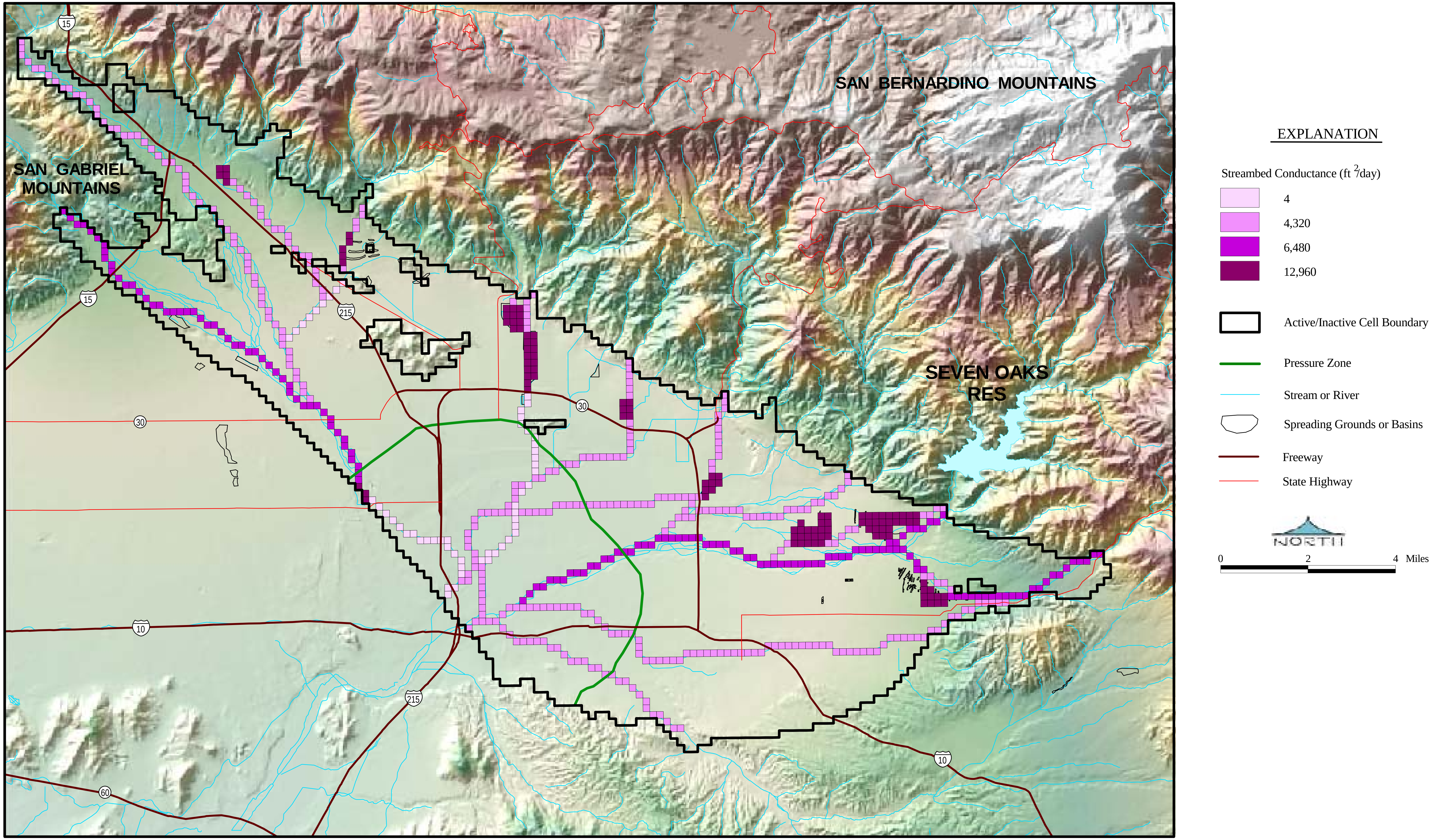
Figure 6.2-6. Locations of Stream Segments



During the period from 1945 to 1998, the streamflow ranges from 35,900 acre-ft to 674,000 acre-ft with an annual average of 146,700 acre-ft/yr.

Source: USGS

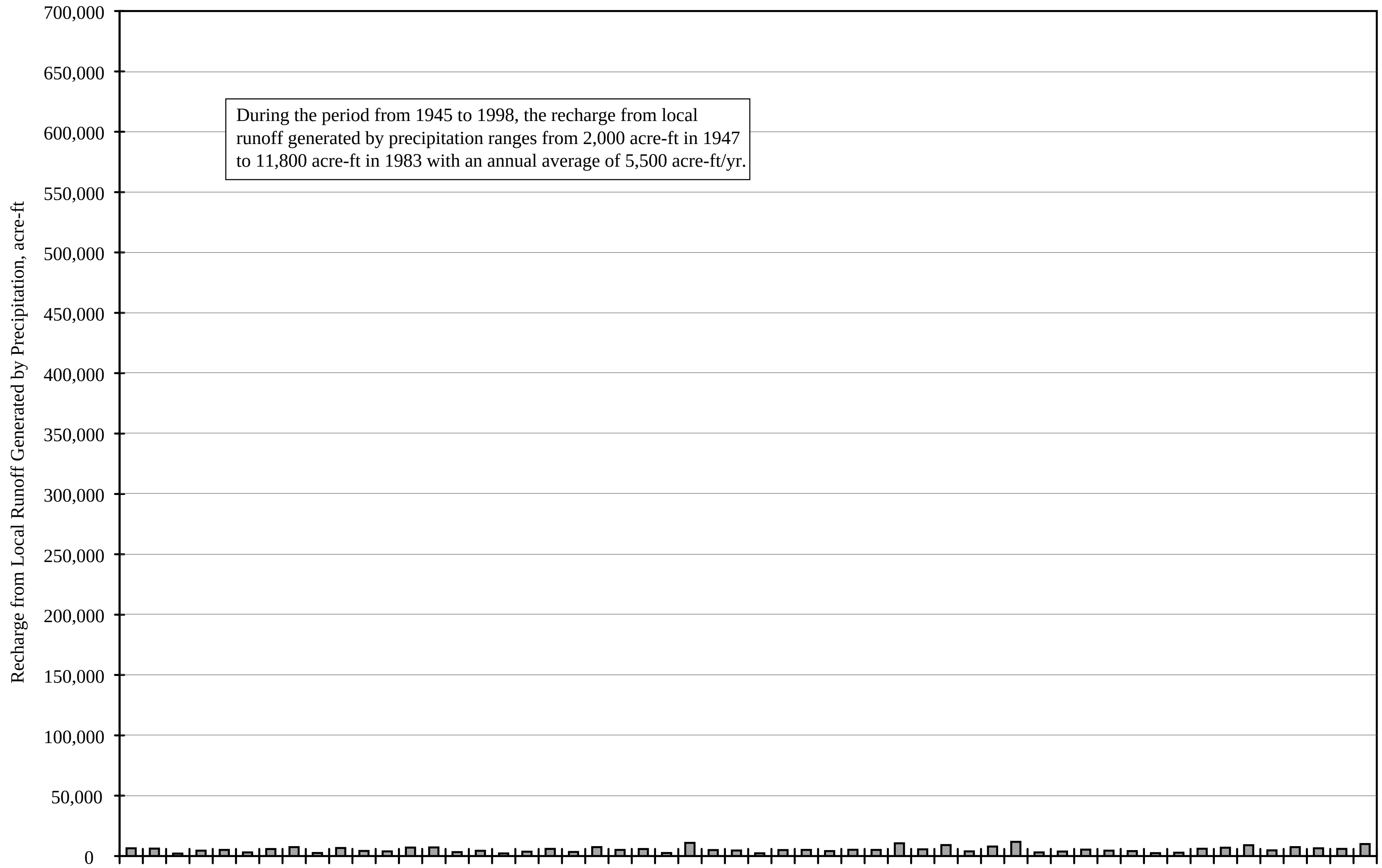
Figure 6.2-7. Total Annual Streamflow Inflow for the SBBA 1945 - 1998



Map Projection:
State Plane 1927 (California Zone V)

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R.,
"Hydrology, description of computer models, and evaluation of
selected water-management alternatives in the San Bernardino area,
California" US. Geological Survey, draft in preparation.

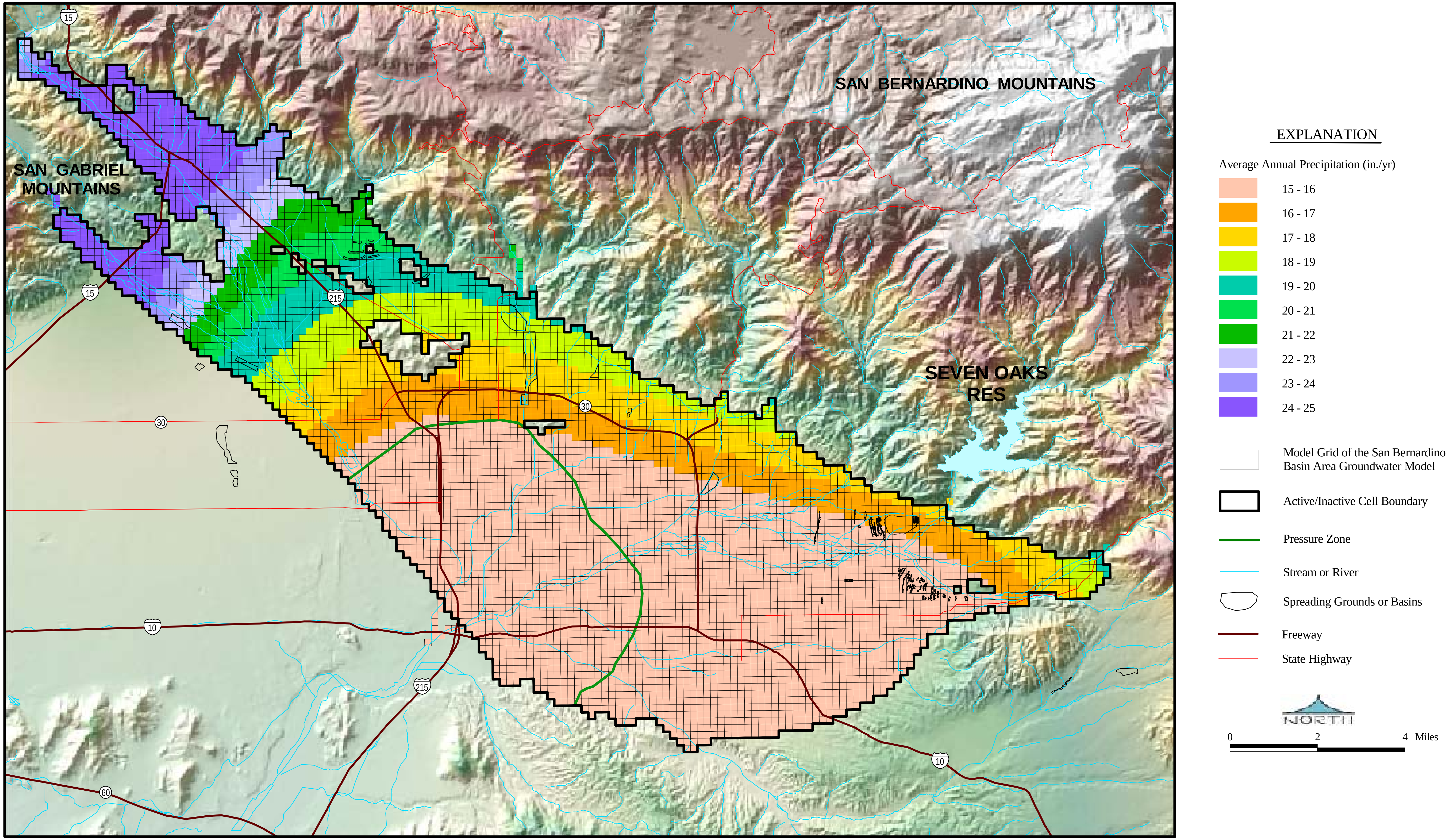
Figure 6.2-8. Streambed Conductance Values for Stream Segments



During the period from 1945 to 1998, the recharge from local runoff generated by precipitation ranges from 2,000 acre-ft in 1947 to 11,800 acre-ft in 1983 with an annual average of 5,500 acre-ft/yr.

Source: USGS

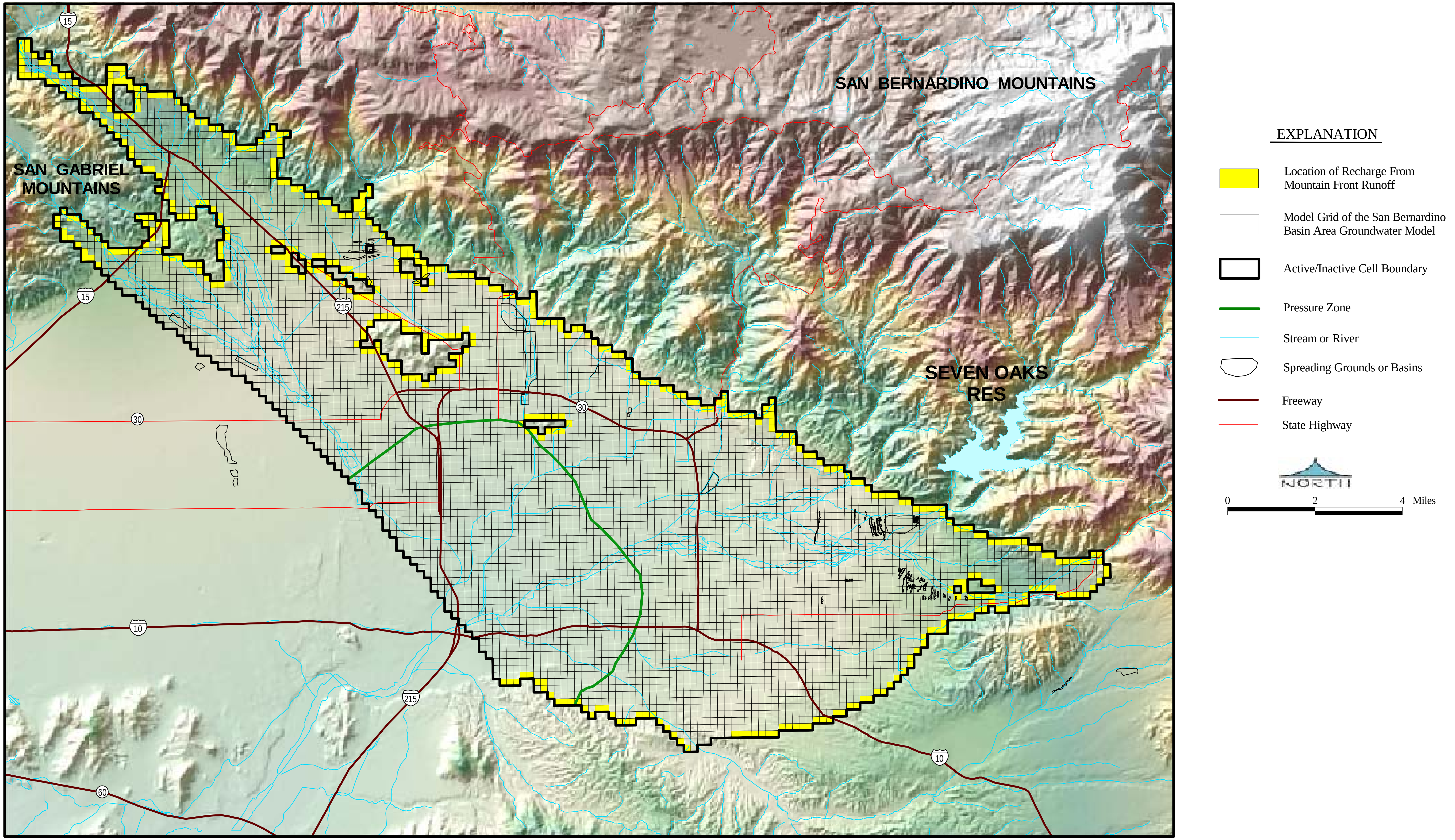
Figure 6.2-9. Recharge from Local Runoff Generated by Precipitation for the SBBA 1945 - 1998



Map Projection:
State Plane 1927 (California Zone V)

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R.,
"Hydrology, description of computer models, and evaluation of
selected water-management alternatives in the San Bernardino area,
California" US. Geological Survey, draft in preparation.

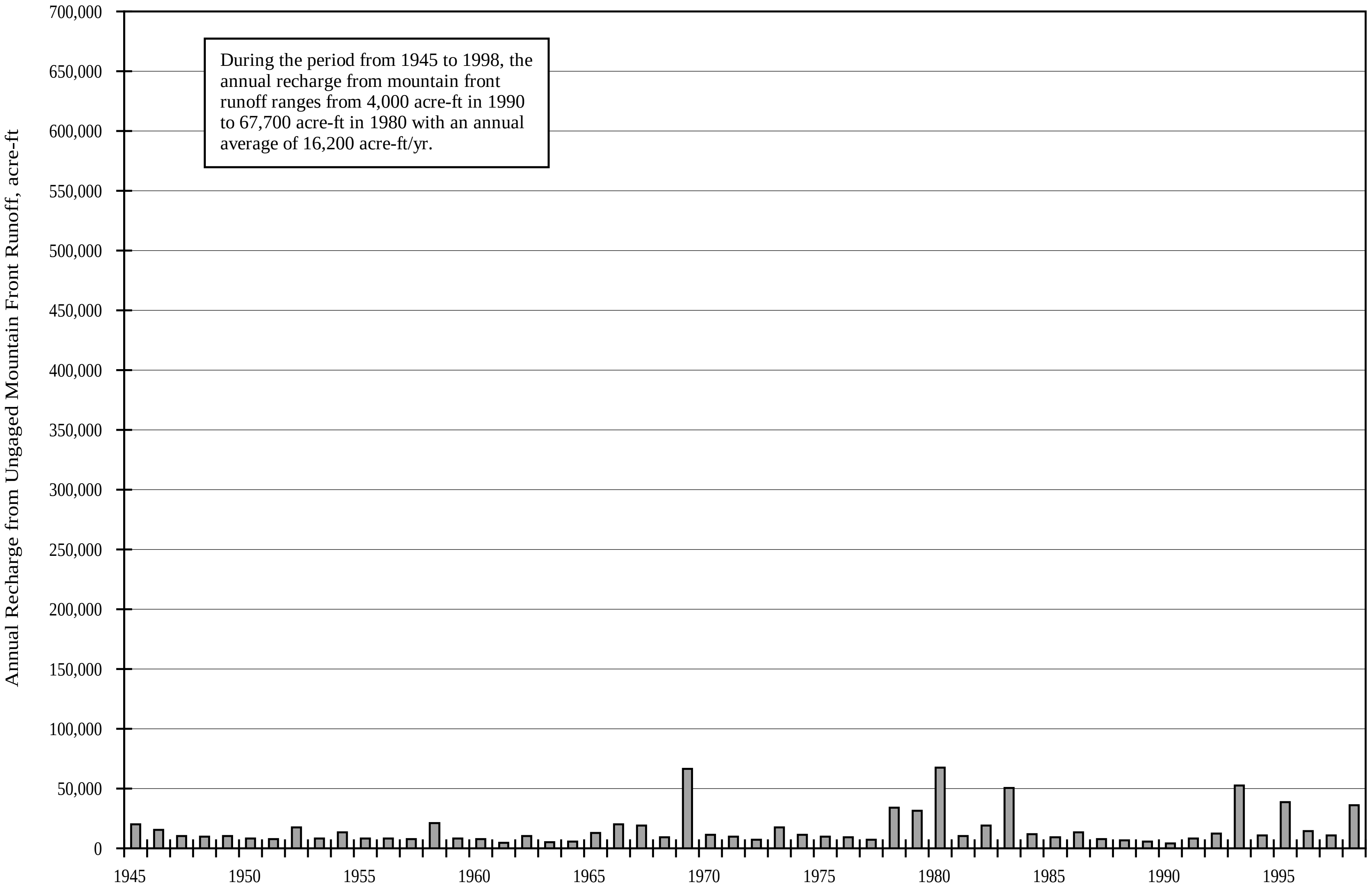
Figure 6.2-10. Average Annual Precipitation for the San Bernardino Basin Area



Map Projection:
State Plane 1927 (California Zone V)

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R.,
"Hydrology, description of computer models, and evaluation of
selected water-management alternatives in the San Bernardino area,
California" US. Geological Survey, draft in preparation.

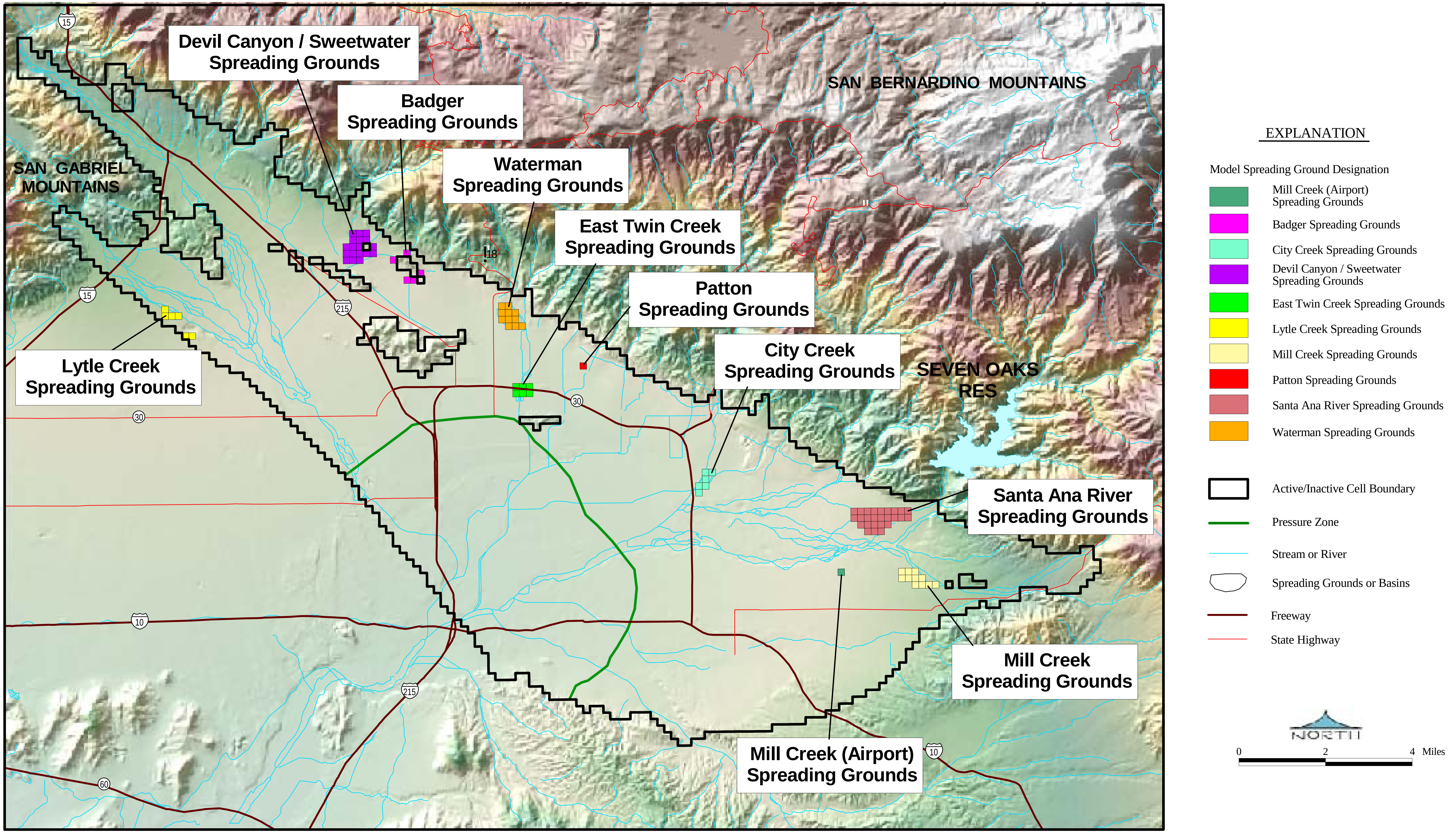
Figure 6.2-11. Locations of Recharge from Mountain Front Runoff
]



During the period from 1945 to 1998, the annual recharge from mountain front runoff ranges from 4,000 acre-ft in 1990 to 67,700 acre-ft in 1980 with an annual average of 16,200 acre-ft/yr.

Source: USGS

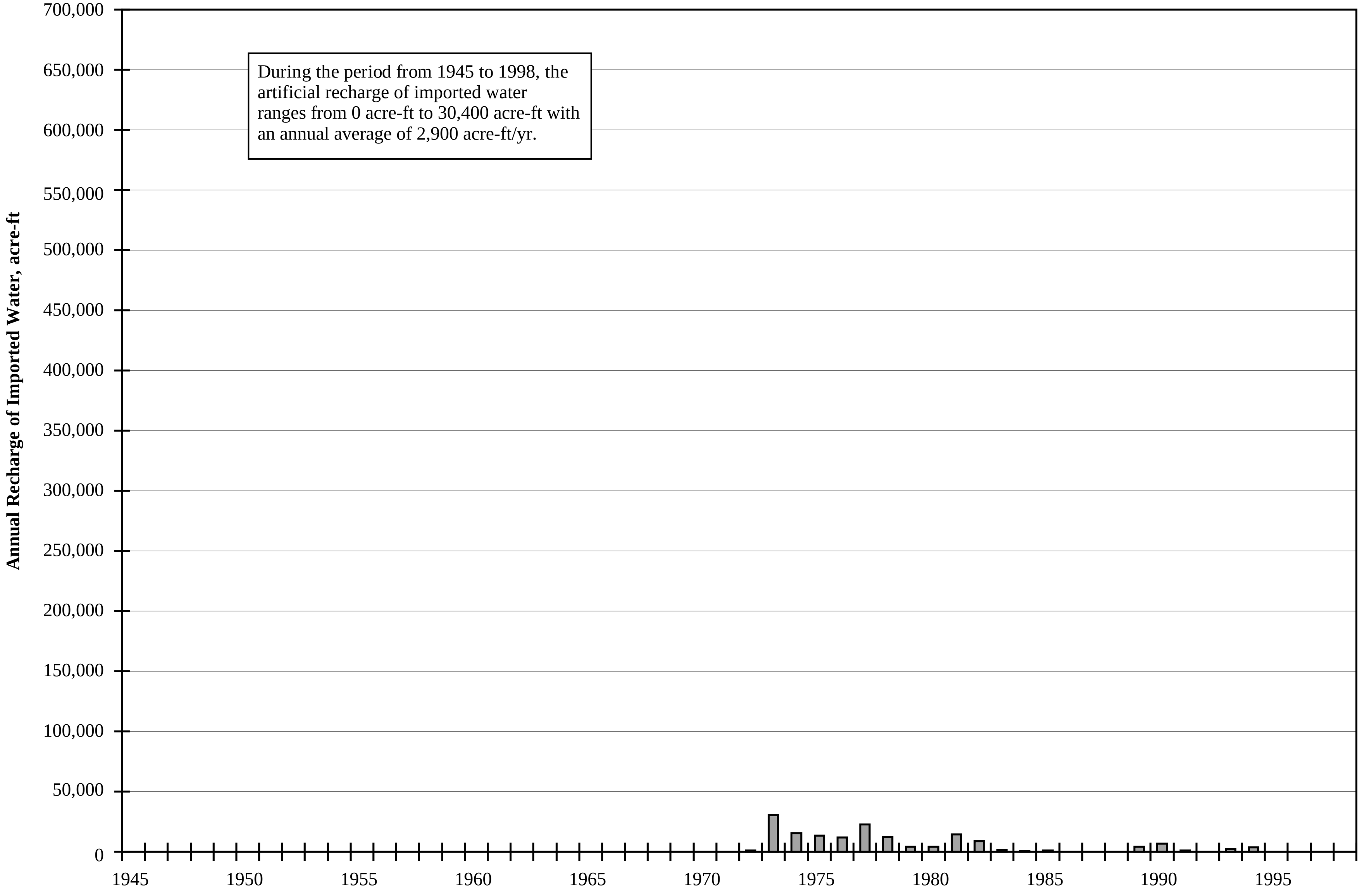
Figure 6.2-12. Annual Recharge from Mountain Front Runoff for the SBBA 1945 - 1998



Map Projection:
State Plane 1927 (California Zone V)

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R., "Hydrology, description of computer models, and evaluation of selected water-management alternatives in the San Bernardino area, California" US. Geological Survey, draft in preparation.

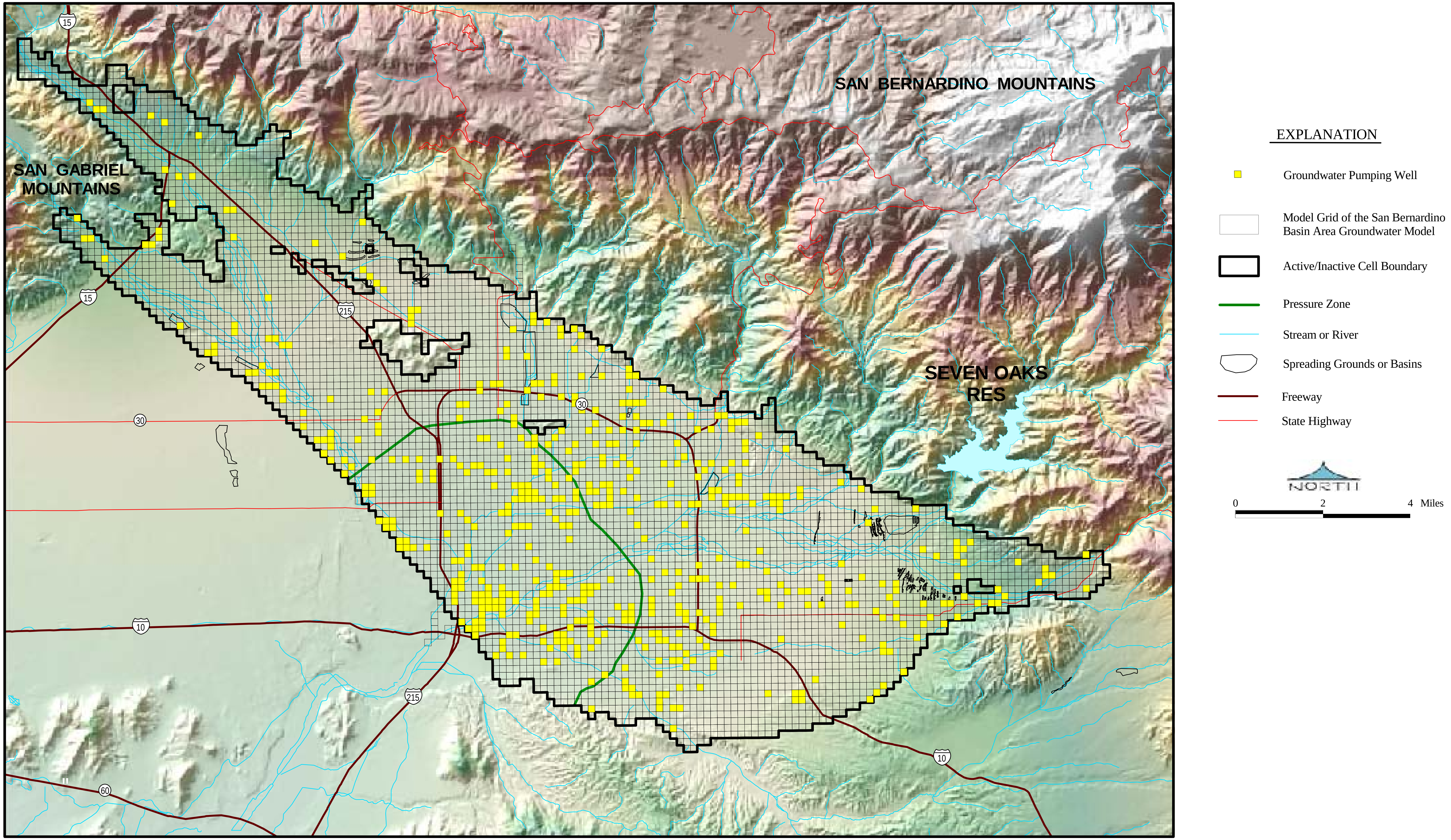
Figure 6.2-13. Locations of Artificial Recharge of Imported Water



During the period from 1945 to 1998, the artificial recharge of imported water ranges from 0 acre-ft to 30,400 acre-ft with an annual average of 2,900 acre-ft/yr.

Source: USGS

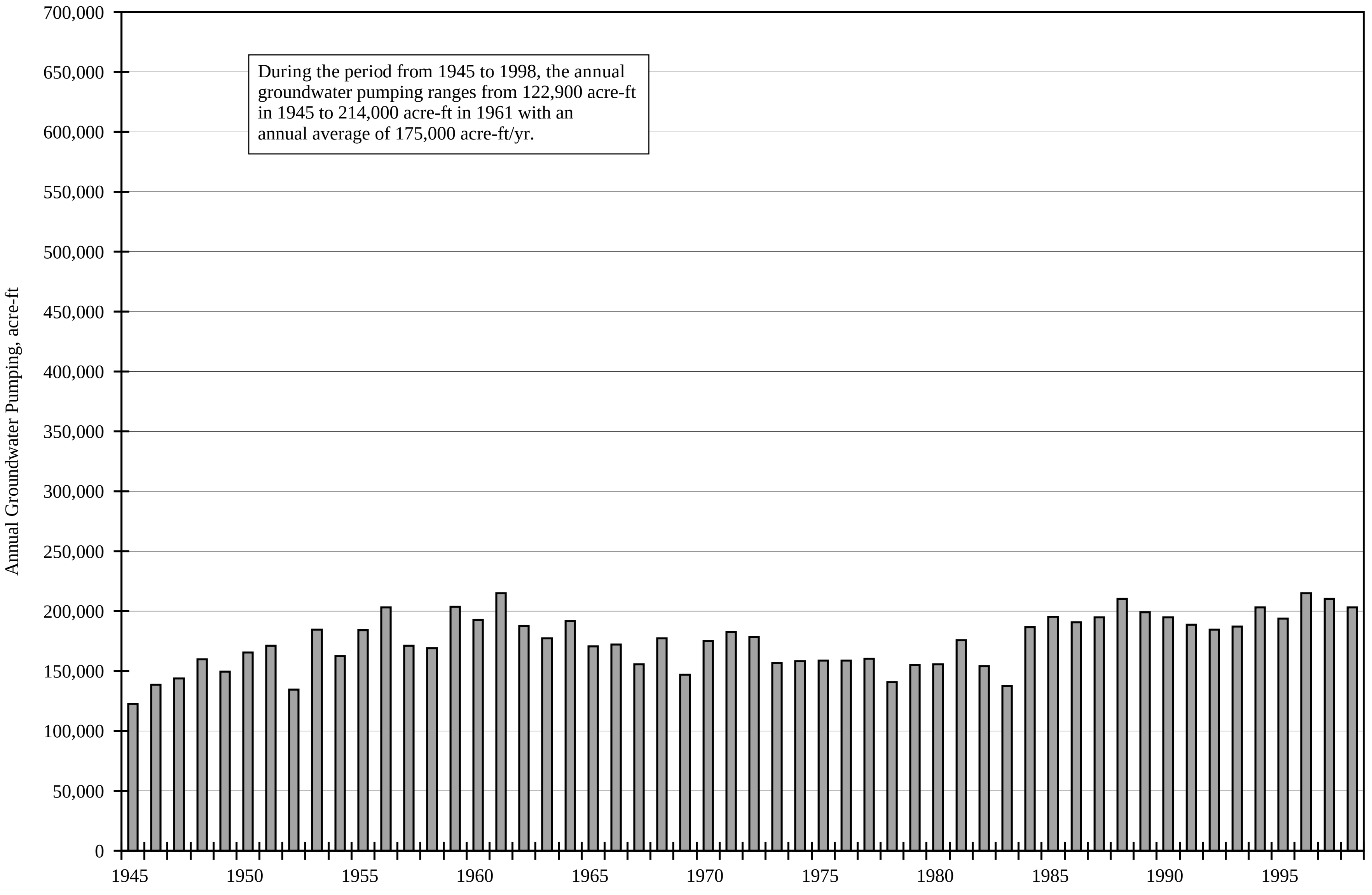
Figure 6.2-14. Annual Artificial Recharge of Imported Water for the SBBA 1945 - 1998



Map Projection:
State Plane 1927 (California Zone V)

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R.,
"Hydrology, description of computer models, and evaluation of
selected water-management alternatives in the San Bernardino area,
California" US. Geological Survey, draft in preparation.

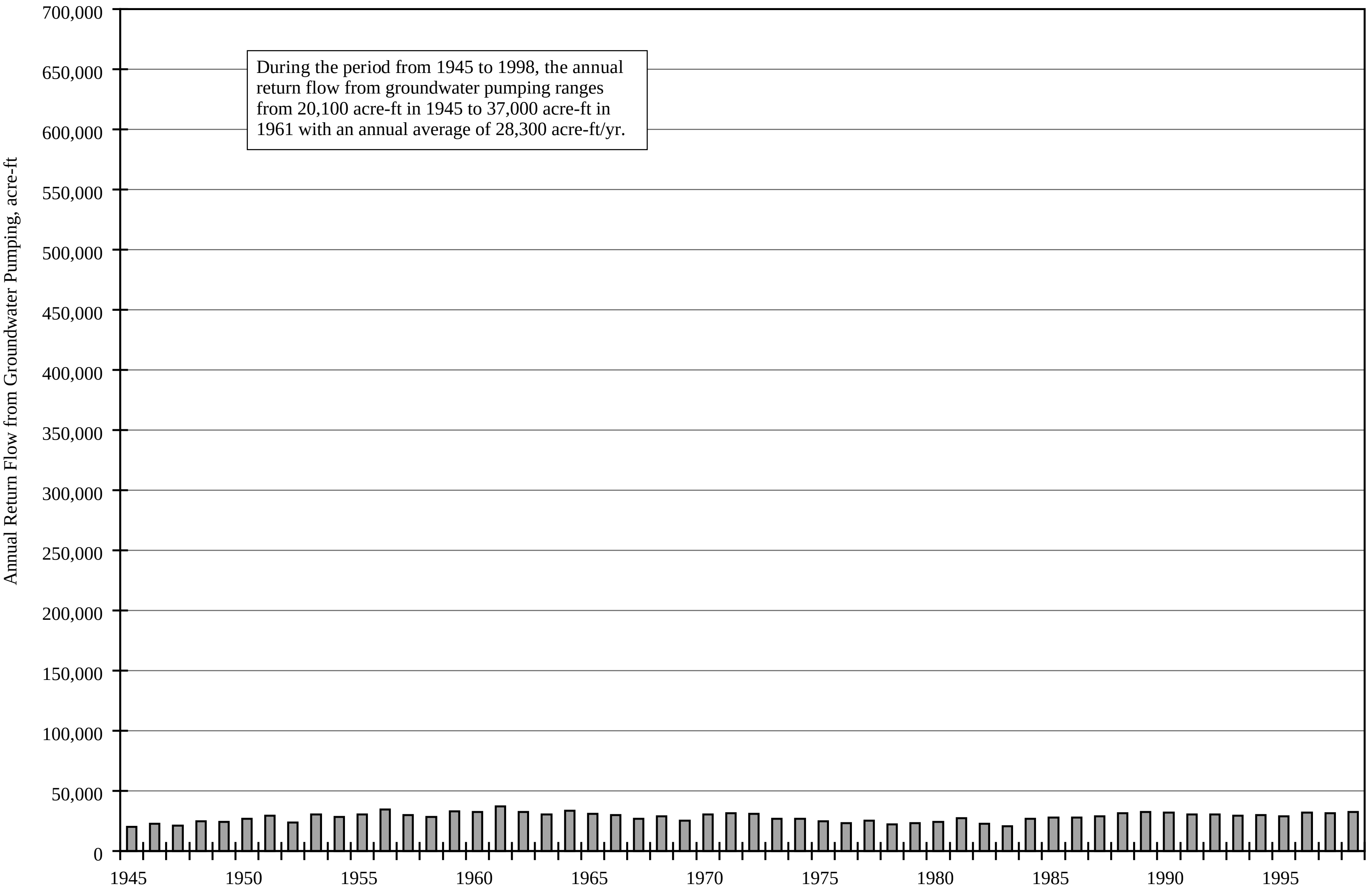
Figure 6.2-15. Locations of Groundwater Pumping Wells



During the period from 1945 to 1998, the annual groundwater pumping ranges from 122,900 acre-ft in 1945 to 214,000 acre-ft in 1961 with an annual average of 175,000 acre-ft/yr.

Source: USGS

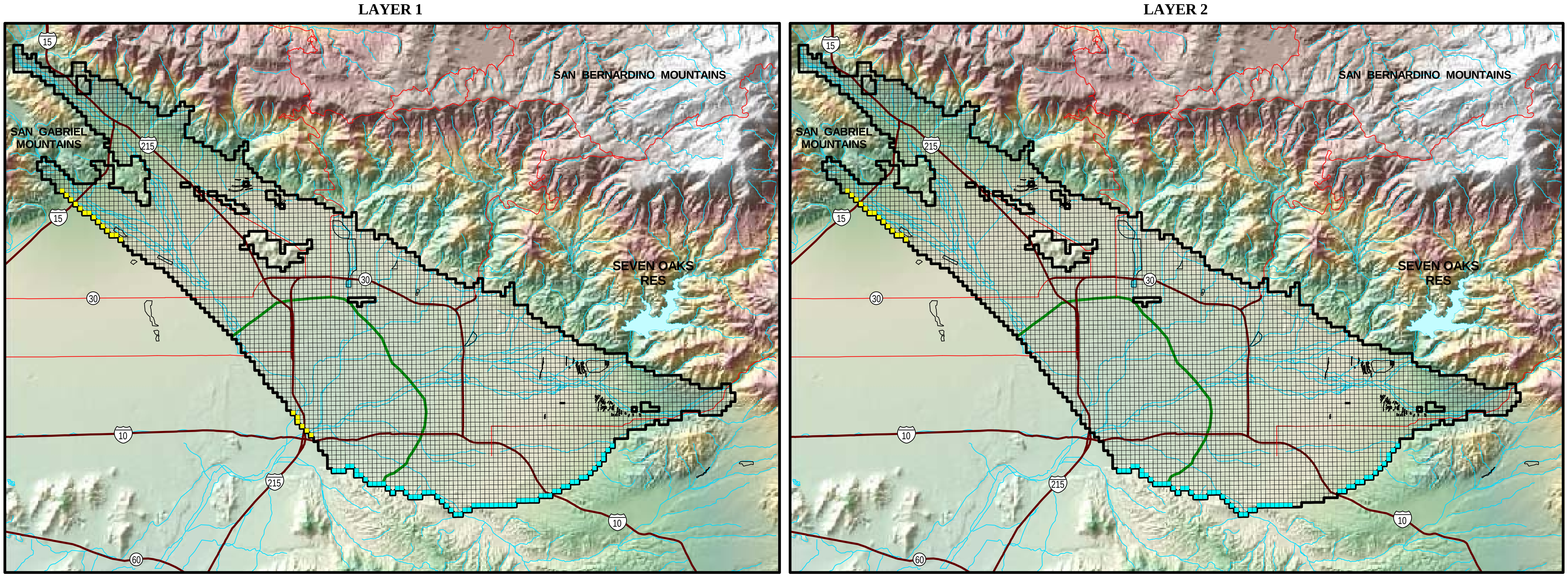
Figure 6.2-16. Annual Groundwater Pumping of the SBBA 1945 - 1998



During the period from 1945 to 1998, the annual return flow from groundwater pumping ranges from 20,100 acre-ft in 1945 to 37,000 acre-ft in 1961 with an annual average of 28,300 acre-ft/yr.

Source: USGS

Figure 6.2-17. Annual Return Flow from Groundwater Pumping of the SBBA 1945 - 1998



EXPLANATION

- 🟦 Underflow Recharge
- 🟨 Underflow Discharge
- ☐ Model Grid of the San Bernardino Basin Area Groundwater Model
- ☐ Active/Inactive Cell Boundary
- Pressure Zone
- Stream or River
- Spreading Grounds or Basins
- Freeway
- State Highway

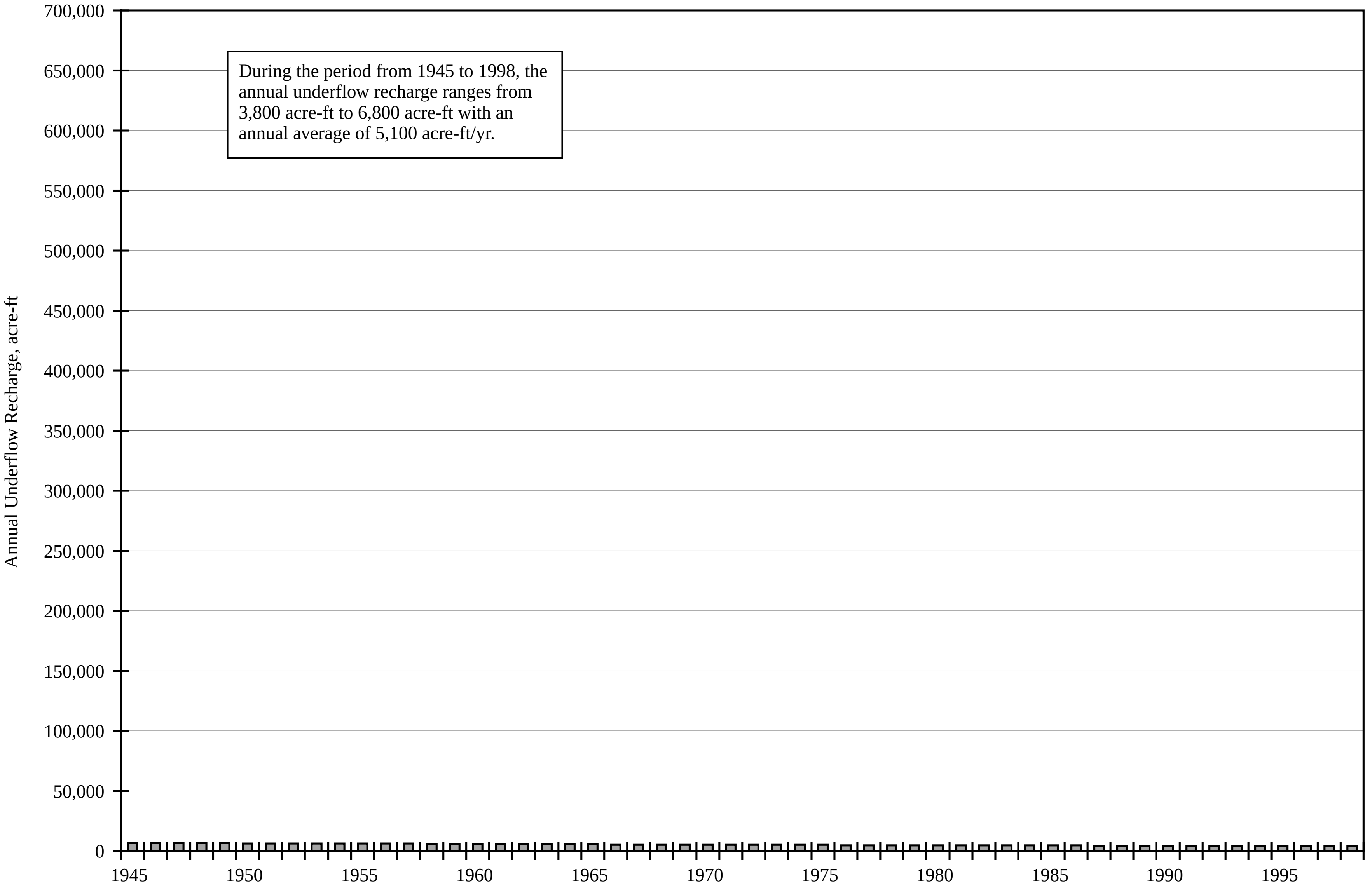
NORTH

0 3 6 Miles

Source:
Danskin, W.R., McPherson, K.R., and Woolfenden, L.R.,
"Hydrology, description of computer models, and evaluation of
selected water-management alternatives in the San Bernardino area,
California" US. Geological Survey, draft in preparation.

Map Projection:
State Plane 1927 (California Zone V)

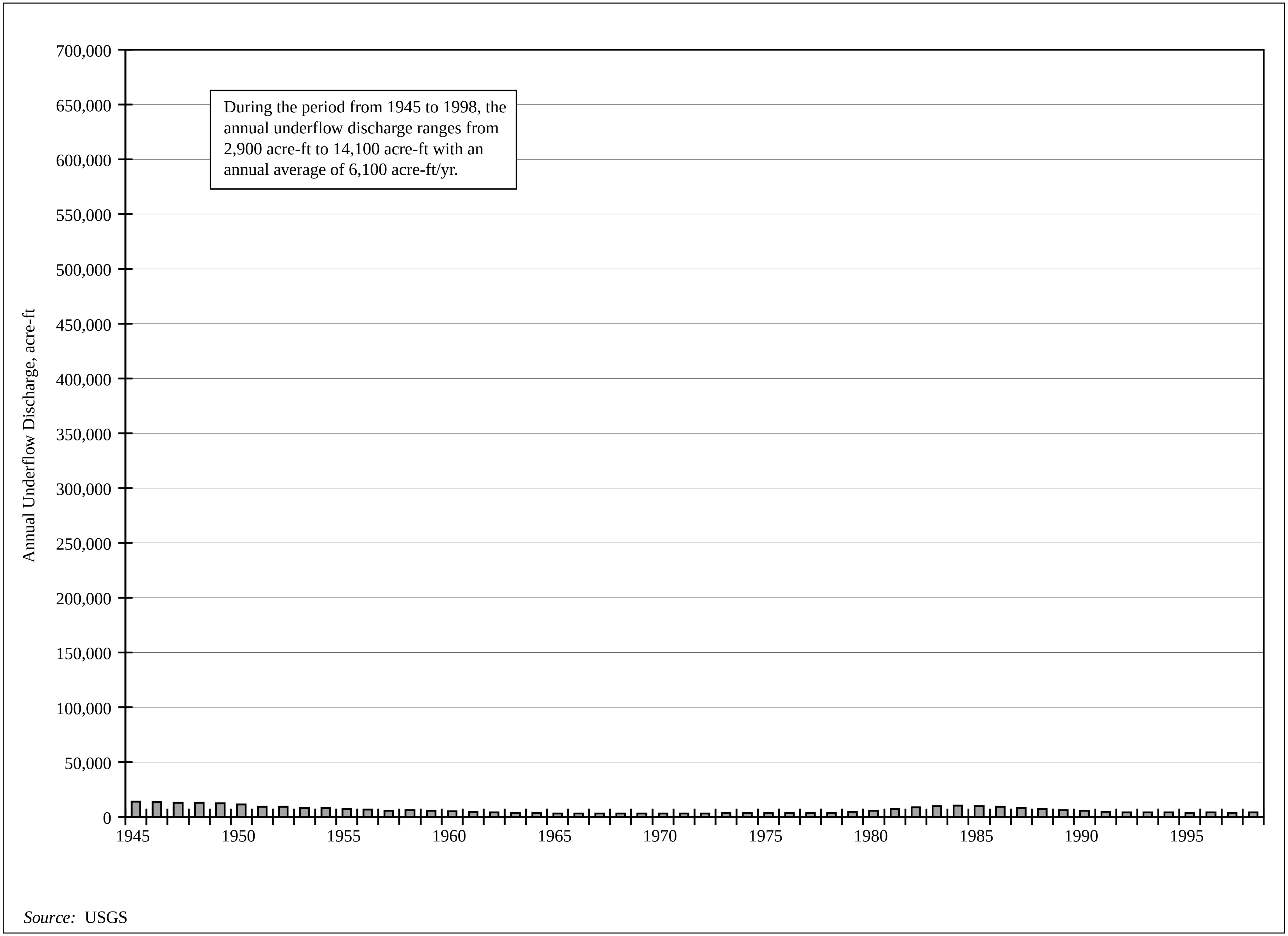
Figure 6.2-18. Locations of Underflow Recharge and Discharge



During the period from 1945 to 1998, the annual underflow recharge ranges from 3,800 acre-ft to 6,800 acre-ft with an annual average of 5,100 acre-ft/yr.

Source: USGS

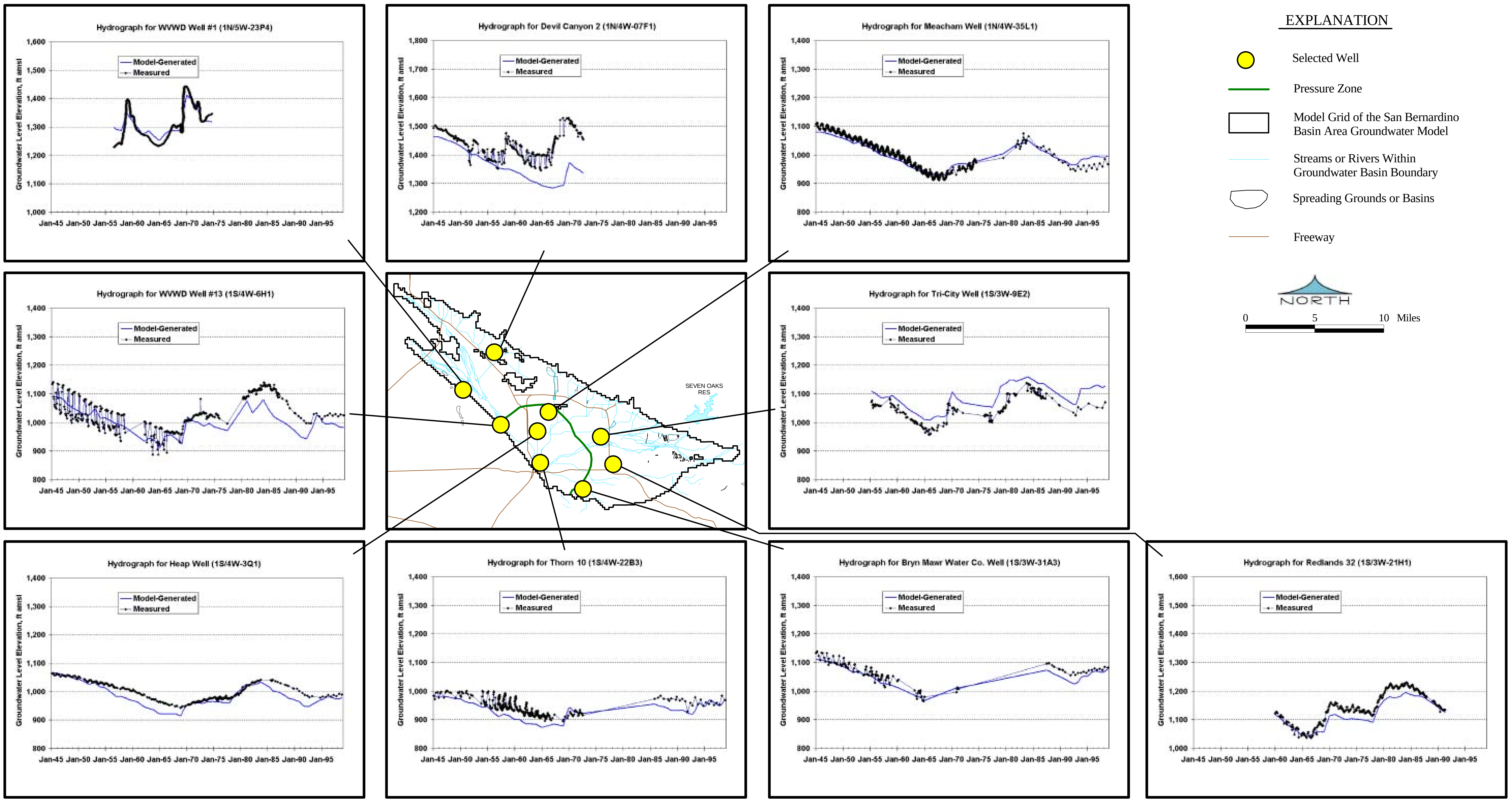
Figure 6.2-19. Annual Underflow Recharge of the SBBA 1945 - 1998



During the period from 1945 to 1998, the annual underflow discharge ranges from 2,900 acre-ft to 14,100 acre-ft with an annual average of 6,100 acre-ft/yr.

Source: USGS

Figure 6.2-20. Annual Underflow Discharge of the SBBA 1945 - 1998



Map Projection:
State Plane 1927 (California Zone V)

Figure 6.2-21. Selected Hydrographs
Flow Model Calibration (1945 - 1998)

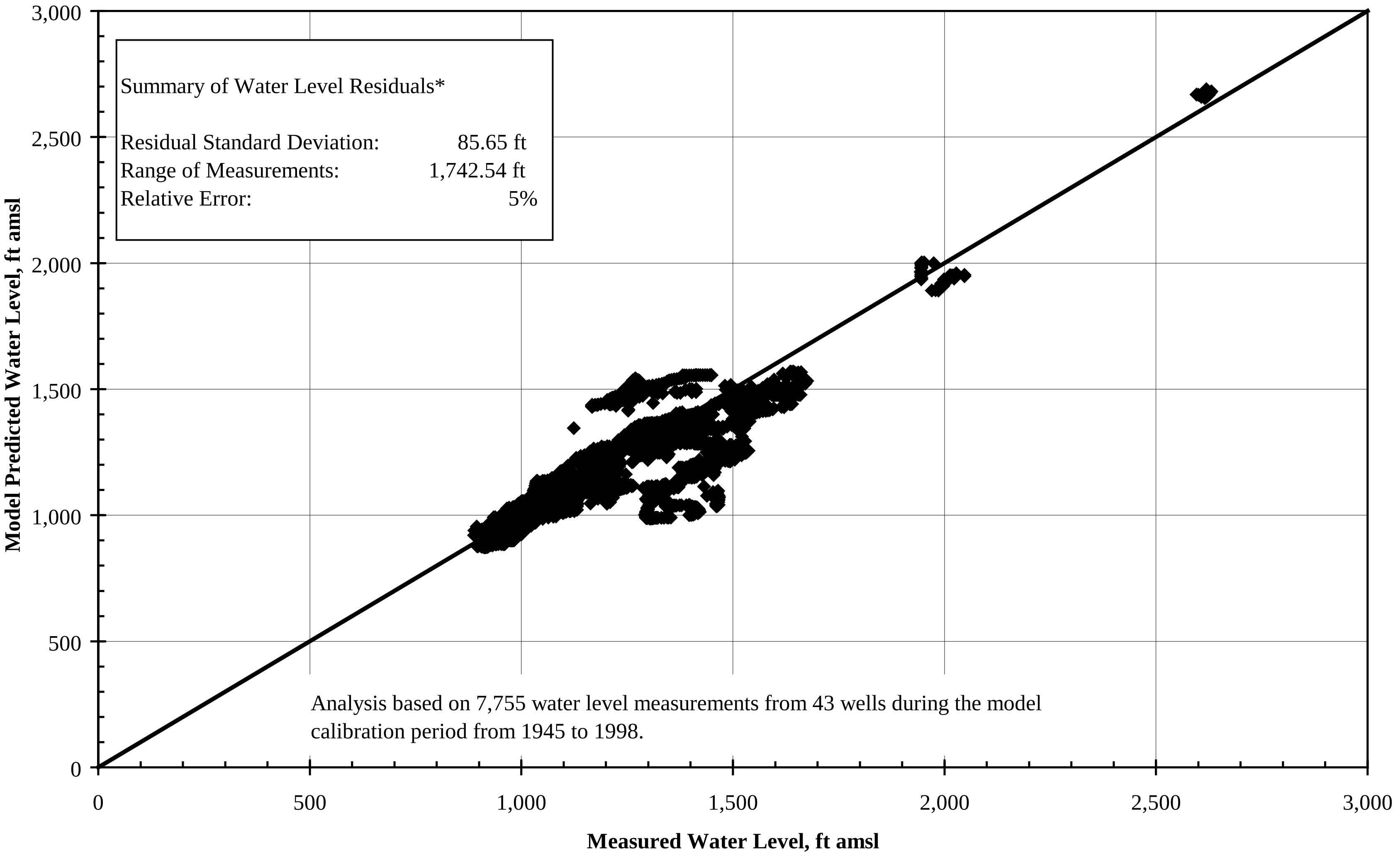
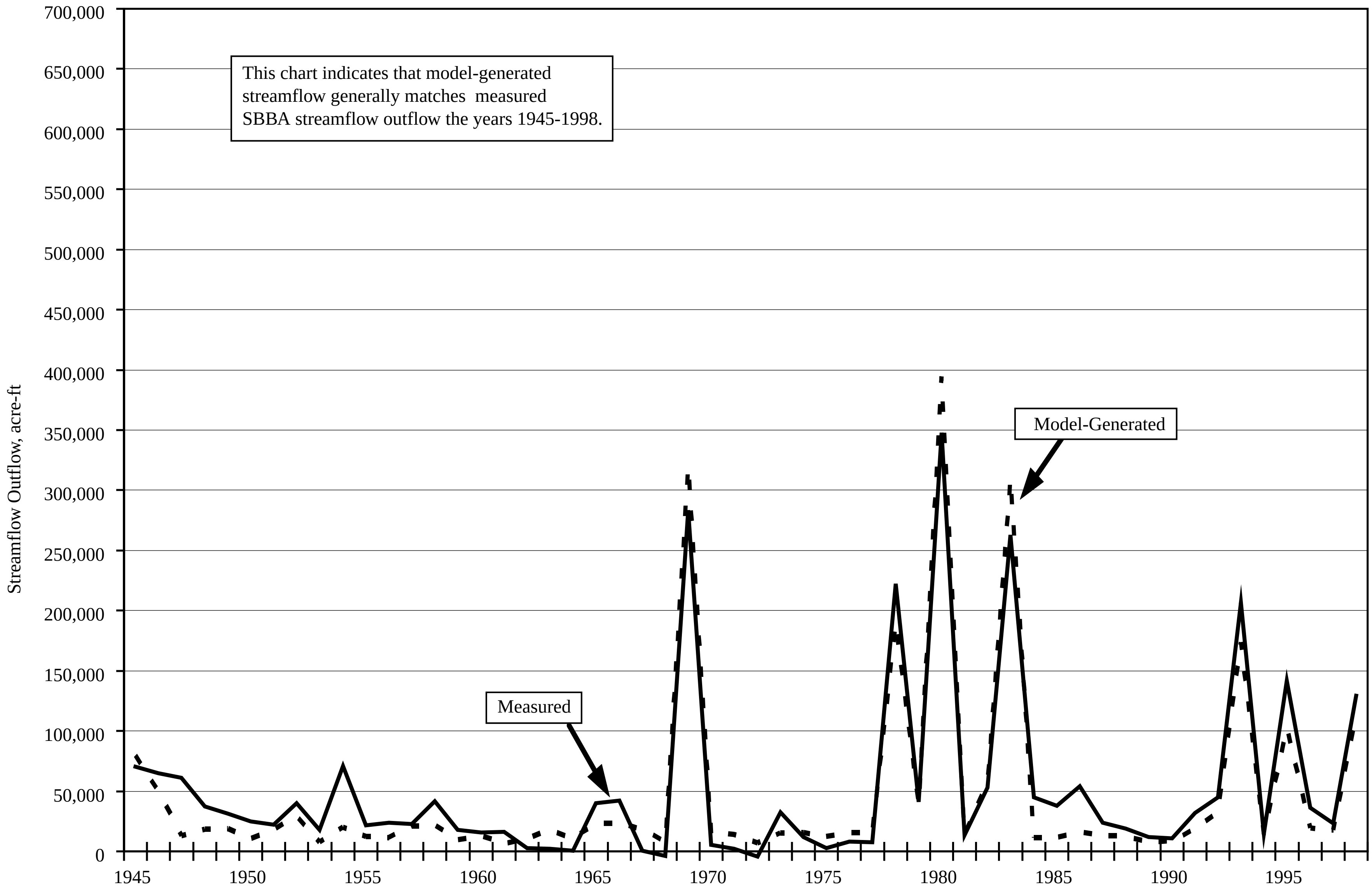
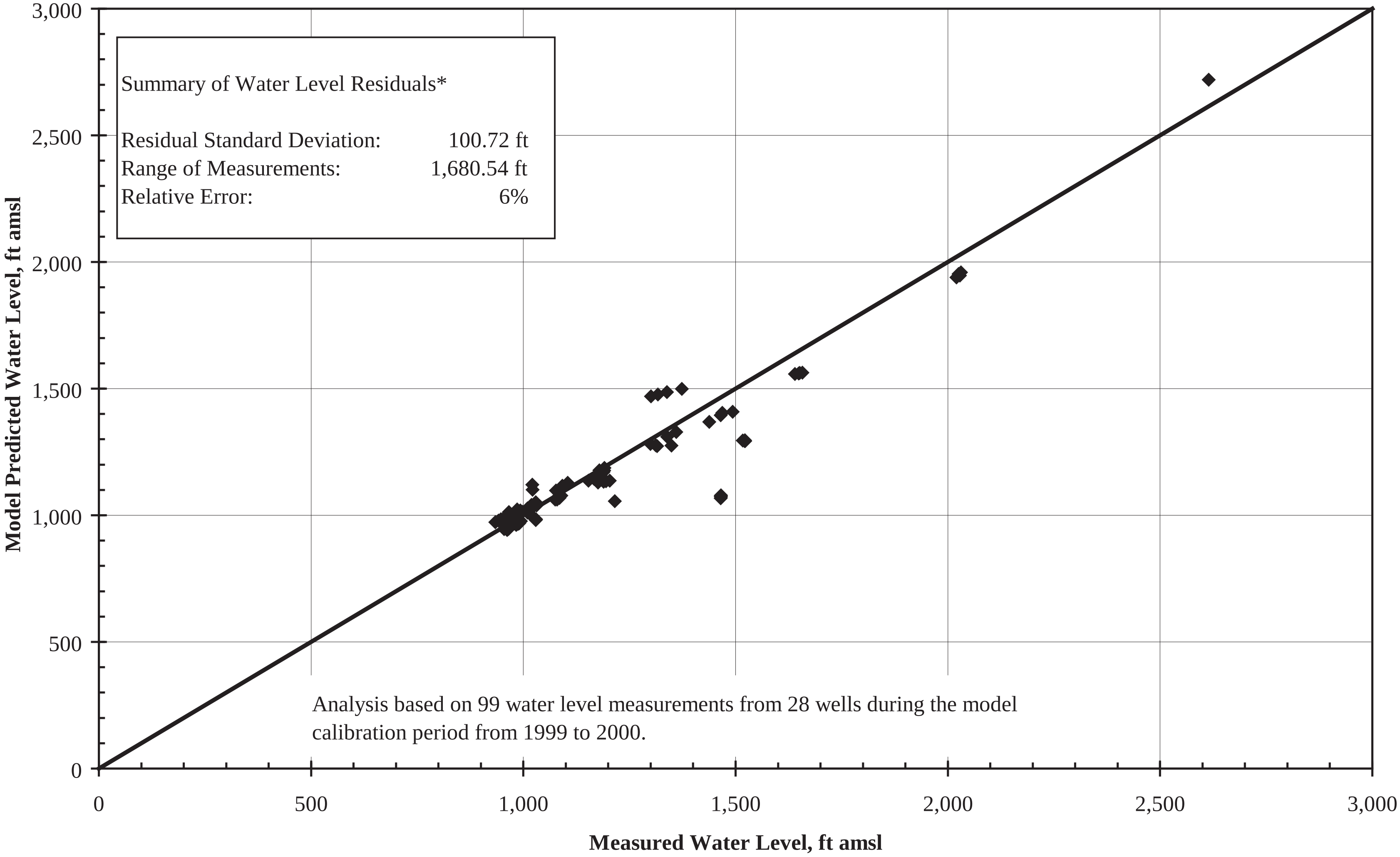


Figure 6.2-22. Comparison of Measured and Model-Generated Groundwater Levels Model Calibration (1945 - 1998)



Source: USGS

Figure 6.2-23. Comparison of Measured and Model-Generated SBBA Streamflow Outflow Model Calibration 1945 - 1998



Summary of Water Level Residuals*

Residual Standard Deviation:	100.72 ft
Range of Measurements:	1,680.54 ft
Relative Error:	6%

Analysis based on 99 water level measurements from 28 wells during the model calibration period from 1999 to 2000.

Figure 6.2-24. Comparison of Measured and Model-Generated Groundwater Levels Model Verification (1999 - 2000)

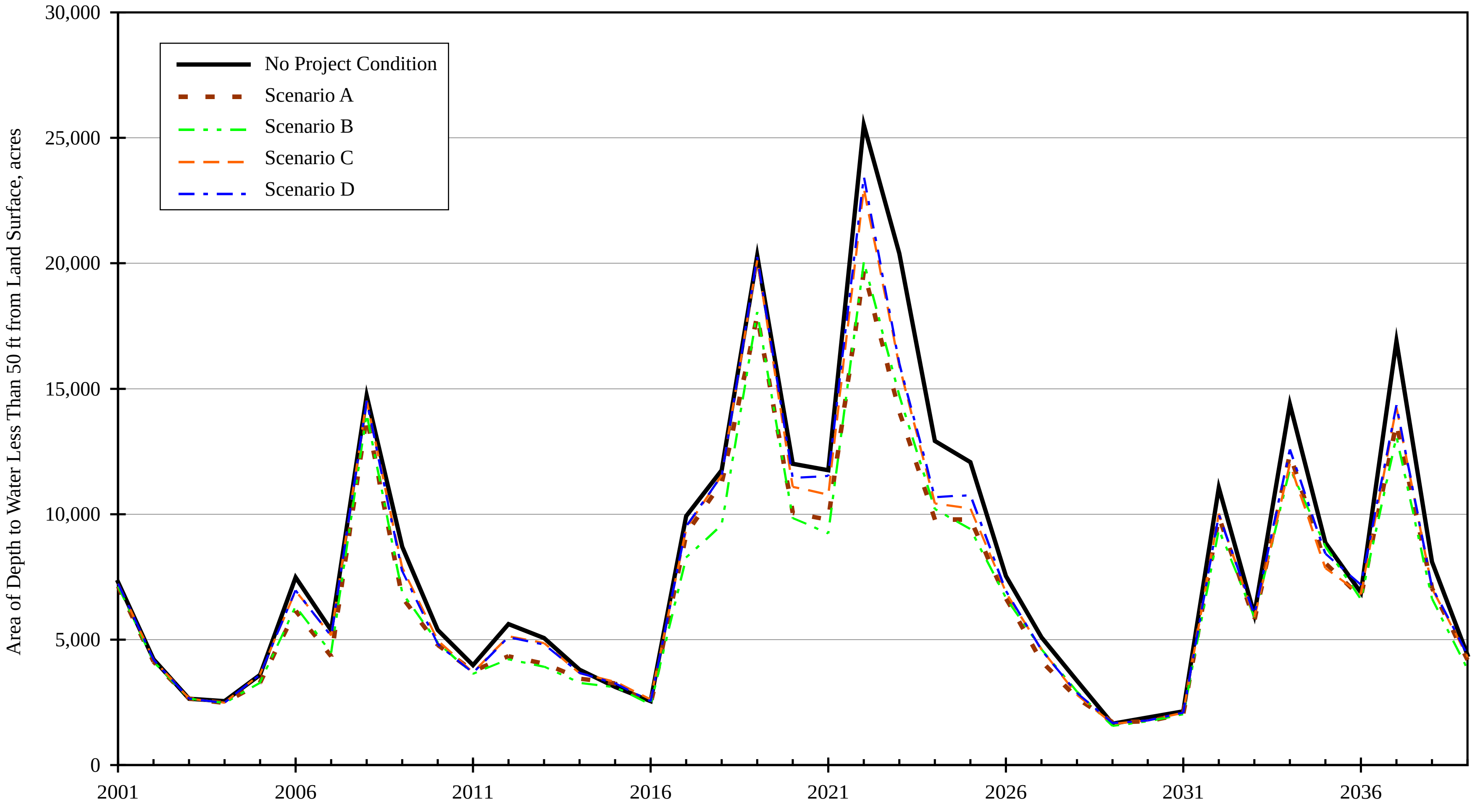
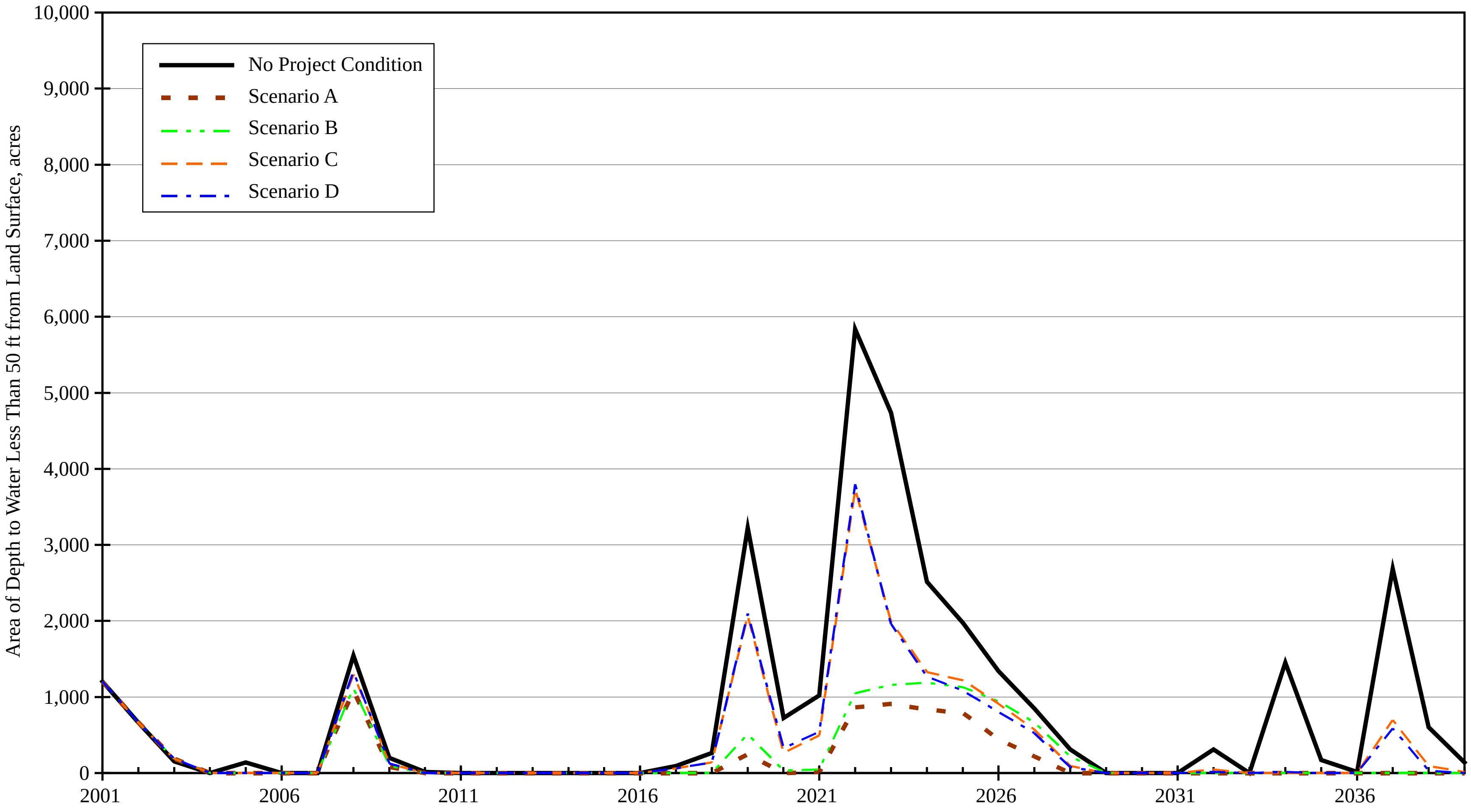
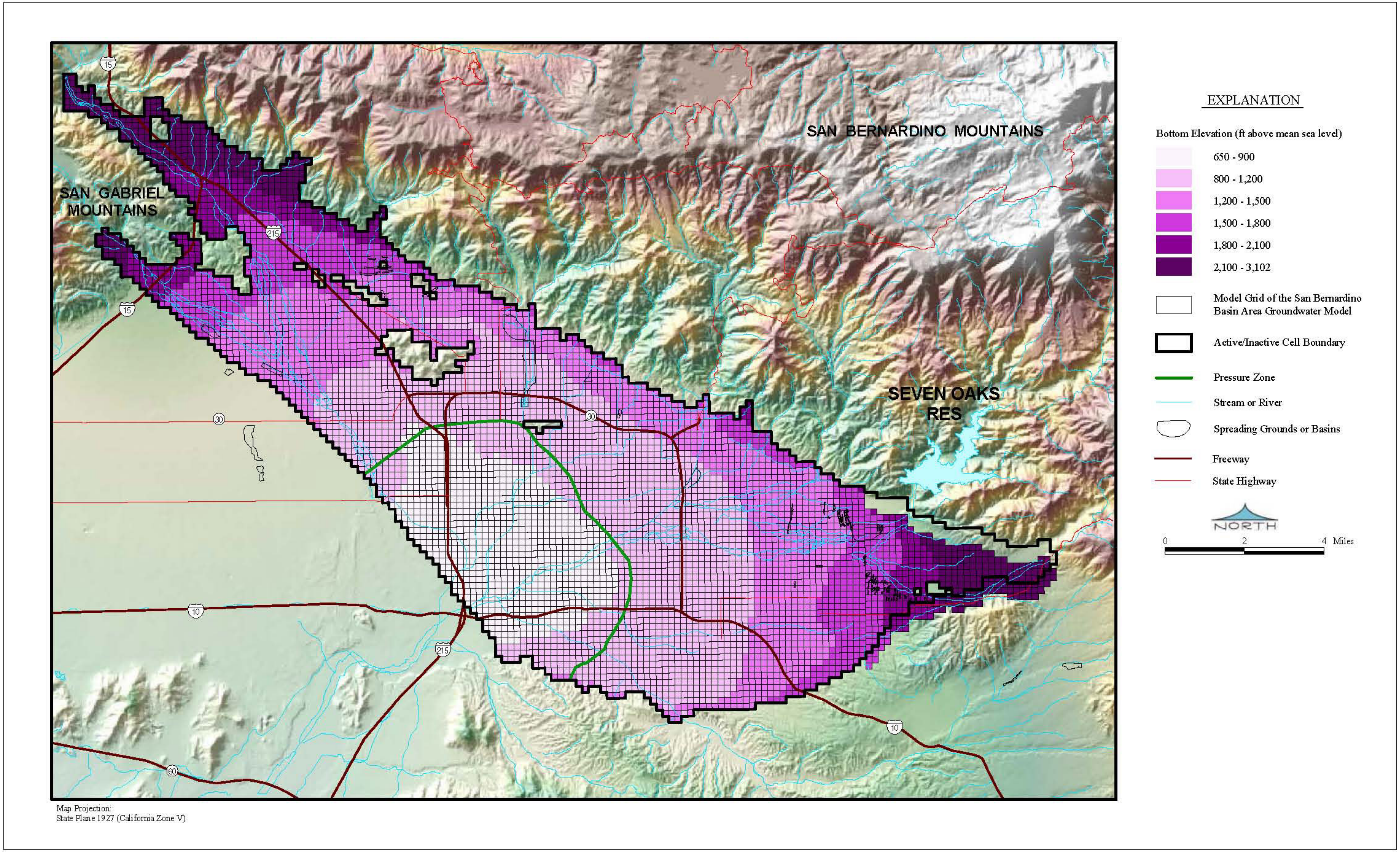


Figure 6.2-25. Area of Depth to Water Less Than 50 ft. from Land Surface of SBBA for Model Scenarios - 2001 to 2039



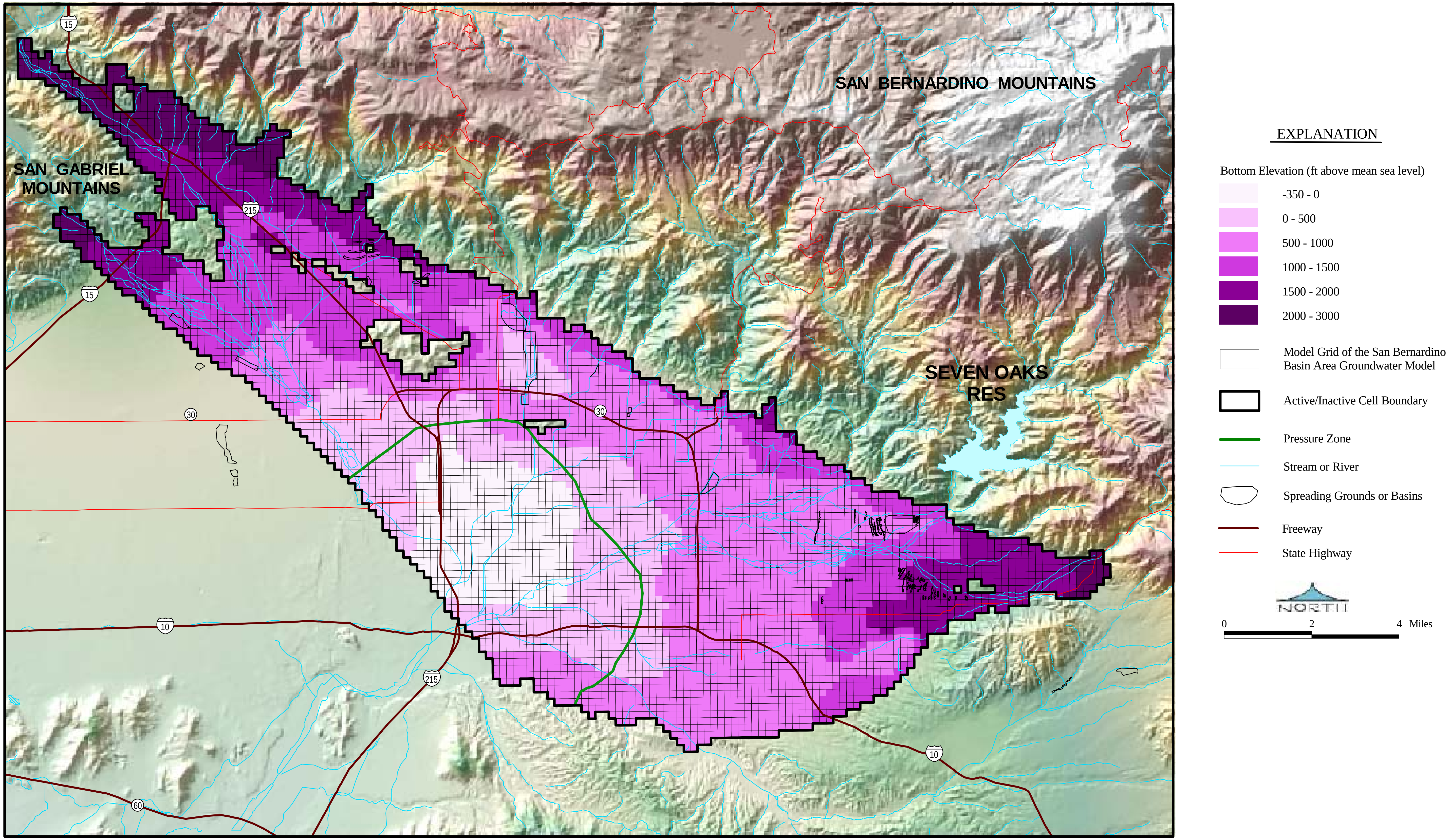
*Not including river channels in the Pressure Zone

Figure 6.2-26. Area of Depth to Water Less Than 50 ft from Land Surface Within the Pressure Zone* for Model Scenarios - 2001 to 2039



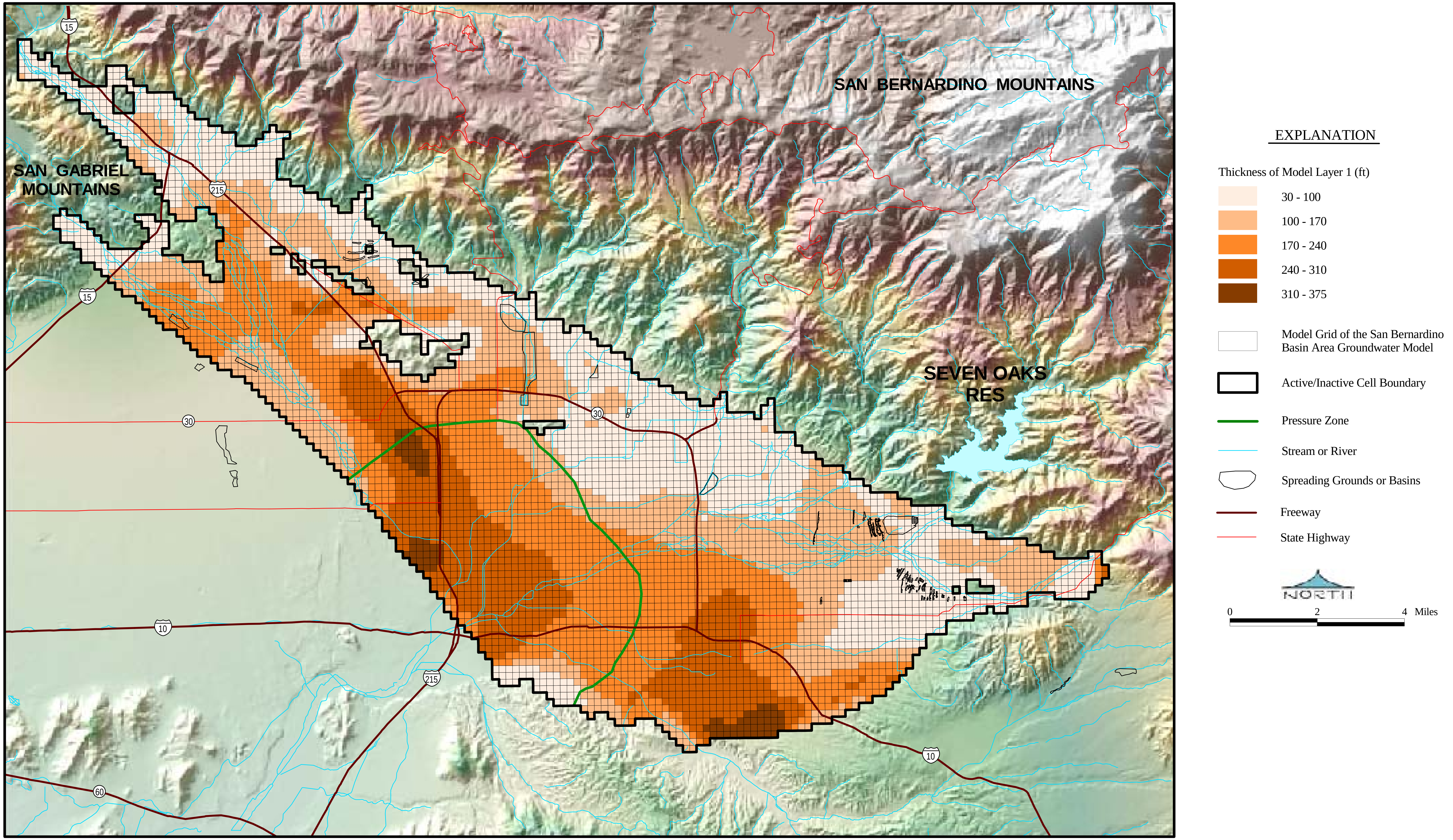
Map Projection:
State Plane 1927 (California Zone V)

Figure 6.3-1. Bottom Elevation of Model Layer 1



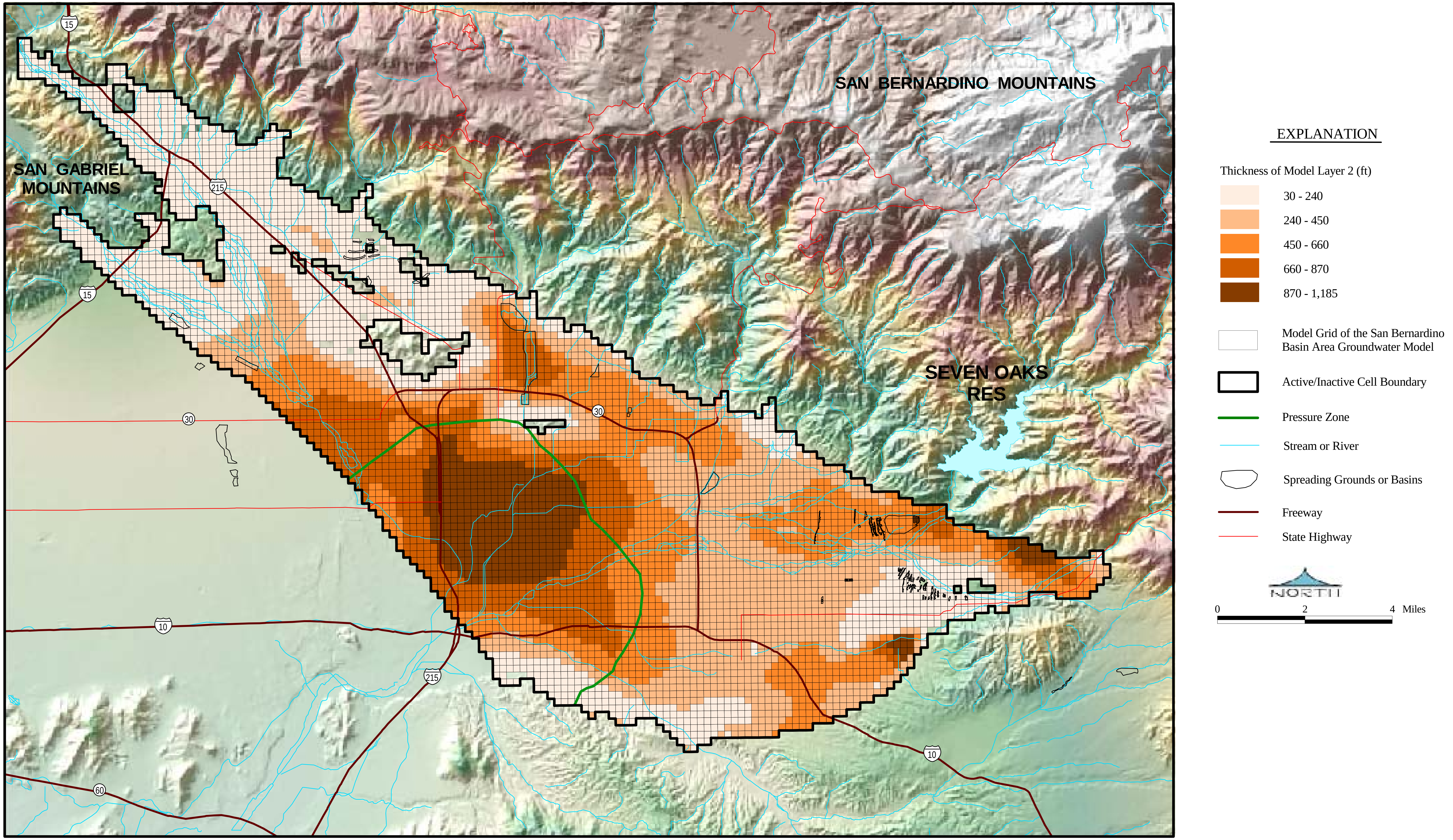
Map Projection:
State Plane 1927 (California Zone V)

Figure 6.3-2. Bottom Elevation of Model Layer 2



Map Projection:
State Plane 1927 (California Zone V)

Figure 6.3-3. Thickness of Model Layer 1



Map Projection:
State Plane 1927 (California Zone V)

Figure 6.3-4. Thickness of Model Layer 2

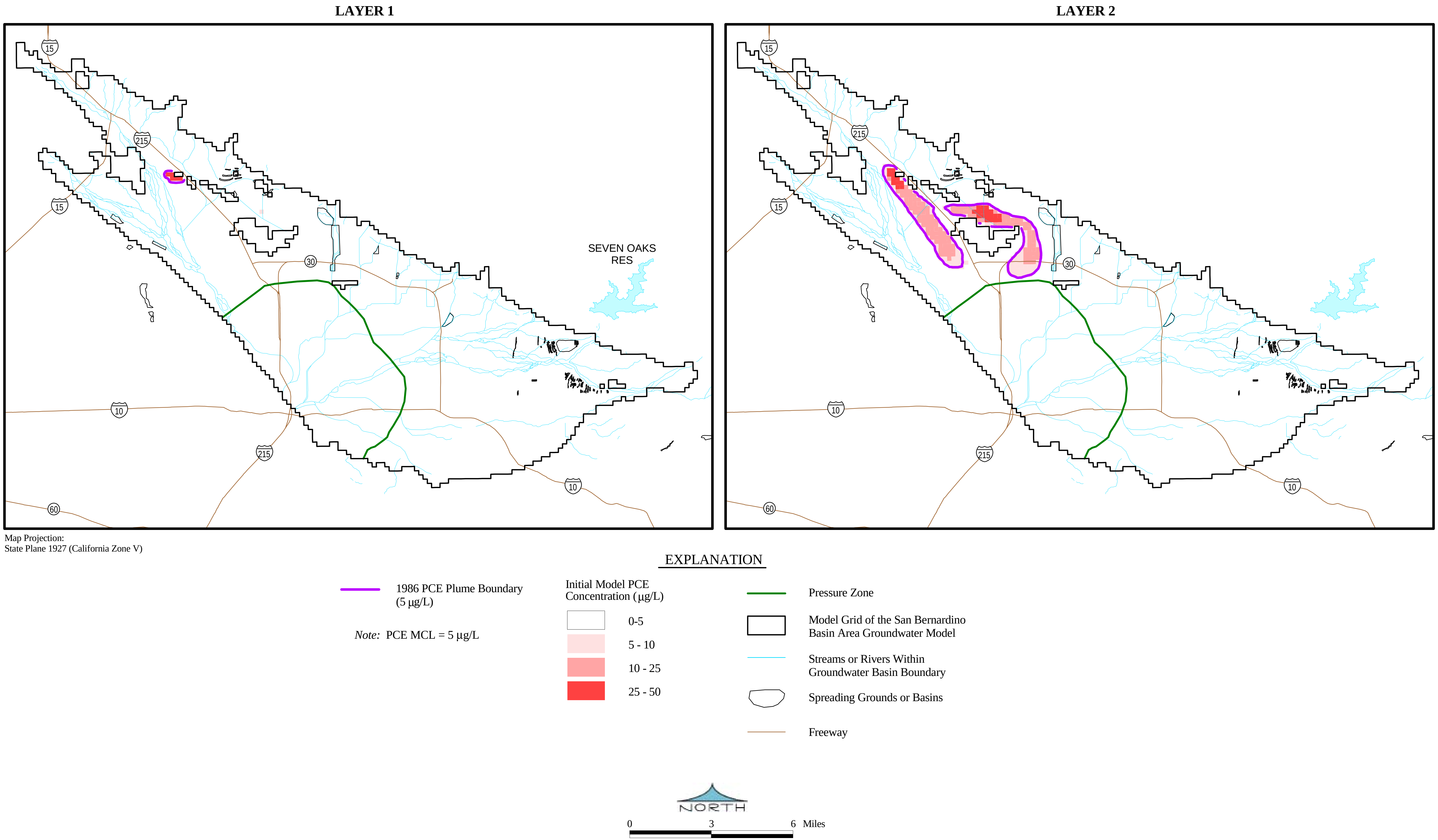


Figure 6.4-1. Initial PCE Concentrations for Model Calibration

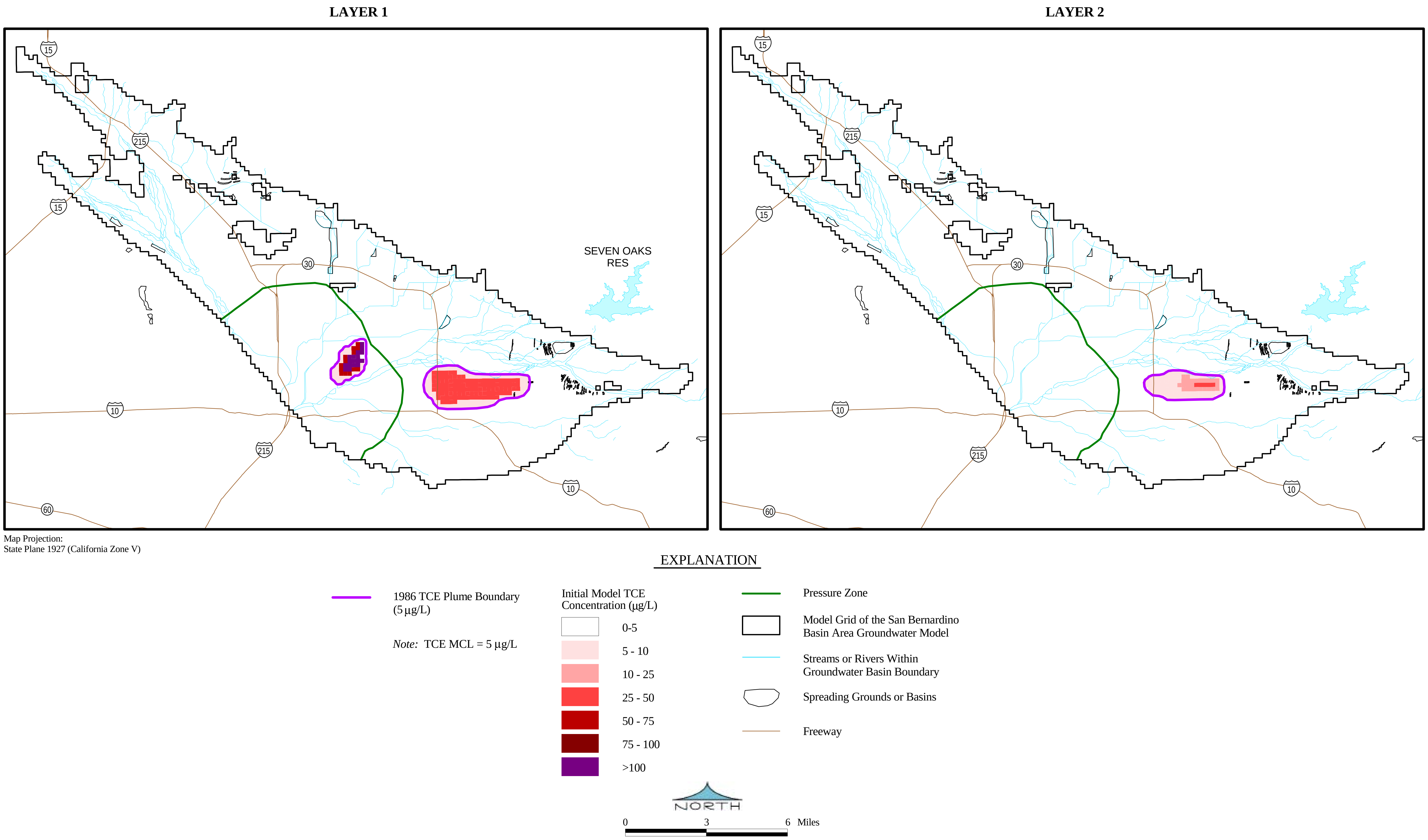


Figure 6.4-2. Initial TCE Concentrations for Model Calibration

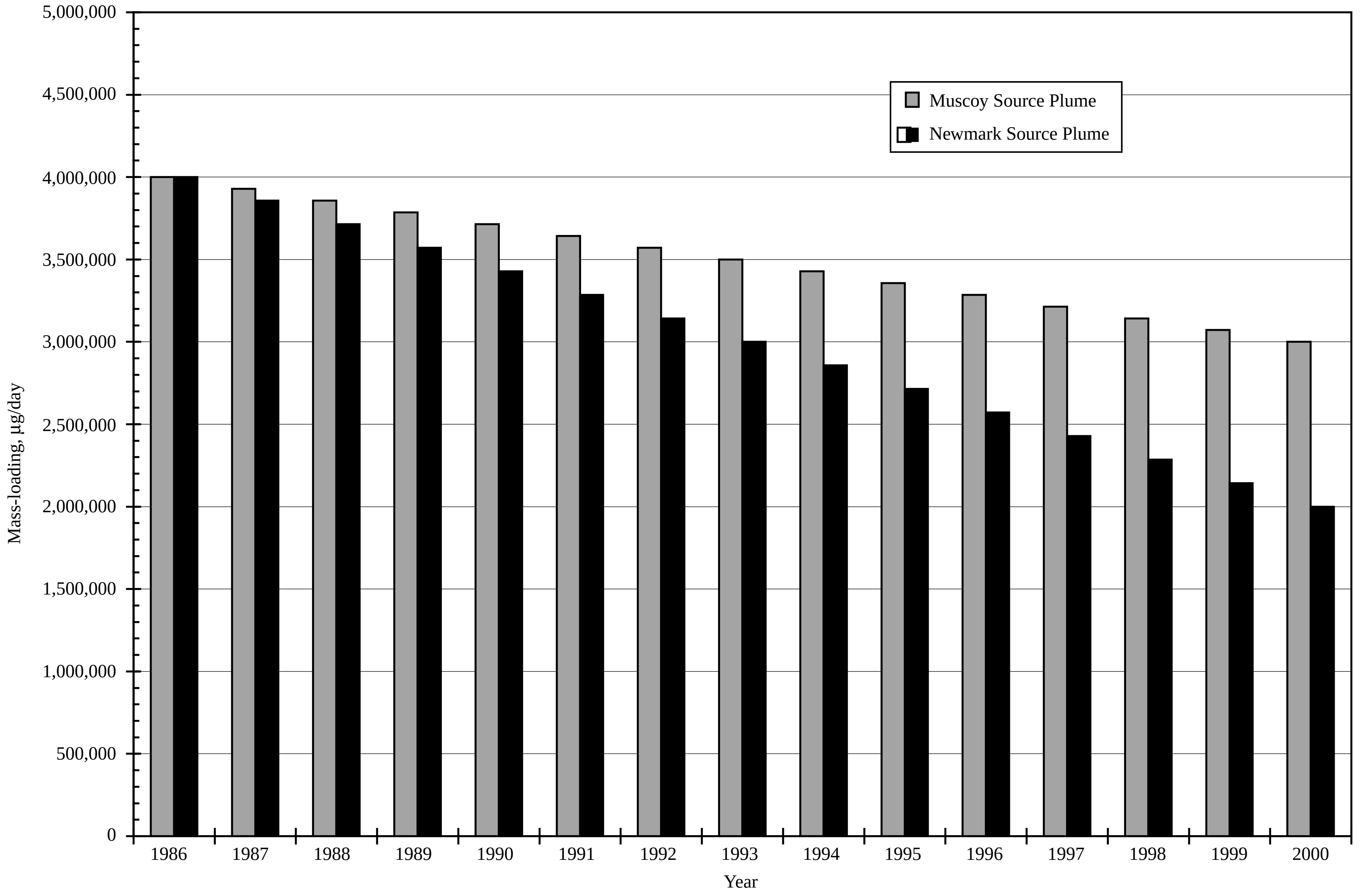


Figure 6.4-3. Mass-Loading for PCE Calibration Model

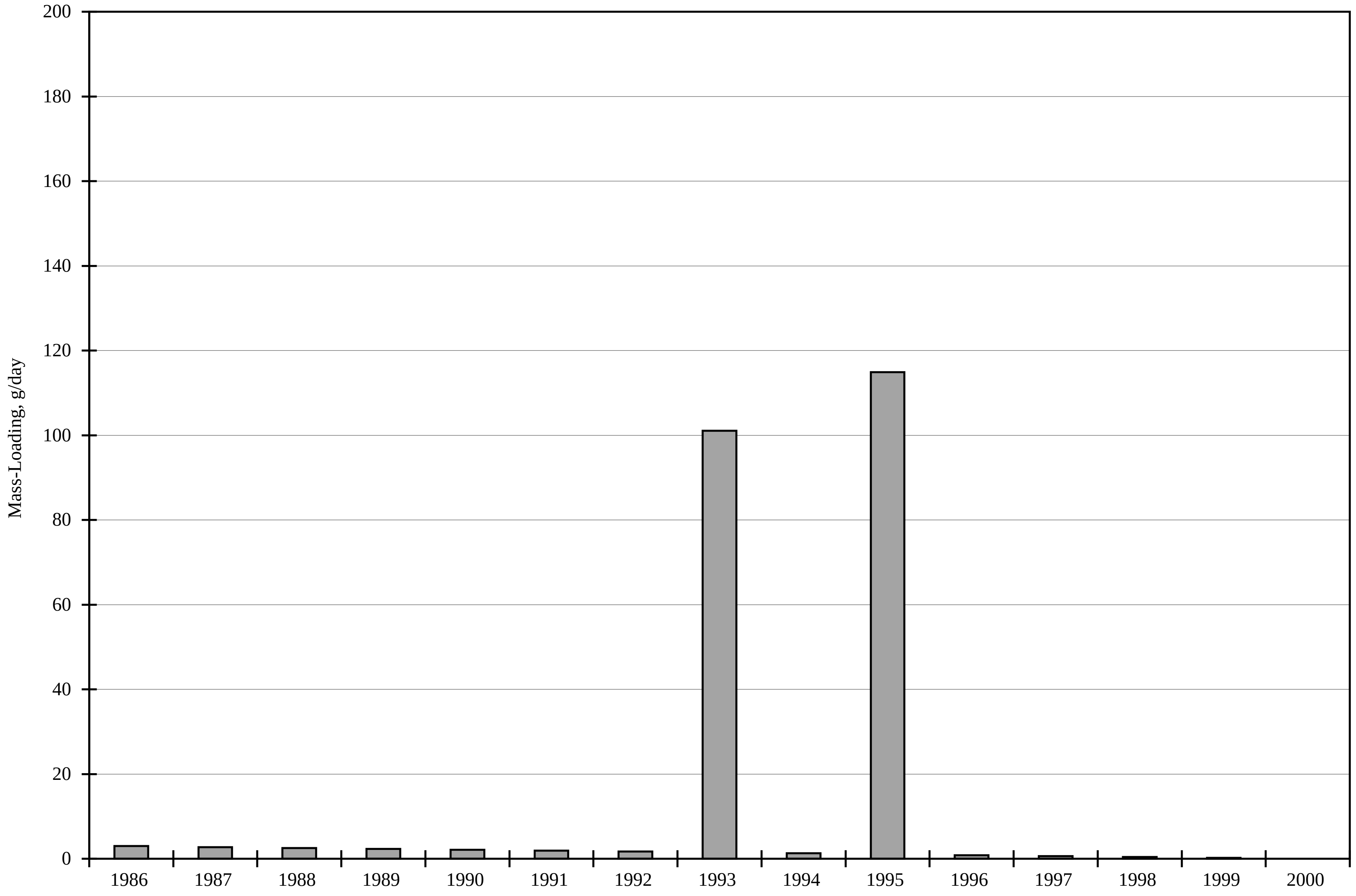


Figure 6.4-4. Mass-Loading for TCE Model Calibration 1986 - 2000

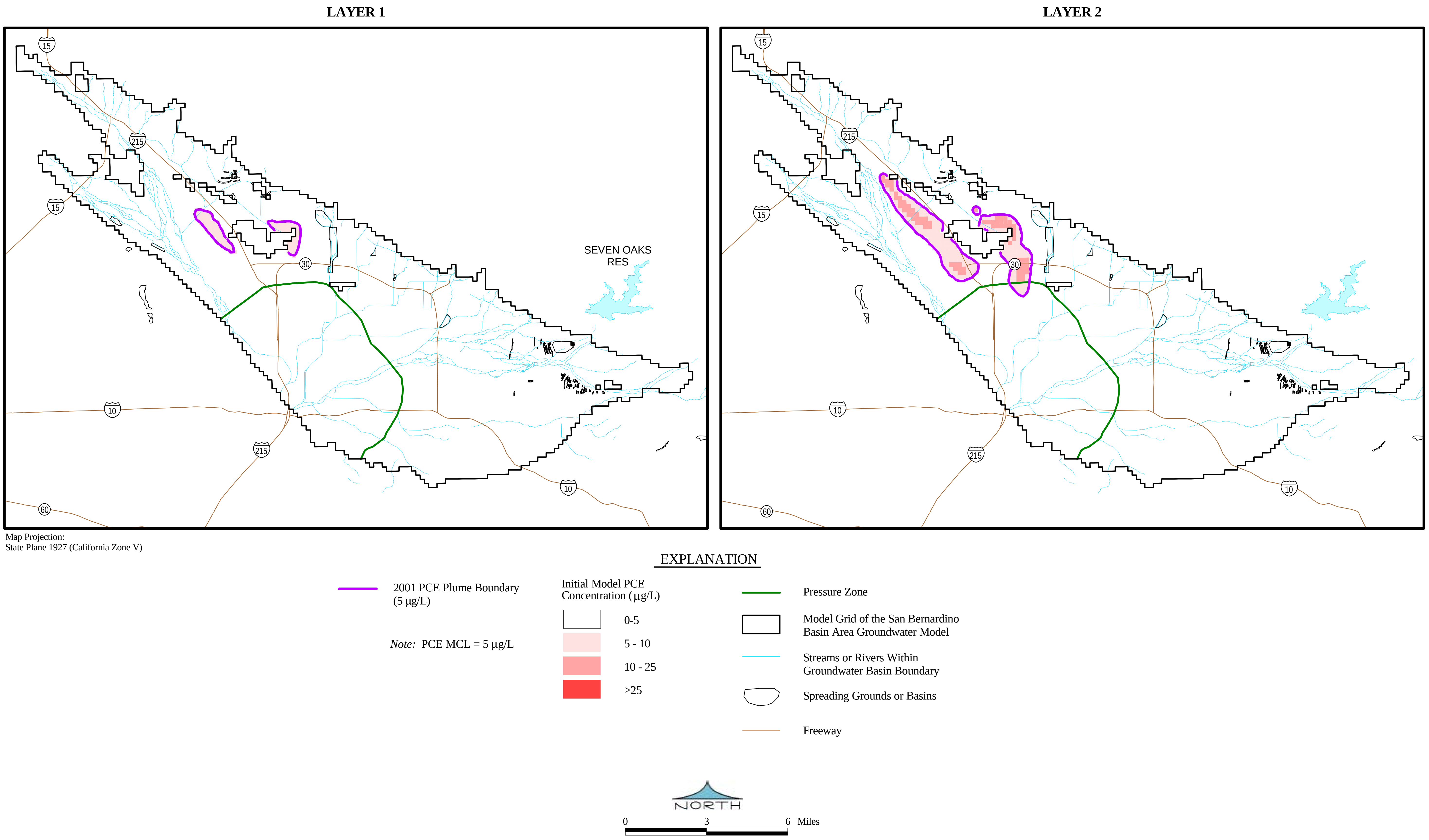


Figure 6.4-5. Initial PCE Concentrations for Model Scenarios - Layers 1 and 2

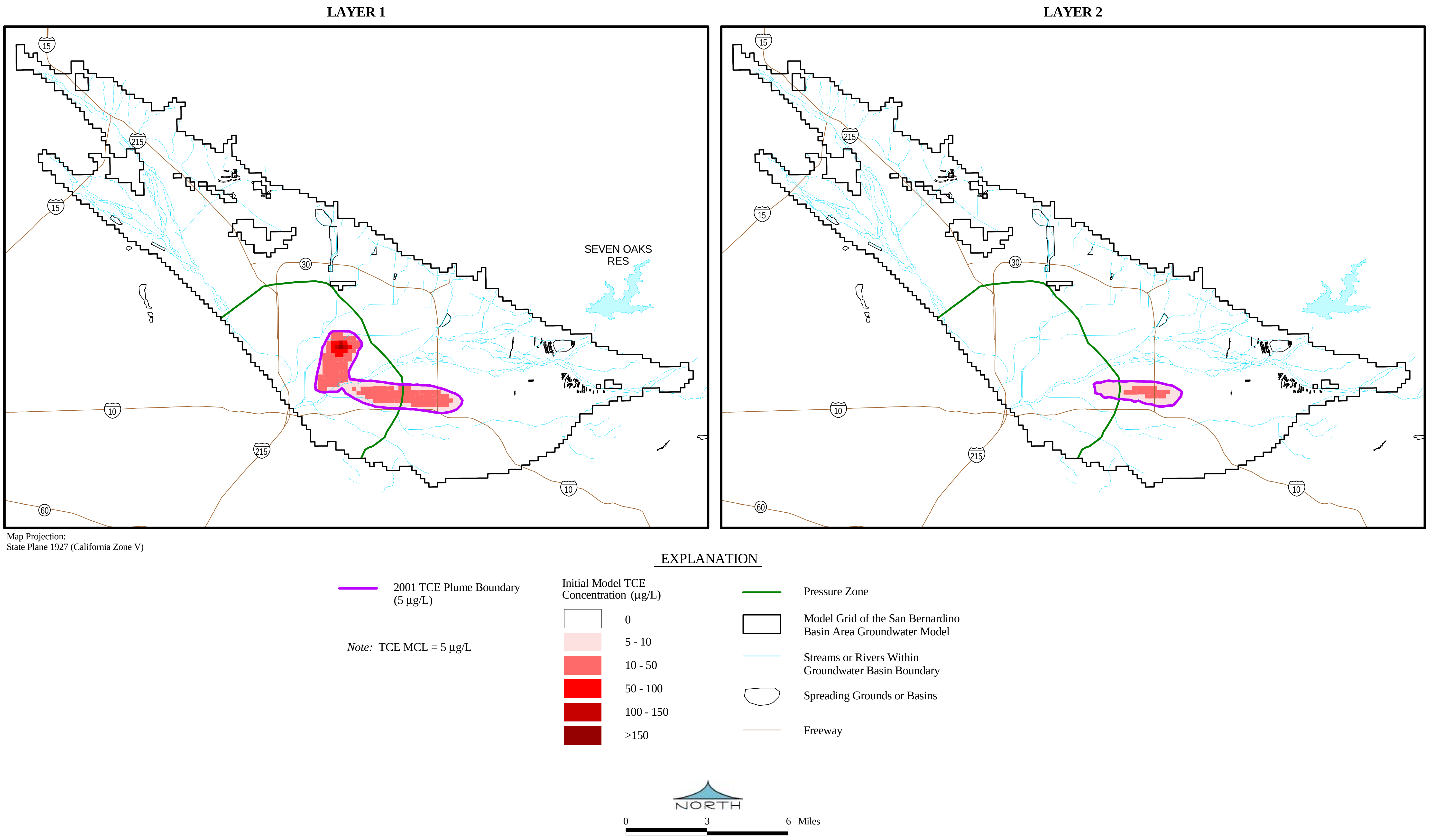


Figure 6.4-6. Initial TCE Concentrations for Model Scenarios - Layers 1 and 2

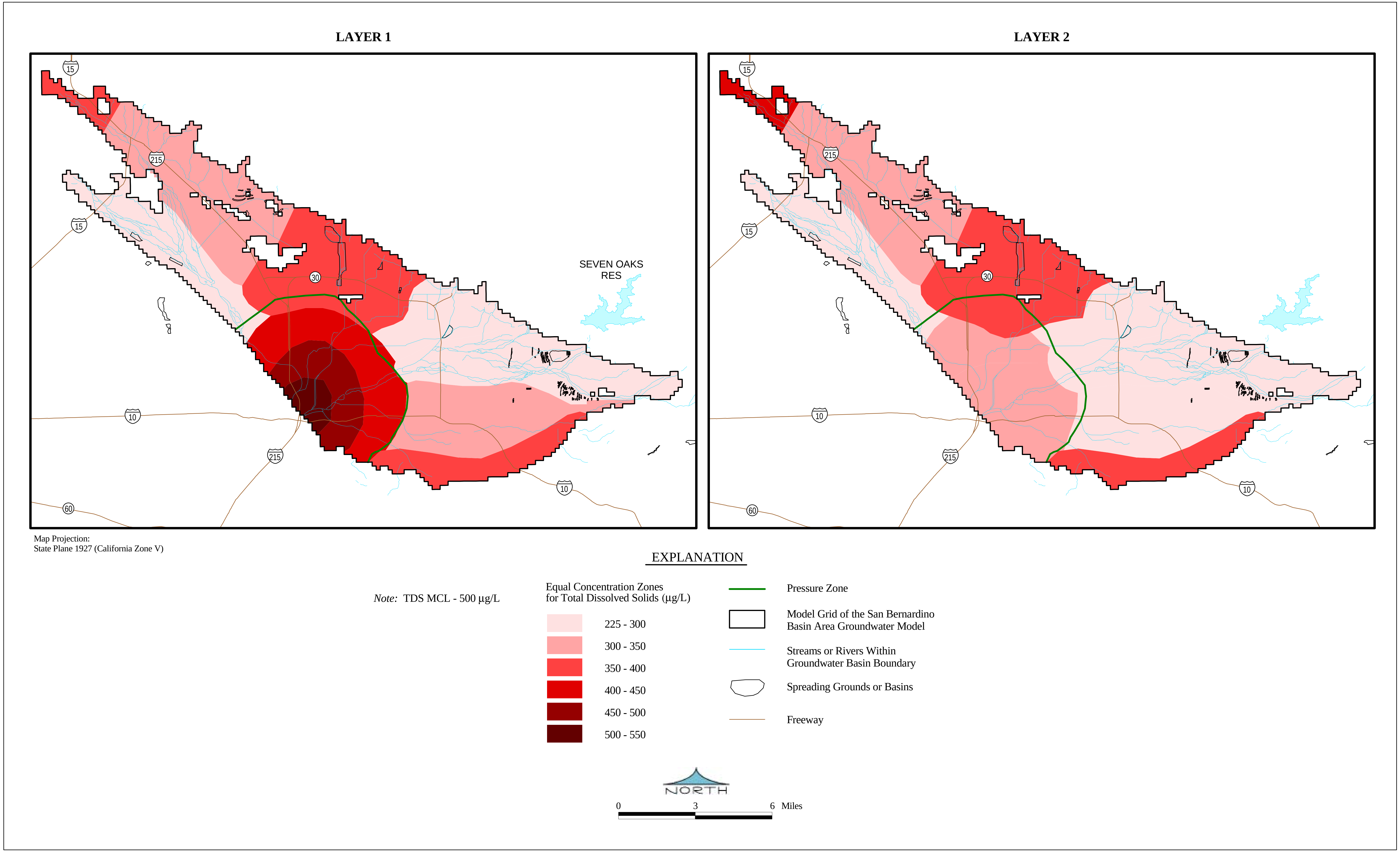


Figure 6.4-7. Equal Concentration Zones for TDS Layers 1 and 2

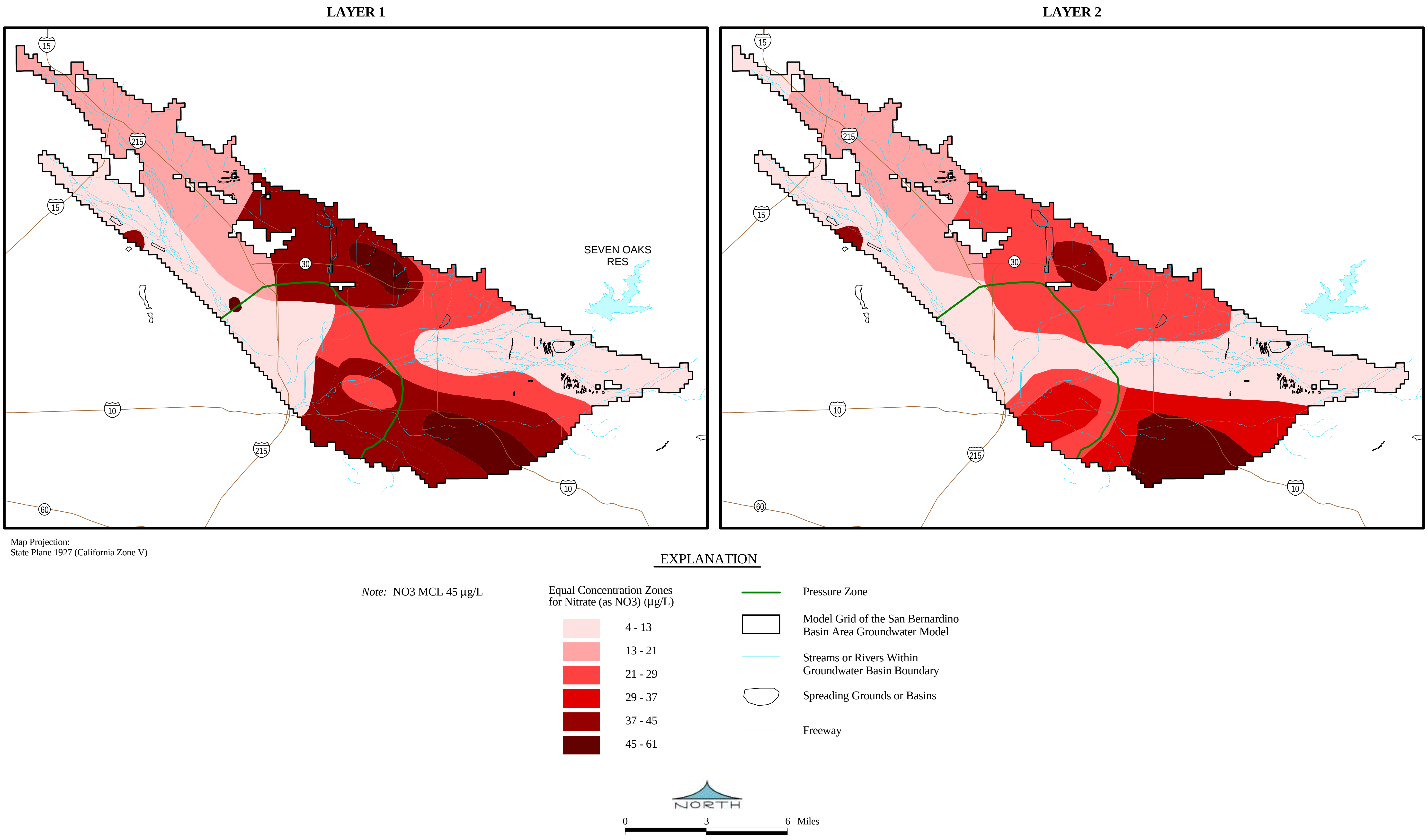
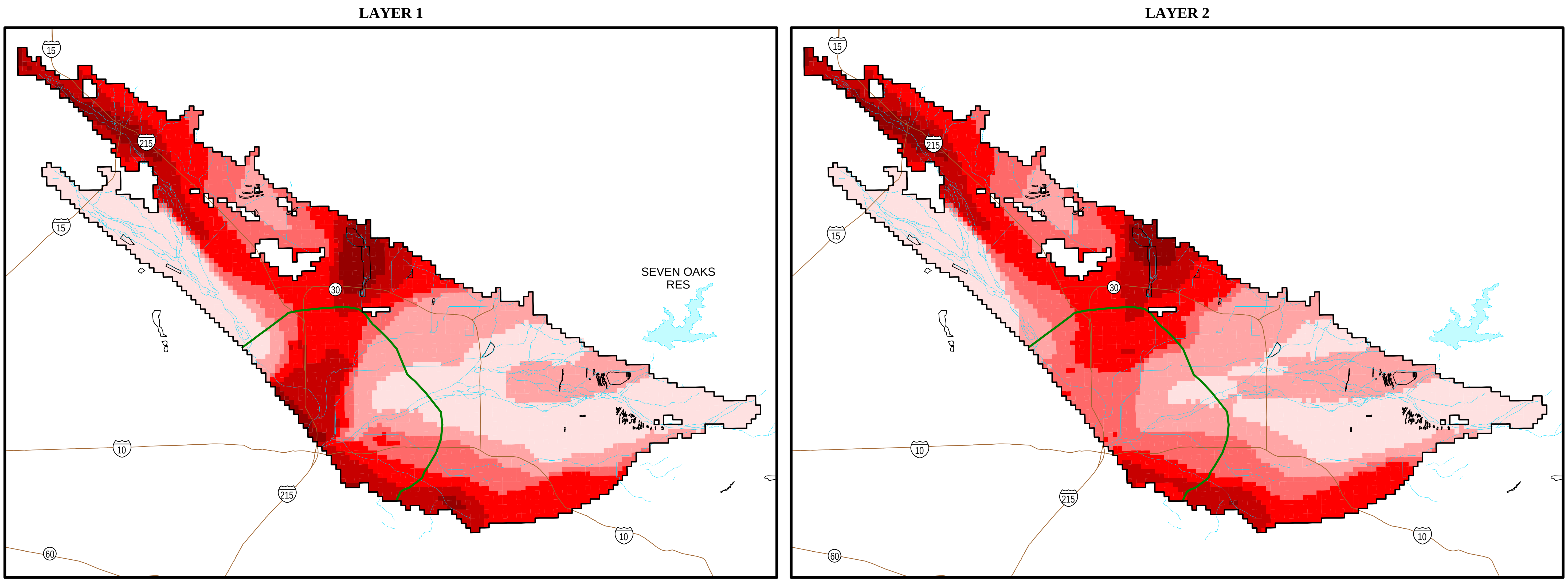


Figure 6.4-8. Equal Concentration Zones for Nitrate (as NO3) - Layers 1 and 2



Map Projection:
State Plane 1927 (California Zone V)

EXPLANATION

Note: TDS MCL = 500 µg/L

Initial Total Dissolved Solids Concentration (µg/L)

- ▨ <250
- ▨ 250 - 300
- ▨ 300 - 350
- ▨ 350 - 400
- ▨ 400 - 450
- ▨ 450 - 500

- Pressure Zone
- Model Grid of the San Bernardino Basin Area Groundwater Model
- Streams or Rivers Within Groundwater Basin Boundary
- Spreading Grounds or Basins
- Freeway

NORTH

0 3 6 Miles

Figure 6.4-9. Initial TDS Concentrations for Model Scenarios - Layers 1 and 2

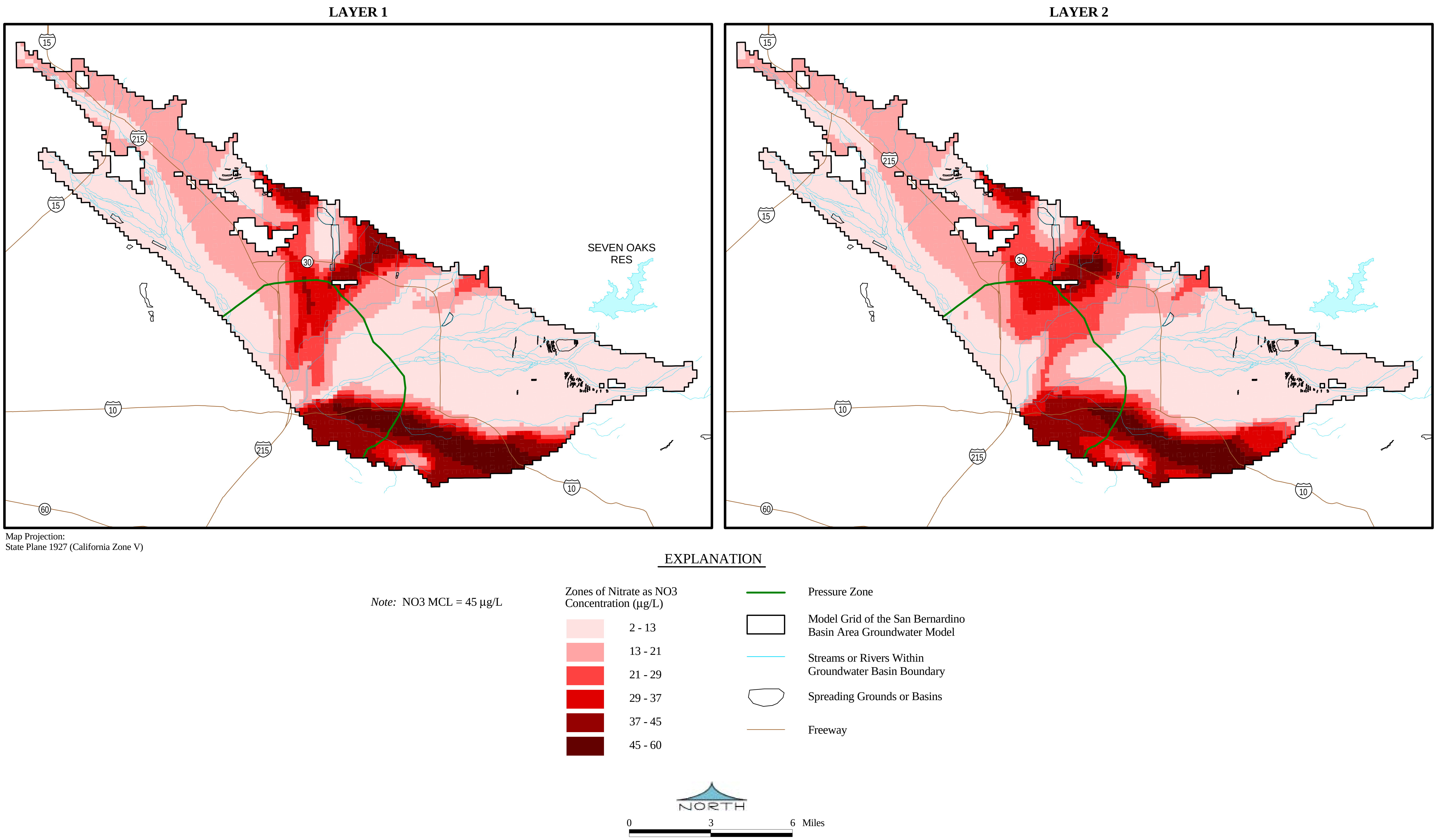


Figure 6.4-10. Initial Nitrate (as NO3) Concentrations for Model Scenarios - Layers 1 and 2

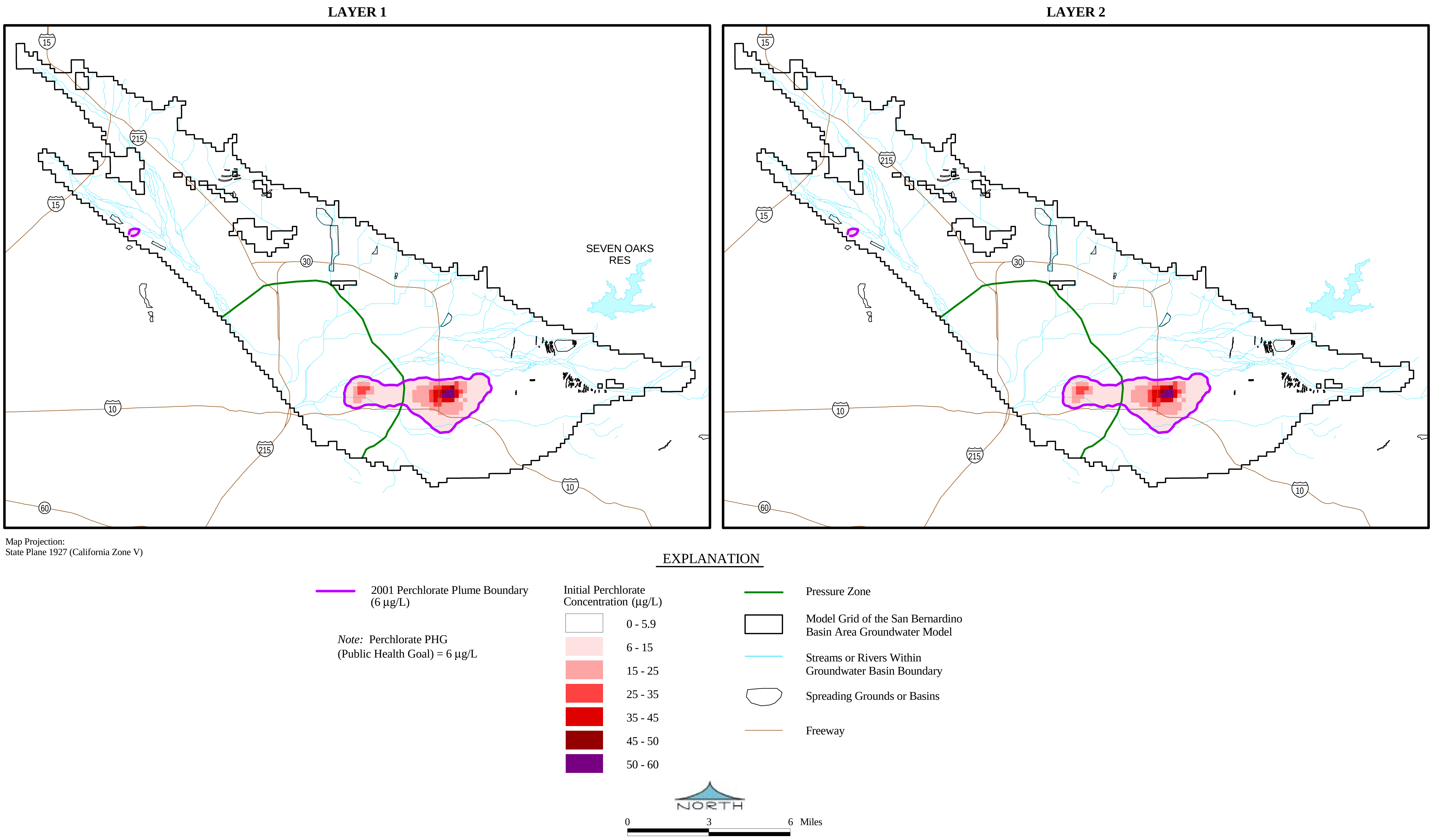


Figure 6.4-11. Initial Perchlorate Concentrations for Model Scenarios - Layers 1 and 2

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8.0 ACRONYMS

af	acre feet
afy	acre feet per year
amsl	above mean sea level
CCR	California Code of Regulations
CDMG	California Division of Mines and Geology
cfs	cubic feet per second
Cl	chloride
cm	centimeter
CRA	Colorado River Aqueduct
DBCP	dibromochloropropane
1,2-DCE	1,2-dichloroethylene
DHS	California Department of Health Services
DWR	California Department of Water Resources
EC	electrical conductivity
EIR	environmental impact report
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
ft	feet
g	gram
gpd	gallons per day
in	inches
LUFT	leaking underground fuel tank
MCL	maximum contaminant level
mg/L	milligrams per liter
MTBE	methyl tertiary butyl ether
MT3DMS	Modular 3-Dimensional Multispecies Transport Model for Simulation
Muni	San Bernardino Valley Municipal Water District
N/A	not applicable
Na	sodium
N	nitrogen
N.D.	no date
NO_3	nitrate

NRC	National Research Council
OEHHA	Office of Environmental Health Hazard Assessment
PCE	tetrachloroethylene
PHG	public health goal
ppb	parts per billion
RWQCB	Regional Water Quality Control Board
SAR	Santa Ana River
SARWQCB	Santa Ana Regional Water Quality Control Board
SAWPA	Santa Ana River Watershed Project Authority
SBBA	San Bernardino Basin Area
SBCFCD	San Bernardino County Flood Control District
SCEC	Southern California Earthquake Center
SG	spreading grounds
SO_4	sulfate
SOC	synthetic organic chemical
SWP	State Water Project
SWRCB	State Water Resources Control Board
TCE	trichloroethylene
TDS	total dissolved solids
TIN	Total Inorganic Nitrogen
TRW	TRW, Incorporated
µg/L	micrograms per liter
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	volatile organic compound
WCD	San Bernardino Valley Water Conservation District
Western	Western Municipal Water District of Riverside County
WQO	water quality objective

9.0 TERMS AND DEFINITIONS

Unless otherwise noted, the terms used in this report are definitions taken from the State of California Department of Water Resources, Bulletin No. 118 (September 1975), the *Handbook of Ground Water* Development (Roscoe Moss 1990), the *Handbook of Hydrology* (Maidment, ed., 1993), or the *Dictionary of Geological Terms* (revised edition, 1976, prepared under direction of the American Geological Institute).

Acre-ft:	The volume of water necessary to cover one acre to a depth of one foot; equal to 43,560 cubic ft or 325,851 gallons.
Advective dispersion:	The process in which the concentration of a solute decreases with distance from the source, because of different flow patterns and velocities, thereby causing a solute plume to spread out. Longitudinal dispersivity is an aquifer property that describes the amount that a solute plume will spread in the direction of flow and is greater than transverse (or lateral) dispersivity, which describes the amount of spreading perpendicular to flow.
Alluvium:	A geological term describing beds of gravel, sand, silt and clay deposited by flowing water.
Aquifer:	A geologic formation that stores, transmits, and yields significant quantities of water to wells and springs. The term may denote a single bed, or a sequence of beds whose individual permeable beds may be lenticular and vaguely individual, but which generally are not separated by extensive, relatively impermeable beds (USGS Professional Paper 486-J). See also "confined aquifer."
Aquitard:	A less permeable geologic unit that stores but does not readily transmit water. Aquitards are also known as "semi-confining" or "leaky" layers. Groundwater may flow through aquitards – the rate being dependent upon both the difference in hydraulic head across the layer and the leakance.
Confined Aquifer:	A permeable geologic unit located beneath a relatively impermeable unit whose piezometric water level is higher than the confining layer.
Effective Porosity:	A fraction of void space which forms part of the interconnected flow paths through the medium, per unit volume of porous medium (excluding void space isolated or dead-end pores).
Effluent:	A stream which gains water from an aquifer

Extraction:	Generally refers to the pumping of groundwater from wells.
Fault:	A fracture in the earth's crust, with displacement of one side of the fracture with respect to the other. A fault frequently acts as a barrier to the movement of groundwater.
Formation:	A geologic term that designates a specific group of underground beds or strata which have been deposited in sequence one above the other and during the same period of geologic time.
Groundwater:	The water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined or semi-confined aquifer.
Groundwater Basin:	An alluvial aquifer or stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and a definable bottom.
Hydraulic Characteristic Value:	The barrier transmissivity divided by the width of the horizontal-flow barrier)
Hydraulic Conductivity:	The measure of the ability of the aquifer to transmit water. Hydraulic conductivity depends upon both the properties of the material and those of the fluid.
Hydraulic Gradient:	The rate of change in hydraulic head per unit distance of flow in a given direction; (e.g., the slope of the water table).
Hydrology:	The origin, distribution, and circulation of water of the earth, including precipitation, stream flow, infiltration, groundwater storage, and evaporation.
Infiltration:	The process of water entry into the soil surface from rainfall, snowmelt, or irrigation and the subsequent percolation downward through the soil. (Stored soil water may be consumptively used by vegetation, may percolate further downward to groundwater storage, or may exit the soil surface as seeps or springs.
Influent:	A stream which loses water to an aquifer.
MODFLOW:	A modular finite difference groundwater flow model developed by the USGS.
MODPATH:	A particle-tracking program utilizing flow directions and seepage velocities from the groundwater flow model (MODFLOW)

Percolation:	The flow or trickling of water through the soil or alluvium to the groundwater table.
Permeability:	The capability of soil or other geologic formations to transmit water. The term is used to separate the effects of the medium from those of the fluid on the hydraulic conductivity.
Porosity:	Fraction of void space per unit volume of porous medium.
Recharge:	Flow to groundwater storage from precipitation, infiltration from streams, and other sources of water.
Retardation Factor:	The retardation factor determines the amount that the movement of a solute is slowed in relationship to the flow of groundwater as a result of adsorption of the solute to the aquifer materials.
Return Flow:	That portion of water used for irrigation and domestic purposes which returns either to the ground or surface stream system, expressed as a percent of total water used.
Specific Capacity:	The ratio of a well's yield to its drawdown – usually expressed as gpm/ft.
Specific Yield:	Equal to effective porosity.
Storage:	The amount of groundwater storage in an aquifer is determined by the volume of saturated material multiplied by the effective porosity (i.e., specific yield).
Storativity:	An aquifer parameter defined as the product of specific storativity and saturated aquifer thickness. In unconfined aquifers storativity equals effective porosity.
Streamflow:	Flow rate along a defined natural channel (usually measured in cubic feet per second [cfs])
Transmissivity:	Rate of flow of water through an aquifer. The product of hydraulic conductivity and the layer thickness.
Unconfined aquifer:	A permeable geologic unit with the water table forming its upper boundary.
Water table:	The surface where groundwater is encountered in a water well in an unconfined aquifer.

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ADDENDUM TO APPENDIX B

LIST OF FIGURES

ADDENDUM TO APPENDIX B

LIST OF TABLES

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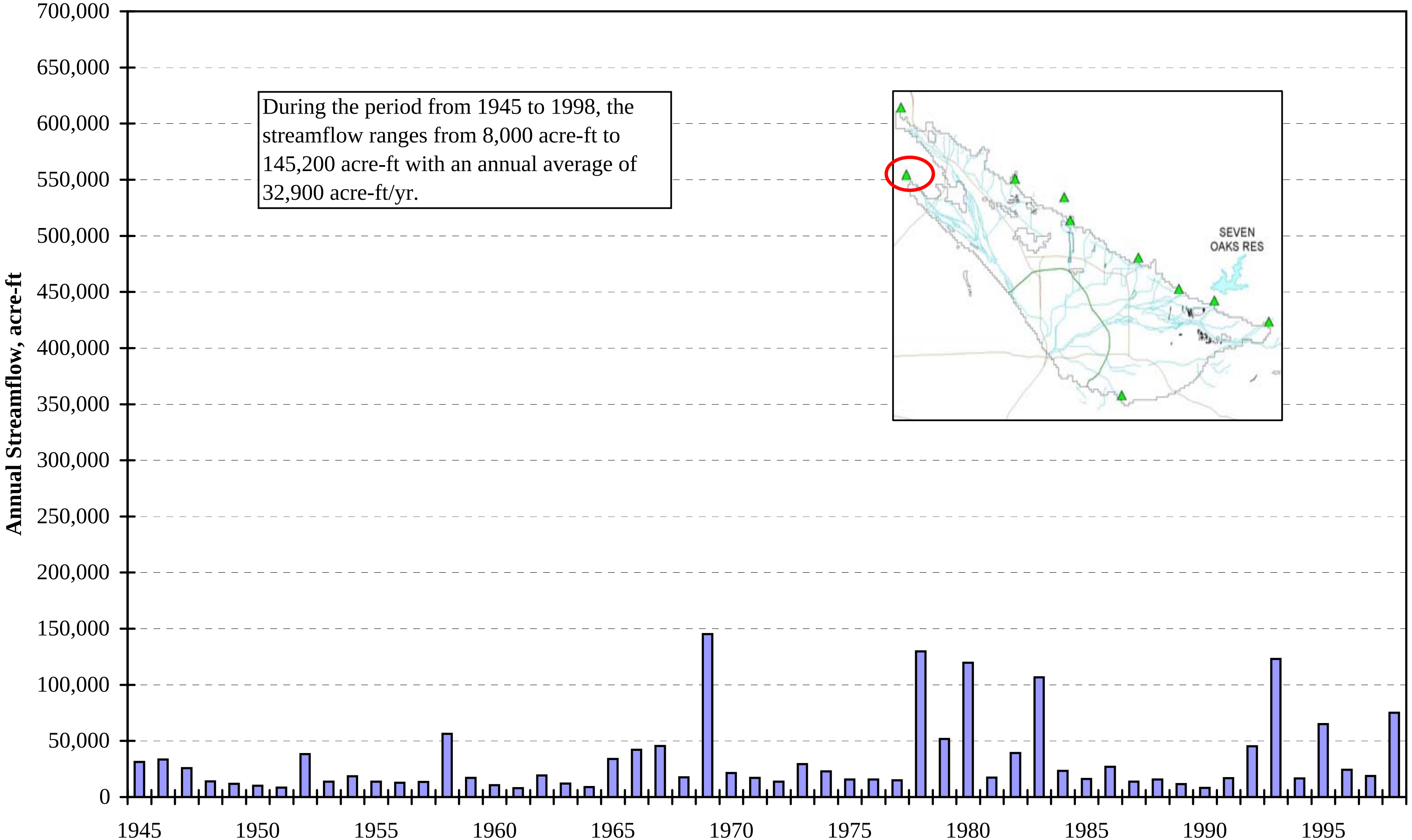
Annual Streamflow at Lytle Creek near Fontana Gaging Station
1945-1998

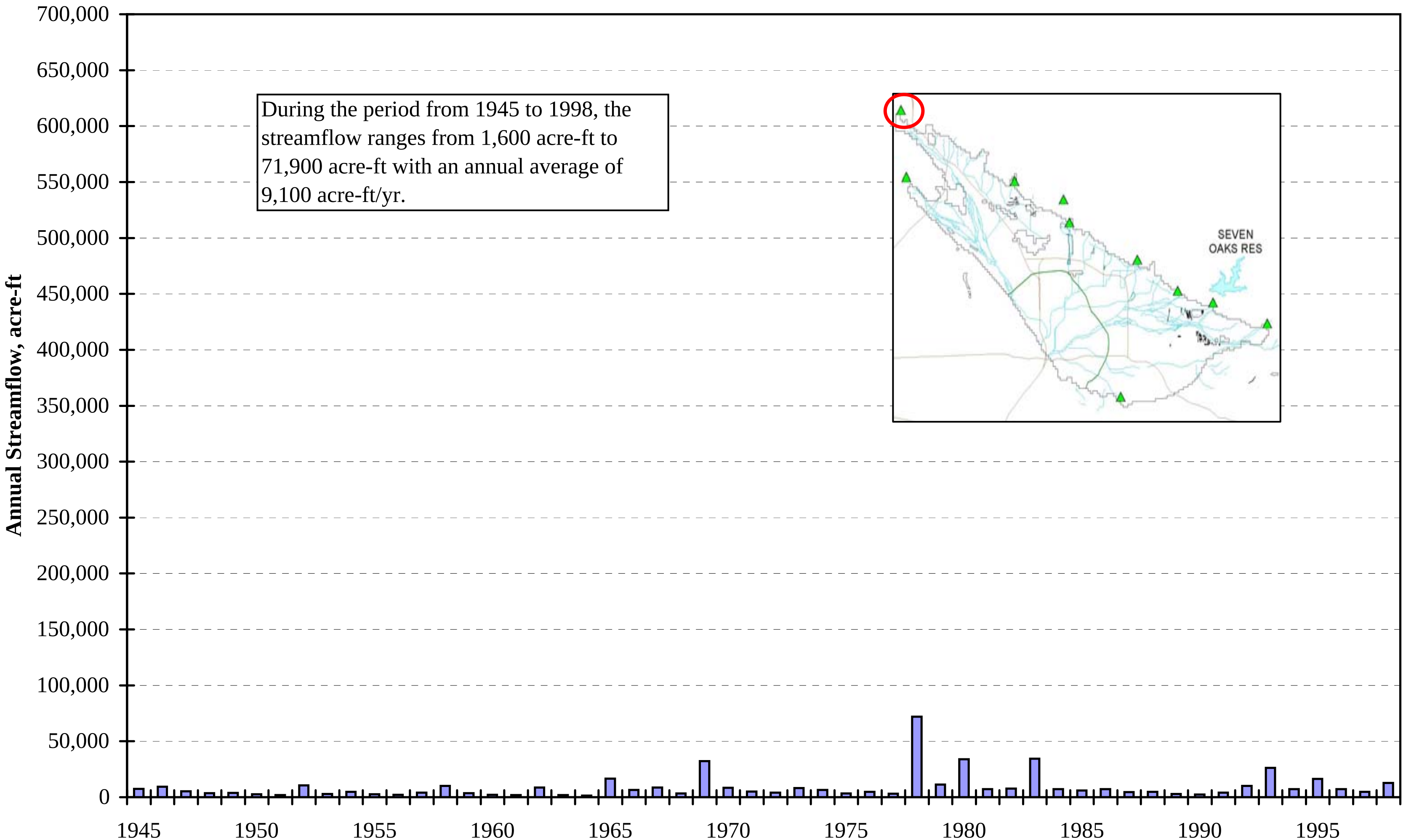


During the period from 1945 to 1998, the streamflow ranges from 8,000 acre-ft to 145,200 acre-ft with an annual average of 32,900 acre-ft/yr.

Source: USGS

Figure B 1

Annual Streamflow at Cajon Creek below Lone Pine Creek near Keenbrook Gaging Station 1945-1998

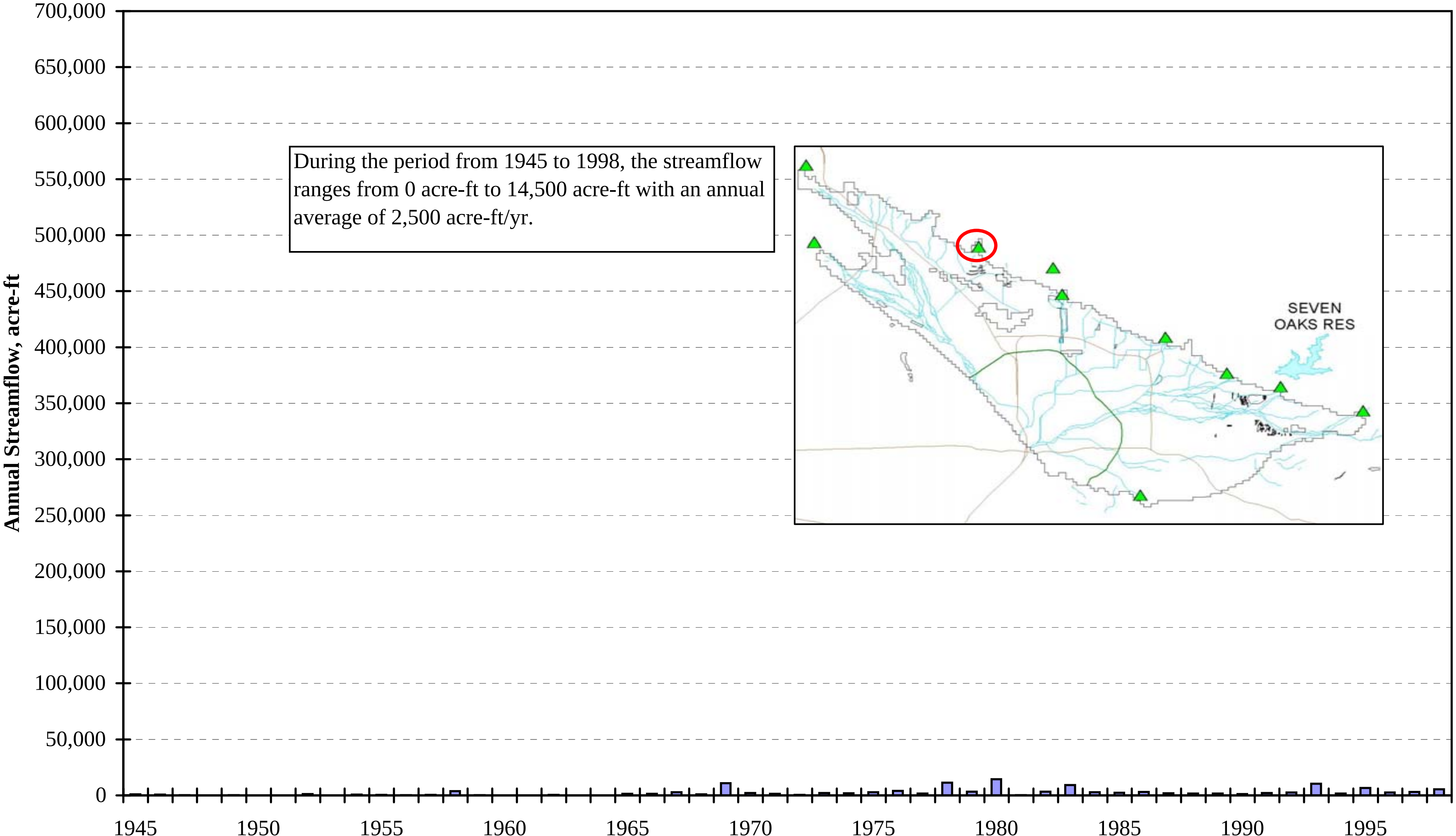


During the period from 1945 to 1998, the streamflow ranges from 1,600 acre-ft to 71,900 acre-ft with an annual average of 9,100 acre-ft/yr.

Source: USGS

Figure B 2

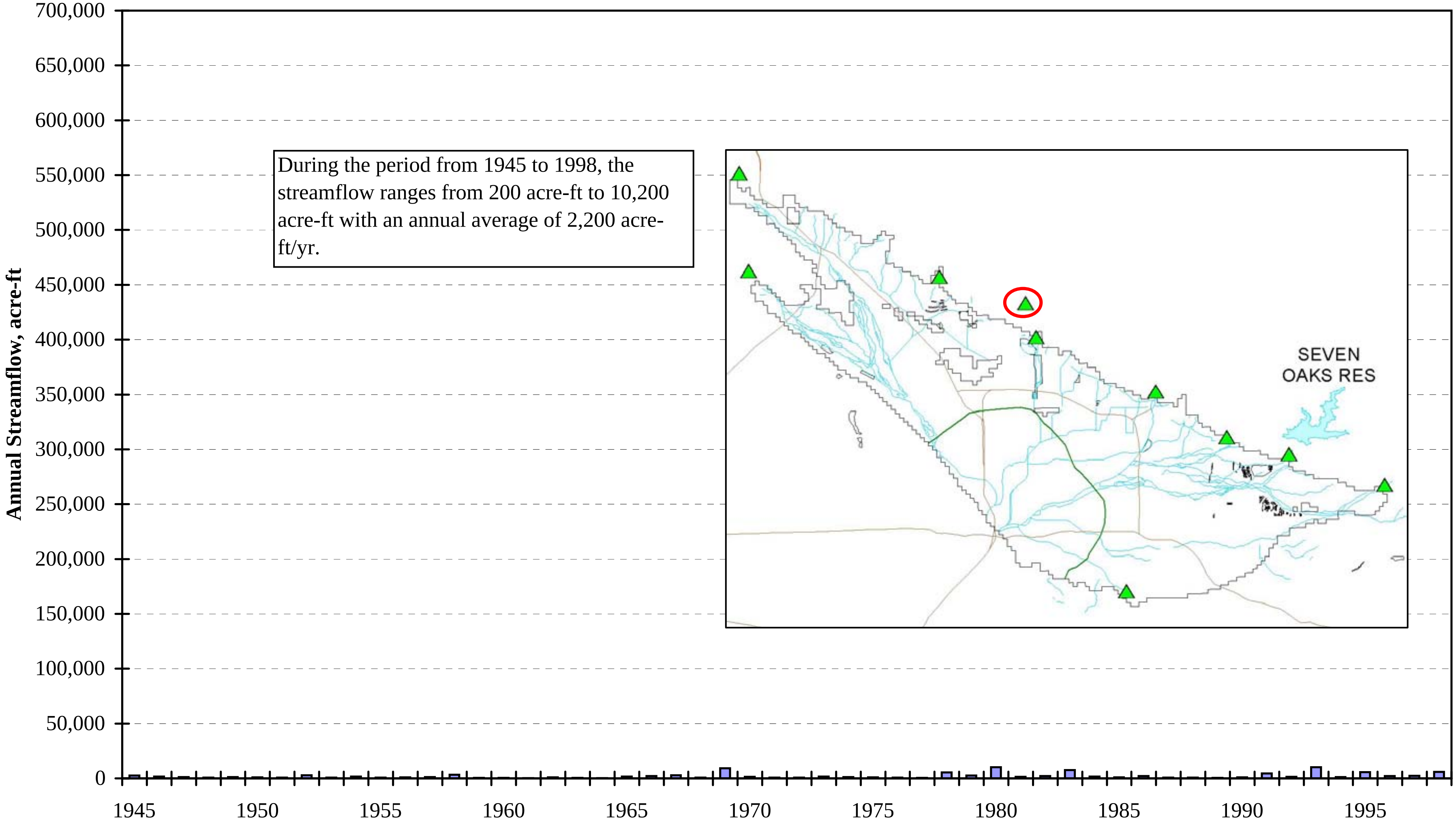
Annual Streamflow at Devil Canyon Creek near San Bernardino Gaging Station
1945-1998


During the period from 1945 to 1998, the streamflow ranges from 0 acre-ft to 14,500 acre-ft with an annual average of 2,500 acre-ft/yr.

Source: USGS

Figure B 3

Annual Streamflow at Waterman Canyon Creek near Arrowhead Springs Gaging Station
1945-1998

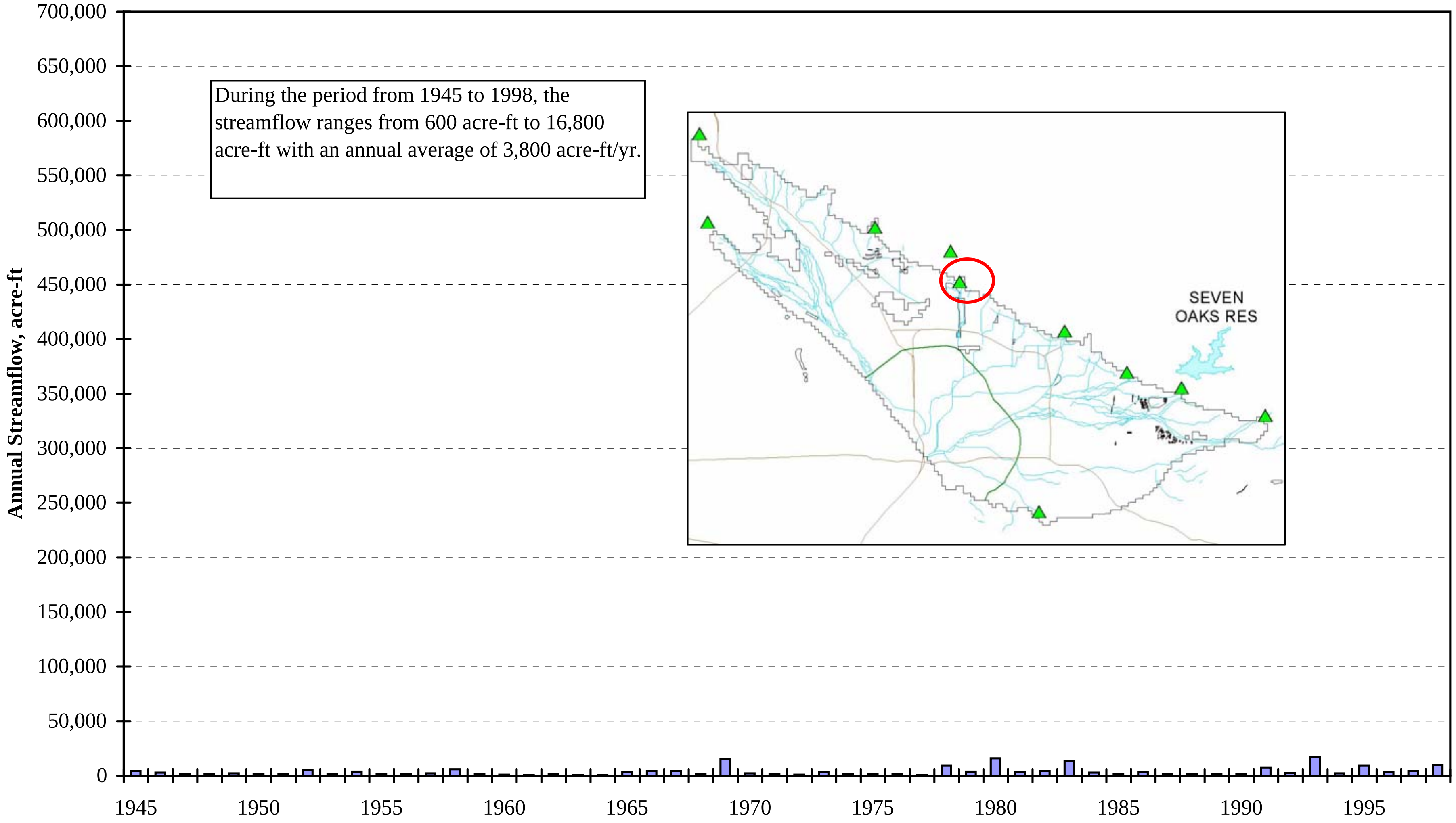


During the period from 1945 to 1998, the streamflow ranges from 200 acre-ft to 10,200 acre-ft with an annual average of 2,200 acre-ft/yr.

Source: USGS

Figure B 4

Annual Streamflow at East Twin Creek near Arrowhead Springs Gaging Station
1945-1998

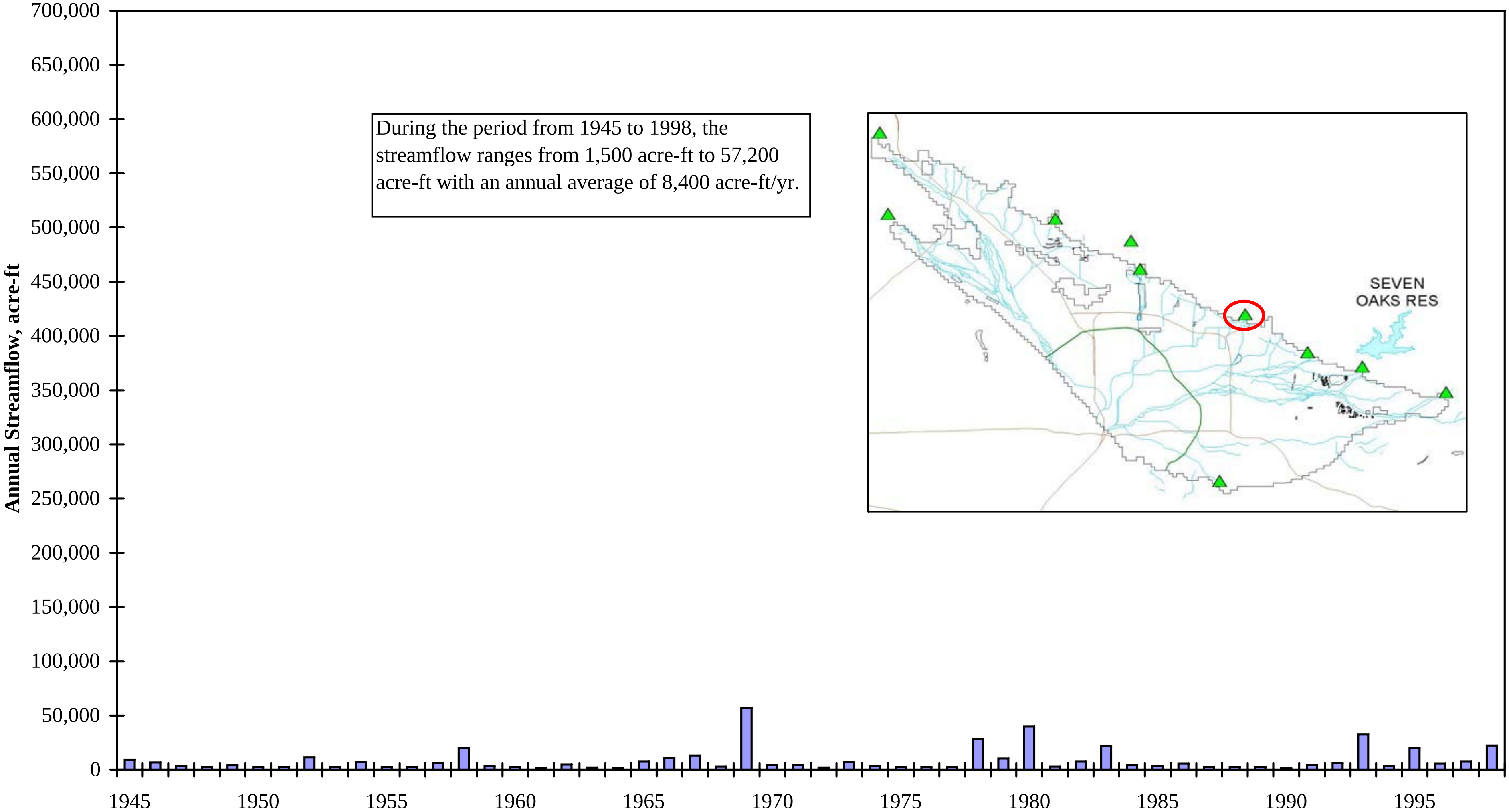


During the period from 1945 to 1998, the streamflow ranges from 600 acre-ft to 16,800 acre-ft with an annual average of 3,800 acre-ft/yr.

Source: USGS

Figure B 5

Annual Streamflow at City Creek near Highland Gaging Station
1945-1998

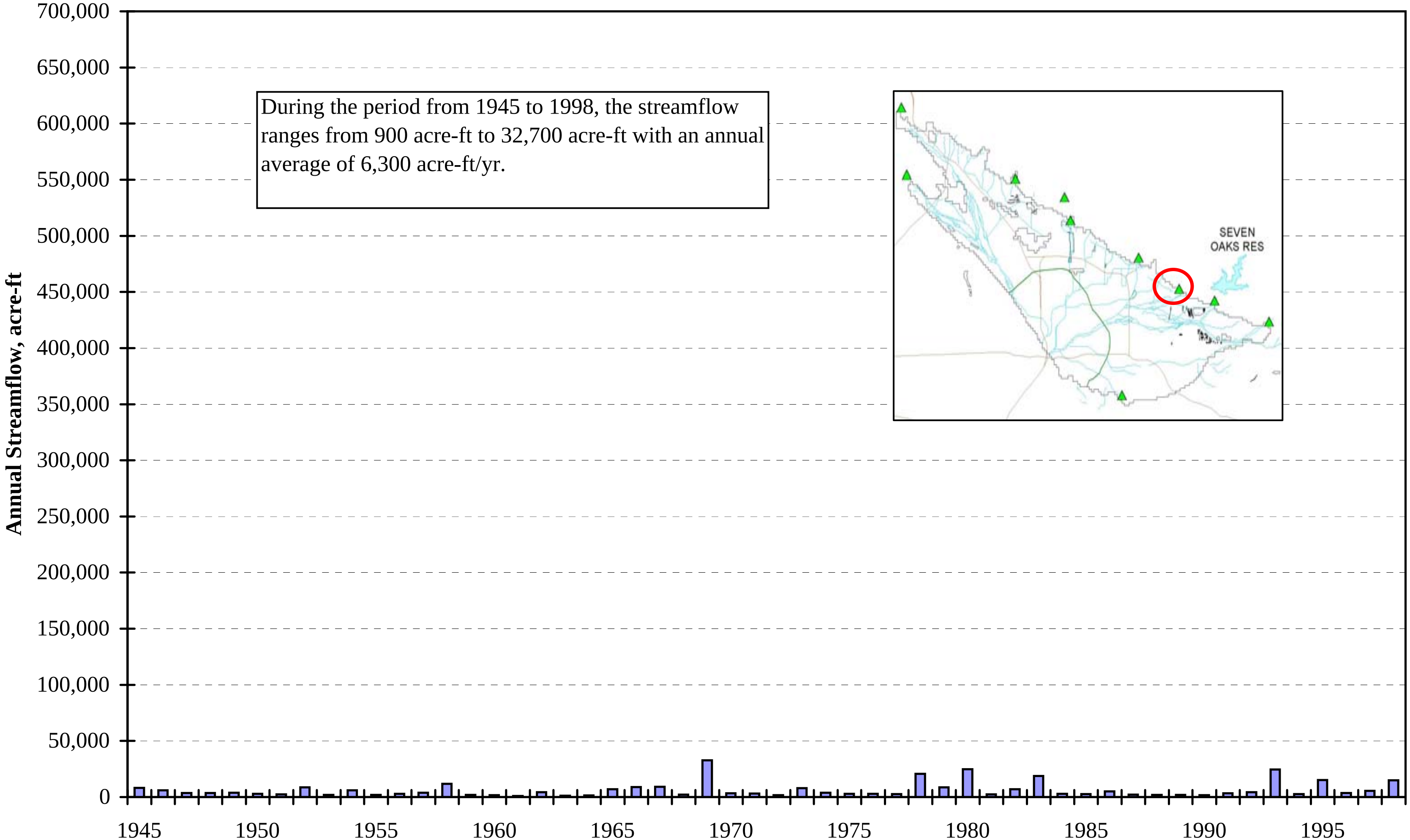


During the period from 1945 to 1998, the streamflow ranges from 1,500 acre-ft to 57,200 acre-ft with an annual average of 8,400 acre-ft/yr.

Source: USGS

Figure B 6

Annual Streamflow at Plunge Creek near East Highlands Gaging Station
1945-1998

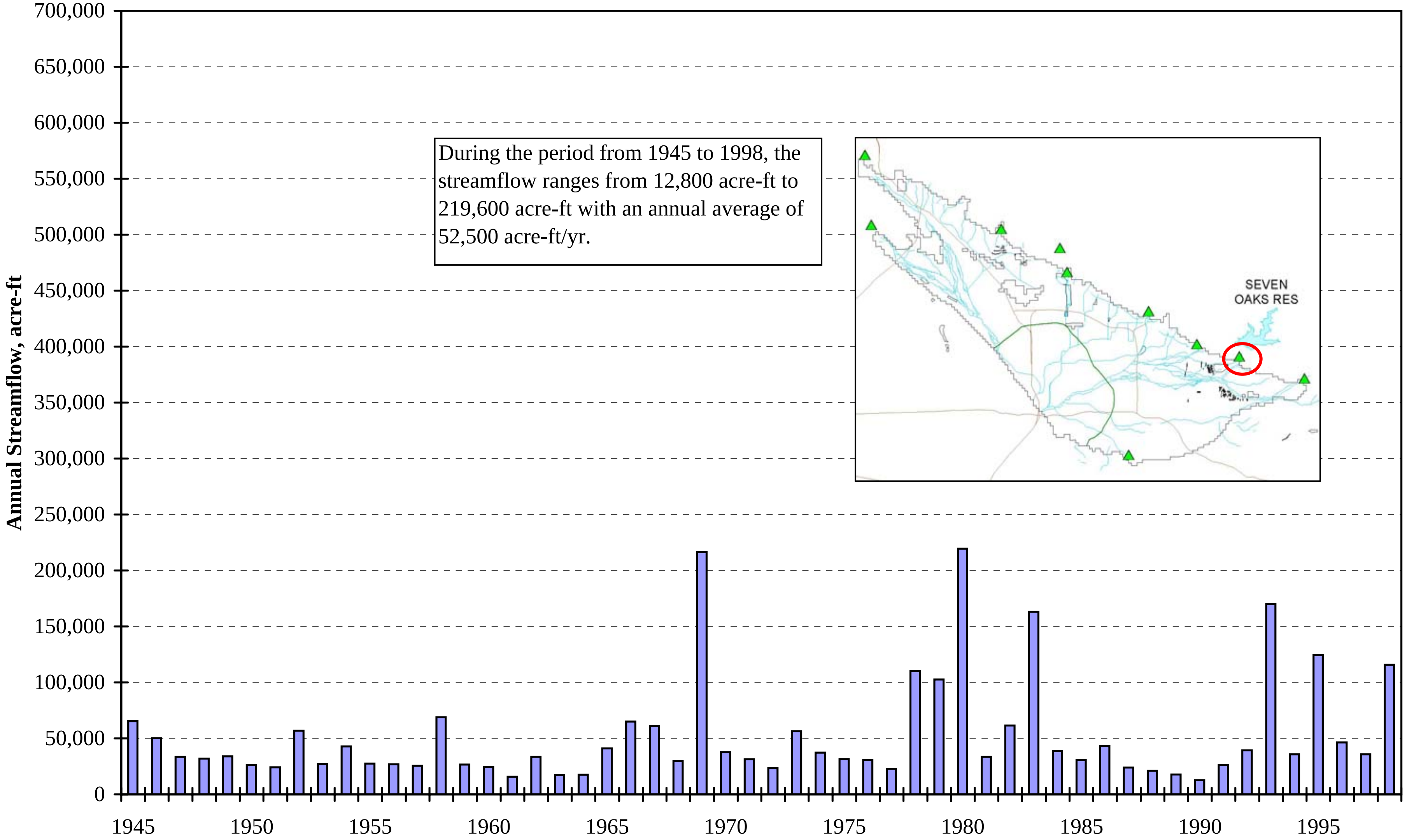


During the period from 1945 to 1998, the streamflow ranges from 900 acre-ft to 32,700 acre-ft with an annual average of 6,300 acre-ft/yr.

Source: USGS

Figure B 7

Annual Streamflow at Santa Ana River near Mentone Gaging Station
1945-1998

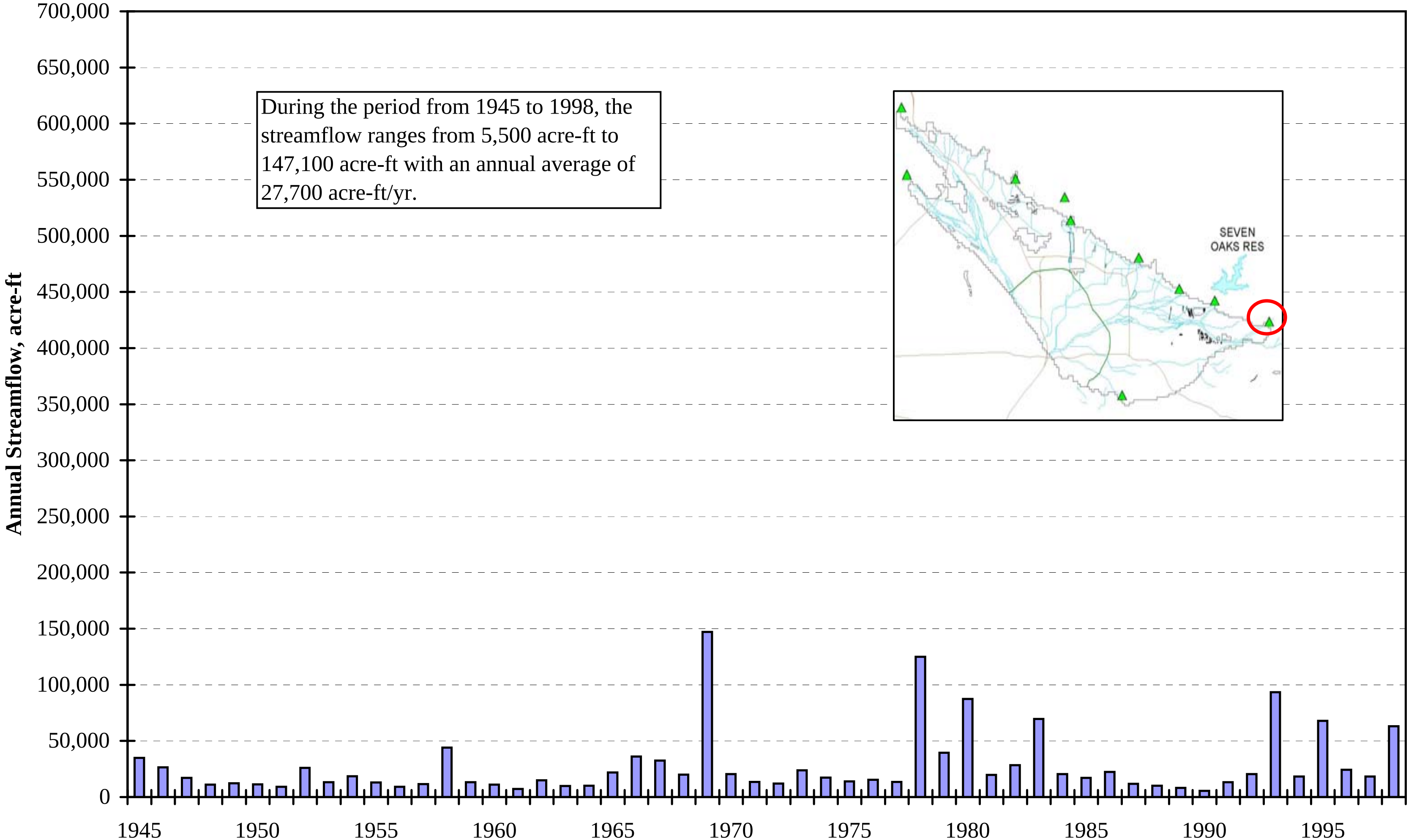


During the period from 1945 to 1998, the streamflow ranges from 12,800 acre-ft to 219,600 acre-ft with an annual average of 52,500 acre-ft/yr.

Source: USGS

Figure B 8

Annual Streamflow at Mill Creek near Yucaipa Gaging Station
1945-1998

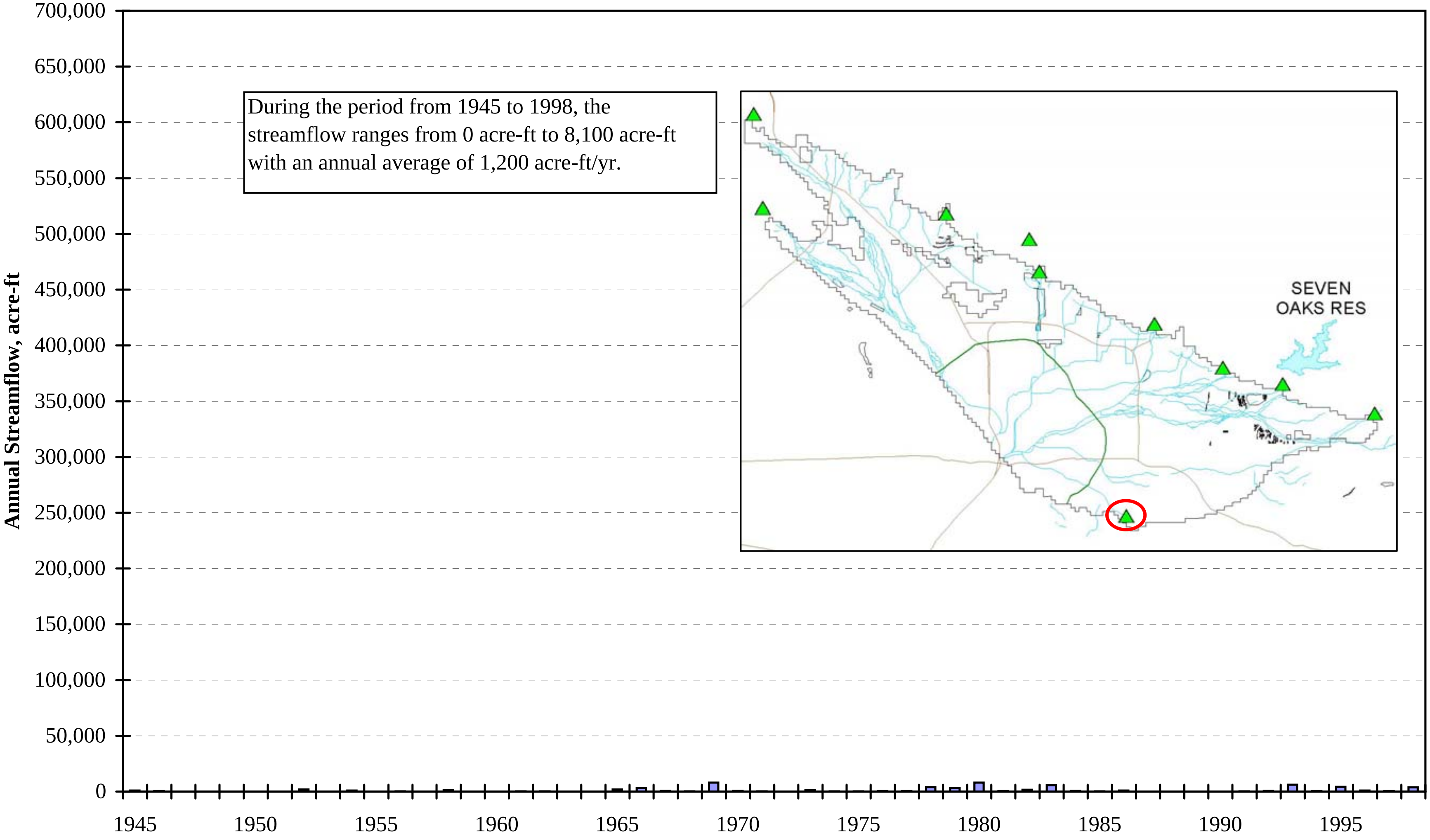


During the period from 1945 to 1998, the streamflow ranges from 5,500 acre-ft to 147,100 acre-ft with an annual average of 27,700 acre-ft/yr.

Source: USGS

Figure B 9

Annual Streamflow at San Timoteo Creek near Redlands Gaging Station
1945-1998

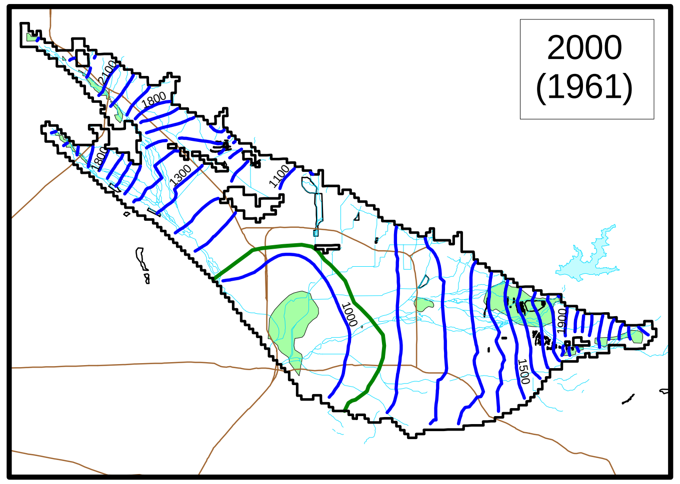


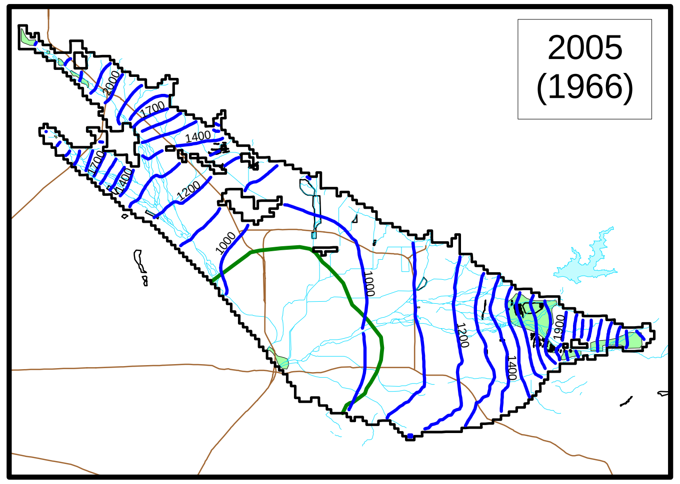
During the period from 1945 to 1998, the streamflow ranges from 0 acre-ft to 8,100 acre-ft with an annual average of 1,200 acre-ft/yr.

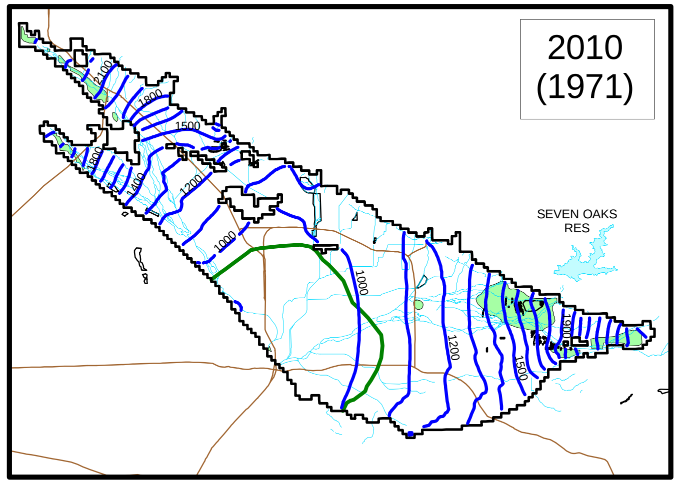
Source: USGS

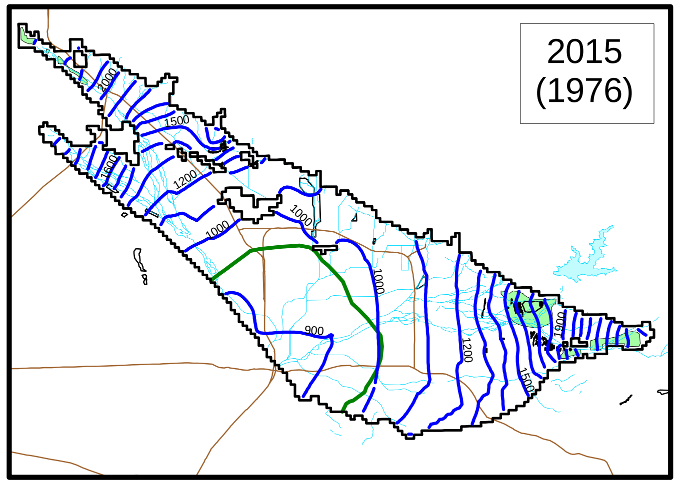
Figure B 10

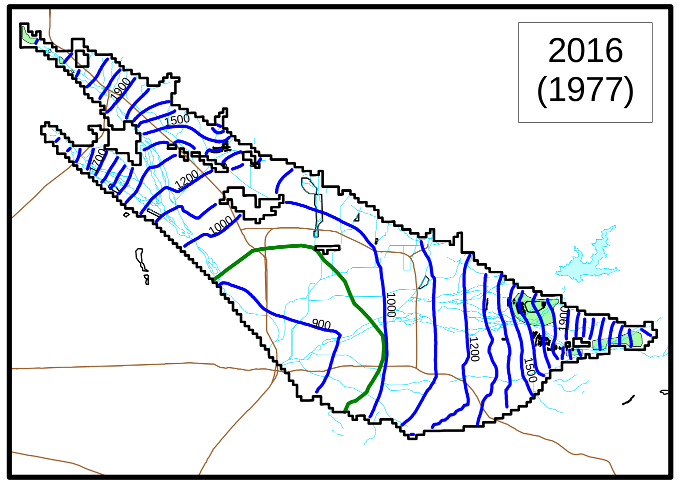
GROUNDWATER ELEVATIONS AND AREAS OF DEPTH TO WATER LESS THAN 50 FT FROM LAND SURFACE
LAYER 1
NO PROJECT CONDITION

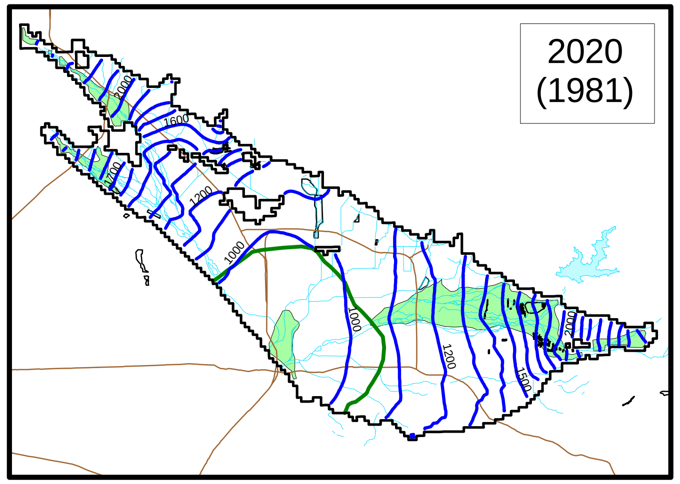


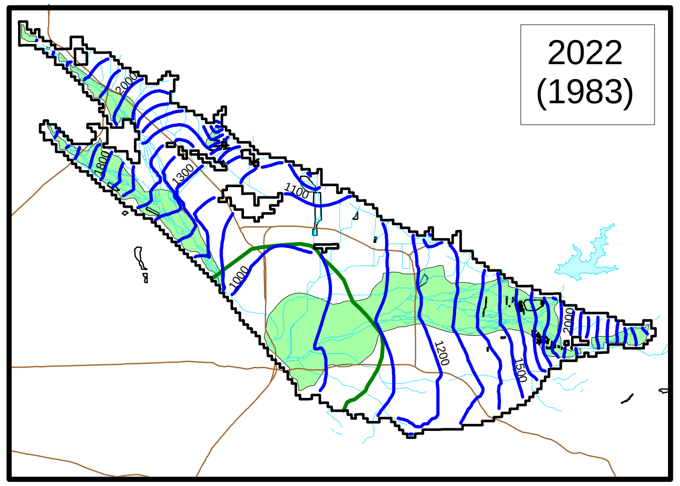


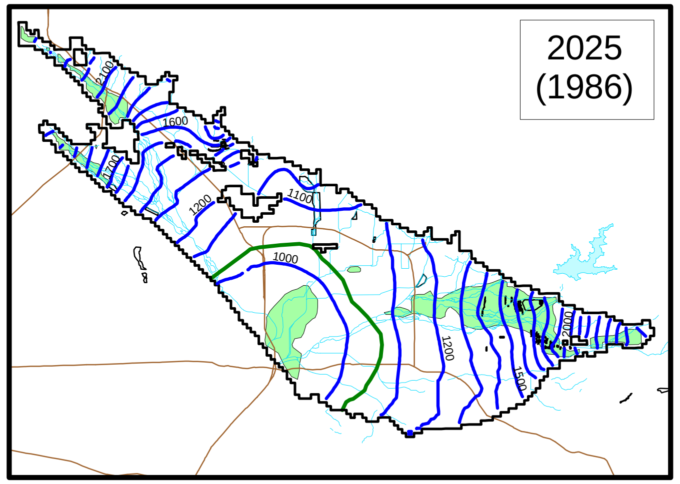


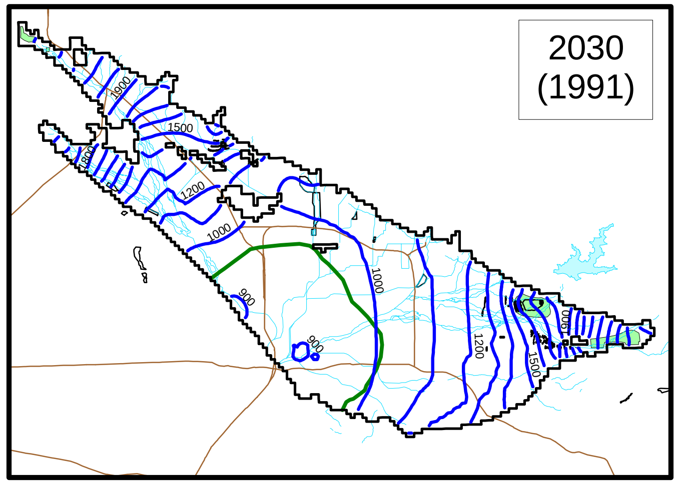


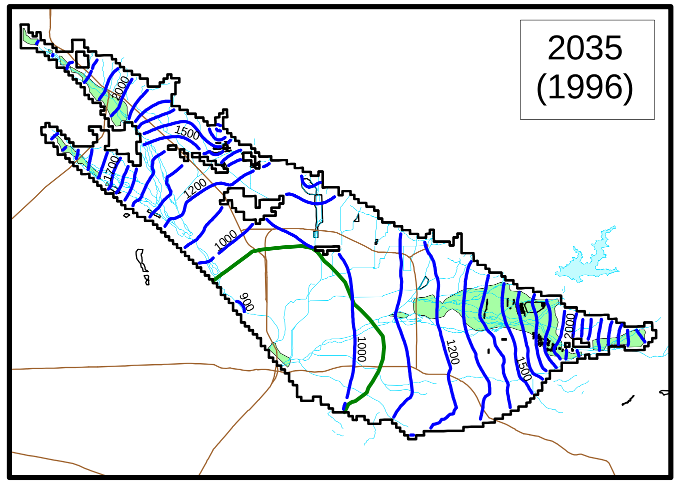


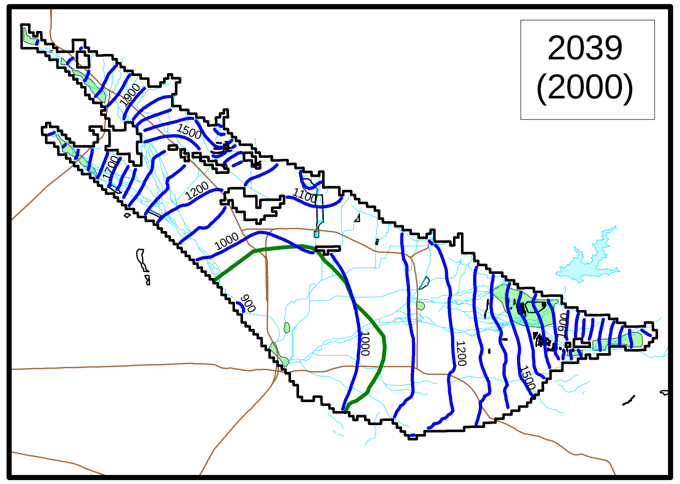












EXPLANATION

🟩	Depth to Water Less Than 50 ft From Land Surface
1000	Groundwater Contour (100 ft interval) (ft above mean sea level)
2000 (1961)	Model Year (Hydrological Year)
	Pressure Zone
☐	Model Grid of the San Bernardino Basin Area Groundwater Model
	Streams or Rivers Within Groundwater Basin Boundary
	Spreading Grounds or Basins
	Freeway

Area with Depth to Water less than 50 ft from land surface (acres)

Year	SBBA	PZ*
2001	7,301	1,204
2002	4,214	664
2003	2,640	154
2004	2,547	0
2005	3,597	139
2006	7,487	0
2007	5,372	0
2008	14,726	1,544
2009	8,706	201
2010	5,387	15
2011	3,983	0
2012	5,619	0
2013	5,063	0
2014	3,797	0
2015	3,118	0
2016	2,547	0
2017	9,925	93
2018	11,747	262
2019	20,299	3,226
2020	12,009	726
2021	11,747	1,019
2022	25,516	5,835
2023	20,391	4,739
2024	12,920	2,516
2025	12,071	1,976
2026	7,533	1,343
2027	5,094	849
2028	3,365	309
2029	1,652	0
2030	1,899	0
2031	2,146	0
2032	11,052	309
2033	5,989	0
2034	14,387	1,451
2035	8,860	170
2036	6,869	15
2037	16,903	2,686
2038	8,104	602
2039	4,384	139
Total	**320,964**	**32,184**

SBBA = San Bernardino Basin Area
PZ = Pressure Zone, not including river channels

NORTH

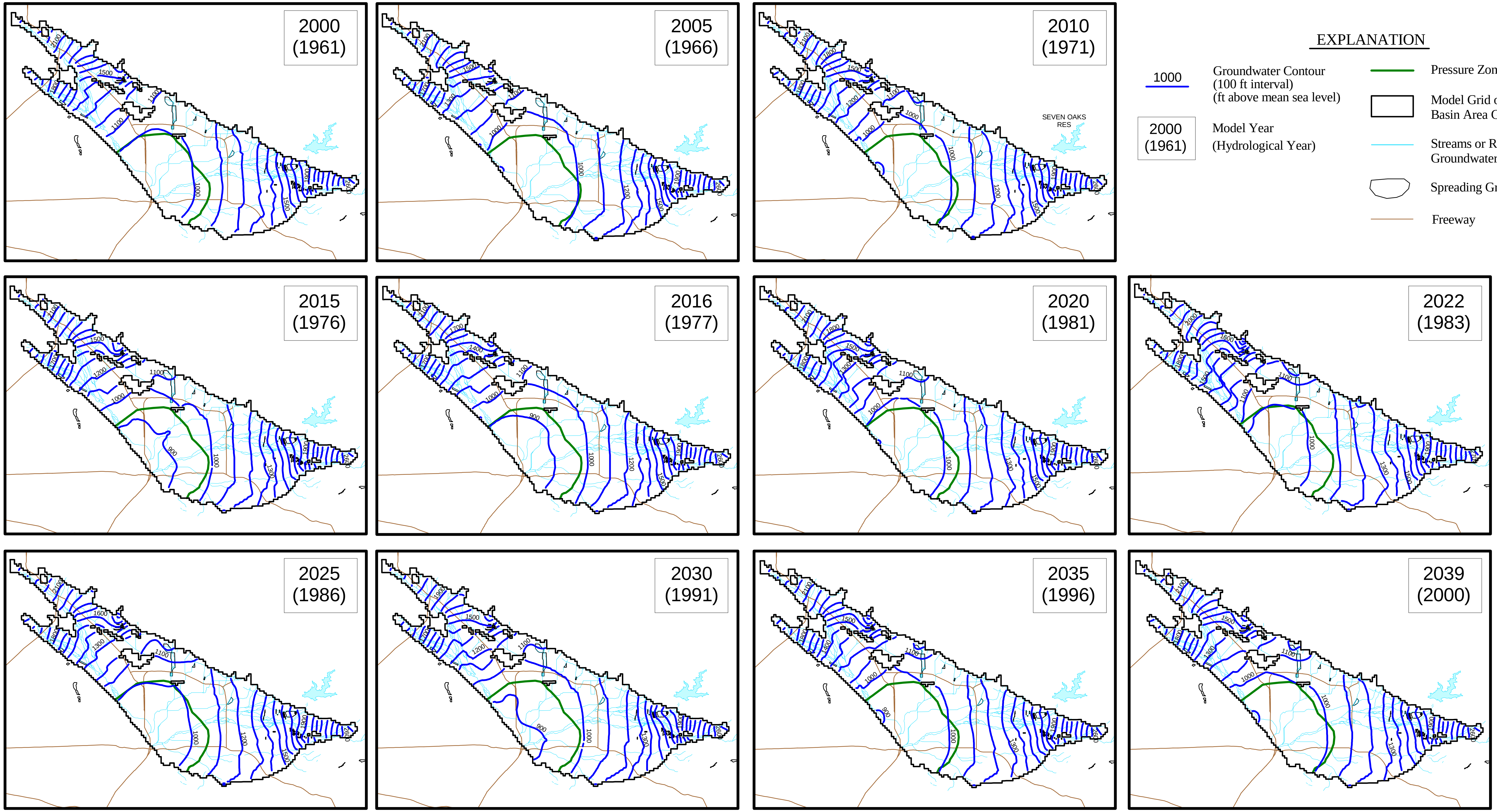
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 11

GROUNDWATER TECHNICAL APPENDIX
SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

GROUNDWATER ELEVATIONS
LAYER 2
NO PROJECT CONDITION



EXPLANATION

1000 — Groundwater Contour
(100 ft interval)
(ft above mean sea level)

2000 (1961) — Model Year
(Hydrological Year)

Pressure Zone

Model Grid of the San Bernardino
Basin Area Groundwater Model

Streams or Rivers Within
Groundwater Basin Boundary

Spreading Grounds or Basins

Freeway

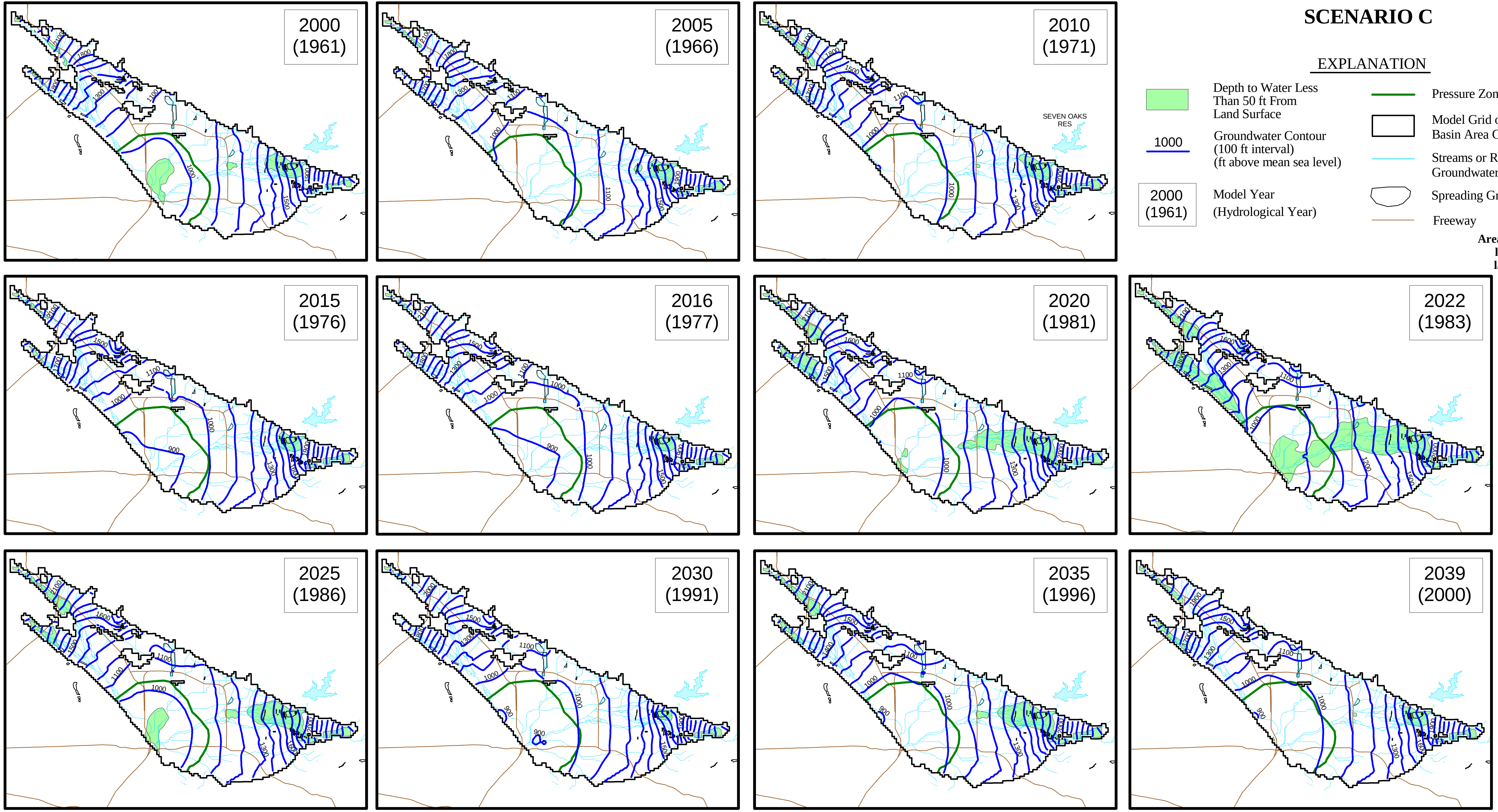
NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 12

GROUNDWATER ELEVATIONS AND AREAS OF DEPTH TO WATER LESS THAN 50 FT FROM LAND SURFACE
LAYER 1
SCENARIO C



Area with Depth to Water less than 50 ft from land surface (acres)

Year	SBBA	PZ*
2001	7,224	1,204
2002	4,199	664
2003	2,640	185
2004	2,485	0
2005	3,612	0
2006	6,931	0
2007	5,156	0
2008	14,525	1,297
2009	7,857	123
2010	4,970	0
2011	3,689	0
2012	5,140	0
2013	4,862	0
2014	3,658	0
2015	3,319	0
2016	2,609	0
2017	9,416	62
2018	11,546	139
2019	20,129	2,068
2020	11,083	262
2021	10,774	494
2022	22,984	3,736
2023	15,915	1,991
2024	10,419	1,328
2025	10,219	1,219
2026	6,869	911
2027	4,600	571
2028	2,794	93
2029	1,636	0
2030	1,775	0
2031	2,084	0
2032	10,018	46
2033	5,881	0
2034	12,009	0
2035	7,842	0
2036	6,807	0
2037	14,248	695
2038	7,039	93
2039	4,291	15
Total	**293,257**	**17,196**

SBBA = San Bernardino Basin Area
PZ = Pressure Zone, not including river channels

NORTH

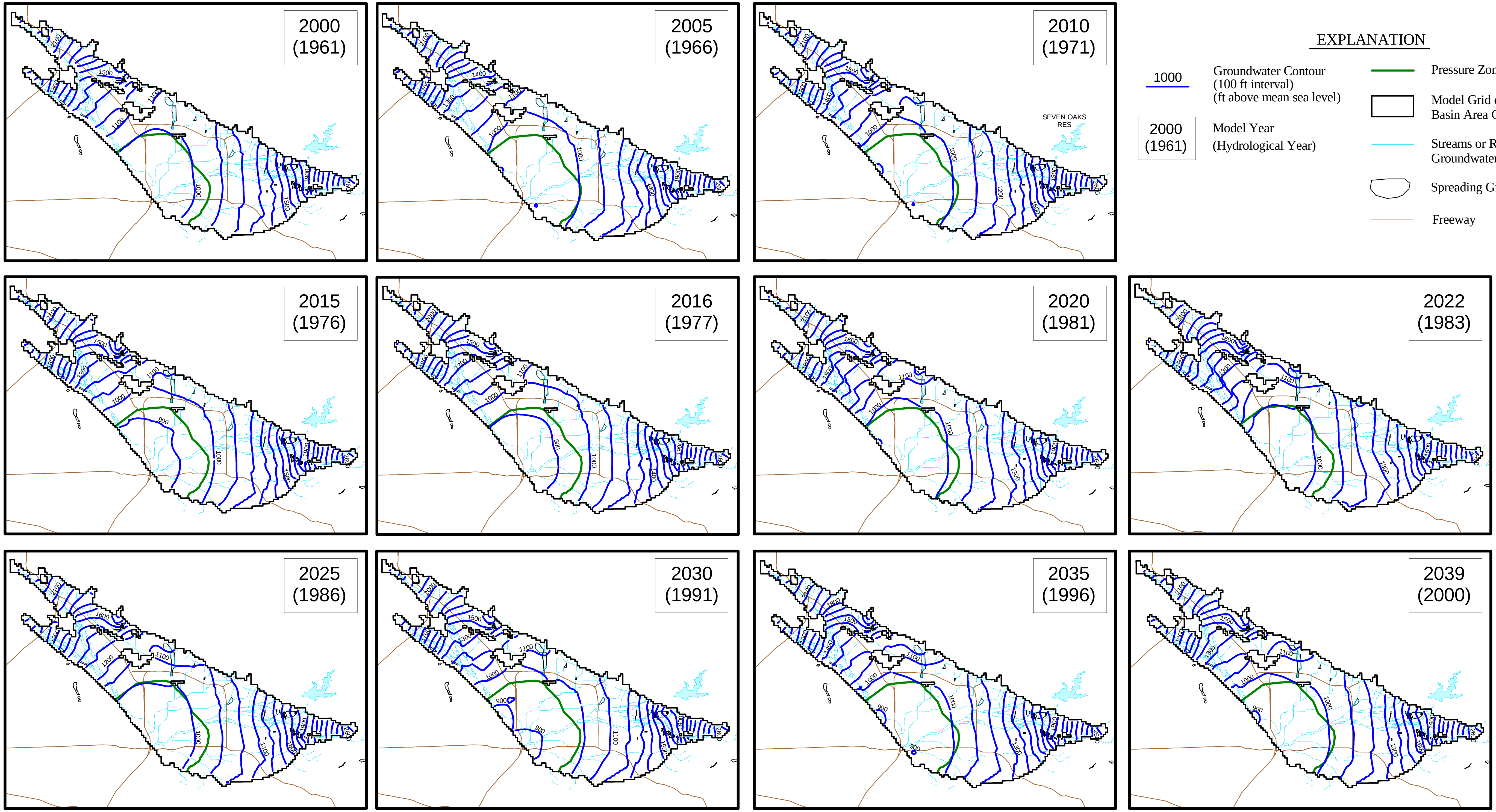
Map Projection:
State Plane 1927 (California Zone V)

0 5 10 Miles

Figure B 13

GROUNDWATER TECHNICAL APPENDIX
SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

GROUNDWATER ELEVATIONS
LAYER 2
SCENARIO C



EXPLANATION

1000 — Groundwater Contour (100 ft interval) (ft above mean sea level)

2000 (1961) — Model Year (Hydrological Year)

Pressure Zone

Model Grid of the San Bernardino Basin Area Groundwater Model

Streams or Rivers Within Groundwater Basin Boundary

Spreading Grounds or Basins

Freeway

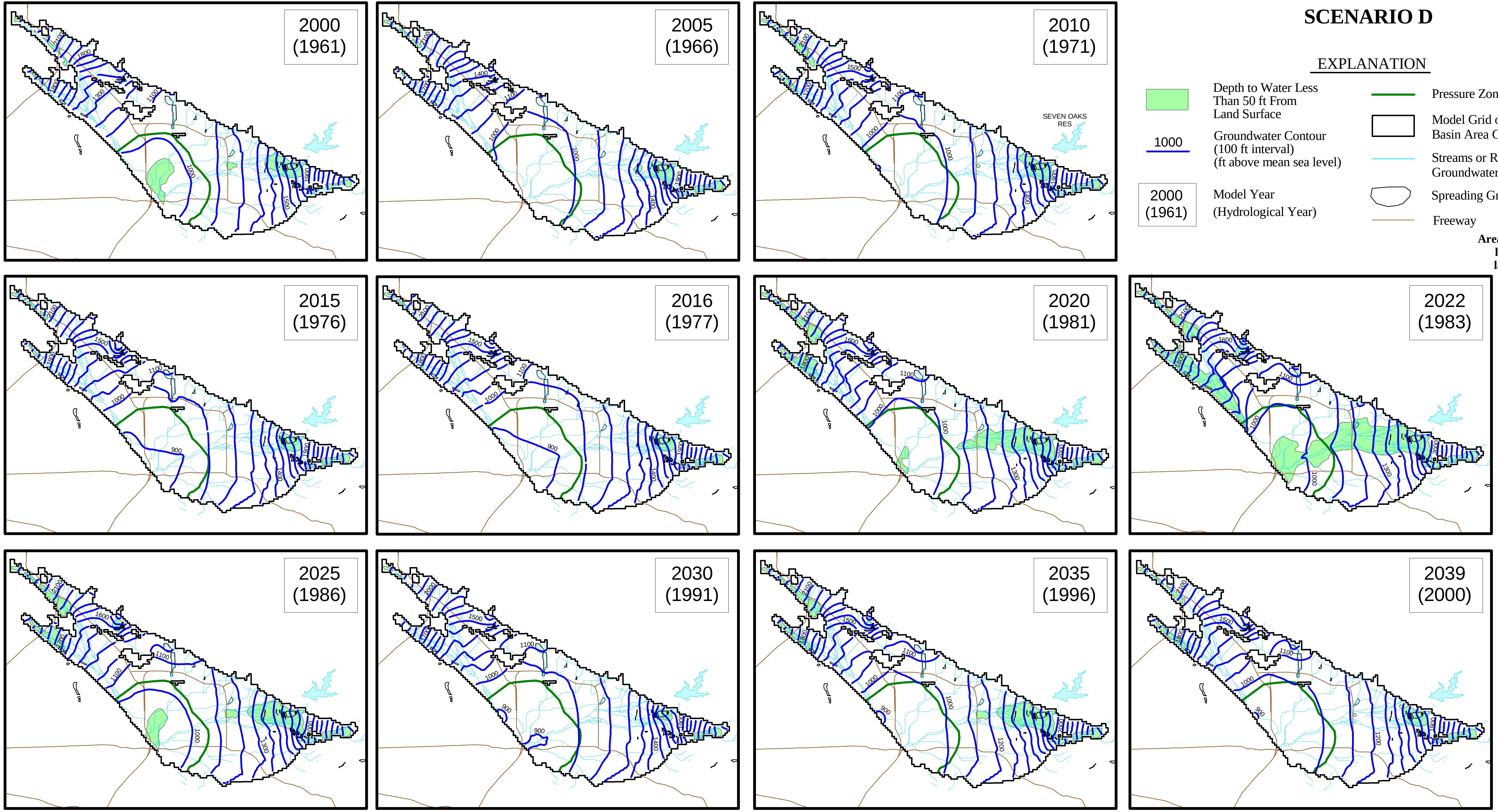
NORTH

Map Projection:
State Plane 1927 (California Zone V)

0 5 10 Miles

Figure B 14

GROUNDWATER ELEVATIONS AND AREAS OF DEPTH TO WATER LESS THAN 50 FT FROM LAND SURFACE
LAYER 1
SCENARIO D



EXPLANATION

🟩 Depth to Water Less Than 50 ft From Land Surface

1000 Groundwater Contour (100 ft interval) (ft above mean sea level)

2000 (1961) Model Year (Hydrological Year)

Pressure Zone

Model Grid of the San Bernardino Basin Area Groundwater Model

Streams or Rivers Within Groundwater Basin Boundary

Spreading Grounds or Basins

Freeway

Area with Depth to Water less than 50 ft from land surface (acres)

Year	SBBA	PZ*
2001	7,224	1,204
2002	4,199	664
2003	2,640	185
2004	2,485	0
2005	3,612	0
2006	6,962	0
2007	5,140	0
2008	14,510	1,328
2009	7,718	123
2010	4,801	0
2011	3,674	0
2012	5,094	0
2013	4,801	0
2014	3,674	0
2015	3,257	0
2016	2,532	0
2017	9,509	62
2018	11,531	139
2019	20,252	2,099
2020	11,438	324
2021	11,531	540
2022	23,448	3,797
2023	16,007	1,960
2024	10,682	1,266
2025	10,759	1,081
2026	6,931	803
2027	4,585	525
2028	2,871	77
2029	1,667	0
2030	1,775	0
2031	2,084	0
2032	9,972	15
2033	5,989	0
2034	12,580	15
2035	8,428	0
2036	7,178	0
2037	14,340	587
2038	7,085	31
2039	4,384	0
Total	297,347	16,825

SBBA = San Bernardino Basin Area
PZ = Pressure Zone, not including river channels

NORTH

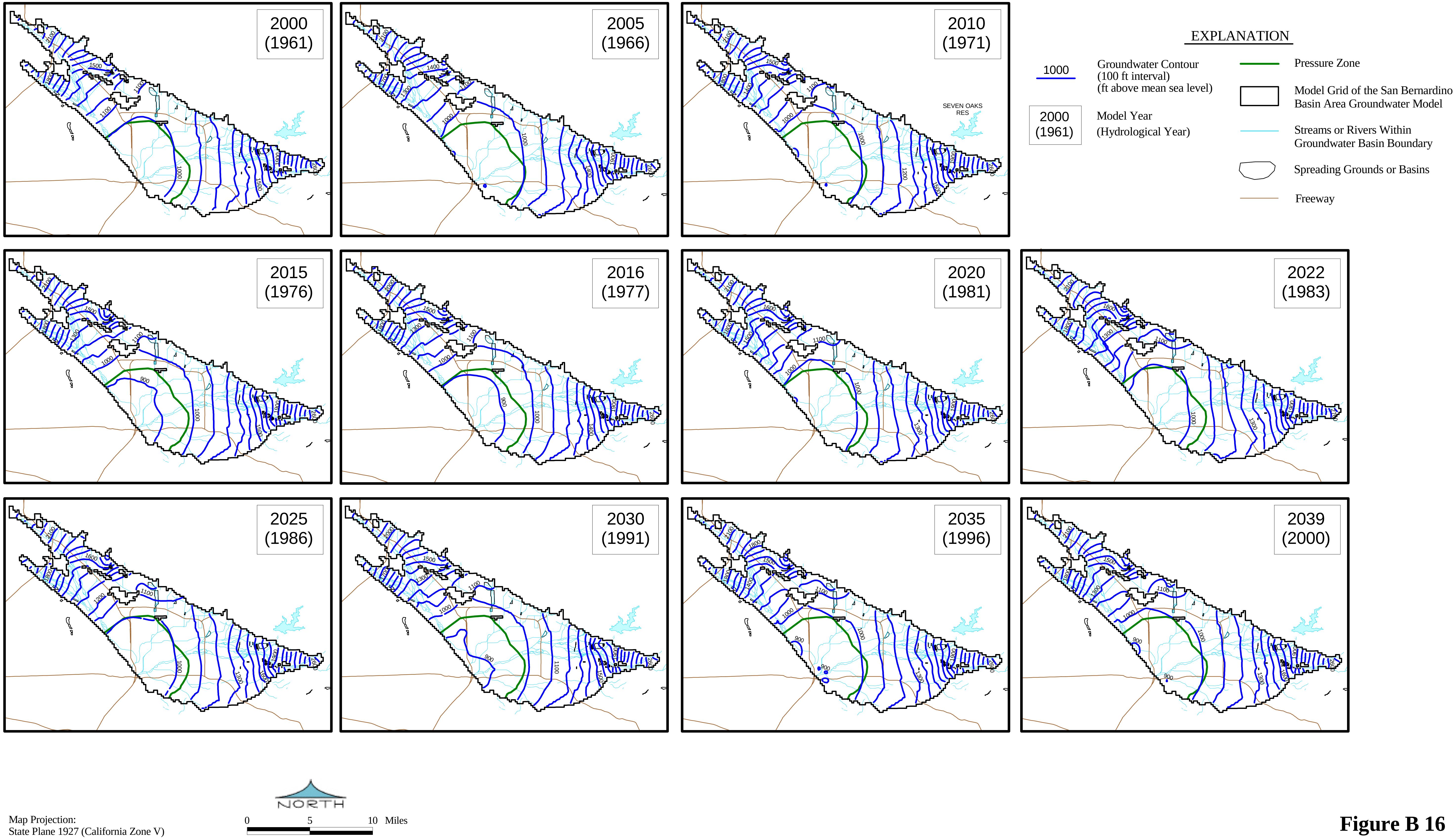
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 15

GROUNDWATER TECHNICAL APPENDIX
SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

GROUNDWATER ELEVATIONS
LAYER 2
SCENARIO D



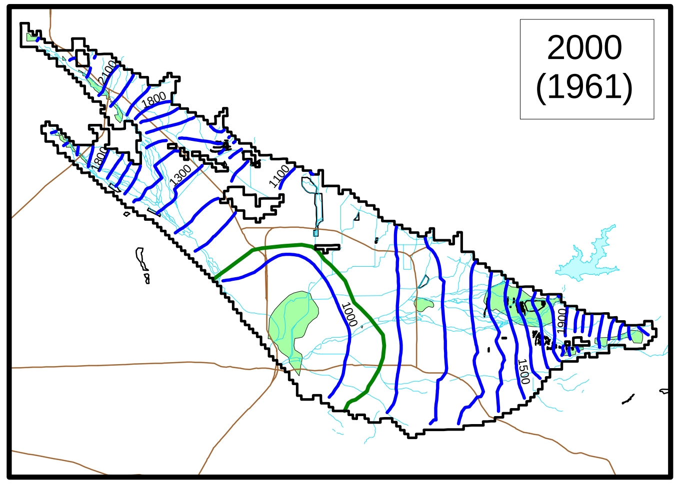
Map Projection:
State Plane 1927 (California Zone V)

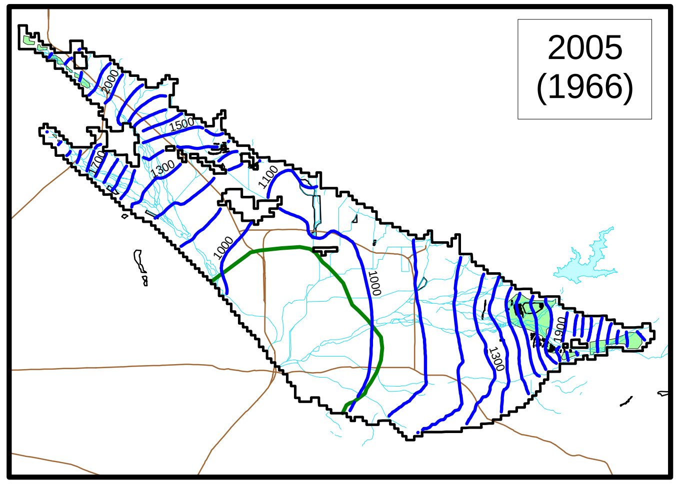
Figure B 16

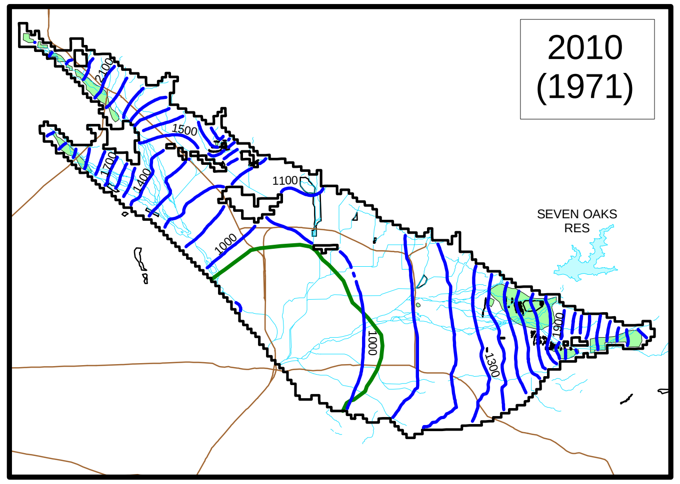
GROUNDWATER ELEVATIONS AND AREAS OF DEPTH TO WATER LESS THAN 50 FT FROM LAND SURFACE
LAYER 1
SCENARIO A

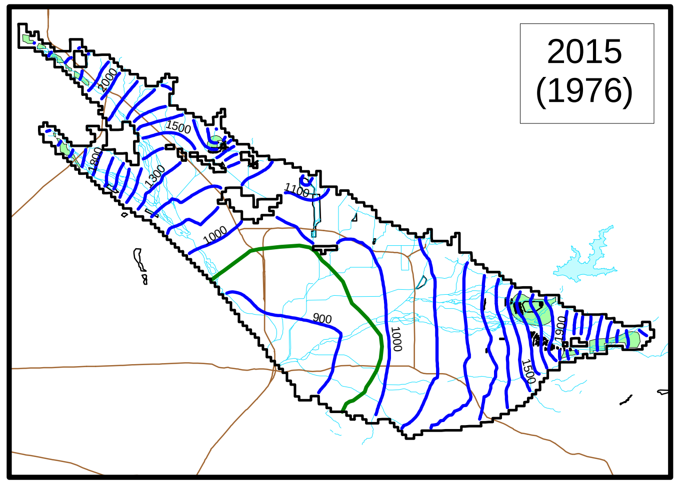
EXPLANATION

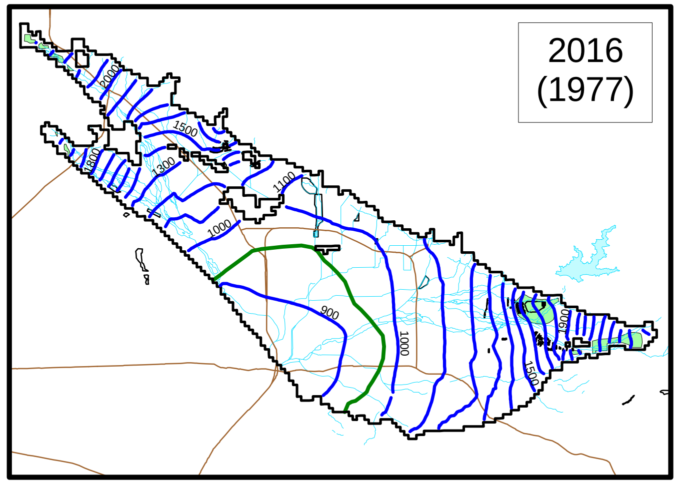
🟩	Depth to Water Less Than 50 ft From Land Surface
1000	Groundwater Contour (100 ft interval) (ft above mean sea level)
2000 (1961)	Model Year (Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

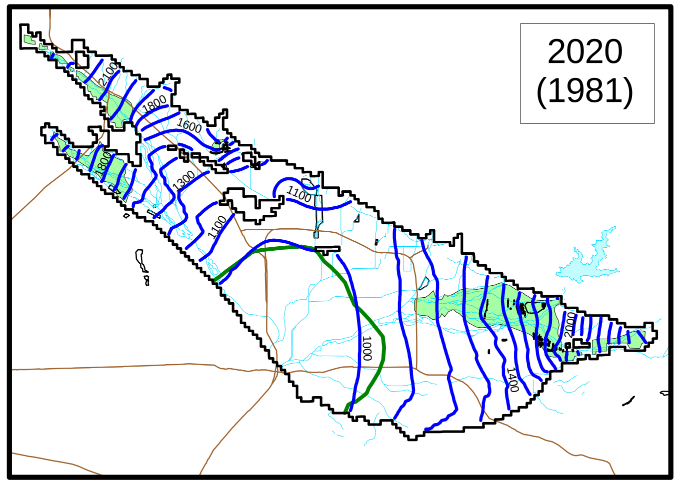


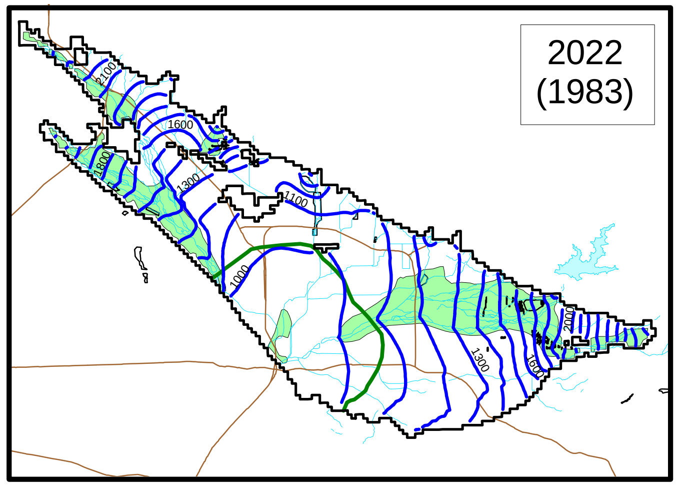


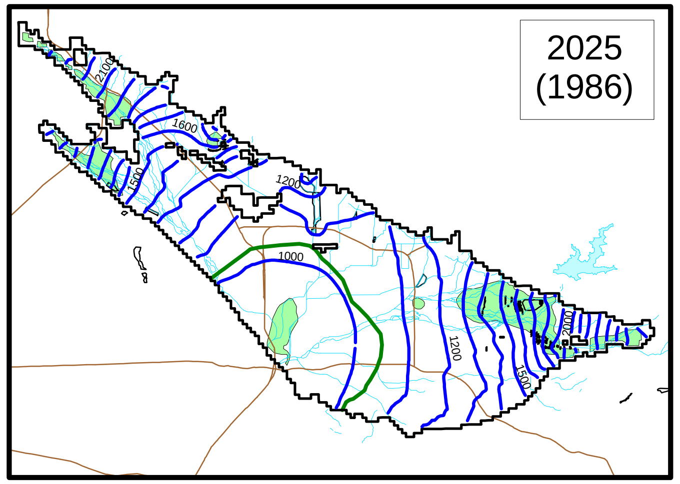


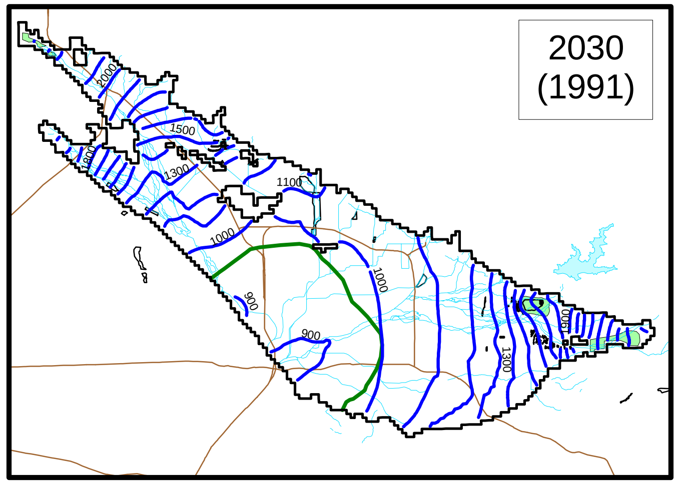


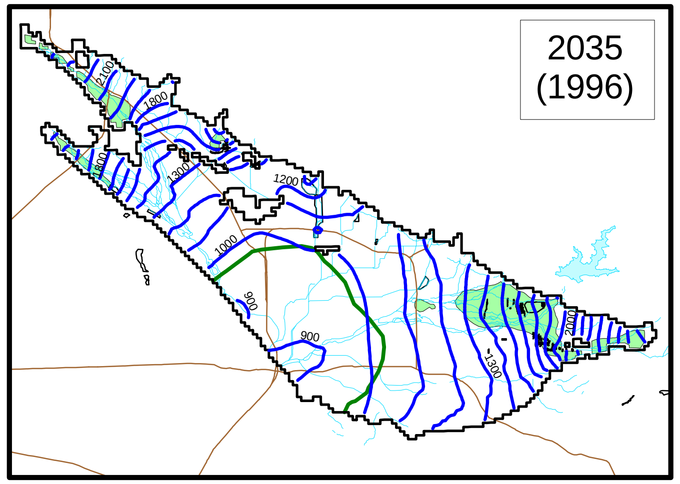


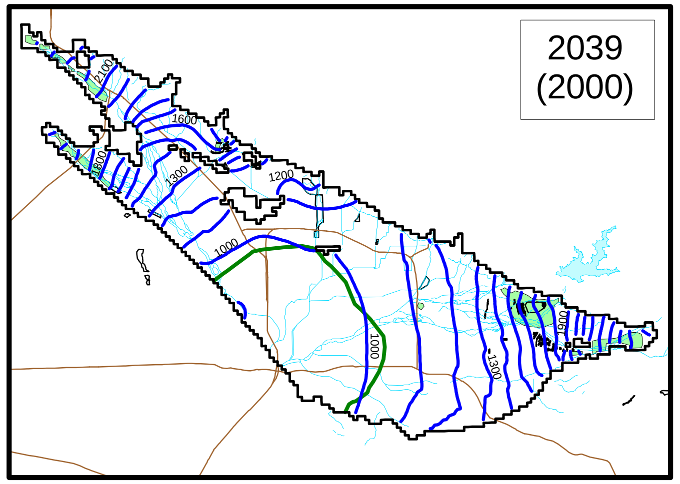












Area with Depth to Water less than 50 ft from land surface (acres)

Year	SBBA	PZ*
2001	7,116	1,204
2002	4,121	664
2003	2,640	185
2004	2,470	0
2005	3,272	0
2006	6,144	0
2007	4,338	0
2008	13,877	1,081
2009	6,668	77
2010	4,785	0
2011	3,736	0
2012	4,338	0
2013	4,044	0
2014	3,442	0
2015	3,257	0
2016	2,423	0
2017	9,200	0
2018	11,253	0
2019	17,891	247
2020	10,049	0
2021	9,787	15
2022	19,681	864
2023	14,062	911
2024	9,771	834
2025	9,787	787
2026	6,653	448
2027	4,137	216
2028	2,655	0
2029	1,698	0
2030	1,744	0
2031	2,038	0
2032	9,895	0
2033	5,758	0
2034	12,380	0
2035	8,042	0
2036	6,684	0
2037	13,615	0
2038	7,039	0
2039	4,183	0
Total	274,671	7,533

SBBA = San Bernardino Basin Area
PZ = Pressure Zone, not including river channels

NORTH

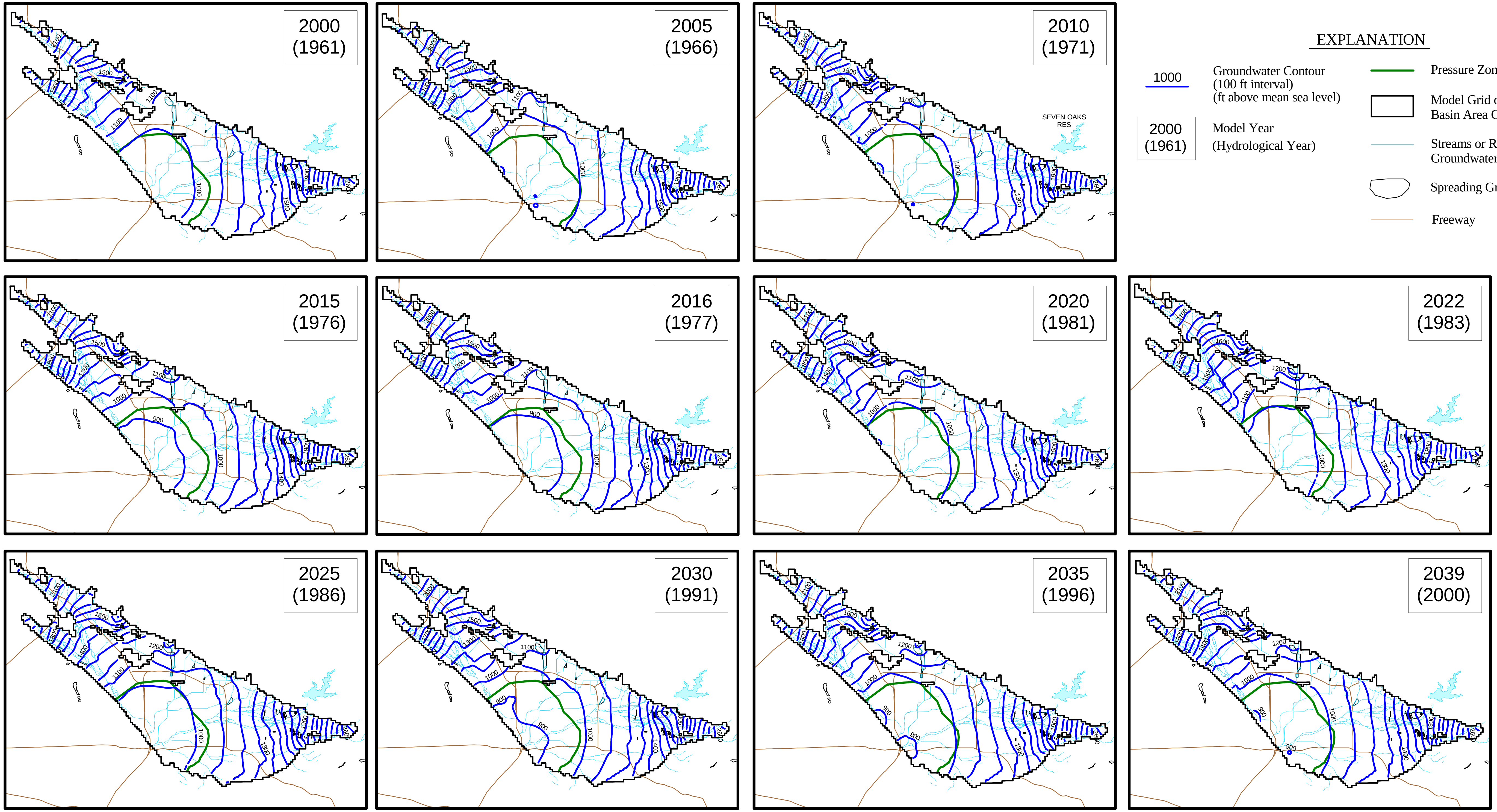
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 17

GROUNDWATER TECHNICAL APPENDIX
SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

GROUNDWATER ELEVATIONS
LAYER 2
SCENARIO A



EXPLANATION

1000 Groundwater Contour
(100 ft interval)
(ft above mean sea level)

2000
(1961) Model Year
(Hydrological Year)

Pressure Zone

▭ Model Grid of the San Bernardino Basin Area Groundwater Model

Streams or Rivers Within Groundwater Basin Boundary

Spreading Grounds or Basins

Freeway

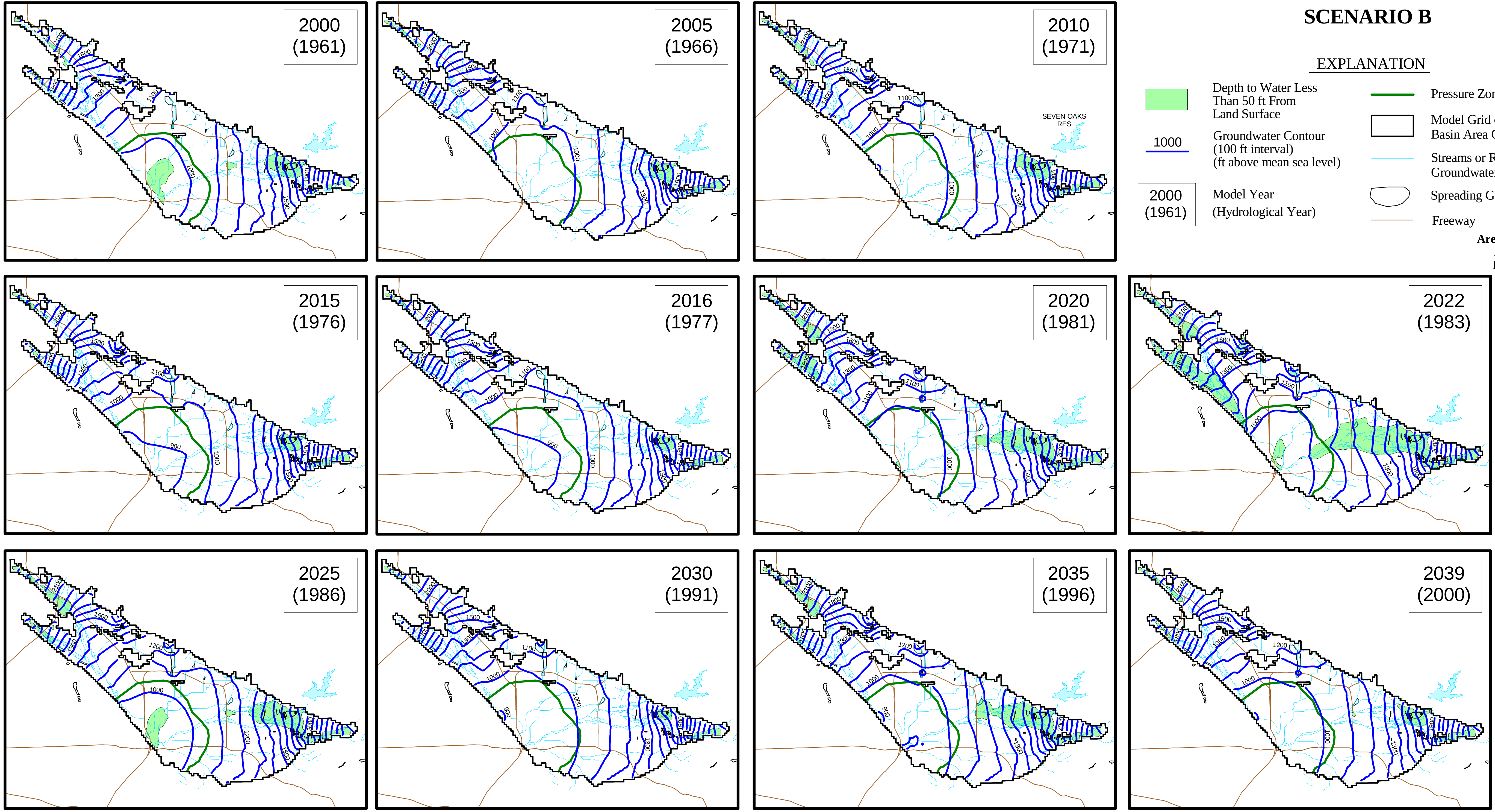
NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 18

GROUNDWATER ELEVATIONS AND AREAS OF DEPTH TO WATER LESS THAN 50 FT FROM LAND SURFACE
LAYER 1
SCENARIO B



EXPLANATION

- 🟩 Depth to Water Less Than 50 ft From Land Surface
- 1000 Groundwater Contour (100 ft interval) (ft above mean sea level)
- 2000 (1961) Model Year (Hydrological Year)
- Pressure Zone
- Model Grid of the San Bernardino Basin Area Groundwater Model
- Streams or Rivers Within Groundwater Basin Boundary
- Spreading Grounds or Basins
- Freeway

Area with Depth to Water less than 50 ft from land surface (acres)

Year	SBBA	PZ*
2001	7,116	1,204
2002	4,121	664
2003	2,640	185
2004	2,470	0
2005	3,272	0
2006	6,313	0
2007	4,476	0
2008	14,001	1,111
2009	6,854	93
2010	4,878	0
2011	3,628	0
2012	4,214	0
2013	3,921	0
2014	3,272	0
2015	3,103	0
2016	2,423	0
2017	8,274	0
2018	9,570	0
2019	18,060	509
2020	9,833	31
2021	9,231	46
2022	20,067	1,050
2023	14,726	1,158
2024	10,203	1,189
2025	9,401	1,127
2026	6,653	942
2027	4,615	664
2028	2,917	216
2029	1,559	0
2030	1,744	0
2031	2,022	0
2032	9,385	0
2033	5,881	0
2034	11,809	0
2035	8,706	0
2036	6,607	0
2037	13,090	0
2038	6,622	0
2039	3,797	0
Total	**271,476**	**10,188**

SBBA = San Bernardino Basin Area
PZ = Pressure Zone, not including river channels

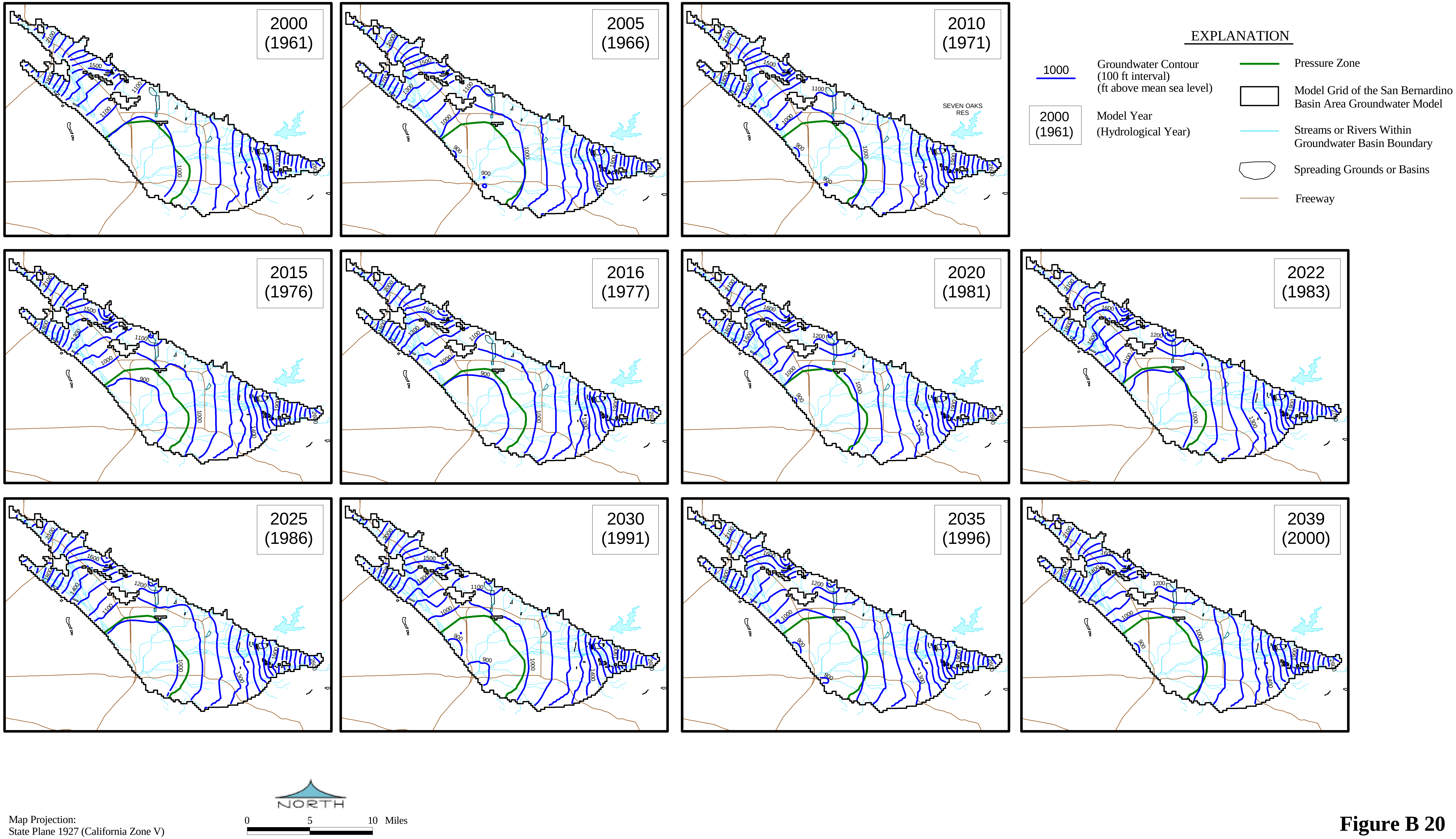
NORTH

Map Projection:
State Plane 1927 (California Zone V)

0 5 10 Miles

Figure B 19

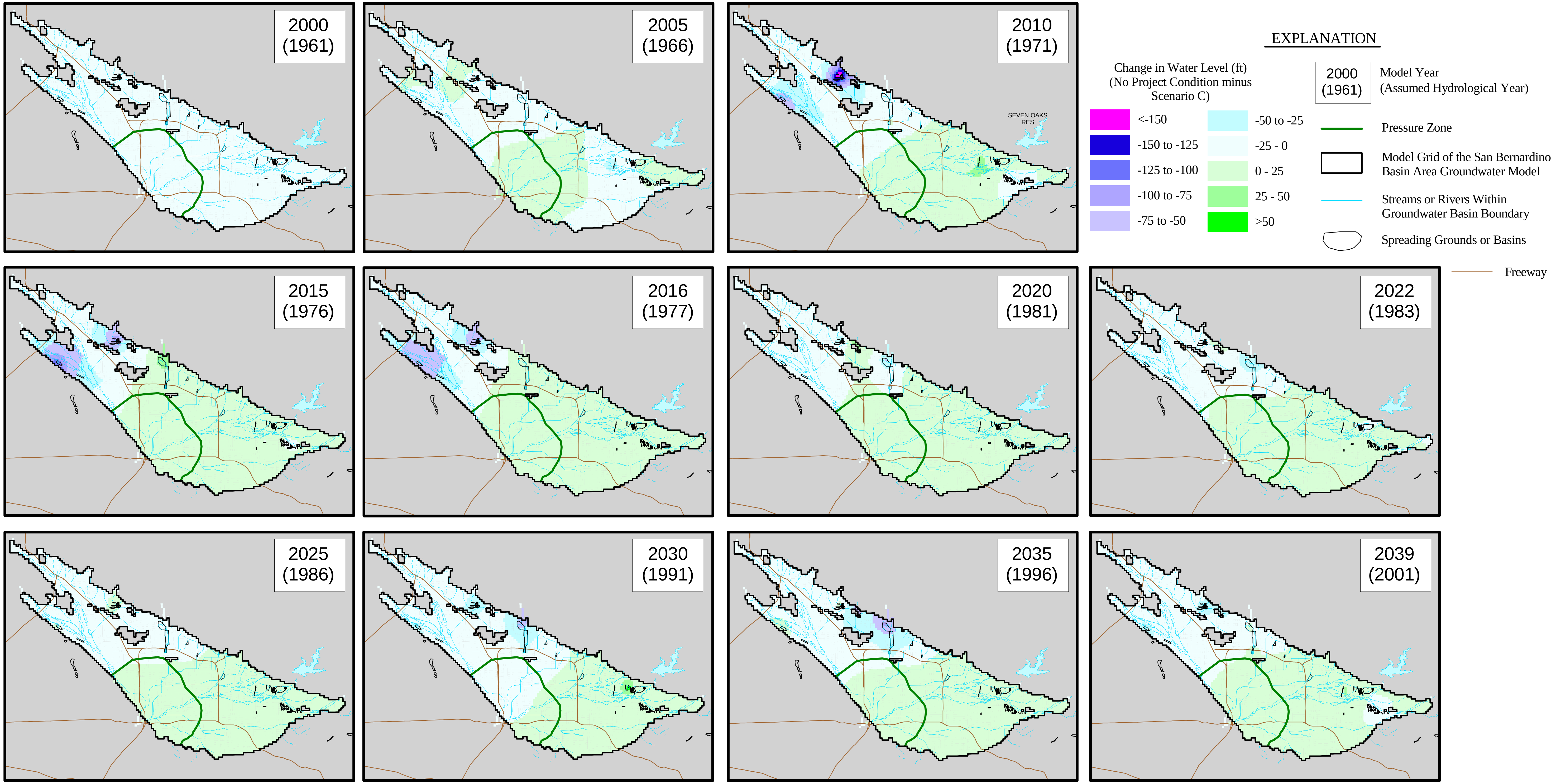
GROUNDWATER ELEVATIONS
LAYER 2
SCENARIO B



Map Projection:
State Plane 1927 (California Zone V)

Figure B 20

DIFFERENCES IN GROUNDWATER LEVEL BETWEEN NO PROJECT CONDITION AND SCENARIO C
LAYER 1

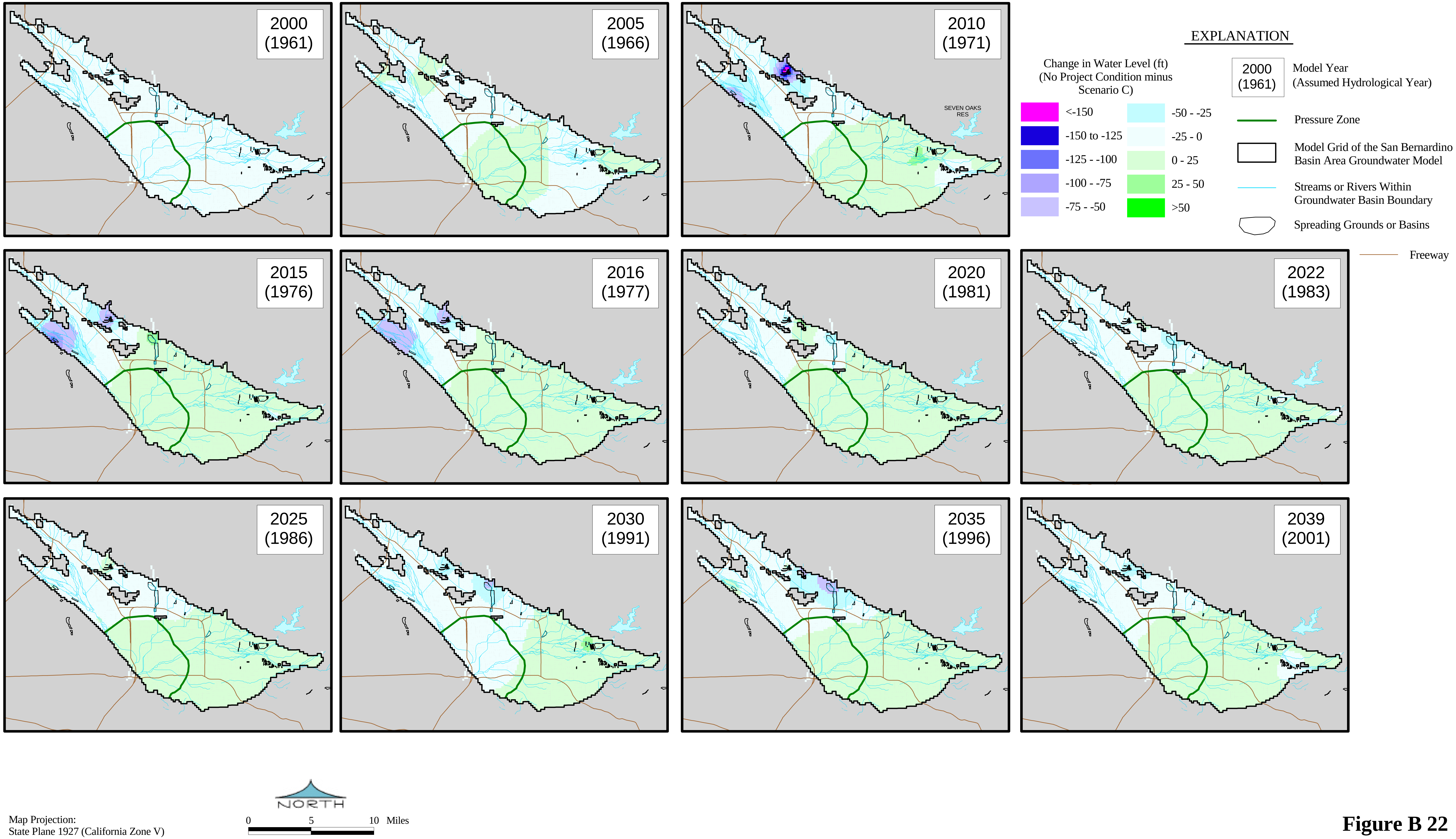


Map Projection:
State Plane 1927 (California Zone V)

Figure B 21

GROUNDWATER TECHNICAL APPENDIX
SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

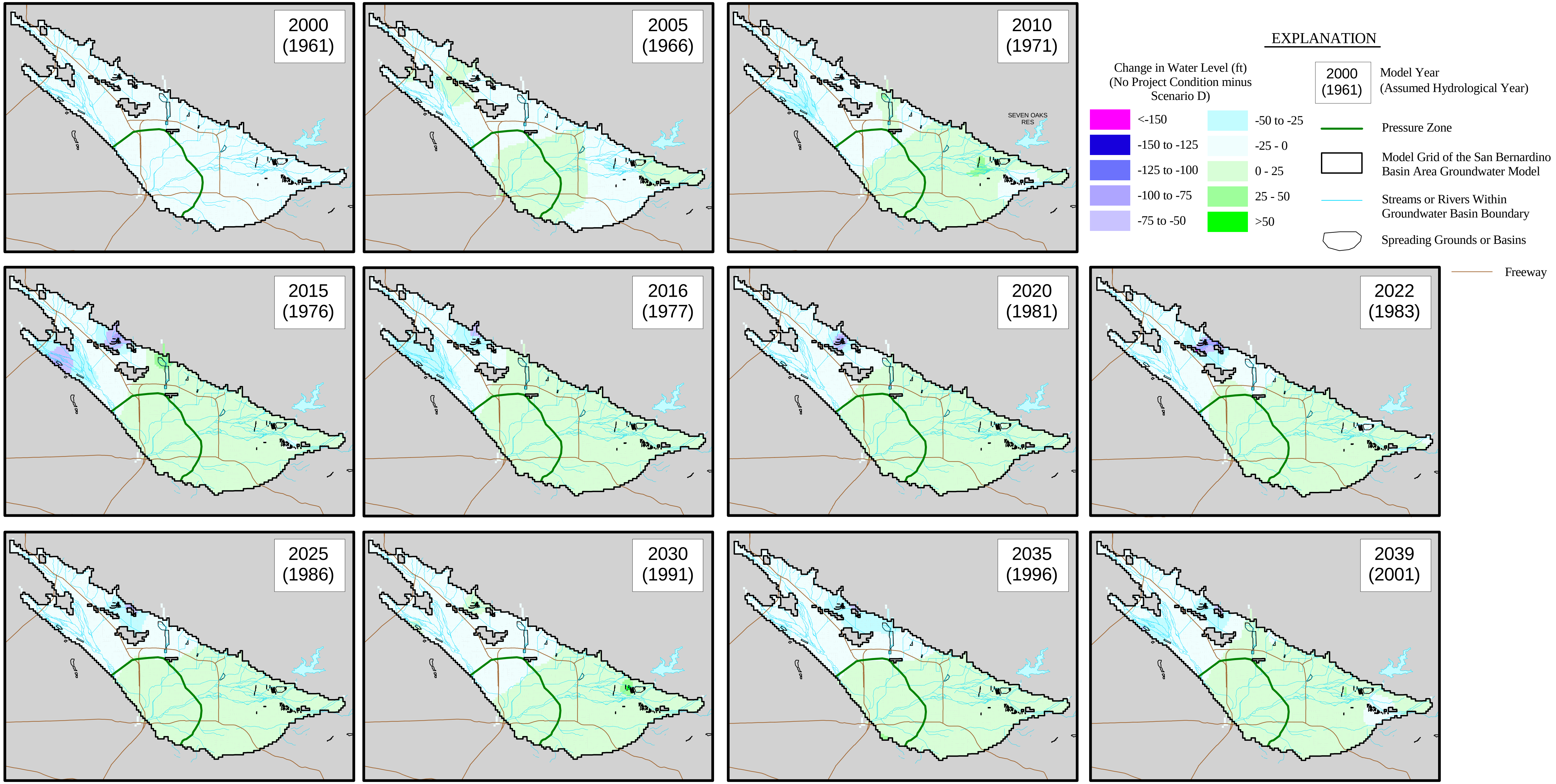
DIFFERENCES IN GROUNDWATER LEVEL BETWEEN NO PROJECT CONDITION AND SCENARIO C
LAYER 2



Map Projection:
State Plane 1927 (California Zone V)

Figure B 22

DIFFERENCES IN GROUNDWATER LEVEL BETWEEN NO PROJECT CONDITION AND SCENARIO D
LAYER 1



NORTH

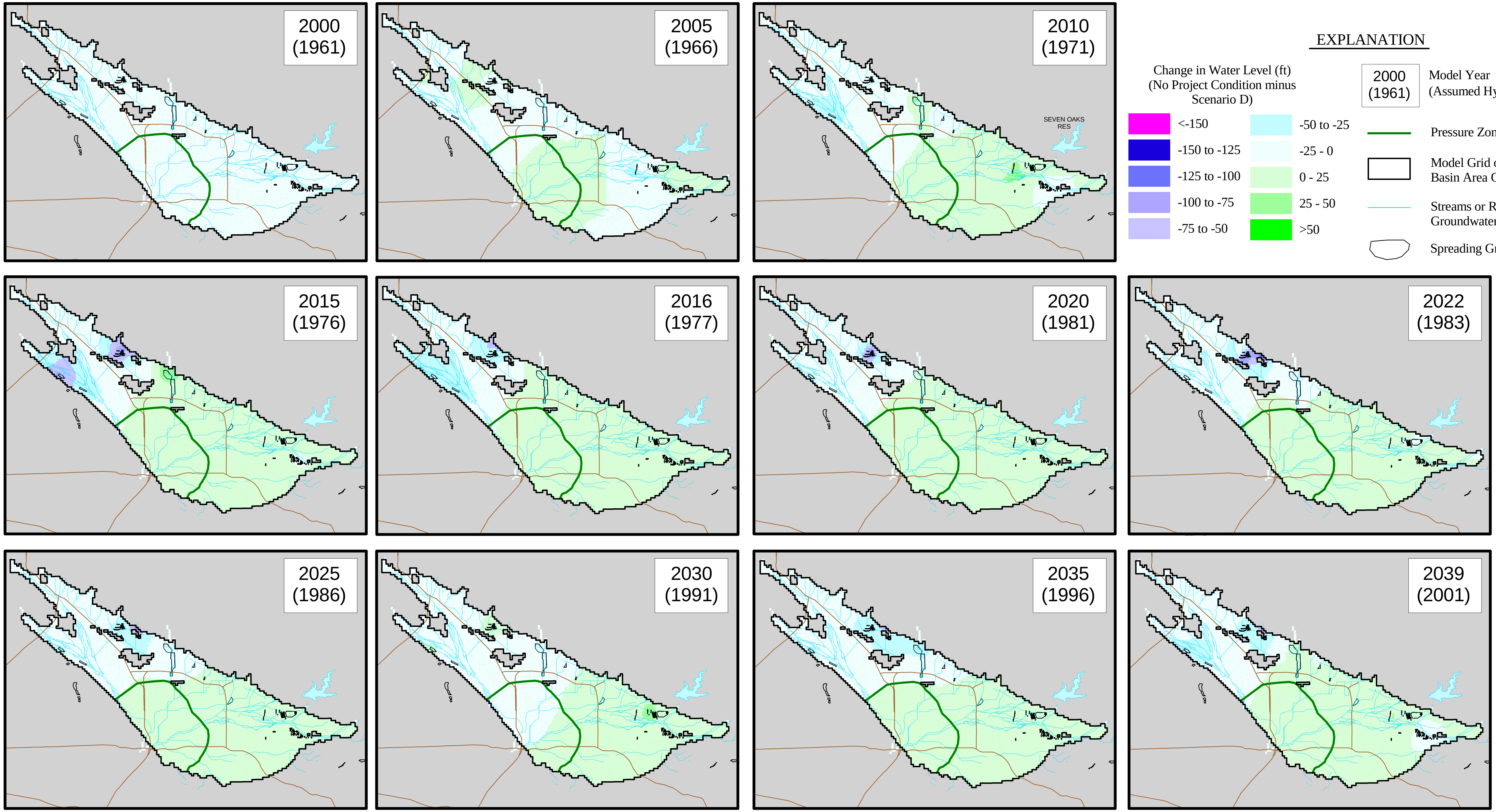
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 23

GROUNDWATER TECHNICAL APPENDIX
SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

DIFFERENCES IN GROUNDWATER LEVEL BETWEEN NO PROJECT CONDITION AND SCENARIO D
LAYER 2



EXPLANATION

Change in Water Level (ft)
(No Project Condition minus Scenario D)

🟪	<-150	🟦	-50 to -25
🟦	-150 to -125	⬜	-25 - 0
🟦	-125 to -100	🟩	0 - 25
🟪	-100 to -75	🟩	25 - 50
🟪	-75 to -50	🟩	>50

2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

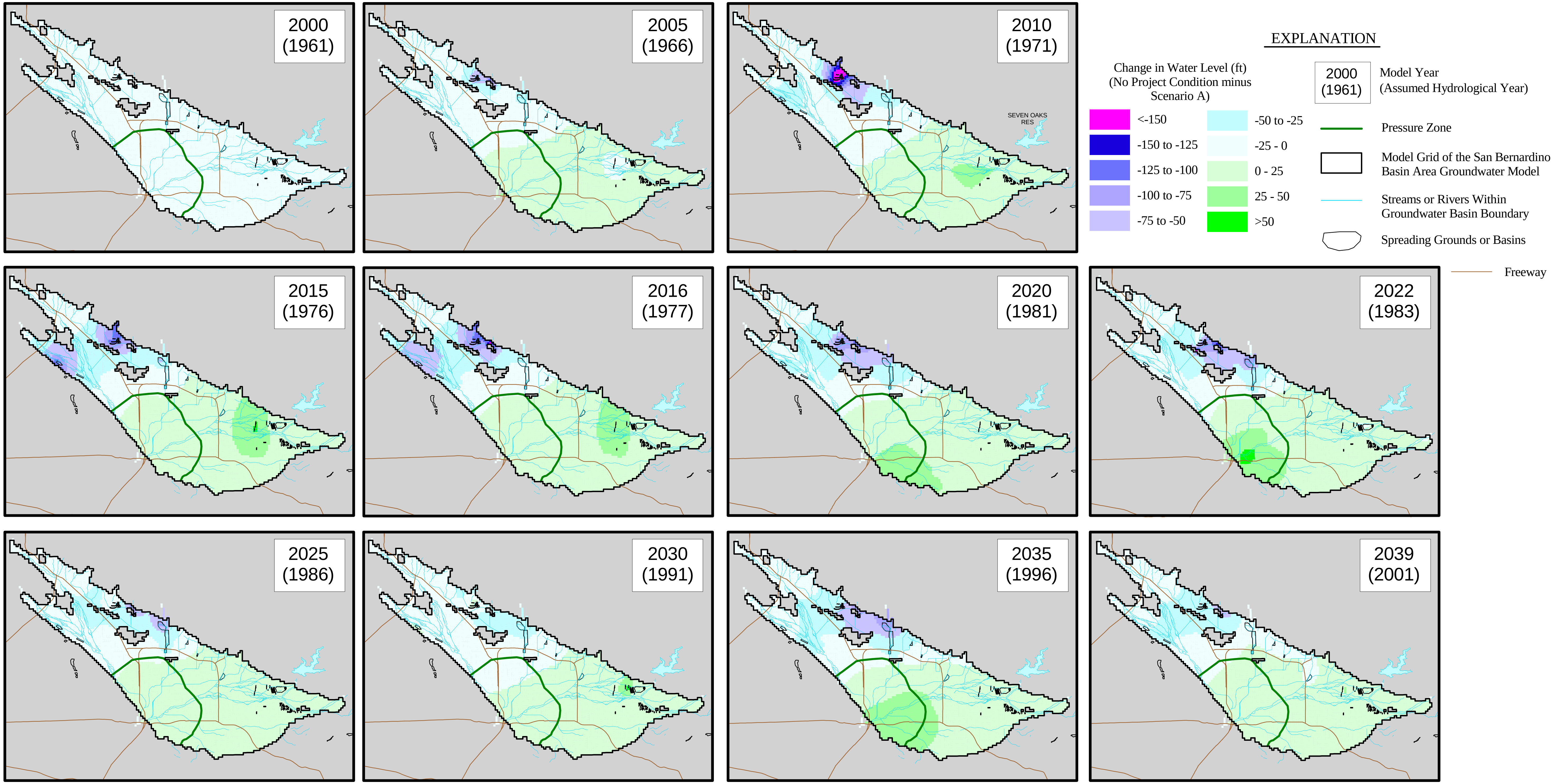
NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 24

DIFFERENCES IN GROUNDWATER LEVEL BETWEEN NO PROJECT CONDITION AND SCENARIO A
LAYER 1



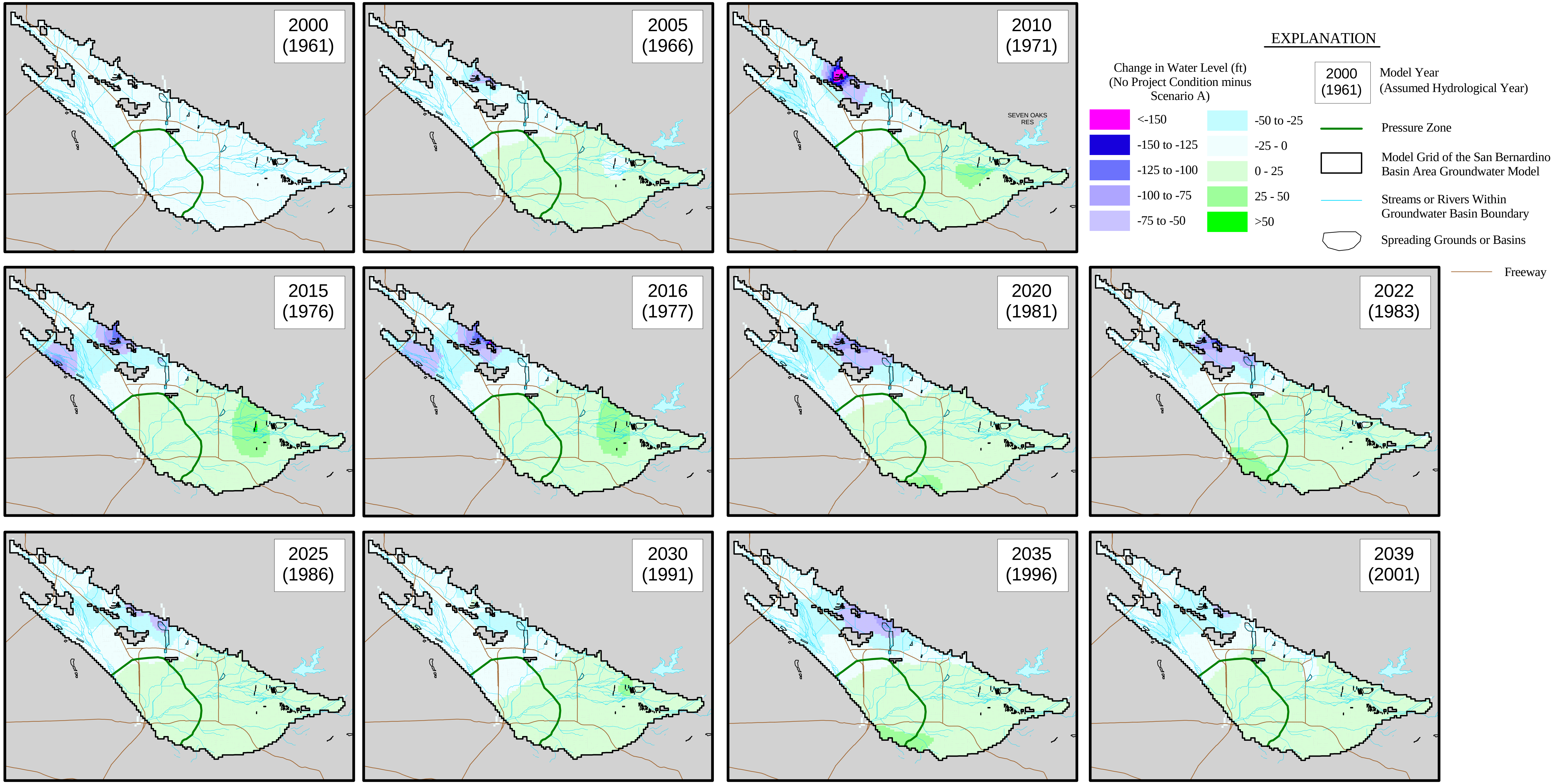
NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 25

DIFFERENCES IN GROUNDWATER LEVEL BETWEEN NO PROJECT CONDITION AND SCENARIO A
LAYER 2



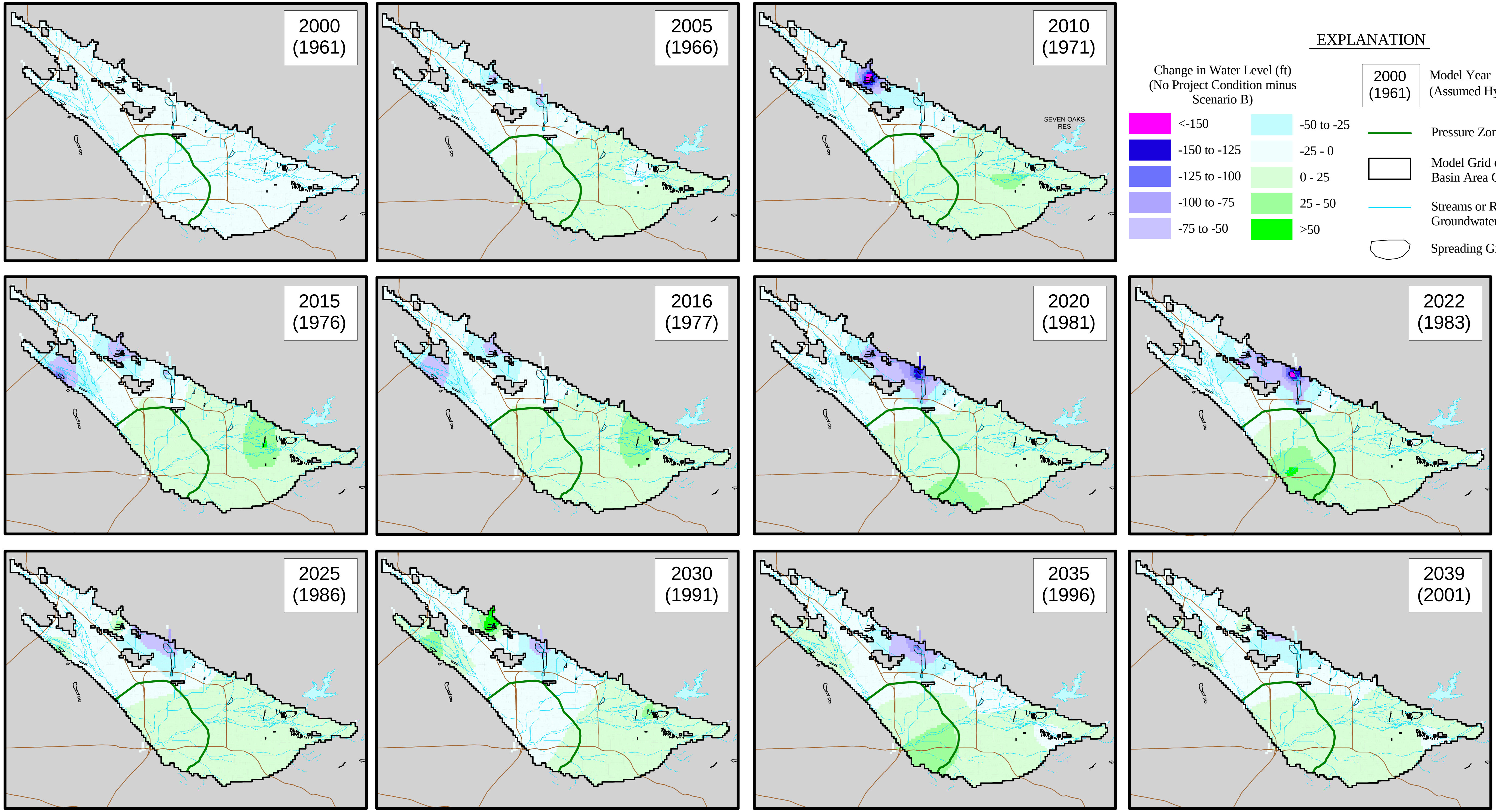
NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 26

DIFFERENCES IN GROUNDWATER LEVEL BETWEEN NO PROJECT CONDITION AND SCENARIO B
LAYER 1



EXPLANATION

Change in Water Level (ft)
(No Project Condition minus
Scenario B)

■	<-150	■	-50 to -25
■	-150 to -125	■	-25 - 0
■	-125 to -100	■	0 - 25
■	-100 to -75	■	25 - 50
■	-75 to -50	■	>50

2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
☐	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
◯	Spreading Grounds or Basins
—	Freeway

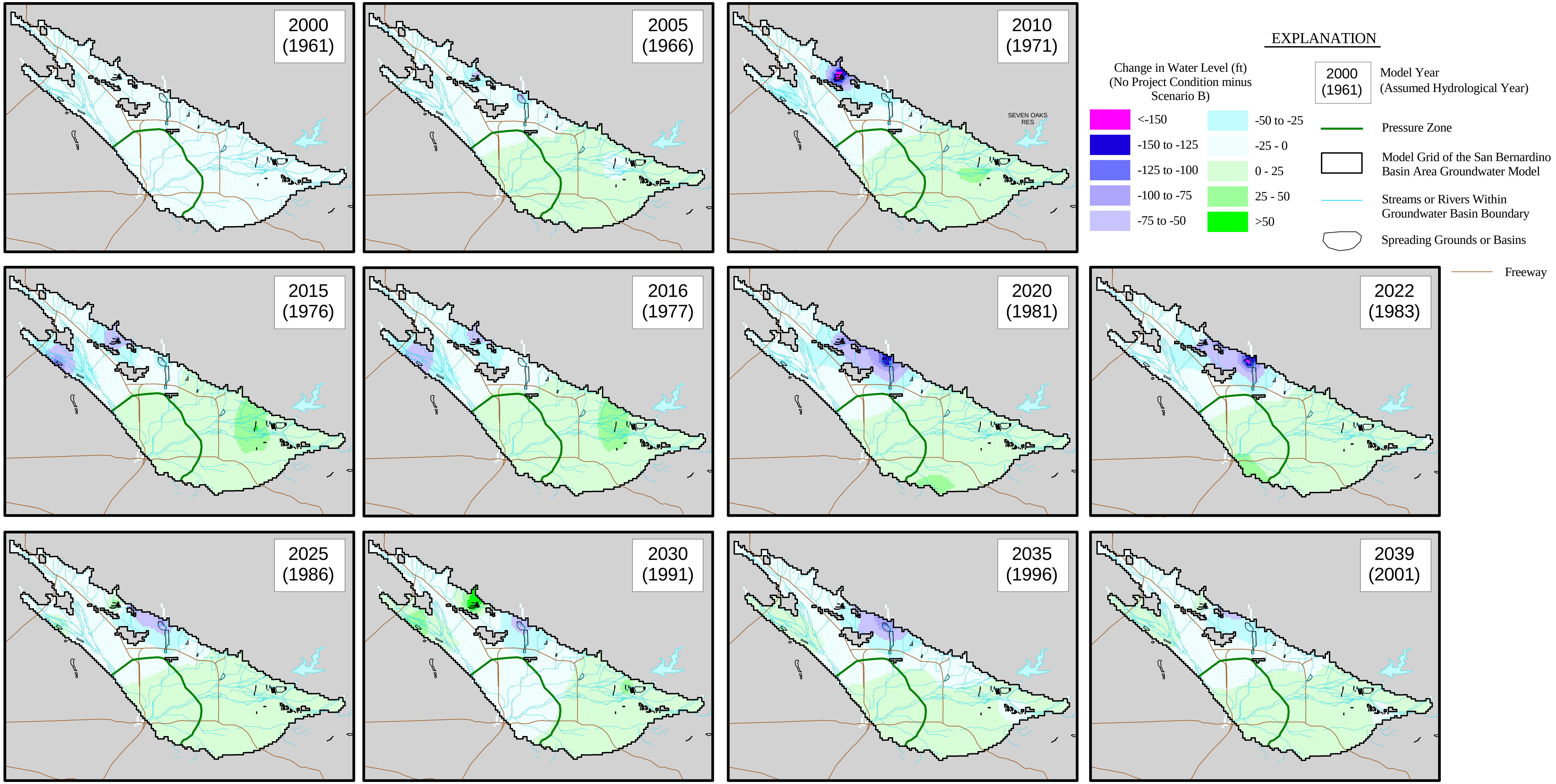
NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 27

DIFFERENCES IN GROUNDWATER LEVEL BETWEEN NO PROJECT CONDITION AND SCENARIO B
LAYER 2



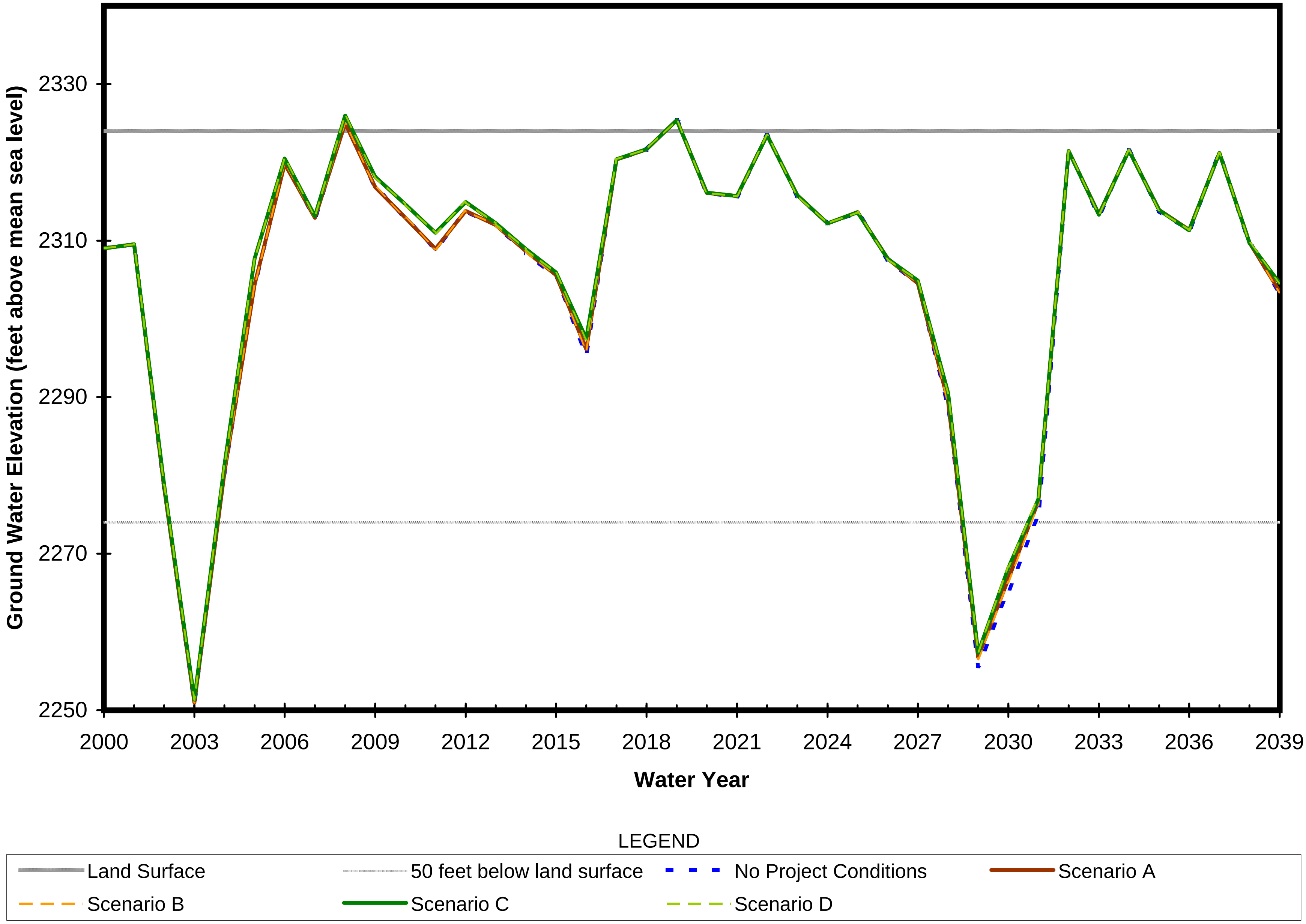
NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 28

Figure B 29a. Hydrograph for IW-01.



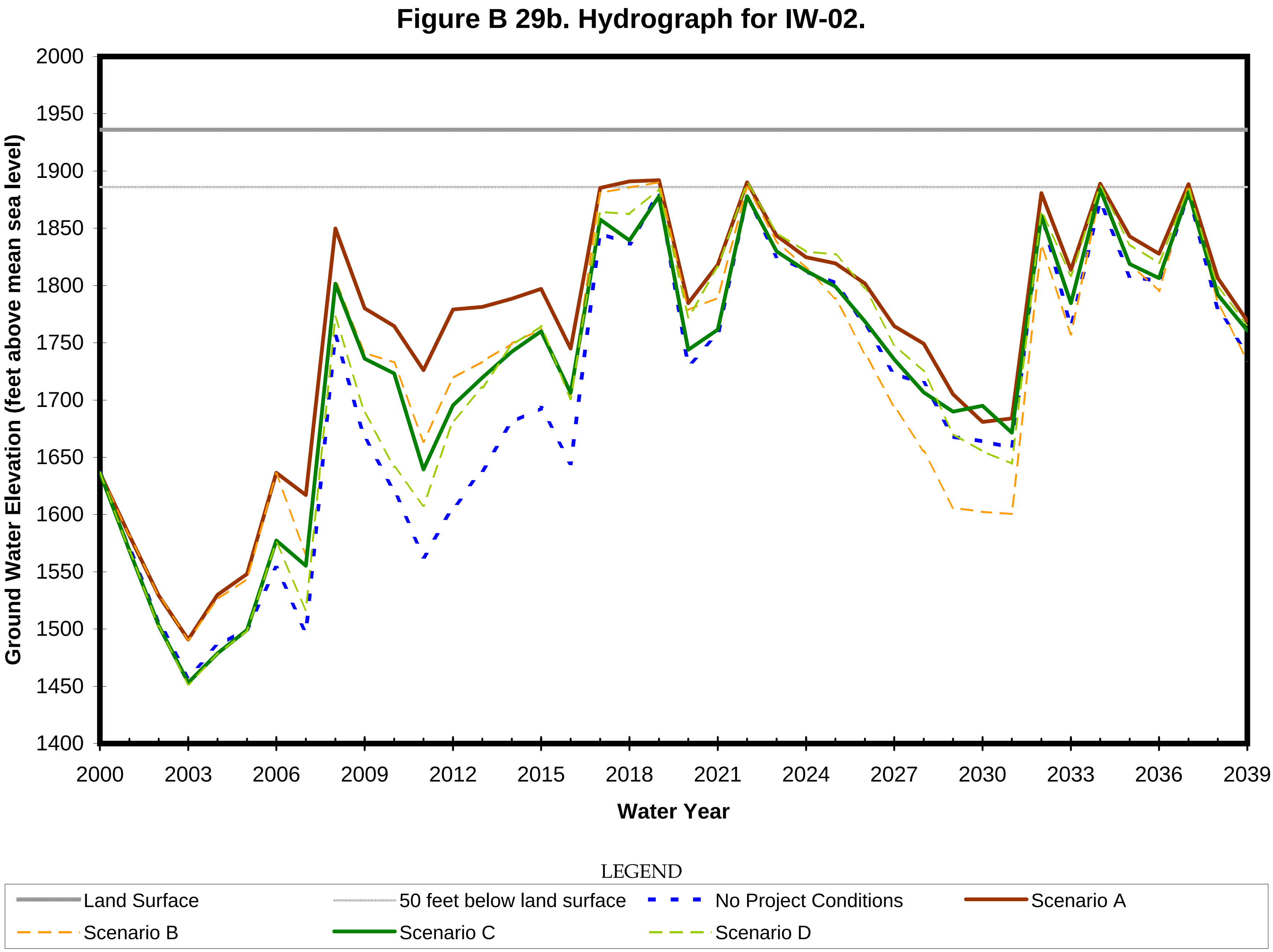


Figure B 29b. Hydrograph for IW-02.
Ground Water Elevation (feet above mean sea level)
2000
1950
1900
1850
1800
1750
1700
1650
1600
1550
1500
1450
1400
2000
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
2033
2036
2039
Water Year
LEGEND
Land Surface
50 feet below land surface
No Project Conditions
Scenario A
Scenario B
Scenario C
Scenario D

Figure B 29c. Hydrograph for IW-03.

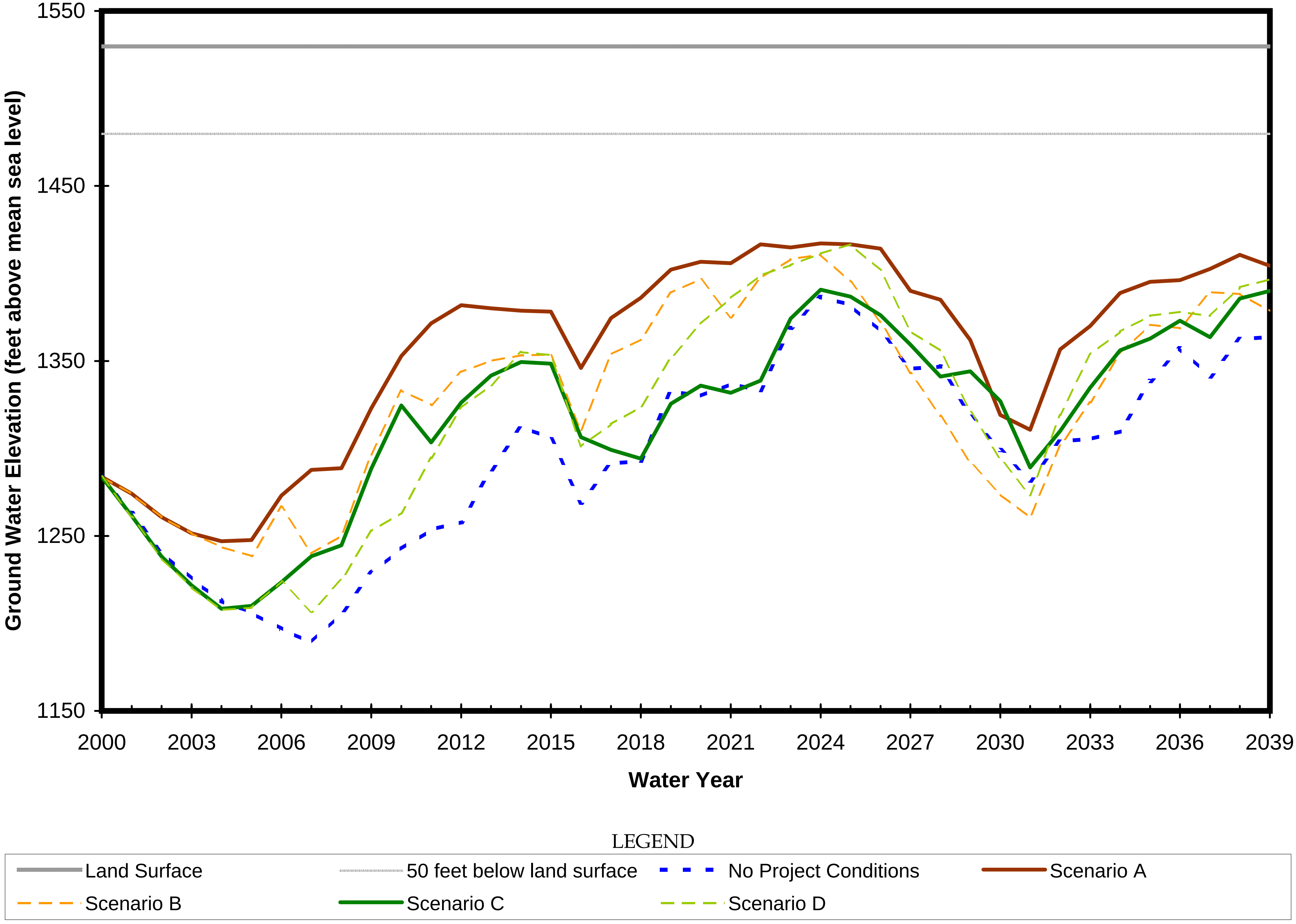
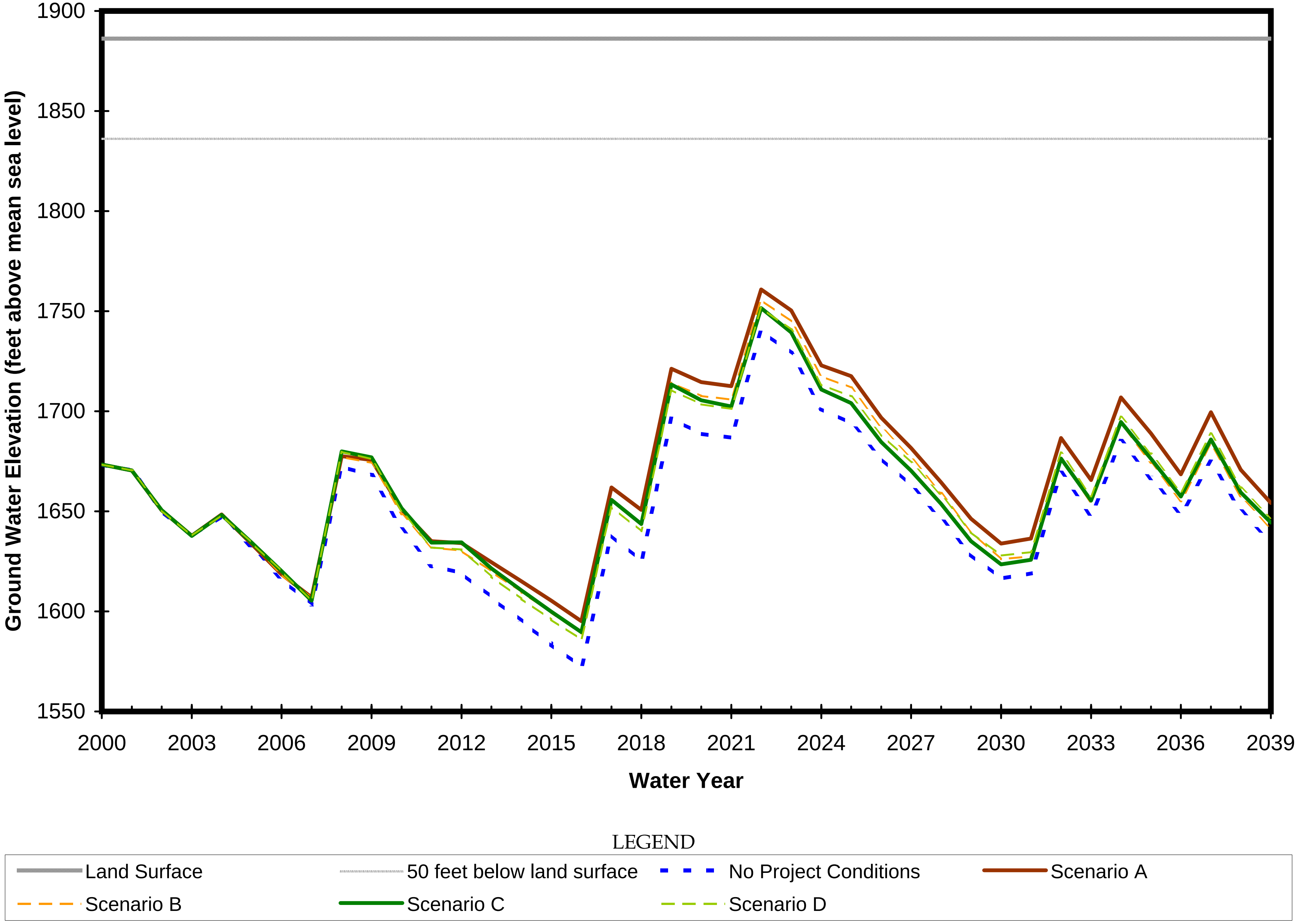


Figure B 29d. Hydrograph for IW-04.



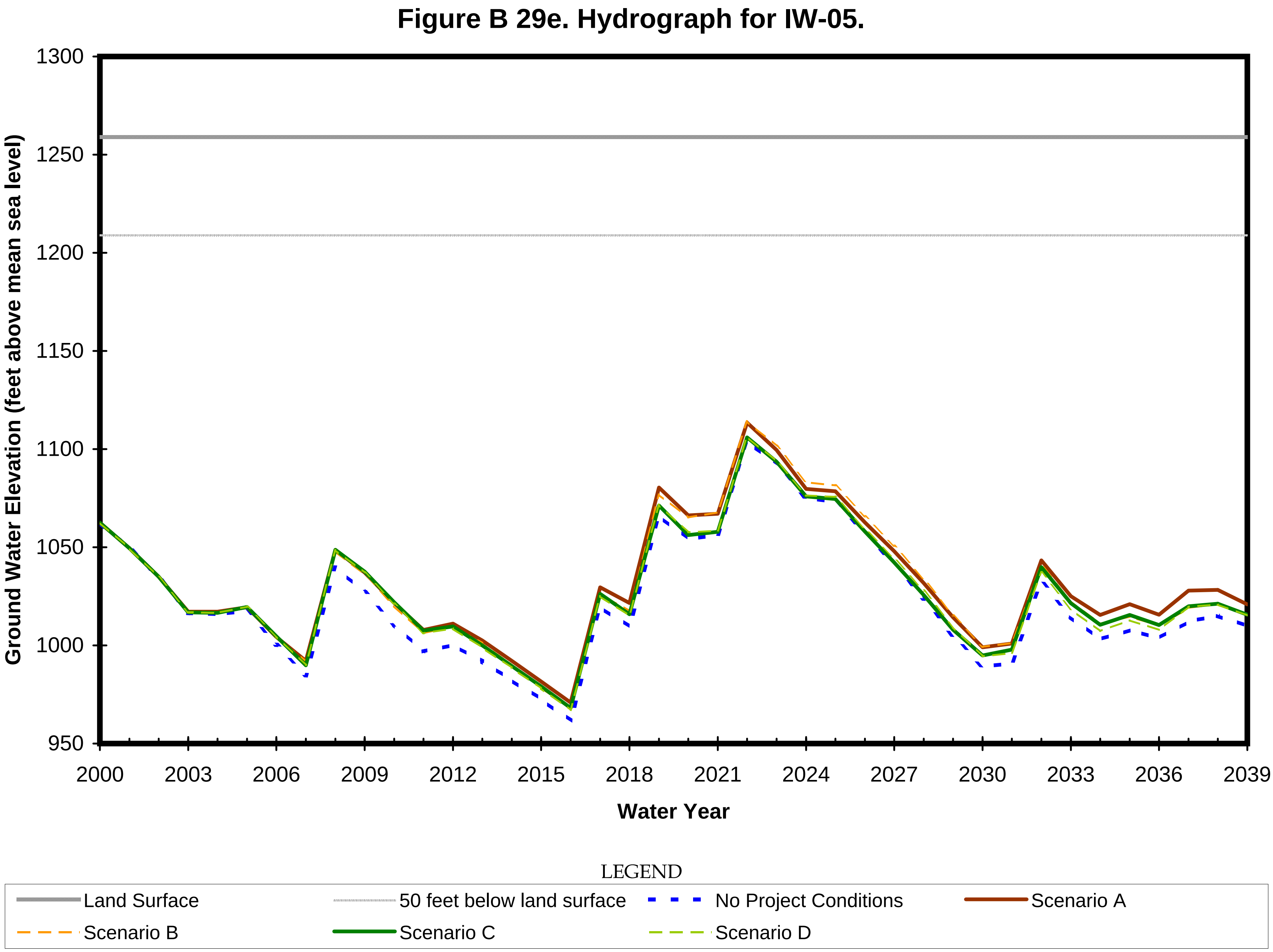


Figure B 29e. Hydrograph for IW-05.
Ground Water Elevation (feet above mean sea level)
1300
1250
1200
1150
1100
1050
1000
950
2000
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
2033
2036
2039
Water Year
LEGEND
Land Surface
50 feet below land surface
No Project Conditions
Scenario A
Scenario B
Scenario C
Scenario D

Figure B 29f. Hydrograph for IW-06.

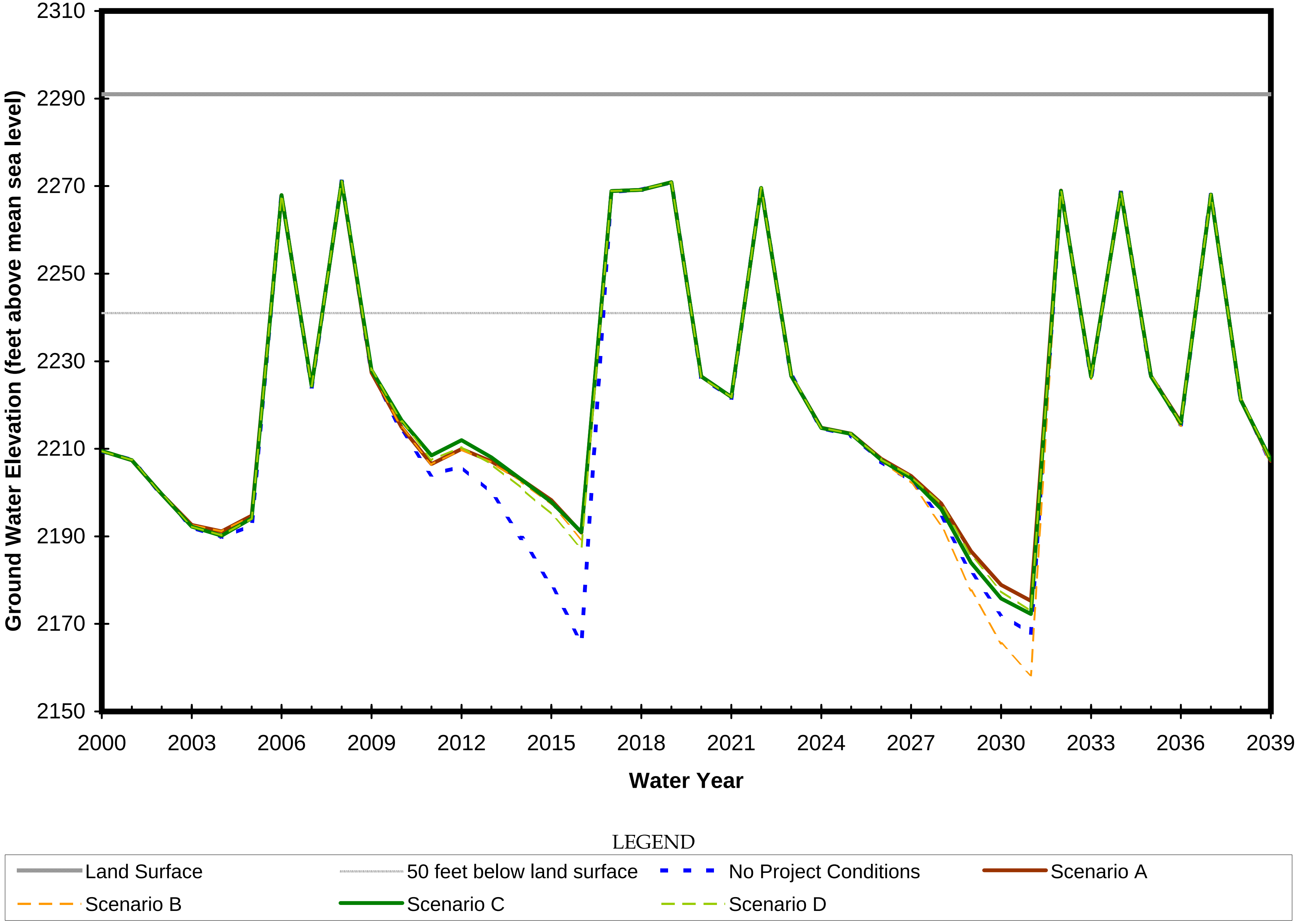


Figure B 29g. Hydrograph for IW-07.

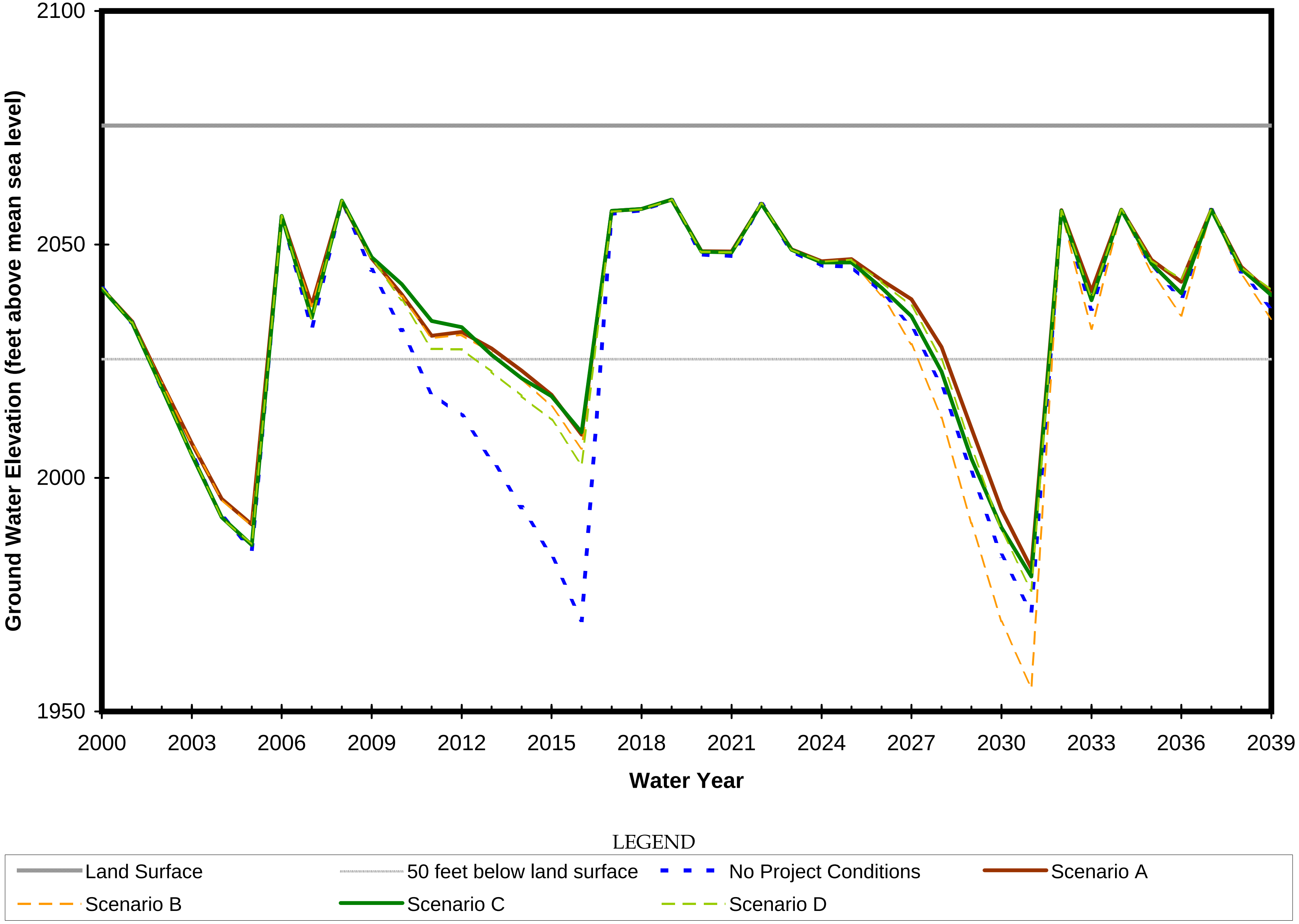


Figure B 29h. Hydrograph for IW-08.

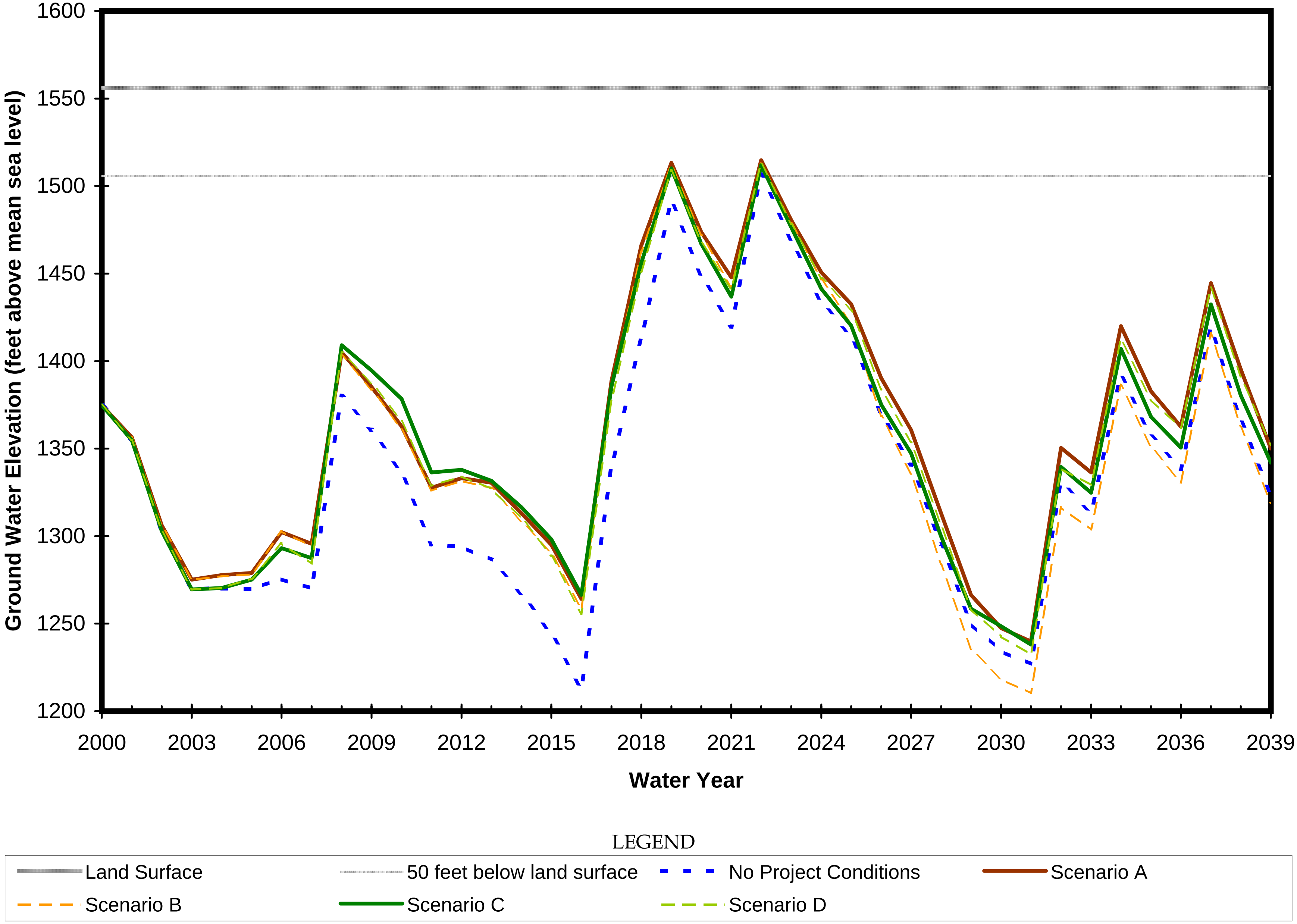


Figure B 29i. Hydrograph for IW-09.

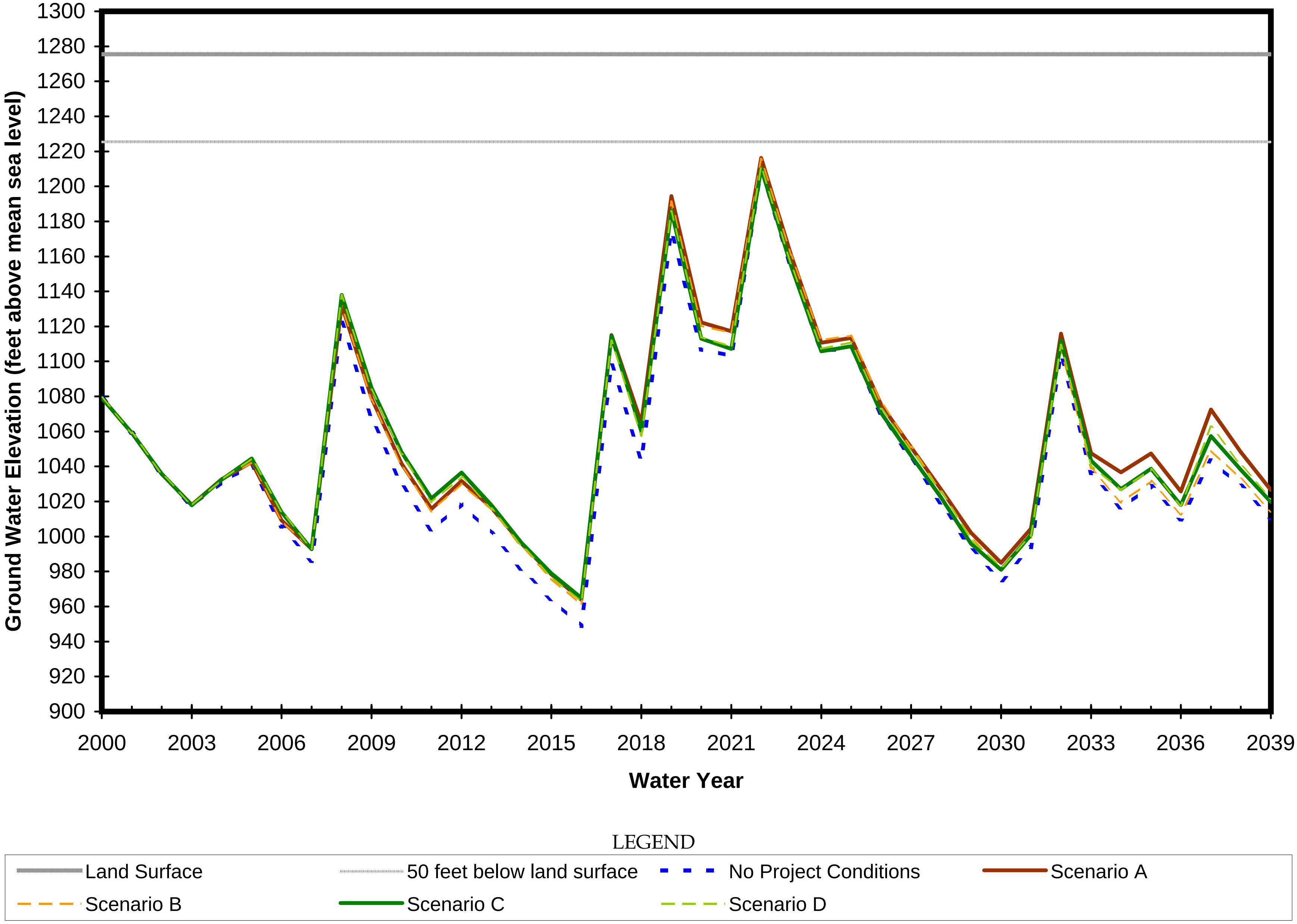


Figure B 29j. Hydrograph for IW-10.

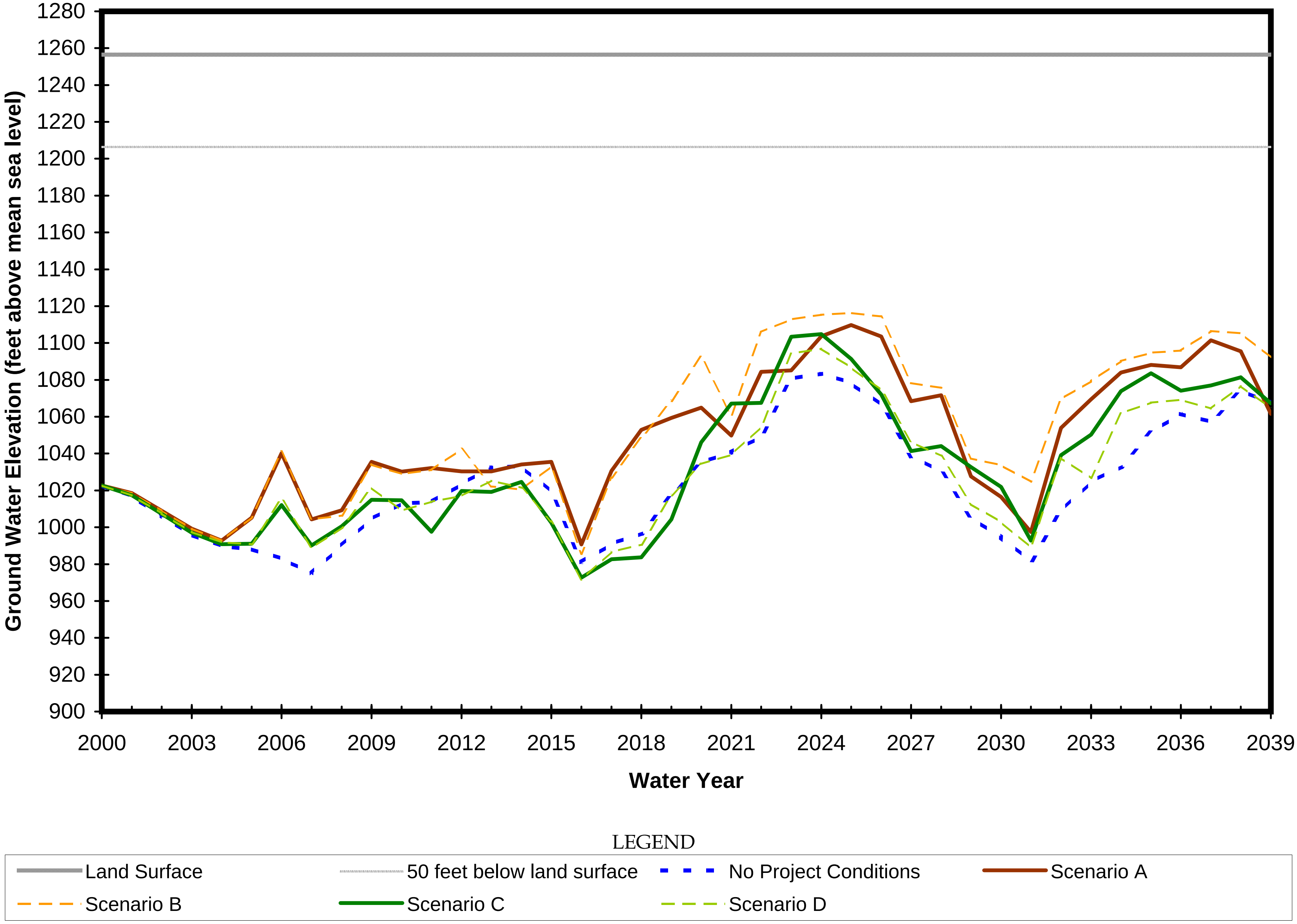


Figure B 29k. Hydrograph for IW-11.

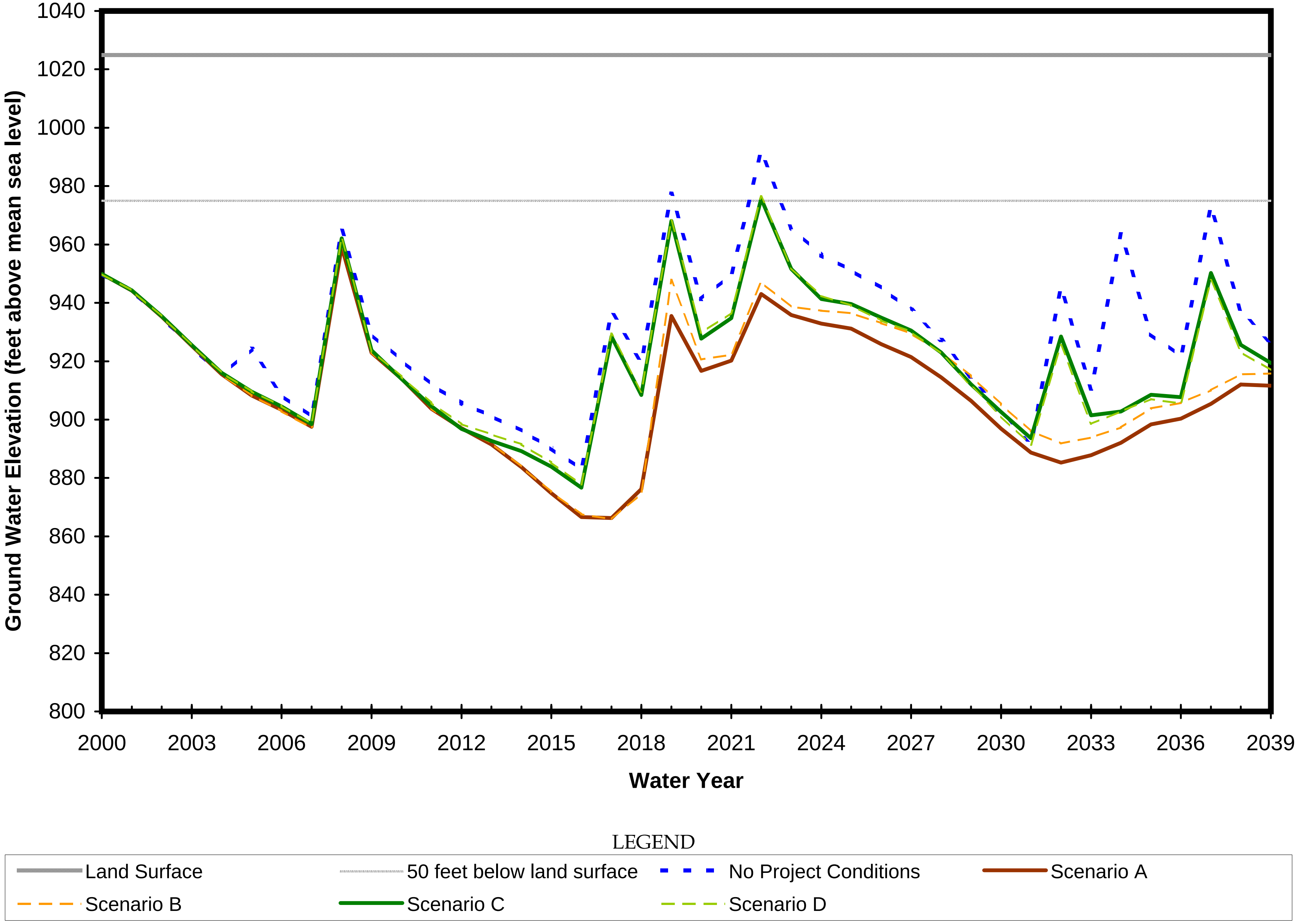
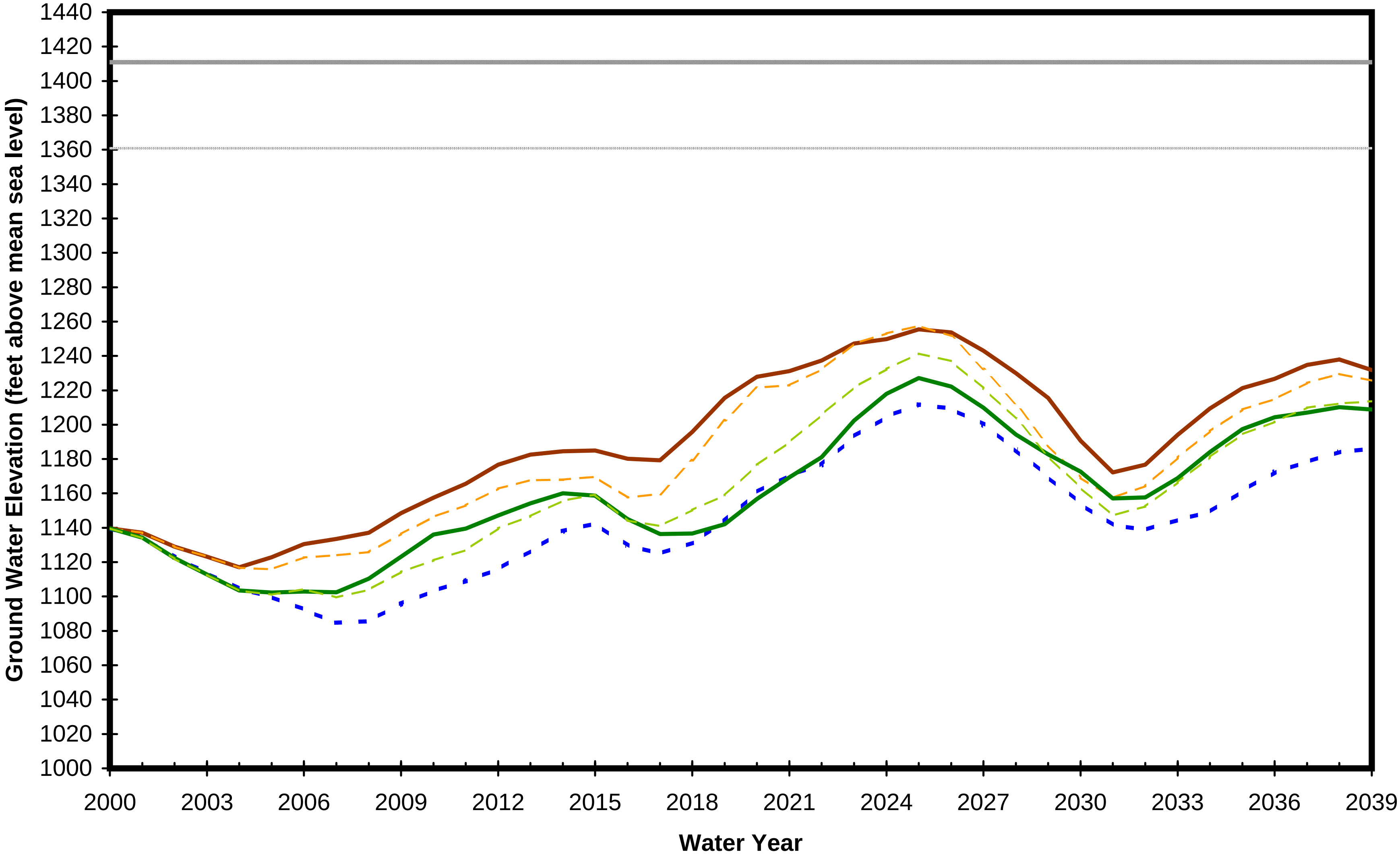


Figure B 29l. Hydrograph for IW-12.

Figure B 29m. Hydrograph for IW-13.



LEGEND

Land Surface	50 feet below land surface	No Project Conditions	Scenario A
Scenario B	Scenario C	Scenario D	

Figure B 29n. Hydrograph for IW-14.

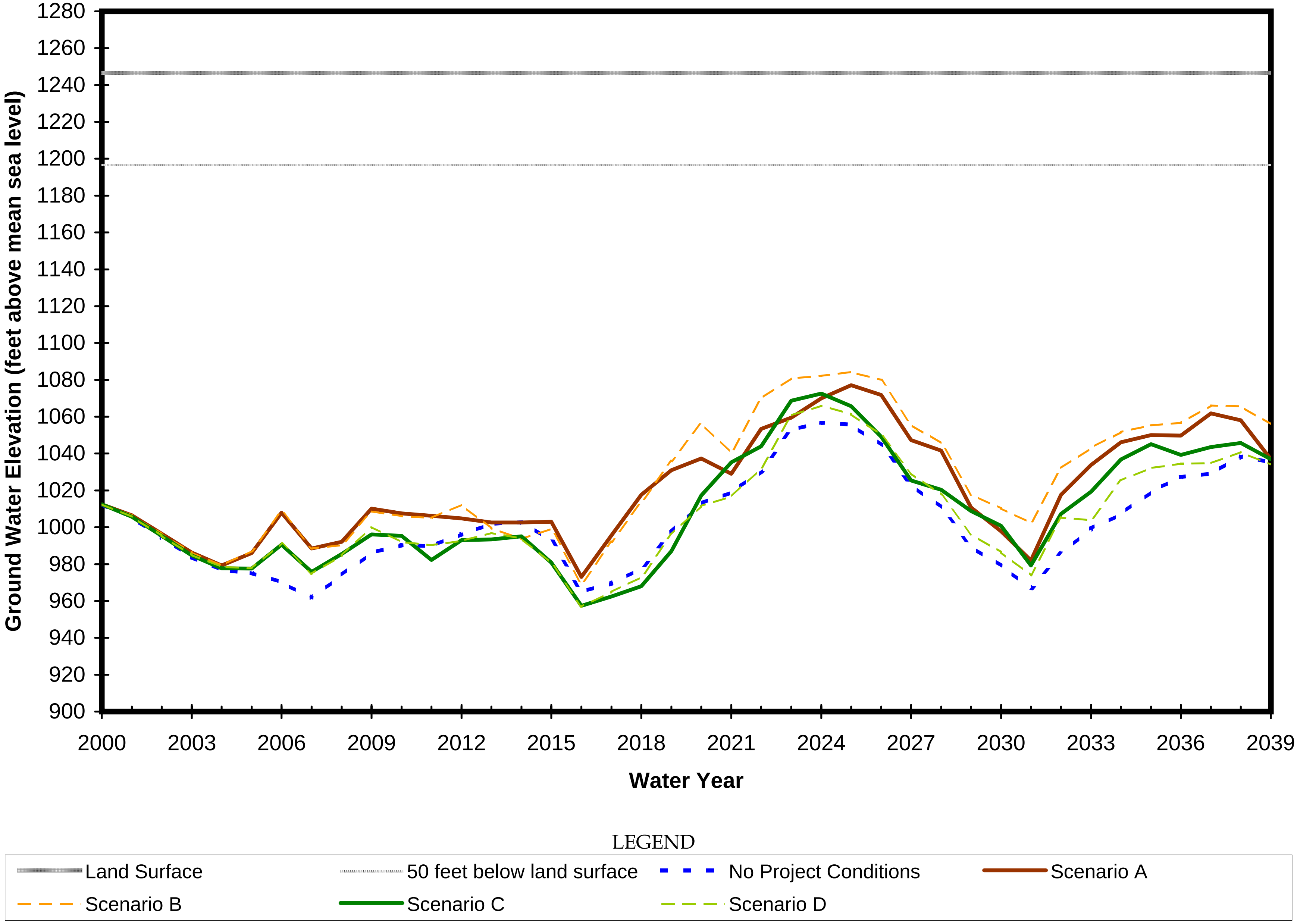


Figure B 29o. Hydrograph for IW-15.

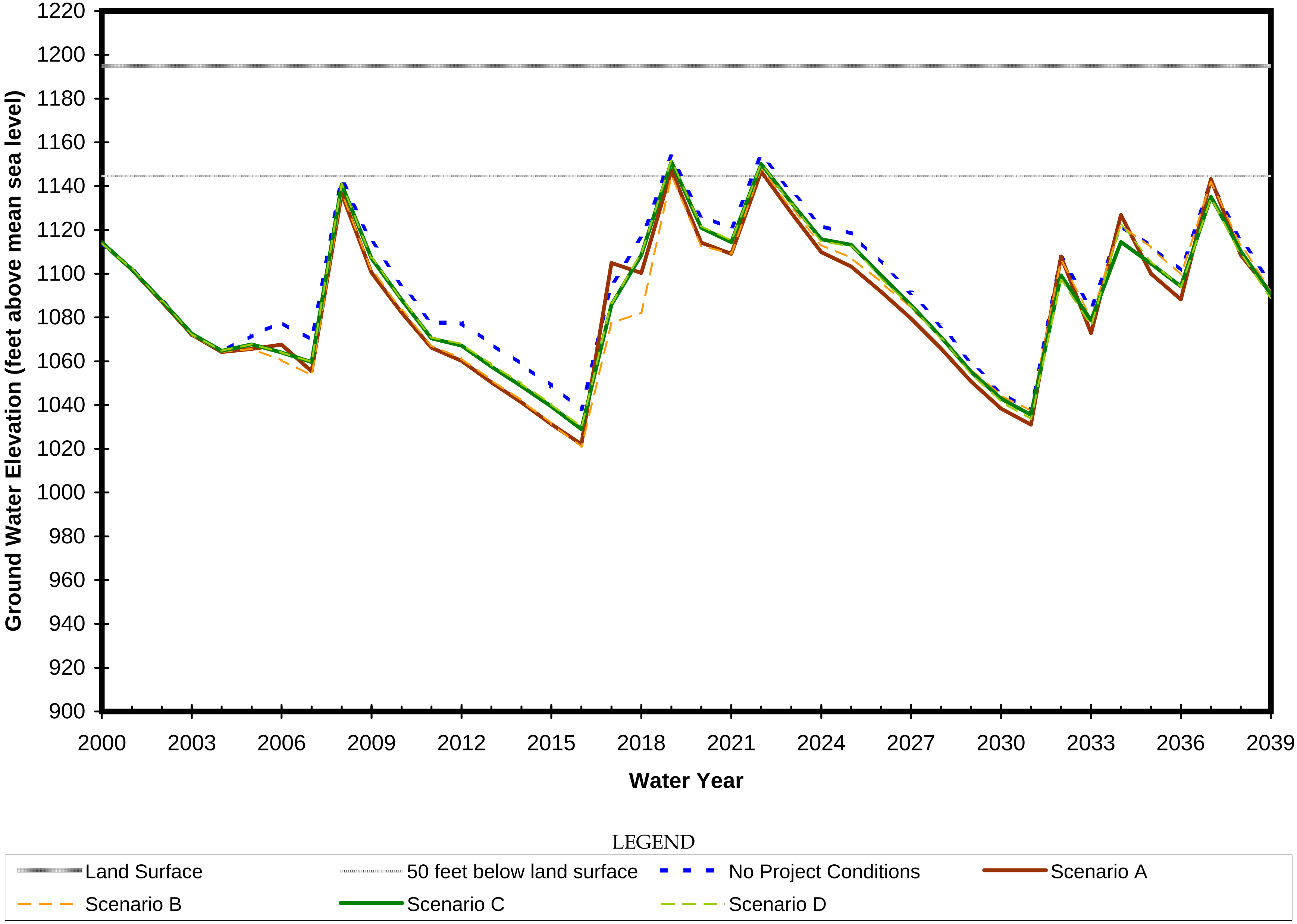


Figure B 29p. Hydrograph for IW-16.

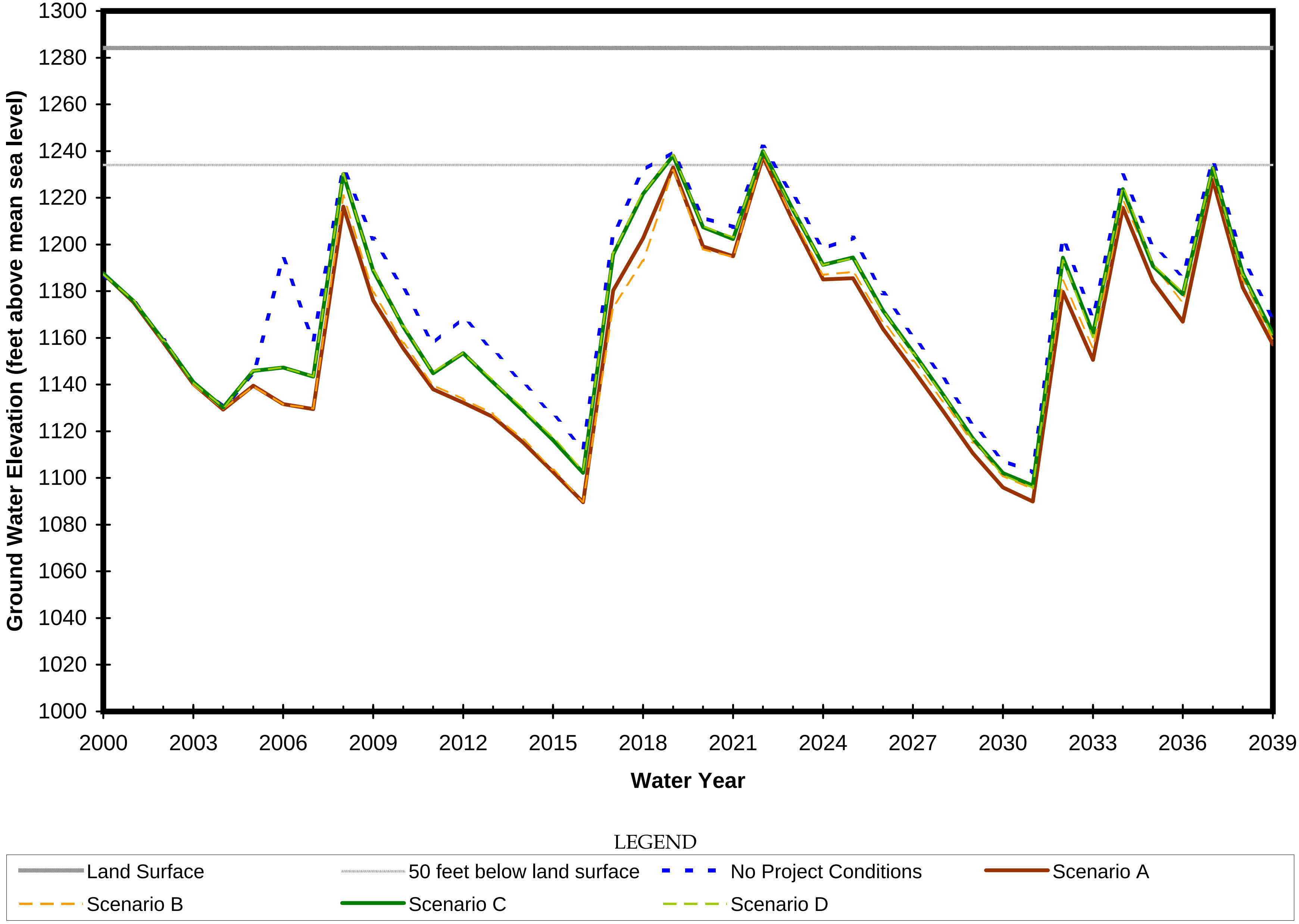


Figure B 29q. Hydrograph for IW-17.

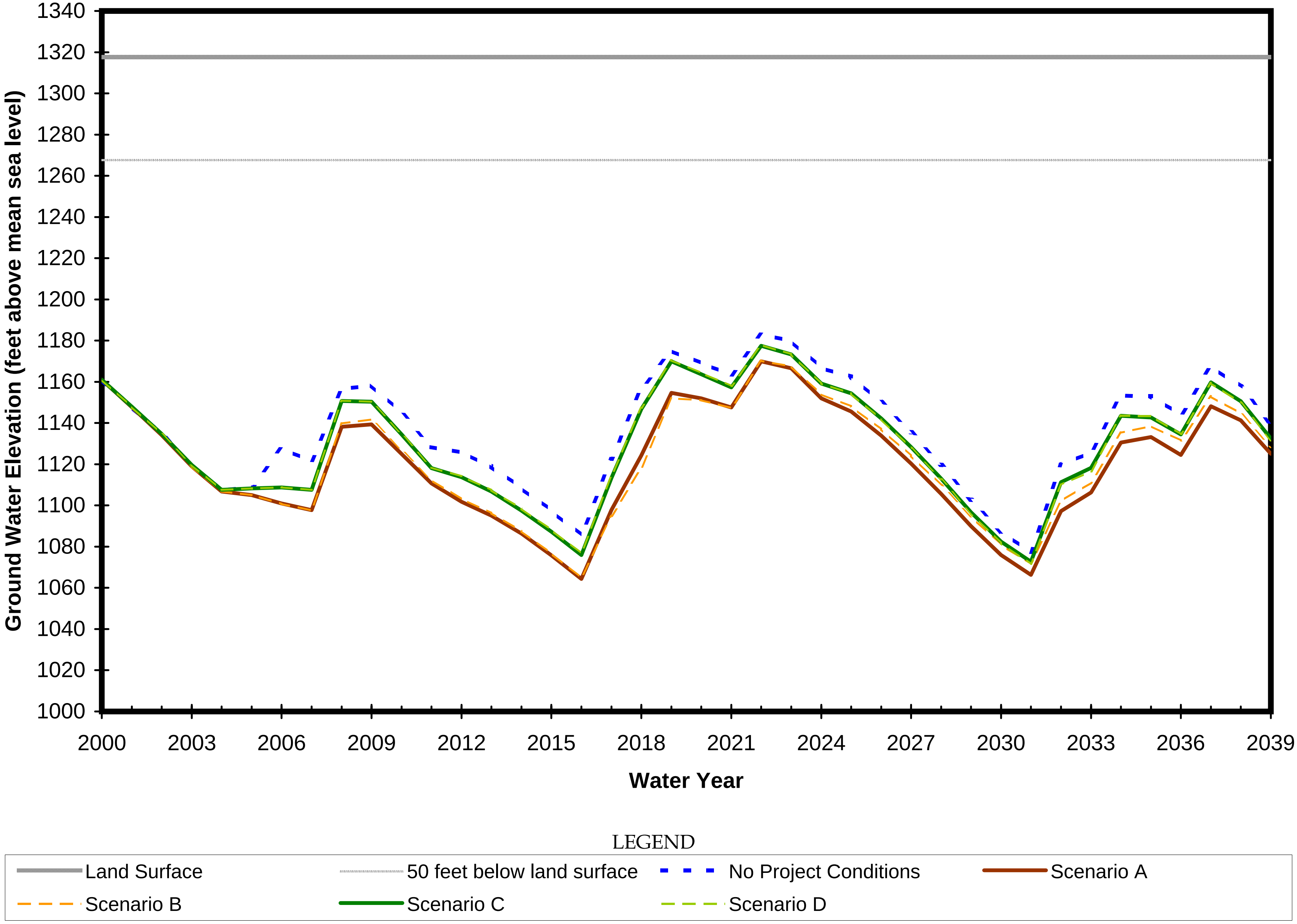


Figure B 29r. Hydrograph for IW-18.

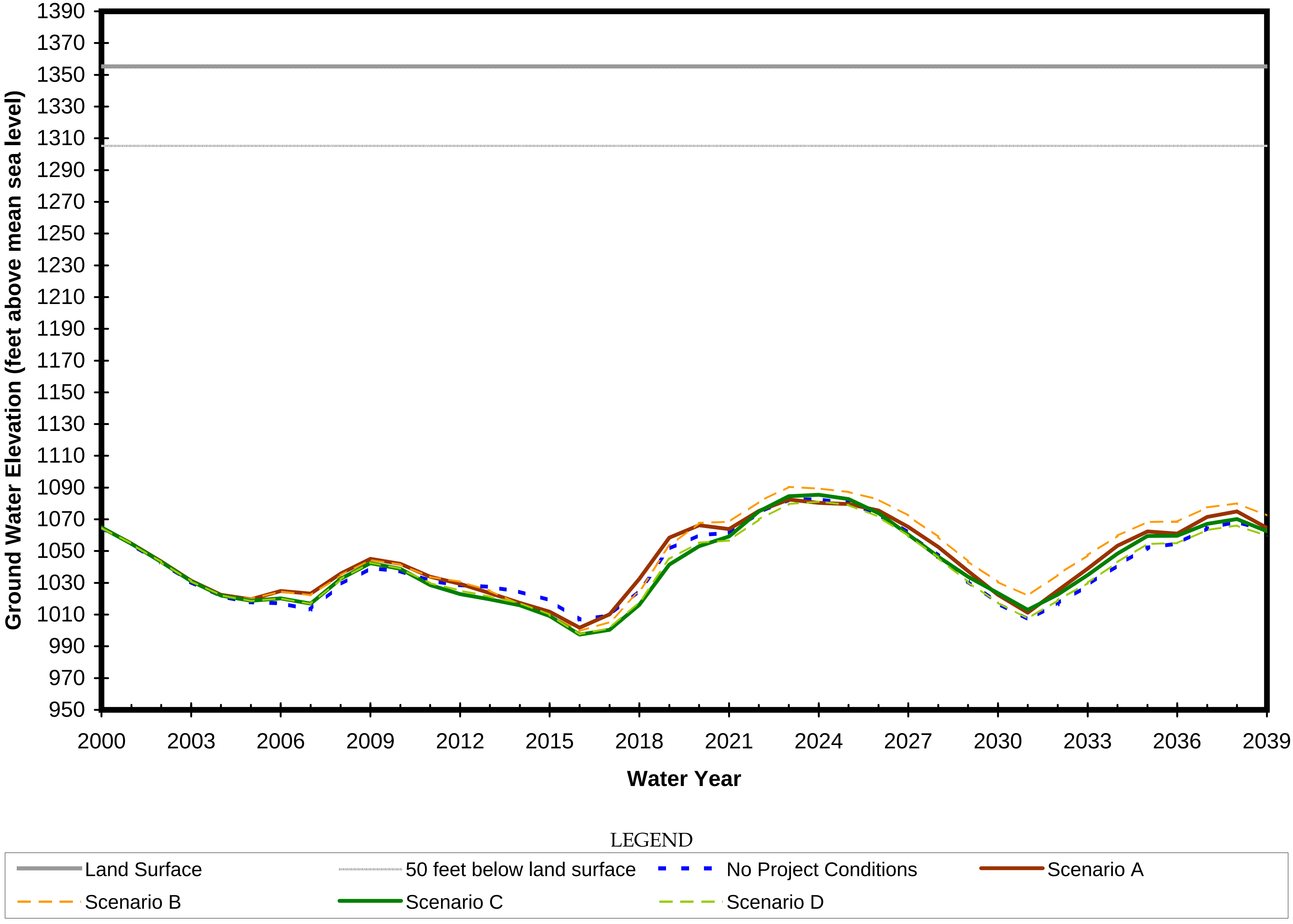


Figure B 29s. Hydrograph for IW-19.

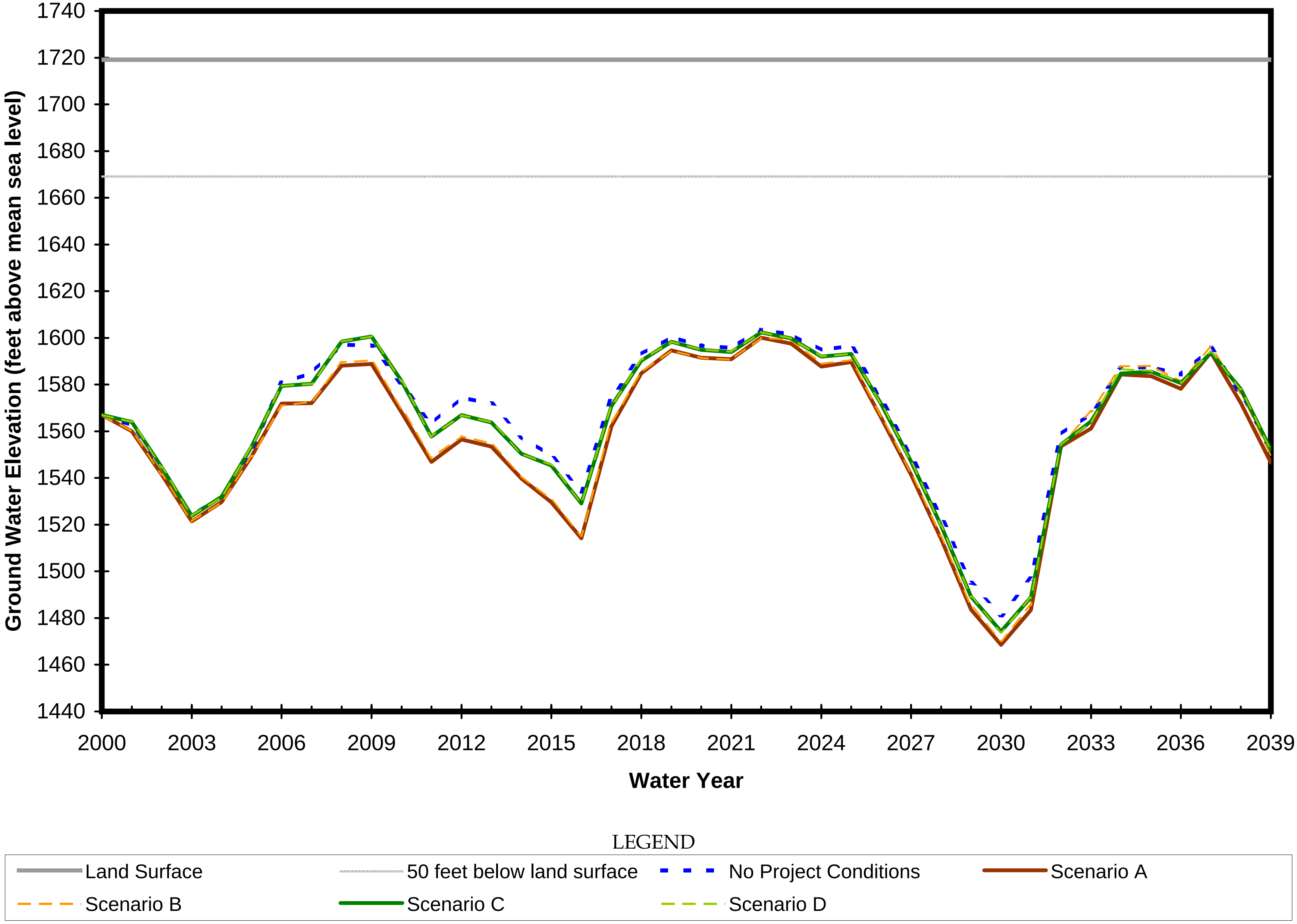


Figure B 29t. Hydrograph for IW-20.

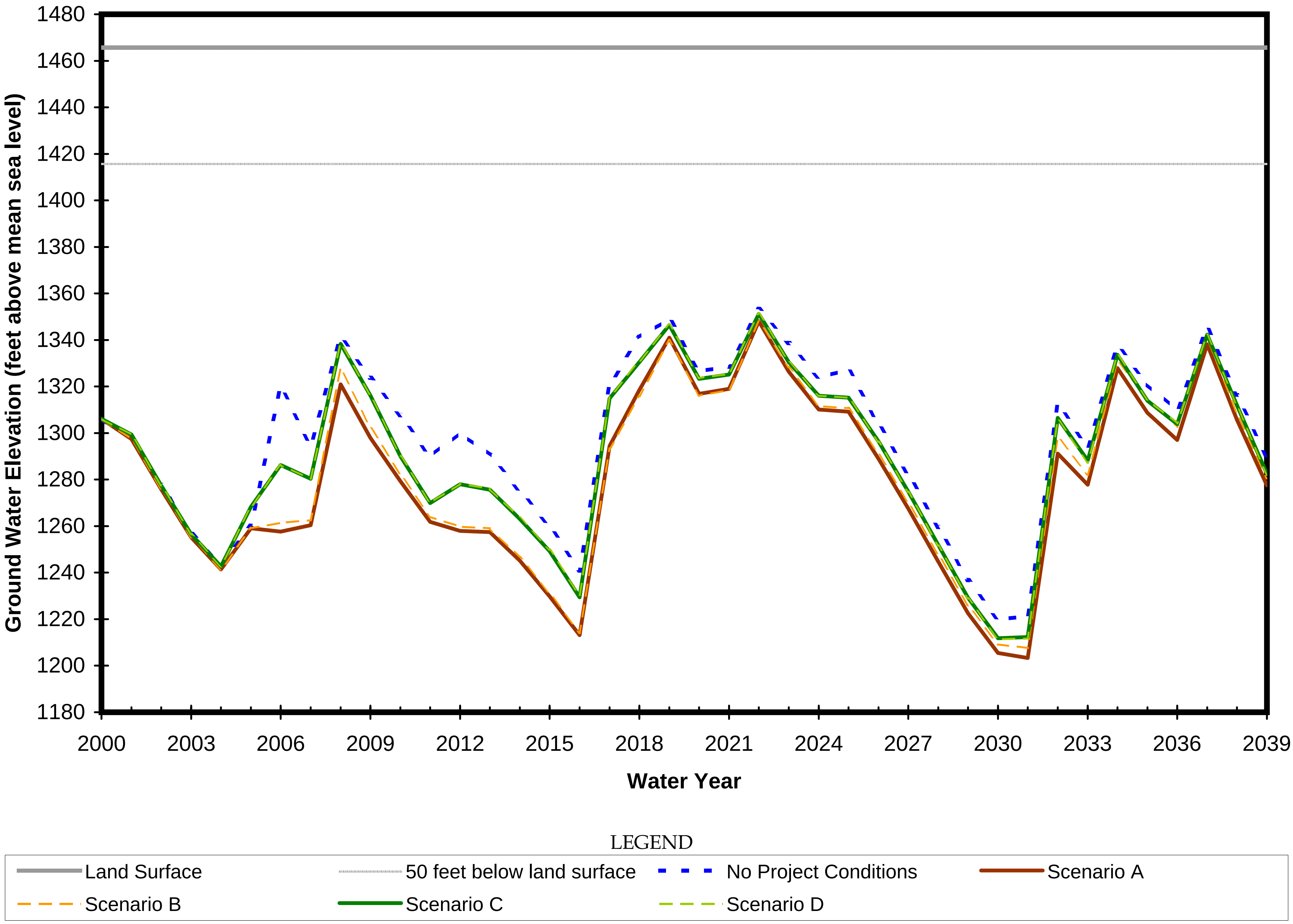


Figure B 29u. Hydrograph for IW-21.

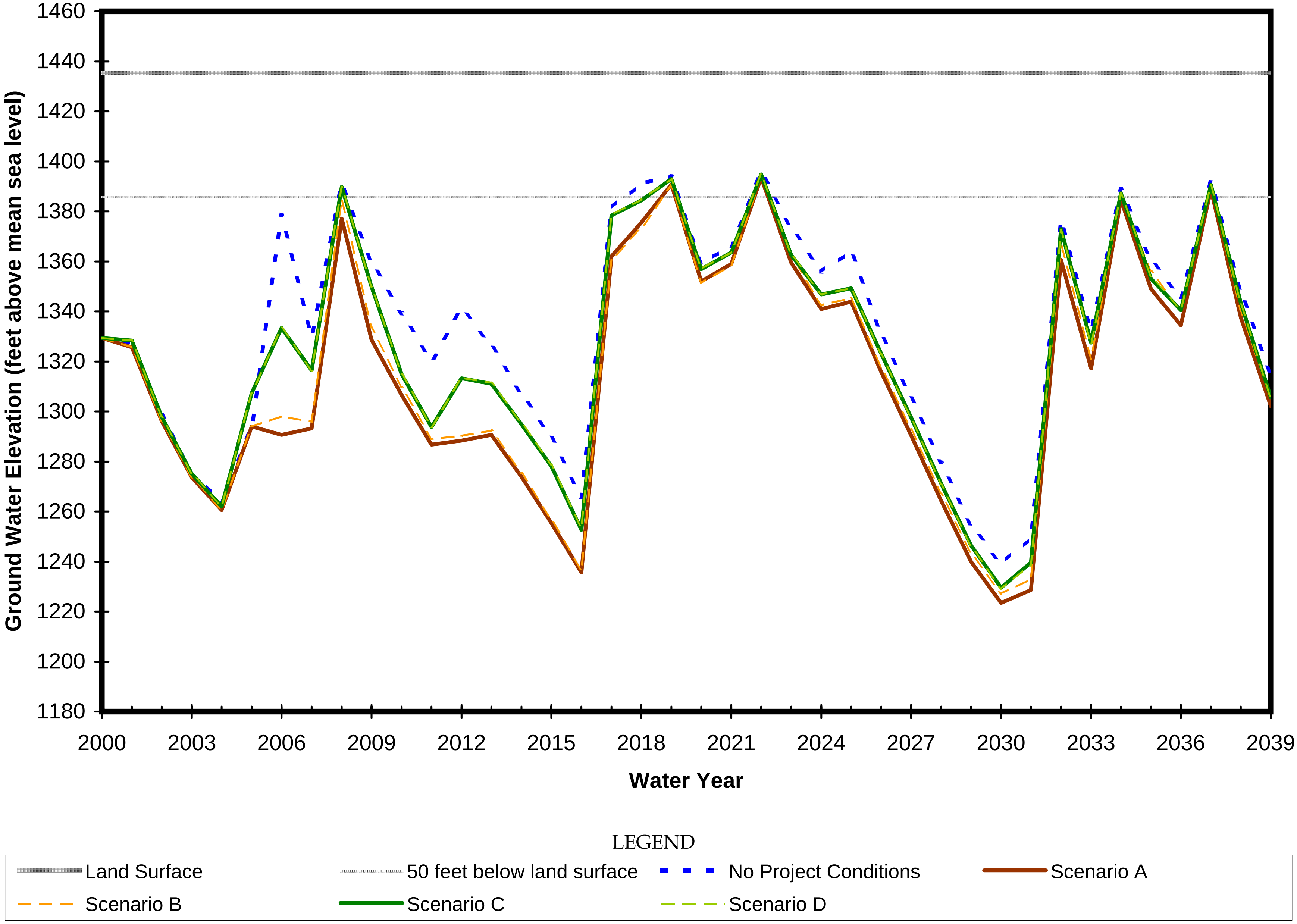


Figure B 29v. Hydrograph for IW-22.

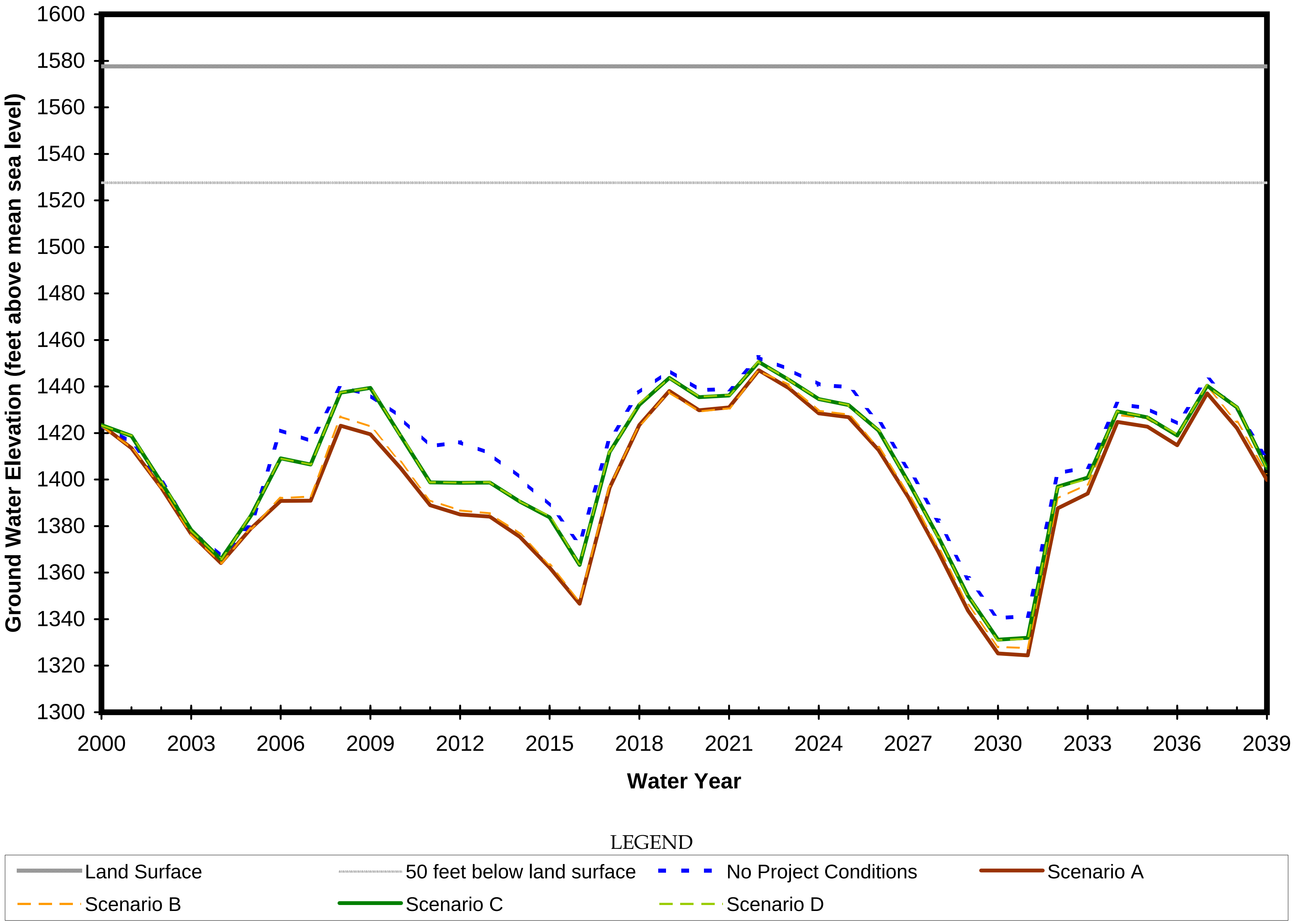


Figure B 29w. Hydrograph for IW-23.

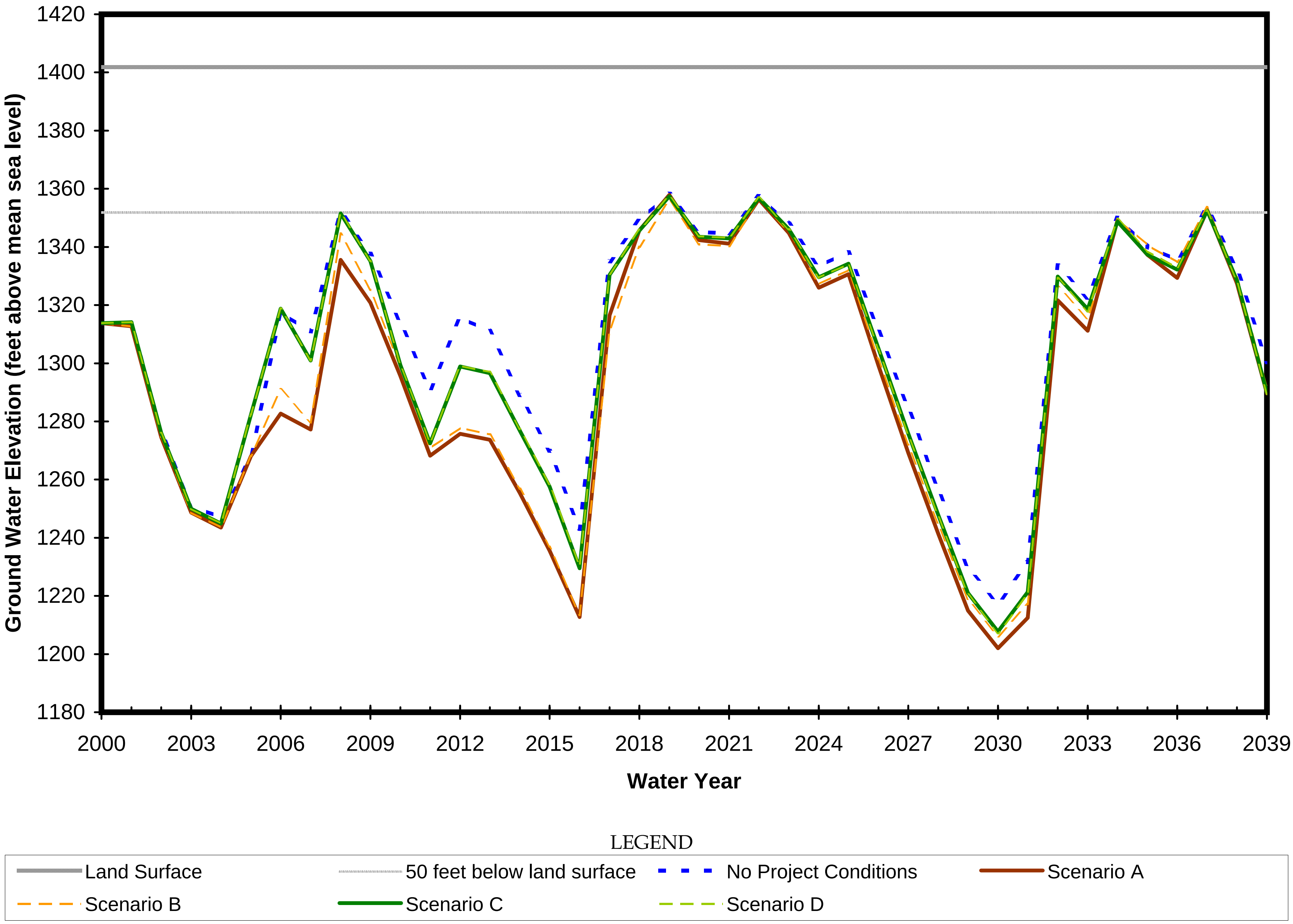


Figure B 29x. Hydrograph for IW-24.

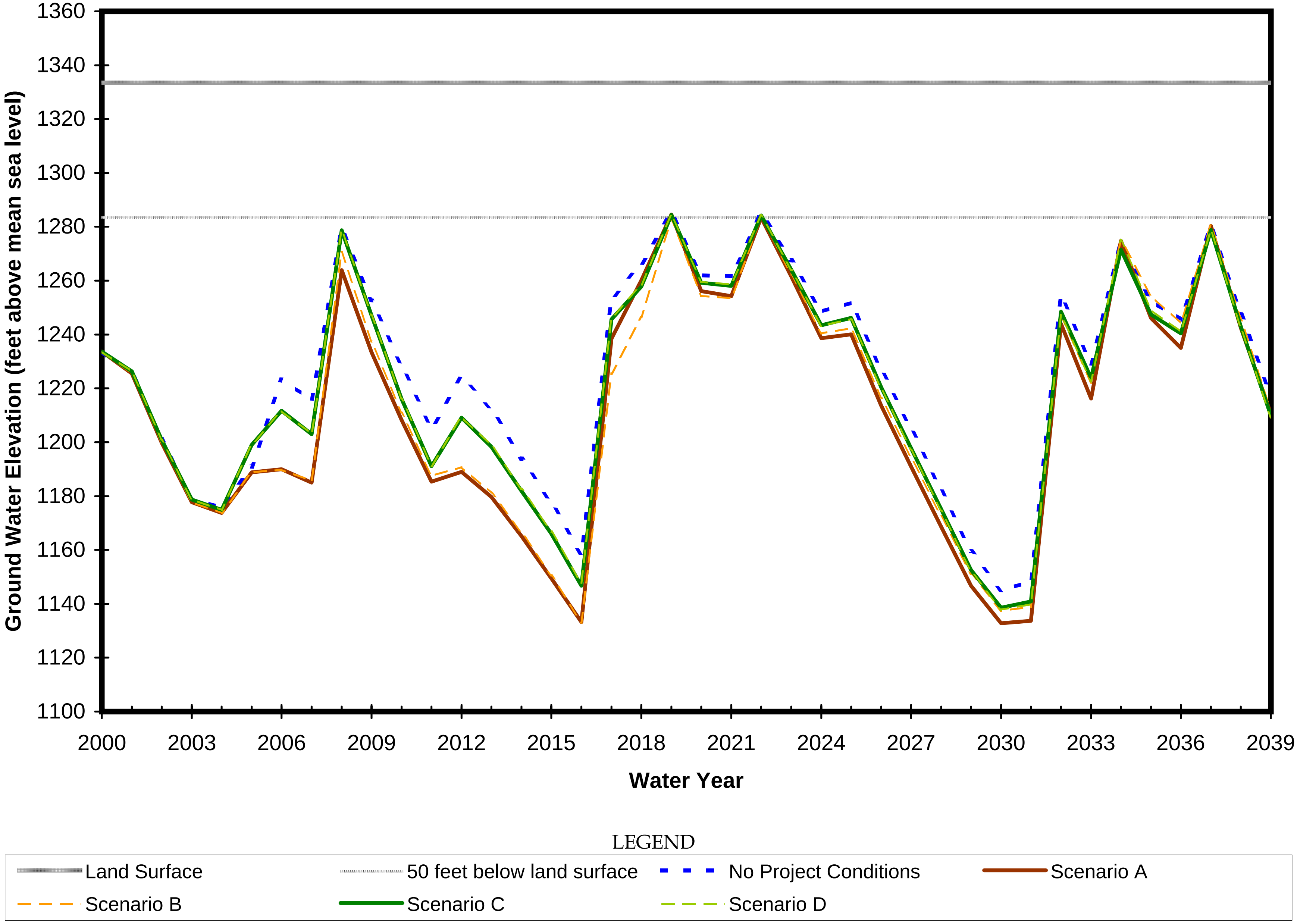


Figure B 29y. Hydrograph for IW-25.

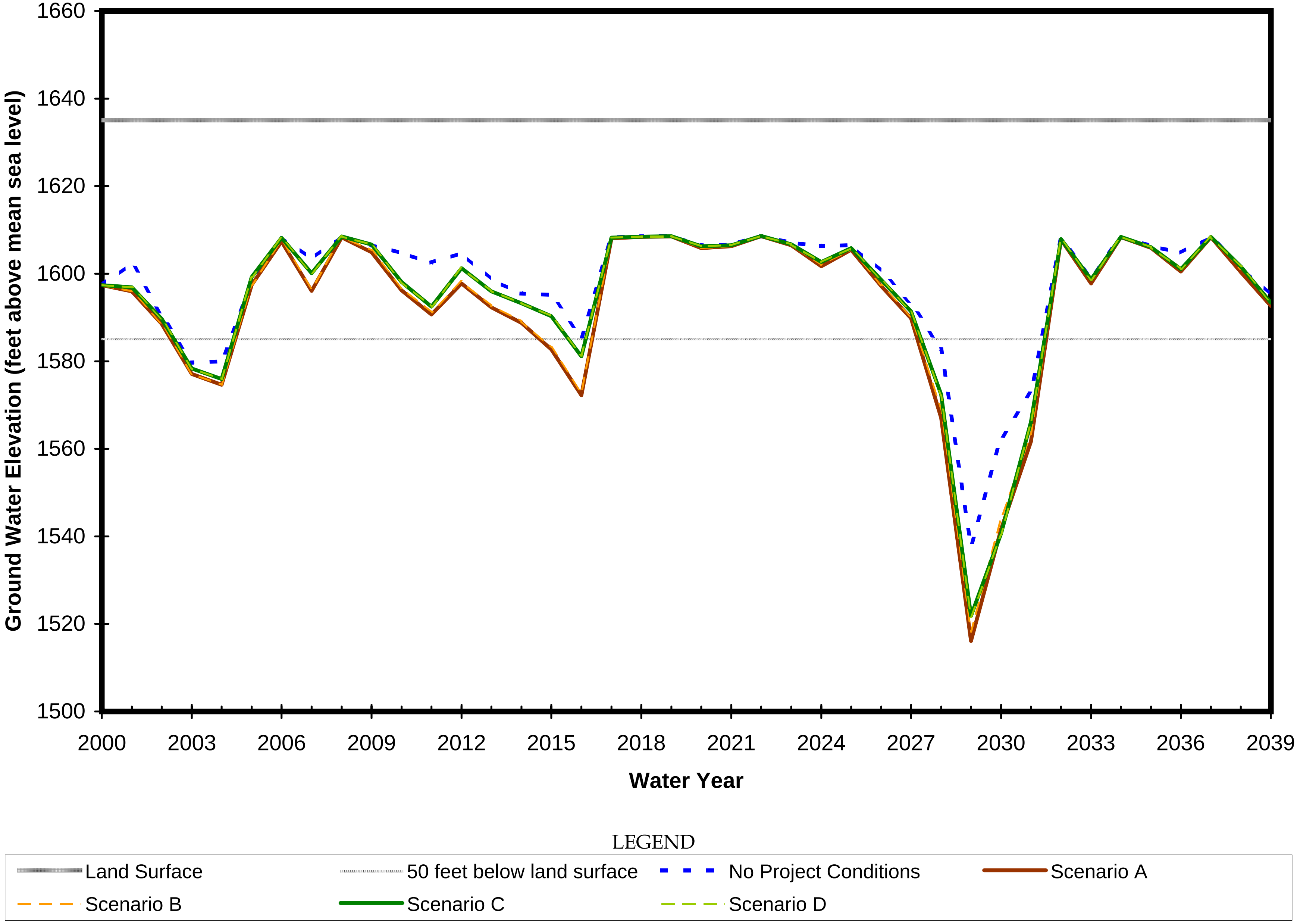


Figure B 29z. Hydrograph for SG-1 Devil Canyon / Sweetwater SG.

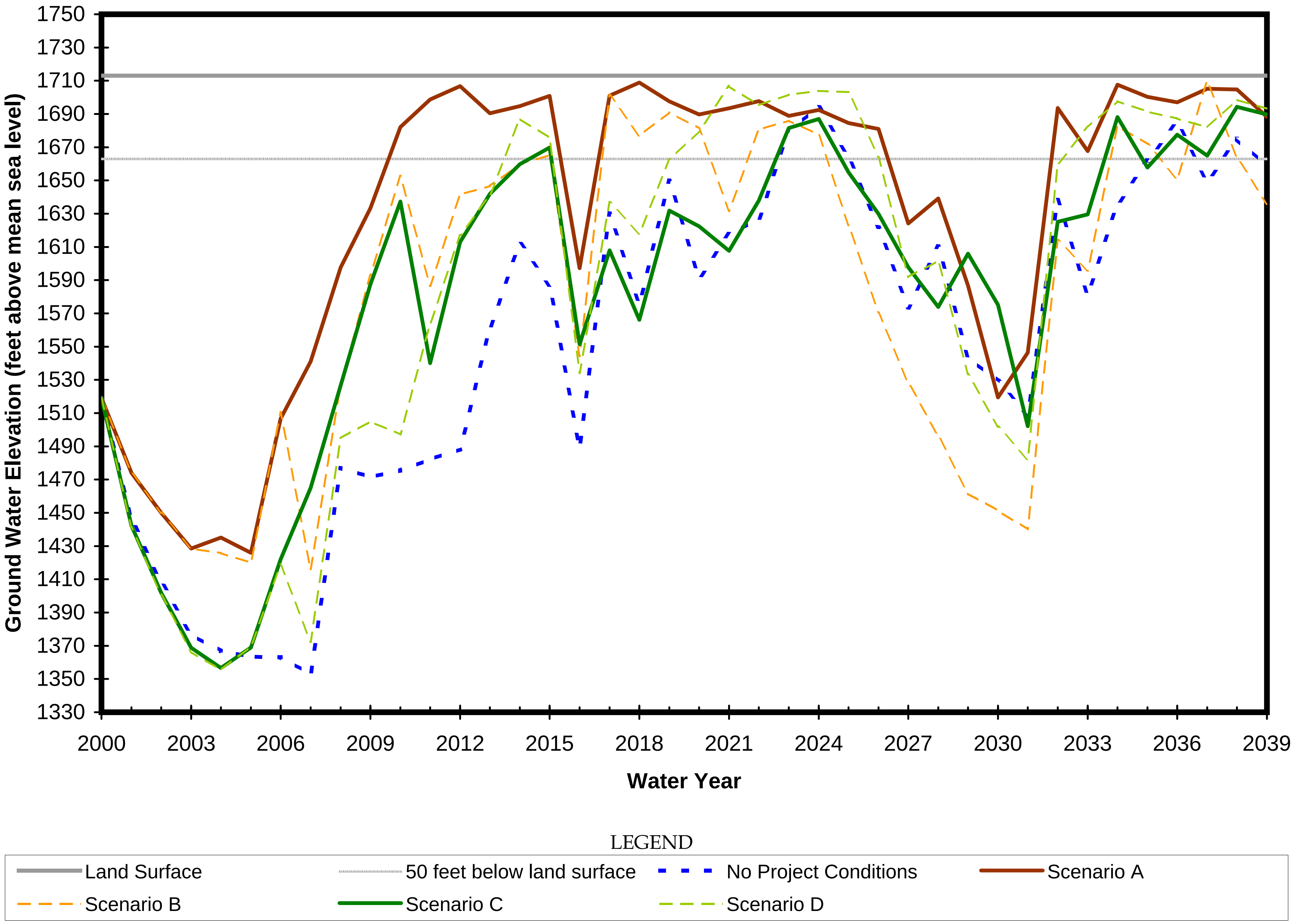


Figure B 29aa. Hydrograph for SG-2 Santa Ana River SG

Figure B 29ab. Hydrograph for SG-3 Waterman SG.

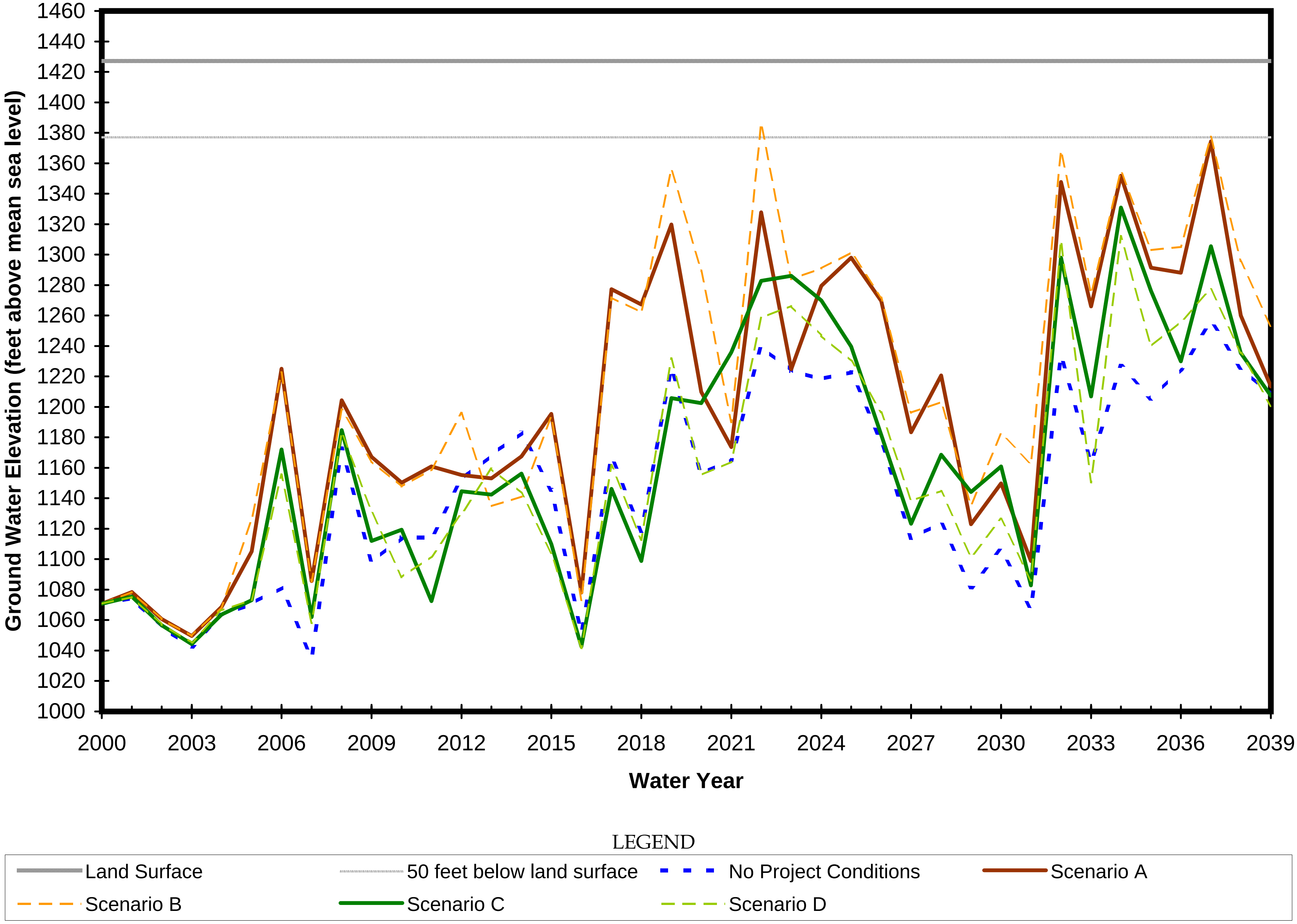


Figure B 29ac. Hydrograph for SG-4 Badger SG.

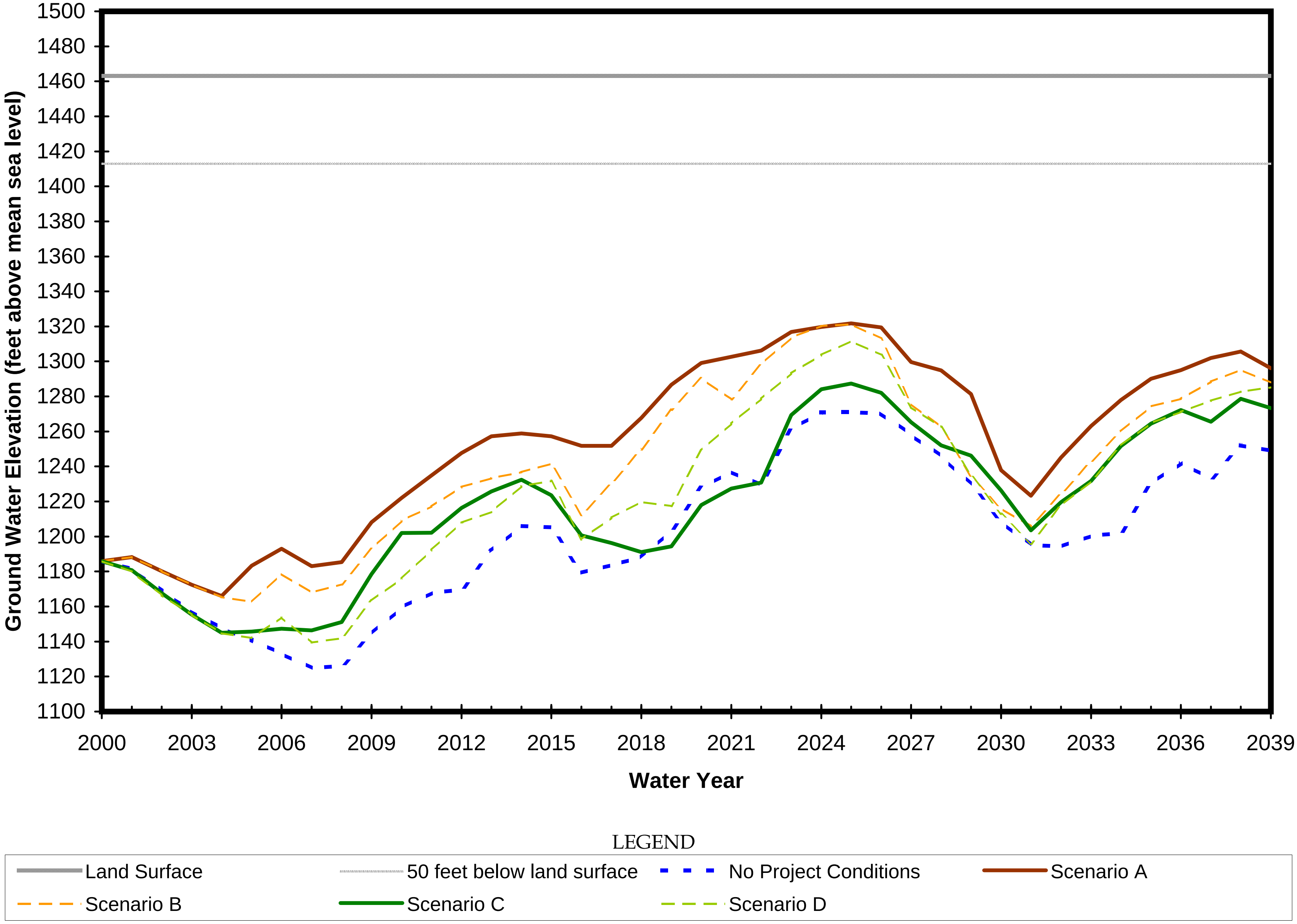


Figure B 29ad. Hydrograph for SG-5 Patton SG.

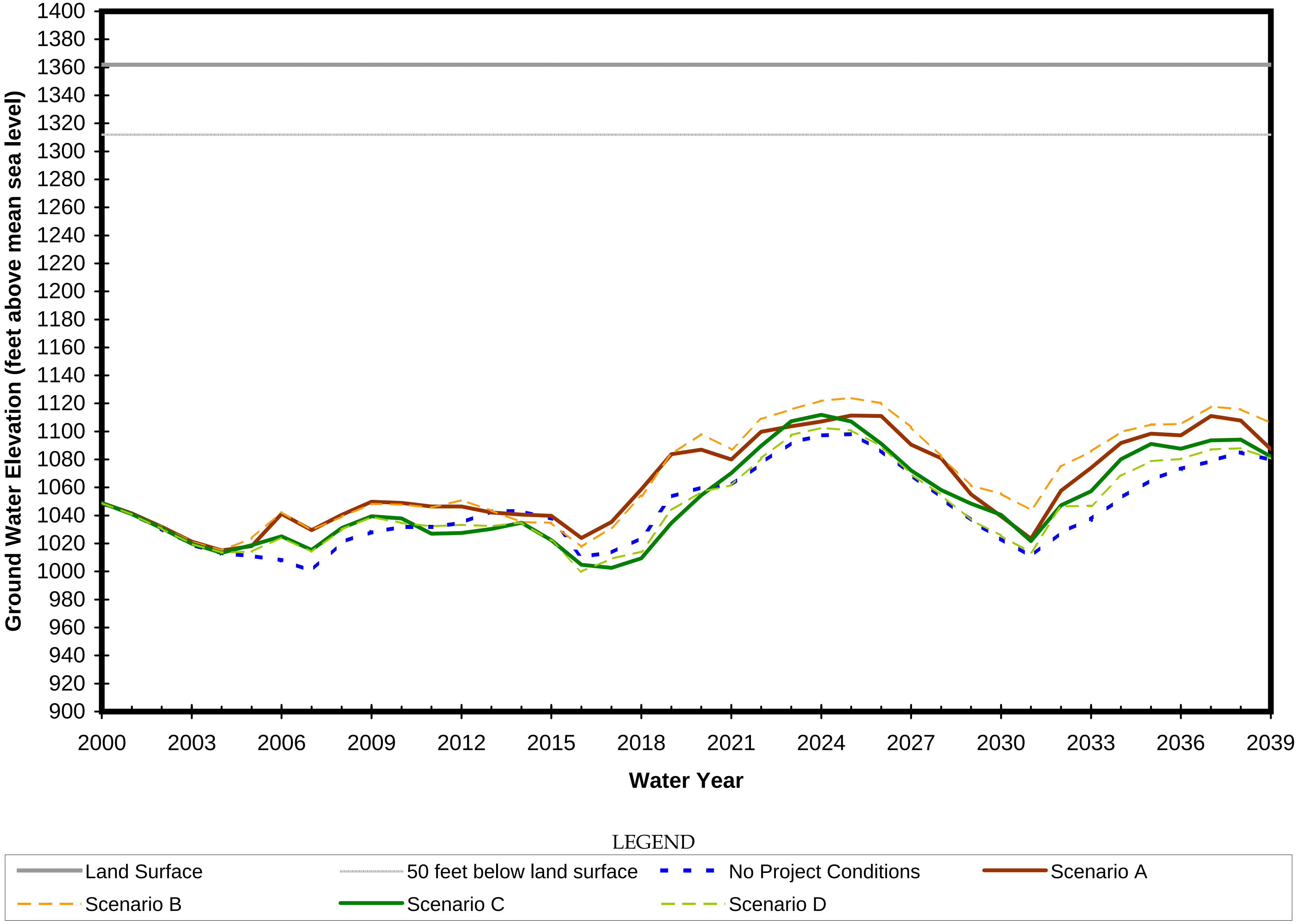


Figure B 29ae. Hydrograph for SG-6 Mill Creek SG.

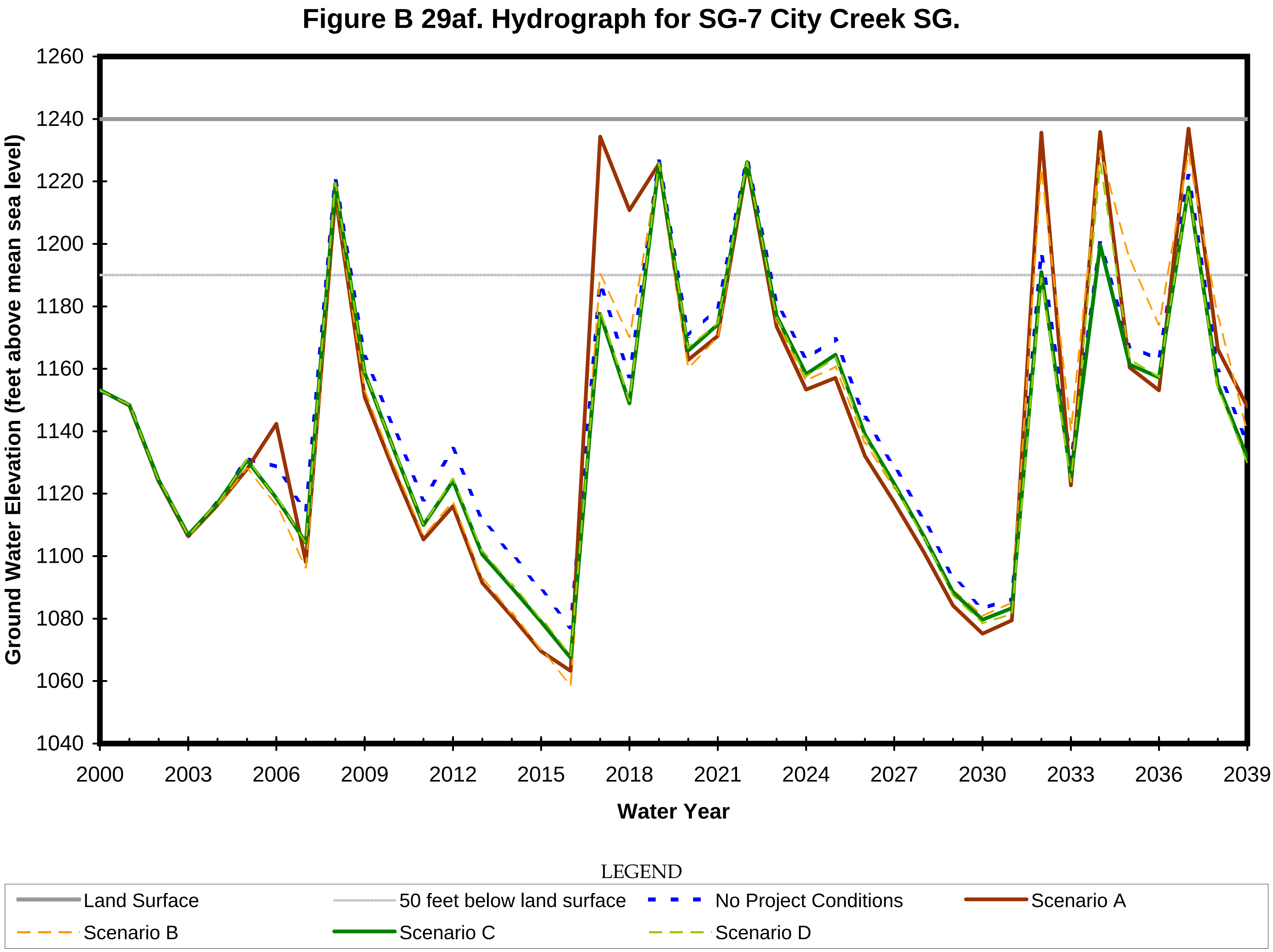
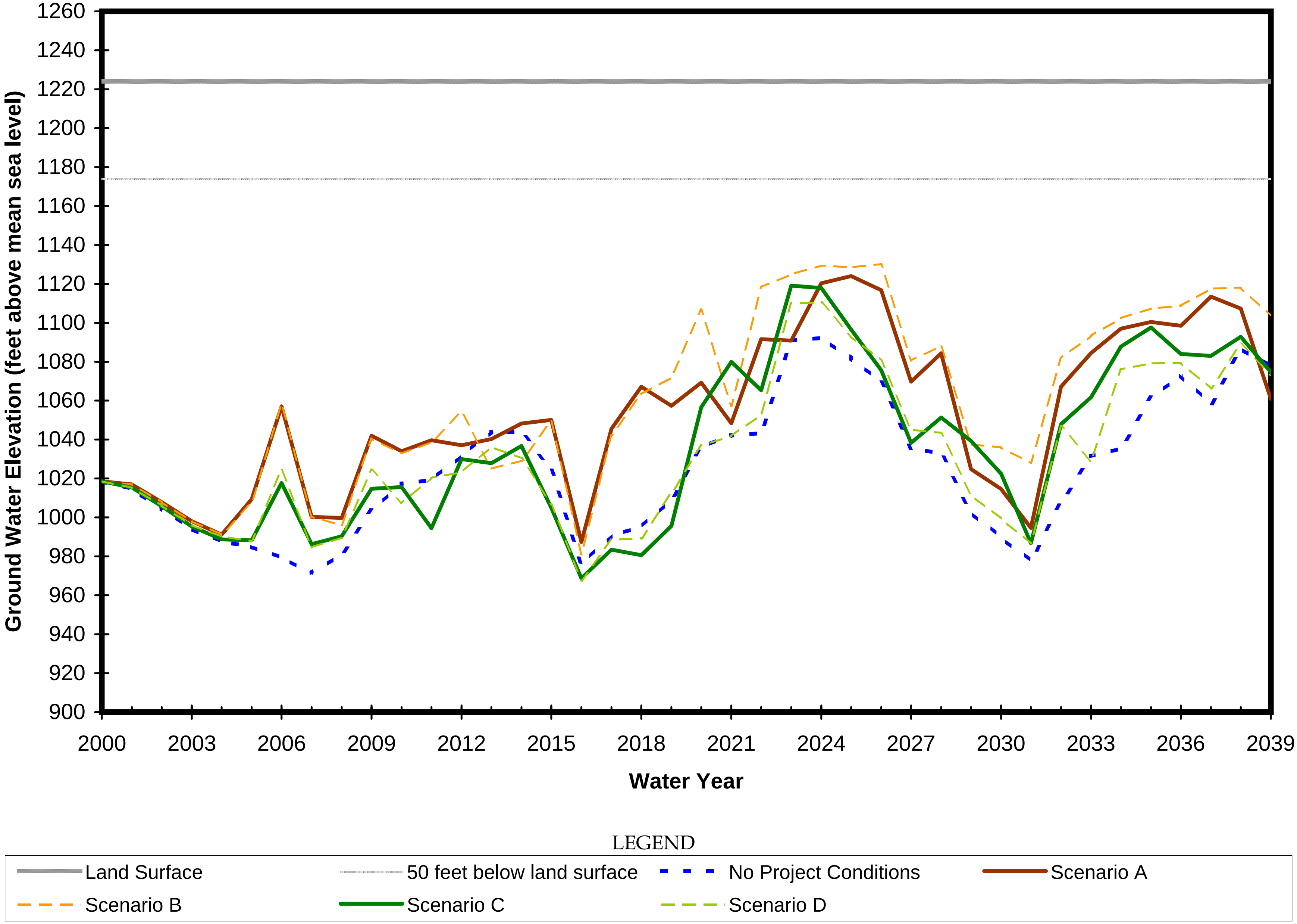
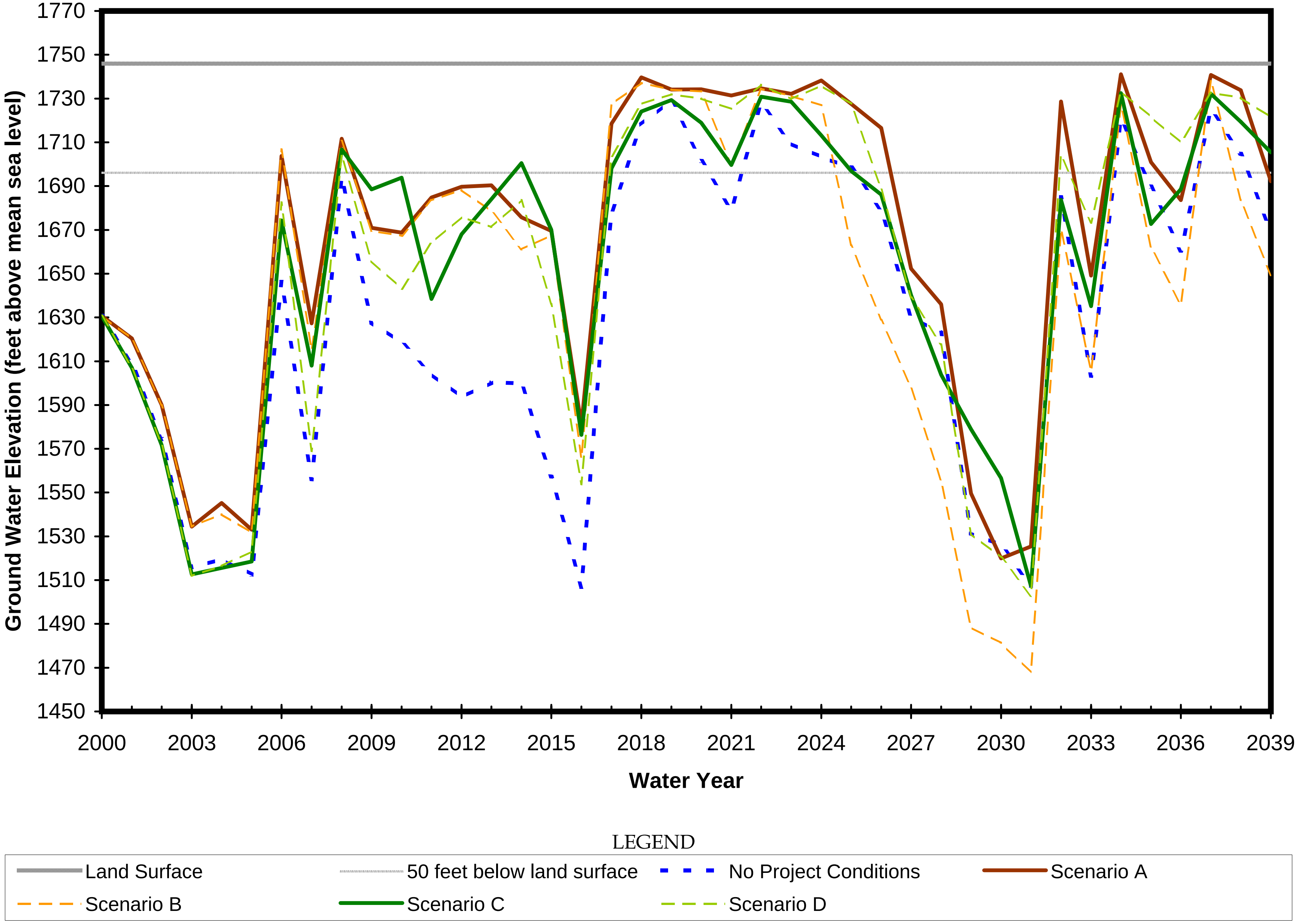


Figure B 29af. Hydrograph for SG-7 City Creek SG.
Ground Water Elevation (feet above mean sea level)
1260
1240
1220
1200
1180
1160
1140
1120
1100
1080
1060
1040
2000
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
2033
2036
2039
Water Year
LEGEND
Land Surface
50 feet below land surface
No Project Conditions
Scenario A
Scenario B
Scenario C
Scenario D

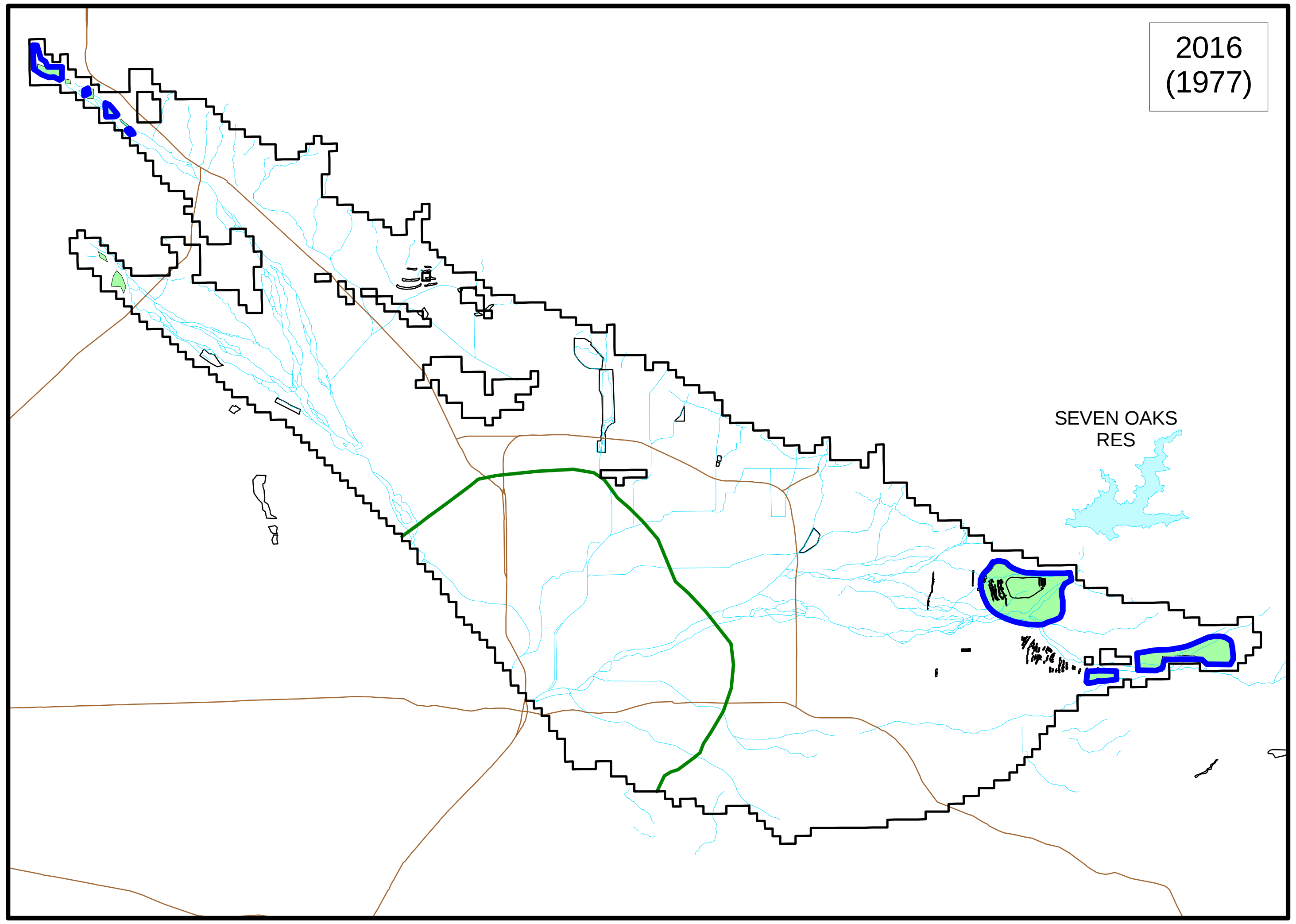
Figure B 29ag. Hydrograph for SG-8 East Twin Creek SG.

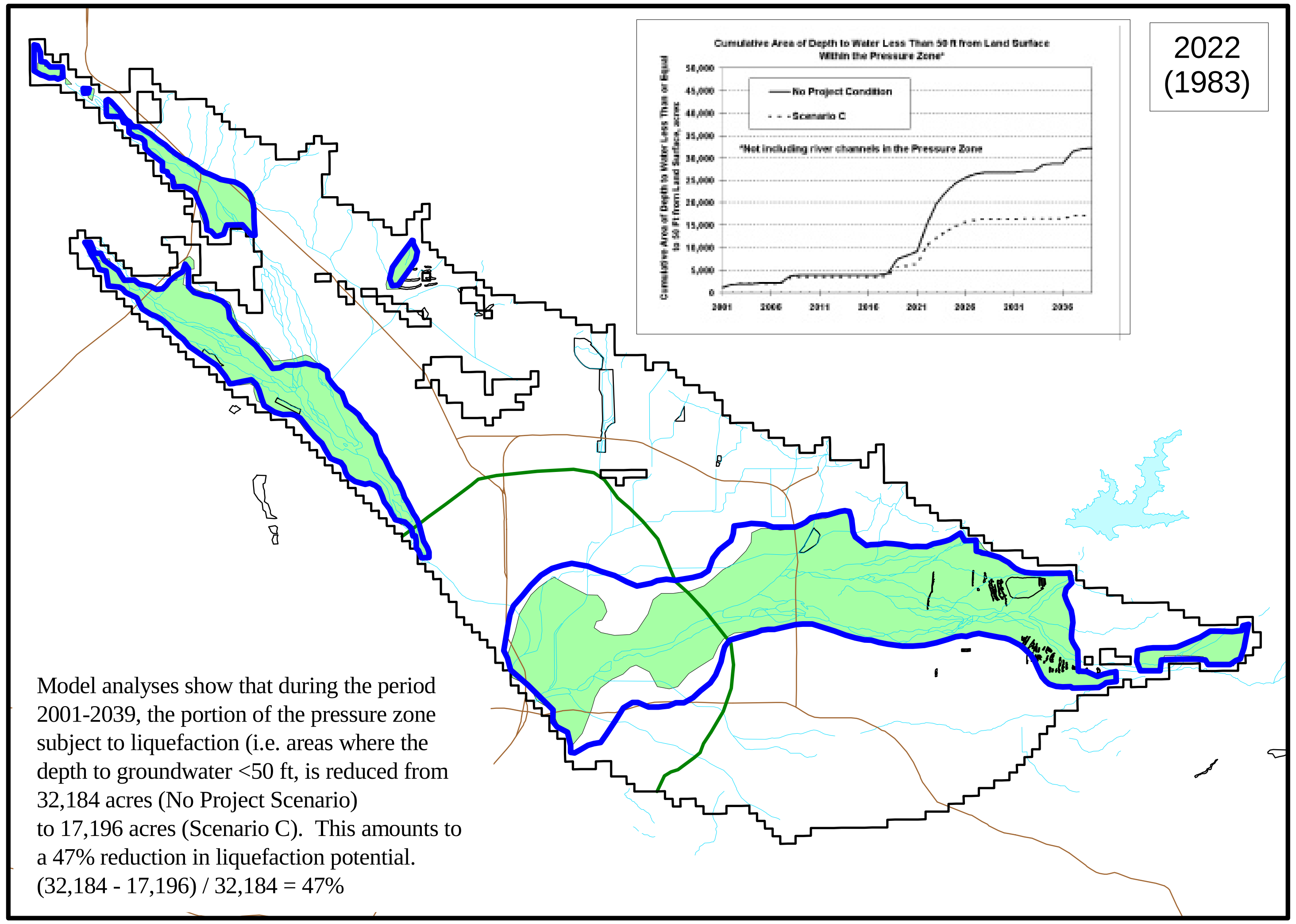


Figureb B 29ah. Hydrograph for SG-9 Lytle Creek SG.



DEPTH TO GROUNDWATER LESS THAN 50 FT FROM LAND SURFACE FOR NO PROJECT CONDITION AND SCENARIO C YEARS 2016 AND 2022





Model analyses show that during the period 2001-2039, the portion of the pressure zone subject to liquefaction (i.e. areas where the depth to groundwater <50 ft, is reduced from 32,184 acres (No Project Scenario) to 17,196 acres (Scenario C). This amounts to a 47% reduction in liquefaction potential. (32,184 - 17,196) / 32,184 = 47%

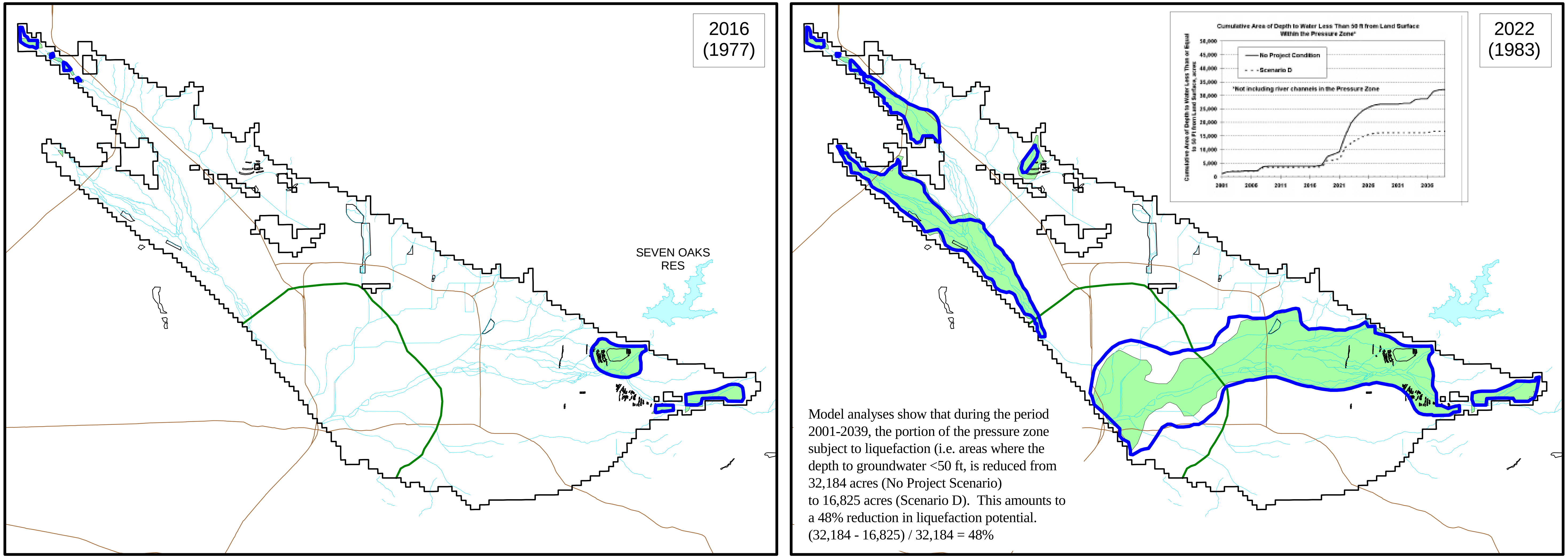
EXPLANATION

⬭	No Project Condition Depth to Water Less Than 50 ft From Land Surface
🟩	Scenario C Depth to Water Less Than 50 ft From Land Surface
2016 (1977)	Model Year (Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

Map Projection:
State Plane 1927 (California Zone V)

Figure B 30

DEPTH TO GROUNDWATER LESS THAN 50 FT FROM LAND SURFACE FOR NO PROJECT CONDITION AND SCENARIO D YEARS 2016 AND 2022



Model analyses show that during the period 2001-2039, the portion of the pressure zone subject to liquefaction (i.e. areas where the depth to groundwater <50 ft, is reduced from 32,184 acres (No Project Scenario) to 16,825 acres (Scenario D). This amounts to a 48% reduction in liquefaction potential. (32,184 - 16,825) / 32,184 = 48%

EXPLANATION

No Project Condition
Depth to Water Less Than 50 ft
From Land Surface

🟩 Scenario D
Depth to Water Less Than 50 ft From Land Surface

2016 (1977) Model Year
(Hydrological Year)

Pressure Zone

Model Grid of the San Bernardino
Basin Area Groundwater Model

Streams or Rivers Within
Groundwater Basin Boundary

Spreading Grounds or Basins

Freeway

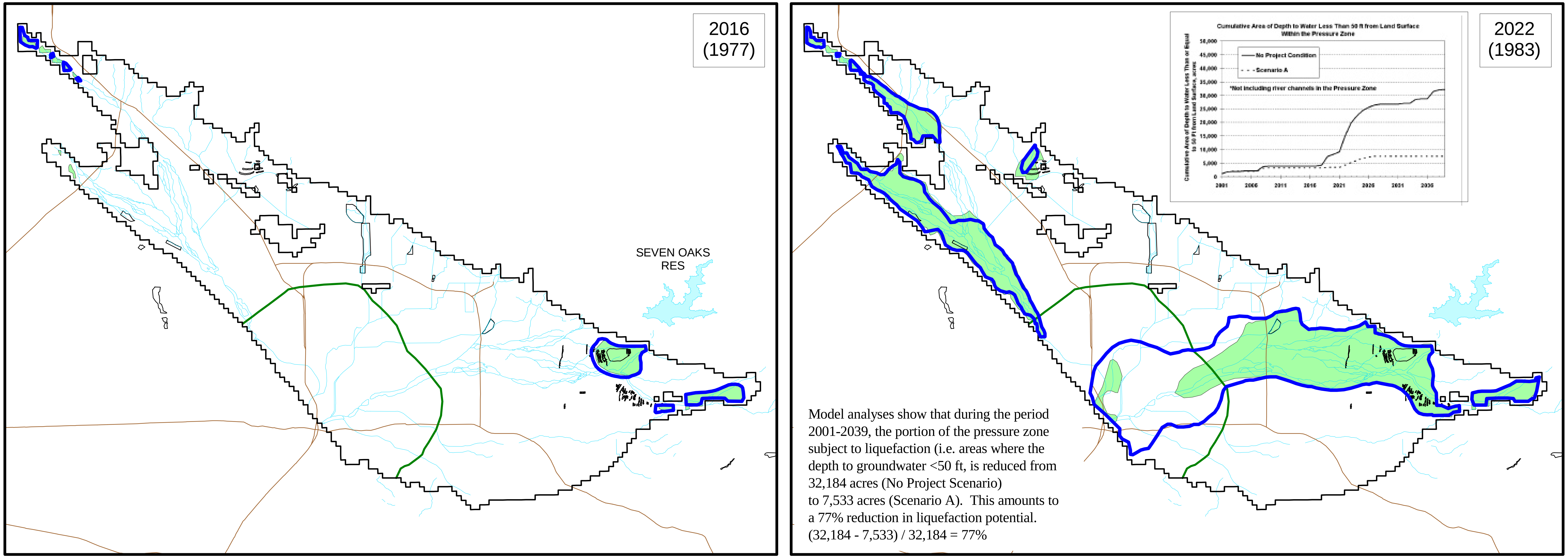
NORTH

0 3 6 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 31

DEPTH TO GROUNDWATER LESS THAN 50 FT FROM LAND SURFACE FOR NO PROJECT CONDITION AND SCENARIO A YEARS 2016 AND 2022



Model analyses show that during the period 2001-2039, the portion of the pressure zone subject to liquefaction (i.e. areas where the depth to groundwater <50 ft, is reduced from 32,184 acres (No Project Scenario) to 7,533 acres (Scenario A). This amounts to a 77% reduction in liquefaction potential. (32,184 - 7,533) / 32,184 = 77%

EXPLANATION

⬭ No Project Condition
Depth to Water Less Than 50 ft
From Land Surface

🟩 Scenario A
Depth to Water Less Than 50 ft From Land Surface

2016 (1977) Model Year
(Hydrological Year)

— Pressure Zone

▭ Model Grid of the San Bernardino
Basin Area Groundwater Model

— Streams or Rivers Within
Groundwater Basin Boundary

⬭ Spreading Grounds or Basins

— Freeway

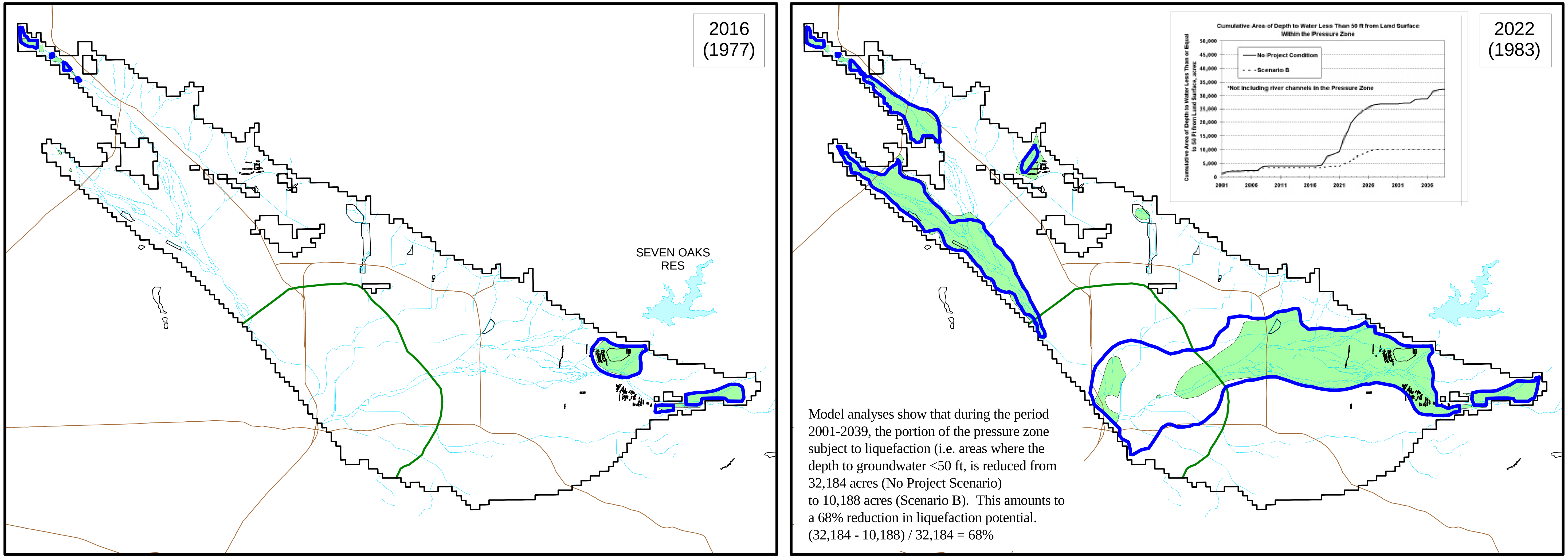
NORTH

0 3 6 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 32

DEPTH TO GROUNDWATER LESS THAN 50 FT FROM LAND SURFACE FOR NO PROJECT CONDITION AND SCENARIO B YEARS 2016 AND 2022



Model analyses show that during the period 2001-2039, the portion of the pressure zone subject to liquefaction (i.e. areas where the depth to groundwater <50 ft, is reduced from 32,184 acres (No Project Scenario) to 10,188 acres (Scenario B). This amounts to a 68% reduction in liquefaction potential. (32,184 - 10,188) / 32,184 = 68%

EXPLANATION

⬭	No Project Condition Depth to Water Less Than 50 ft From Land Surface
🟩	Scenario B Depth to Water Less Than 50 ft From Land Surface
2016 (1977)	Model Year (Hydrological Year)
—	Pressure Zone
☐	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

NORTH

0 3 6 Miles

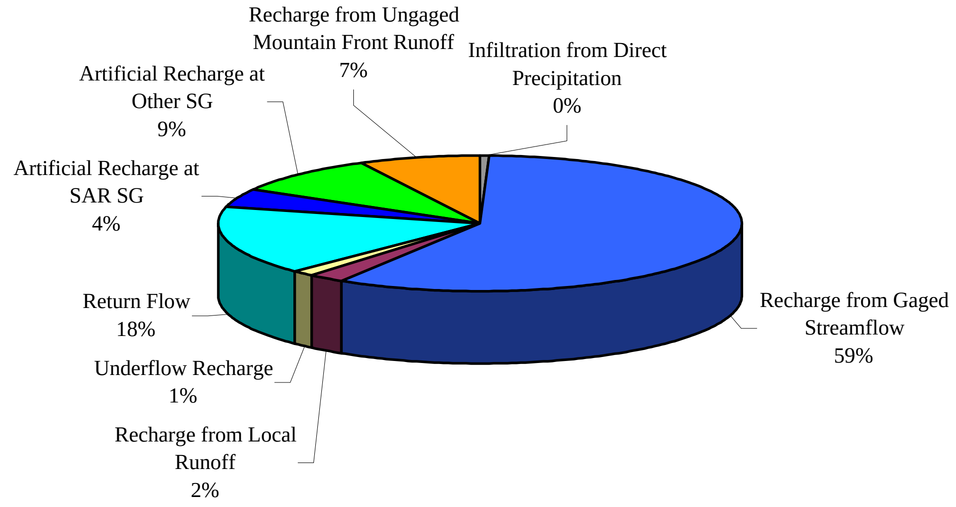
Map Projection:
State Plane 1927 (California Zone V)

Figure B 33

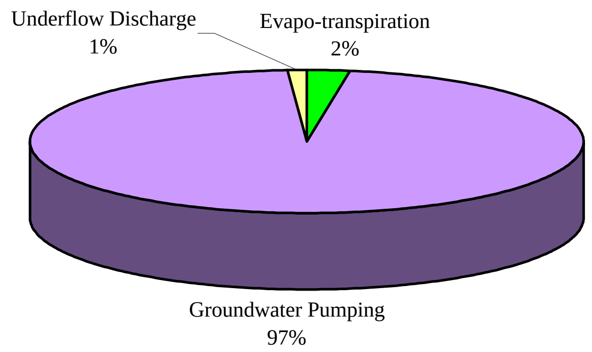
Comparisons of Groundwater Budgets for SBBA Between No Project Condition and Scenario C - 2001 to 2039

No Project Condition
Storage Decline 3,324 acre-ft/yr

INFLOW
(238,989 acre-ft/yr)

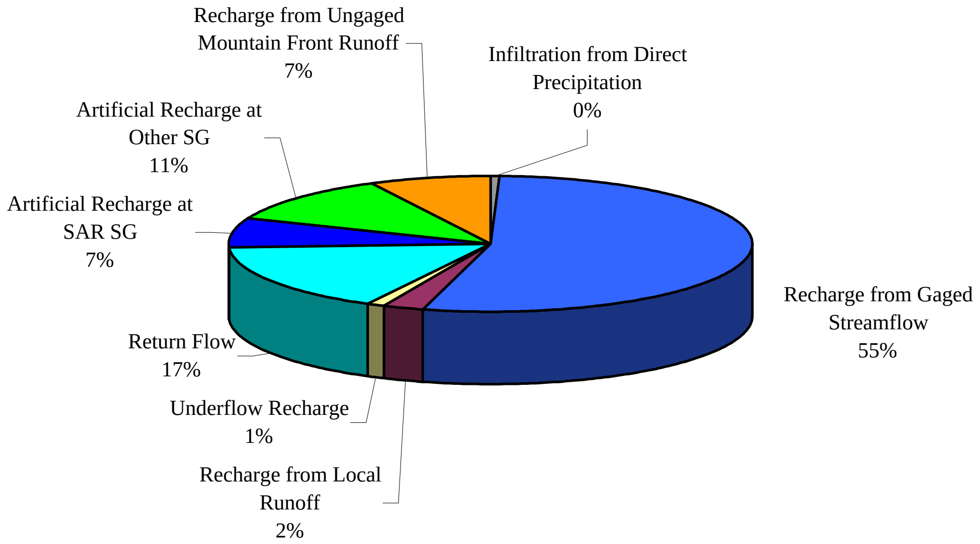


OUTFLOW
(242,313 acre-ft/yr)



Scenario C
Storage Decline 3,326 acre-ft/yr

INFLOW
(239,112 acre-ft/yr)



OUTFLOW
(242,438 acre-ft/yr)

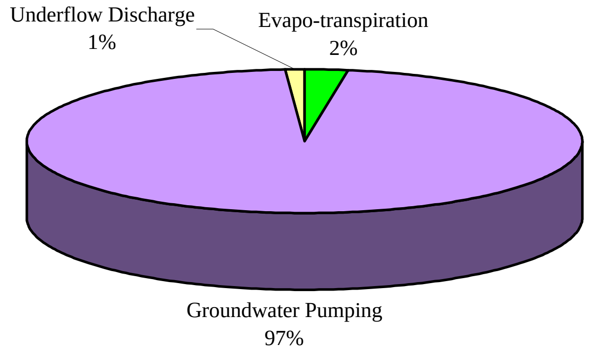
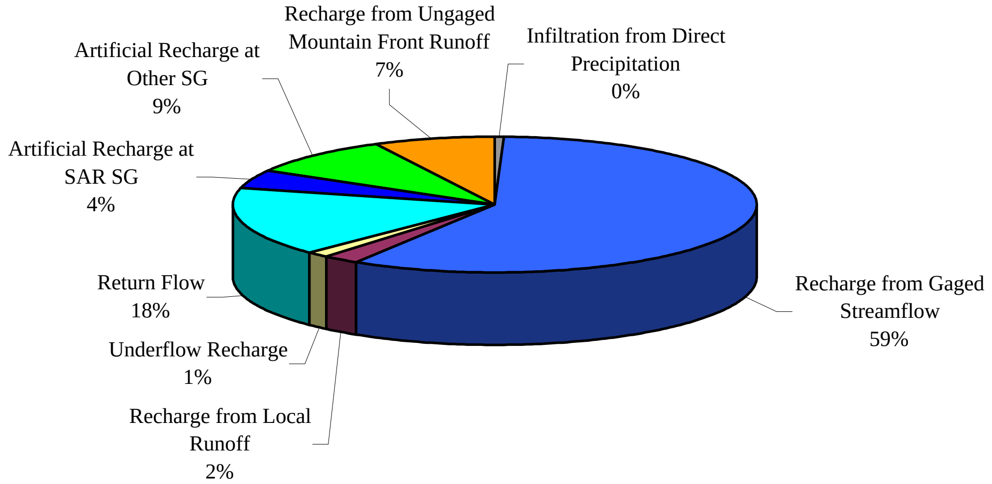


Figure B 34

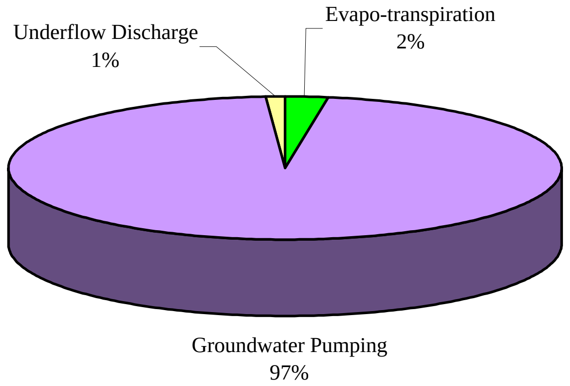
Comparisons of Groundwater Budgets for SBBA Between No Project Condition and Scenario D - 2001 to 2039

No Project Condition
Storage Decline 3,324 acre-ft/yr

INFLOW
(238,989 acre-ft/yr)

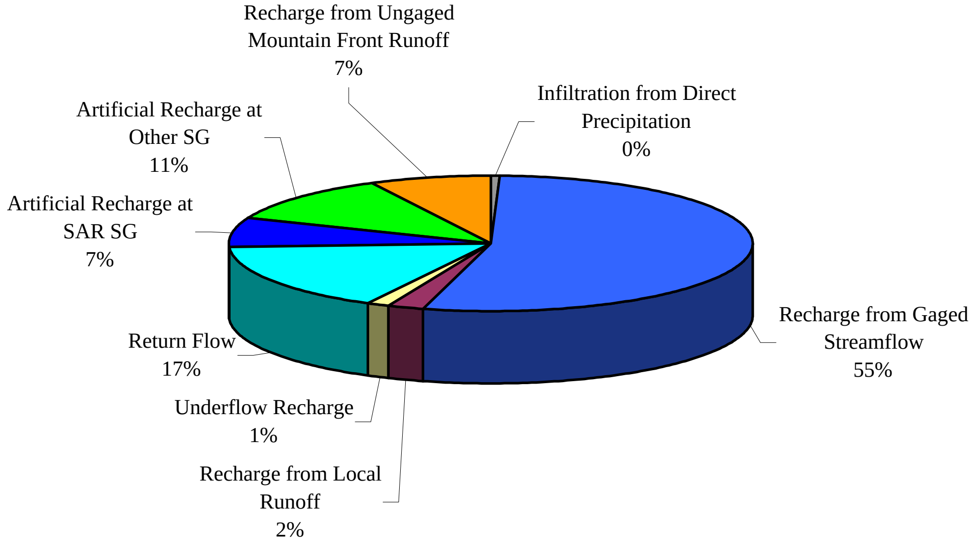


OUTFLOW
(242,313 acre-ft/yr)



Scenario D
Storage Decline 3,374 acre-ft/yr

INFLOW
(238,853 acre-ft/yr)



OUTFLOW
(242,227 acre-ft/yr)

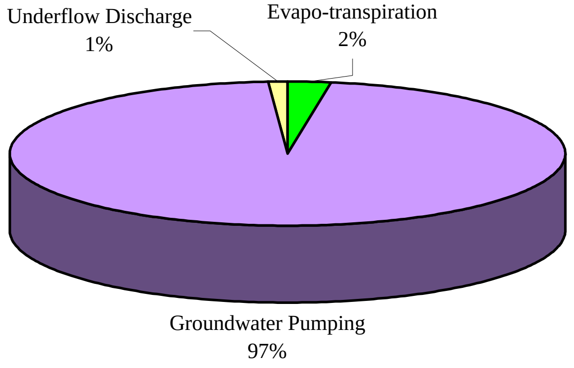
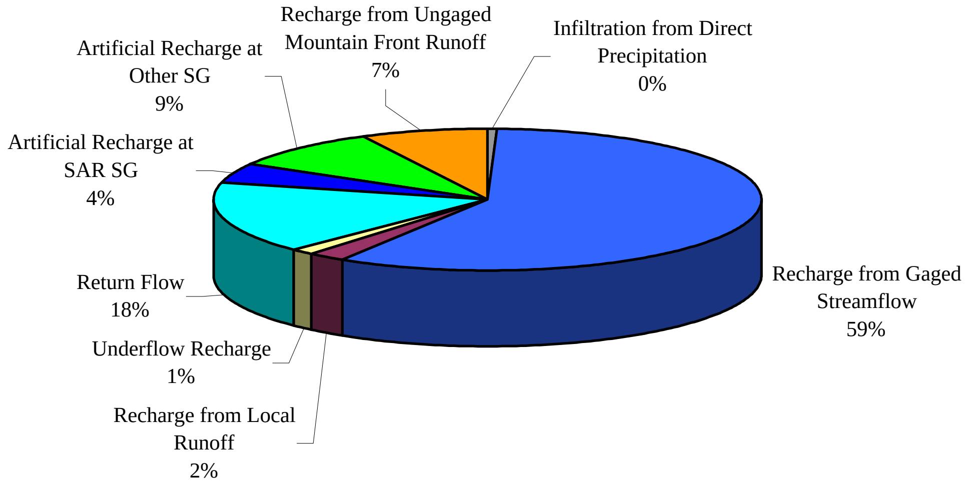


Figure B 35

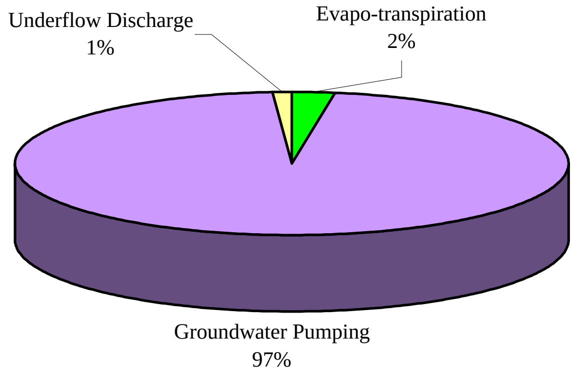
Comparisons of Groundwater Budgets for SBBA Between No Project Condition and Scenario A - 2001 to 2039

No Project Condition
Storage Decline 3,324 acre-ft/yr

INFLOW
(238,989 acre-ft/yr)

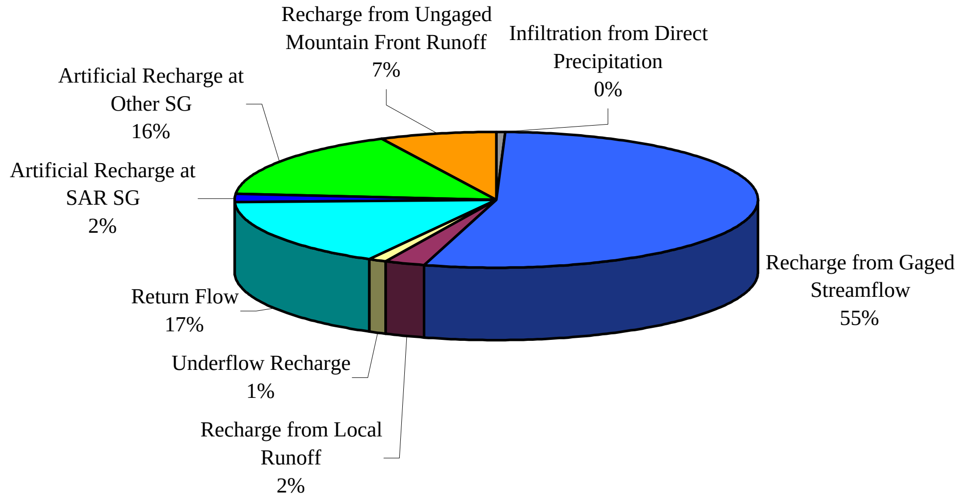


OUTFLOW
(242,313 acre-ft/yr)



Scenario A
Storage Decline 3,406 acre-ft/yr

INFLOW
(242,350 acre-ft/yr)



OUTFLOW
(245,756 acre-ft/yr)

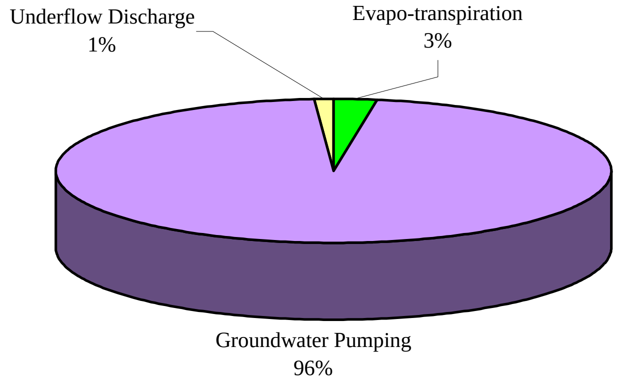
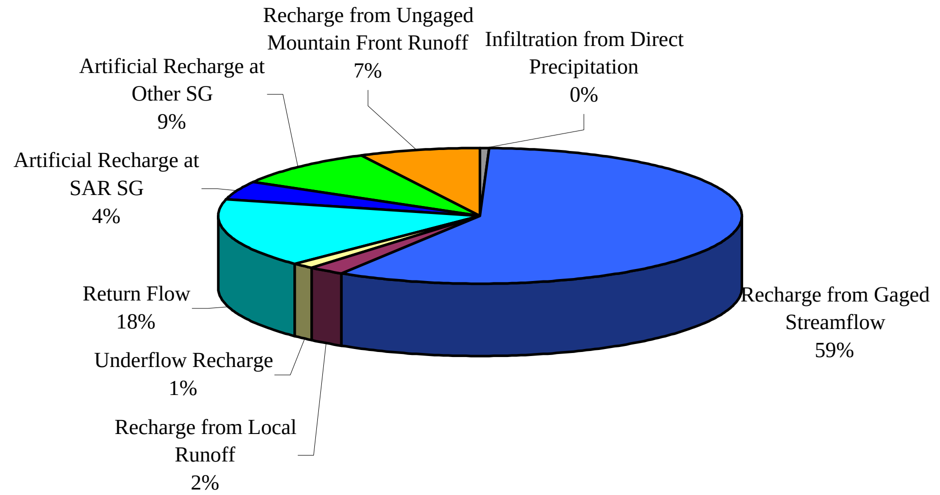


Figure B 36

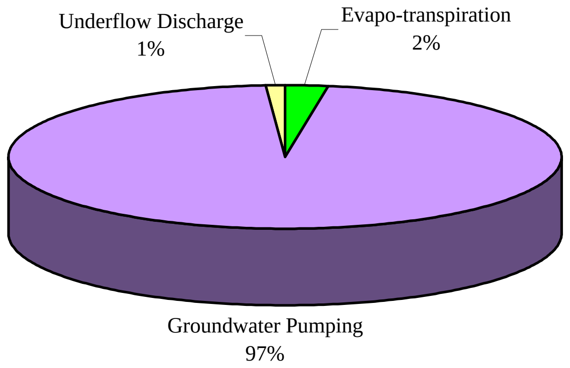
Comparisons of Groundwater Budgets for SBBA Between No Project Condition and Scenario B - 2001 to 2039

No Project Condition
Storage Decline 3,324 acre-ft/yr

INFLOW
(238,989 acre-ft/yr)

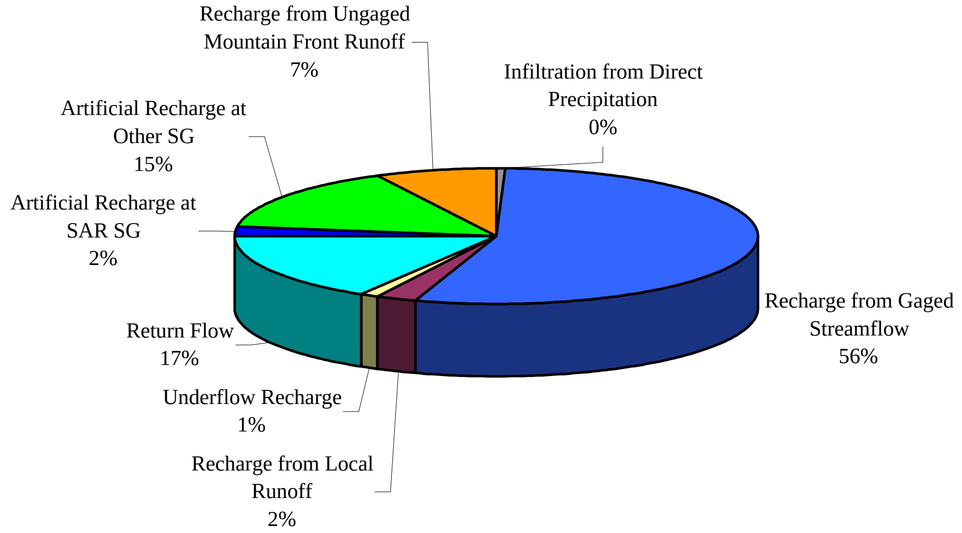


OUTFLOW
(242,313 acre-ft/yr)



Scenario B
Storage Decline 3,391 acre-ft/yr

INFLOW
(241,818 acre-ft/yr)



OUTFLOW
(245,209 acre-ft/yr)

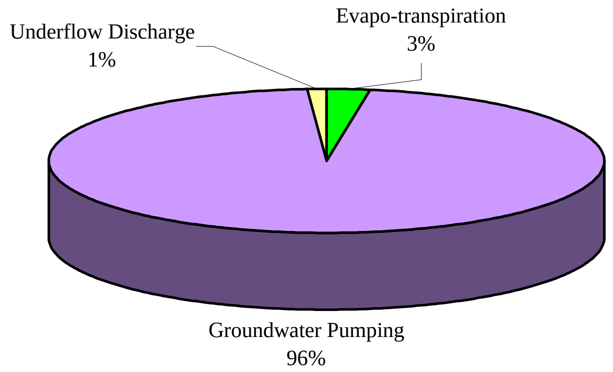
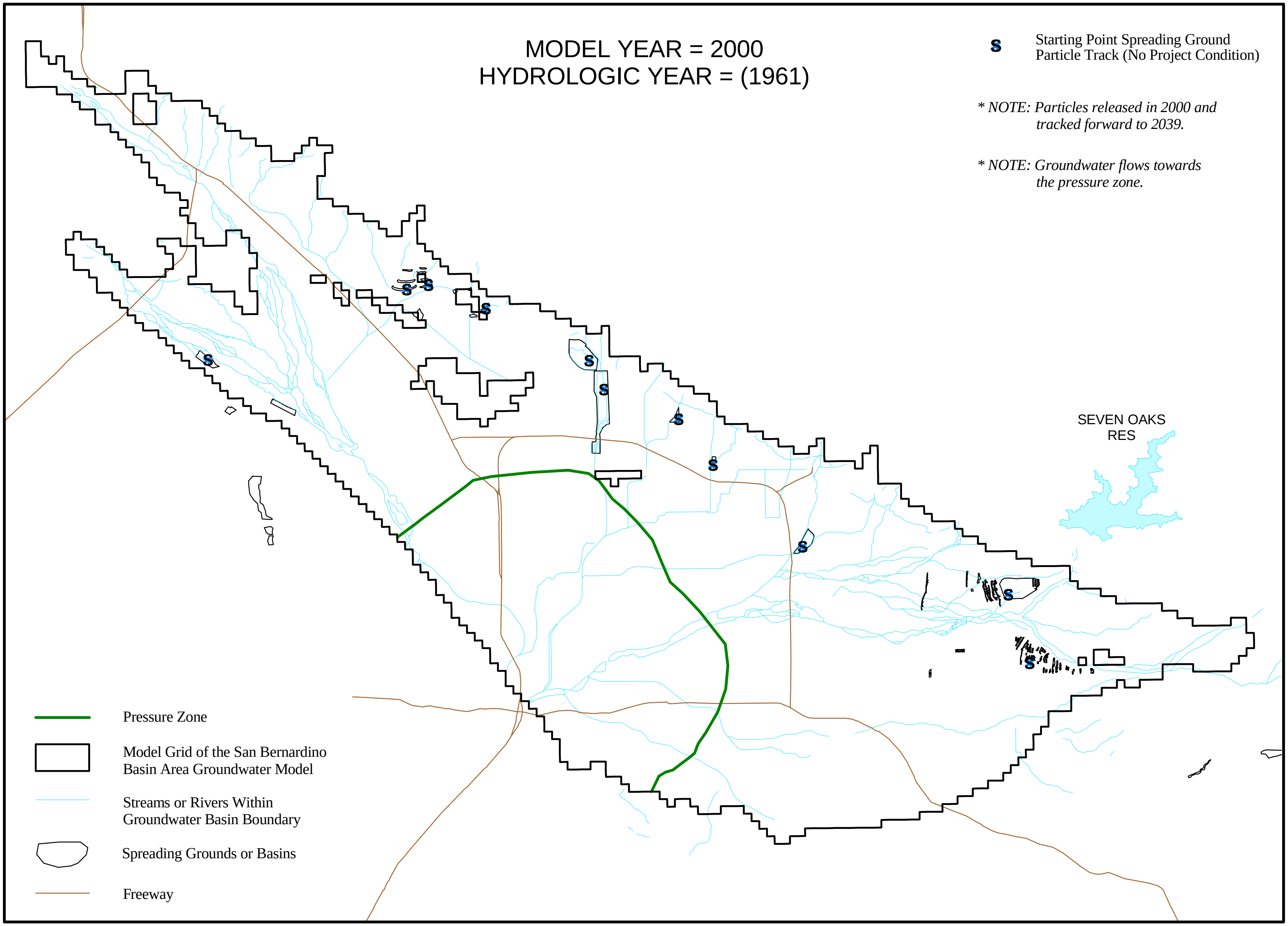
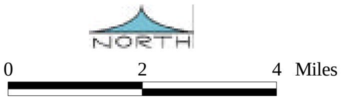


Figure B 37

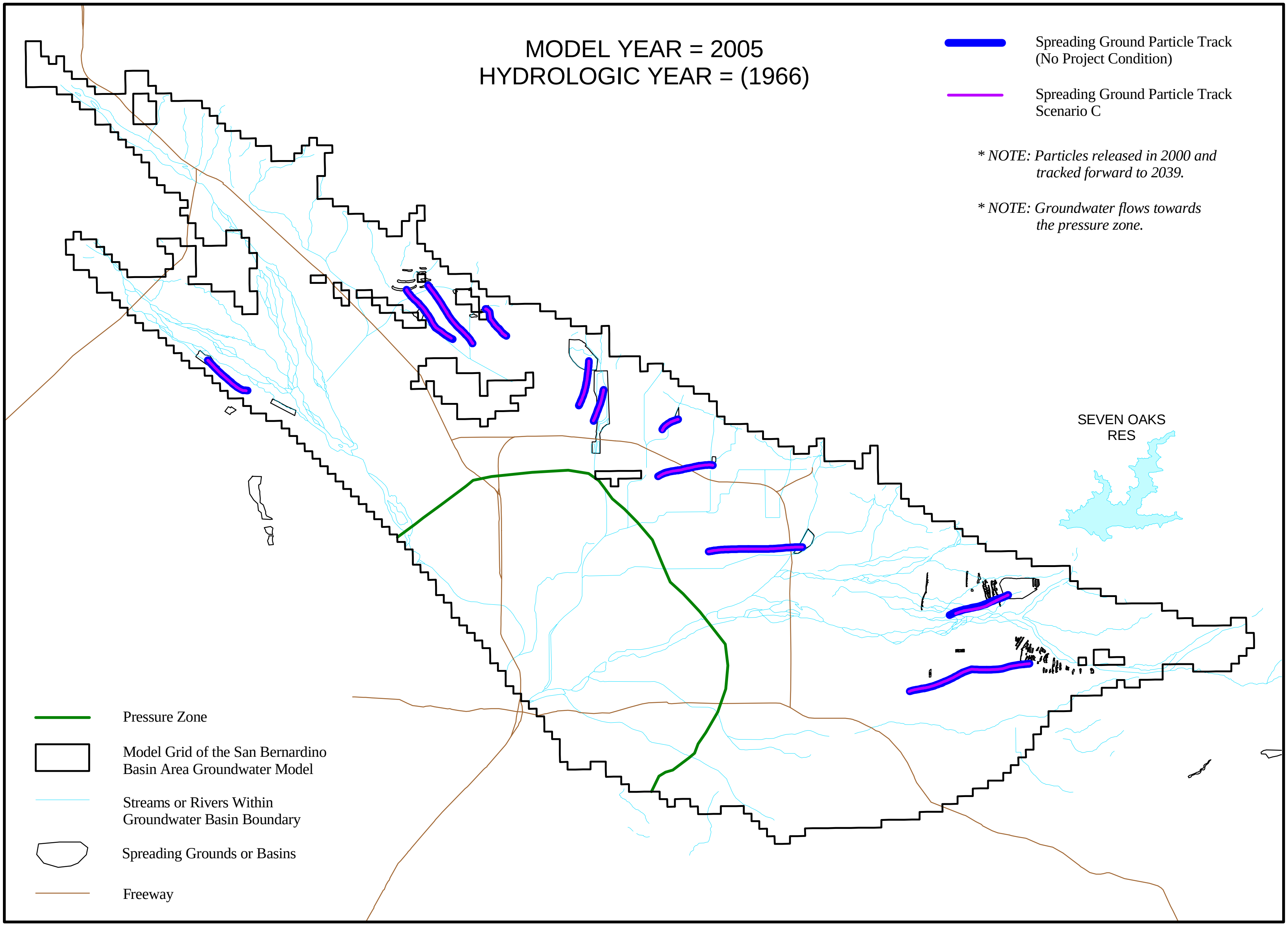




SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2000**

Figure B 38(a)



** NOTE: Particles released in 2000 and tracked forward to 2039.*

** NOTE: Groundwater flows towards the pressure zone.*

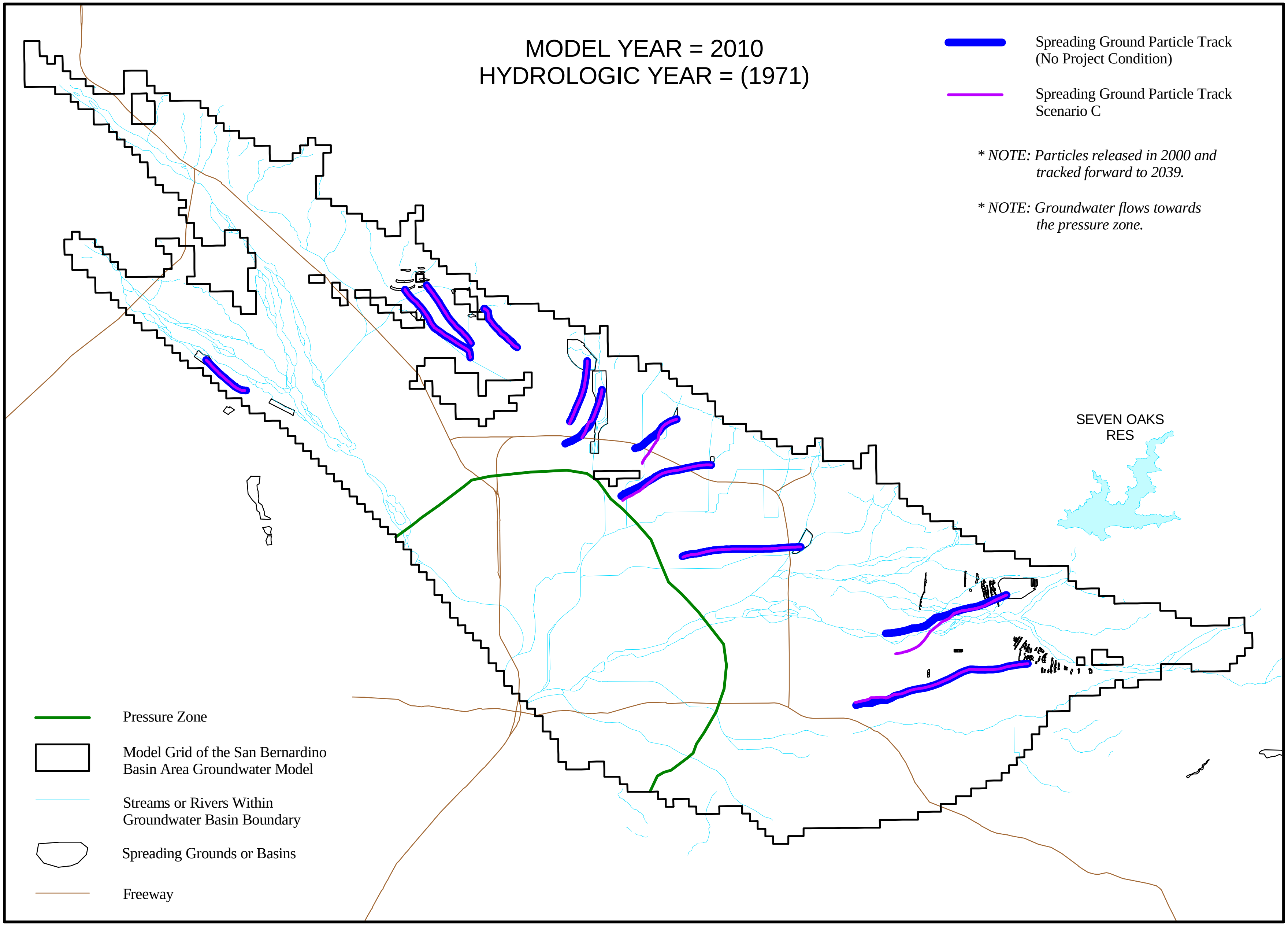
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2005**

Figure B 38(b)



MODEL YEAR = 2010
HYDROLOGIC YEAR = (1971)

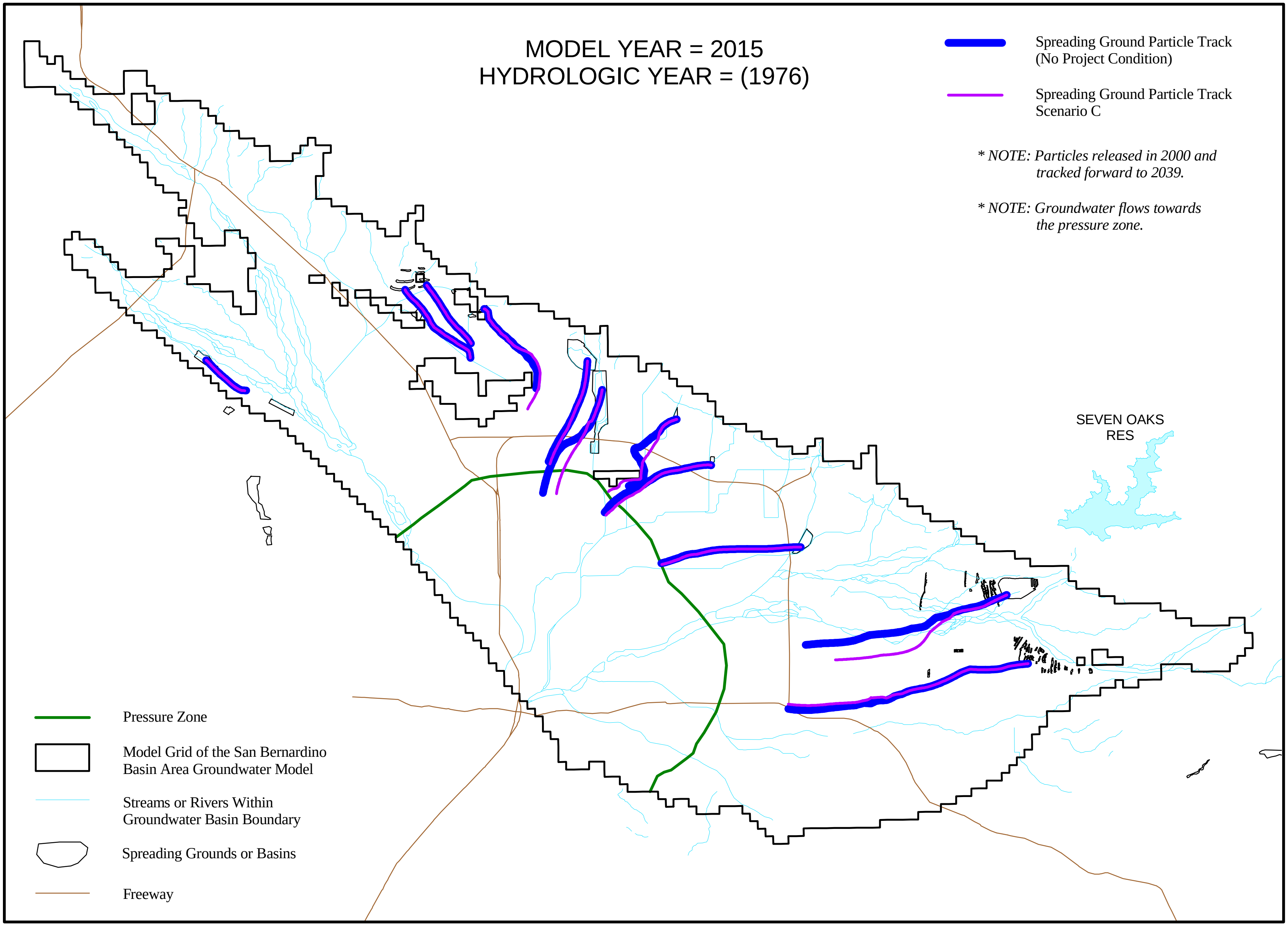
* *NOTE: Particles released in 2000 and tracked forward to 2039.*

* *NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2010

Figure B 38(c)



MODEL YEAR = 2015
HYDROLOGIC YEAR = (1976)

** NOTE: Particles released in 2000 and tracked forward to 2039.*

** NOTE: Groundwater flows towards the pressure zone.*

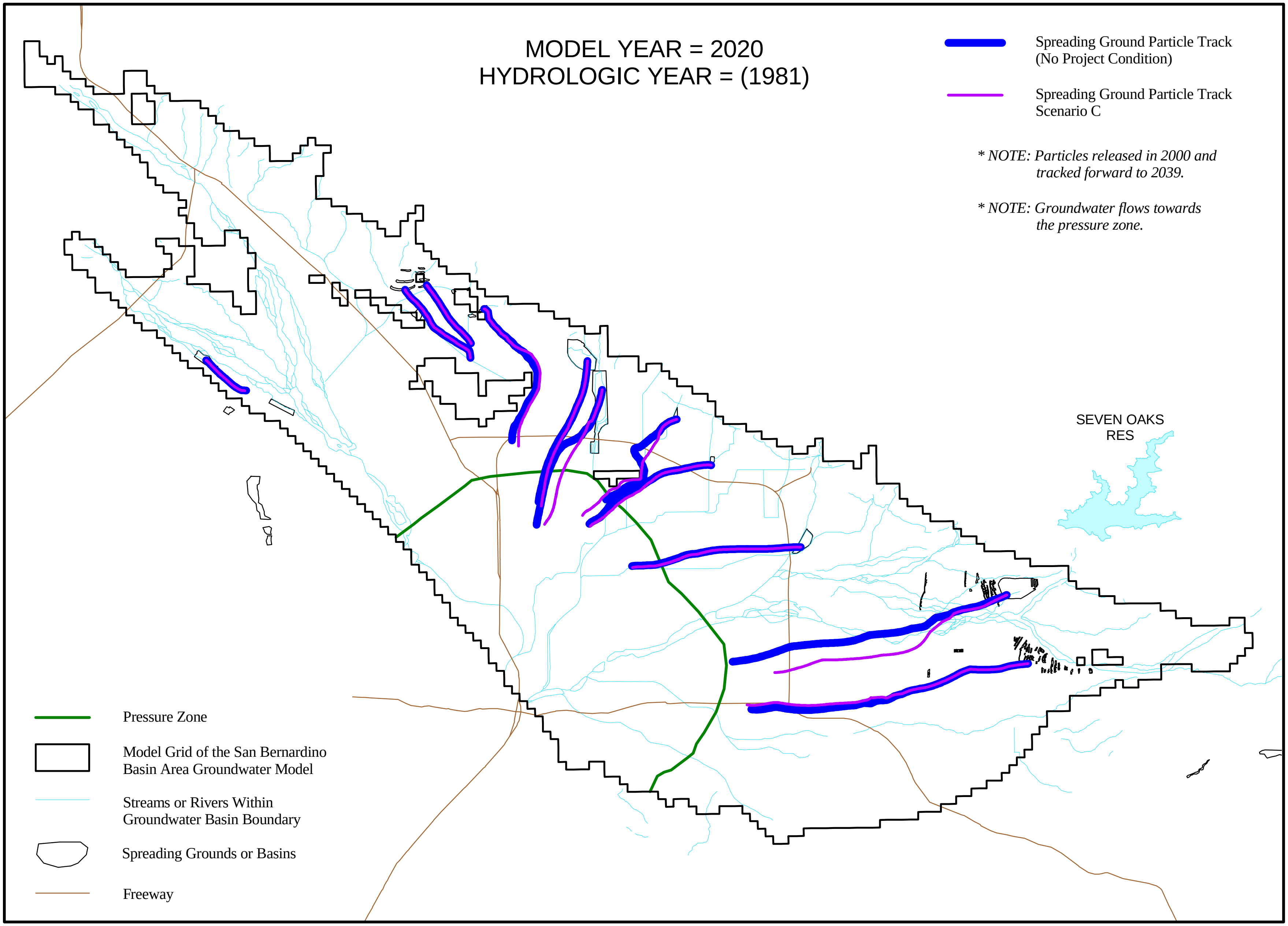
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2015

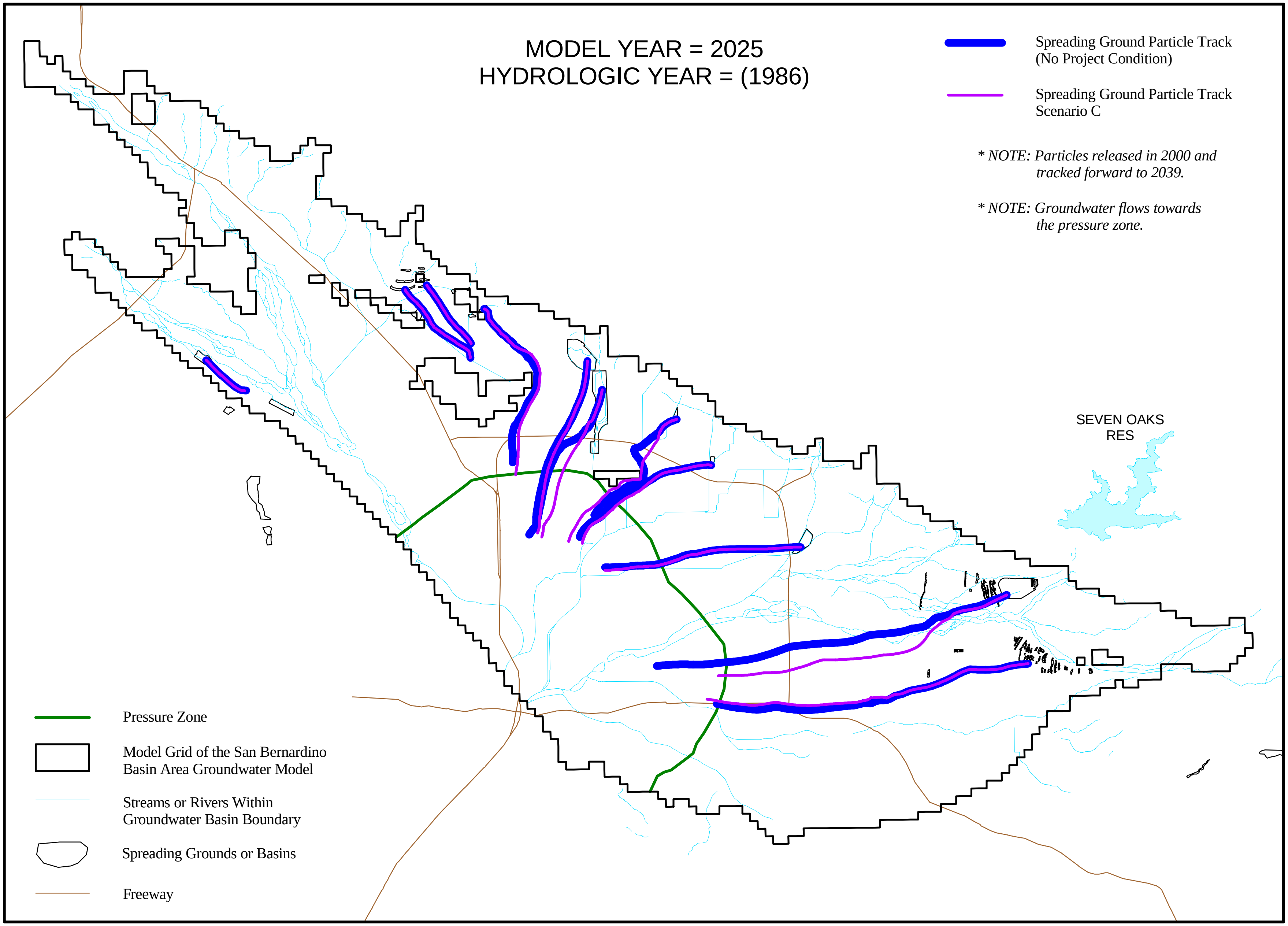
Figure B 38(d)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2020

Figure B 38(e)



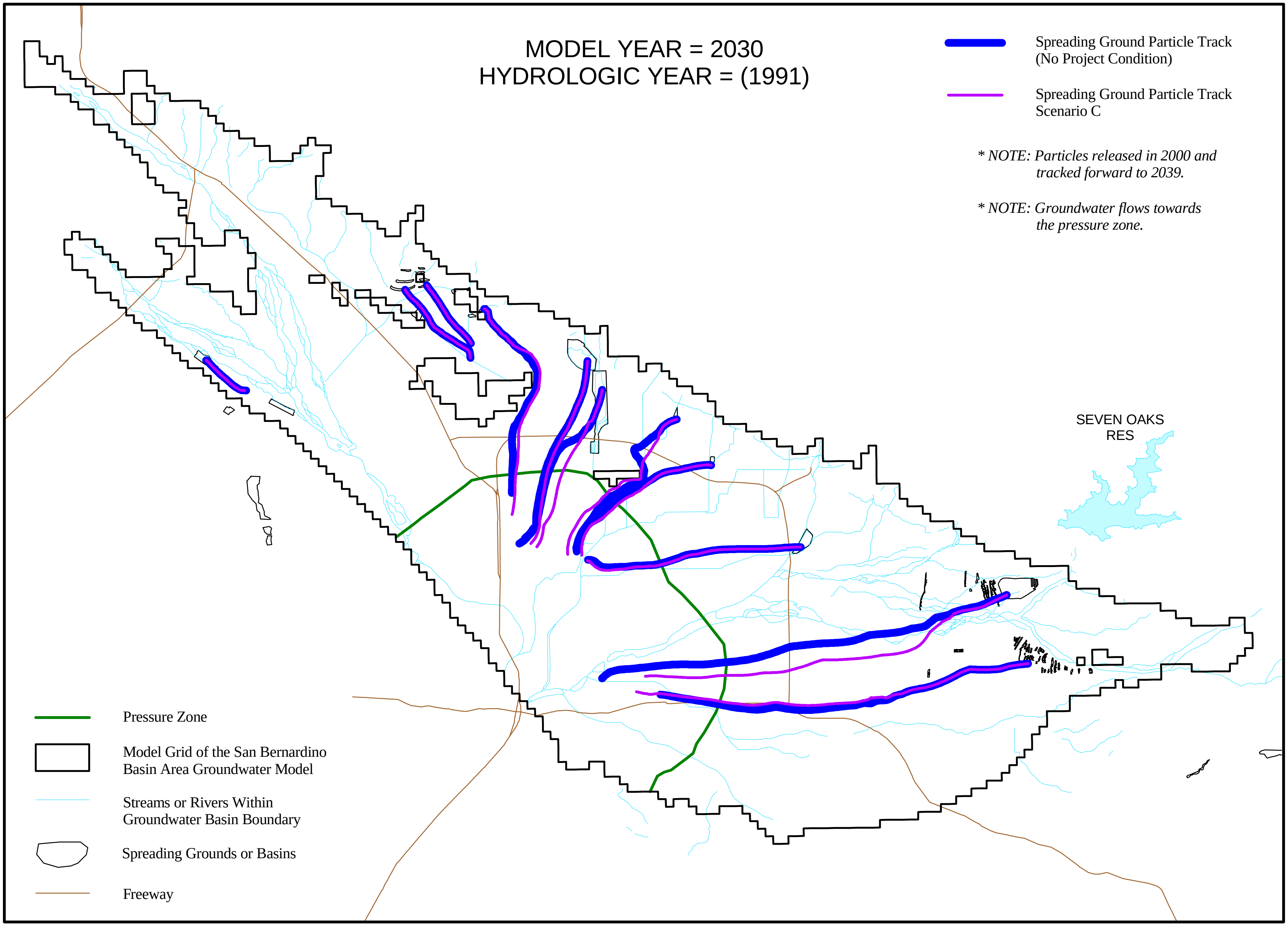
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2025**

Figure B 38(f)



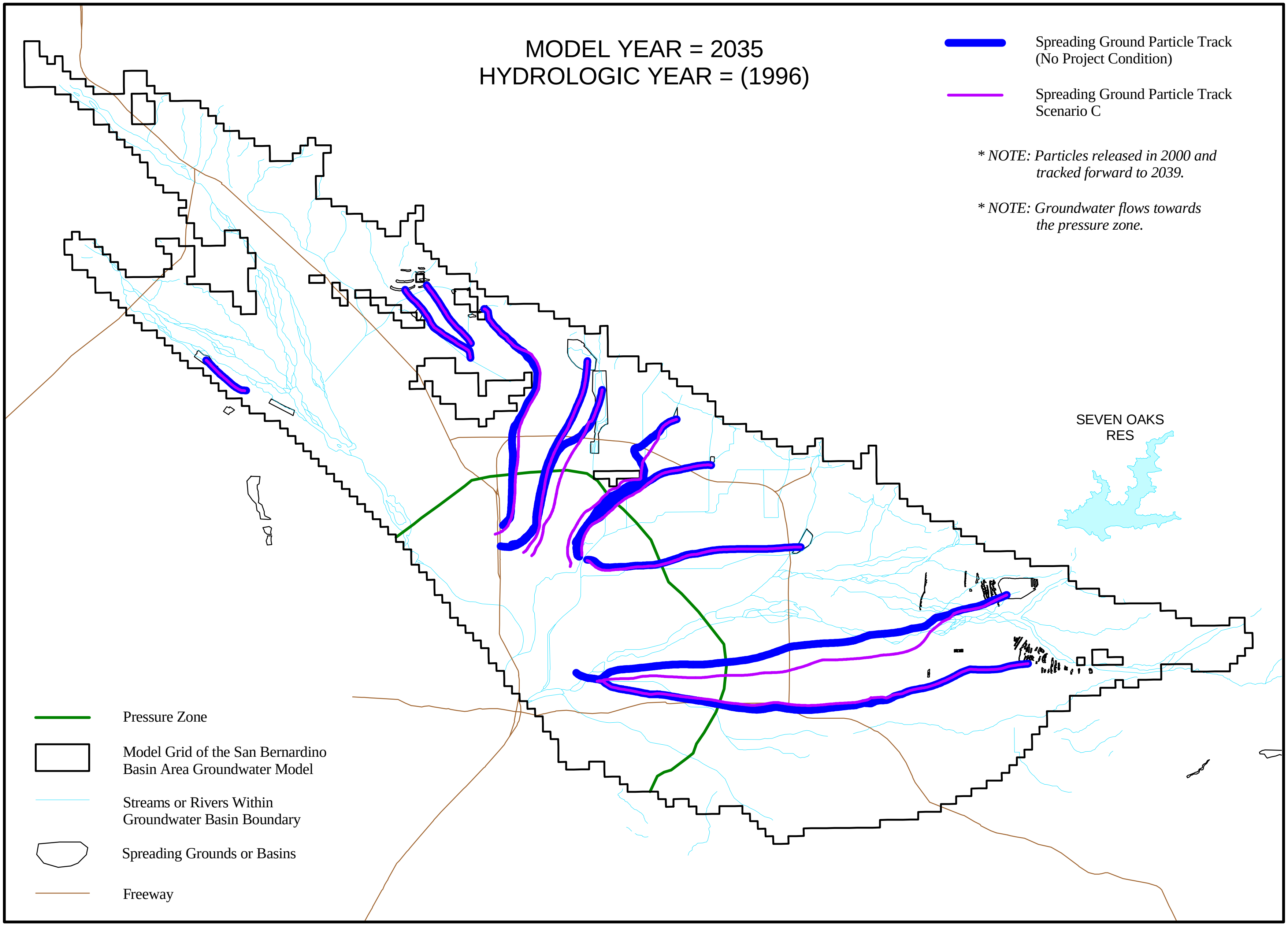
** NOTE: Particles released in 2000 and tracked forward to 2039.*

** NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2030**

Figure B 38(g)



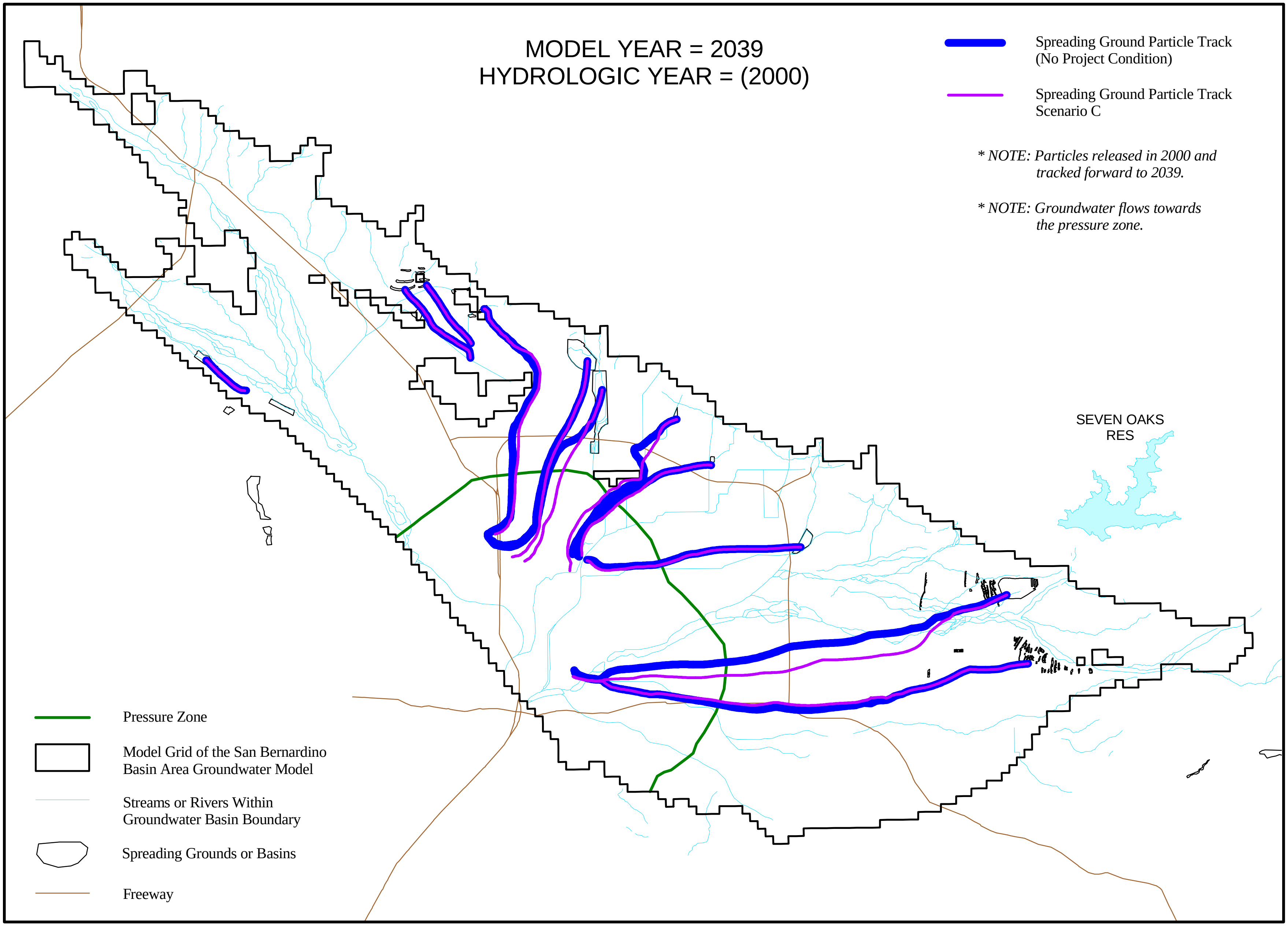
** NOTE: Particles released in 2000 and tracked forward to 2039.*

** NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2035**

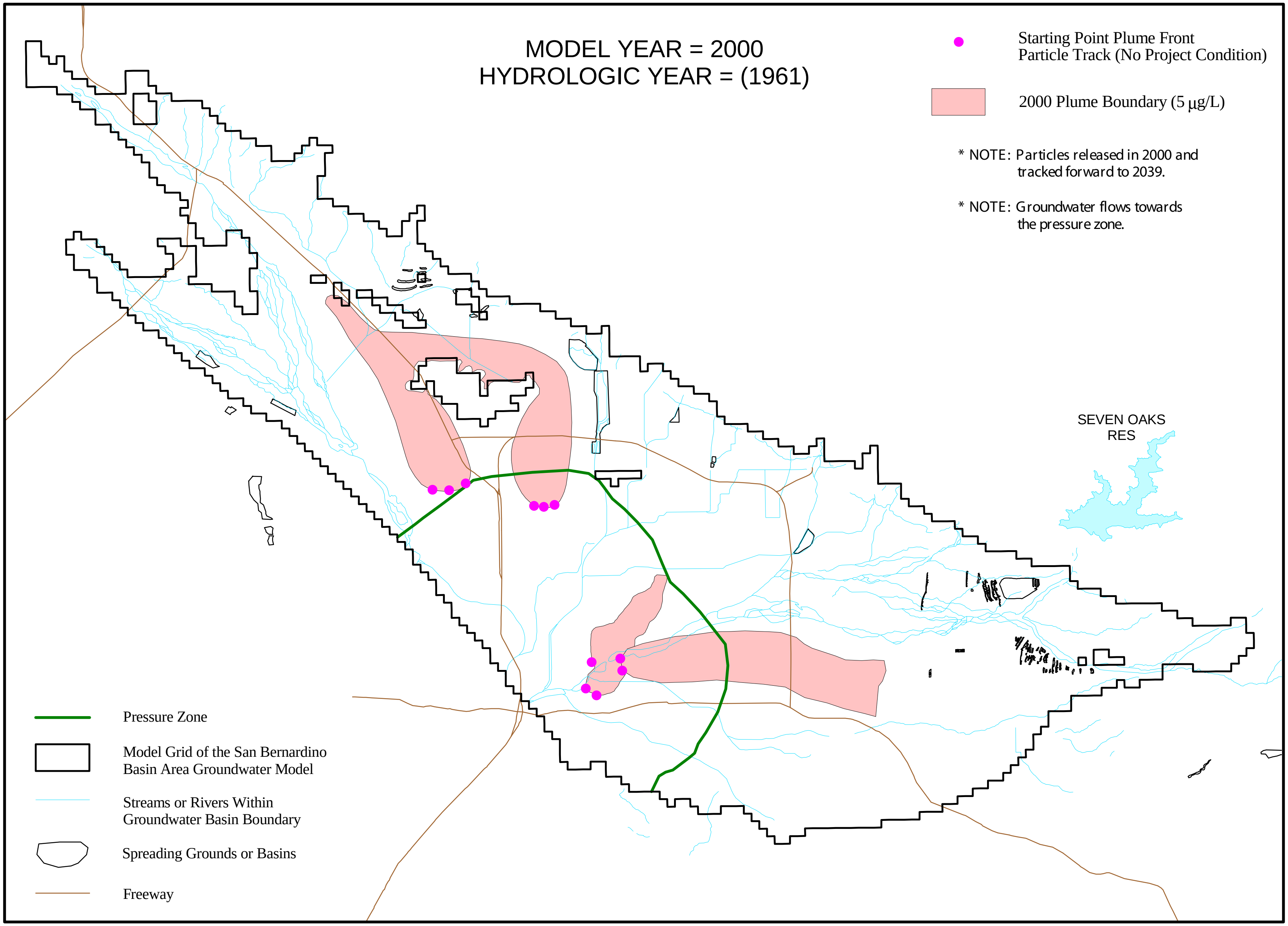
Figure B 38(h)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2039**

Figure B 38(i)


MODEL YEAR = 2000
HYDROLOGIC YEAR = (1961)

● Starting Point Plume Front Particle Track (No Project Condition)

▨ 2000 Plume Boundary (5 μg/L)

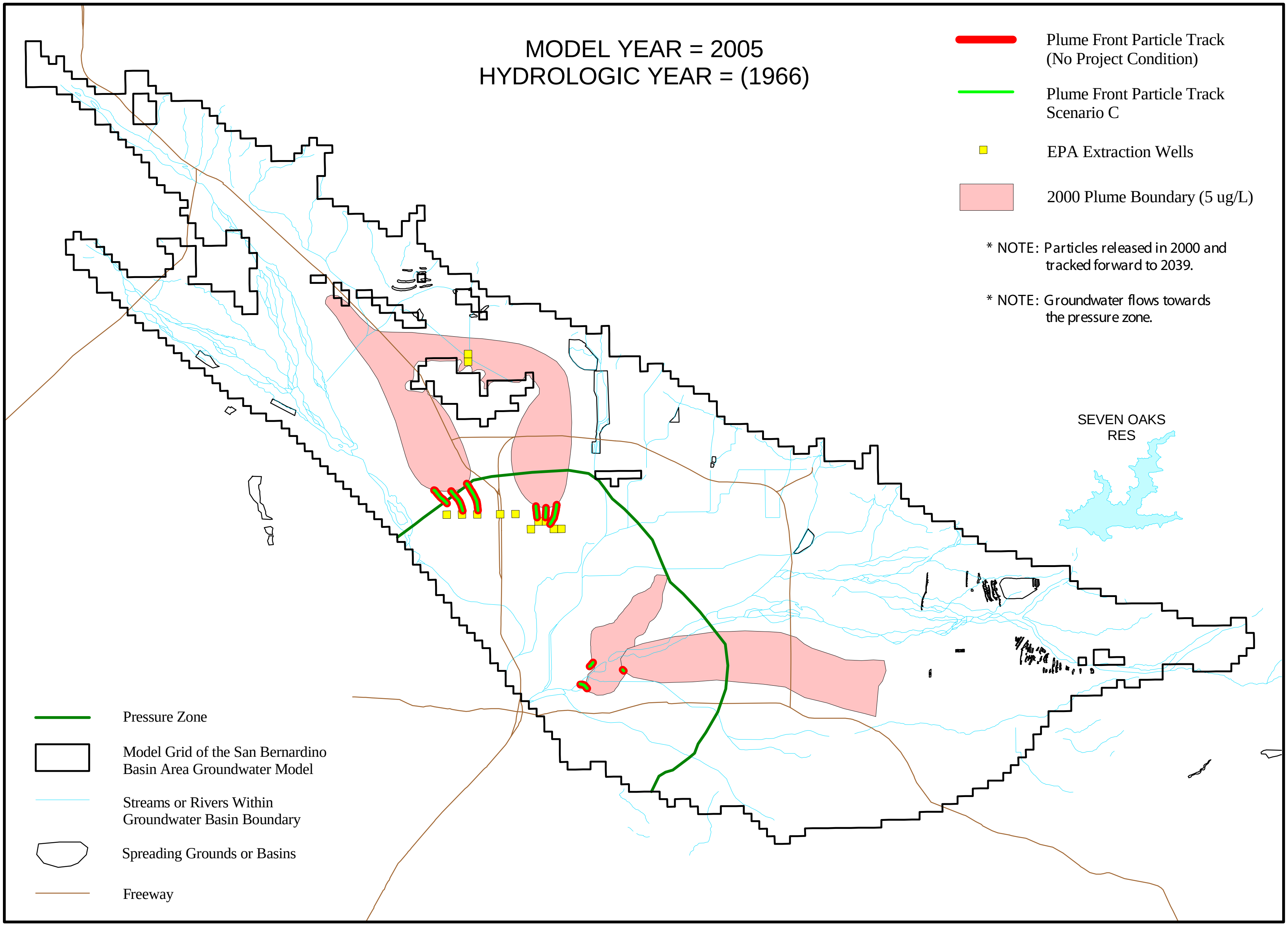
* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2000

Figure B 39(a)



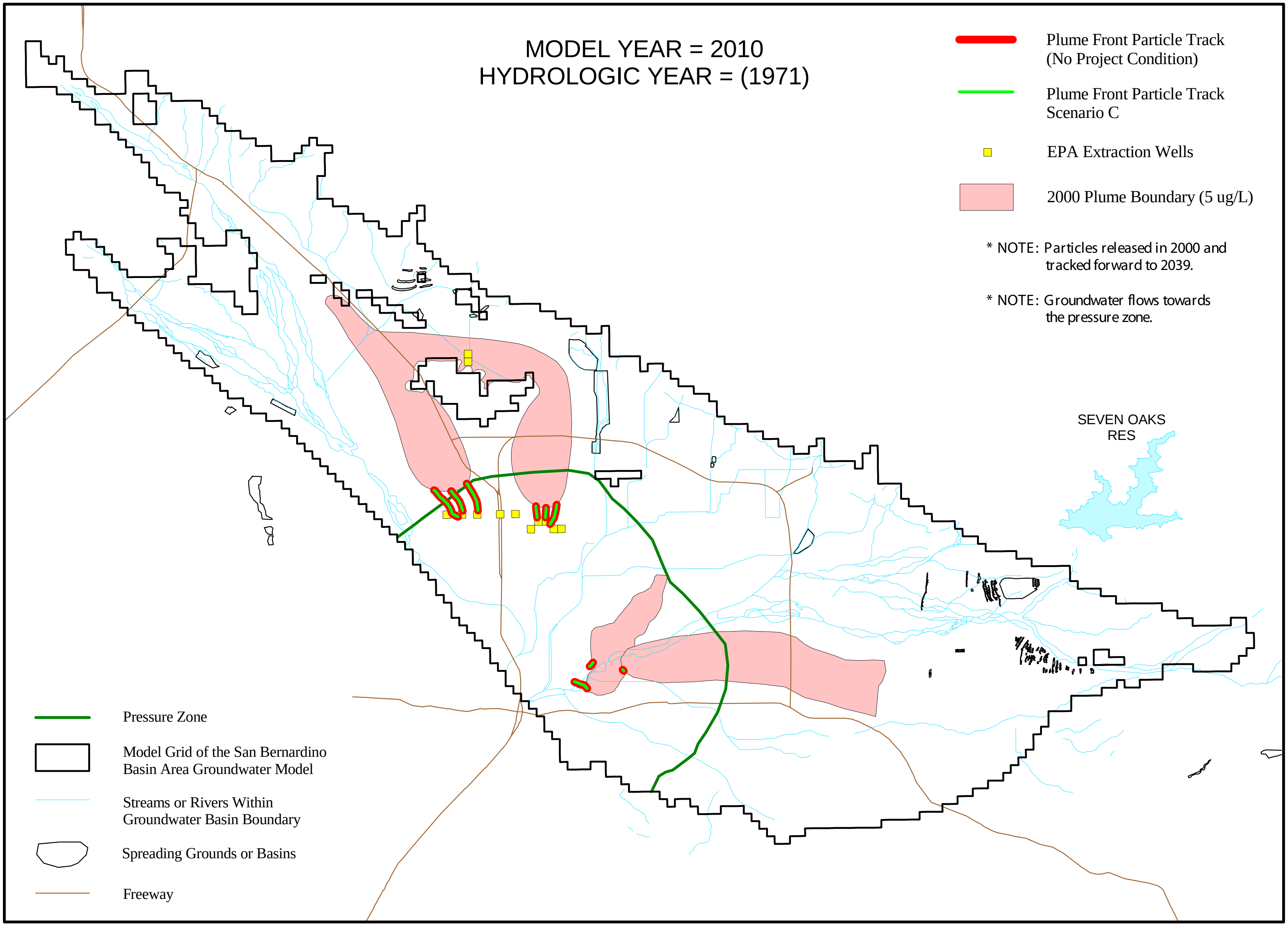
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2005

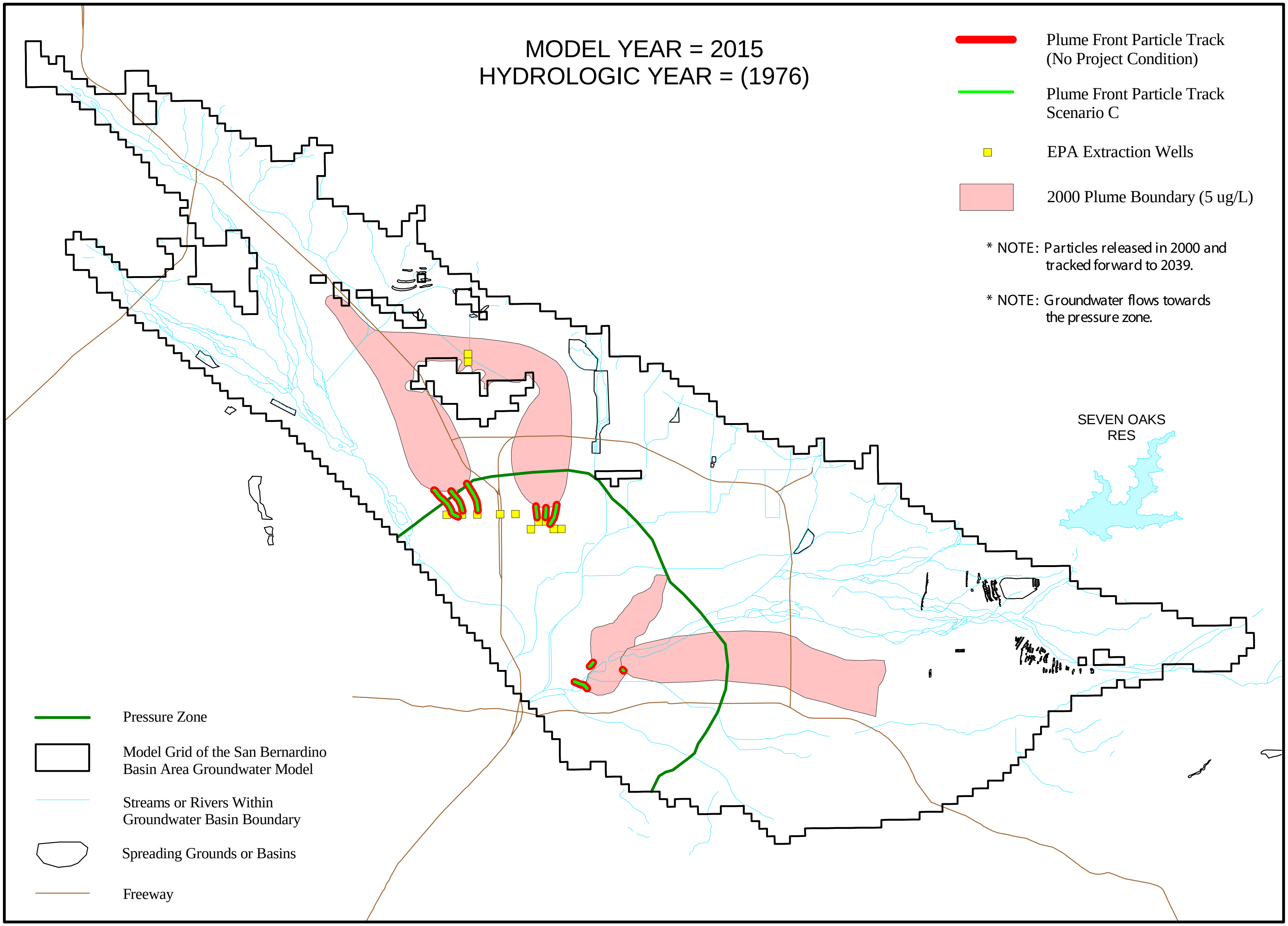
Figure B 39(b)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2010

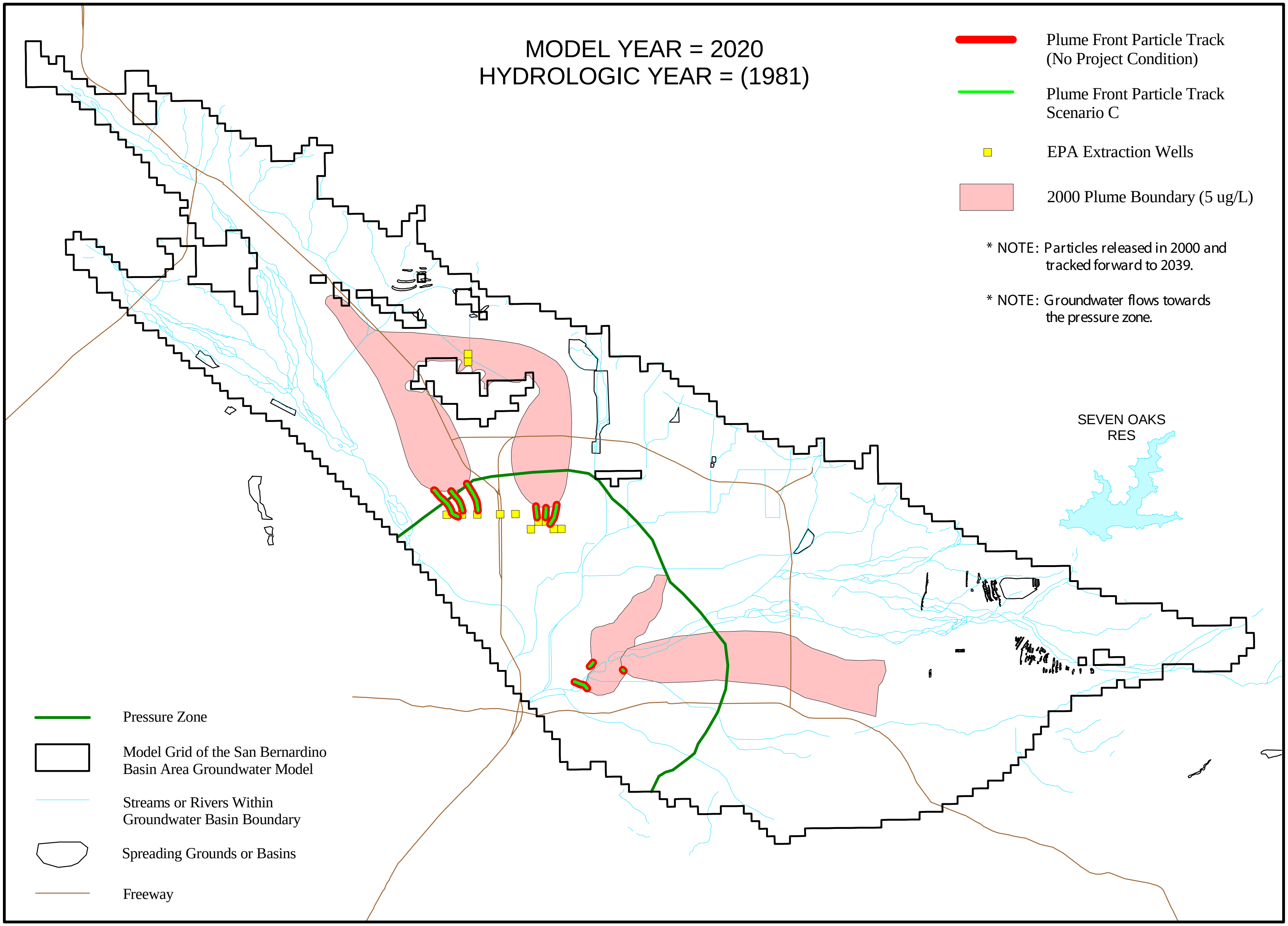
Figure B 39(c)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2015

Figure B 39(d)


MODEL YEAR = 2020
HYDROLOGIC YEAR = (1981)

* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

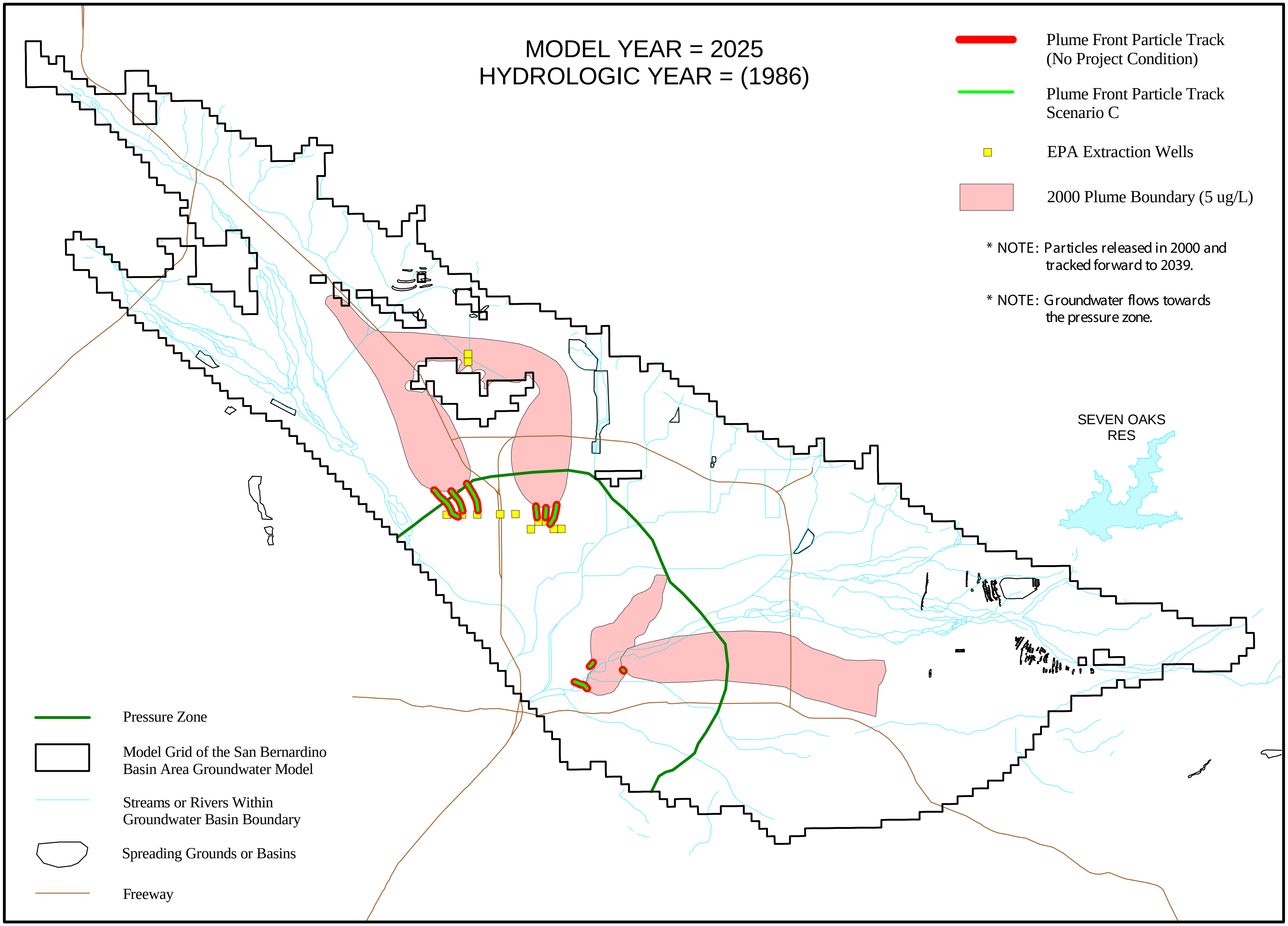
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2020

Figure B 39(e)


MODEL YEAR = 2025
HYDROLOGIC YEAR = (1986)

* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

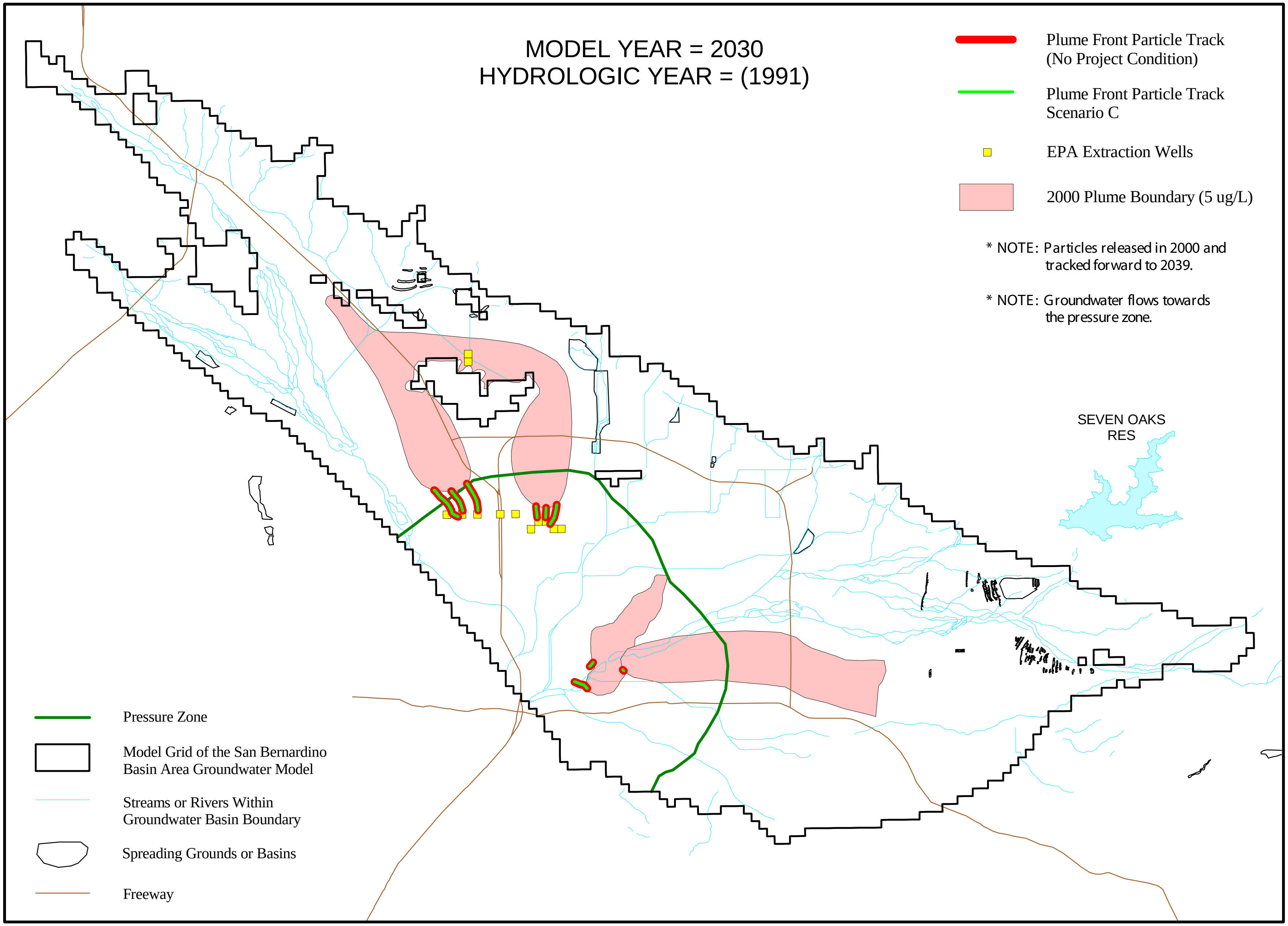
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2025

Figure B 39(f)


MODEL YEAR = 2030
HYDROLOGIC YEAR = (1991)

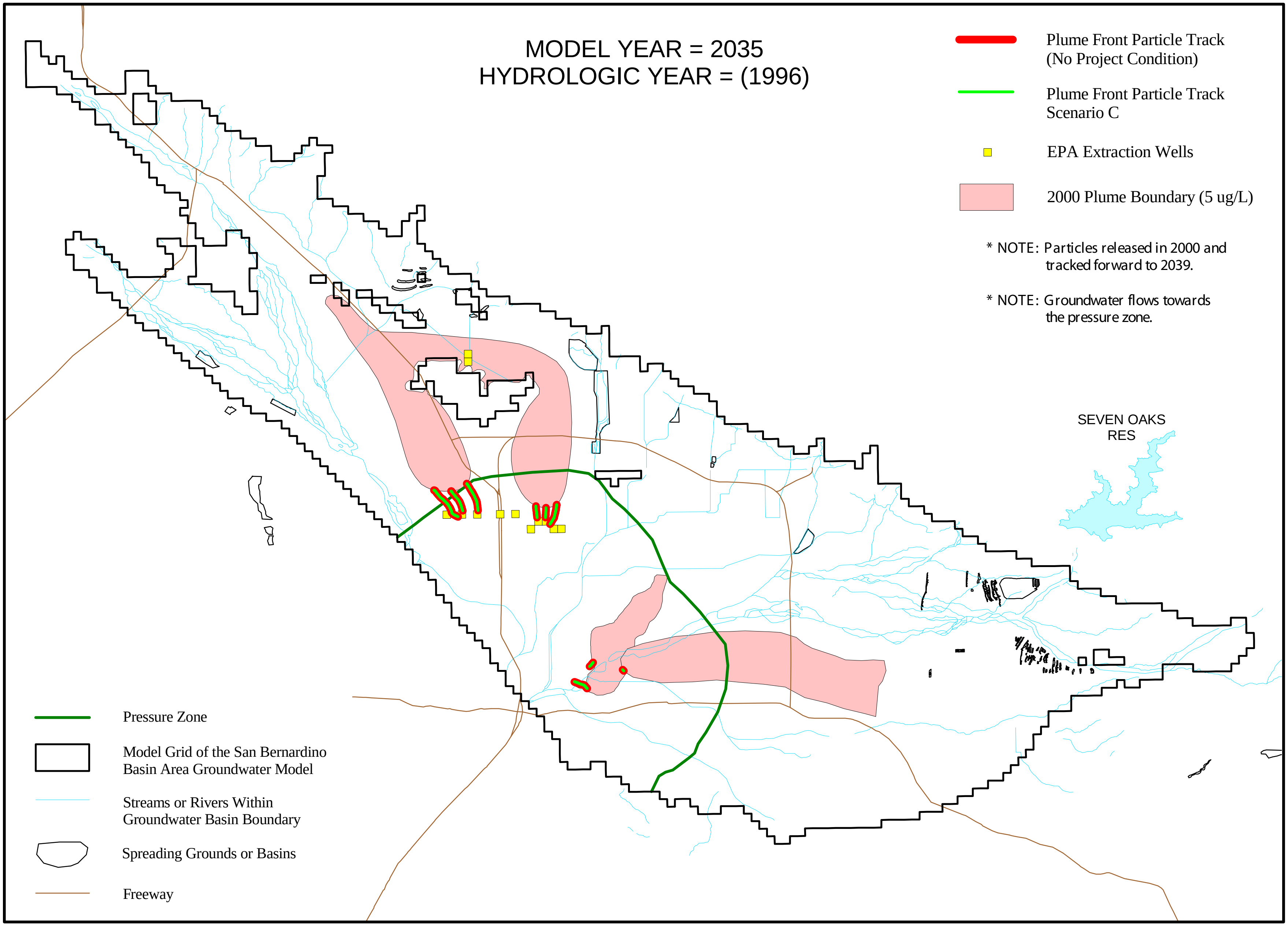
* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2030

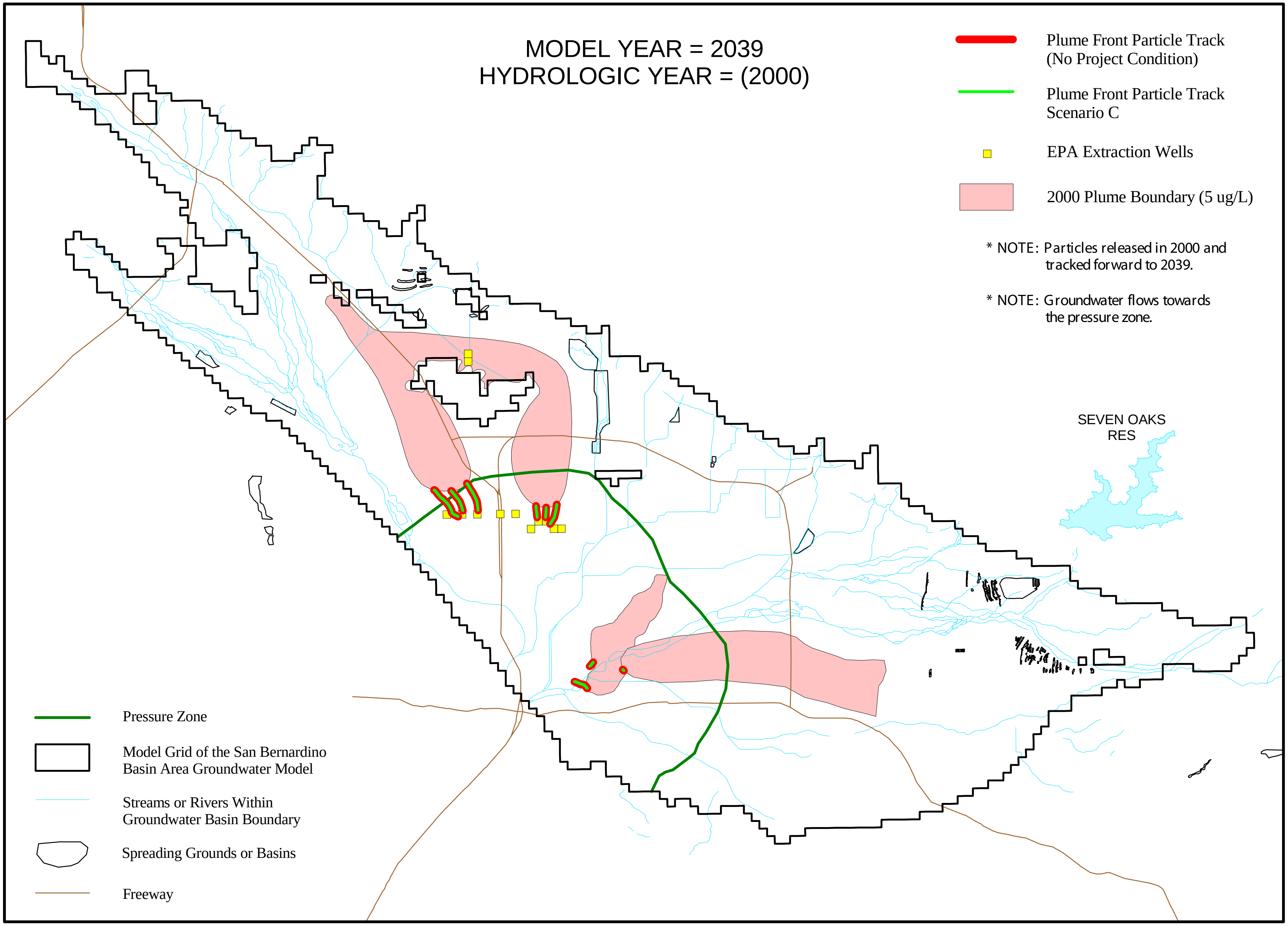
Figure B 39(g)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2035

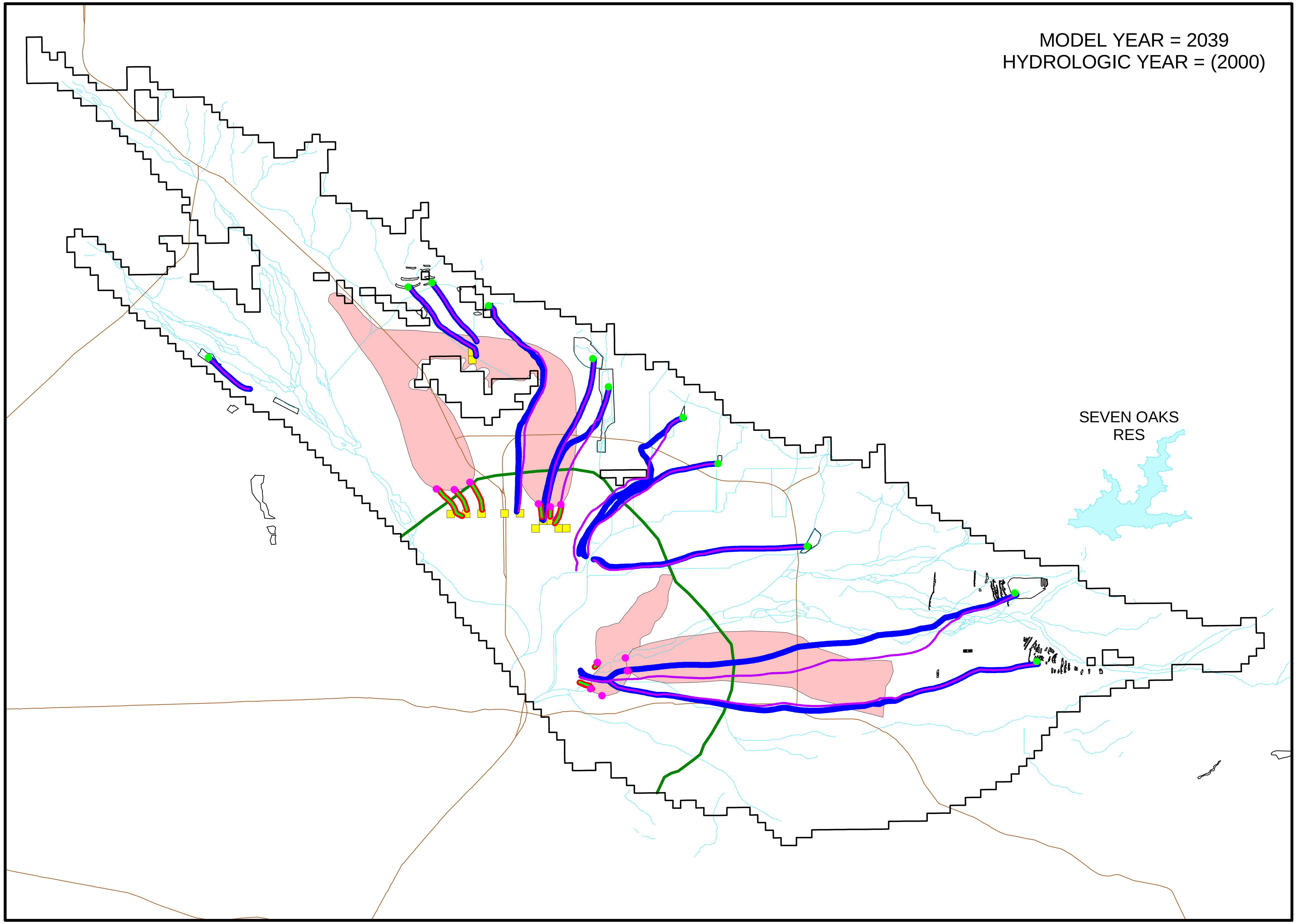
Figure B 39(h)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO C, MODEL YEAR 2039

Figure B 39(i)



PARTICLE TRACKS FROM BOTH SPREADING GROUNDS AND PLUME FRONTS, YEAR 2039, NO PROJECT CONDITION VERSUS SCENARIO C

EXPLANATION

- ● Starting Point Spreading Ground Particle Track (No Project Condition)
- ━ Spreading Ground Particle Track (No Project Condition)
- ─ Spreading Ground Particle Track Scenario C
- ● Starting Point Plume Front Particle Track (No Project Condition)
- ━ Plume Front Particle Track (No Project Condition)
- ─ Plume Front Particle Track Scenario C
- ▫ EPA Extraction Wells
- 🟥 2000 Plume Boundary (5 µg/L)
- ━ Pressure Zone
- ☐ Model Grid of the San Bernardino Basin Area Groundwater Model
- ─ Streams or Rivers Within Groundwater Basin Boundary
- ⬭ Spreading Grounds or Basins
- ─ Freeway

* NOTE: Particles released in 2000 and tracked forward to 2039.

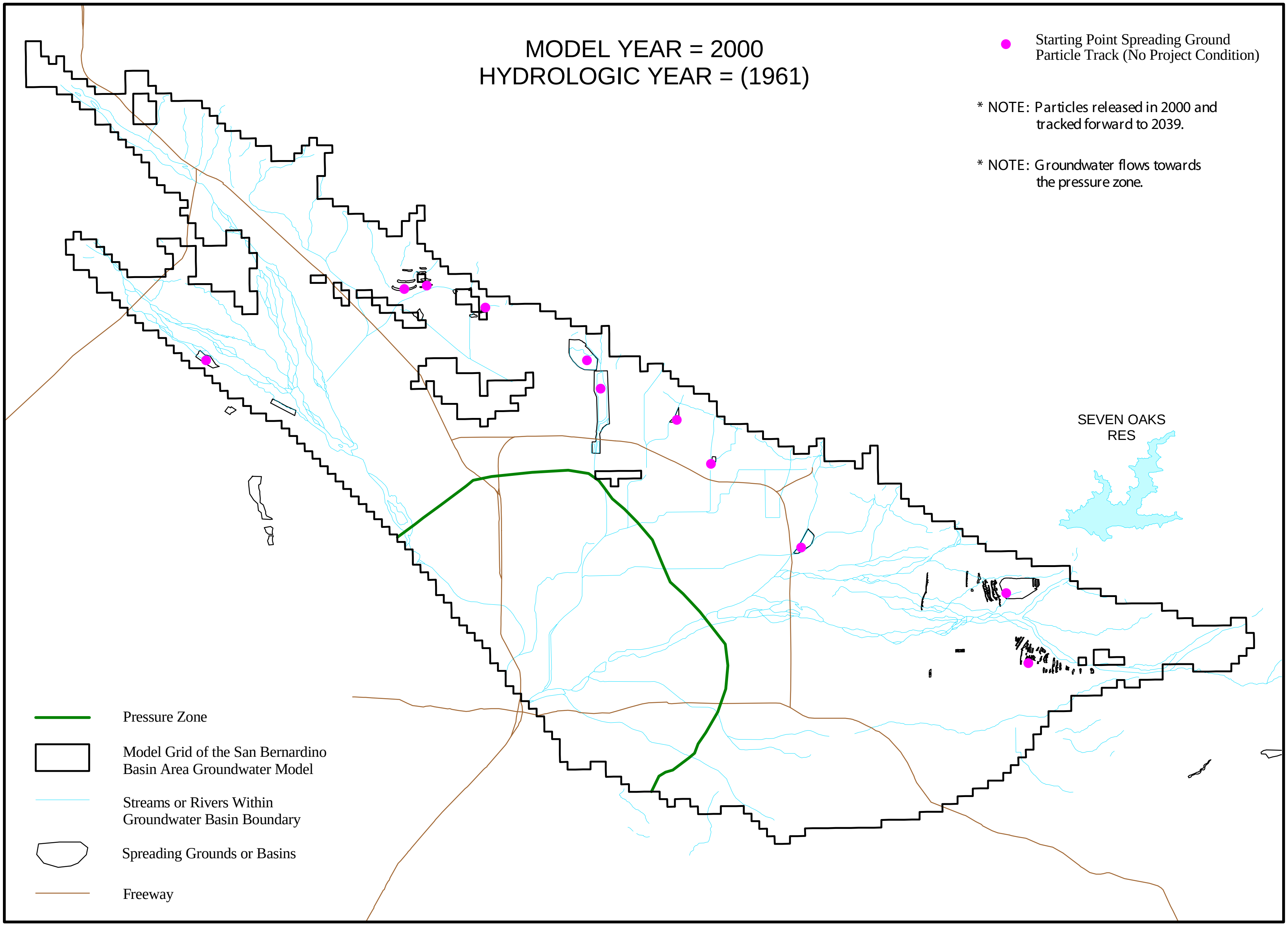
* NOTE: Groundwater flows towards the pressure zone.

NORTH

0 2 4 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 40



* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

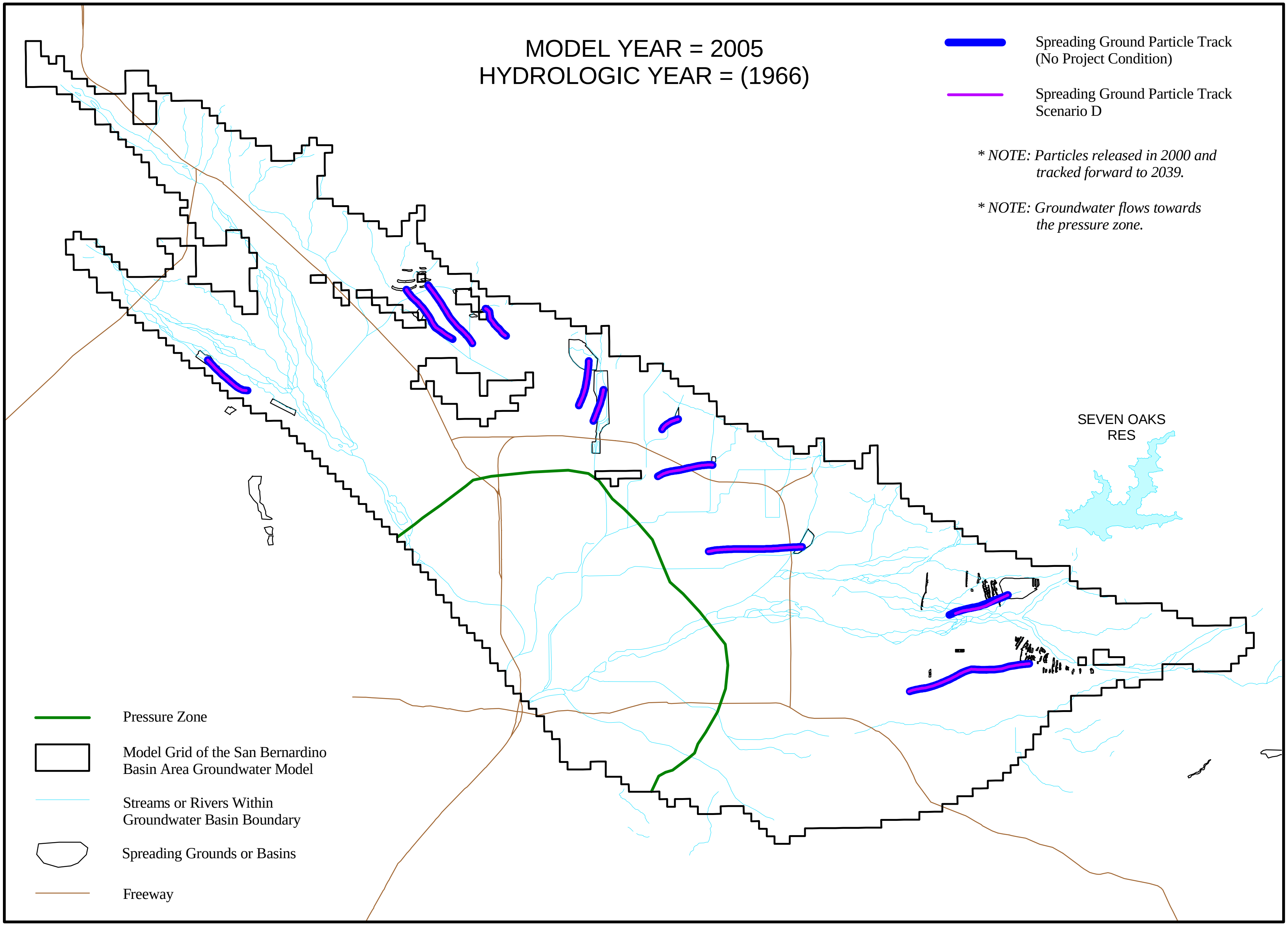
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2000

Figure B 41(a)



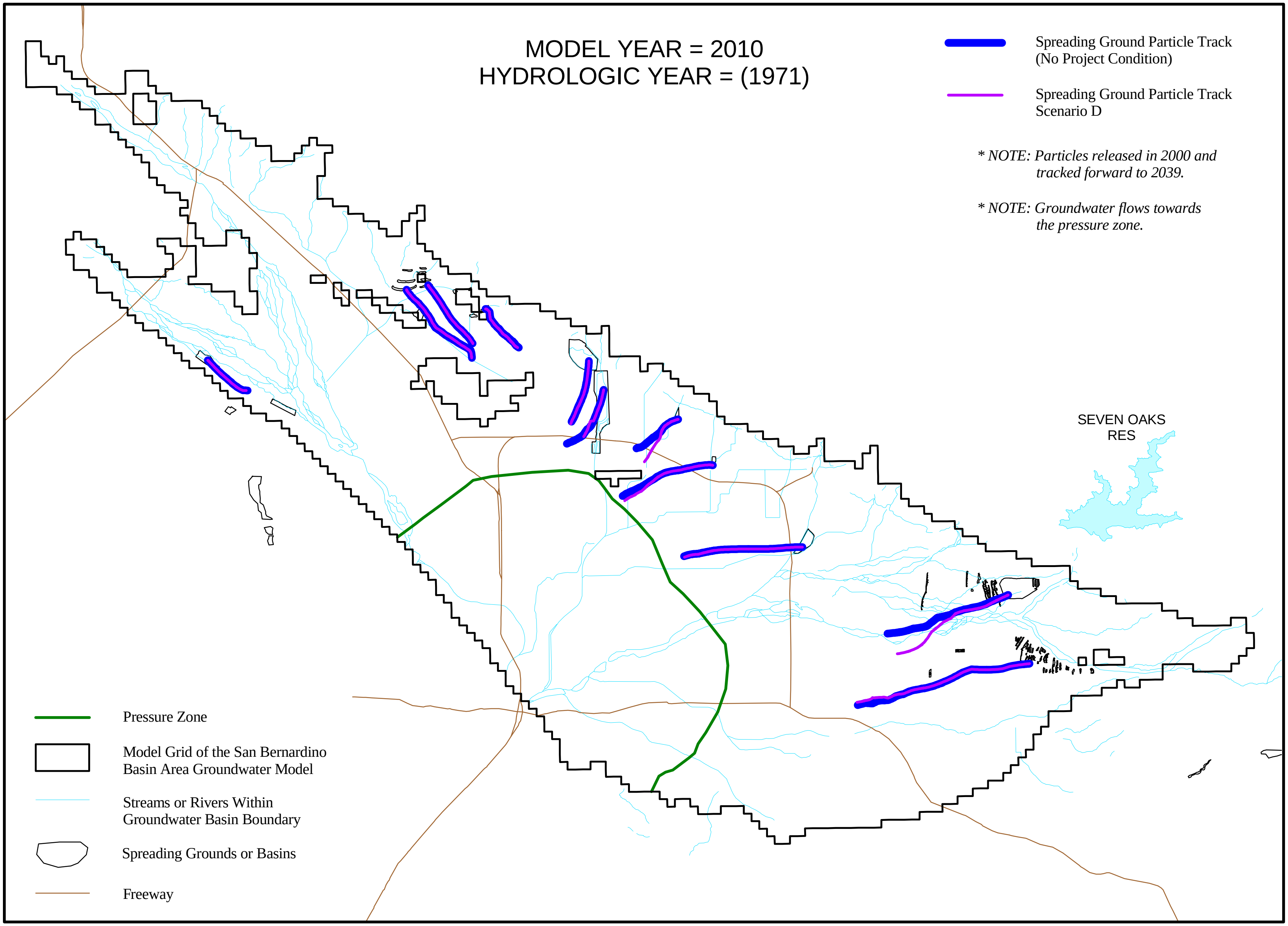
** NOTE: Particles released in 2000 and tracked forward to 2039.*

** NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2005**

Figure B 41(b)



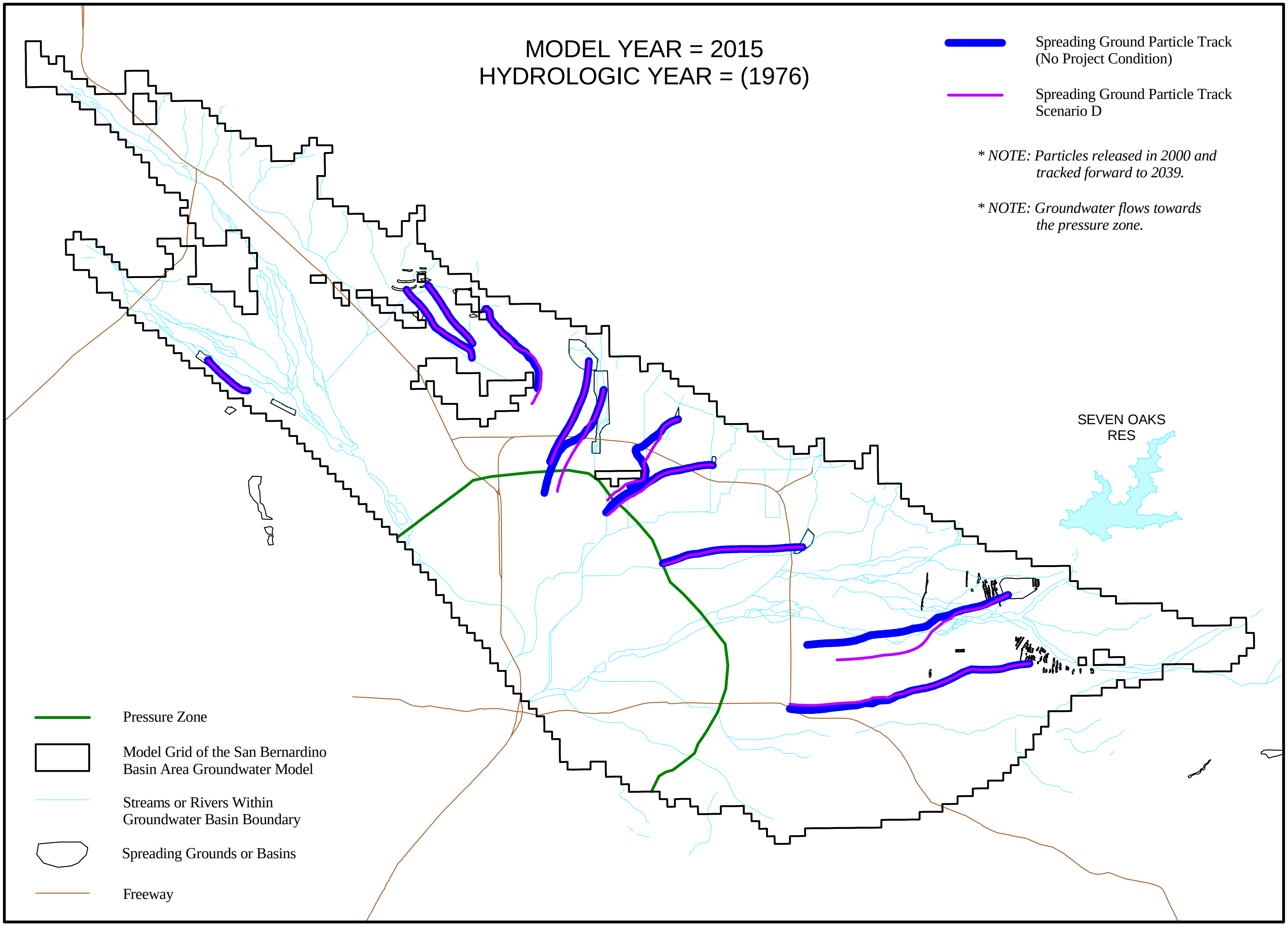
* *NOTE: Particles released in 2000 and tracked forward to 2039.*

* *NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2010**

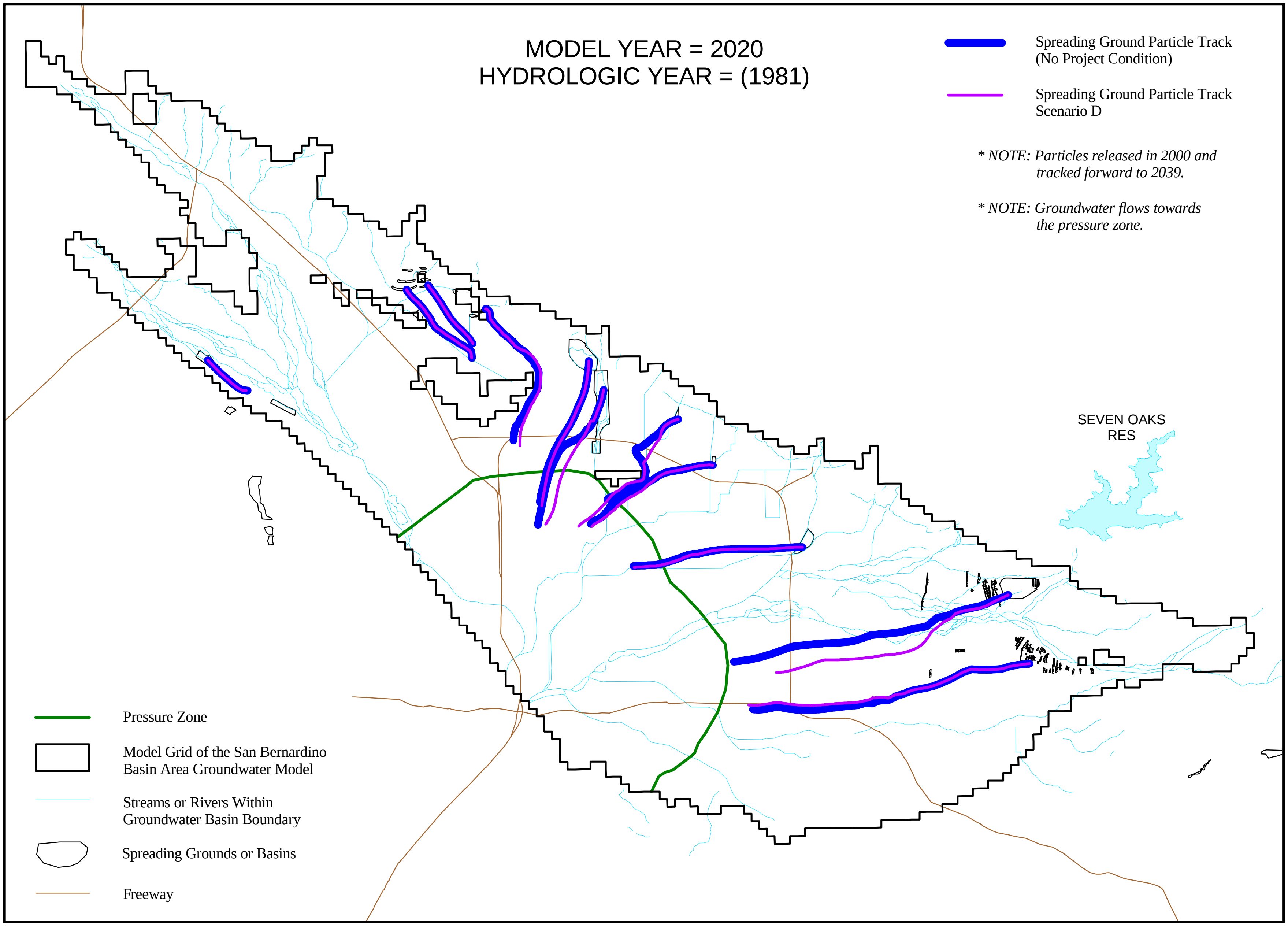
Figure B 41(c)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2015

Figure B 41(d)



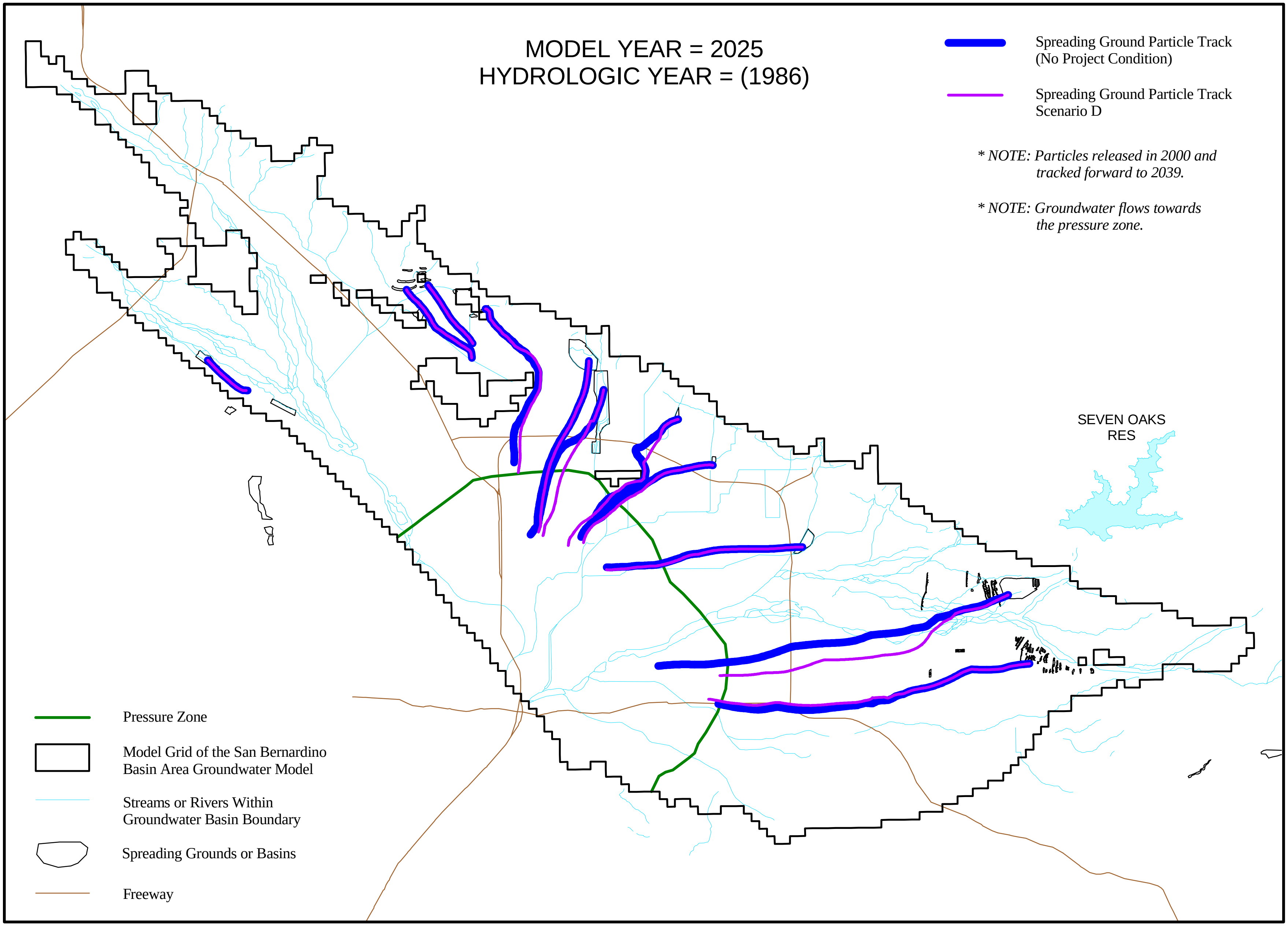
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2020

Figure B 41(e)



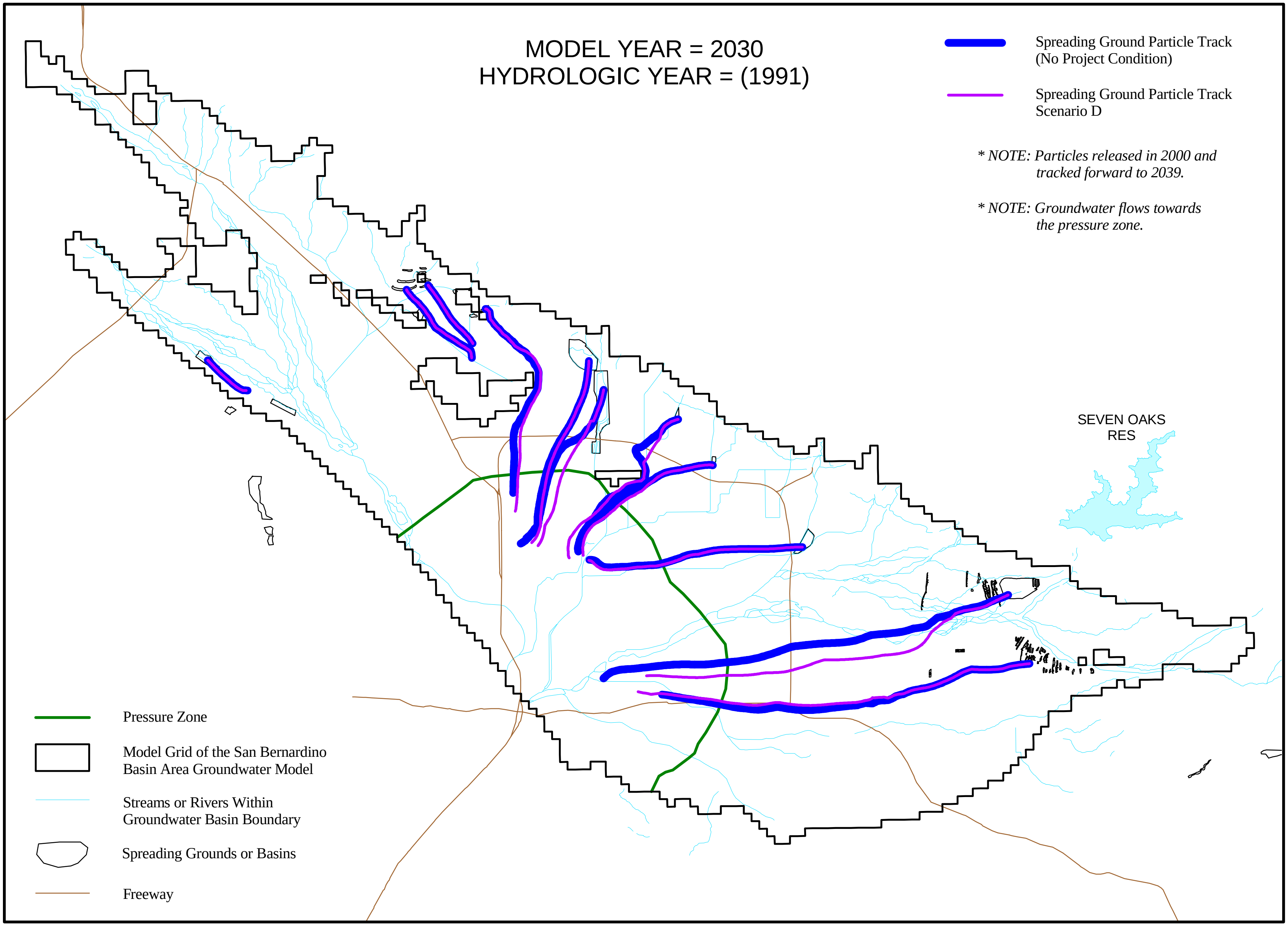
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2025

Figure B 41(f)



MODEL YEAR = 2030
HYDROLOGIC YEAR = (1991)

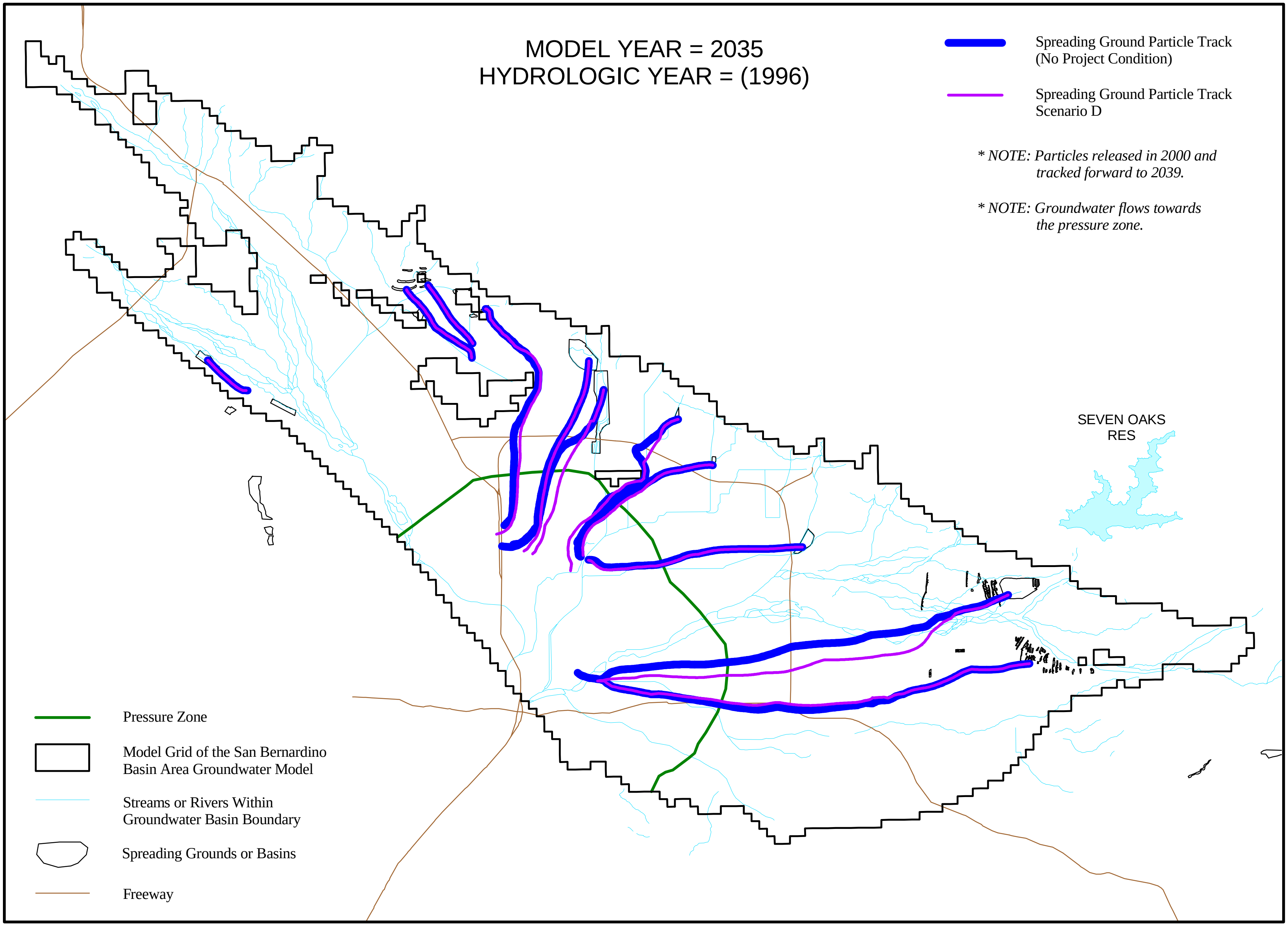
* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2030

Figure B 41(g)



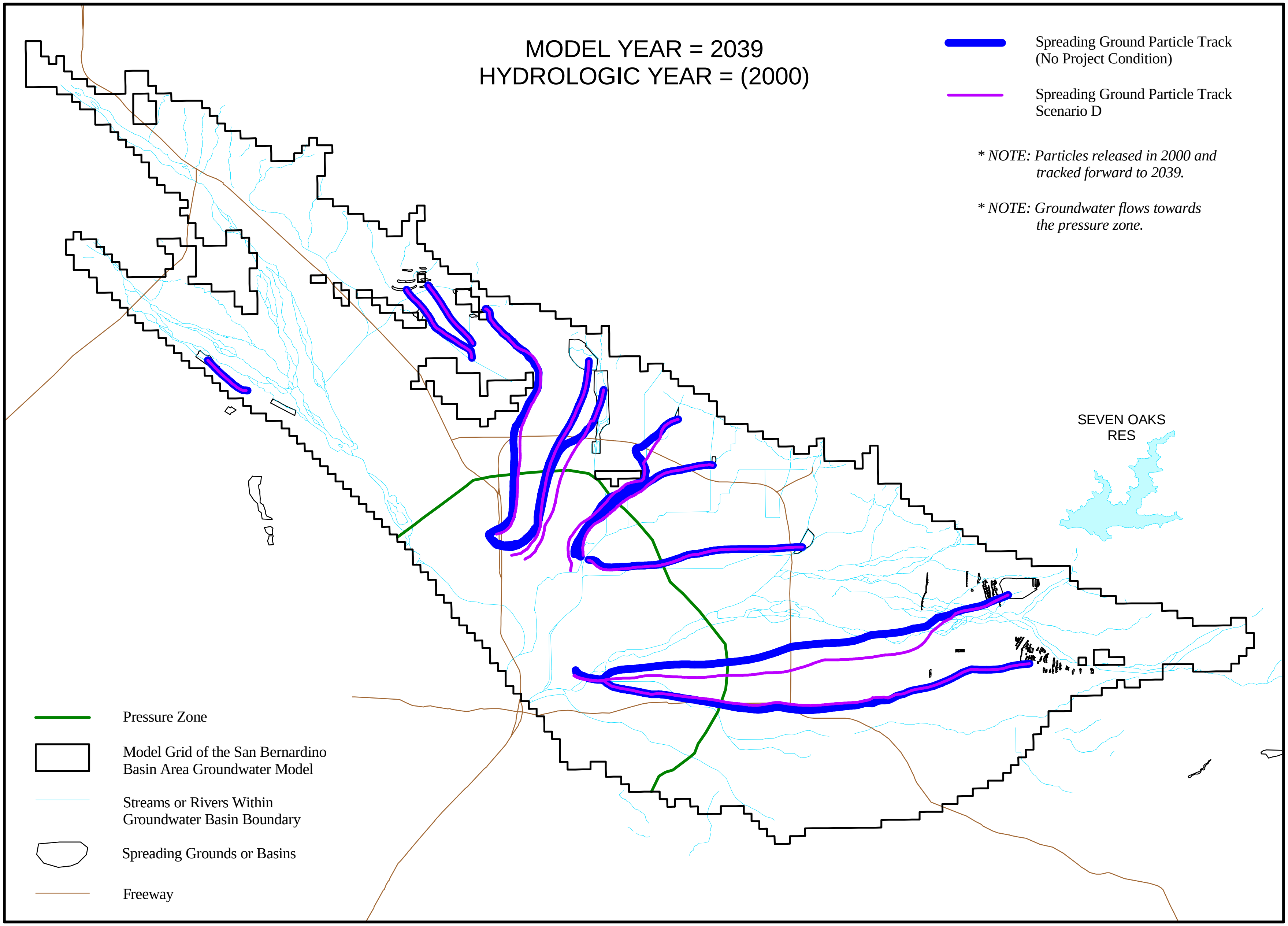
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2035**

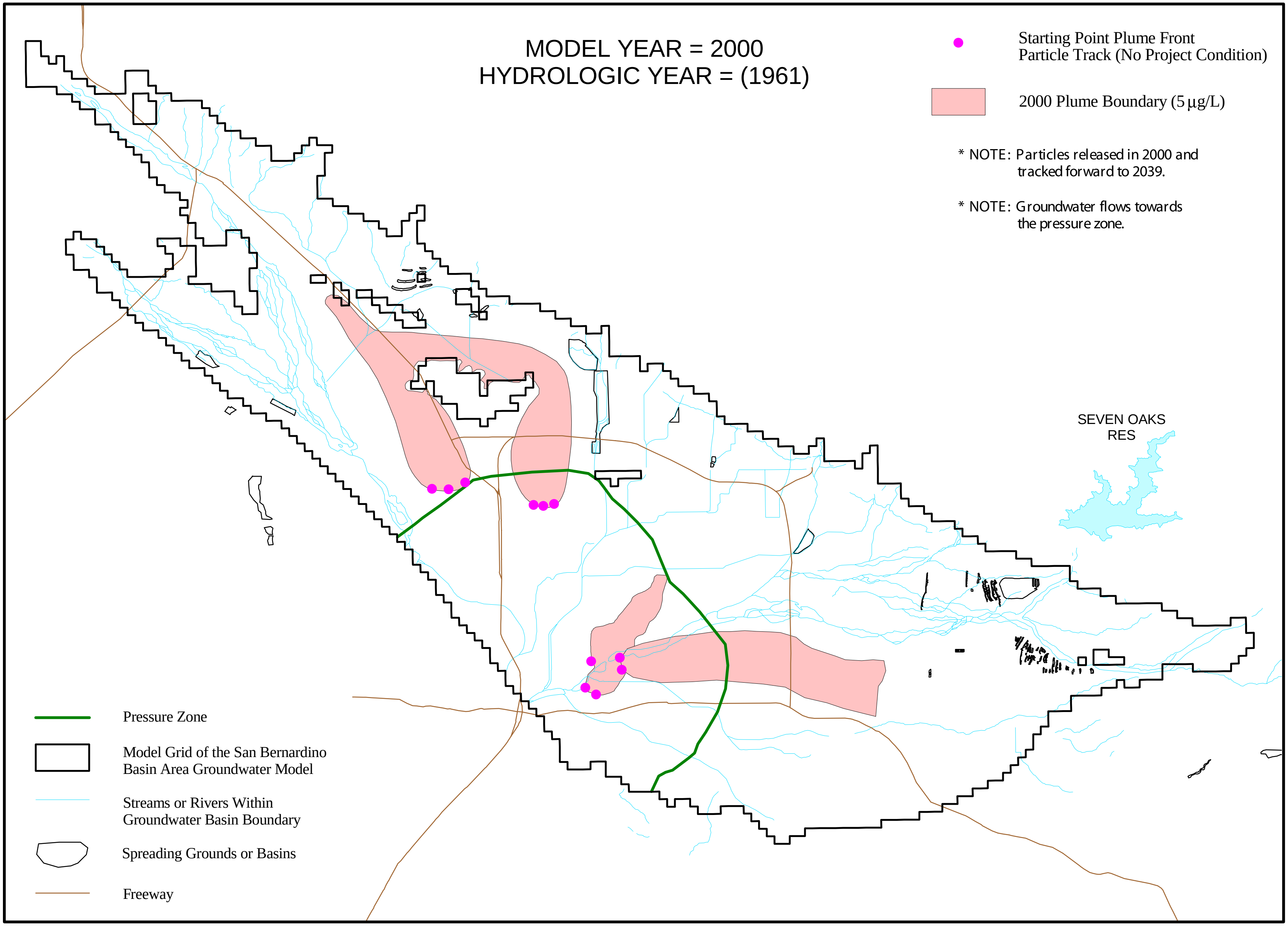
Figure B 41(h)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2039

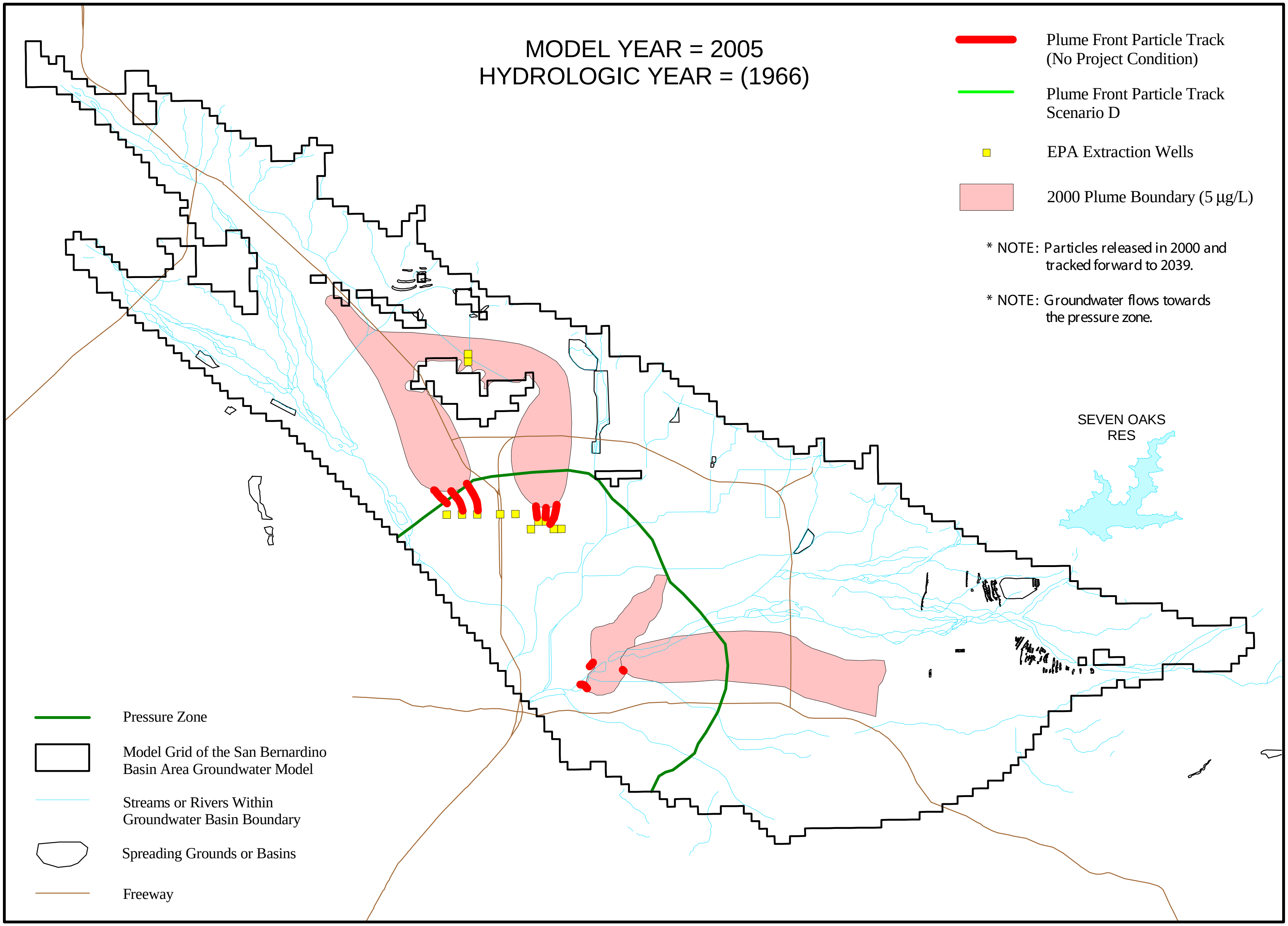
Figure B 41(i)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2000

Figure B 42(a)



MODEL YEAR = 2005
HYDROLOGIC YEAR = (1966)

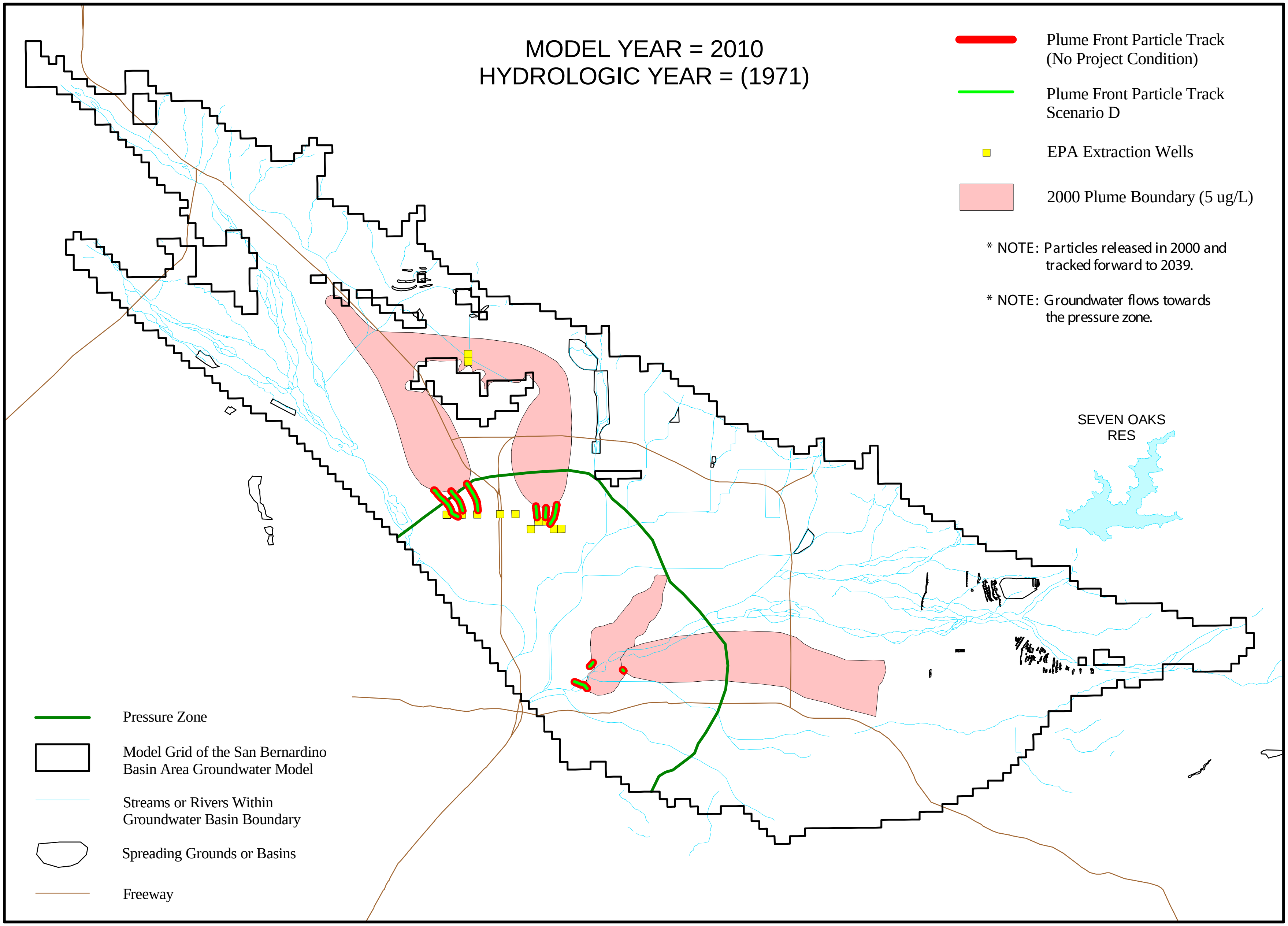
* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2005

Figure B 42(b)



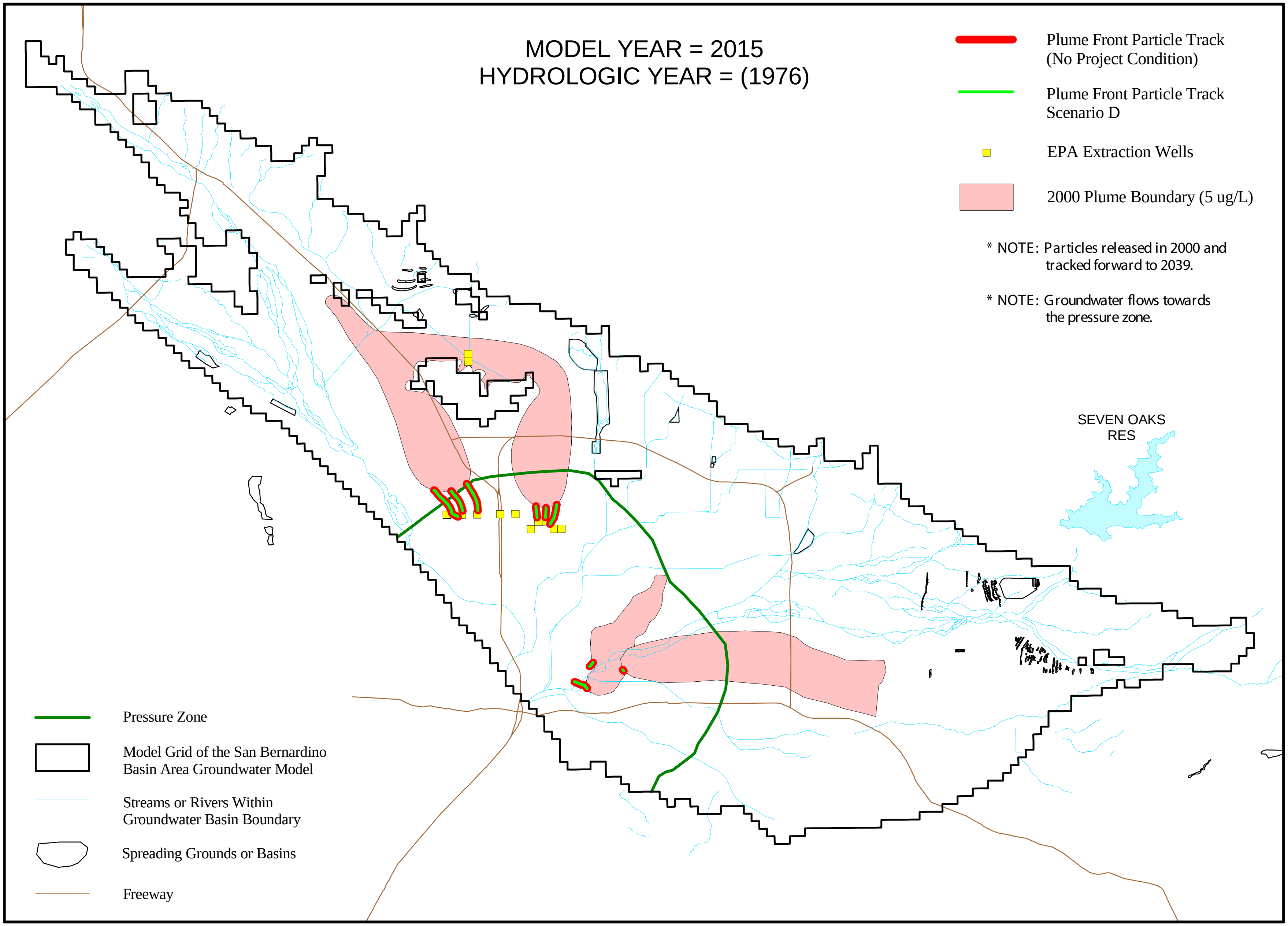
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2010

Figure B 42(c)



* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

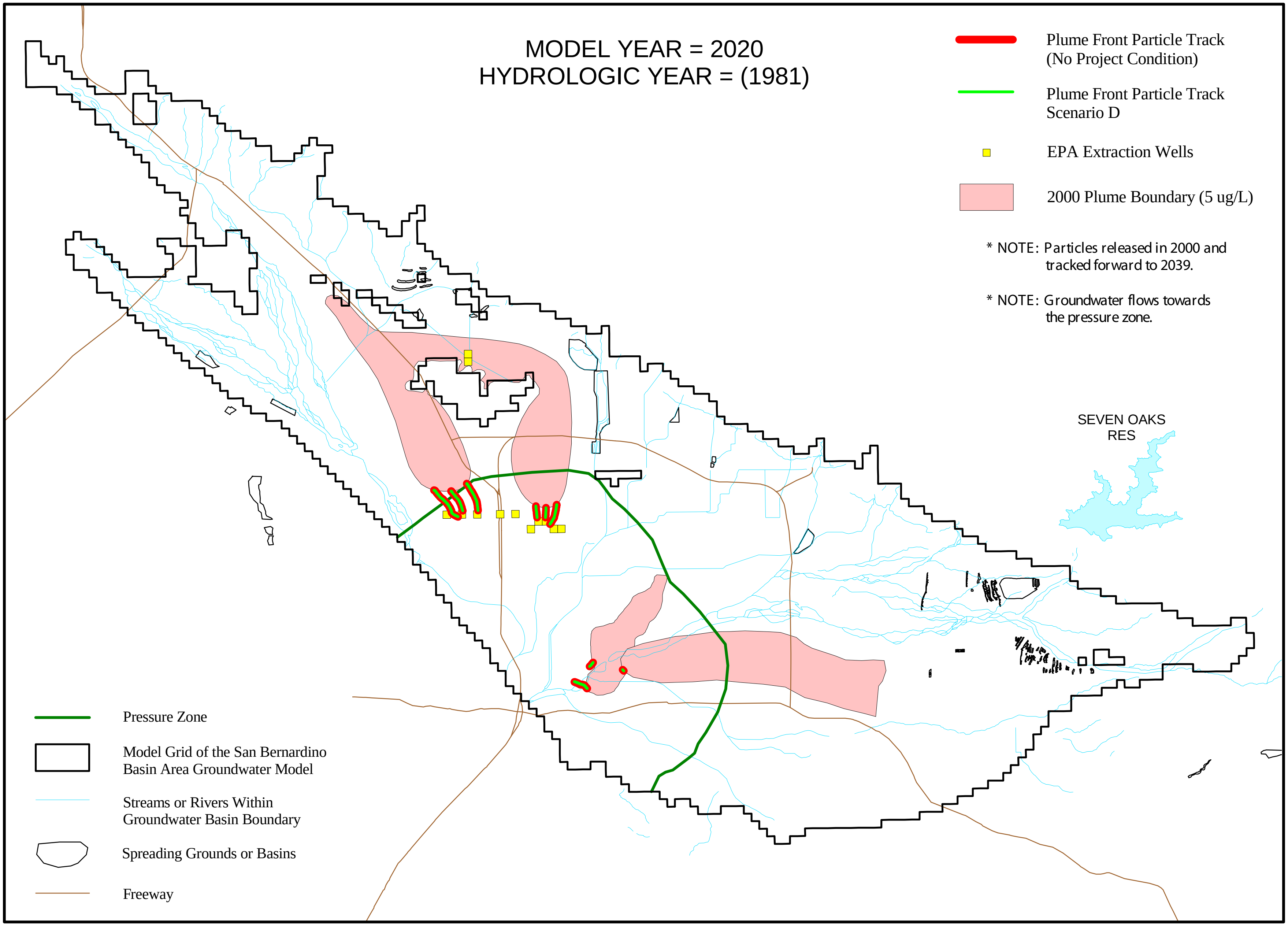
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS, NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2015

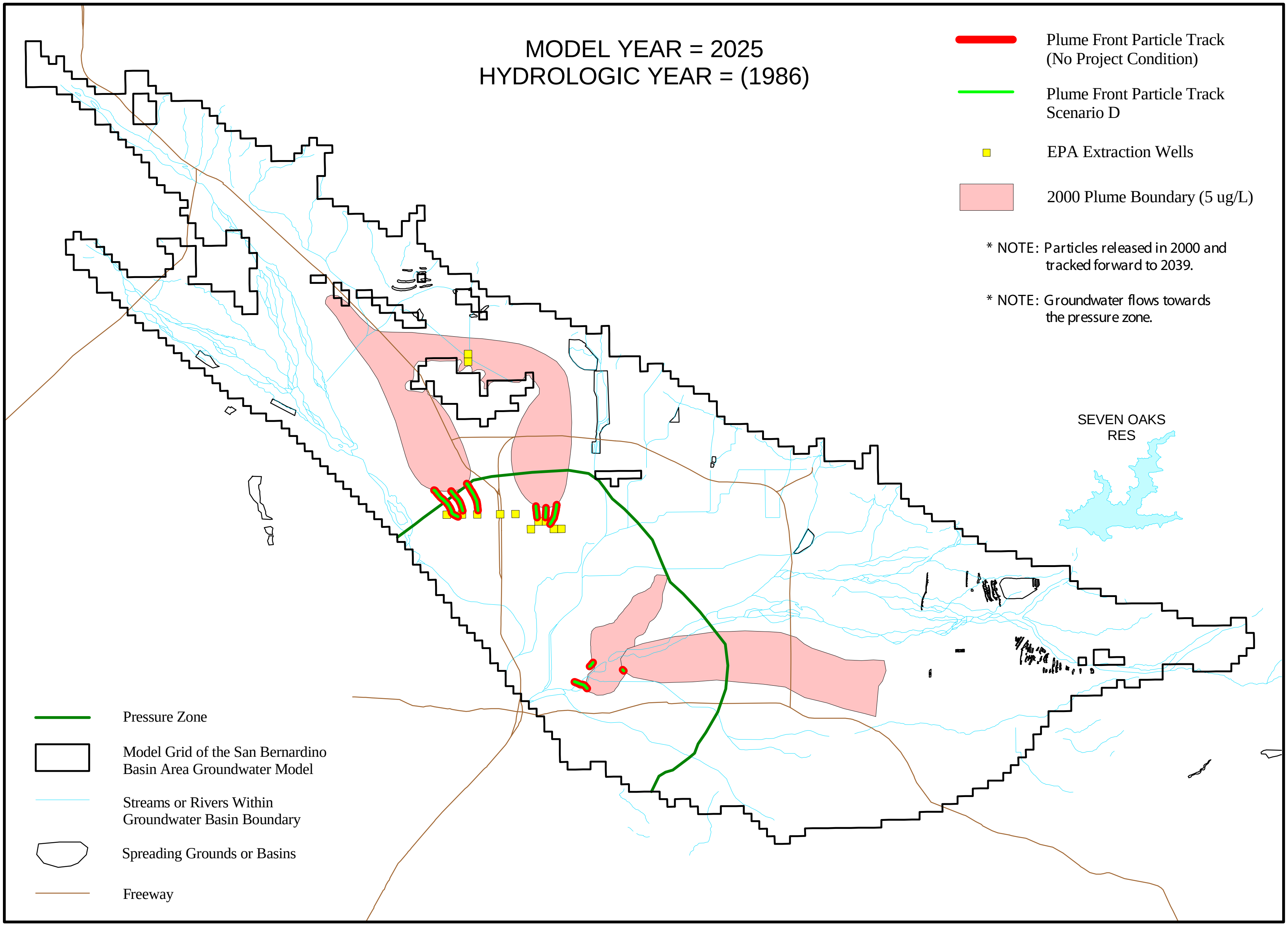
Figure B 42(d)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2020

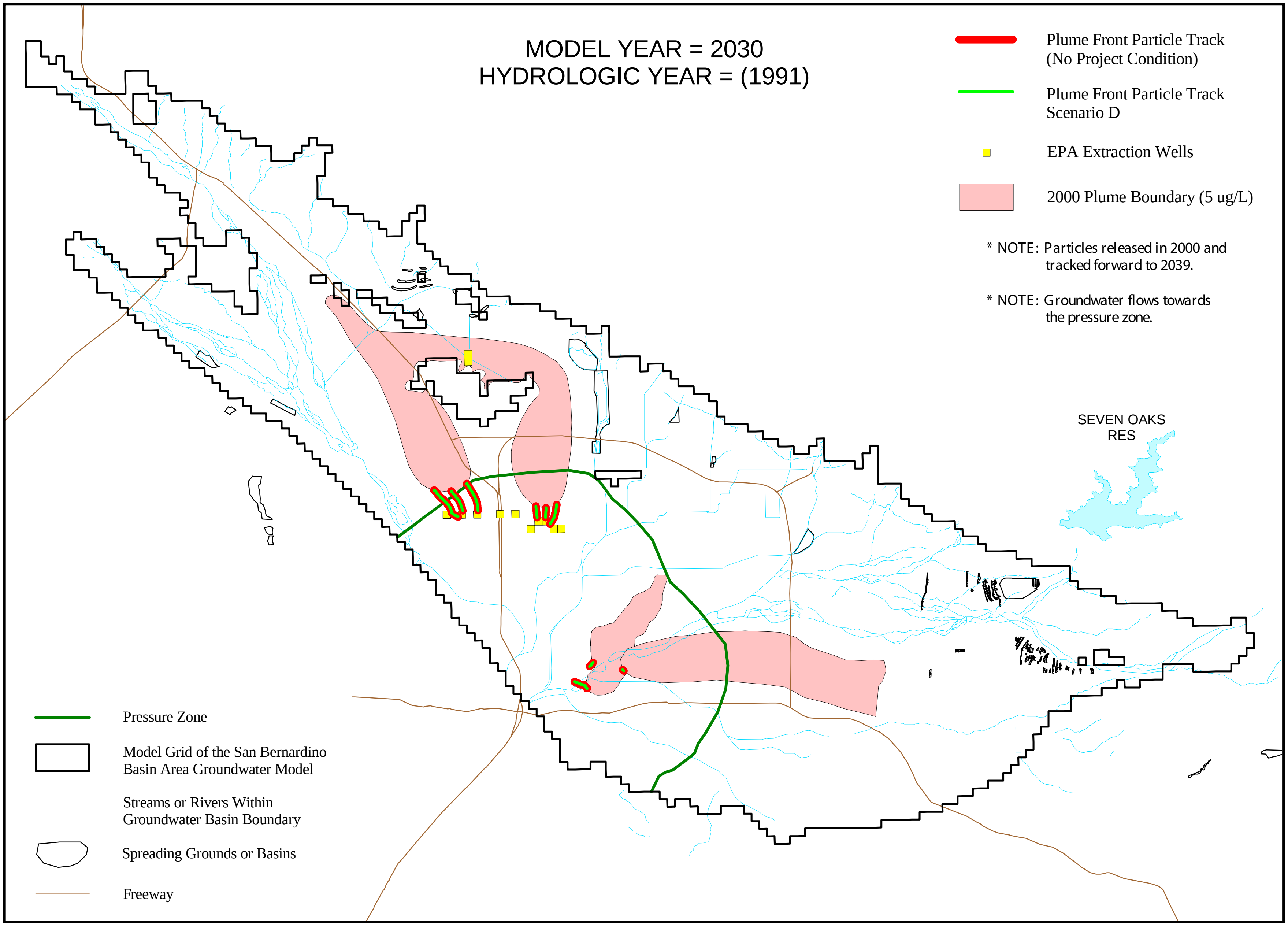
Figure B 42(e)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2025

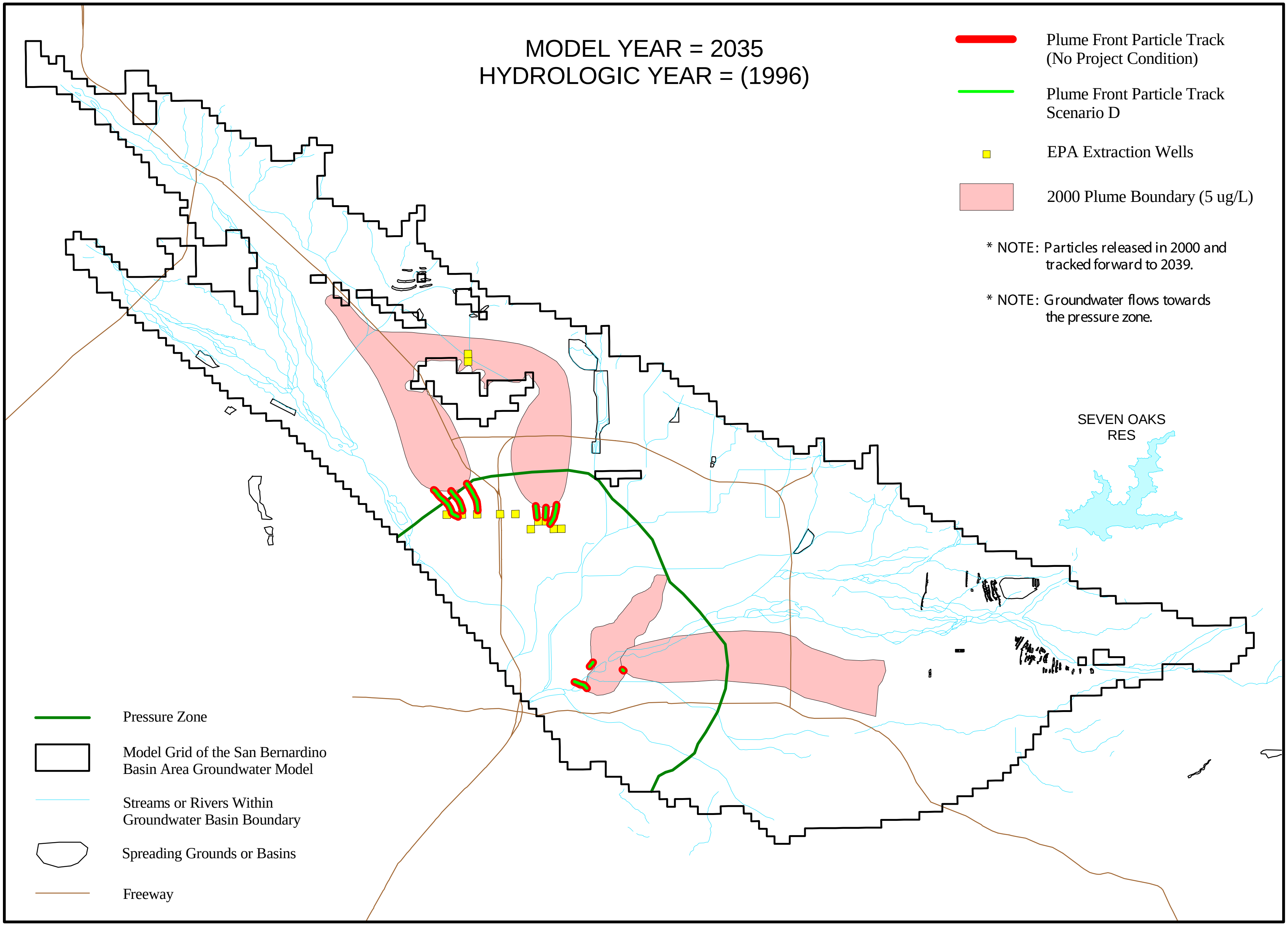
Figure B 42(f)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2030

Figure B 42(g)



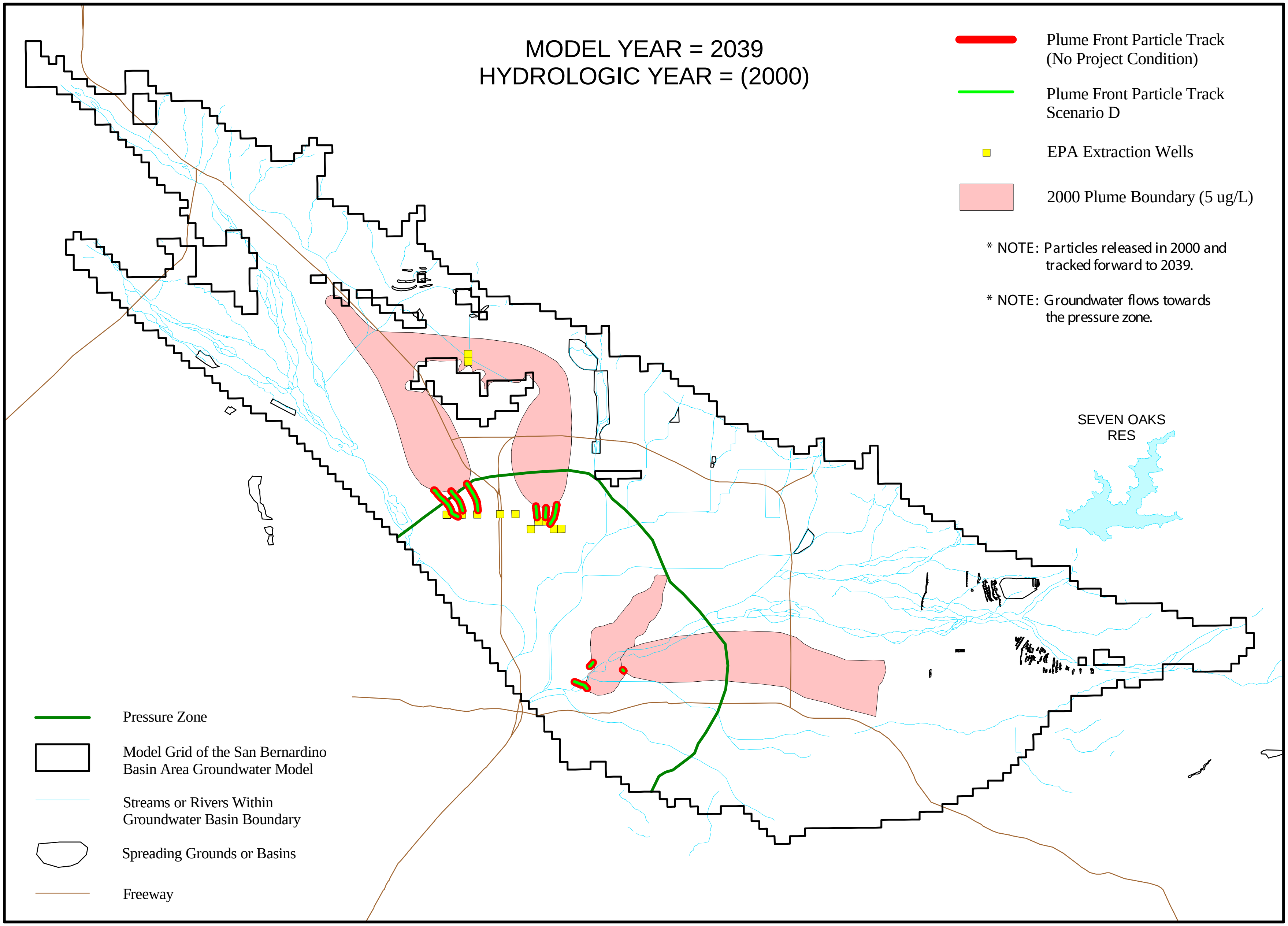
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2035

Figure B 42(h)



* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

NORTH

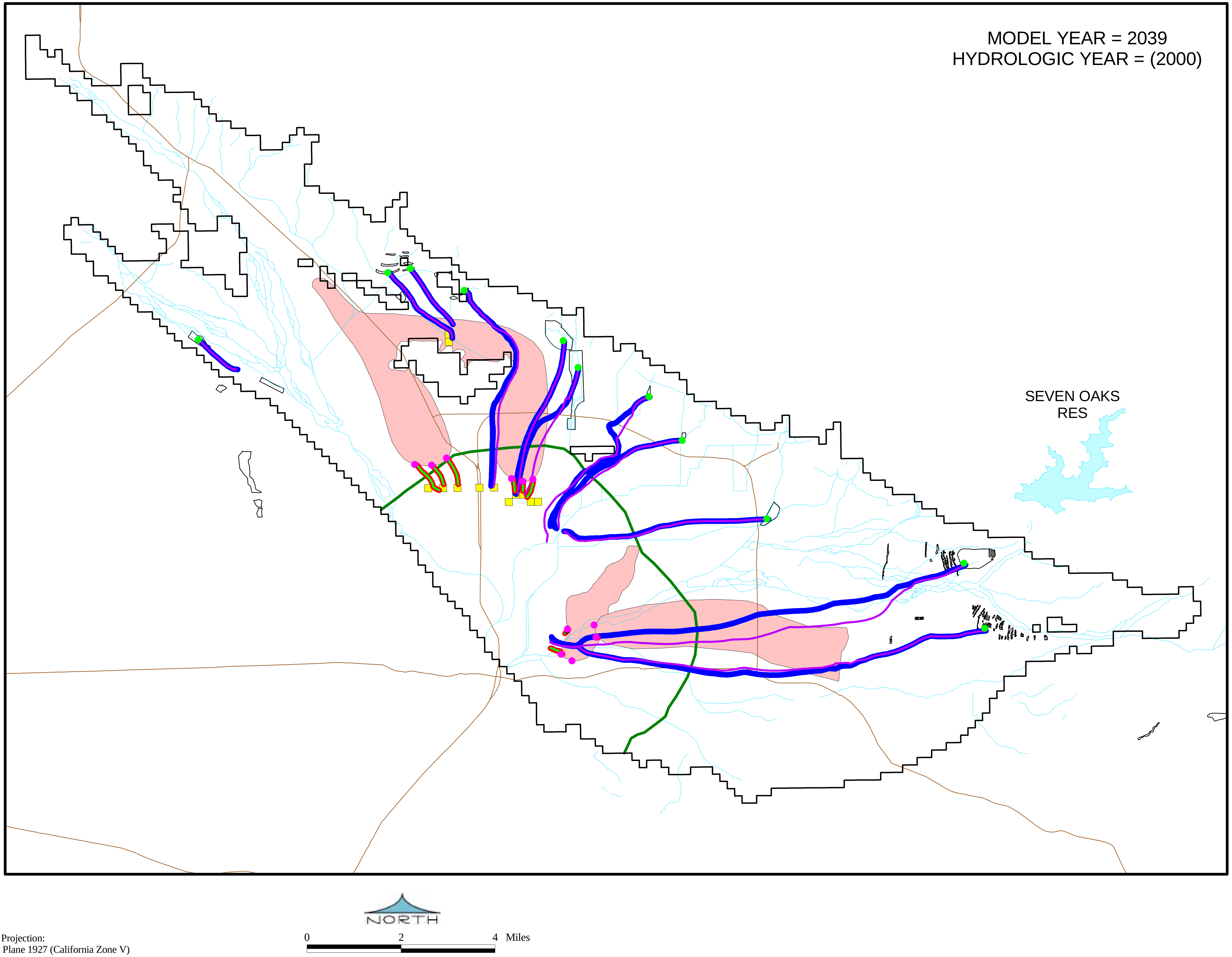
0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO D, MODEL YEAR 2039

Figure B 42(i)

PARTICLE TRACKS FROM BOTH SPREADING GROUNDS AND PLUME FRONTS, YEAR 2039, NO PROJECT CONDITION VERSUS SCENARIO D



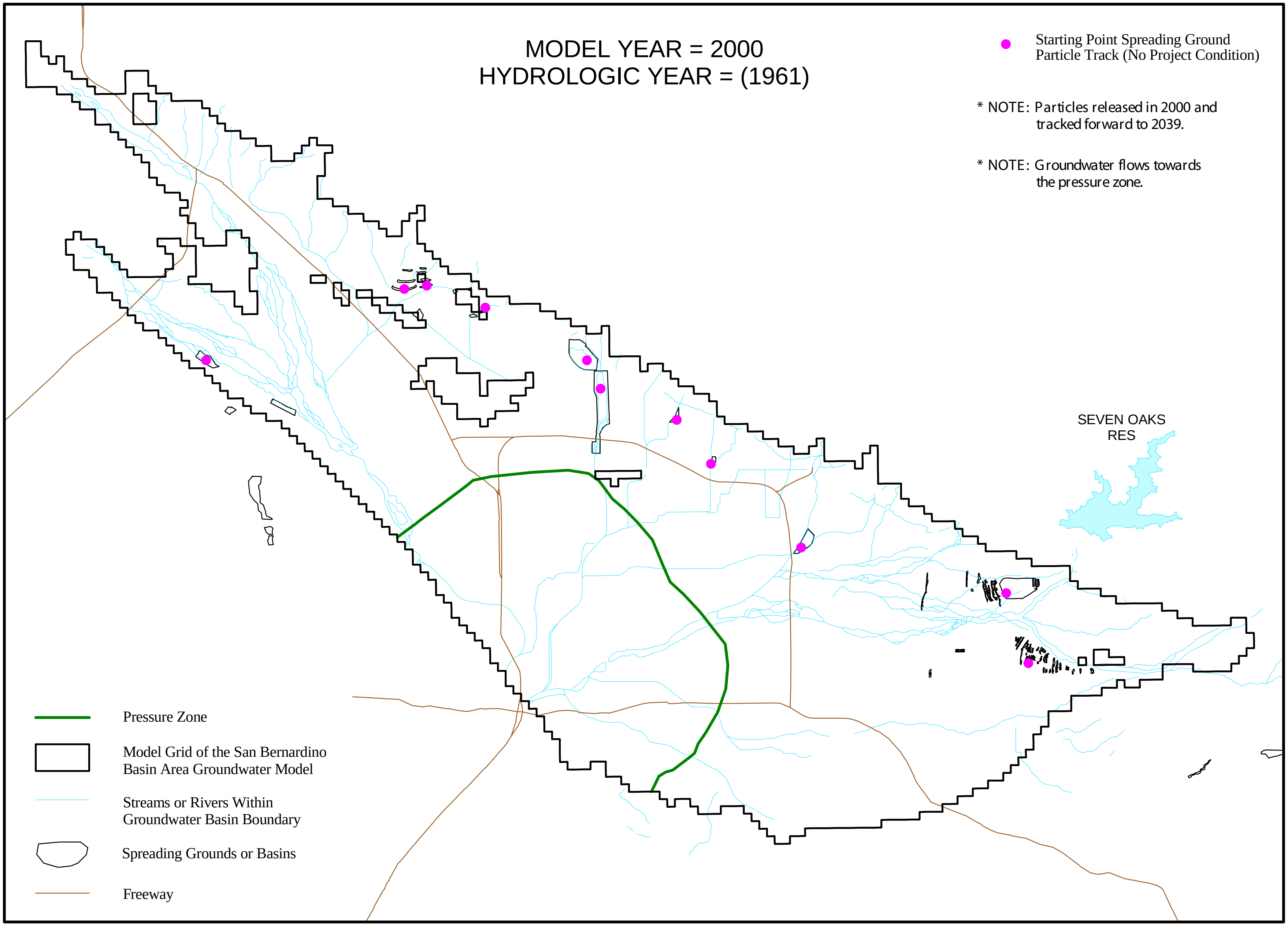
EXPLANATION

●	Starting Point Spreading Ground Particle Track (No Project Condition)
━	Spreading Ground Particle Track (No Project Condition)
─	Spreading Ground Particle Track Scenario D
●	Starting Point Plume Front Particle Track (No Project Condition)
━	Plume Front Particle Track (No Project Condition)
─	Plume Front Particle Track Scenario D
▫	EPA Extraction Wells
▨	2000 Plume Boundary (5 µg/L)
━	Pressure Zone
☐	Model Grid of the San Bernardino Basin Area Groundwater Model
─	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
─	Freeway

* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

Map Projection:
State Plane 1927 (California Zone V)



MODEL YEAR = 2000
HYDROLOGIC YEAR = (1961)

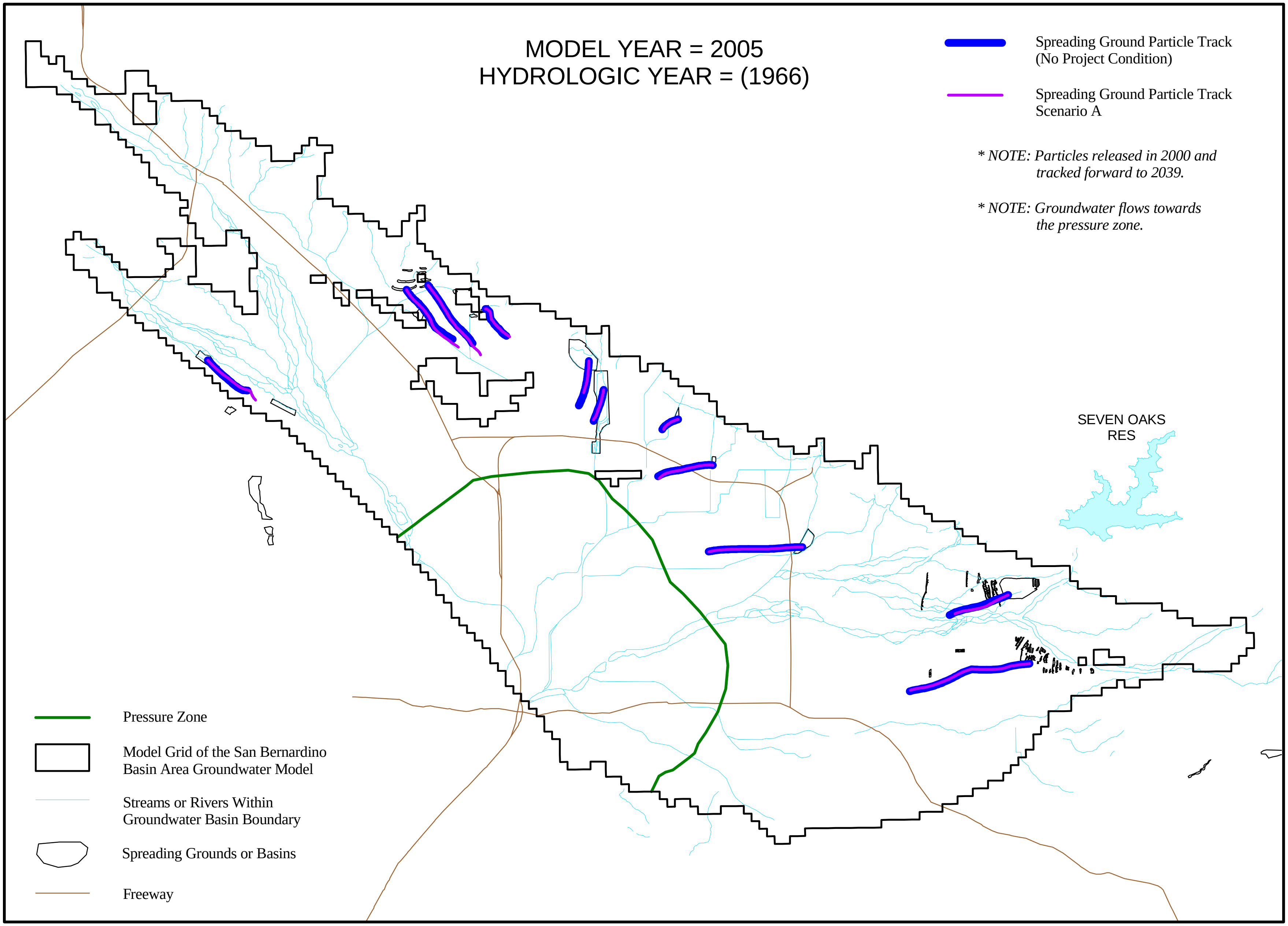
* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2000

Figure B 44(a)



Spreading Ground Particle Track (No Project Condition)

Spreading Ground Particle Track Scenario A

* *NOTE: Particles released in 2000 and tracked forward to 2039.*

* *NOTE: Groundwater flows towards the pressure zone.*

Pressure Zone

Model Grid of the San Bernardino Basin Area Groundwater Model

Streams or Rivers Within Groundwater Basin Boundary

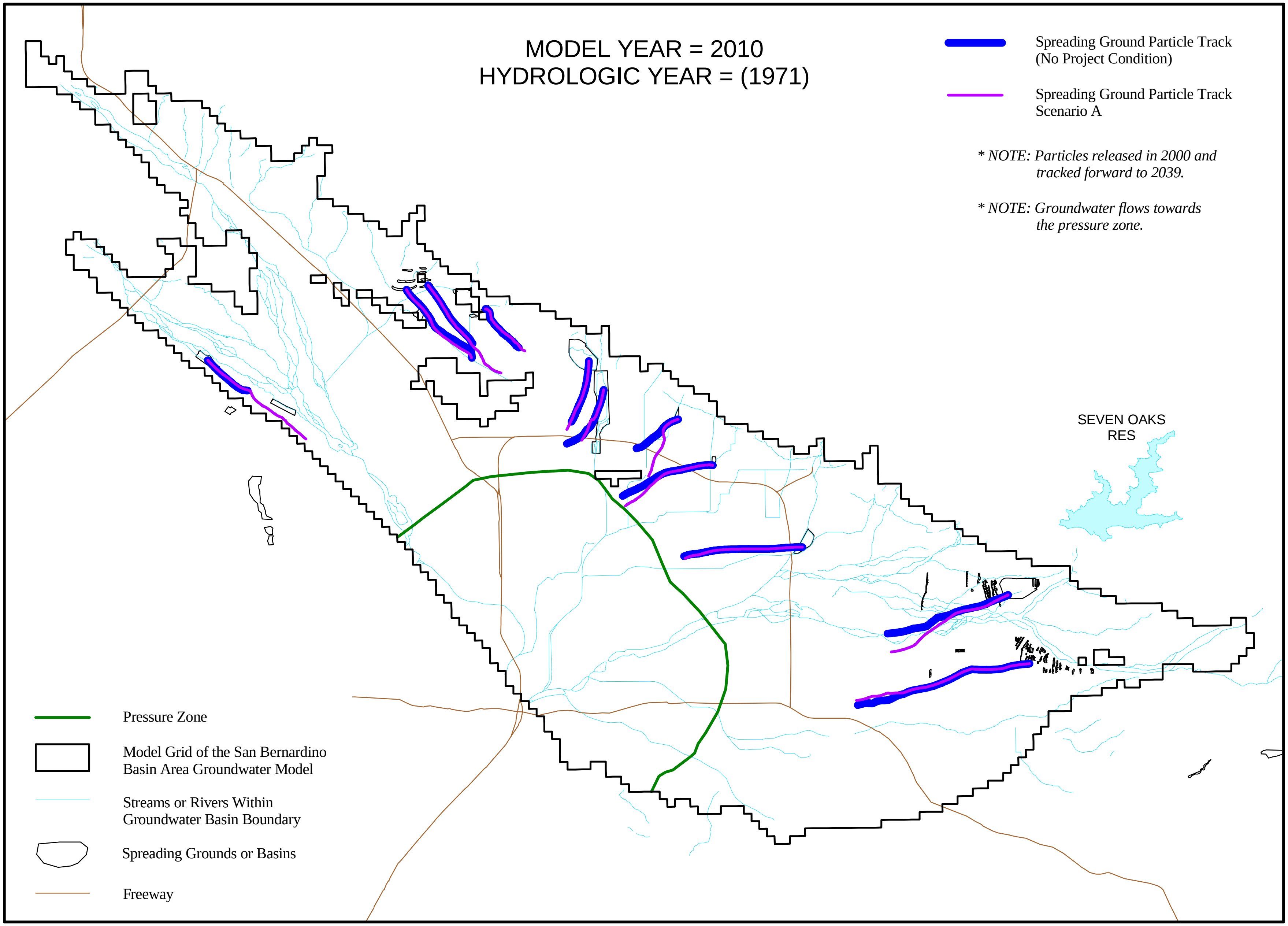
Spreading Grounds or Basins

Freeway

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2005

Figure B 44(b)



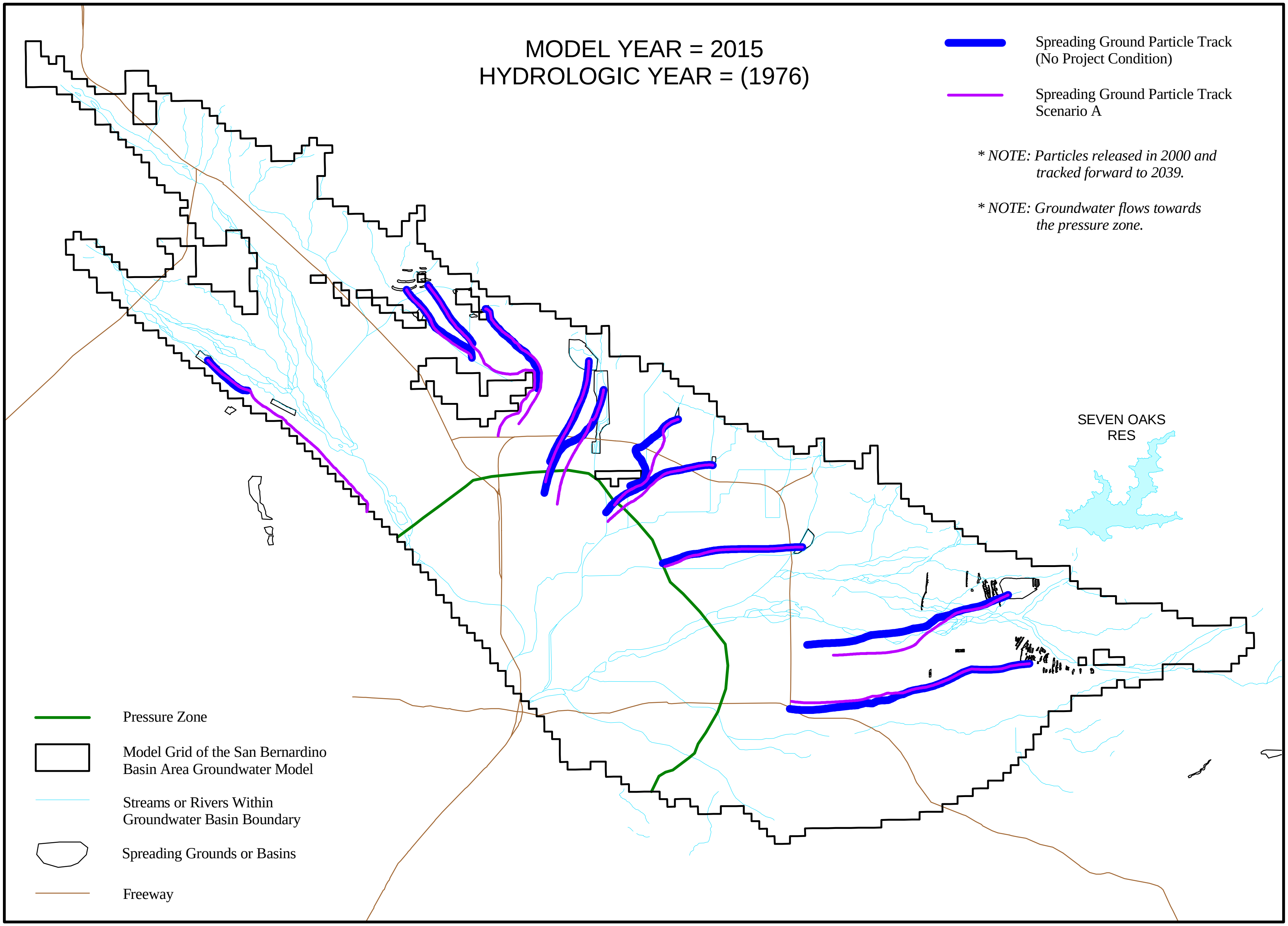
* NOTE: *Particles released in 2000 and tracked forward to 2039.*

* NOTE: *Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2010

Figure B 44(c)



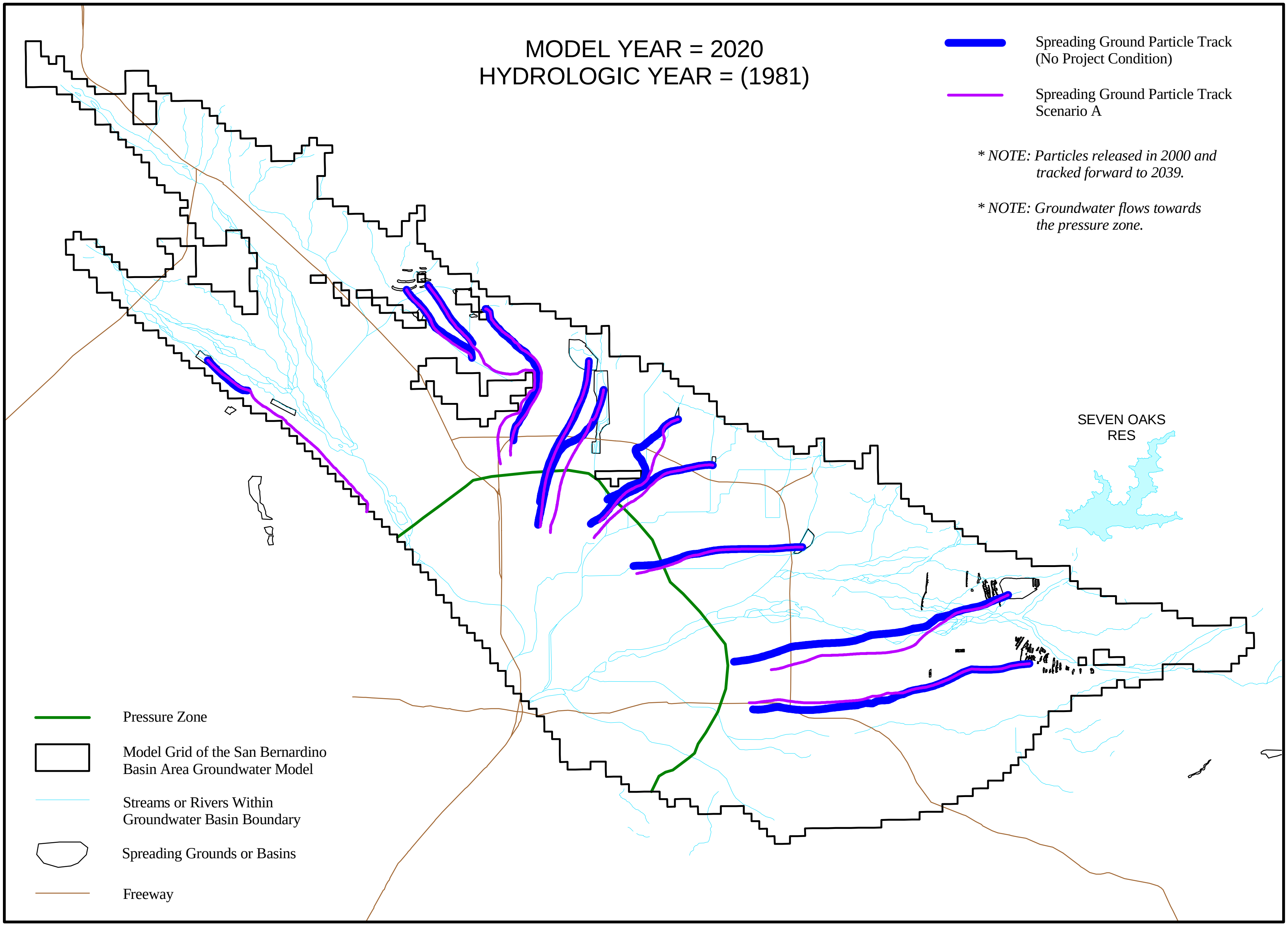
** NOTE: Particles released in 2000 and tracked forward to 2039.*

** NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2015

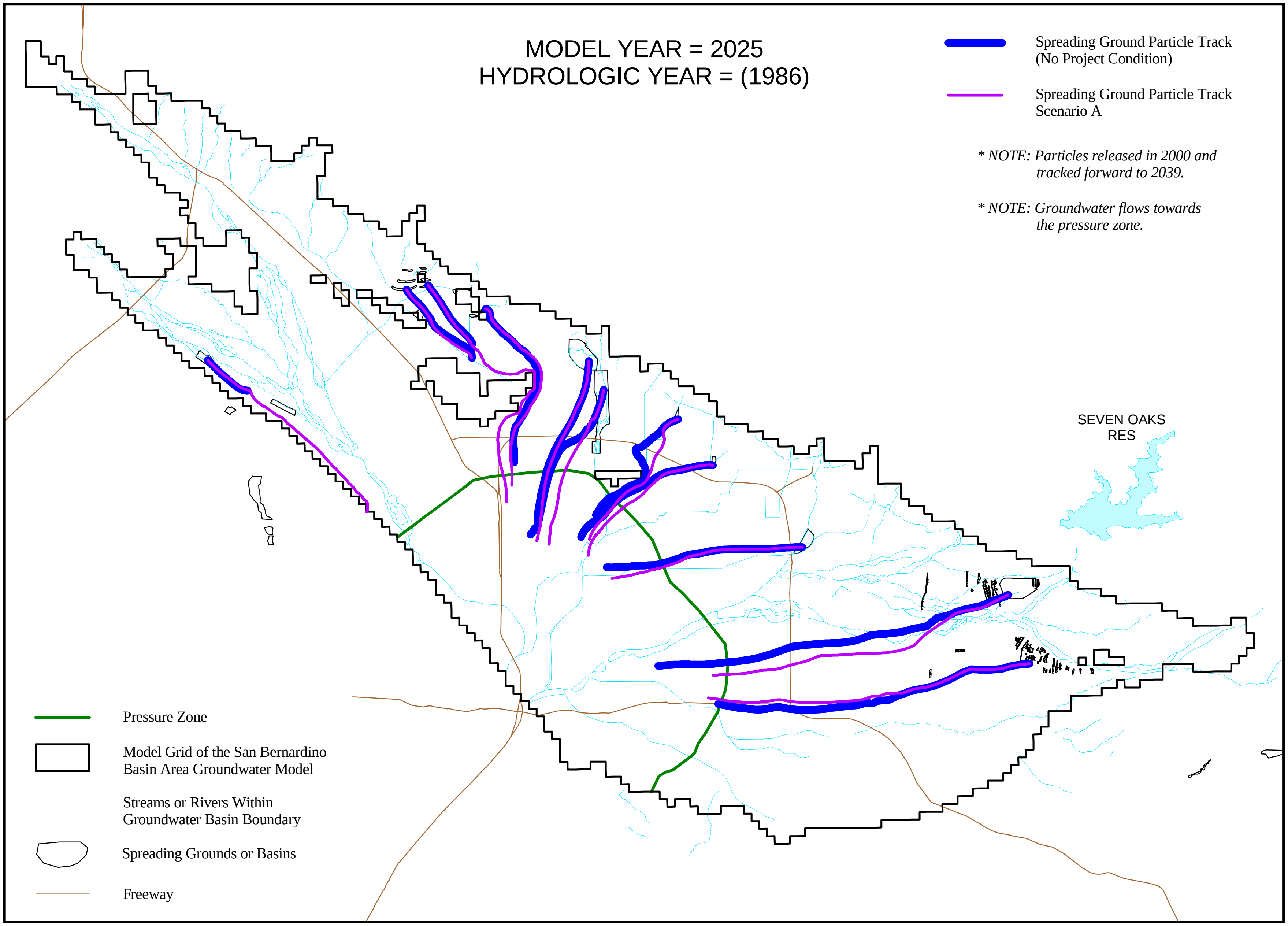
Figure B 44(d)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2020

Figure B 44(e)



MODEL YEAR = 2025
HYDROLOGIC YEAR = (1986)

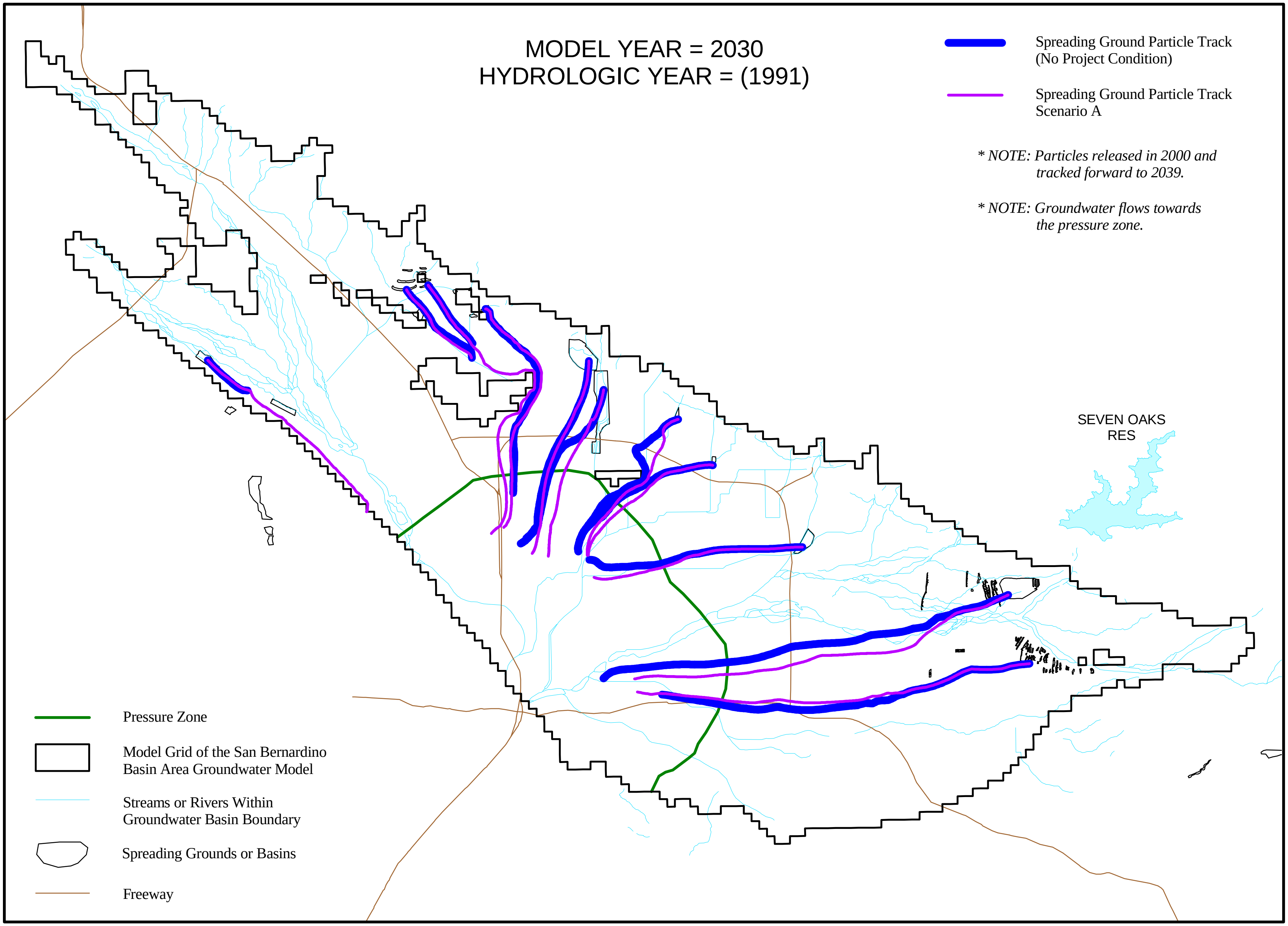
* NOTE: *Particles released in 2000 and tracked forward to 2039.*

* NOTE: *Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2025

Figure B 44(f)



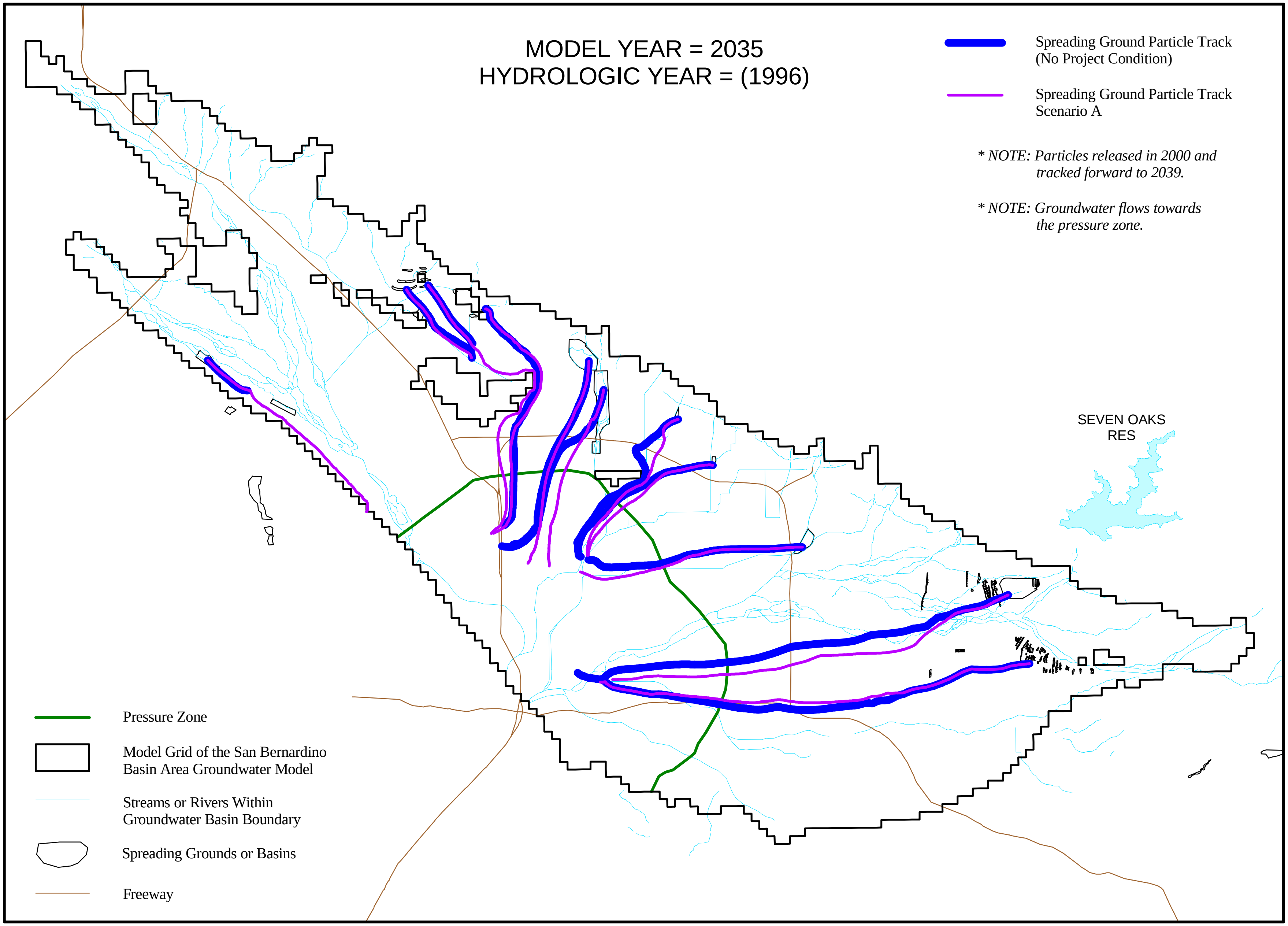
* *NOTE: Particles released in 2000 and tracked forward to 2039.*

* *NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2030

Figure B 44(g)



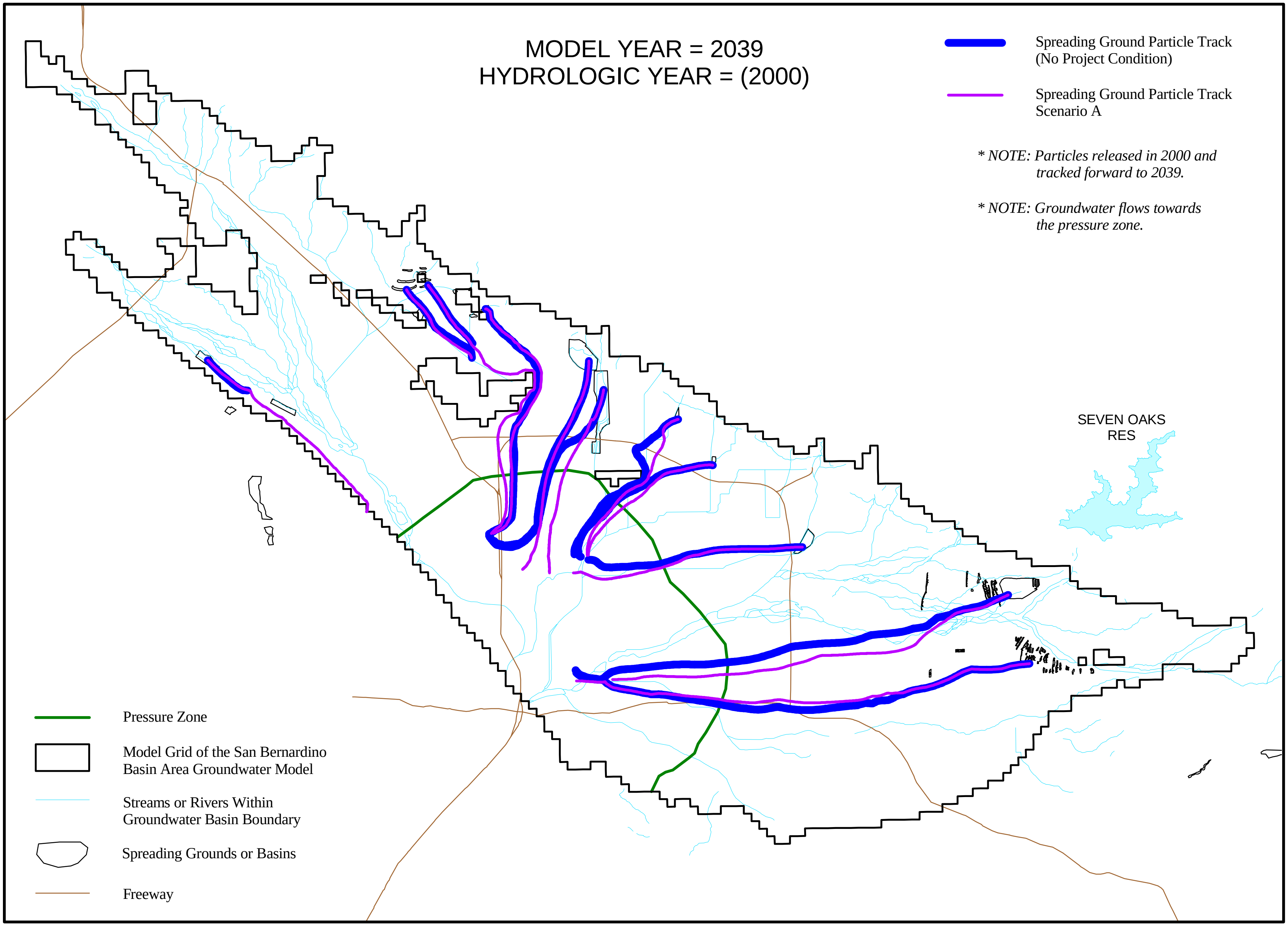
* *NOTE: Particles released in 2000 and tracked forward to 2039.*

* *NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2035**

Figure B 44(h)



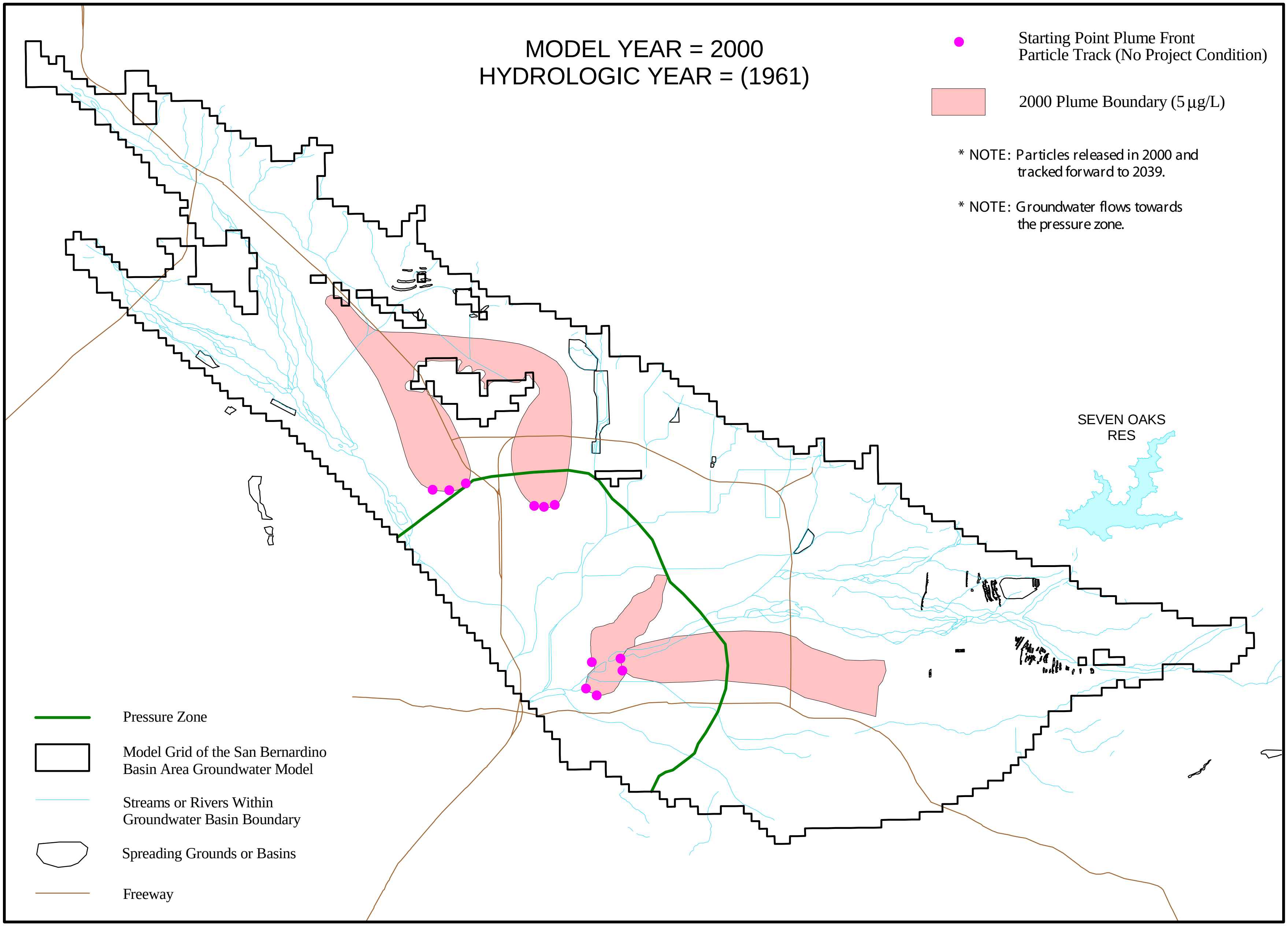
** NOTE: Particles released in 2000 and tracked forward to 2039.*

** NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2039**

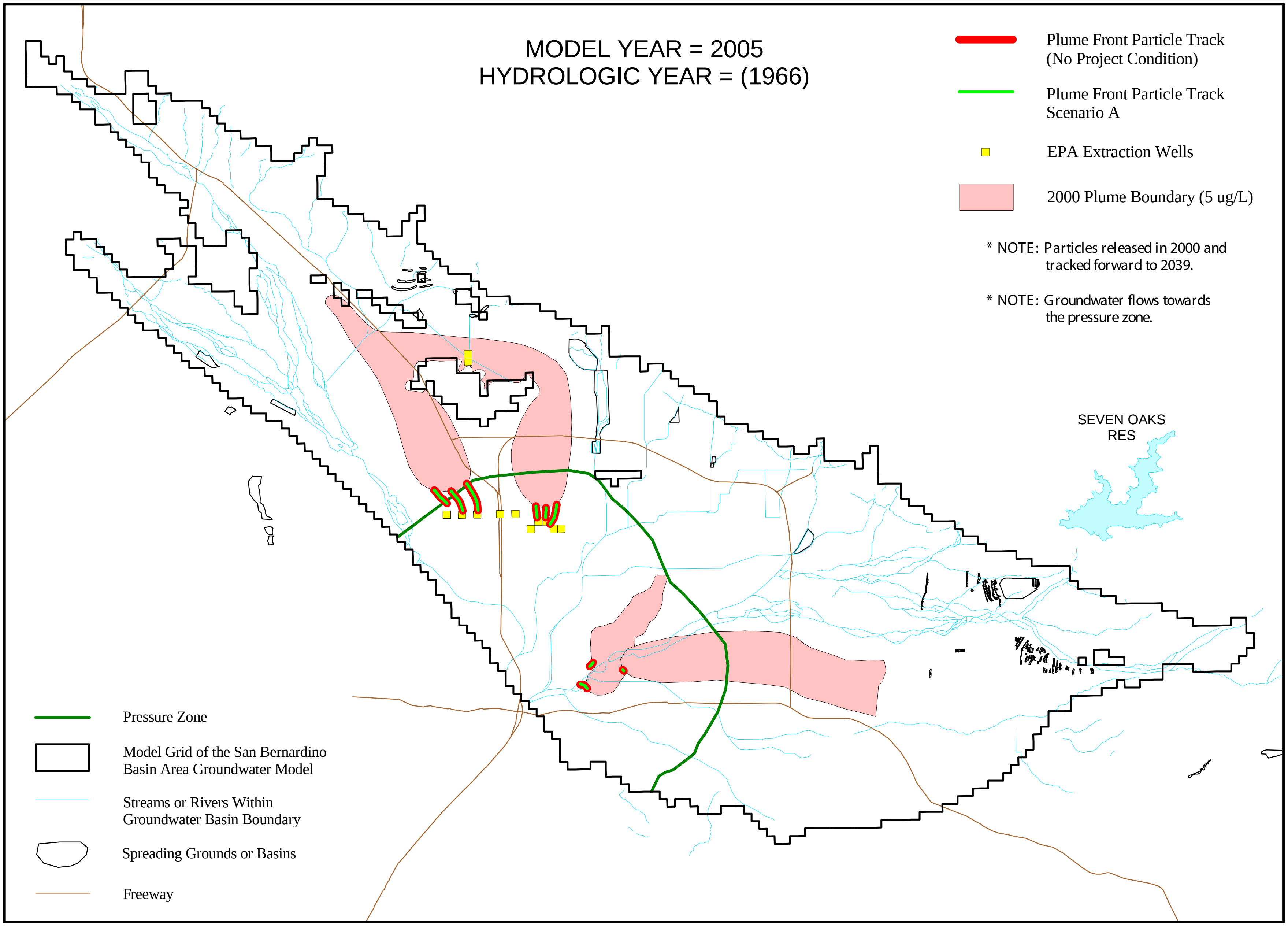
Figure B 44(i)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS, NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2000

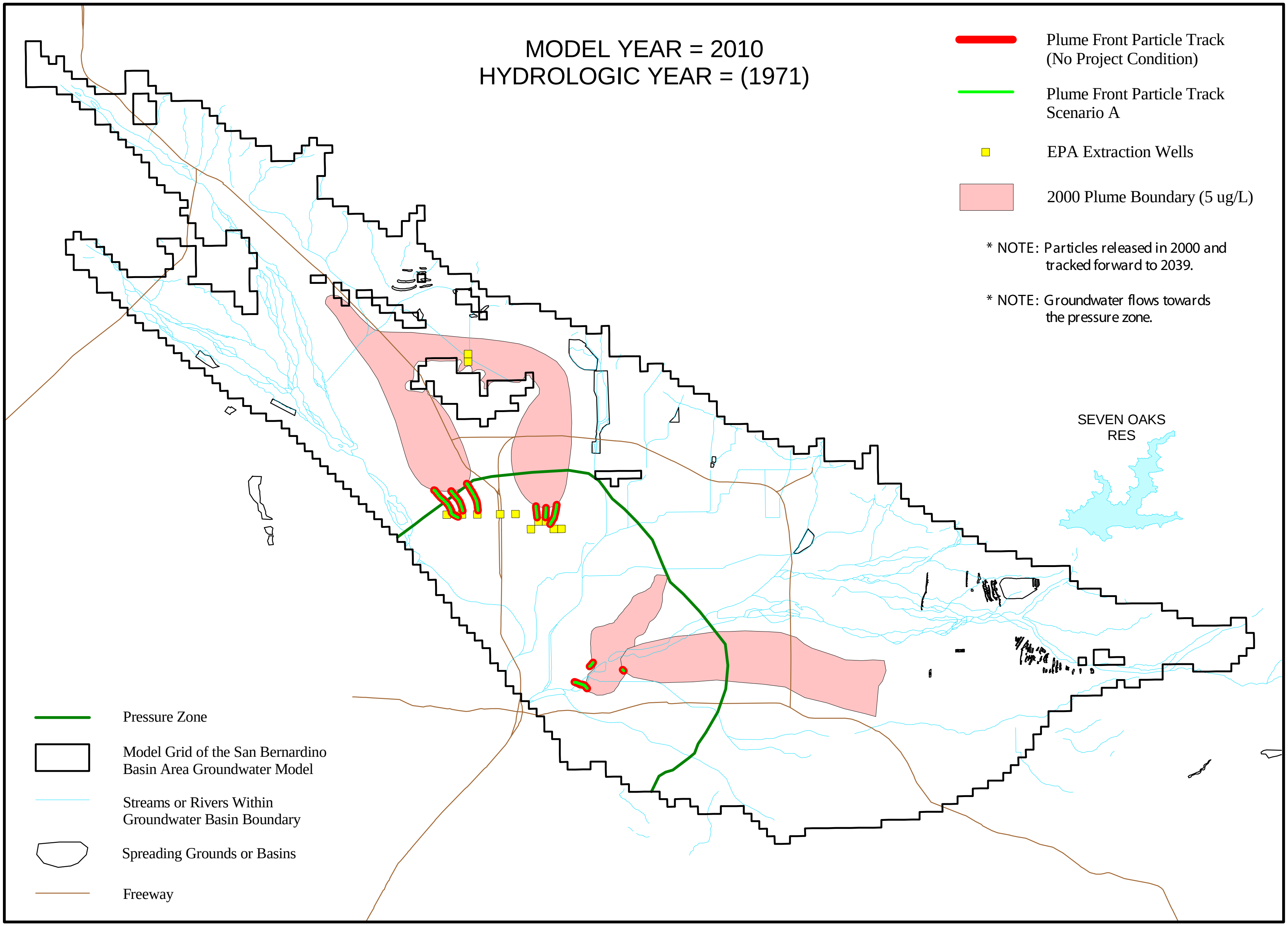
Figure B 45(a)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2005

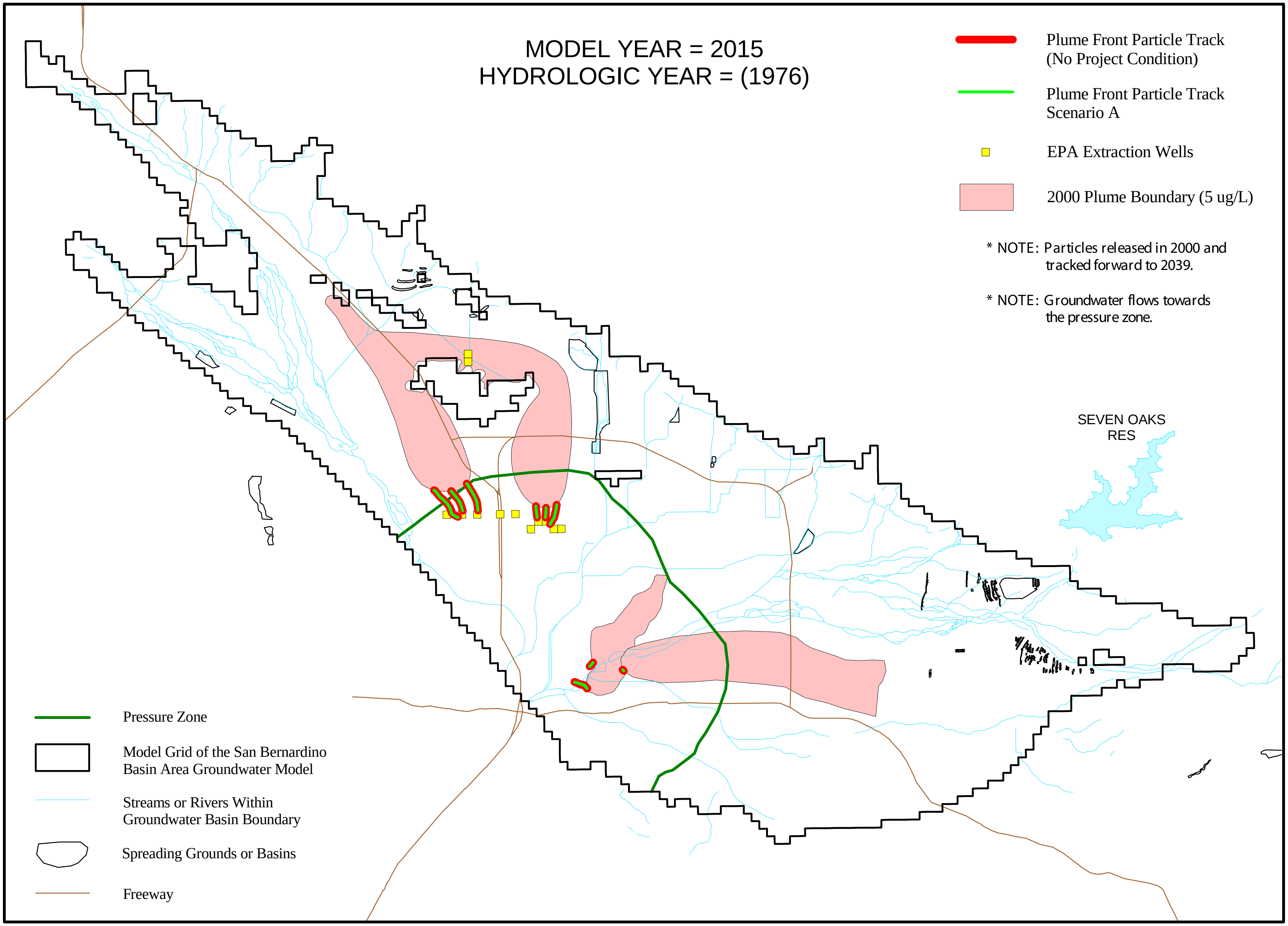
Figure B 45(b)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2010

Figure B 45(c)



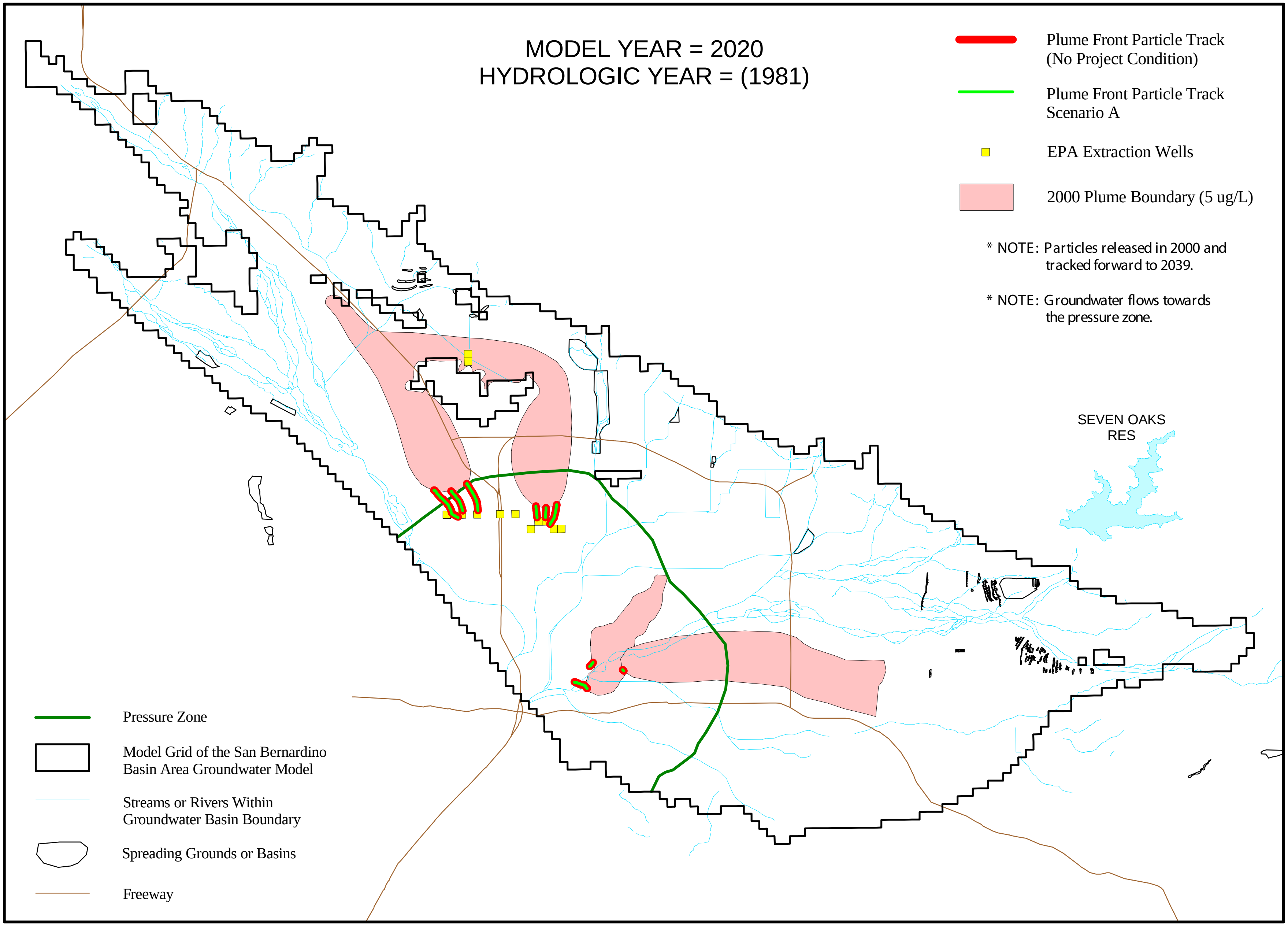
* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2015

Figure B 45(d)



* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

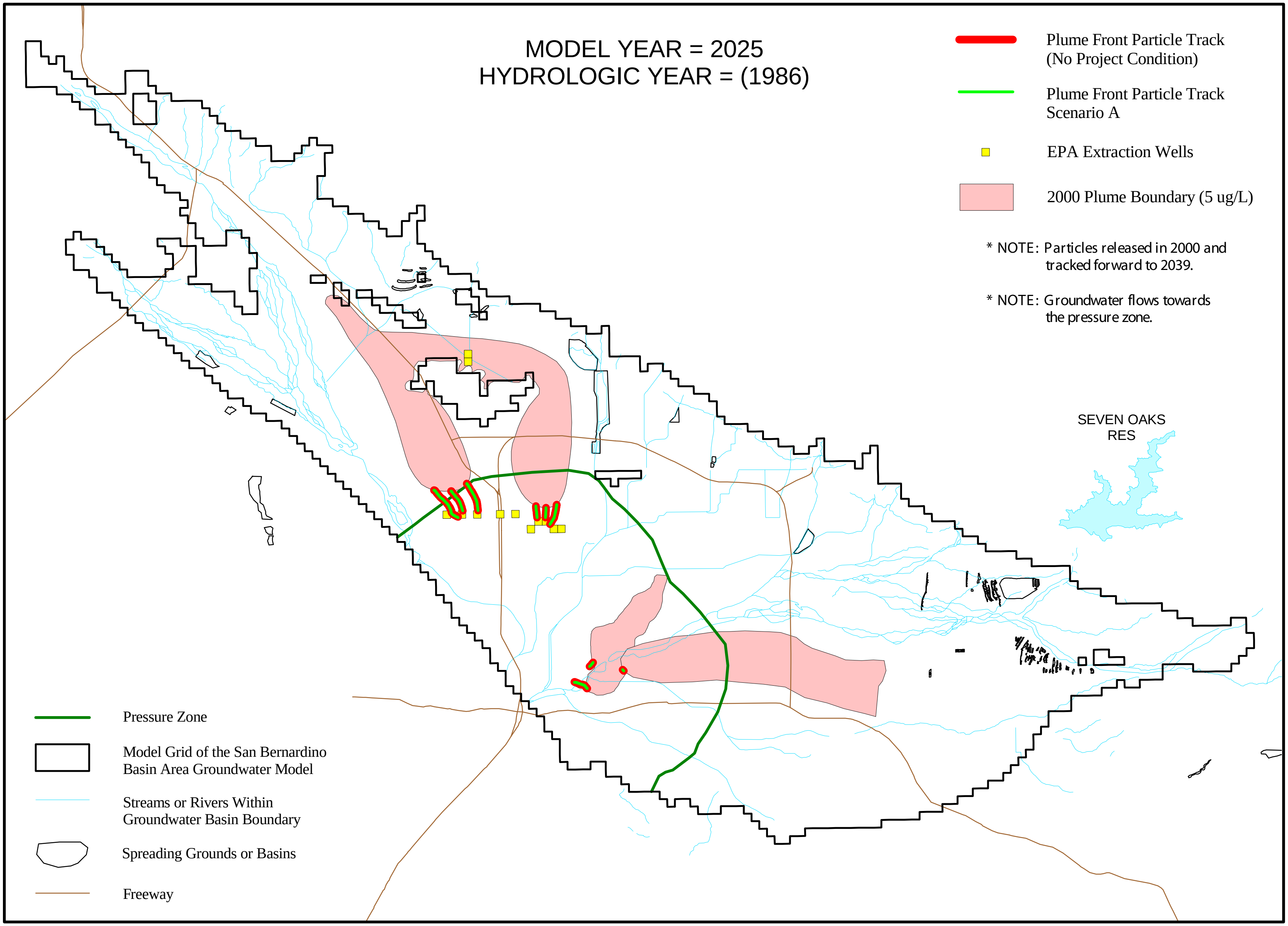
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2020

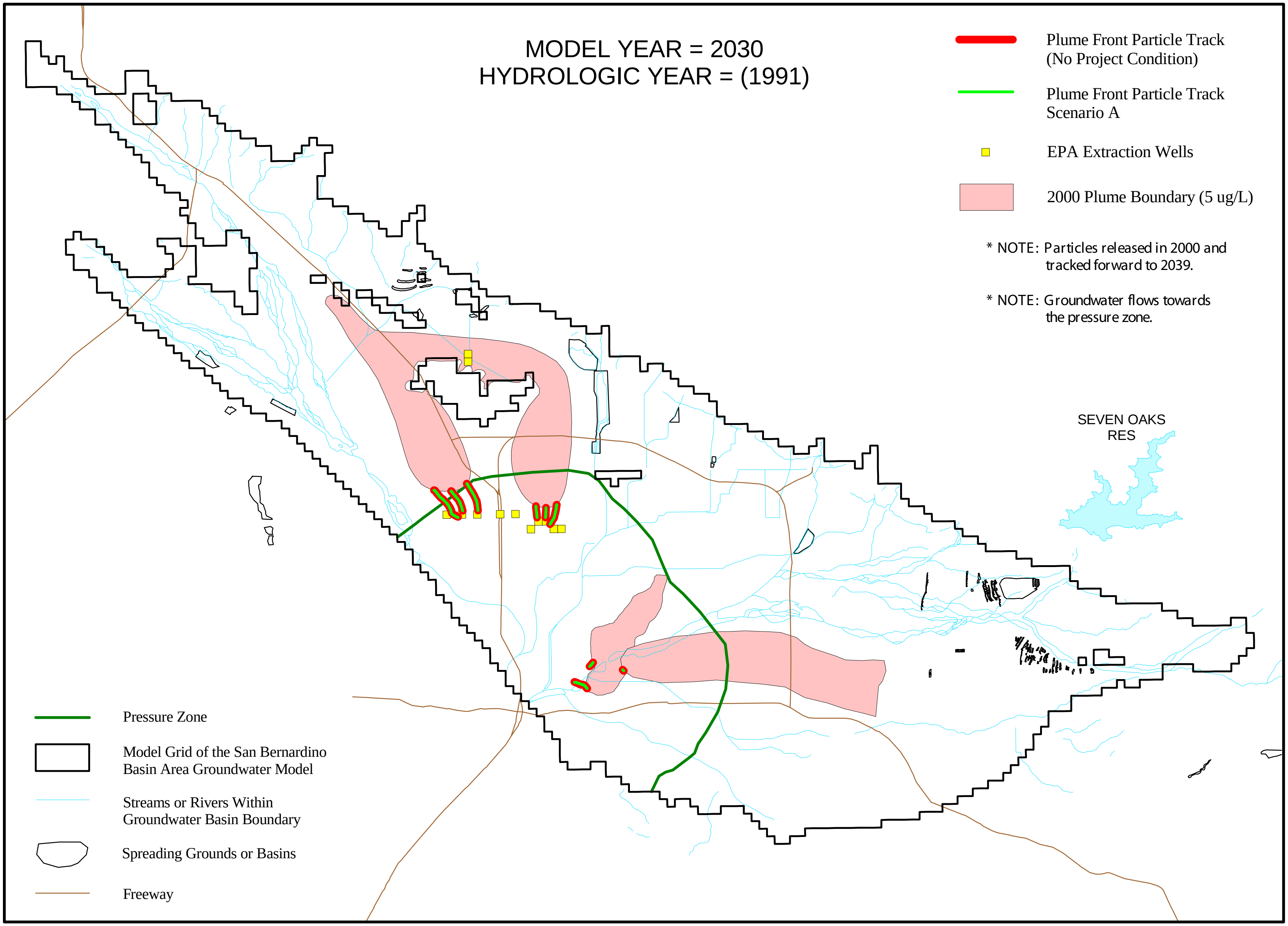
Figure B 45(e)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2025

Figure B 45(f)



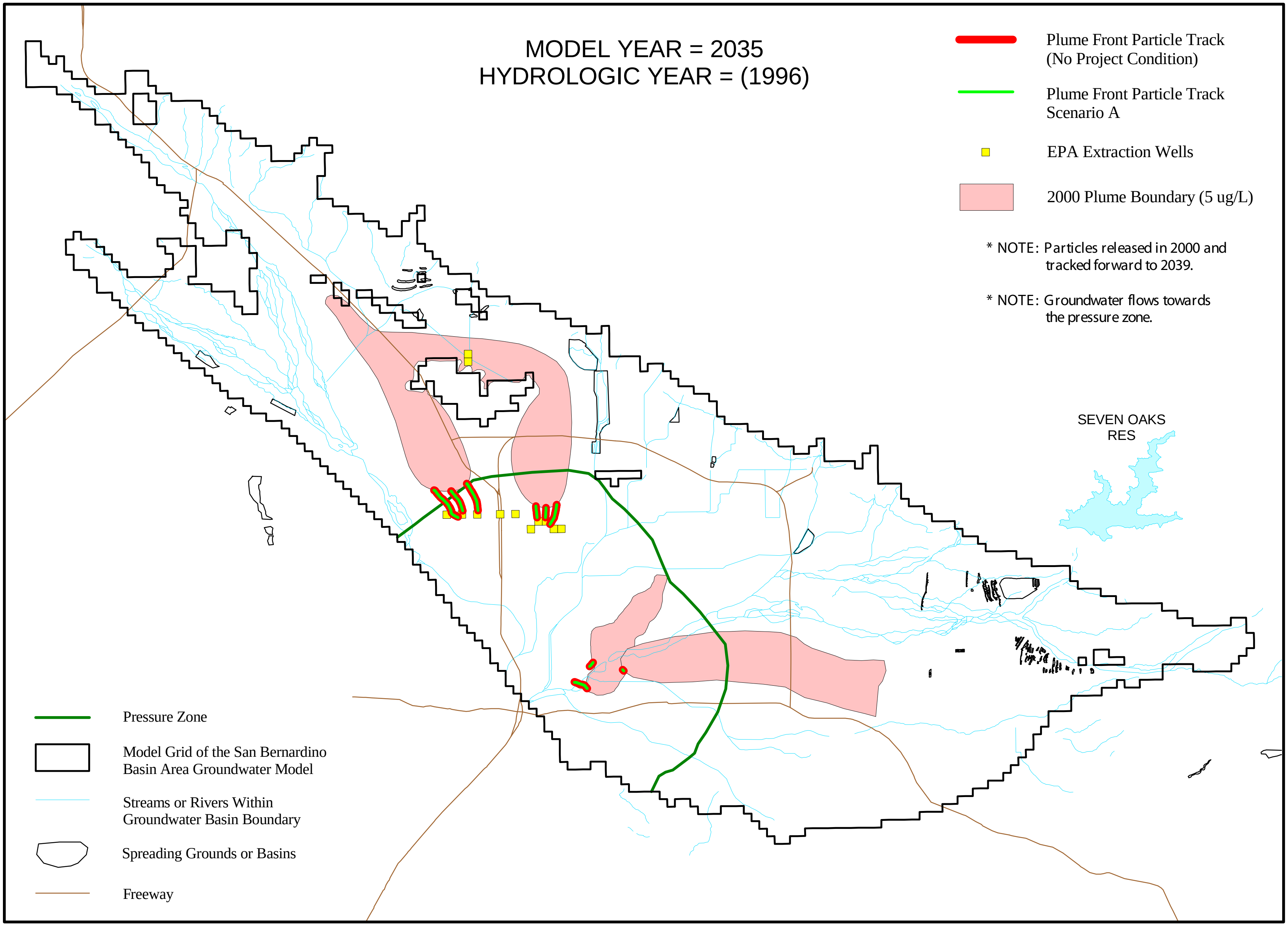
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2030

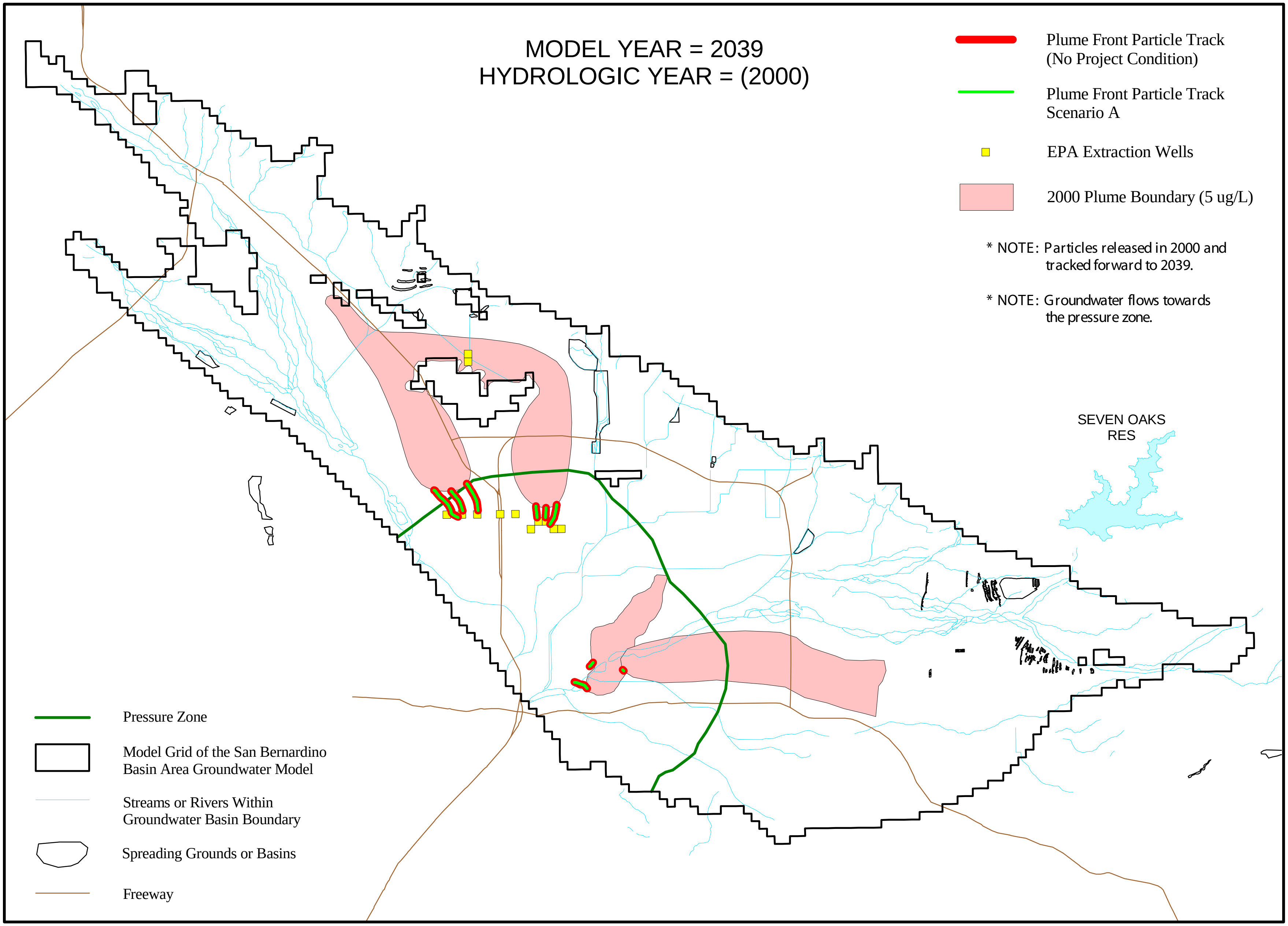
Figure B 45(g)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2035

Figure B 45(h)

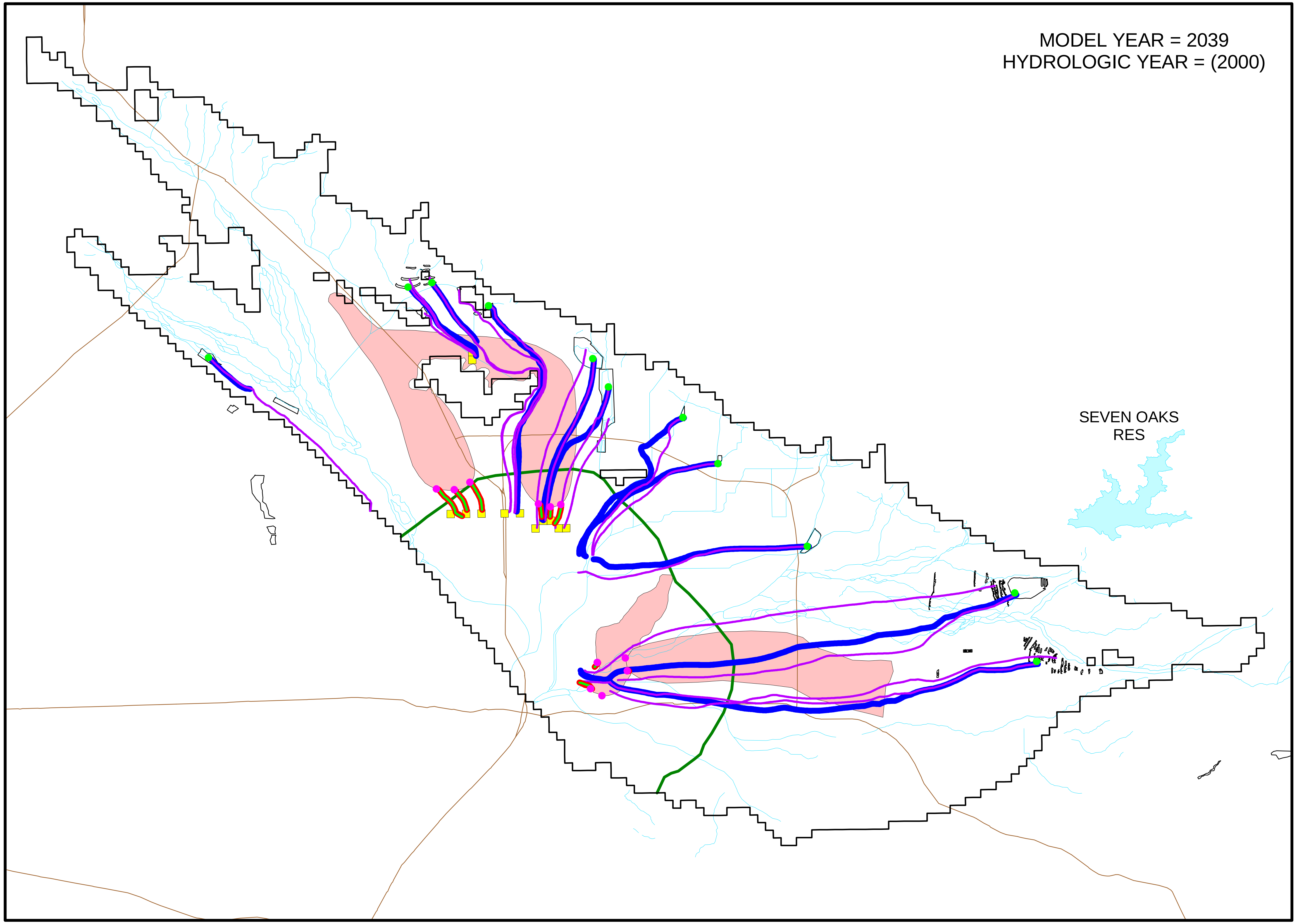


SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO A, MODEL YEAR 2039

Figure B 45(i)

PARTICLE TRACKS FROM BOTH SPREADING GROUNDS AND PLUME FRONTS, YEAR 2039, NO PROJECT CONDITION VERSUS SCENARIO A



EXPLANATION

- ● Starting Point Spreading Ground Particle Track (No Project Condition)
- ▬ Spreading Ground Particle Track (No Project Condition)
- — Spreading Ground Particle Track Scenario A
- ● Starting Point Plume Front Particle Track (No Project Condition)
- ▬ Plume Front Particle Track (No Project Condition)
- — Plume Front Particle Track Scenario A
- ■ EPA Extraction Wells
- ▨ 2000 Plume Boundary (5 µg/L)
- — Pressure Zone
- ☐ Model Grid of the San Bernardino Basin Area Groundwater Model
- — Streams or Rivers Within Groundwater Basin Boundary
- ⬭ Spreading Grounds or Basins
- — Freeway

* NOTE: Particles released in 2000 and tracked forward to 2039.

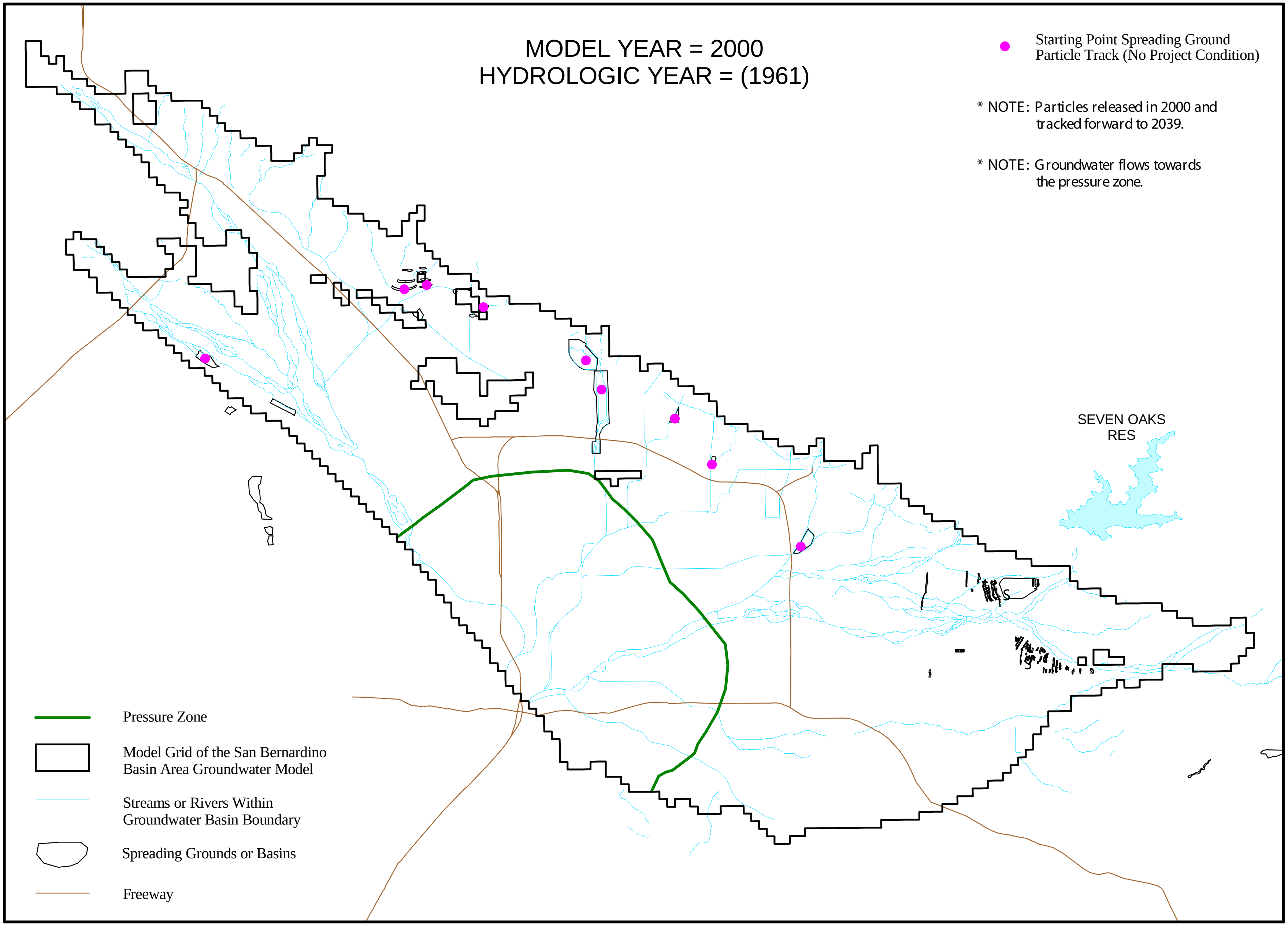
* NOTE: Groundwater flows towards the pressure zone.

NORTH

0 2 4 Miles

Map Projection:
State Plane 1927 (California Zone V)

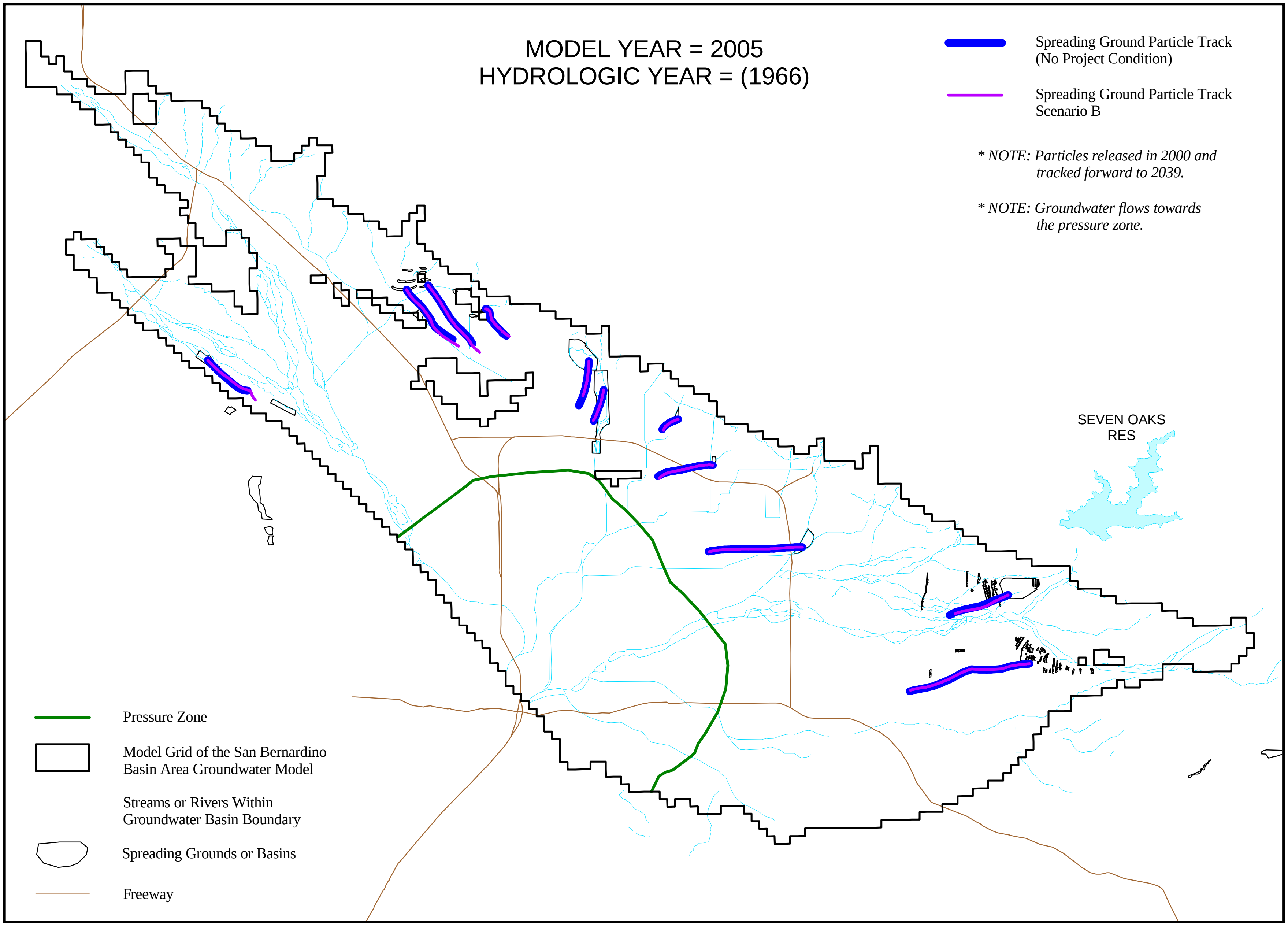
Figure B 46



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2000

Figure B 47(a)



MODEL YEAR = 2005
HYDROLOGIC YEAR = (1966)

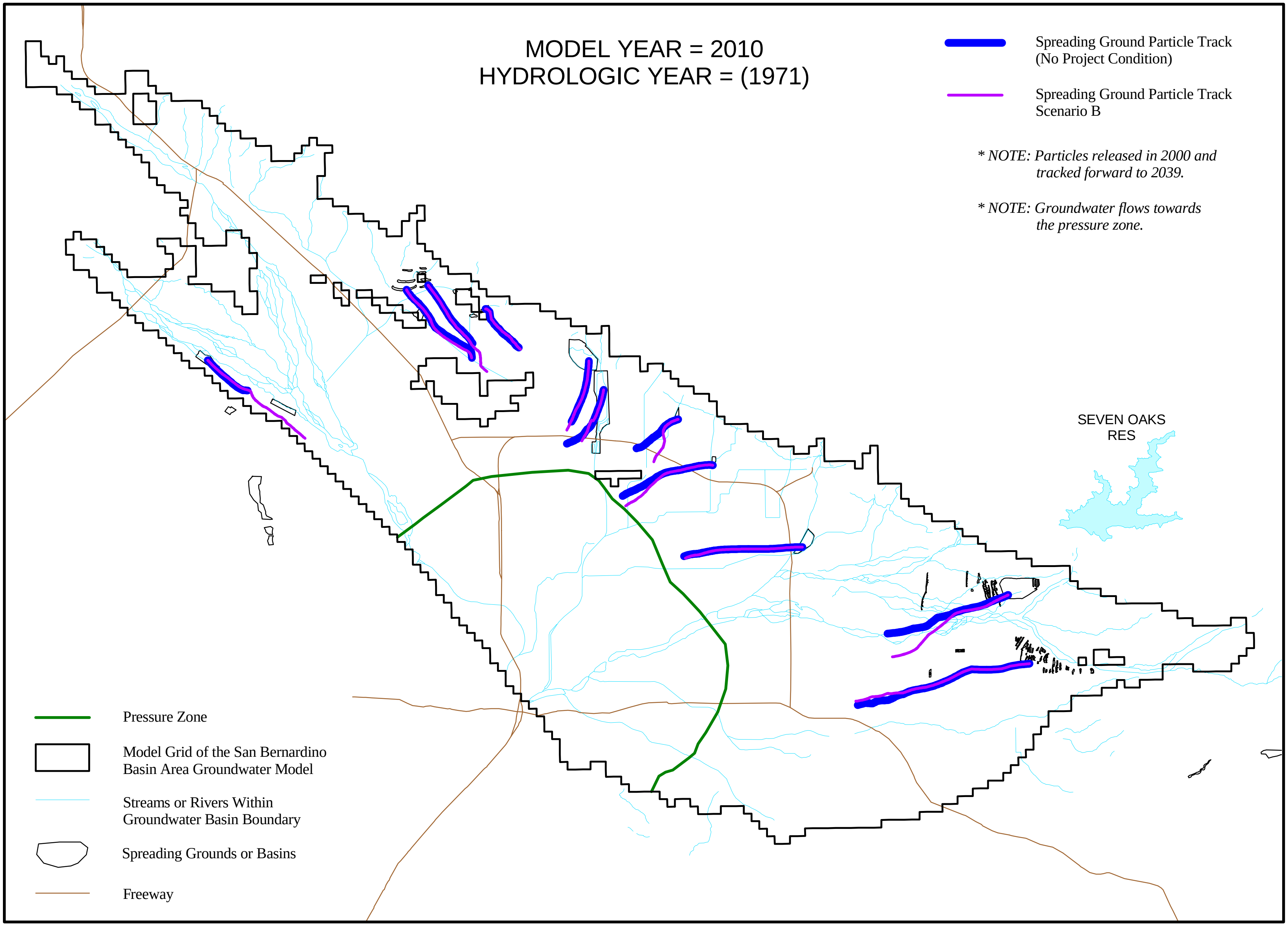
* *NOTE: Particles released in 2000 and tracked forward to 2039.*

* *NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2005

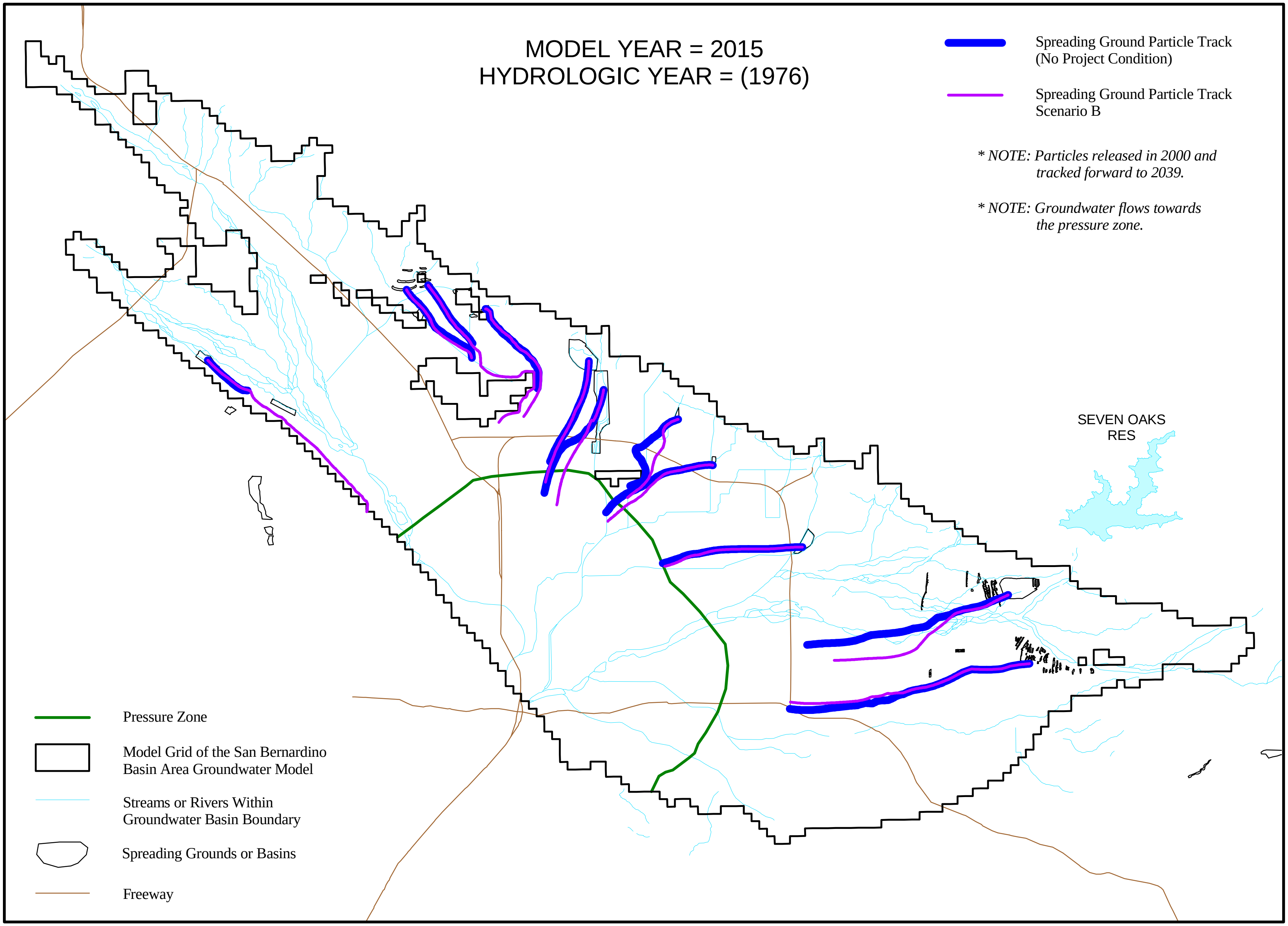
Figure B 47(b)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

**PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2010**

Figure B 47(c)



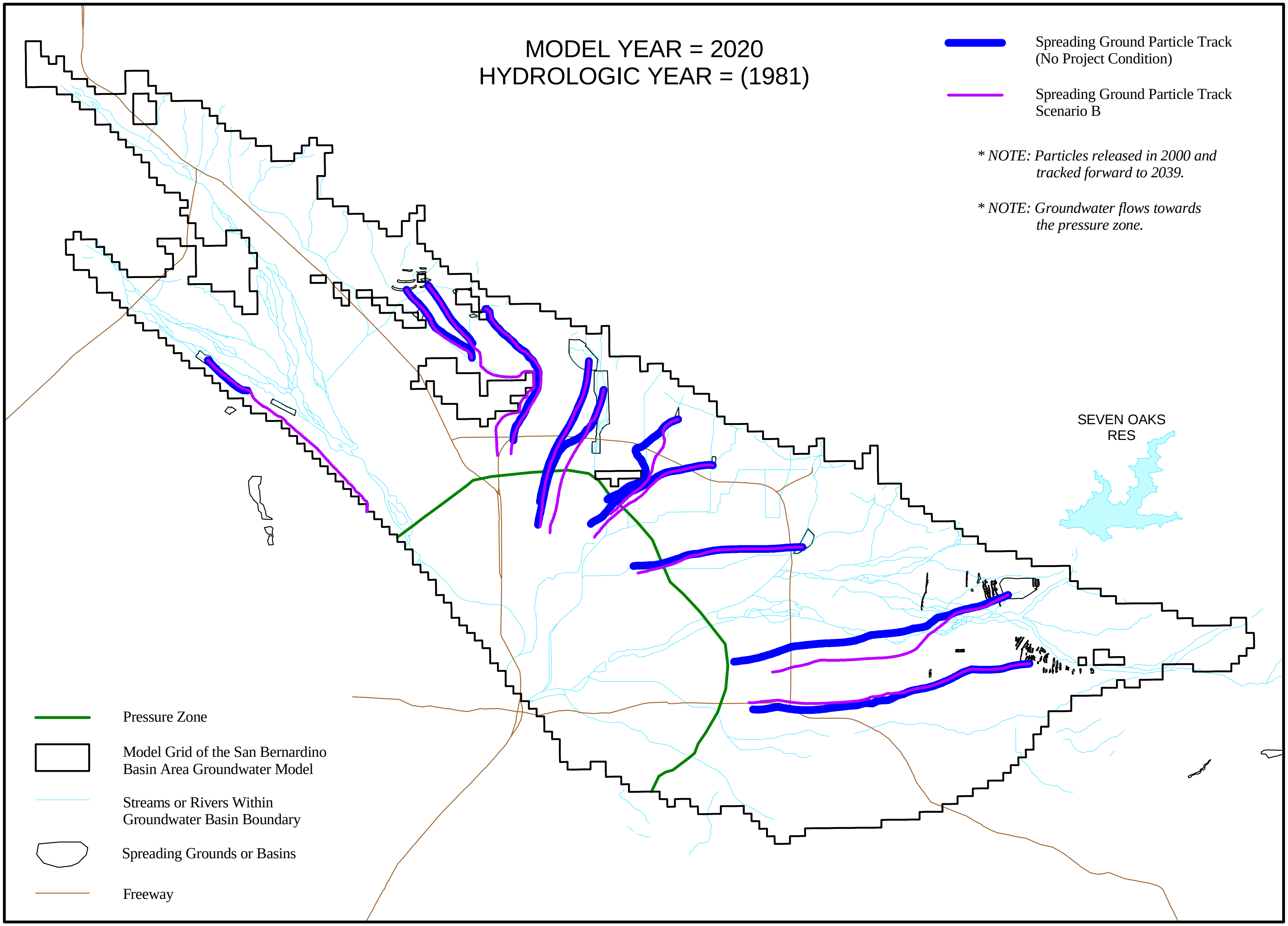
** NOTE: Particles released in 2000 and tracked forward to 2039.*

** NOTE: Groundwater flows towards the pressure zone.*

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2015

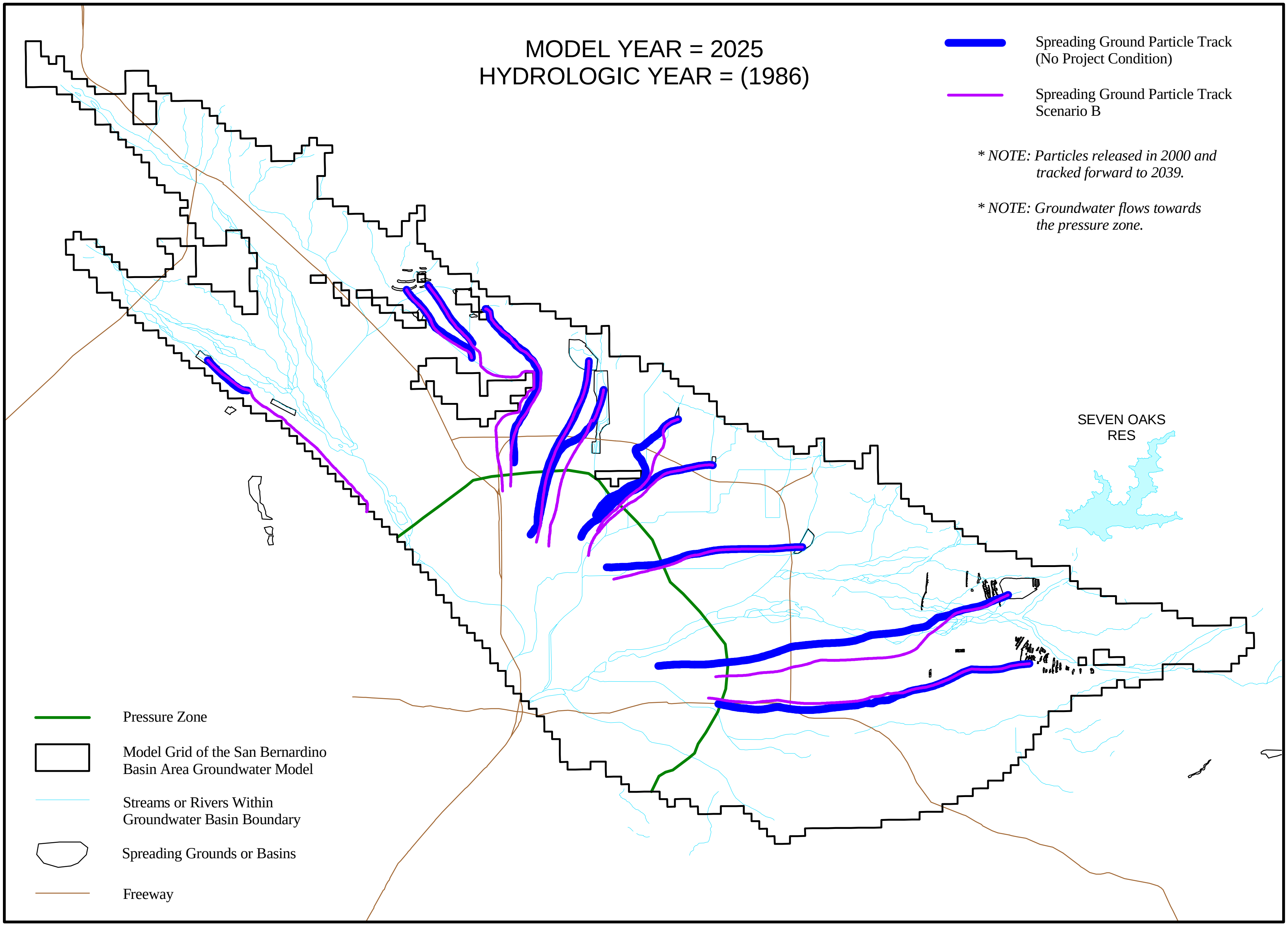
Figure B 47(d)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2020

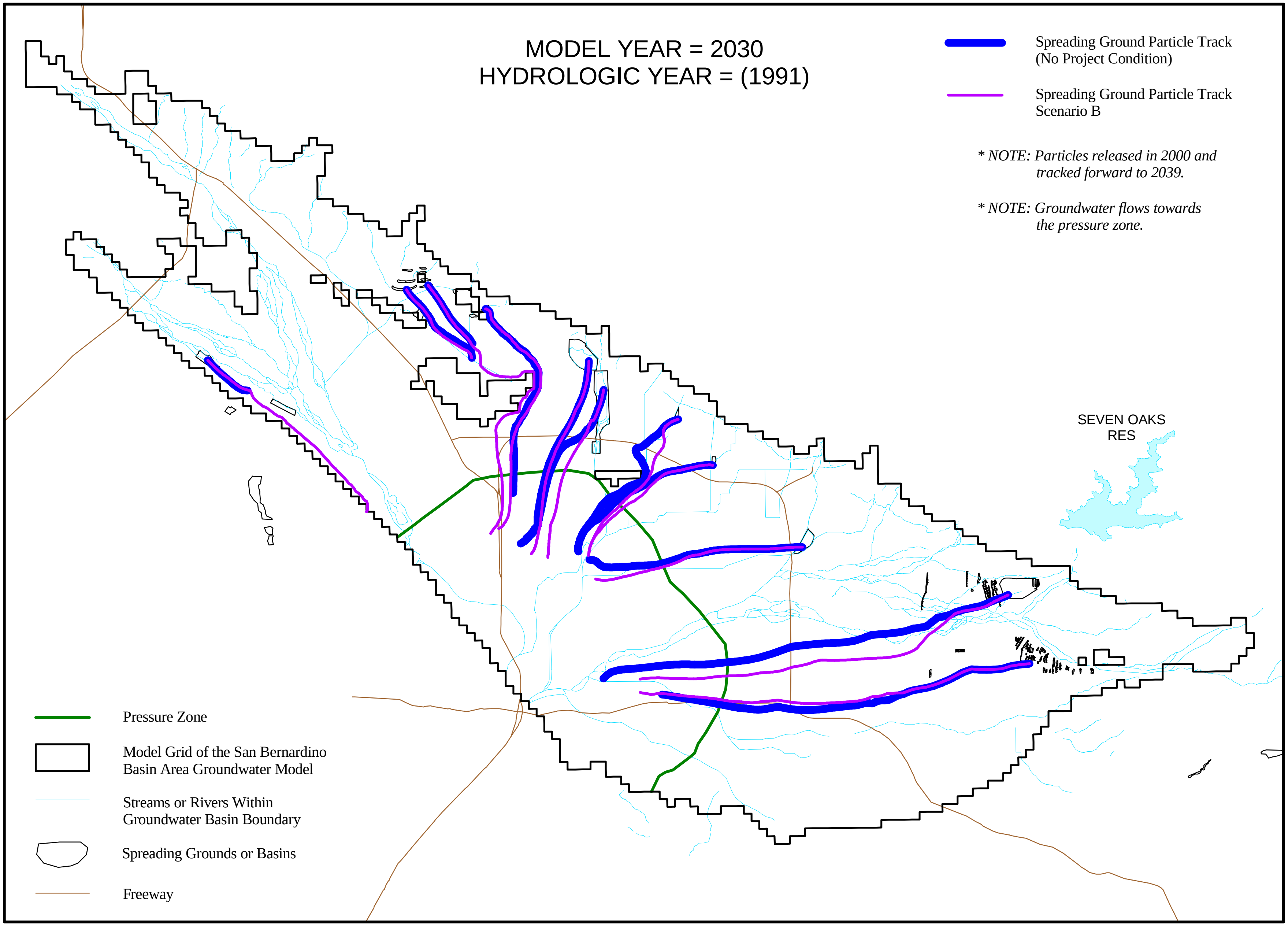
Figure B 47(e)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2025

Figure B 47(f)


MODEL YEAR = 2030
HYDROLOGIC YEAR = (1991)

* NOTE: *Particles released in 2000 and tracked forward to 2039.*

* NOTE: *Groundwater flows towards the pressure zone.*

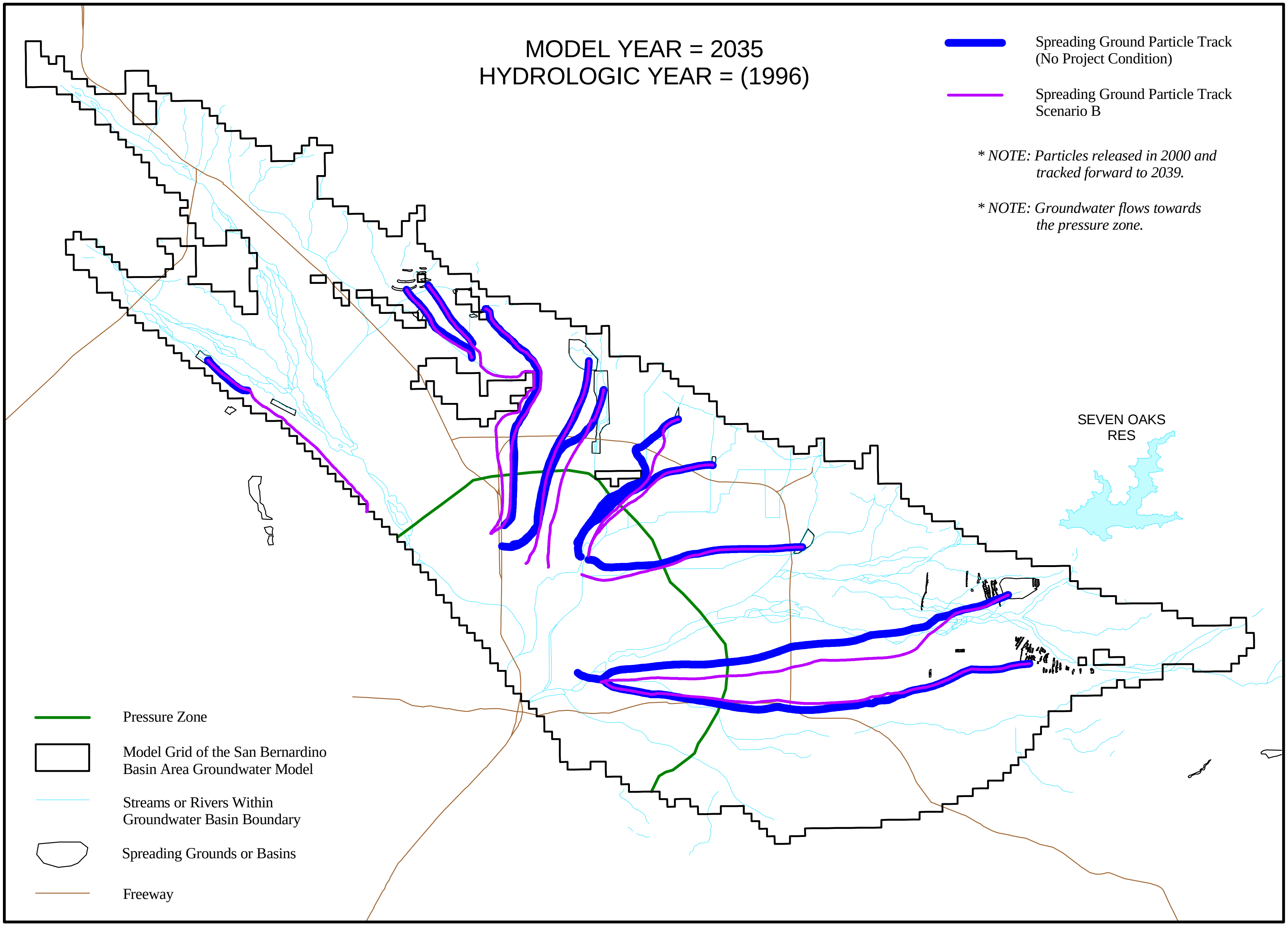
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2030

Figure B 47(g)



* *NOTE: Particles released in 2000 and tracked forward to 2039.*

* *NOTE: Groundwater flows towards the pressure zone.*

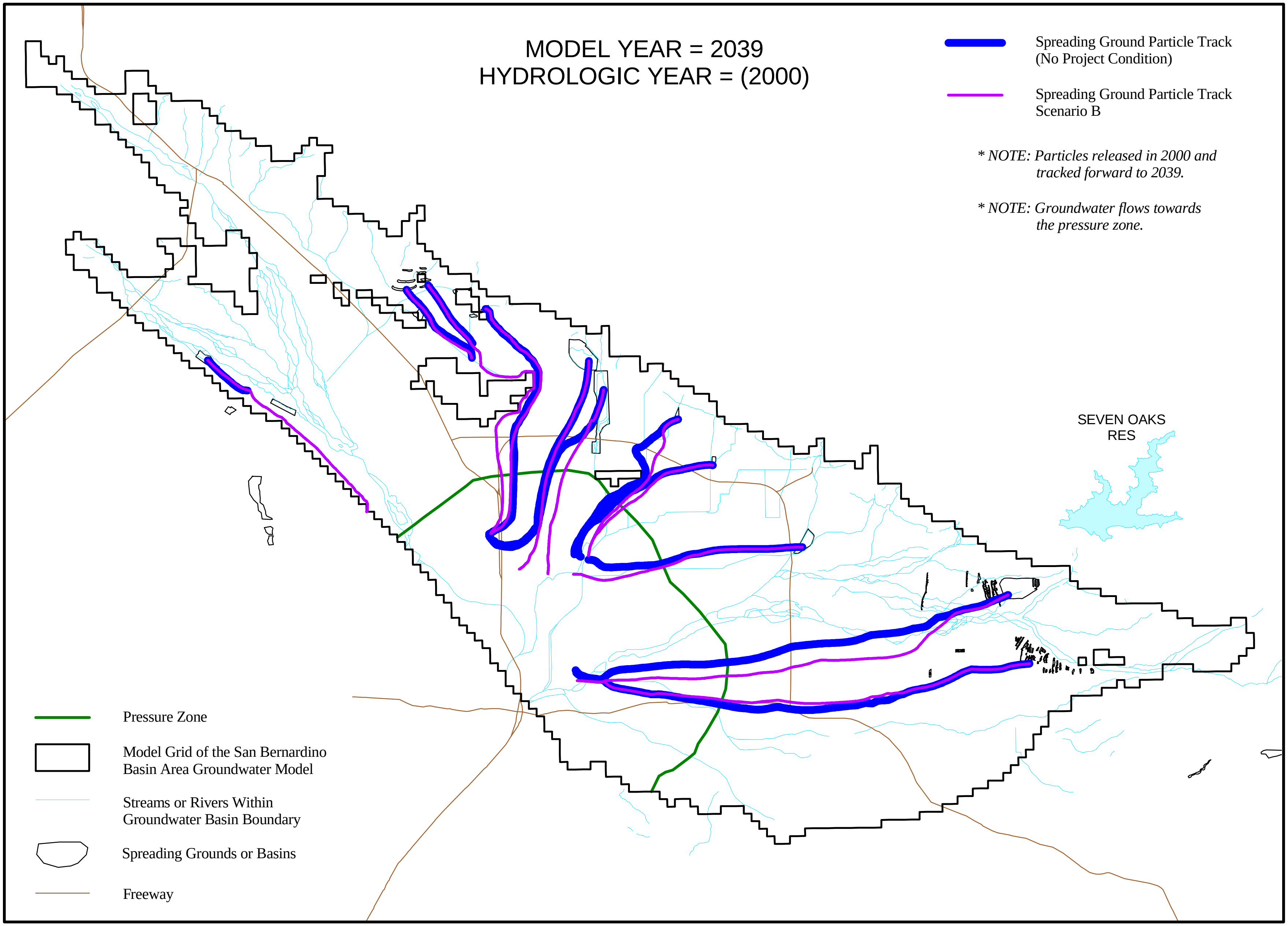
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2035

Figure B 47(h)



MODEL YEAR = 2039
HYDROLOGIC YEAR = (2000)

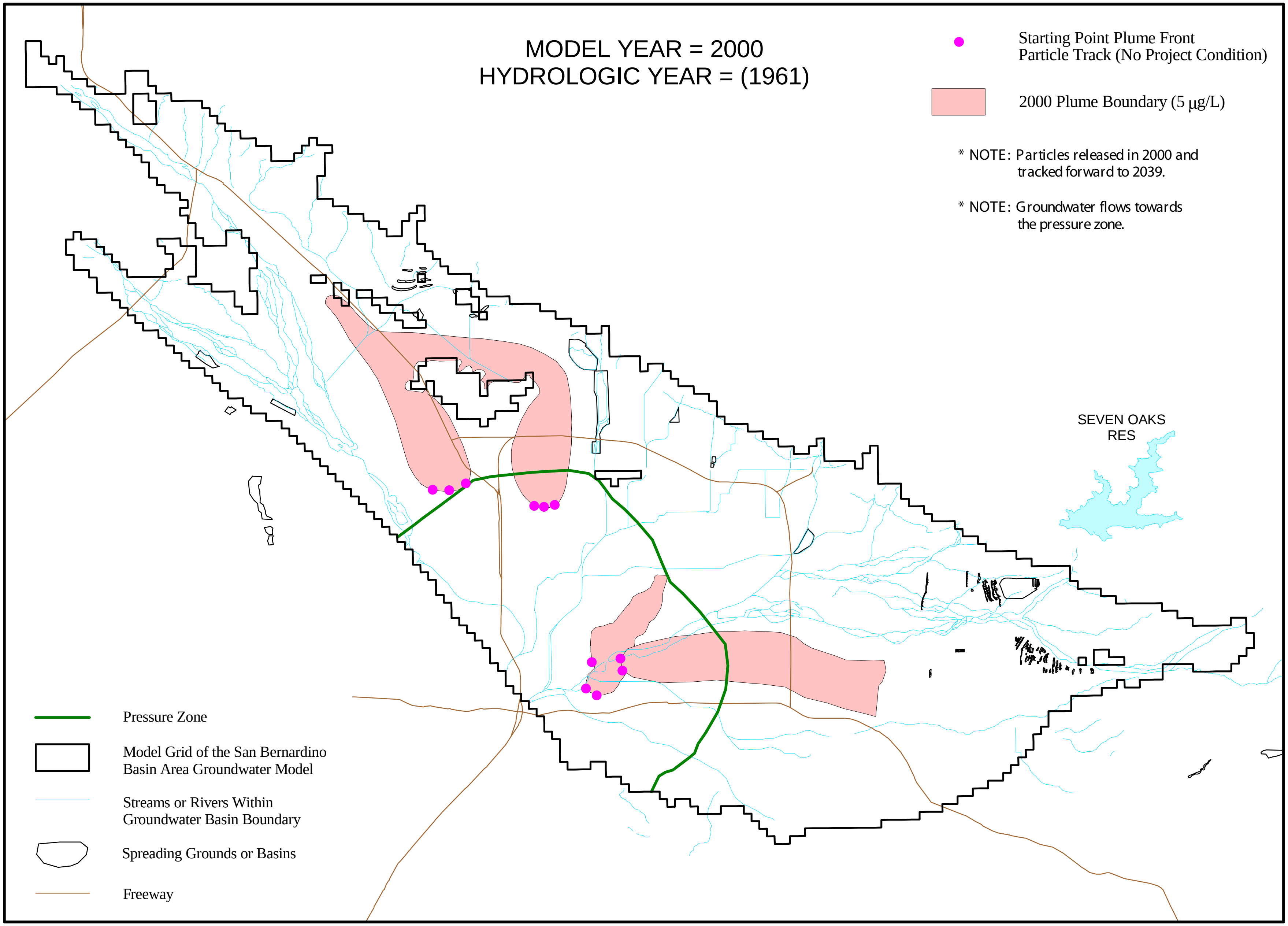
* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM SPREADING GROUNDS, NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2039

Figure B 47(i)


MODEL YEAR = 2000
HYDROLOGIC YEAR = (1961)

* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

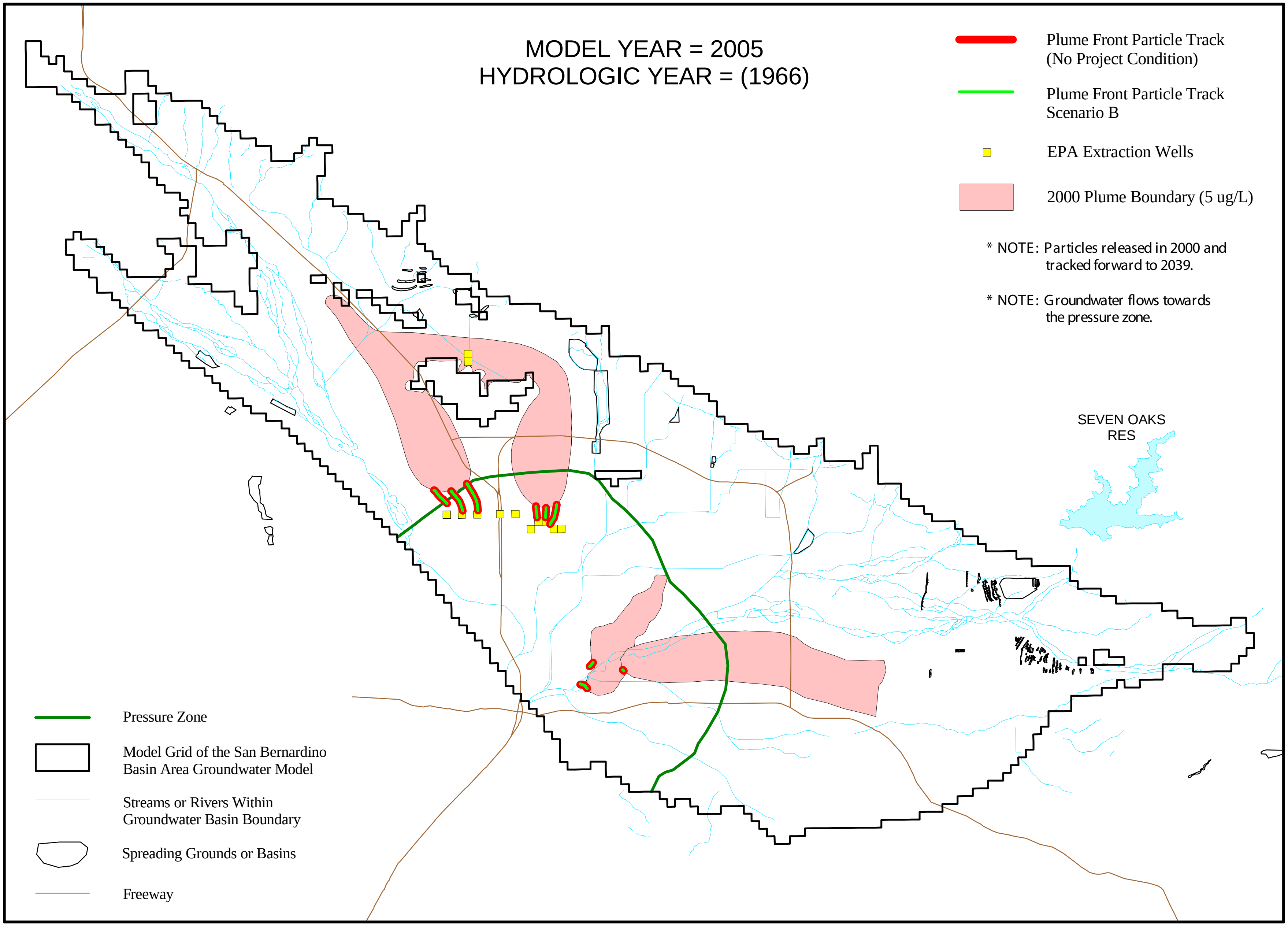
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2000

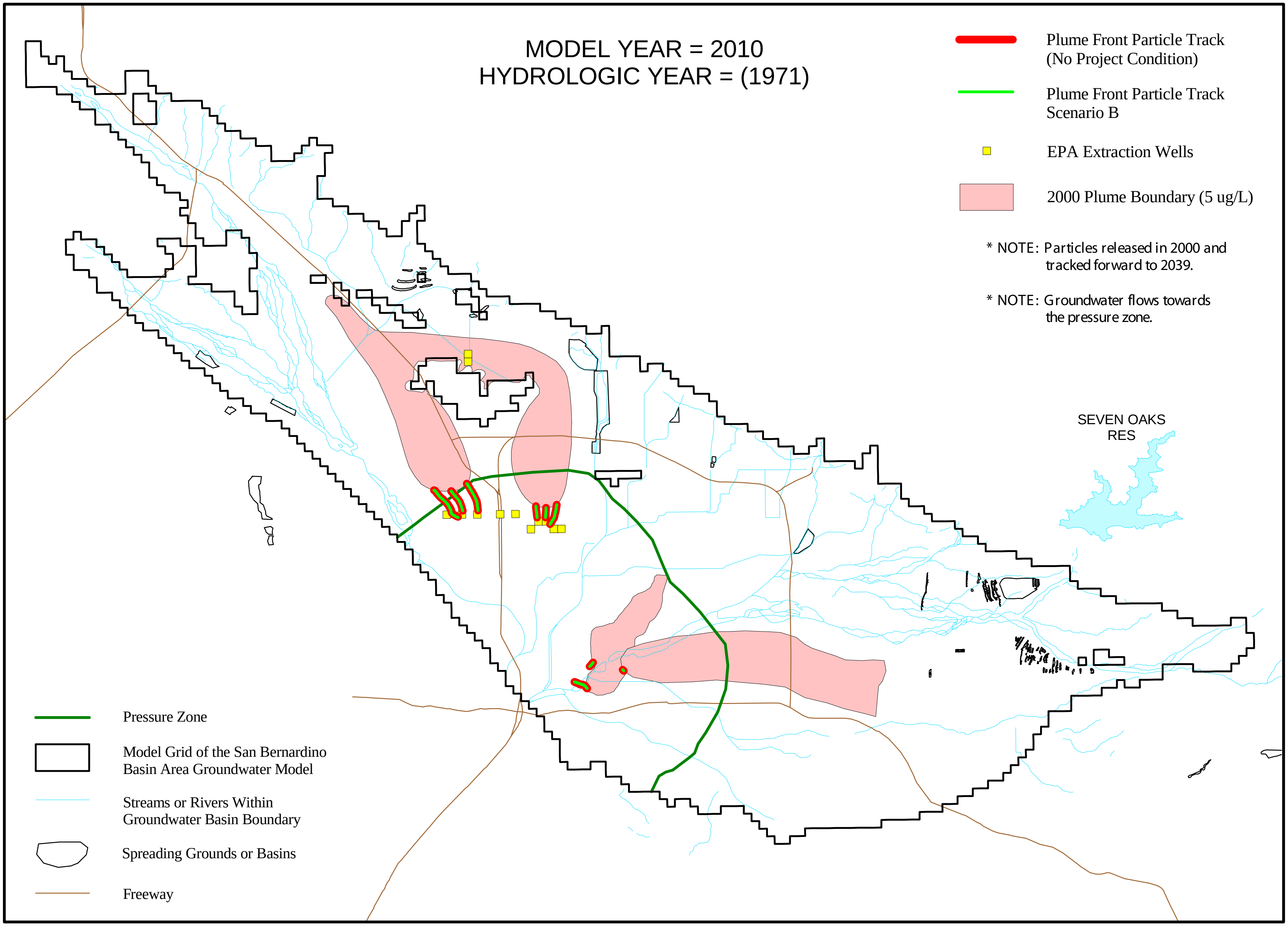
Figure B 48(a)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2005

Figure B 48(b)



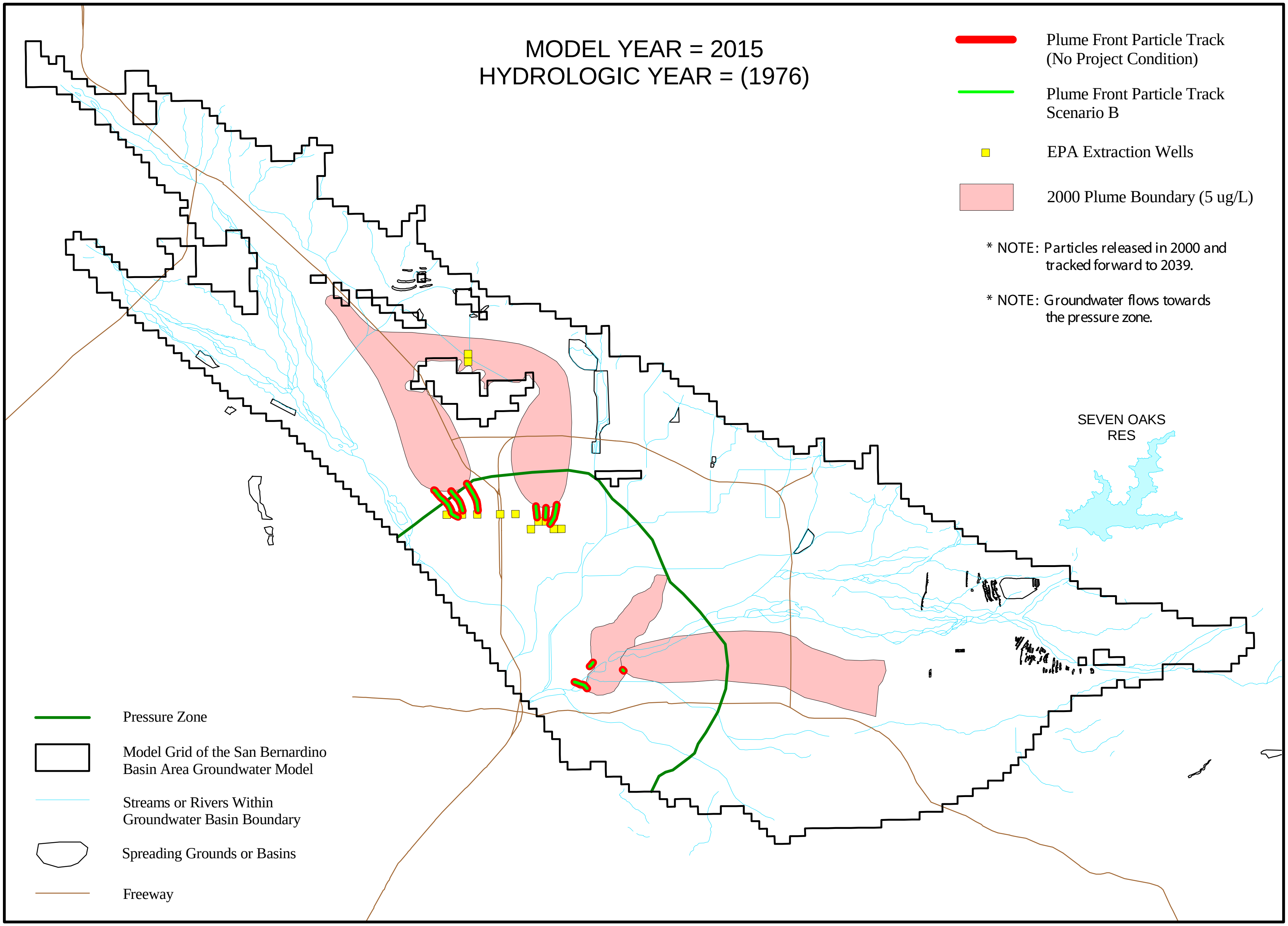
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2010

Figure B 48(c)



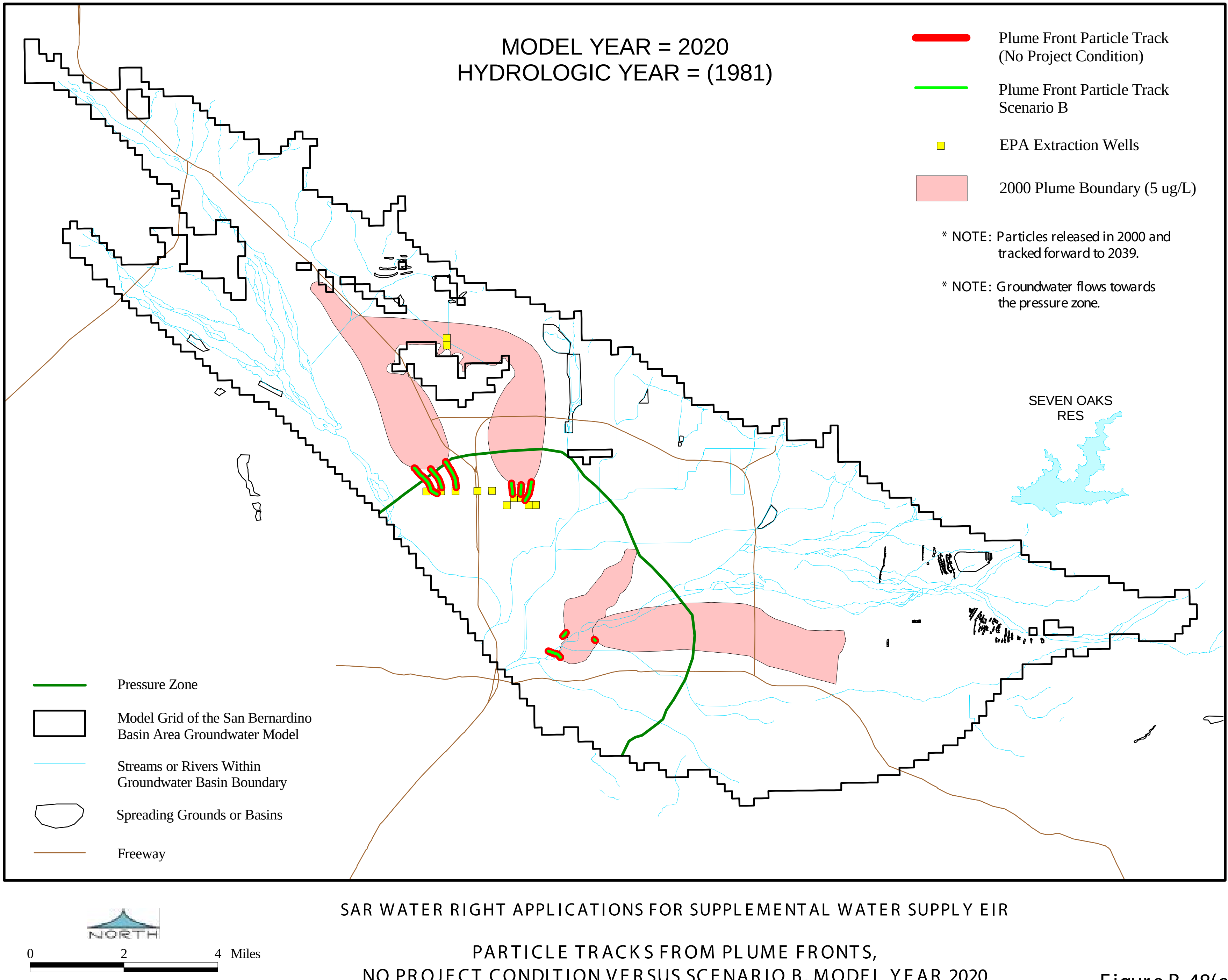
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2015

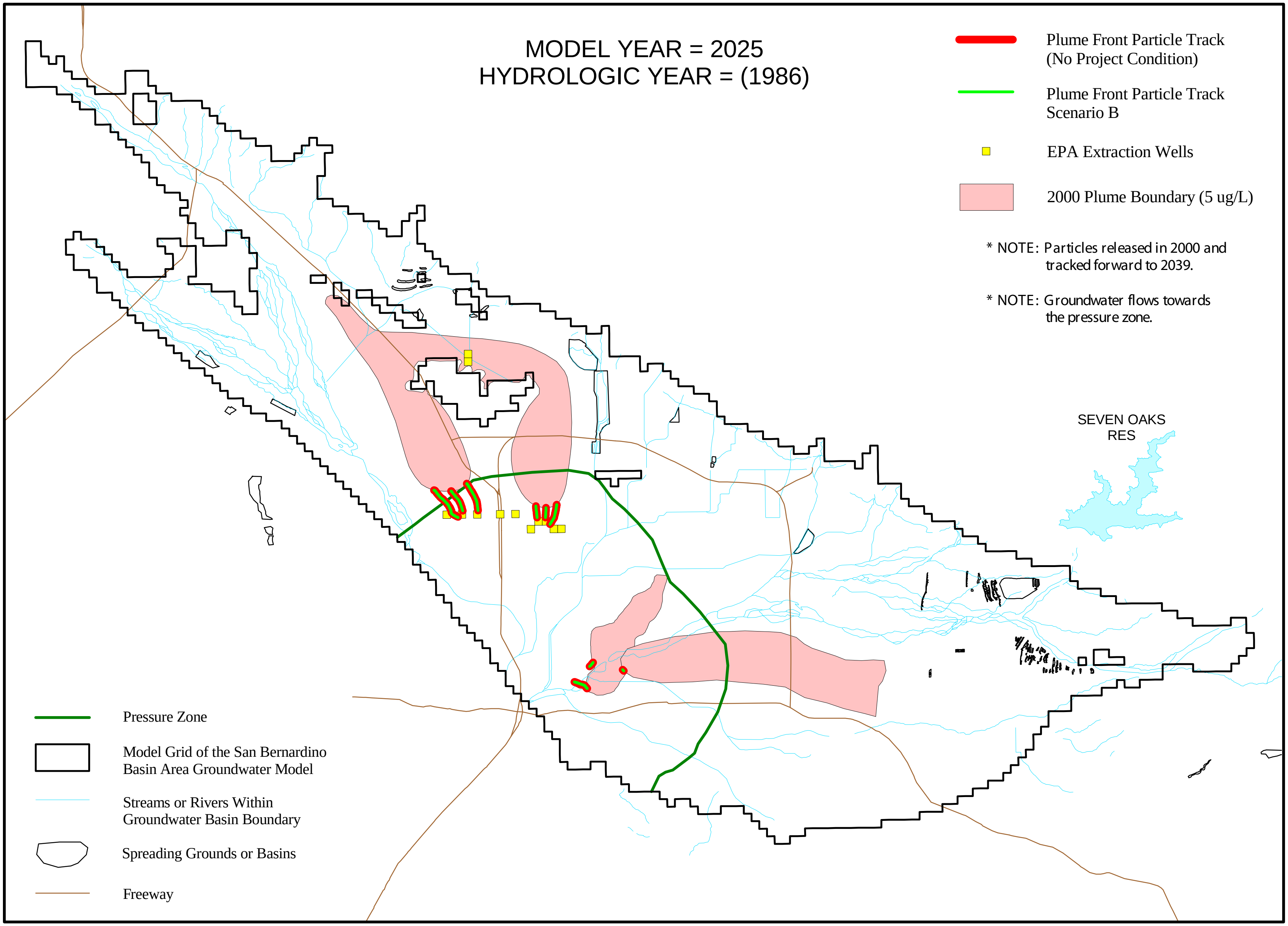
Figure B 48(d)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2020

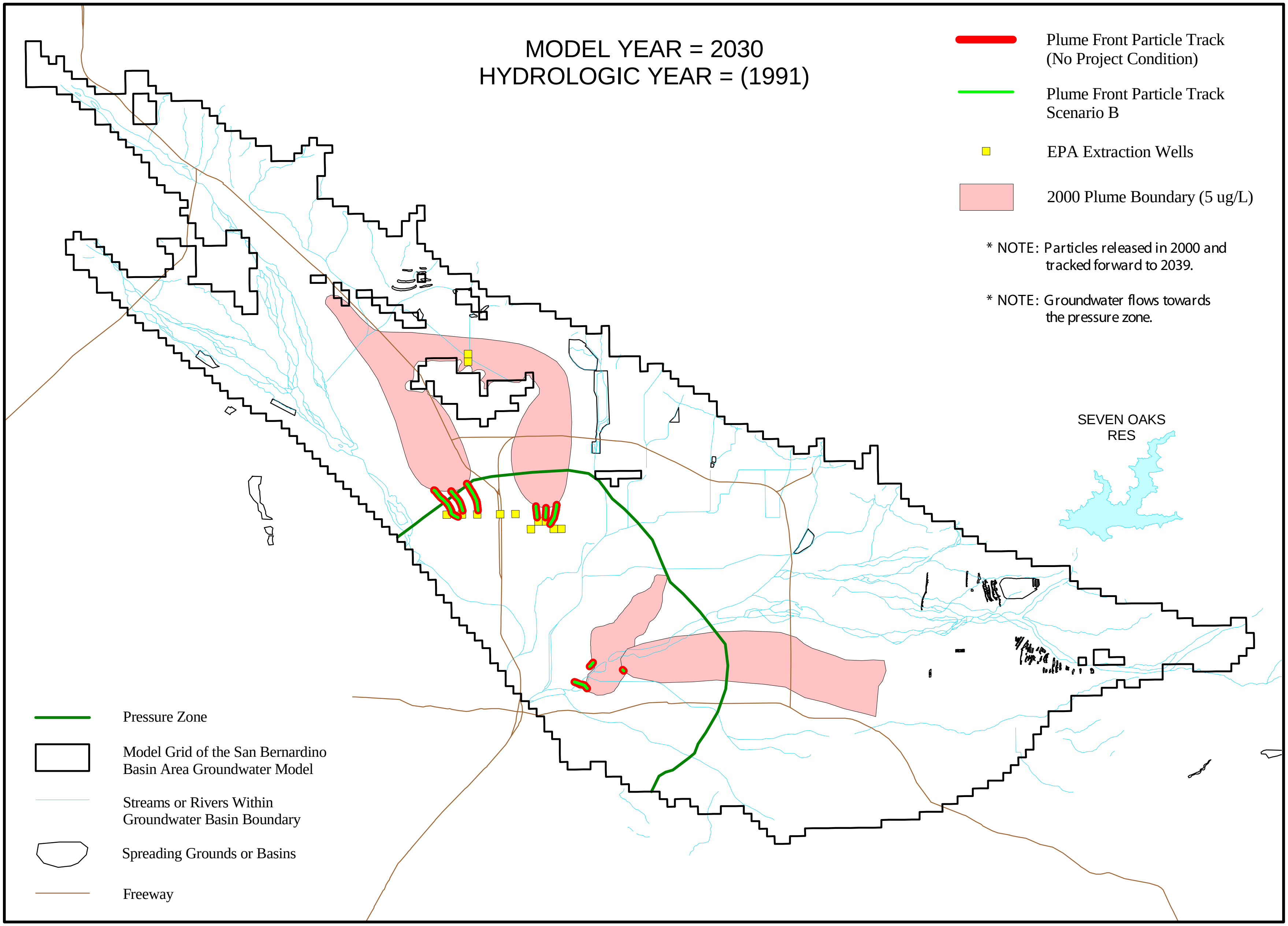
Figure B 48(e)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2025

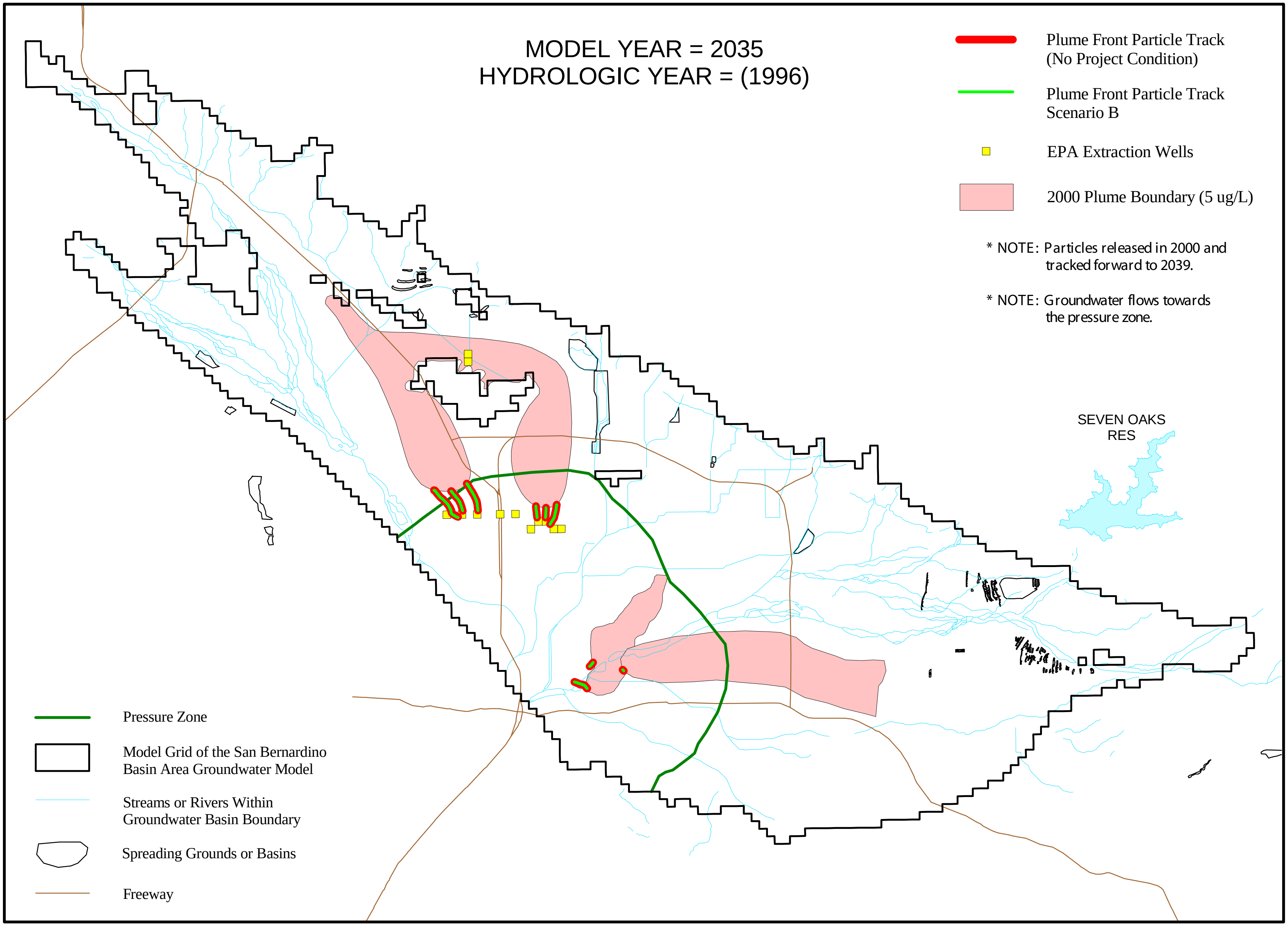
Figure B 48(f)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2030

Figure B 48(g)



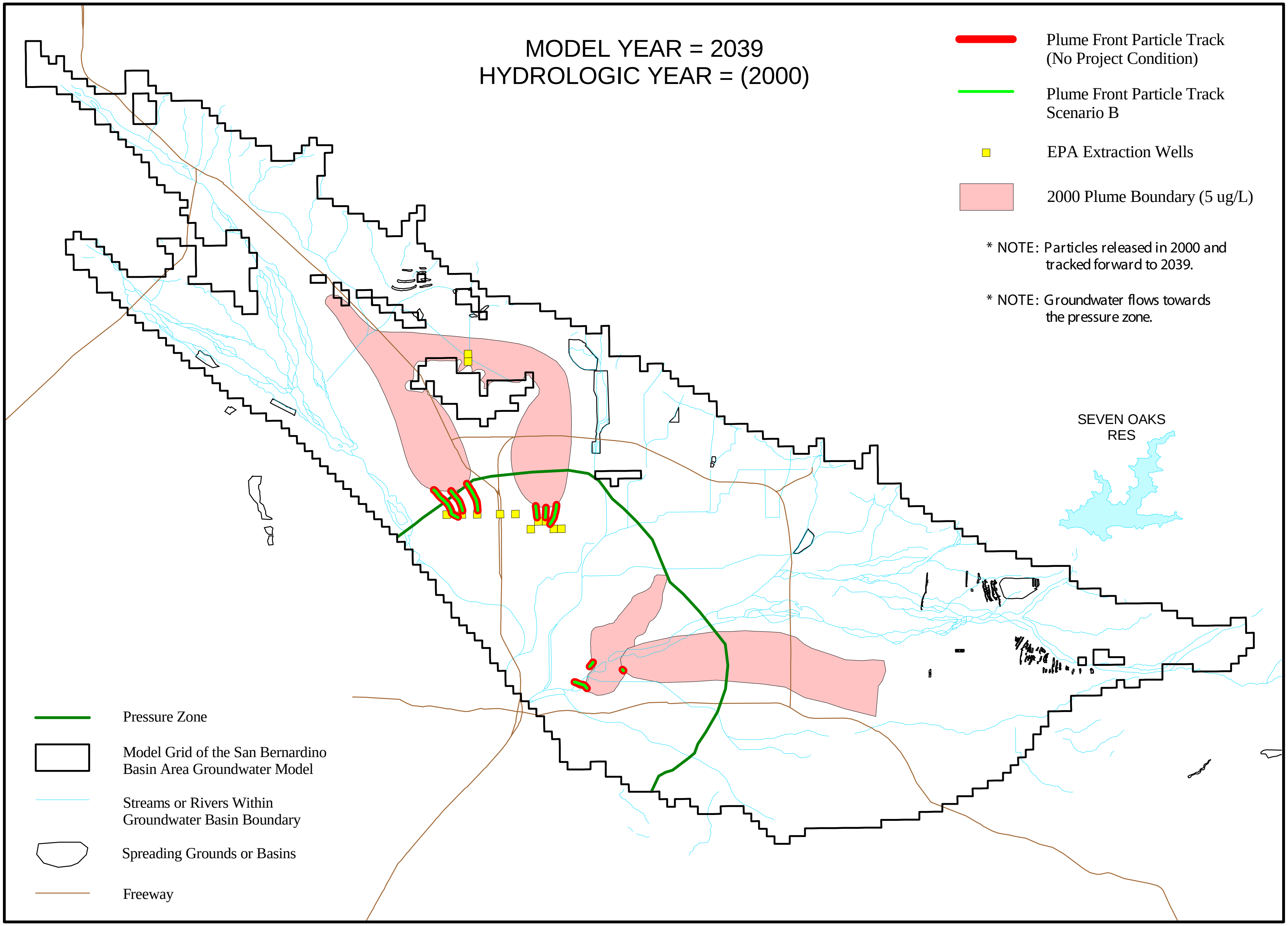
NORTH

0 2 4 Miles

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2035

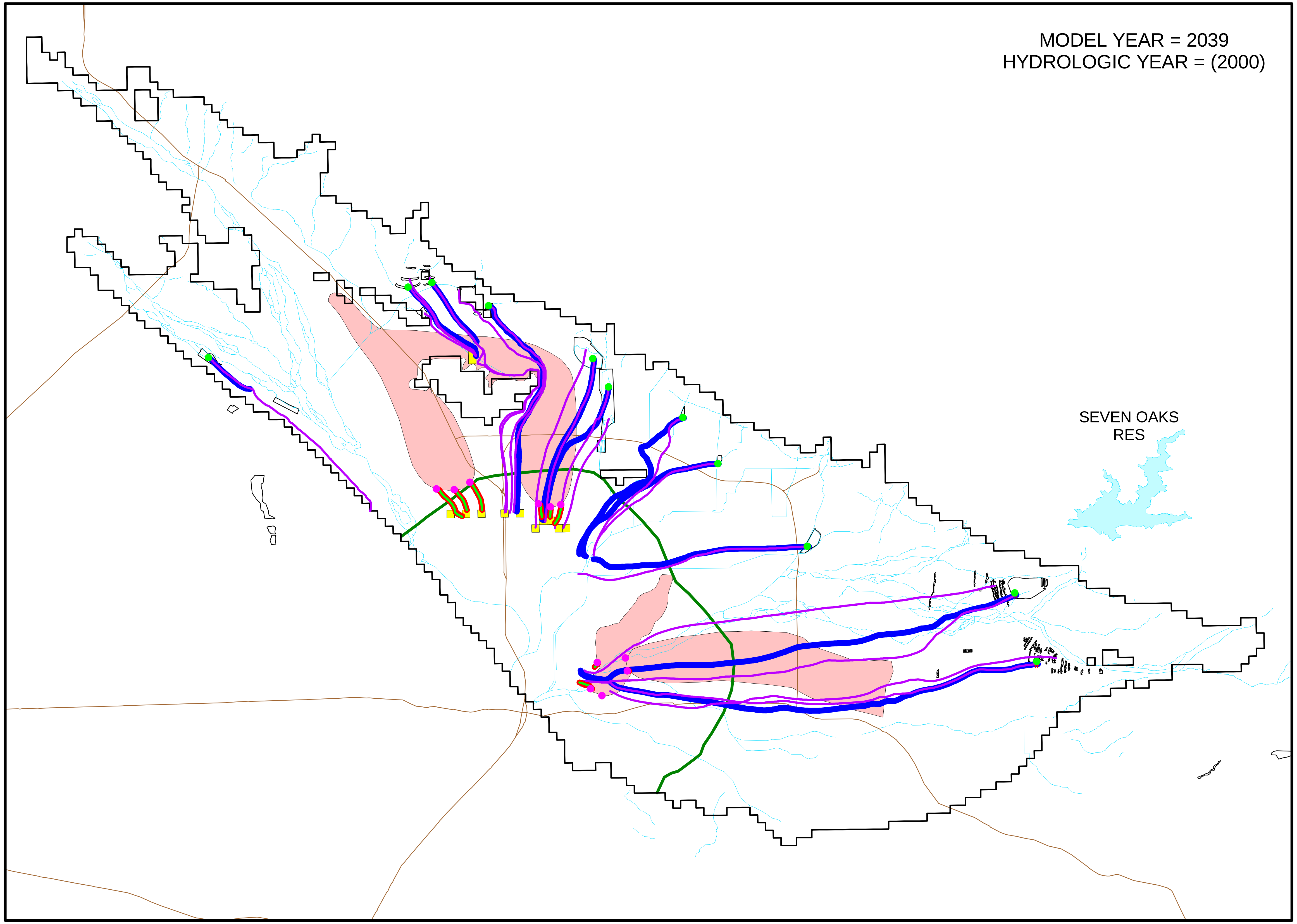
Figure B 48(h)



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PARTICLE TRACKS FROM PLUME FRONTS,
NO PROJECT CONDITION VERSUS SCENARIO B, MODEL YEAR 2039

Figure B 48(i)



PARTICLE TRACKS FROM BOTH SPREADING GROUNDS AND PLUME FRONTS, YEAR 2039, NO PROJECT CONDITION VERSUS SCENARIO B

EXPLANATION

- ● Starting Point Spreading Ground Particle Track (No Project Condition)
- ━ Spreading Ground Particle Track (No Project Condition)
- ─ Spreading Ground Particle Track Scenario B
- ● Starting Point Plume Front Particle Track (No Project Condition)
- ━ Plume Front Particle Track (No Project Condition)
- ─ Plume Front Particle Track Scenario B
- ▫ EPA Extraction Wells
- ▨ 2000 Plume Boundary (5 µg/L)
- ━ Pressure Zone
- ▭ Model Grid of the San Bernardino Basin Area Groundwater Model
- ─ Streams or Rivers Within Groundwater Basin Boundary
- ⬭ Spreading Grounds or Basins
- ─ Freeway

* NOTE: Particles released in 2000 and tracked forward to 2039.

* NOTE: Groundwater flows towards the pressure zone.

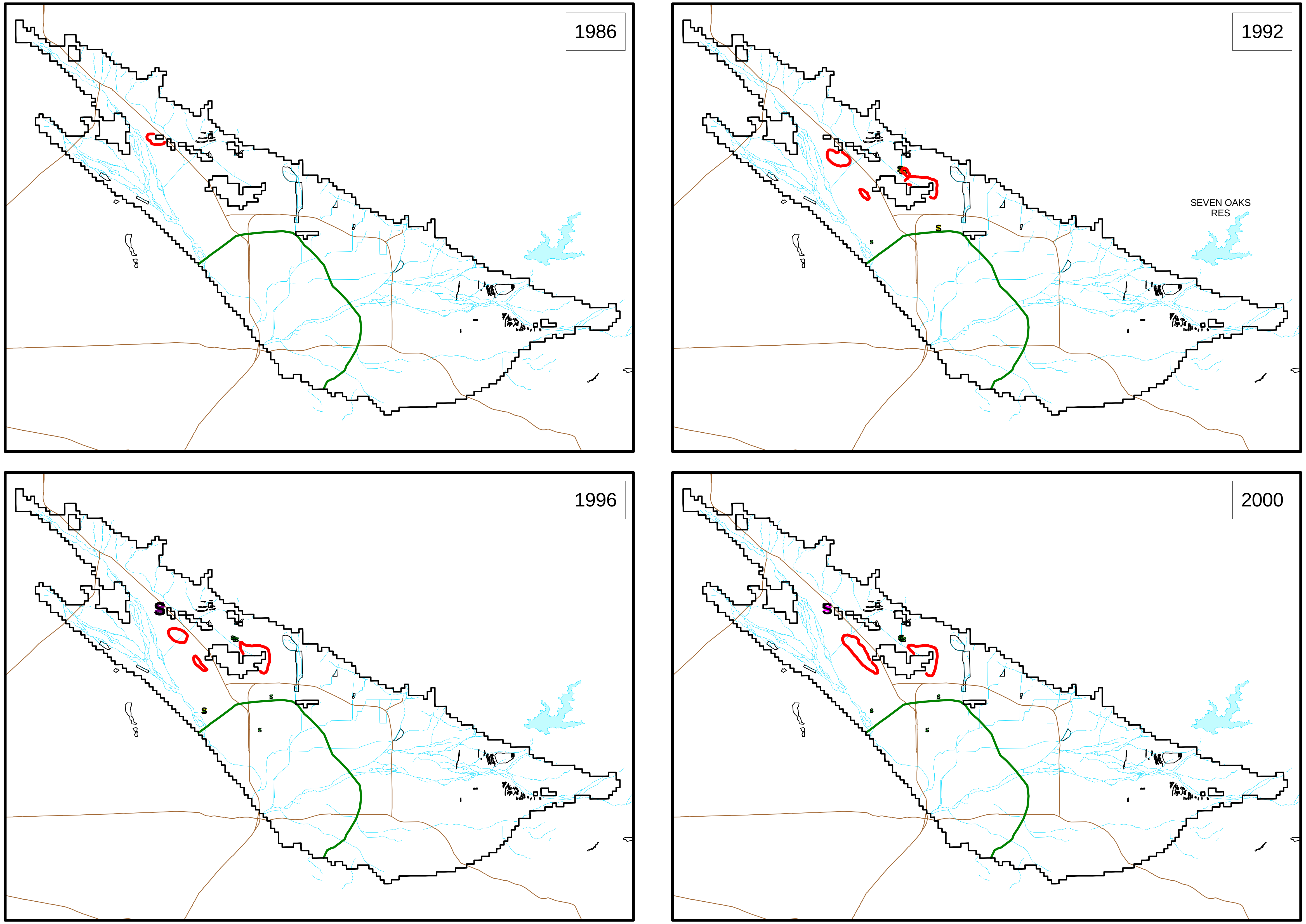
NORTH

0 2 4 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 49

MEASURED AND MODEL-GENERATED PLUME BOUNDARIES FOR PCE MODEL LAYER 1



EXPLANATION

Measured PCE Concentration (ug/L)

s	0
s	<5
s	5 - 10
S	10 - 50
S	50 - 500
S	>500
—	Model-Generated PCE Plume (5 ug/L)
2000	Model Year
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

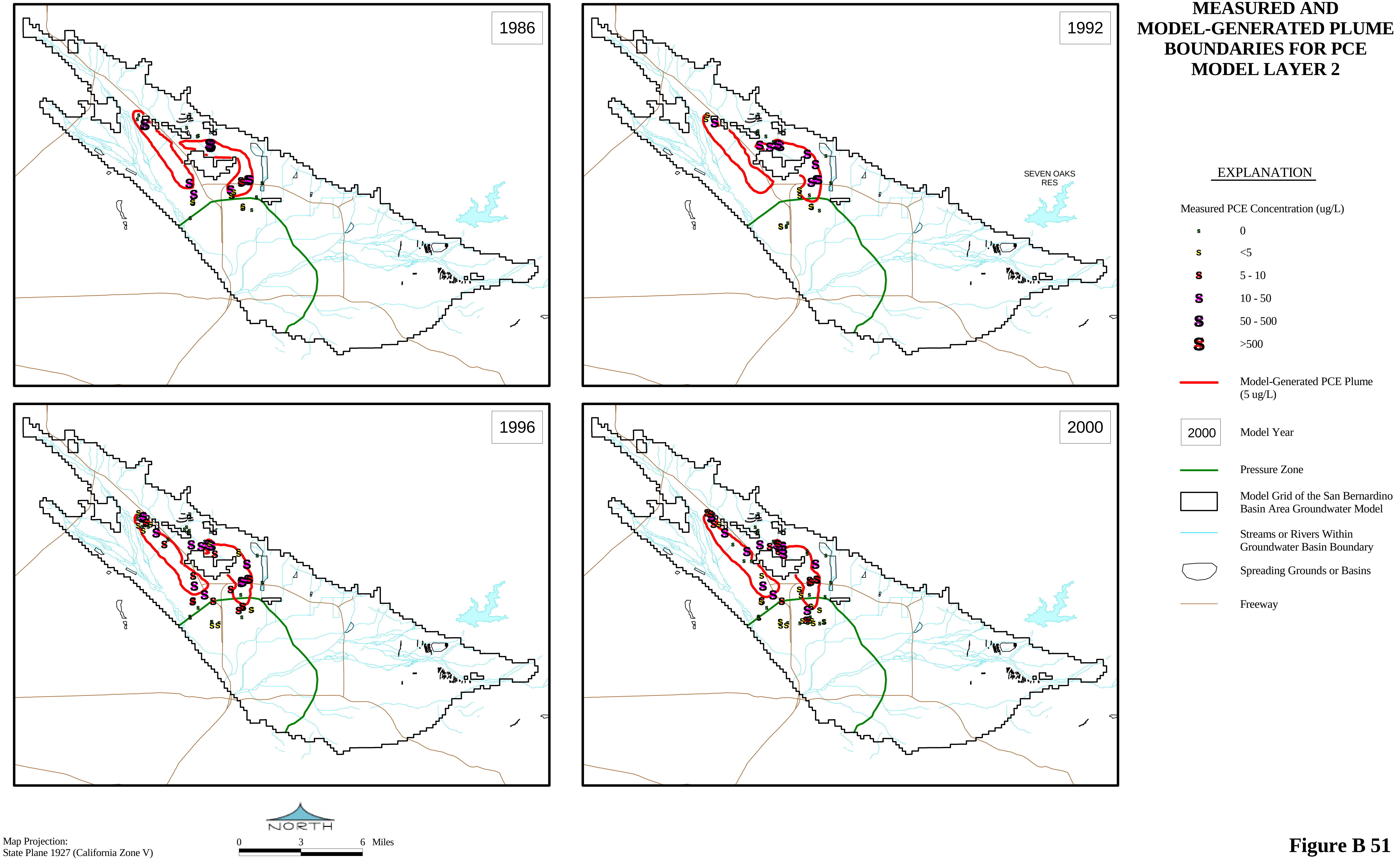
Map Projection:
State Plane 1927 (California Zone V)

NORTH

0 3 6 Miles

Figure B 50

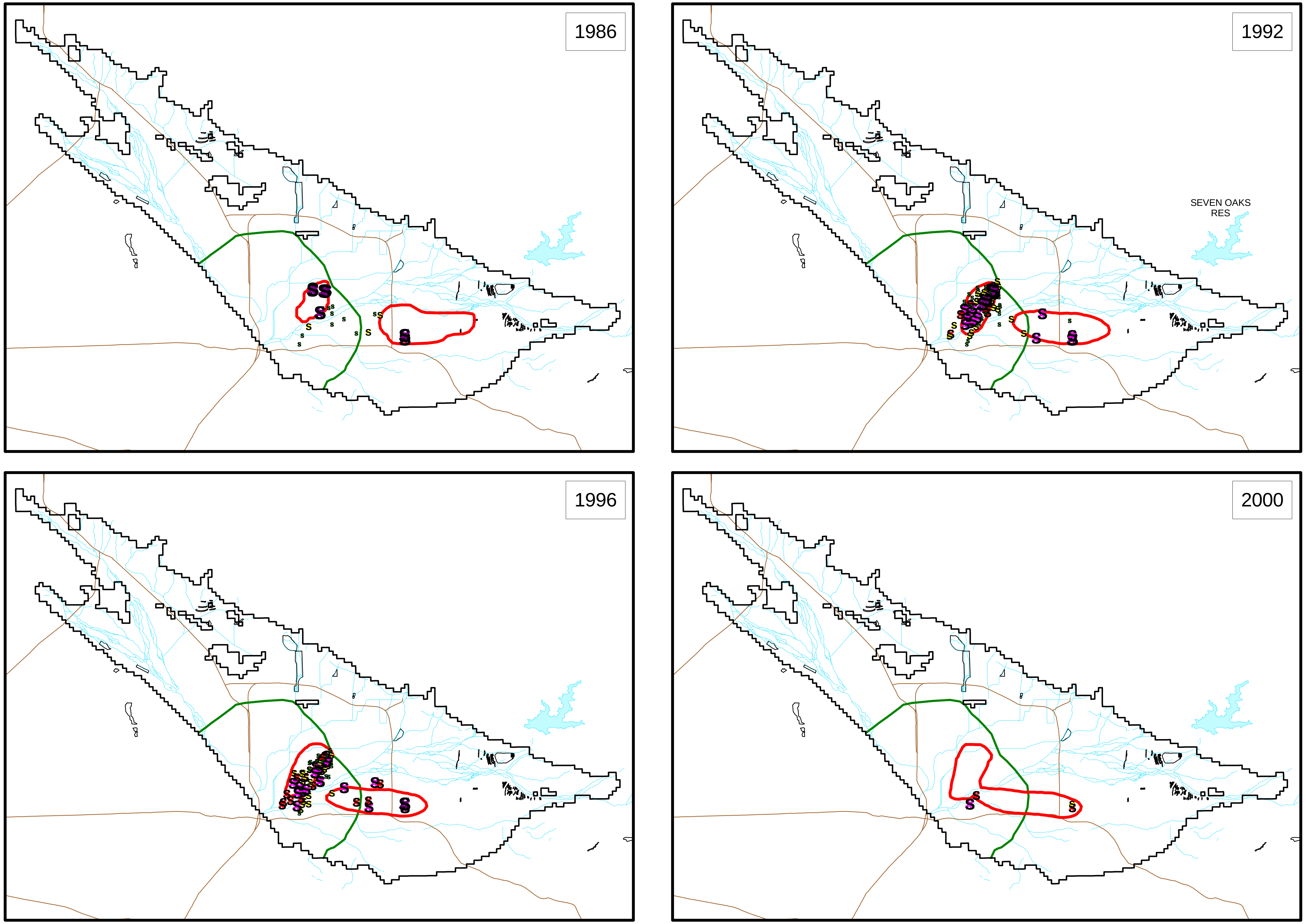
MEASURED AND MODEL-GENERATED PLUME BOUNDARIES FOR PCE MODEL LAYER 2



Map Projection:
State Plane 1927 (California Zone V)

Figure B 51

MEASURED AND MODEL-GENERATED PLUME BOUNDARIES FOR TCE MODEL LAYER 1



EXPLANATION

Measured TCE Concentration (ug/L)

s	0
s	<5
s	5 - 10
s	10 - 50
s	50 - 500
s	>500
—	Model-Generated TCE Plume (5 ug/L)
2000	Model Year
—	Pressure Zone
☐	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
○	Spreading Grounds or Basins
—	Freeway

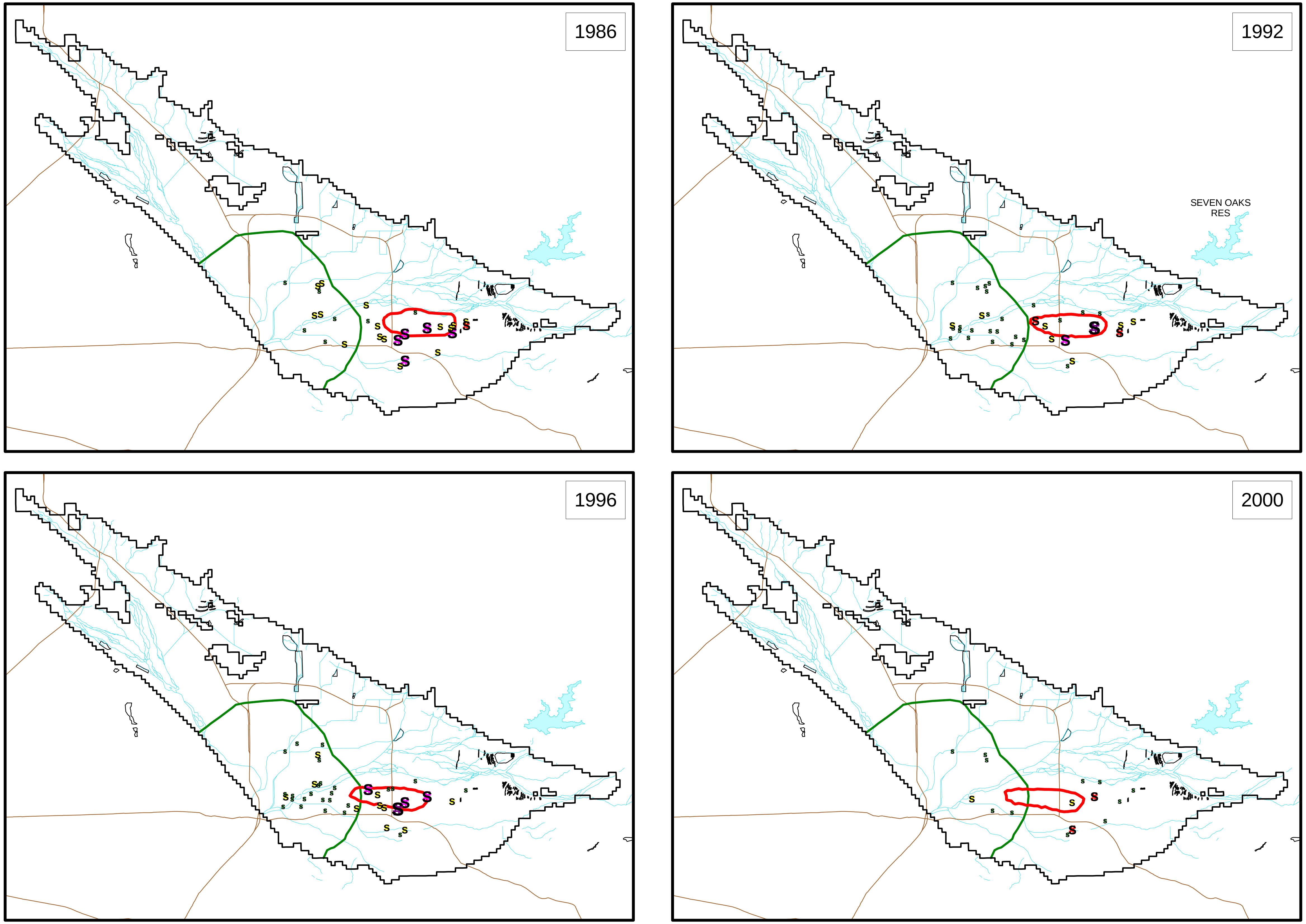
NORTH

0 3 6 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 52

MEASURED AND MODEL-GENERATED PLUME BOUNDARIES FOR TCE MODEL LAYER 2



EXPLANATION

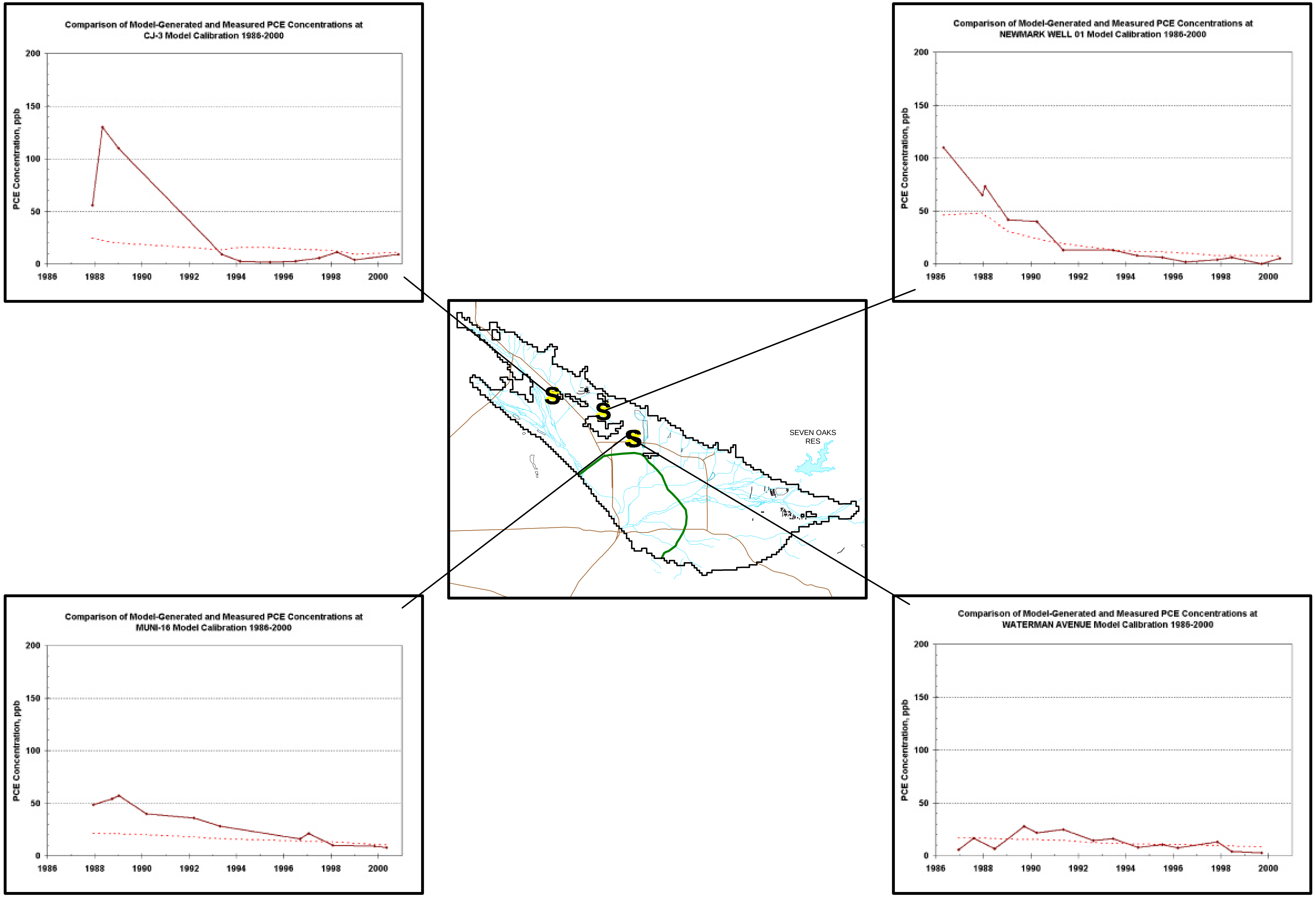
Measured TCE Concentration (ug/L)

s	0
s	<5
s	5 - 10
S	10 - 50
S	50 - 500
S	>500
▬	Model-Generated TCE Plume (5 ug/L)
2000	Model Year
▬	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
─	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
─	Freeway

Map Projection:
State Plane 1927 (California Zone V)

Figure B 53

MEASURED VERSUS MODEL-GENERATED PCE CONCENTRATIONS AT SELECTED LOCATIONS



EXPLANATION

- S Selected Well
- — Measured PCE Concentration (ug/L)
- ----- Model-Generated PCE Concentration (ug/L)
- — Pressure Zone
- ☐ Model Grid of the San Bernardino Basin Area Groundwater Model
- — Streams or Rivers Within Groundwater Basin Boundary
- ⬭ Spreading Grounds or Basins
- — Freeway

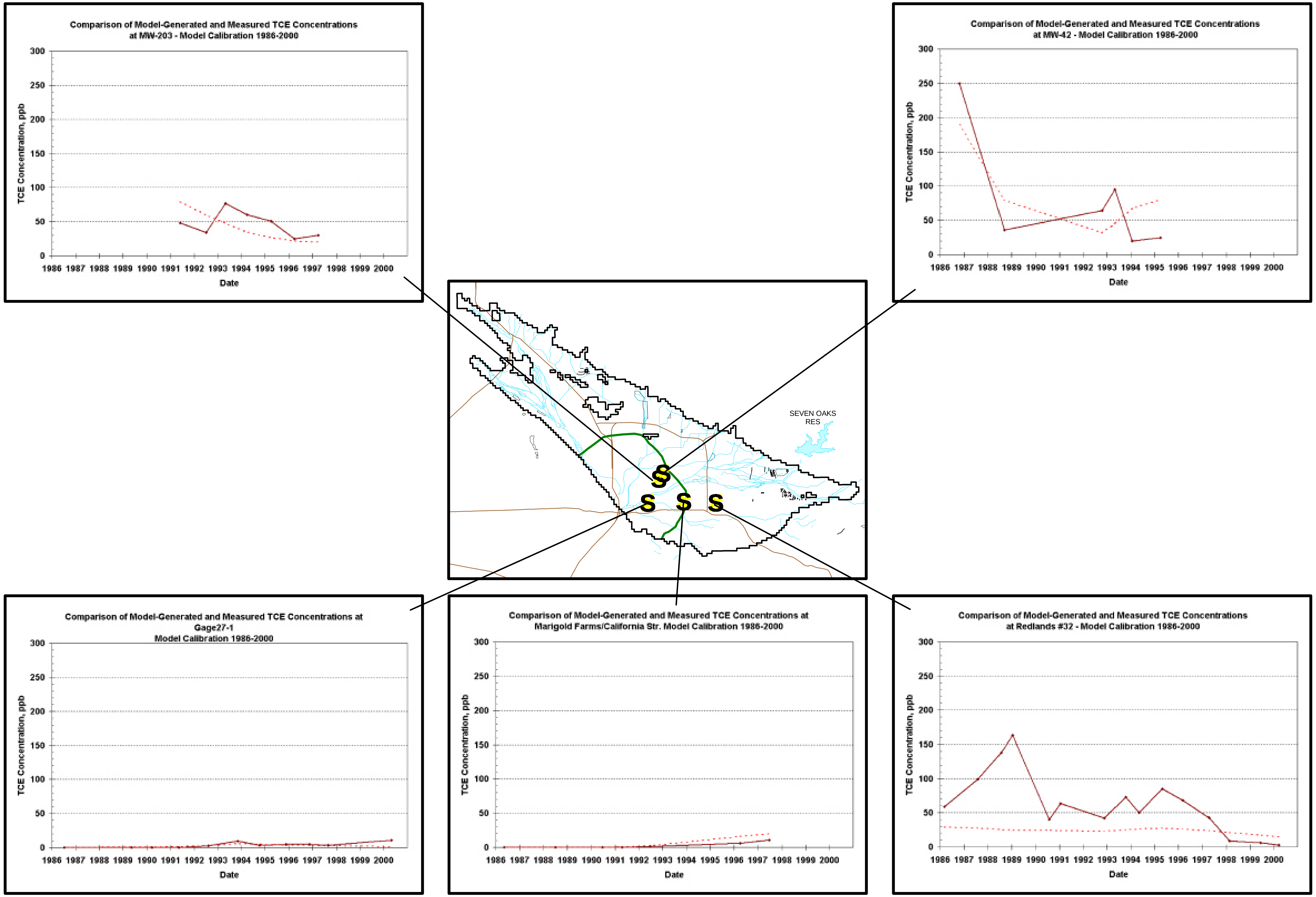
NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 54

MEASURED VERSUS MODEL-GENERATED TCE CONCENTRATIONS AT SELECTED LOCATIONS



EXPLANATION

- S Selected Well
- —— Measured TCE Concentration (ug/L)
- - - - Model-Generated TCE Concentration (ug/L)
- —— Pressure Zone
- ▭ Model Grid of the San Bernardino Basin Area Groundwater Model
- —— Streams or Rivers Within Groundwater Basin Boundary
- ⬭ Spreading Grounds or Basins
- —— Freeway

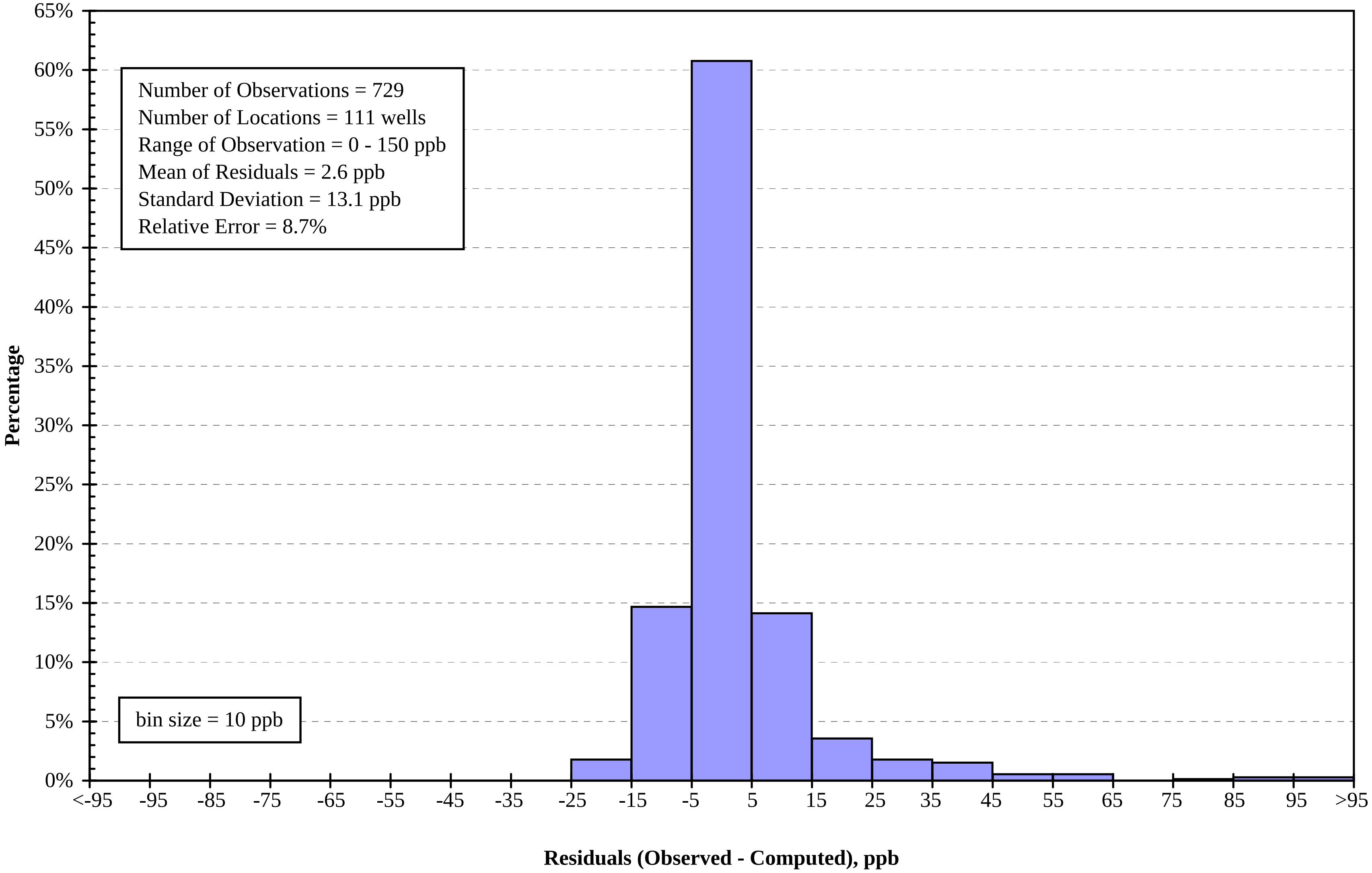
NORTH

Map Projection:
State Plane 1927 (California Zone V)

0 5 10 Miles

Figure B 55

Histogram of PCE Calibration Residuals

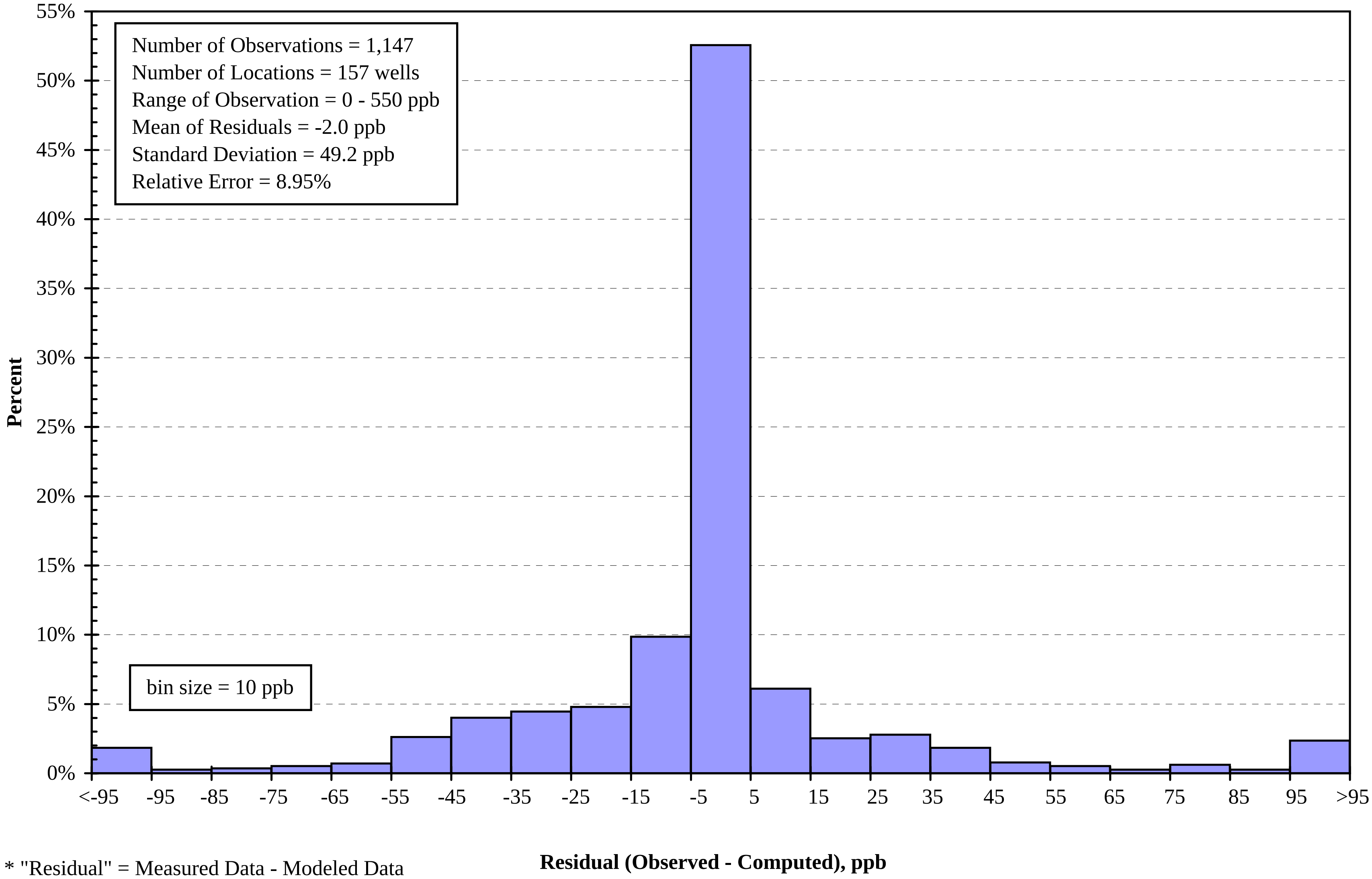


Number of Observations = 729
Number of Locations = 111 wells
Range of Observation = 0 - 150 ppb
Mean of Residuals = 2.6 ppb
Standard Deviation = 13.1 ppb
Relative Error = 8.7%

bin size = 10 ppb

Figure B 56

Histogram of TCE Residuals* for Model Calibration - 1986 to 2000

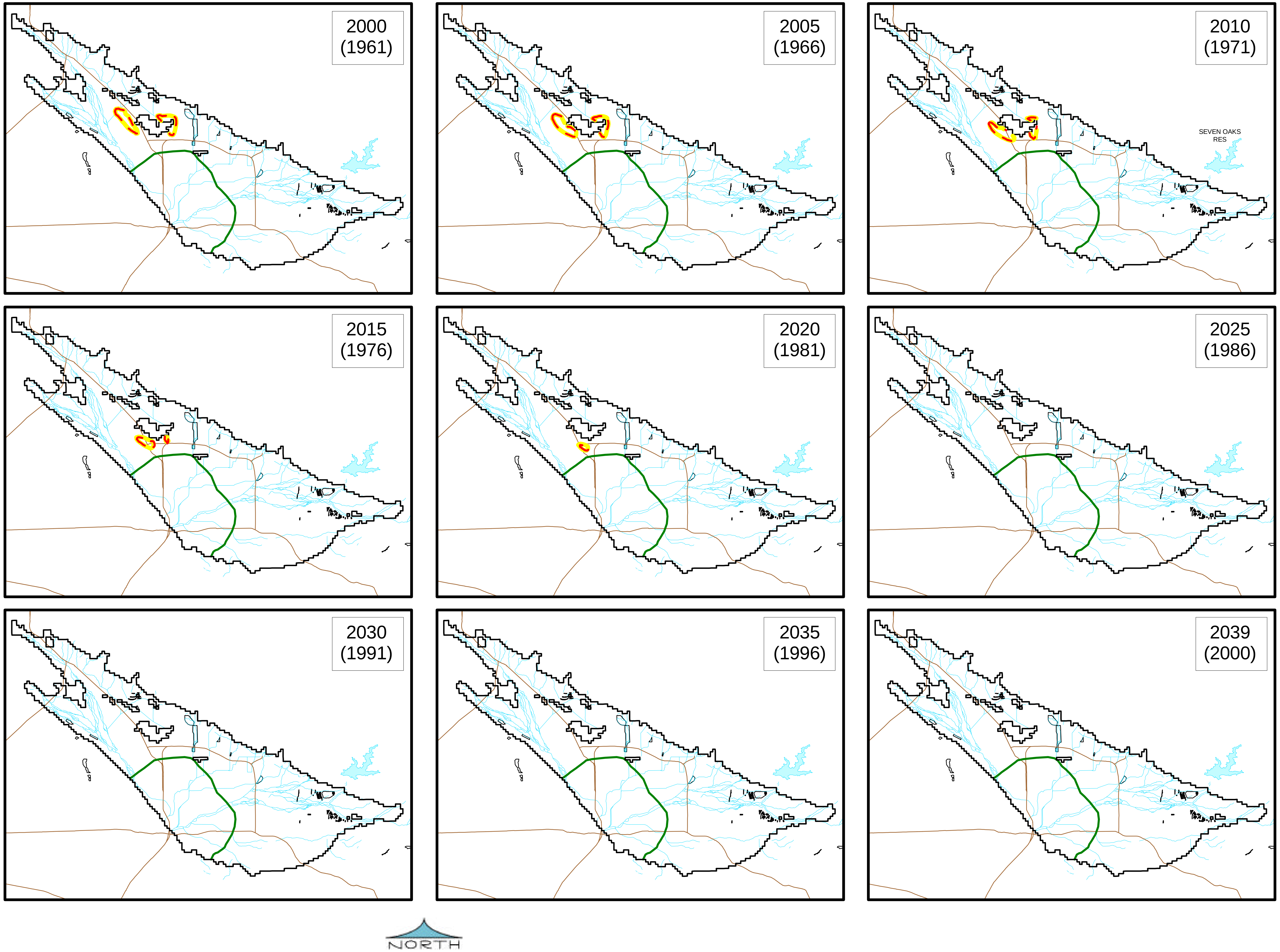


* "Residual" = Measured Data - Modeled Data

Figure B 57

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PCE PLUME BOUNDARY
LAYER 1
NO PROJECT CONDITION
VERSUS SCENARIO C



EXPLANATION

Yellow Line	PCE Plume Boundary (5 ug/L) Layer 1, No Project Condition
- - -	PCE Plume Boundary (5 ug/L) Layer 1, Scenario C
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

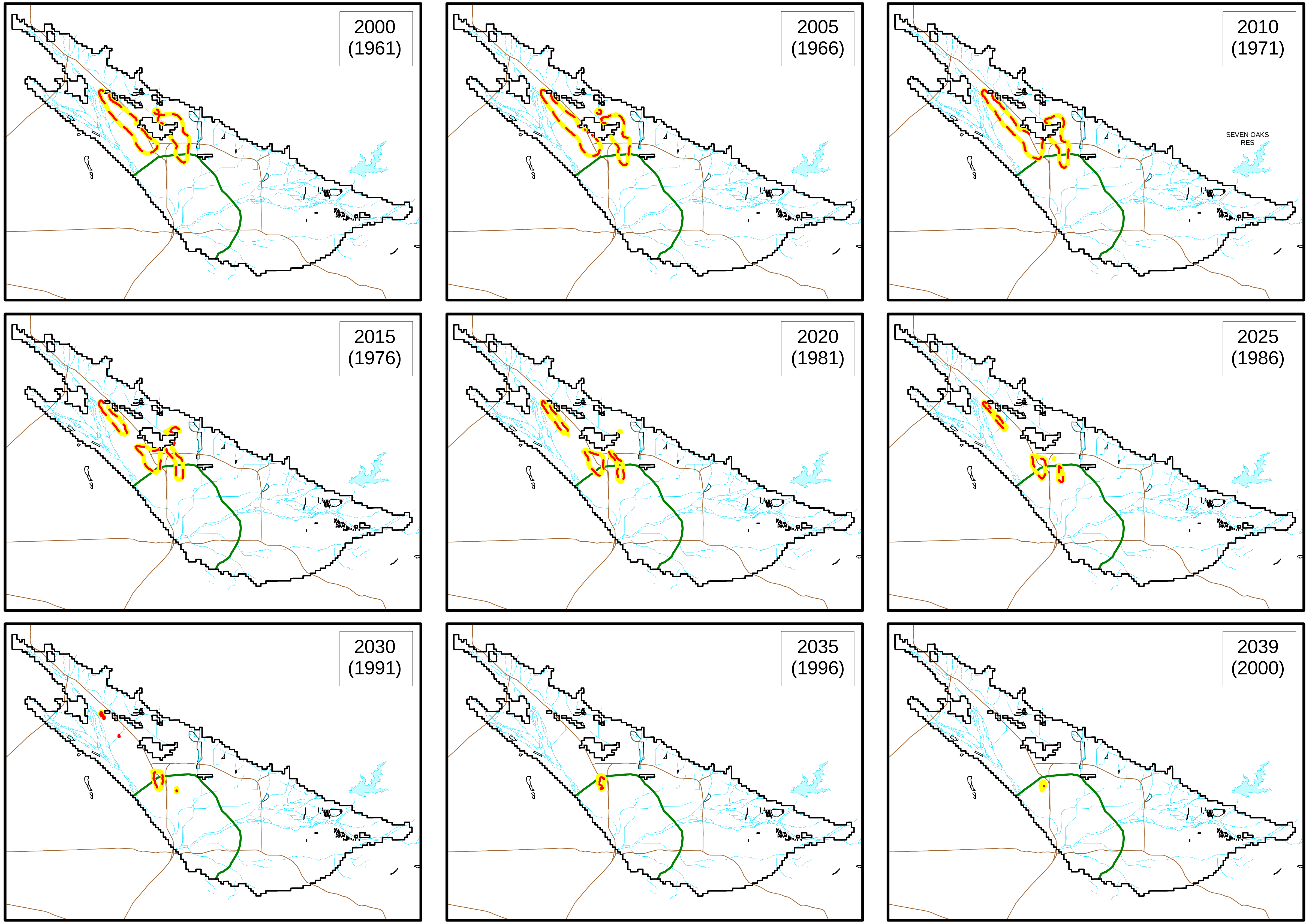
Map Projection:
State Plane 1927 (California Zone V)

0 5 10 Miles

Figure B 58

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PCE PLUME BOUNDARY
LAYER 2
NO PROJECT CONDITION
VERSUS SCENARIO C



EXPLANATION

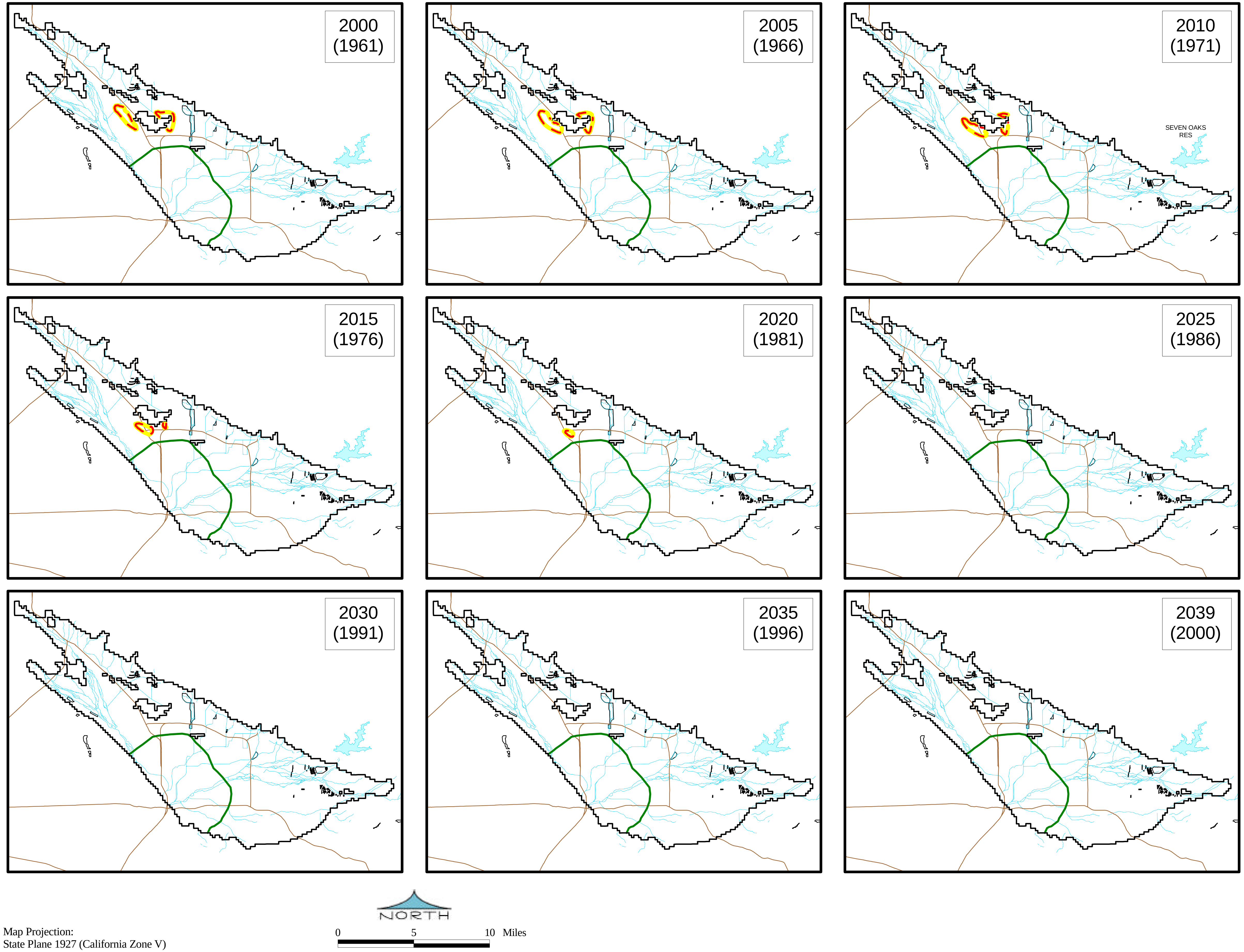
Yellow Line	PCE Plume Boundary (5 ug/L) Layer 2, No Project Condition
- - -	PCE Plume Boundary (5 ug/L) Layer 2, Scenario C
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

Map Projection:
State Plane 1927 (California Zone V)

0 5 10 Miles

Figure B 59

PCE PLUME BOUNDARY LAYER 1 NO PROJECT CONDITION VERSUS SCENARIO D



EXPLANATION

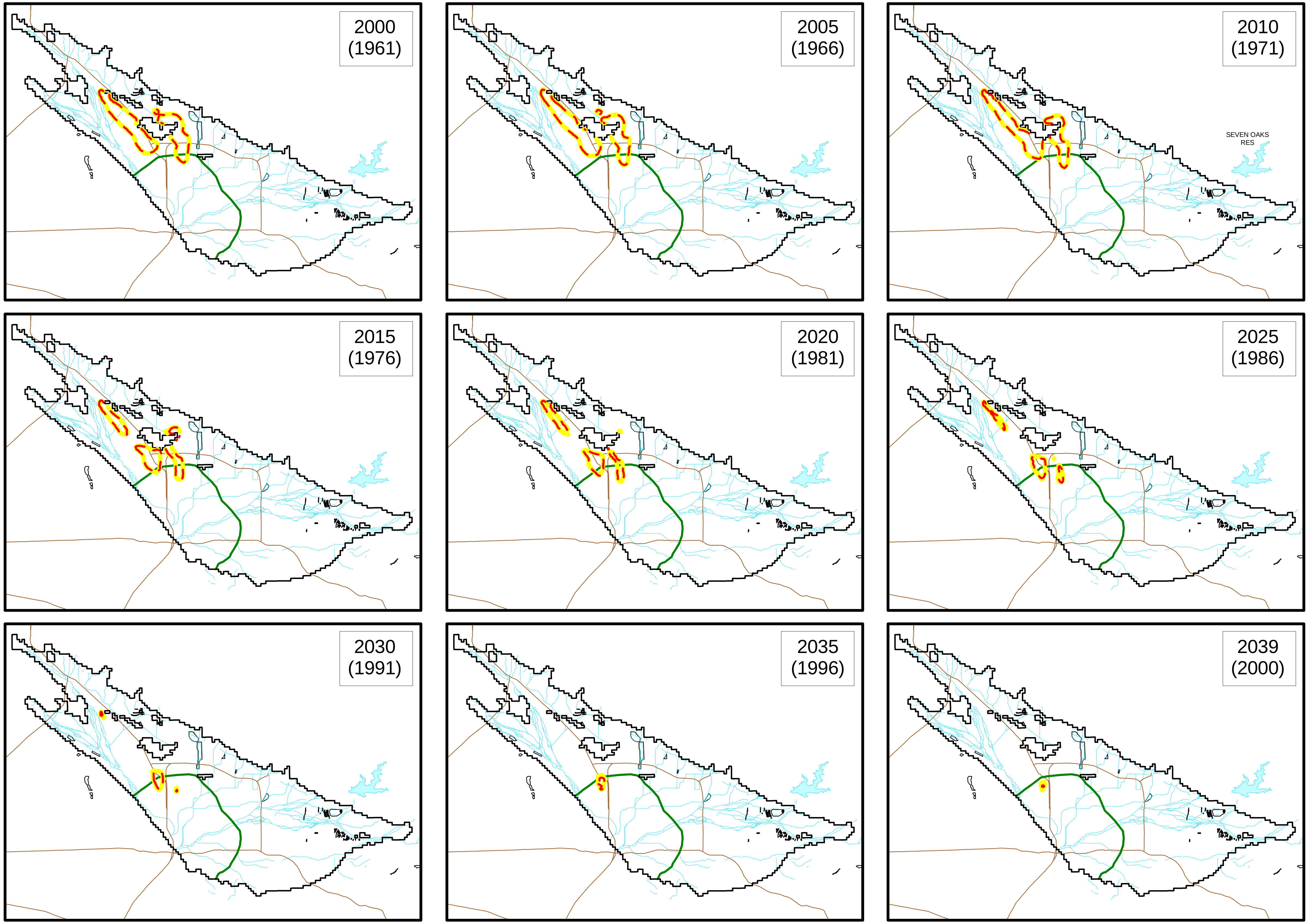
Yellow Line ▬	PCE Plume Boundary (5 ug/L) Layer 1, No Project Condition
- - -	PCE Plume Boundary (5 ug/L) Layer 1, Scenario D
2000 (1961)	Model Year (Assumed Hydrological Year)
―	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
―	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
―	Freeway

Map Projection:
State Plane 1927 (California Zone V)

Figure B 60

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PCE PLUME BOUNDARY
LAYER 2
NO PROJECT CONDITION VERSUS SCENARIO D



EXPLANATION

Yellow Line — PCE Plume Boundary (5 ug/L) Layer 2, No Project Condition

- - - PCE Plume Boundary (5 ug/L) Layer 2, Scenario D

2000 (1961) — Model Year (Assumed Hydrological Year)

Pressure Zone

Model Grid of the San Bernardino Basin Area Groundwater Model

Streams or Rivers Within Groundwater Basin Boundary

Spreading Grounds or Basins

Freeway

NORTH

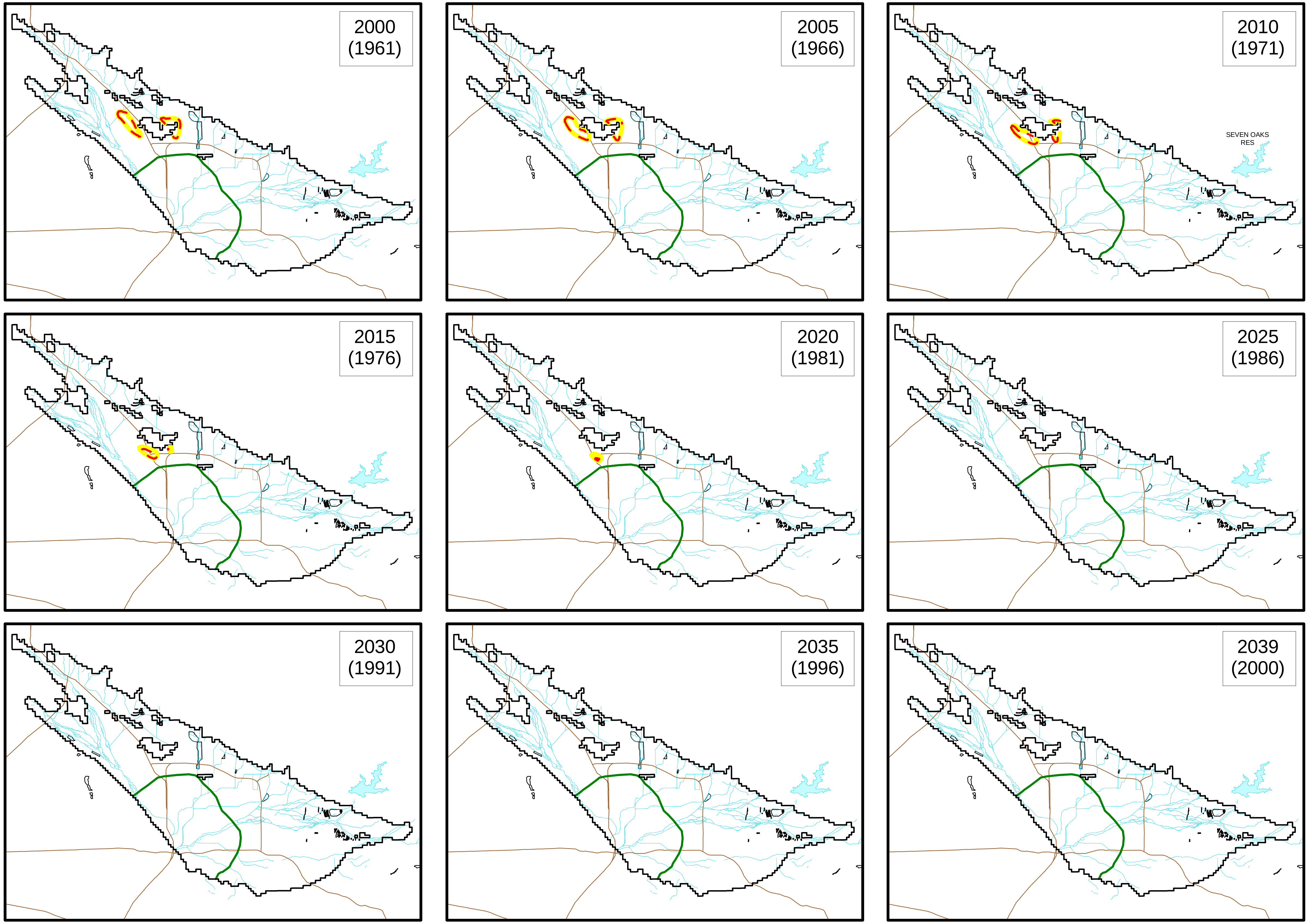
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 61

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PCE PLUME BOUNDARY LAYER 1 NO PROJECT CONDITION VERSUS SCENARIO A



EXPLANATION

Yellow Line — PCE Plume Boundary (5 ug/L) Layer 1, No Project Condition

- - - PCE Plume Boundary (5 ug/L) Layer 1, Scenario A

2000 (1961) — Model Year (Assumed Hydrological Year)

Pressure Zone

▭ Model Grid of the San Bernardino Basin Area Groundwater Model

Streams or Rivers Within Groundwater Basin Boundary

Spreading Grounds or Basins

Freeway

NORTH

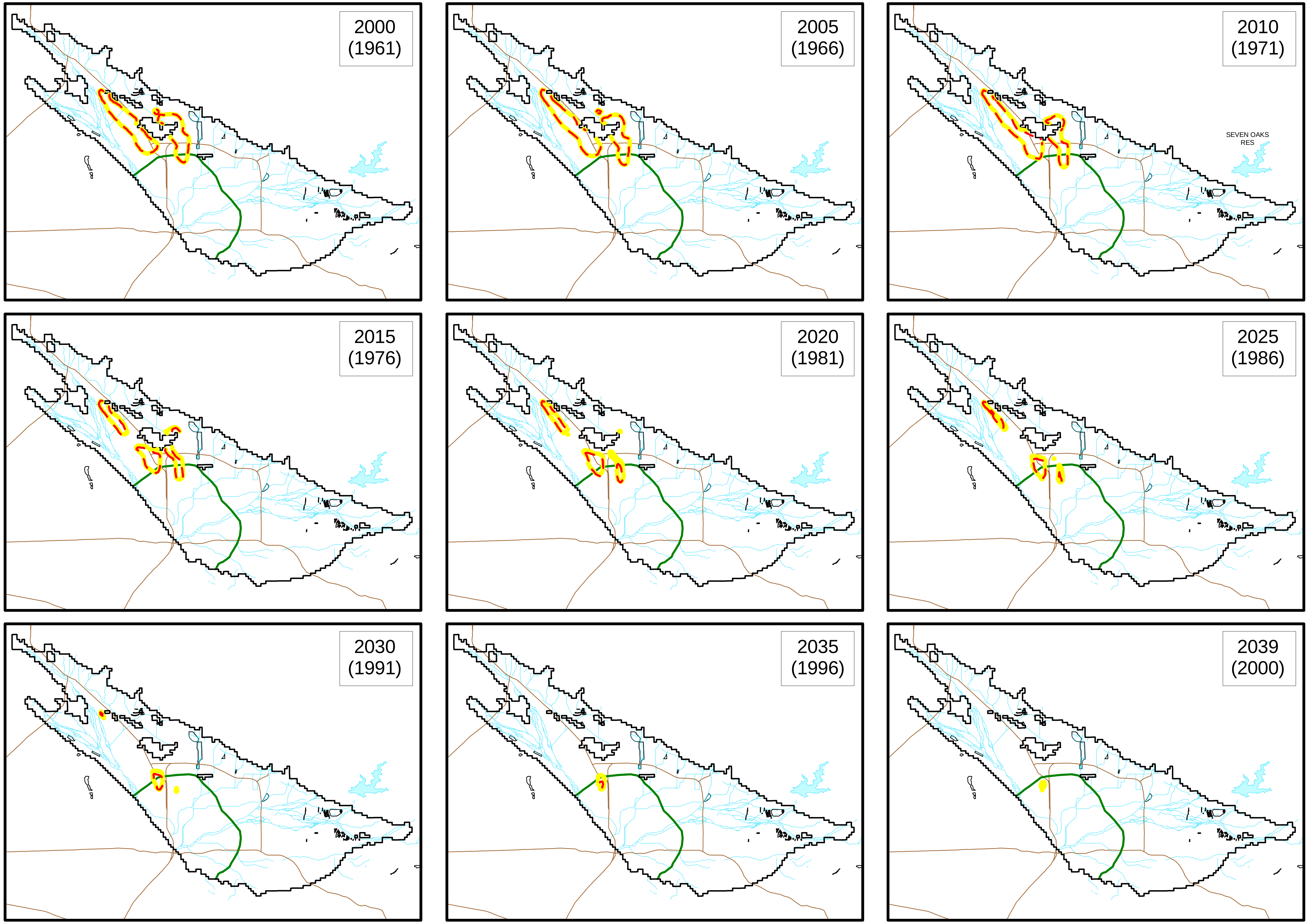
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 62

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PCE PLUME BOUNDARY LAYER 2 NO PROJECT CONDITION VERSUS SCENARIO A



EXPLANATION

Yellow Line	PCE Plume Boundary (5 ug/L) Layer 2, No Project Condition
- - -	PCE Plume Boundary (5 ug/L) Layer 2, Scenario A
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

NORTH

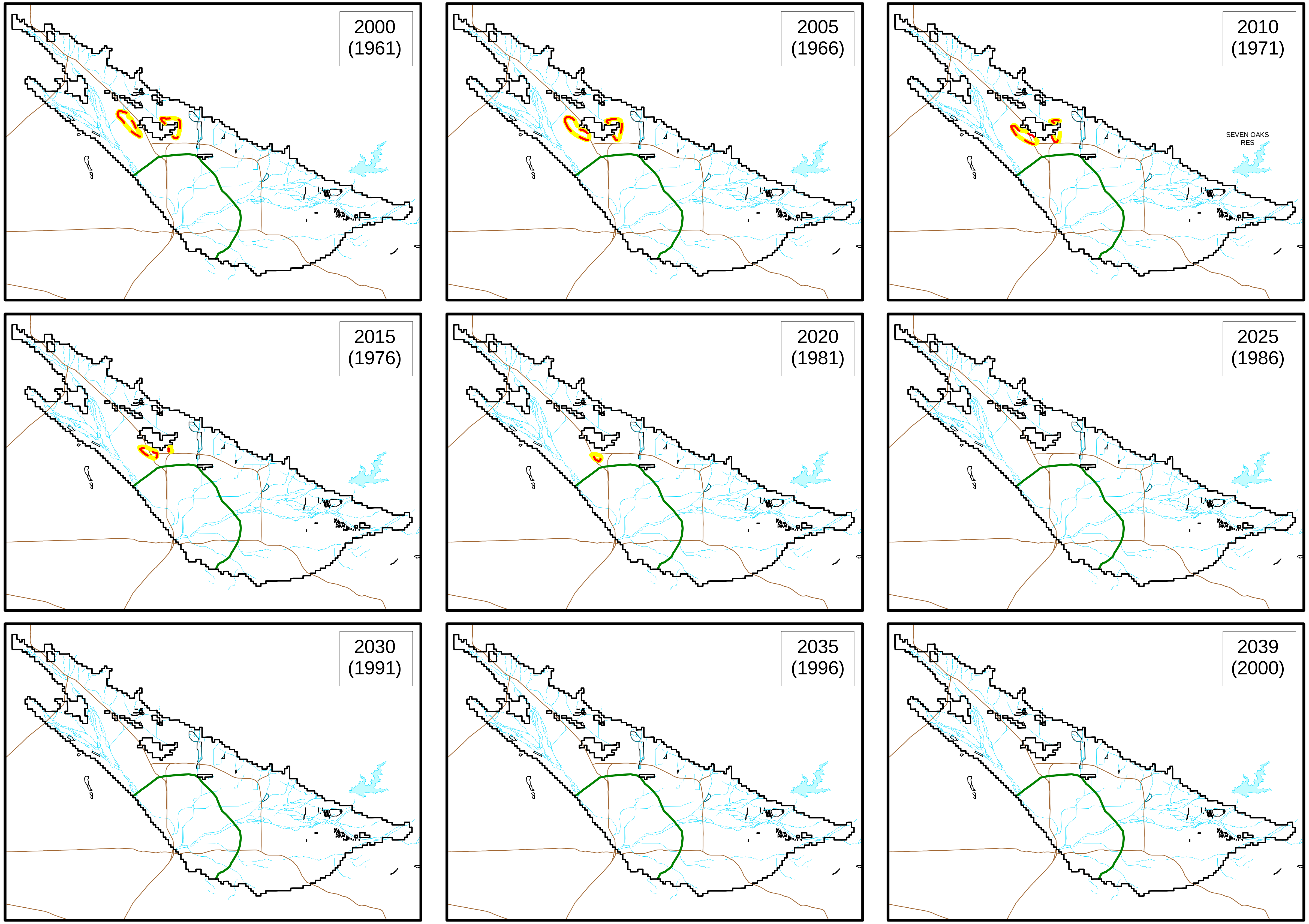
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 63

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PCE PLUME BOUNDARY
LAYER 1
NO PROJECT CONDITION
VERSUS SCENARIO B



EXPLANATION

Yellow Line 🟨	PCE Plume Boundary (5 ug/L) Layer 1, No Project Condition
- - -	PCE Plume Boundary (5 ug/L) Layer 1, Scenario B
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

NORTH

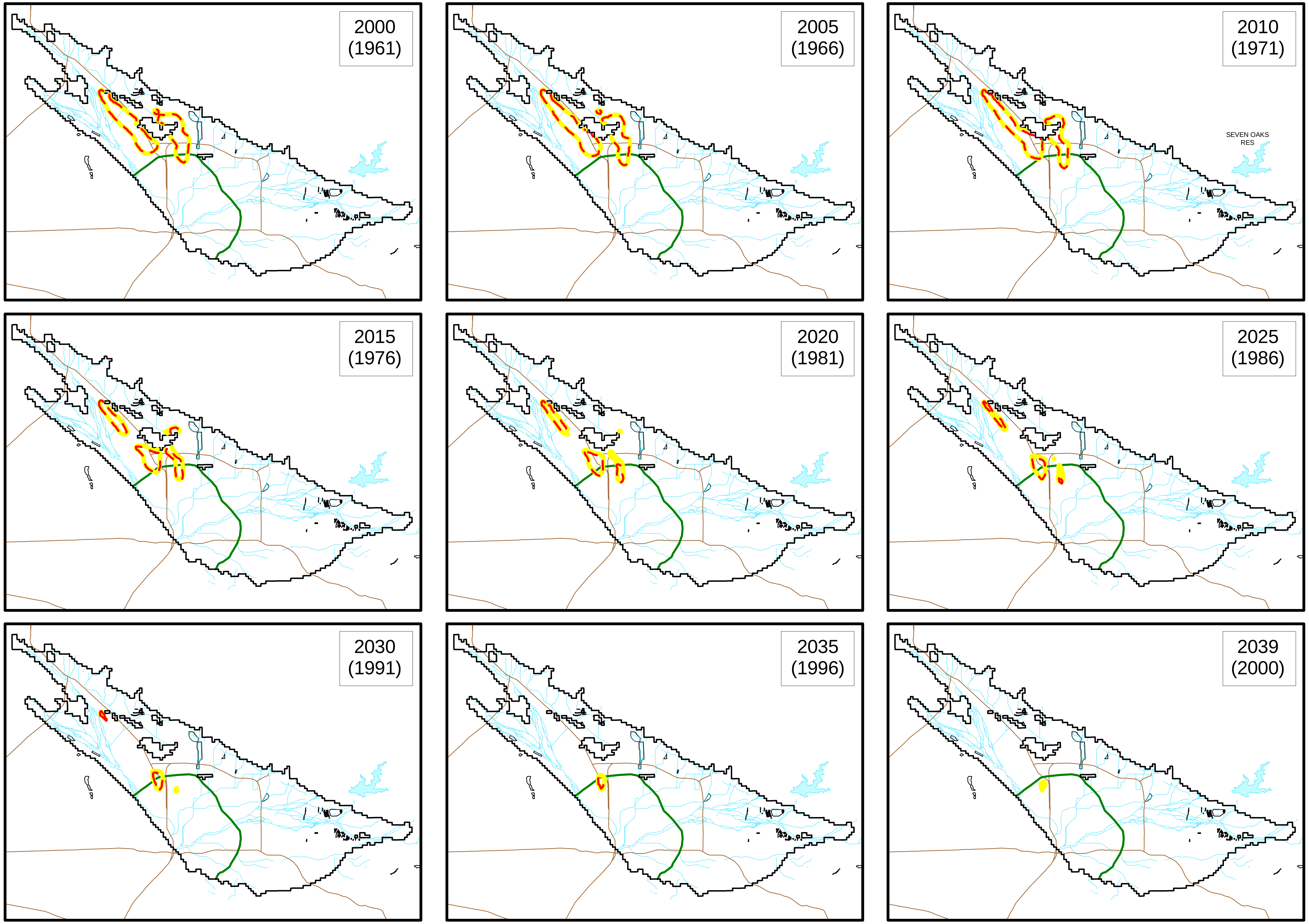
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 64

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PCE PLUME BOUNDARY LAYER 2 NO PROJECT CONDITION VERSUS SCENARIO B



EXPLANATION

Yellow Line	PCE Plume Boundary (5 ug/L) Layer 2, No Project Condition
– – –	PCE Plume Boundary (5 ug/L) Layer 2, Scenario B
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

Map Projection:
State Plane 1927 (California Zone V)

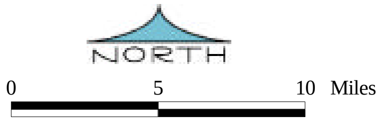
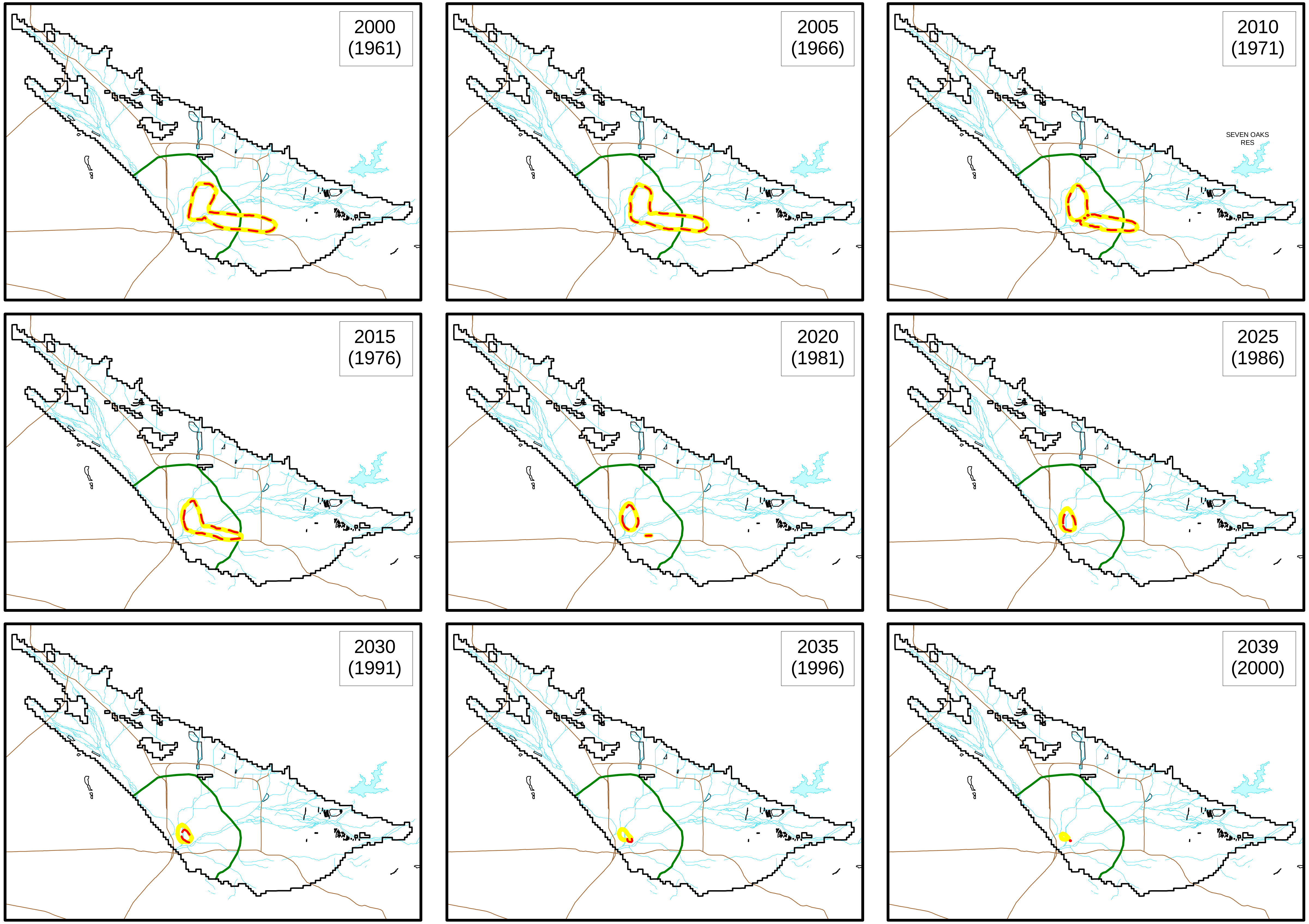


Figure B 65

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

TCE PLUME BOUNDARY
LAYER 1
NO PROJECT CONDITION
VERSUS SCENARIO C



EXPLANATION

Yellow Line 🟨	TCE Plume Boundary (5 ug/L) Layer 1, No Project Condition
– – –	TCE Plume Boundary (5 ug/L) Layer 1, Scenario C
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
☐	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

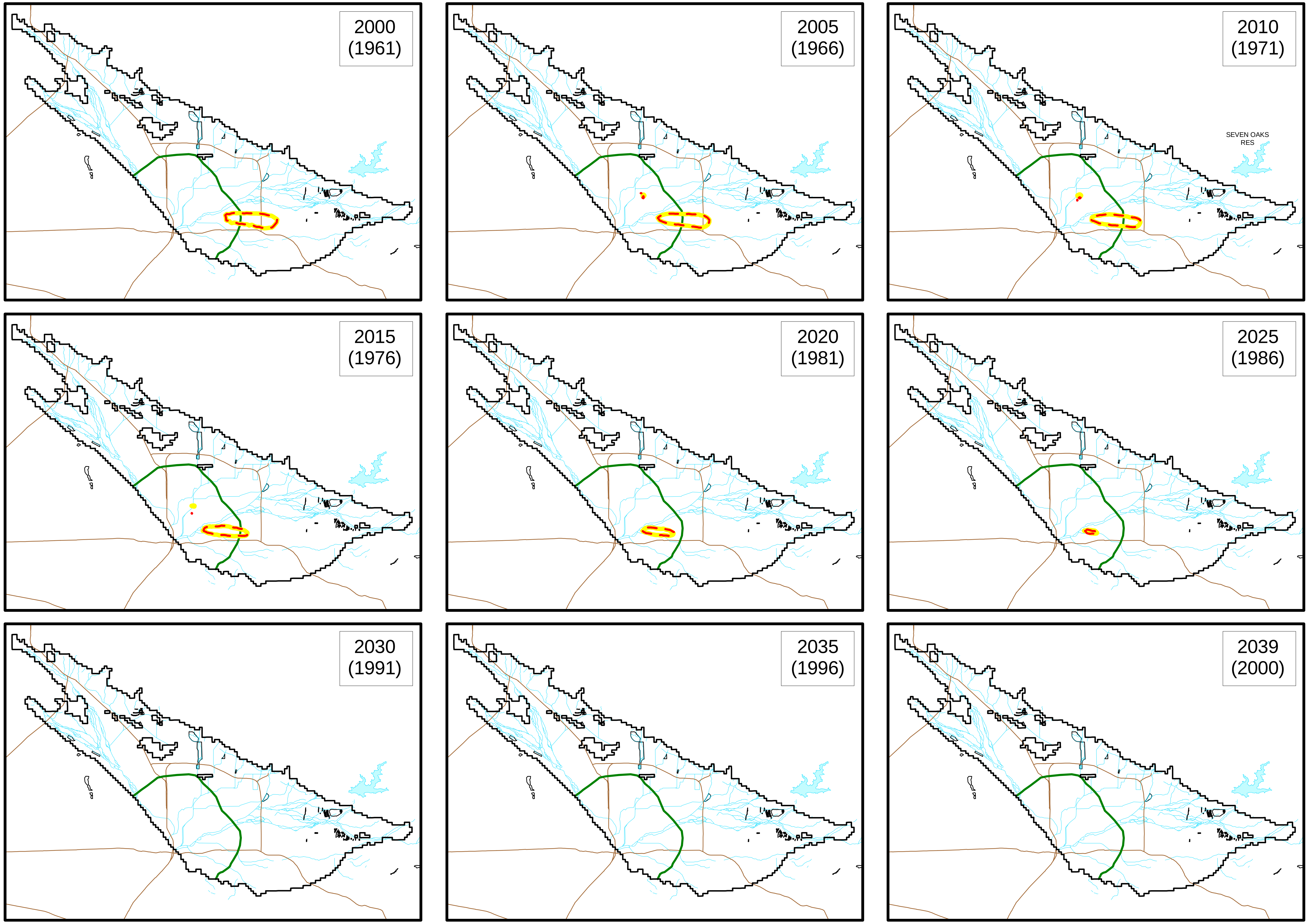
NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 66

TCE PLUME BOUNDARY
LAYER 2
NO PROJECT CONDITION VERSUS SCENARIO C



EXPLANATION

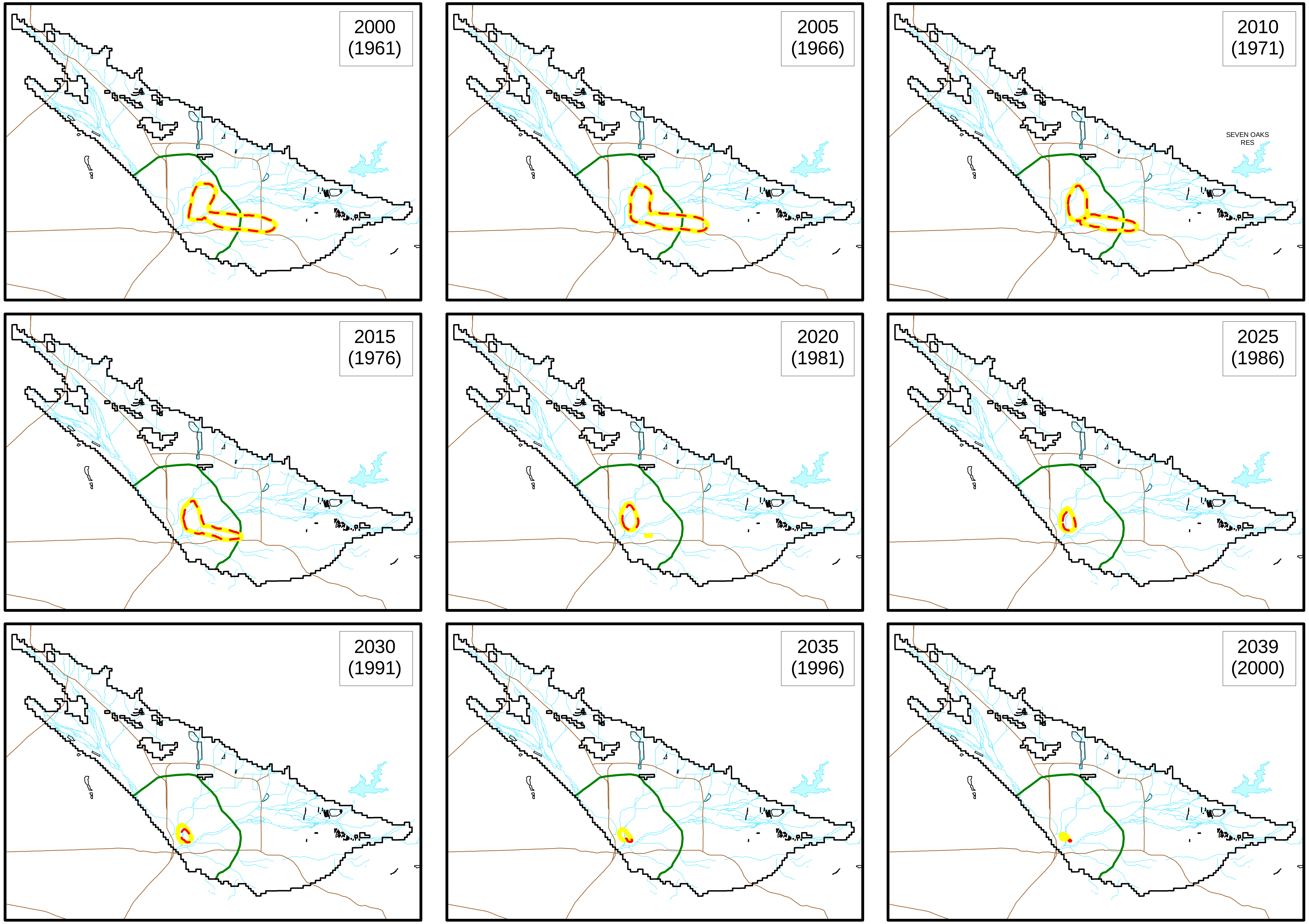
Yellow Line 🟨	TCE Plume Boundary (5 ug/L) Layer 2, No Project Condition
– – –	TCE Plume Boundary (5 ug/L) Layer 2, Scenario C
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

Map Projection:
State Plane 1927 (California Zone V)

Figure B 67

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

TCE PLUME BOUNDARY
LAYER 1
NO PROJECT CONDITION
VERSUS SCENARIO D



EXPLANATION

Yellow Line — TCE Plume Boundary (5 ug/L)
Layer 1, No Project Condition

- - - TCE Plume Boundary (5 ug/L)
Layer 1, Scenario D

2000 (1961) — Model Year
(Assumed Hydrological Year)

— Pressure Zone

▭ Model Grid of the San Bernardino
Basin Area Groundwater Model

— Streams or Rivers Within
Groundwater Basin Boundary

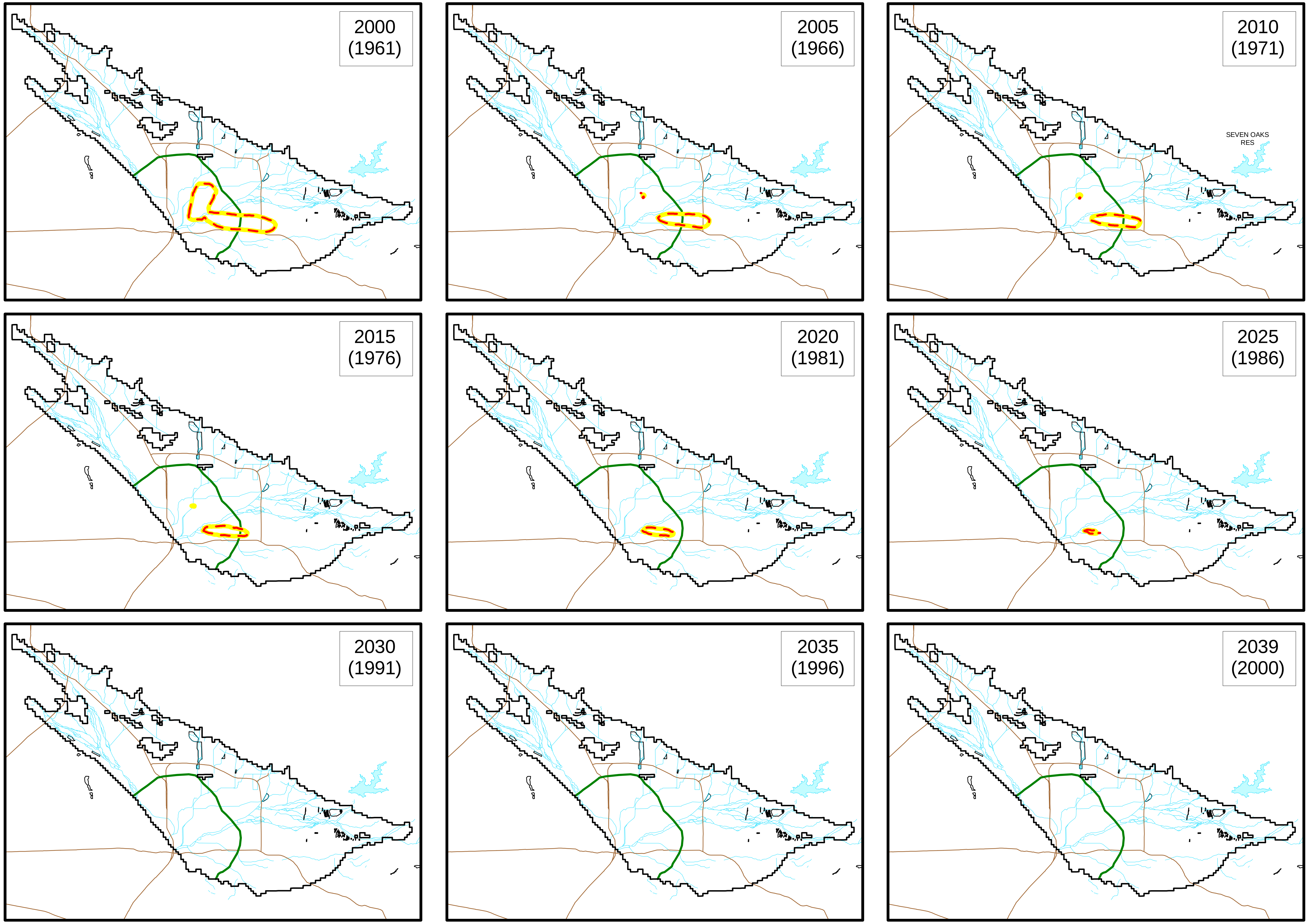
Spreading Grounds or Basins

— Freeway

Map Projection:
State Plane 1927 (California Zone V)

Figure B 68

TCE PLUME BOUNDARY
LAYER 2
NO PROJECT CONDITION VERSUS SCENARIO D



EXPLANATION

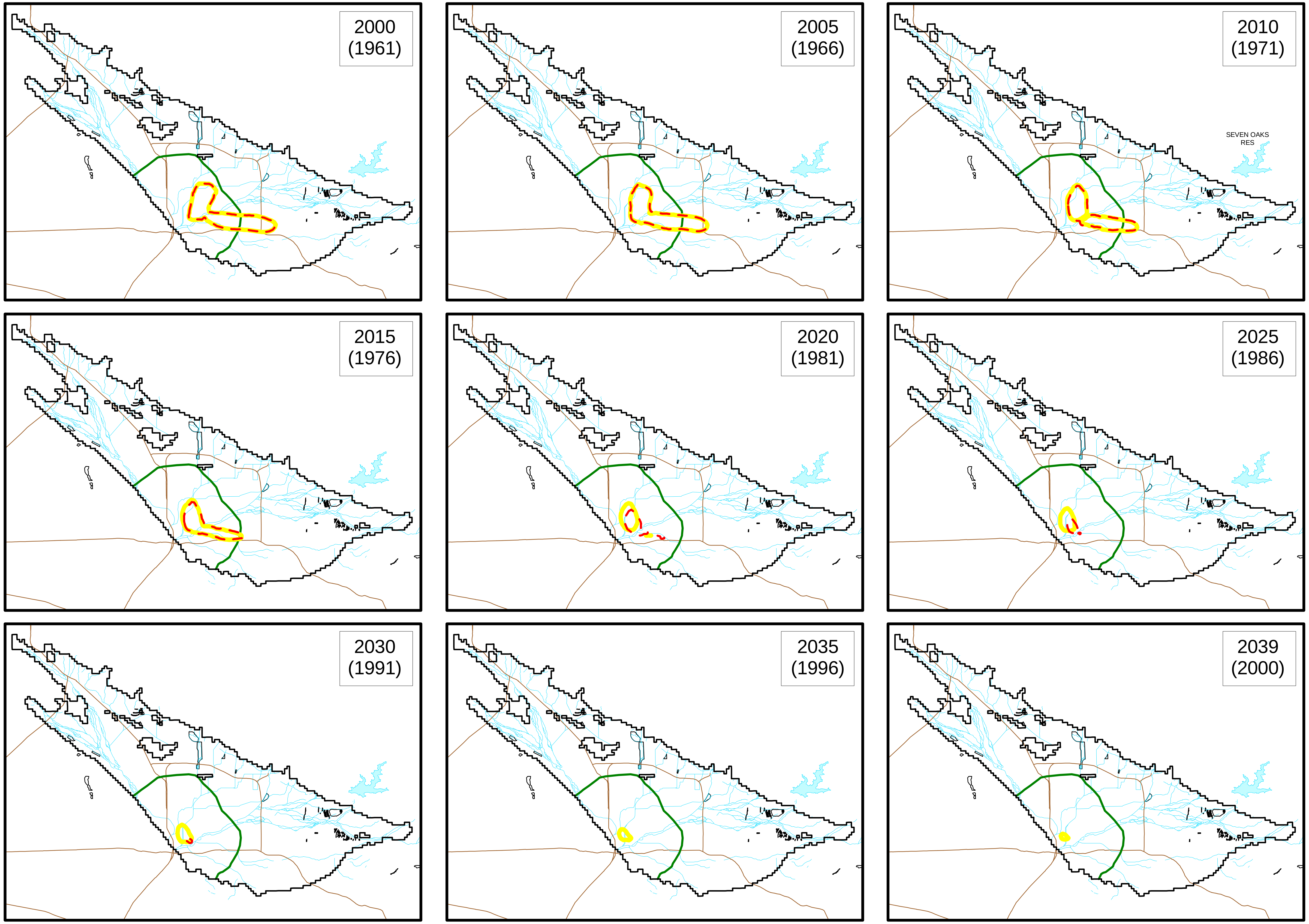
Yellow Line	TCE Plume Boundary (5 ug/L) Layer 2, No Project Condition
– – –	TCE Plume Boundary (5 ug/L) Layer 2, Scenario D
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

Map Projection:
State Plane 1927 (California Zone V)

Figure B 69

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

TCE PLUME BOUNDARY
LAYER 1
NO PROJECT CONDITION
VERSUS SCENARIO A



EXPLANATION

Yellow Line —	TCE Plume Boundary (5 ug/L) Layer 1, No Project Condition
- - -	TCE Plume Boundary (5 ug/L) Layer 1, Scenario A
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

NORTH

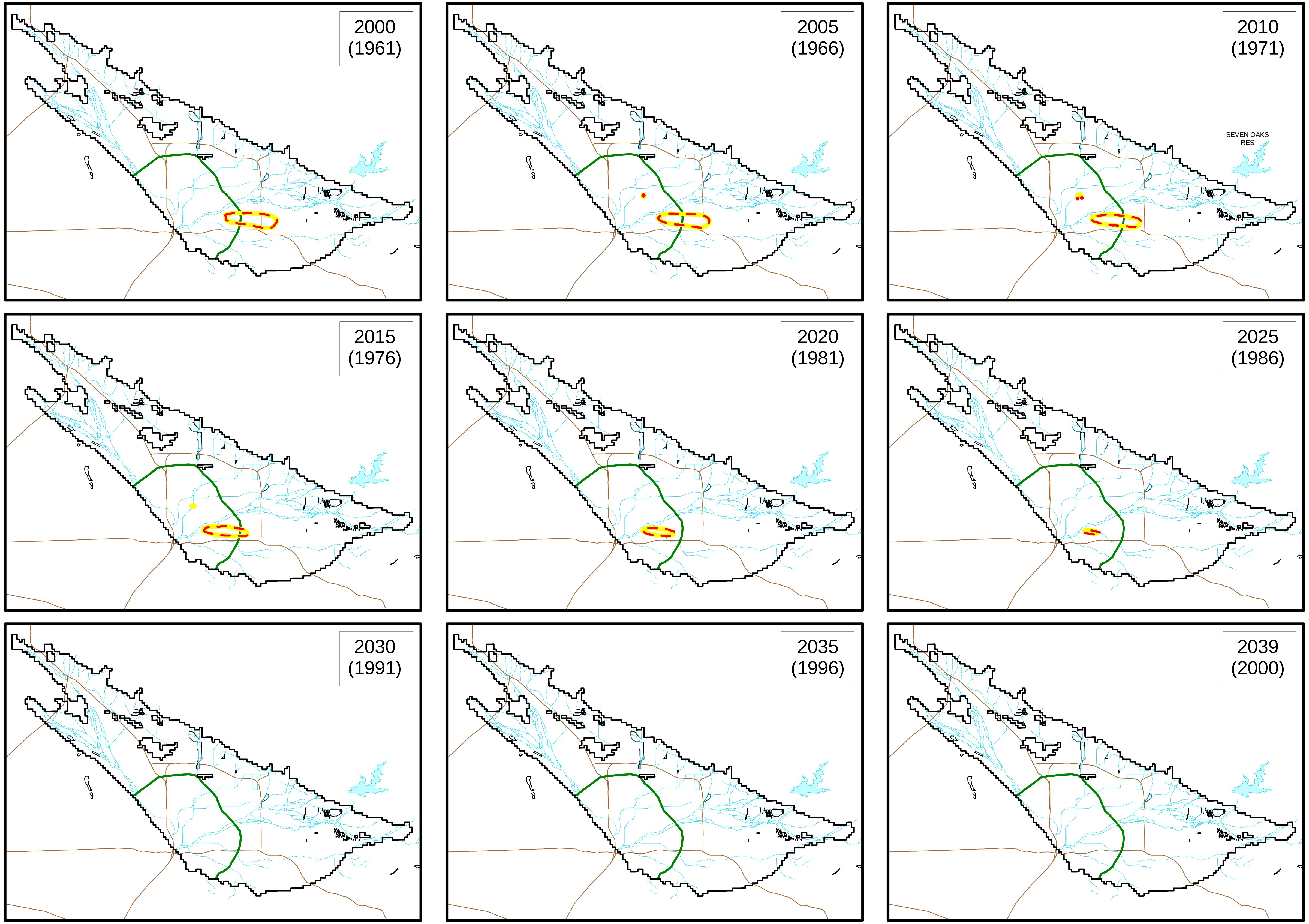
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 70

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

TCE PLUME BOUNDARY LAYER 2 NO PROJECT CONDITION VERSUS SCENARIO A



EXPLANATION

Yellow Line	TCE Plume Boundary (5 ug/L) Layer 2, No Project Condition
- - -	TCE Plume Boundary (5 ug/L) Layer 2, Scenario A
2000 (1961)	Model Year (Assumed Hydrological Year)
▬	Pressure Zone
☐	Model Grid of the San Bernardino Basin Area Groundwater Model
―	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
―	Freeway

NORTH

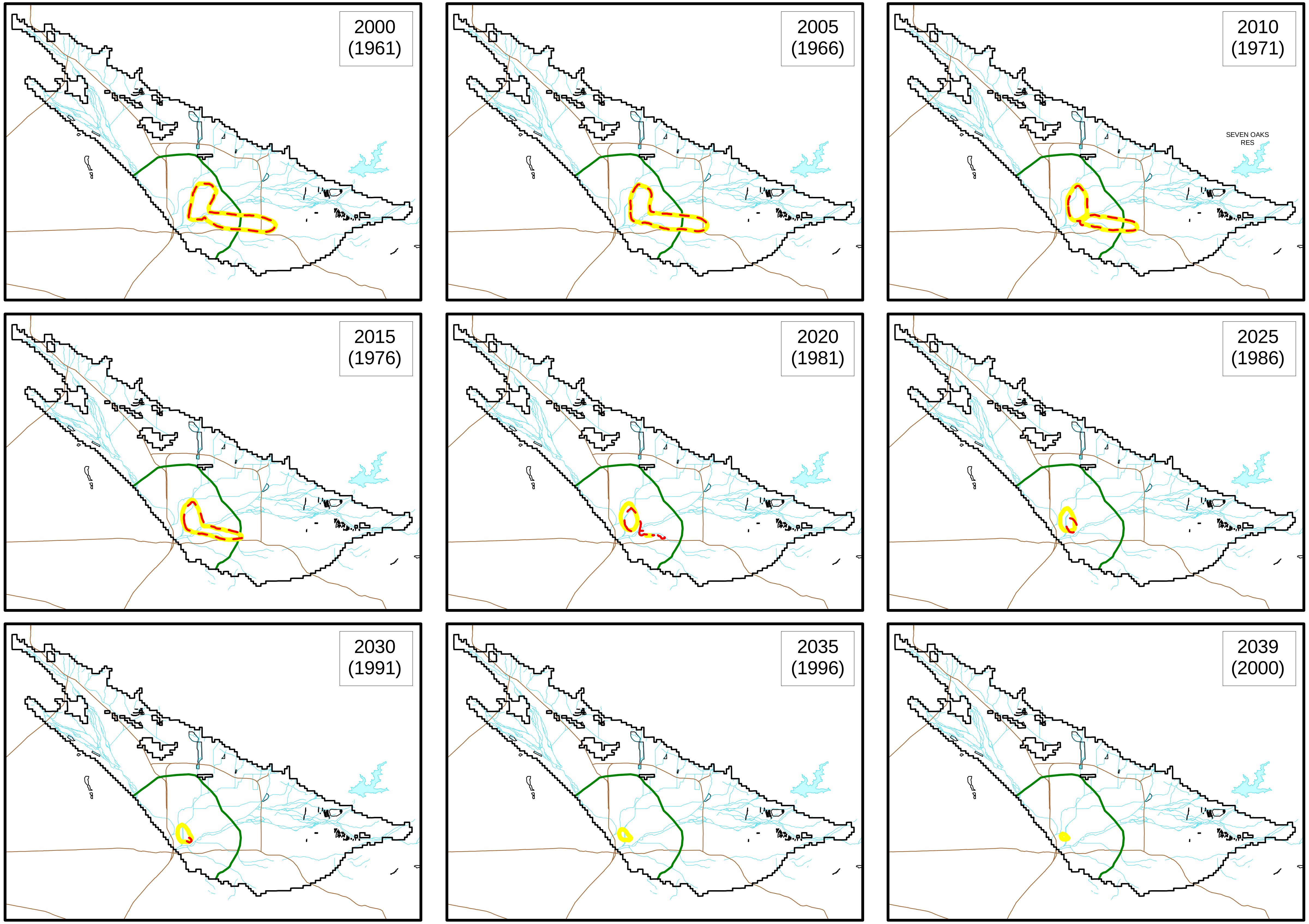
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 71

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

TCE PLUME BOUNDARY
LAYER 1
NO PROJECT CONDITION
VERSUS SCENARIO B



EXPLANATION

Yellow Line — TCE Plume Boundary (5 ug/L)
Layer 1, No Project Condition

- - - TCE Plume Boundary (5 ug/L)
Layer 1, Scenario B

2000 (1961) Model Year
(Assumed Hydrological Year)

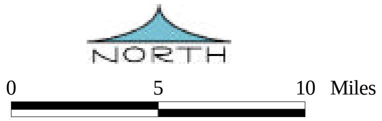
— Pressure Zone

▭ Model Grid of the San Bernardino
Basin Area Groundwater Model

— Streams or Rivers Within
Groundwater Basin Boundary

⬭ Spreading Grounds or Basins

— Freeway

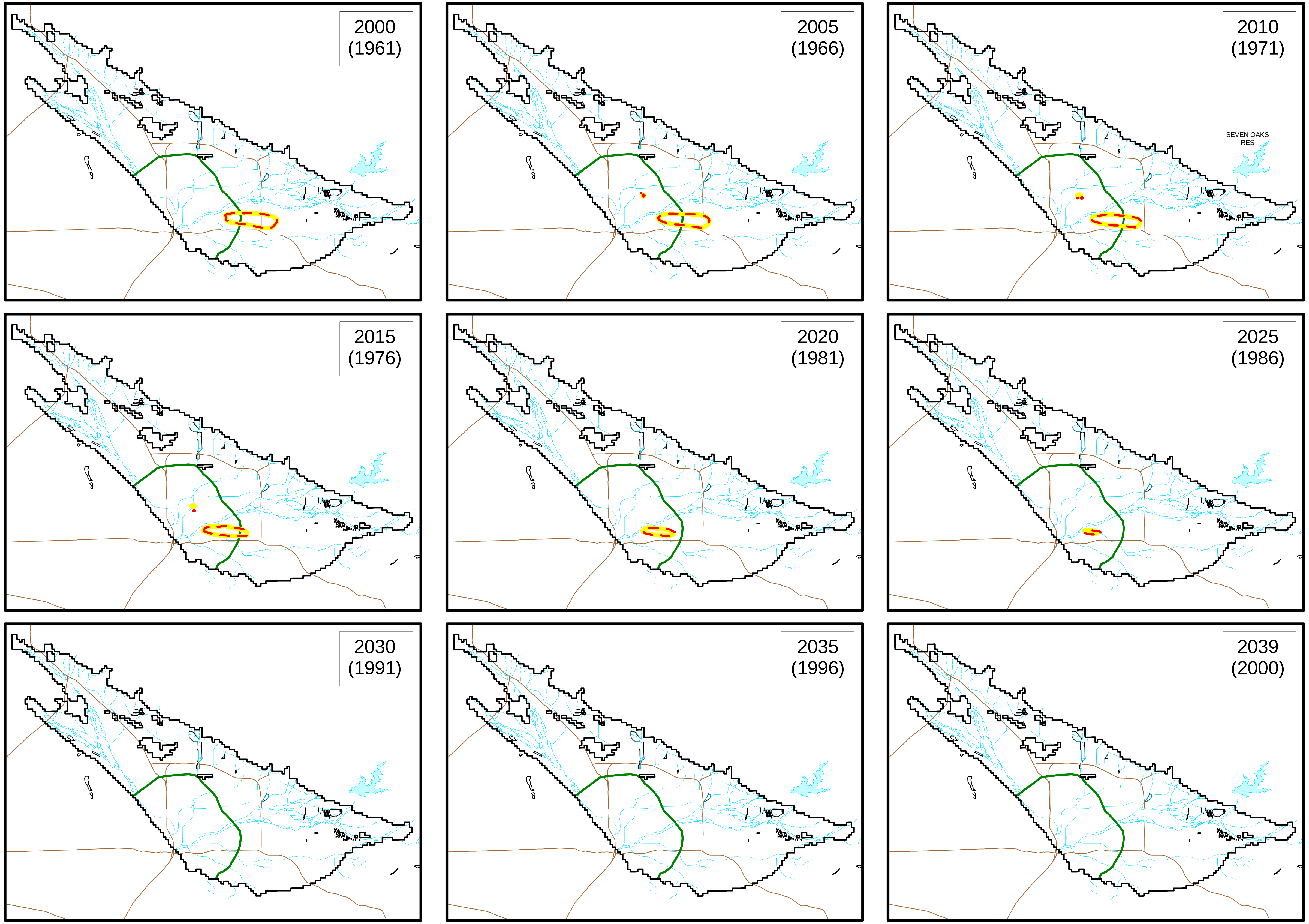


Map Projection:
State Plane 1927 (California Zone V)

Figure B 72

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

TCE PLUME BOUNDARY
LAYER 2
NO PROJECT CONDITION
VERSUS SCENARIO B



EXPLANATION

Yellow Line	TCE Plume Boundary (5 ug/L) Layer 2, No Project Condition
– – –	TCE Plume Boundary (5 ug/L) Layer 2, Scenario B
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
☐	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 73

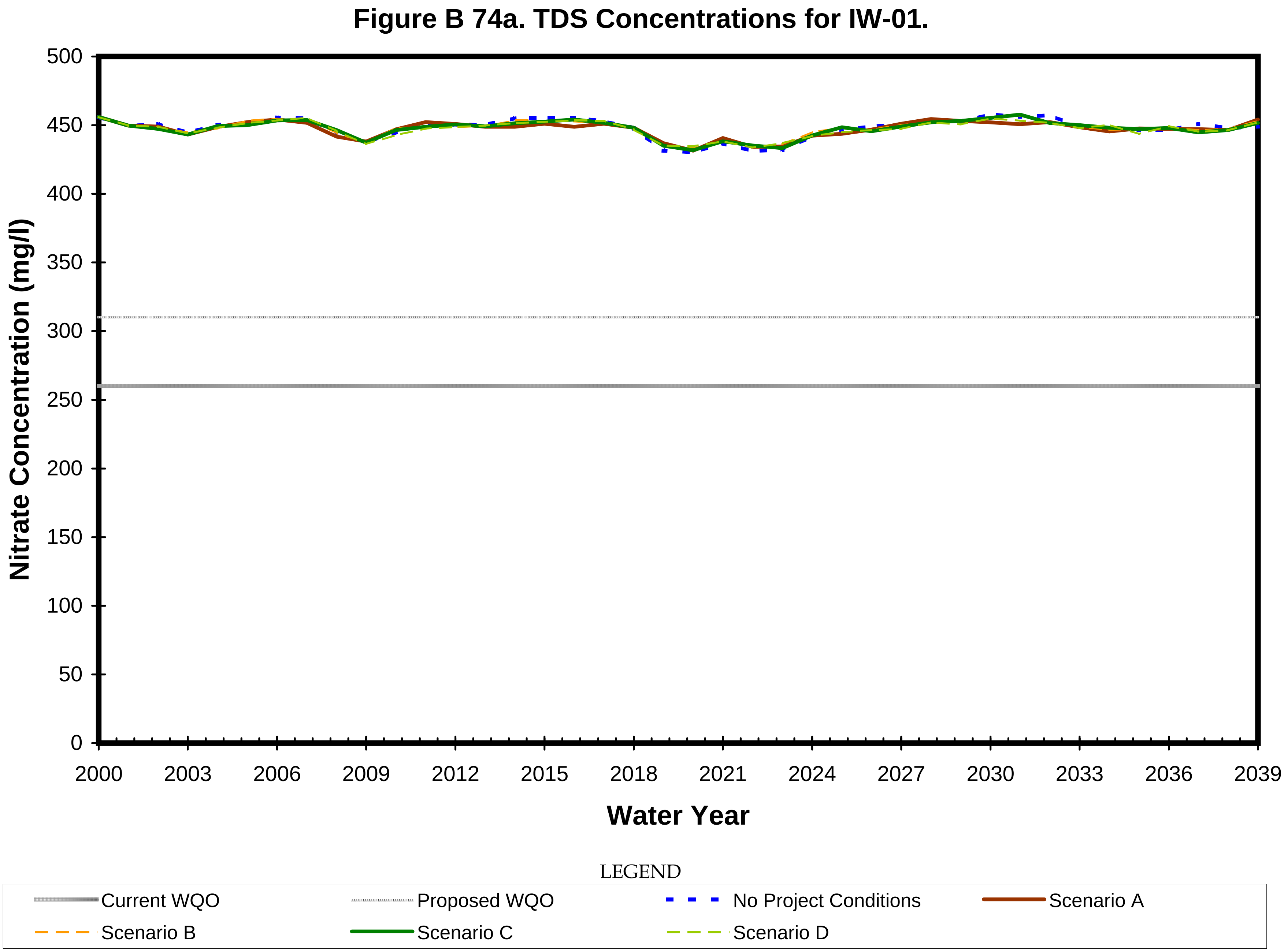
Figure B 74a. TDS Concentrations for IW-01.
Nitrate Concentration (mg/l)
500
450
400
350
300
250
200
150
100
50
0
2000
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
2033
2036
2039
Water Year
LEGEND
Current WQO
Proposed WQO
No Project Conditions
Scenario A
Scenario B
Scenario C
Scenario D

Figure B 74b. TDS Concentrations for IW-02.

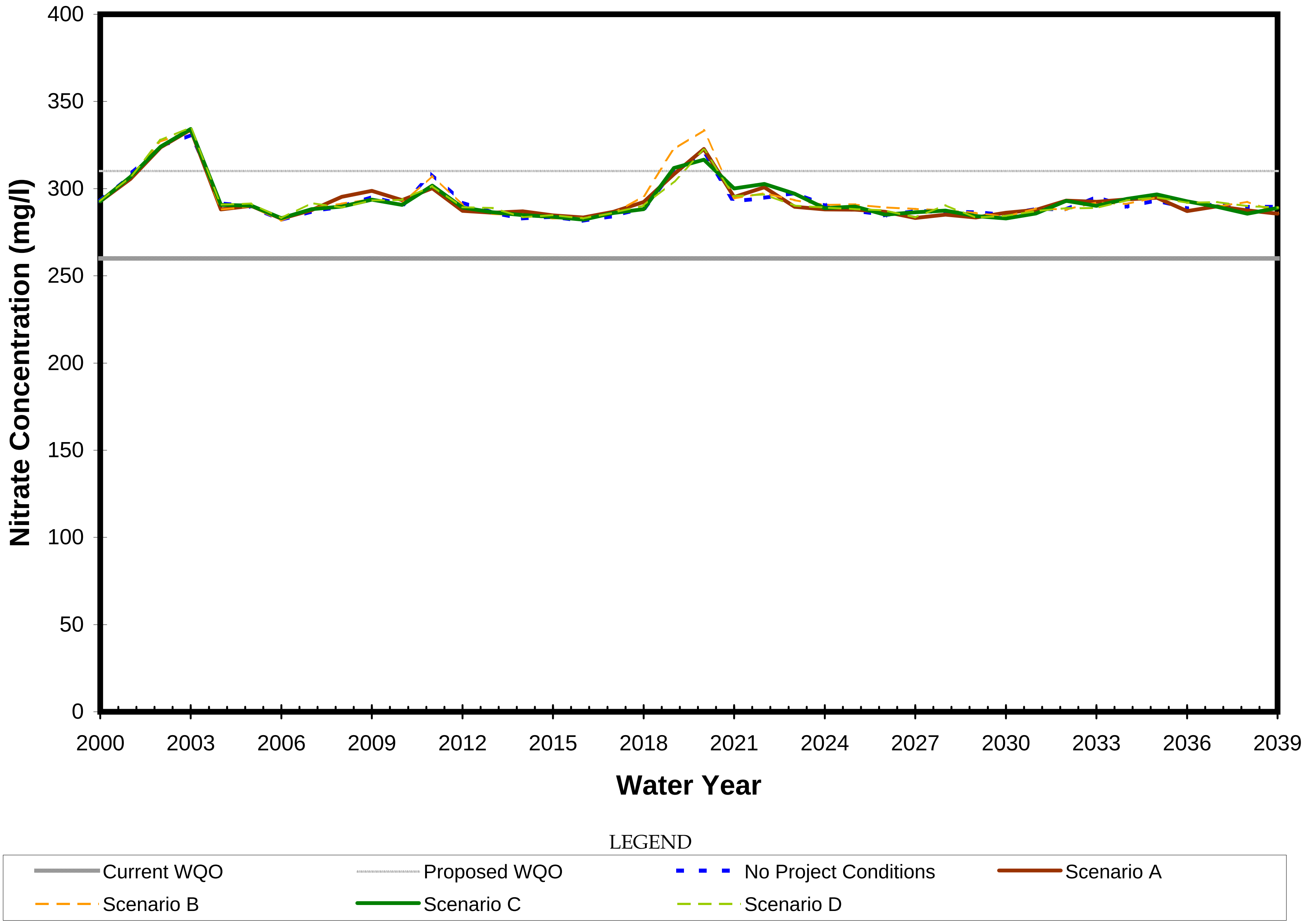


Figure B 74c. TDS Concentrations for IW-03.

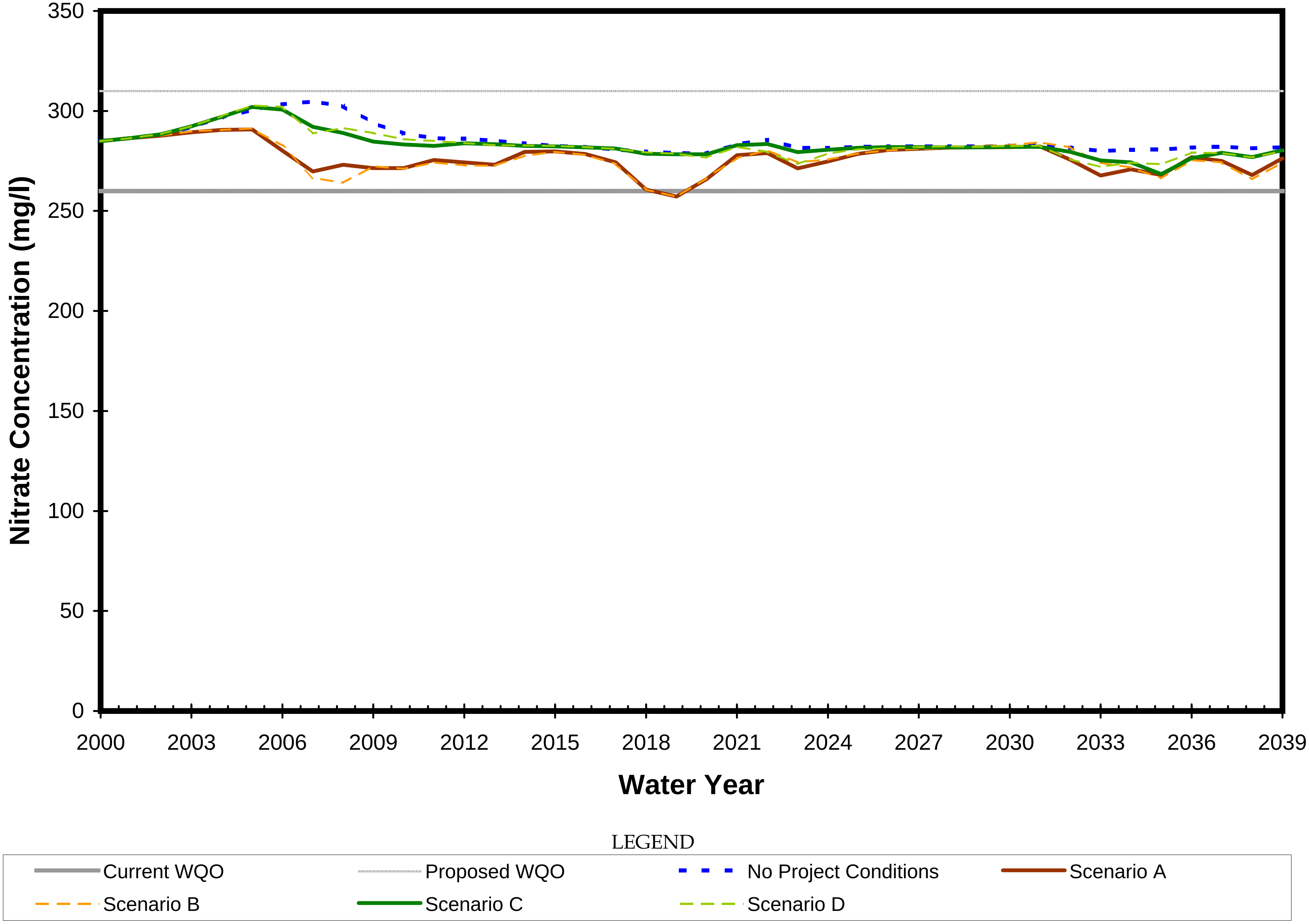


Figure B 74d. TDS Concentrations for IW-04.

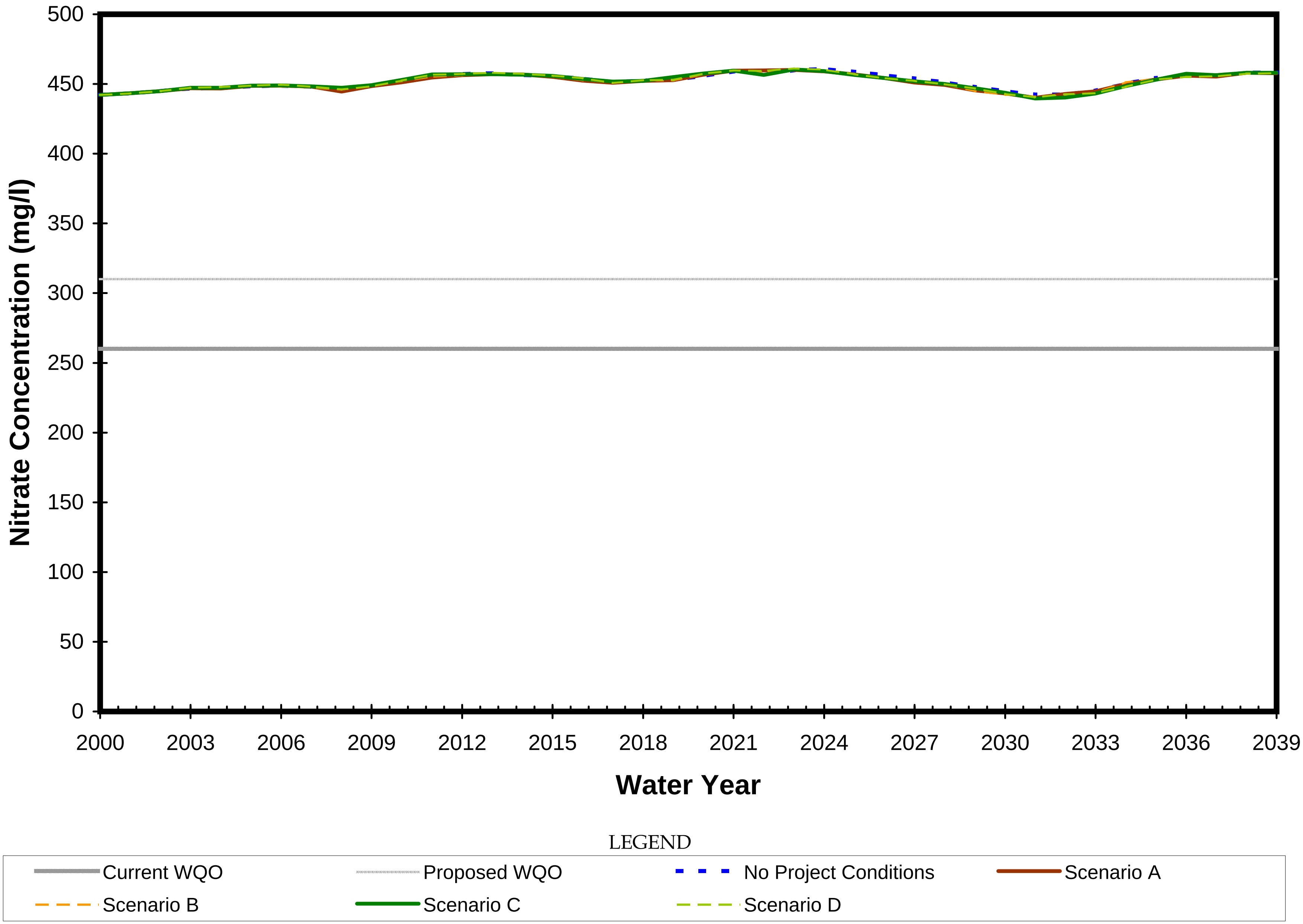


Figure B 74e. TDS Concentrations for IW-05.

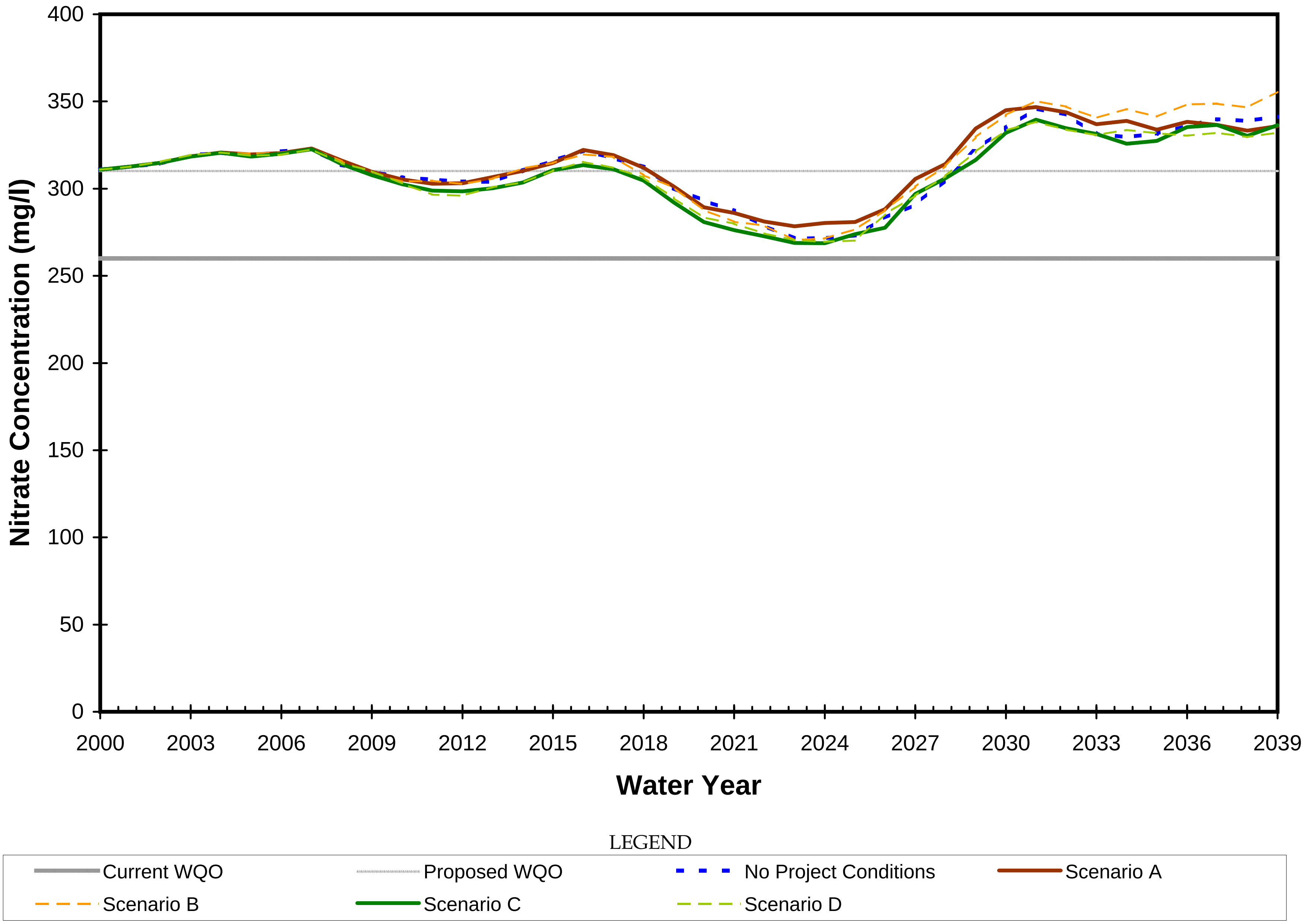
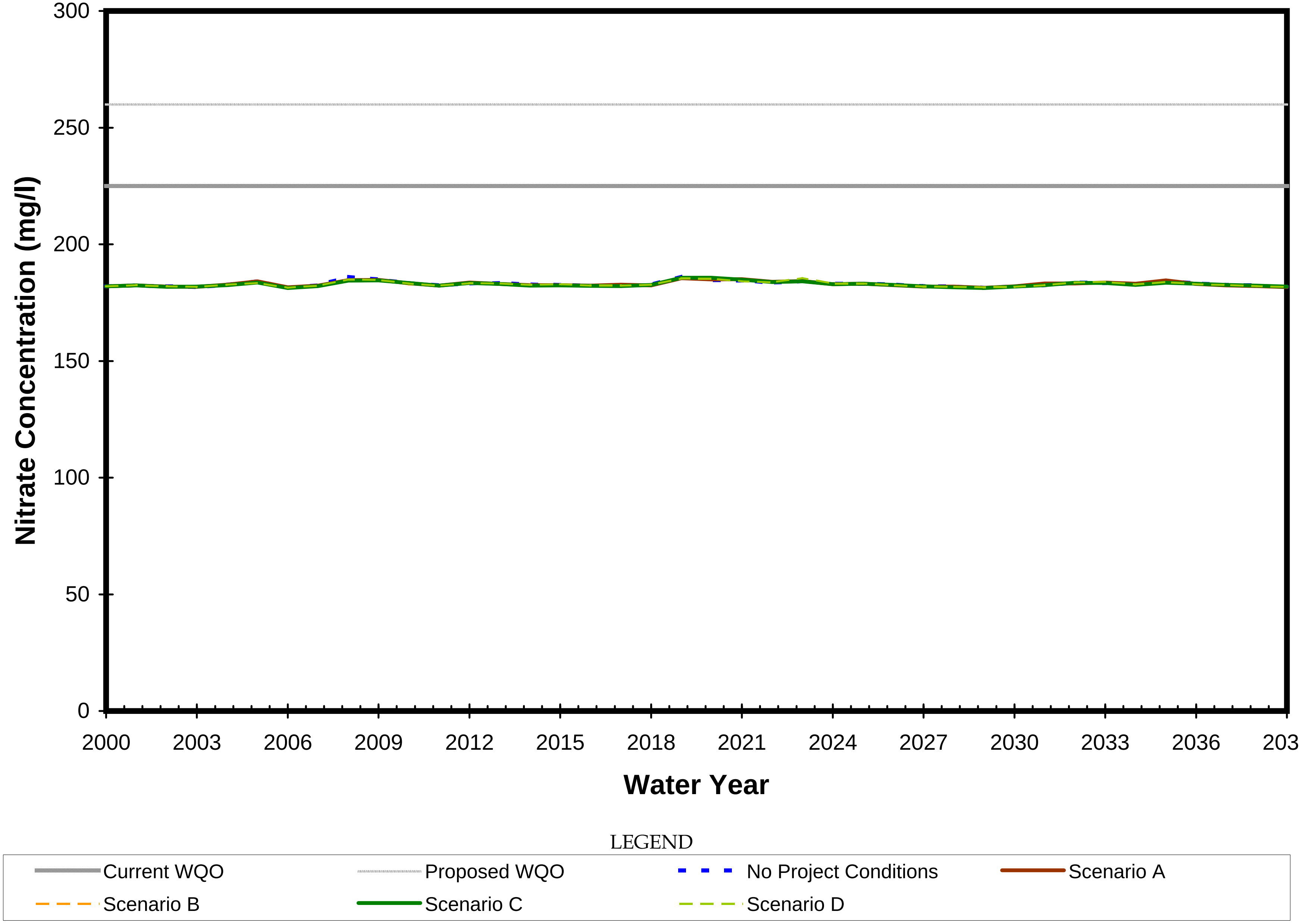


Figure B 74f. TDS Concentrations for IW-06.



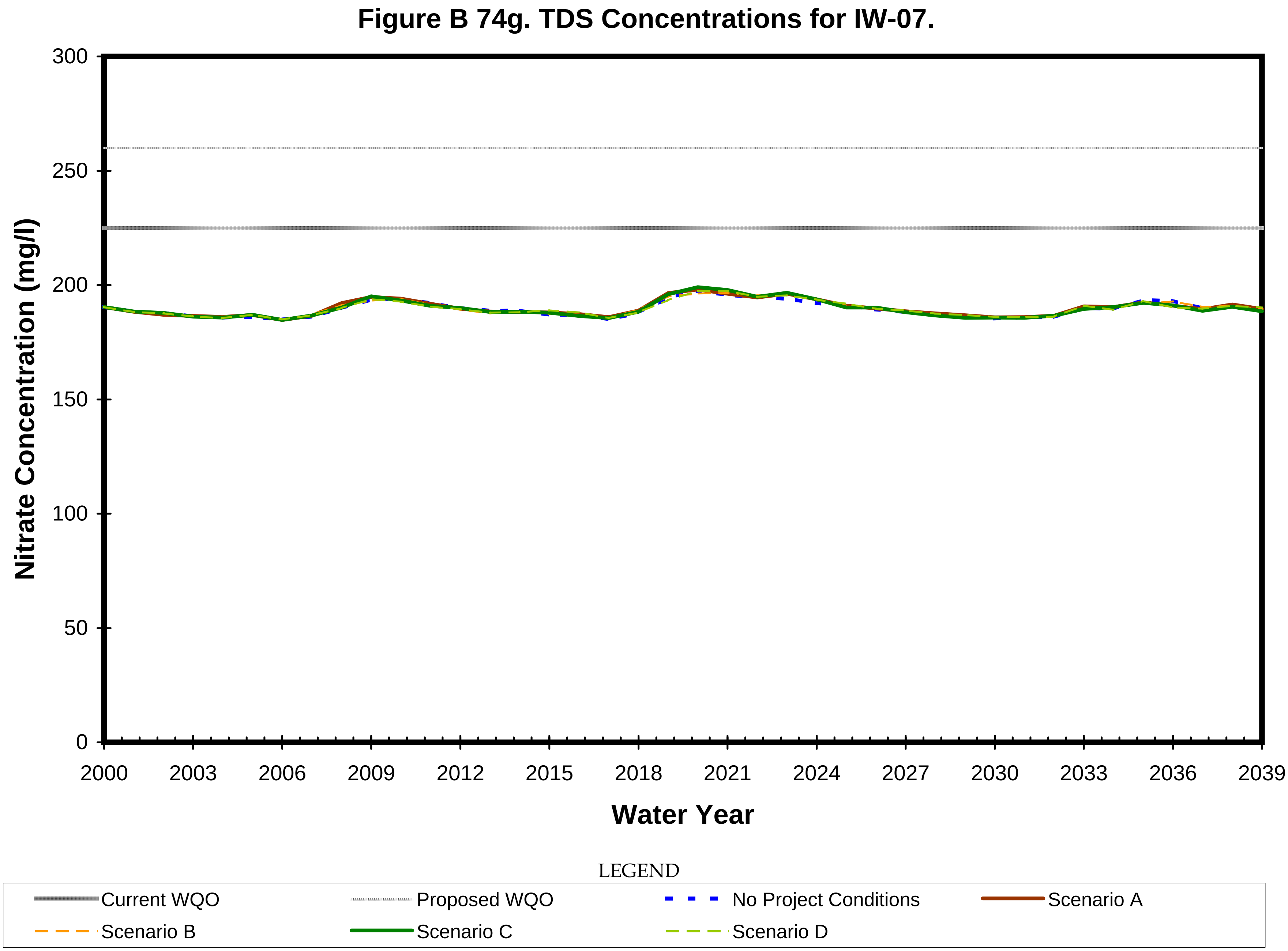


Figure B 74g. TDS Concentrations for IW-07.
Nitrate Concentration (mg/l)
300
250
200
150
100
50
0
2000
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
2033
2036
2039
Water Year
LEGEND
Current WQO
Proposed WQO
No Project Conditions
Scenario A
Scenario B
Scenario C
Scenario D

Figure B 74h. TDS Concentrations for IW-08.

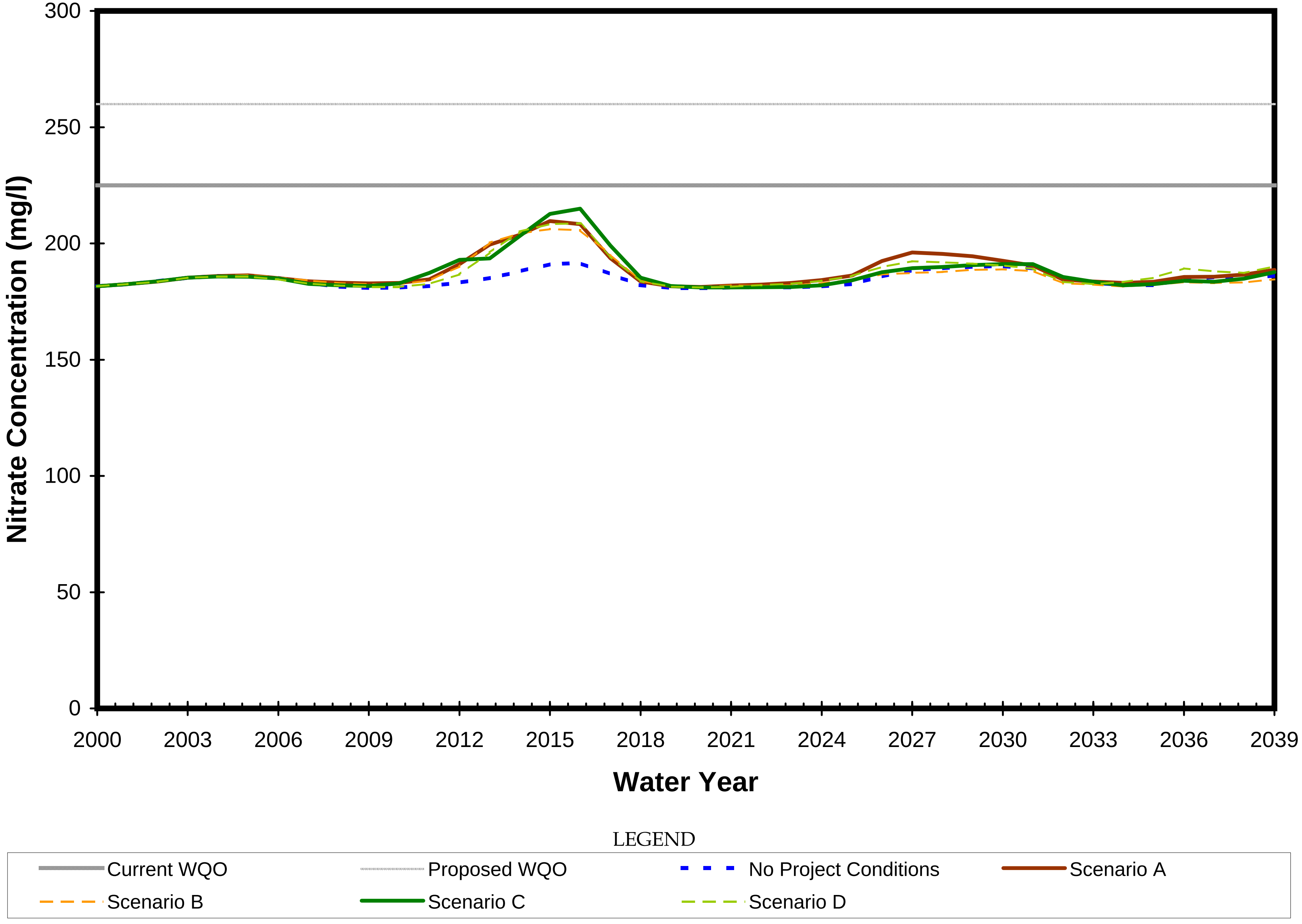


Figure B 74i. TDS Concentrations for IW-09.

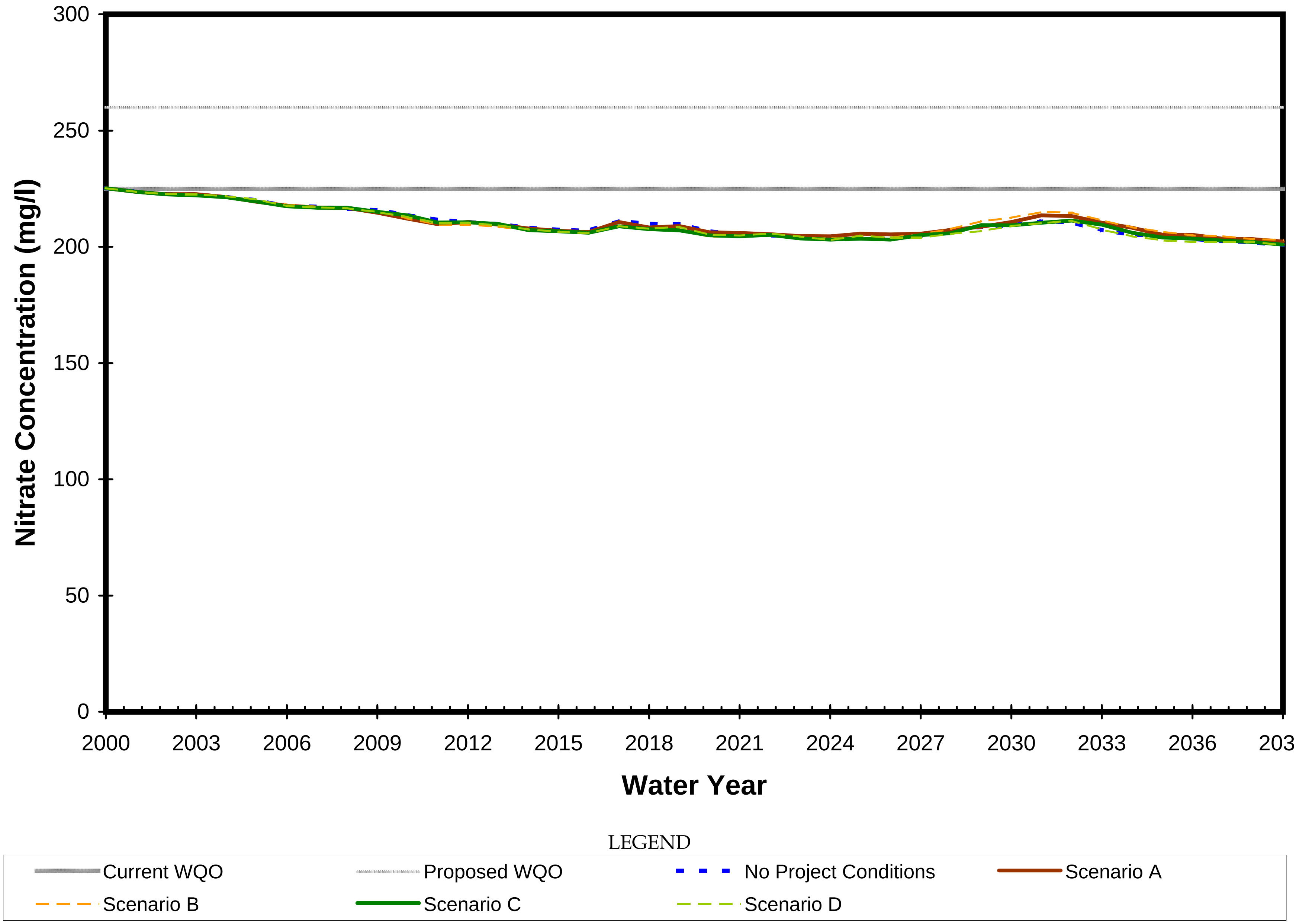


Figure B 74j. TDS Concentrations for IW-10.

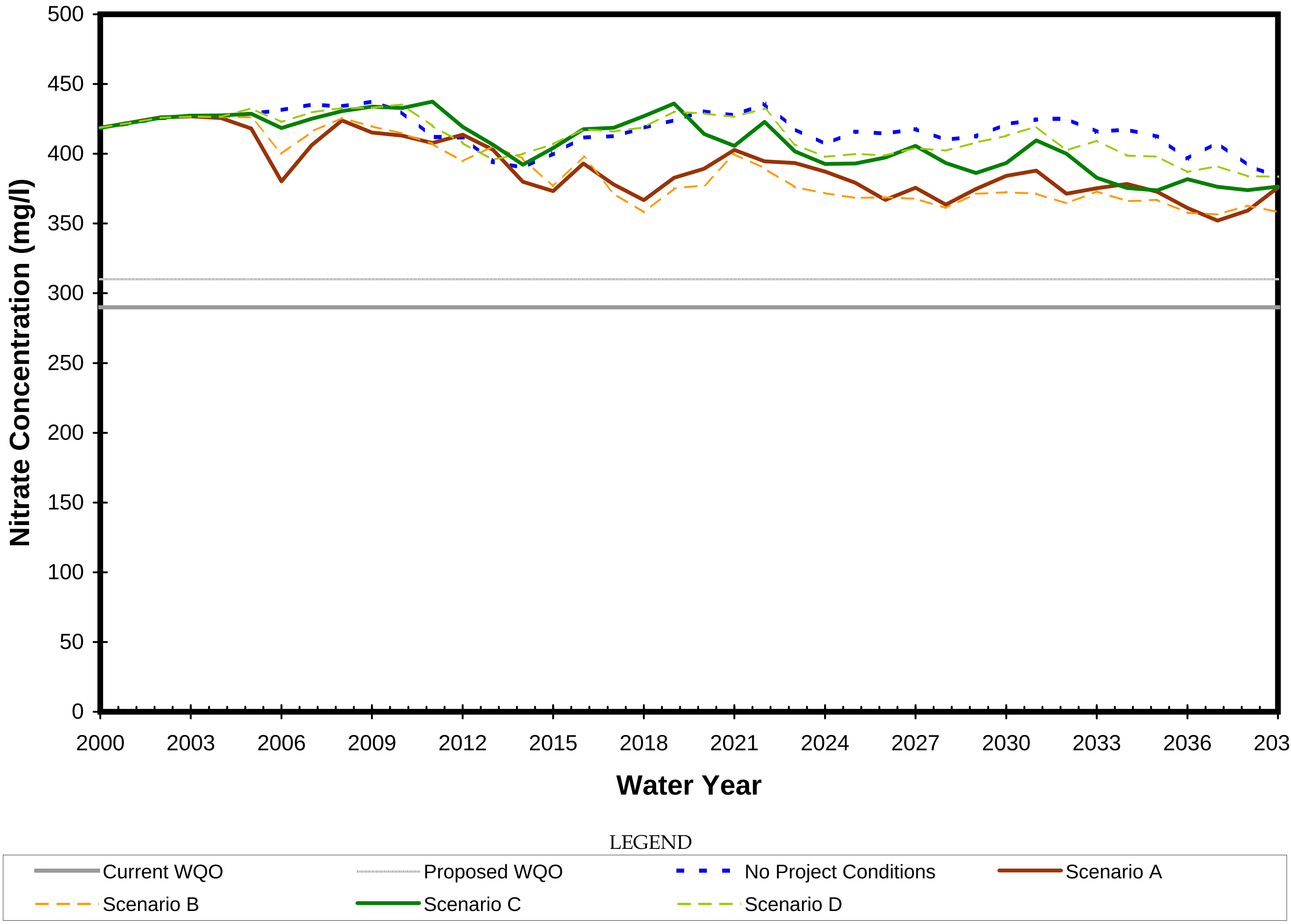


Figure B 74k. TDS Concentrations for IW-11.

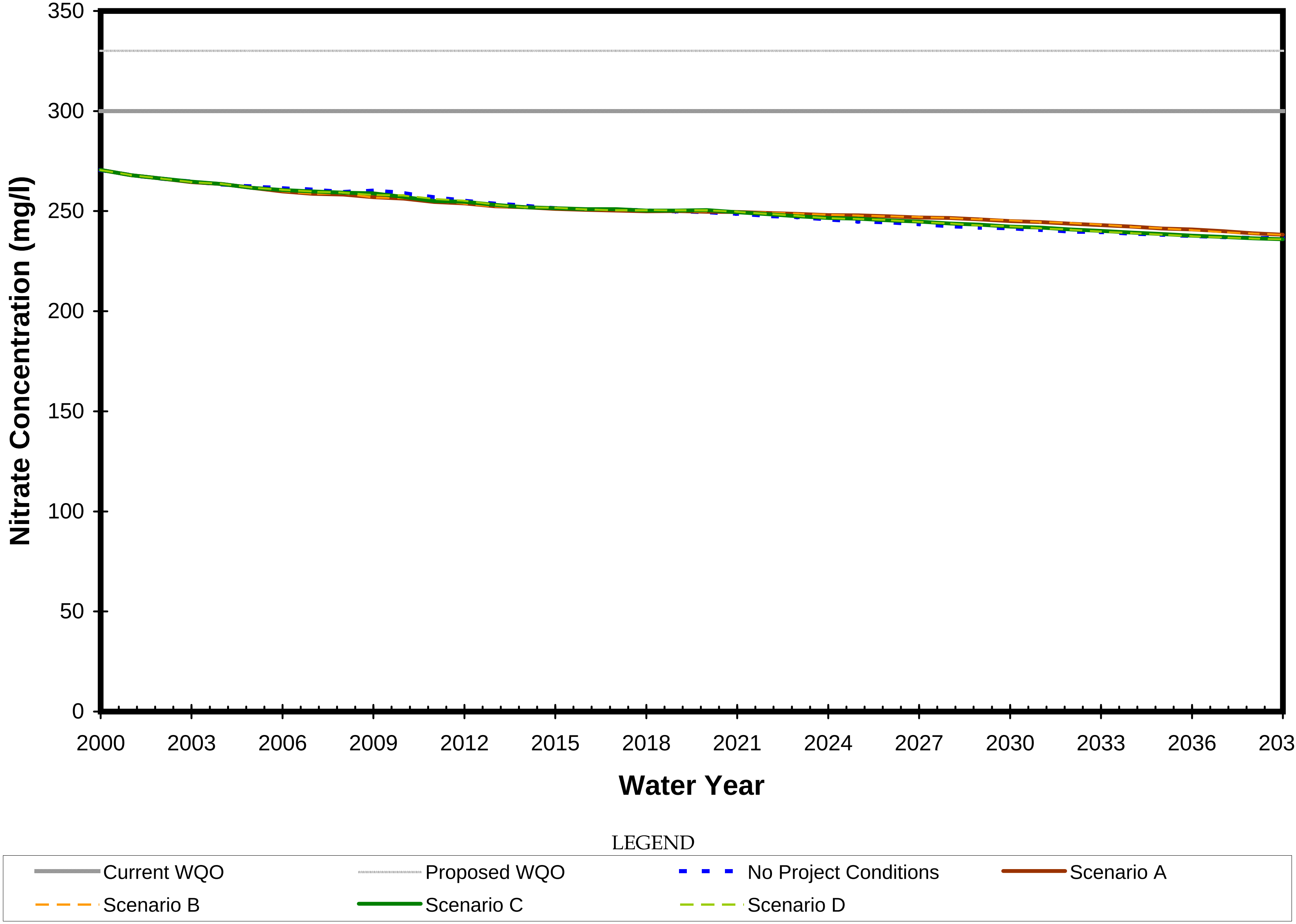


Figure B 74l. TDS Concentrations for IW-12.

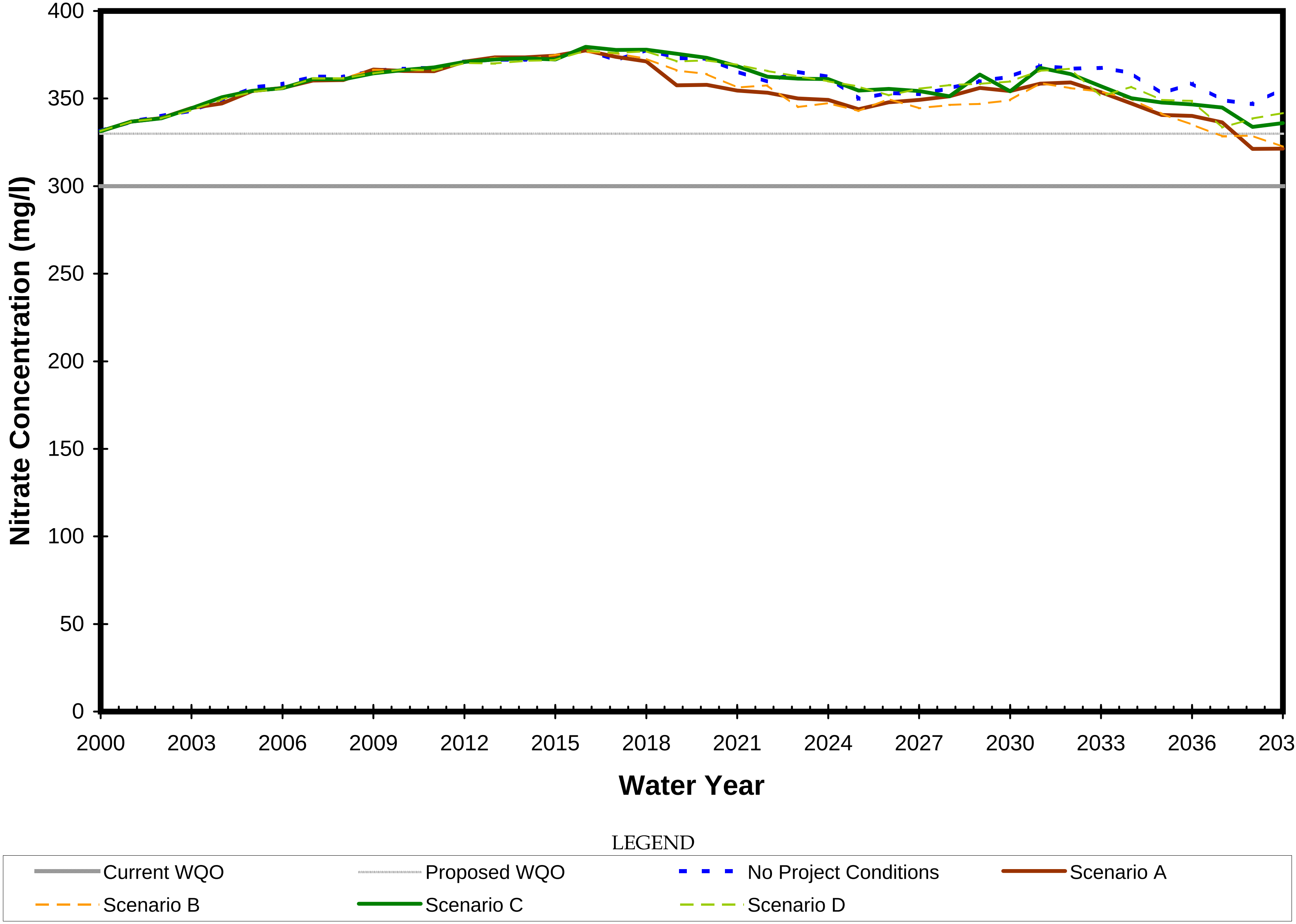


Figure B 74m. TDS Concentrations for IW-13.

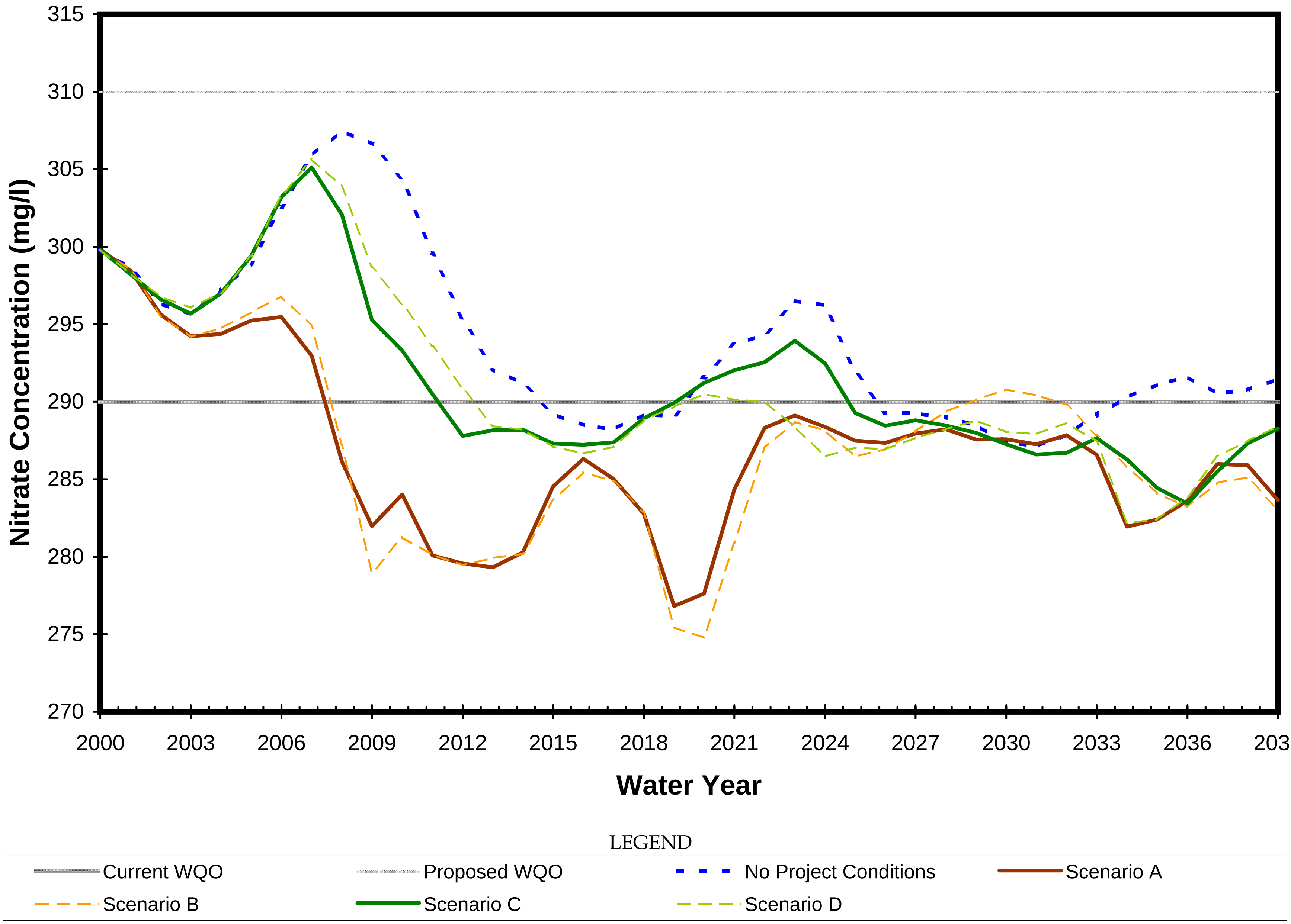


Figure B 74n. TDS Concentrations for IW-14.

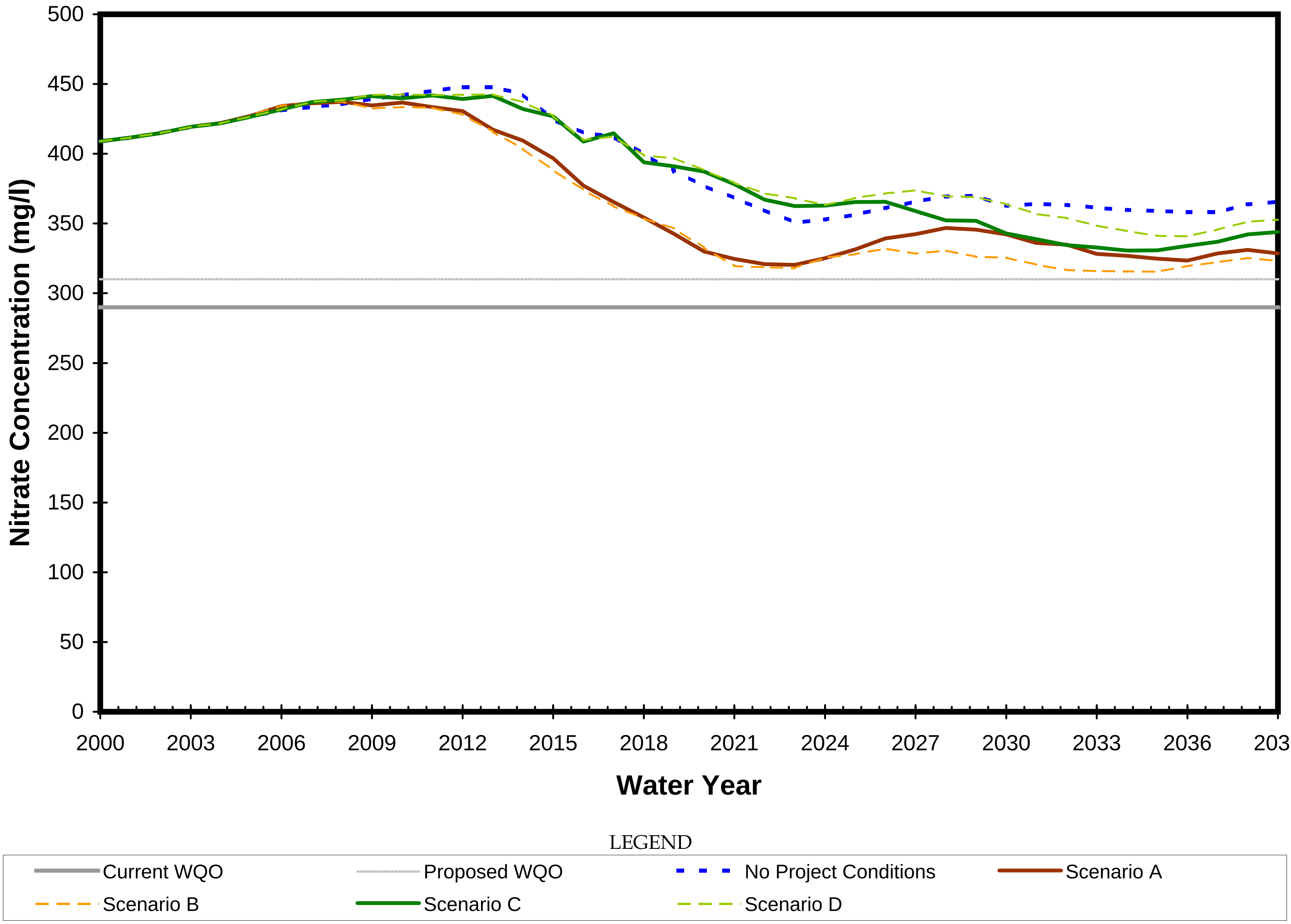


Figure B 74o. TDS Concentrations for IW-15.

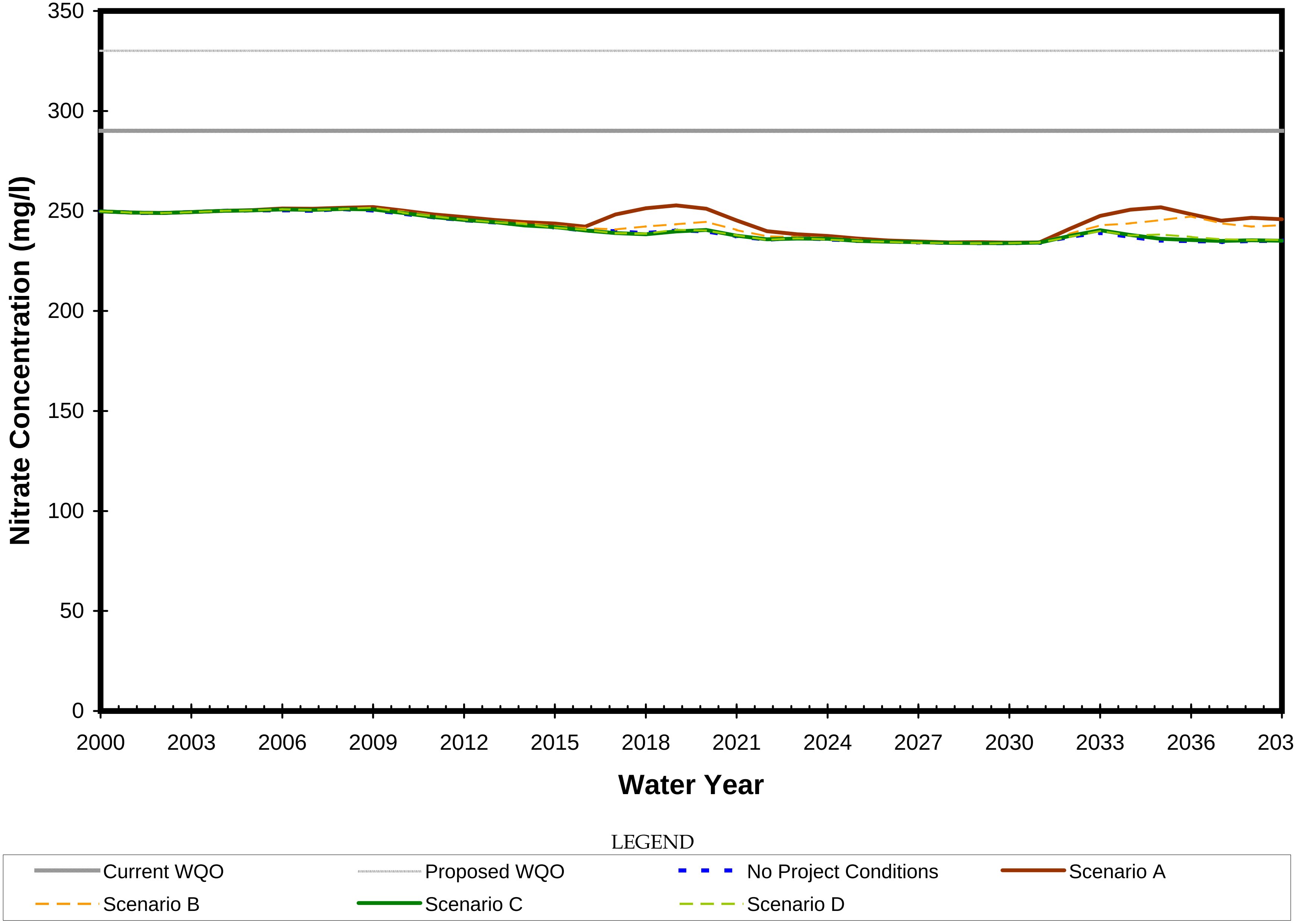


Figure B 74p. TDS Concentrations for IW-16.

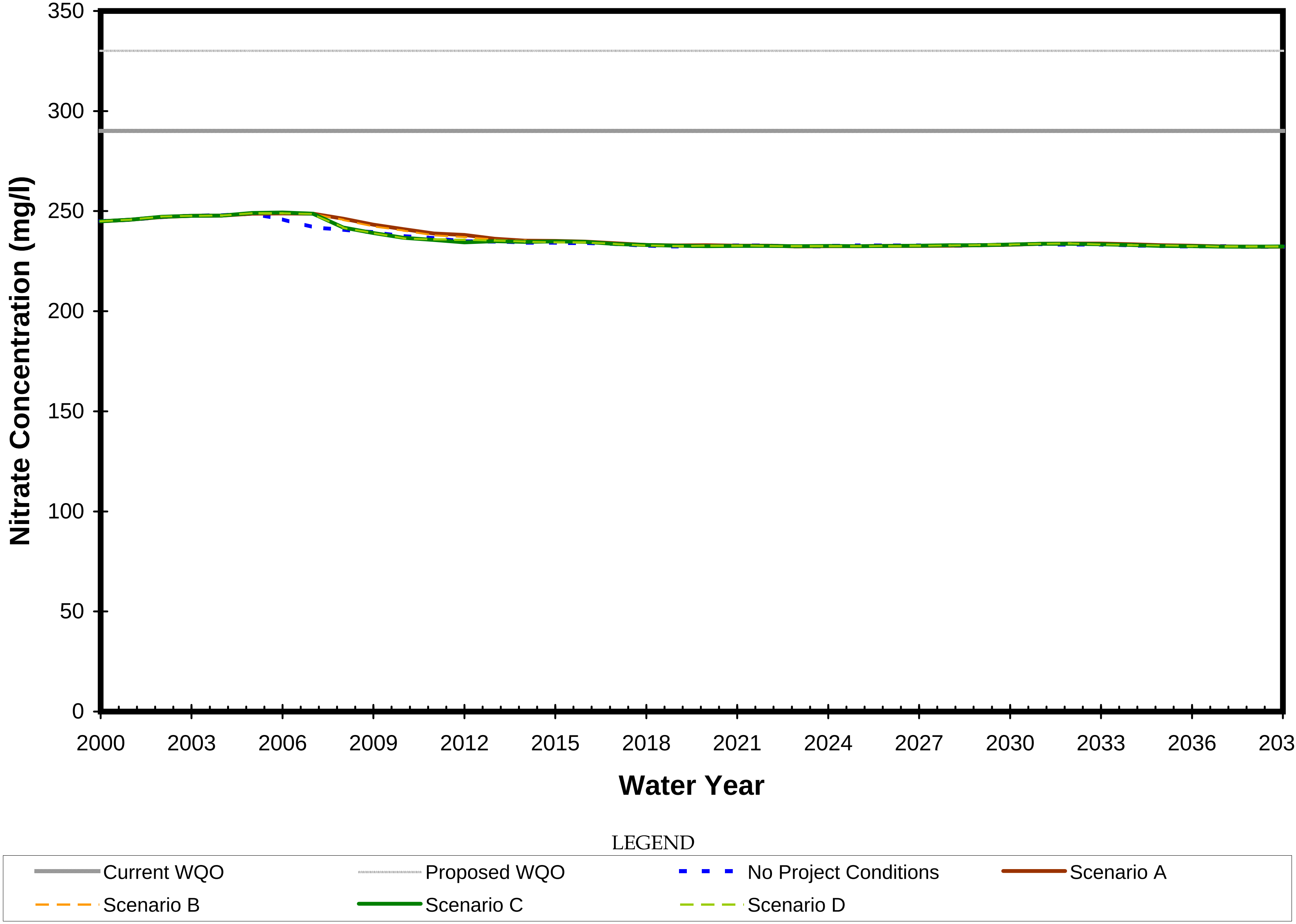
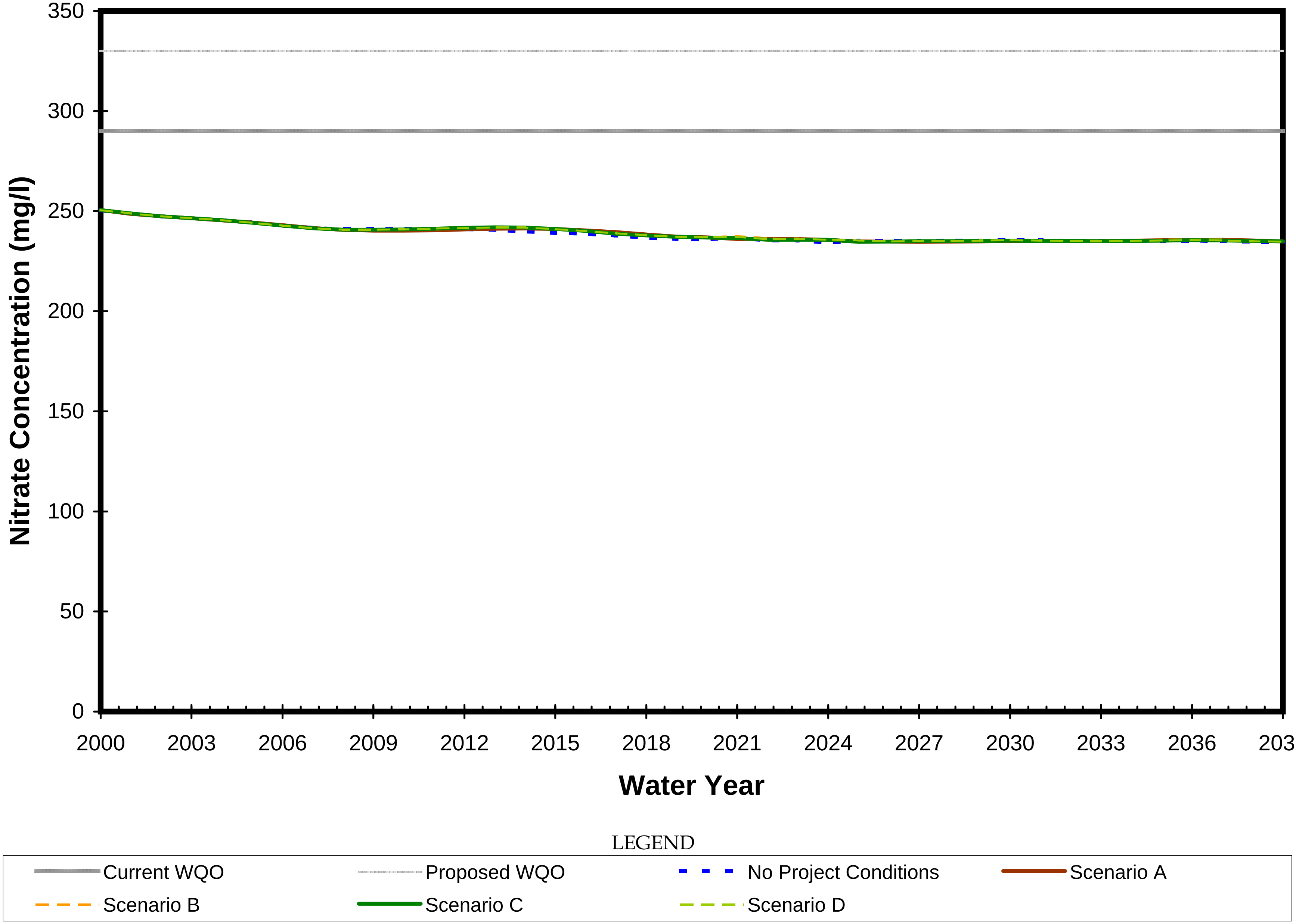


Figure B 74q. TDS Concentrations for IW-17.



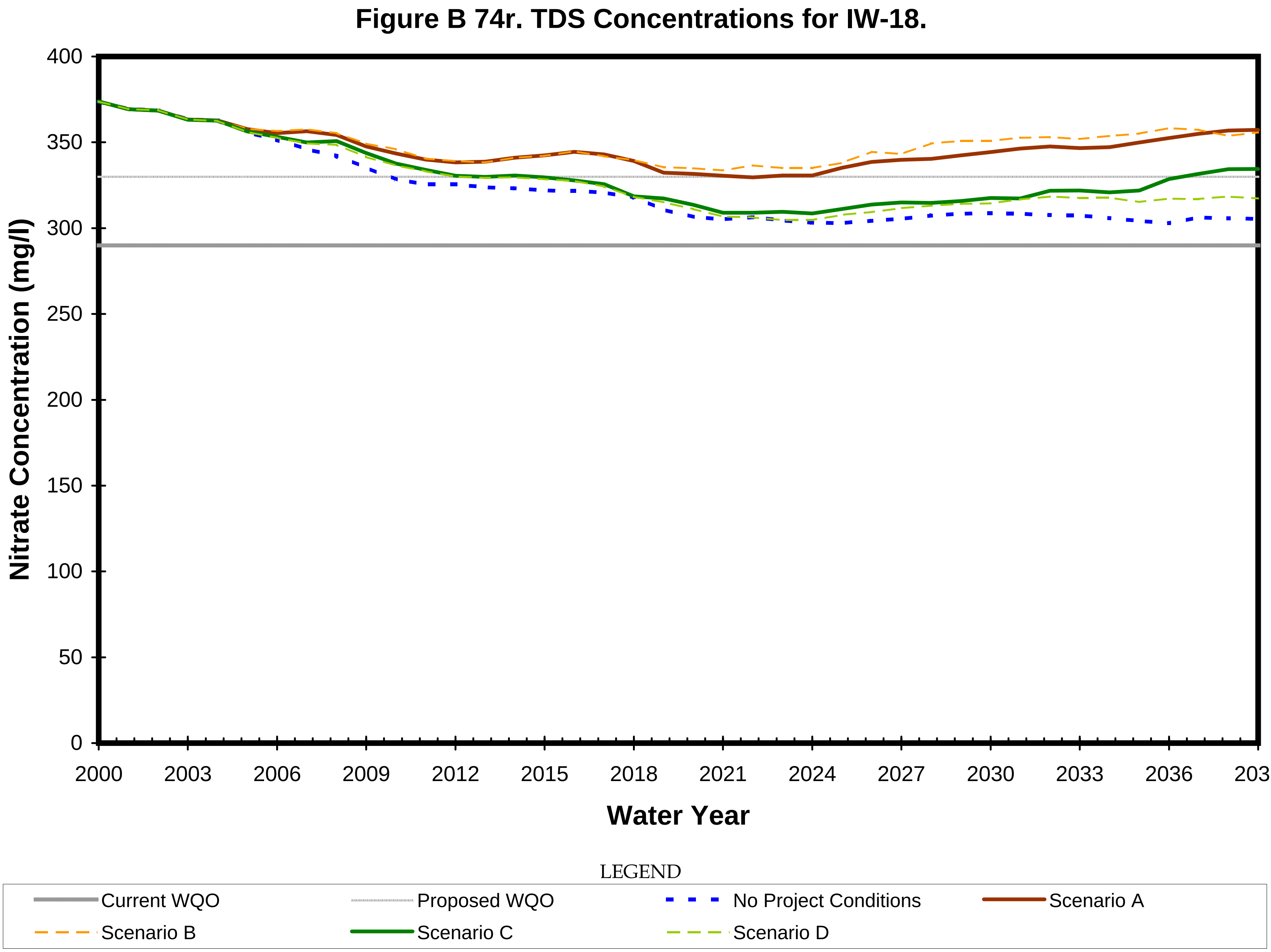


Figure B 74r. TDS Concentrations for IW-18.
Nitrate Concentration (mg/l)
400
350
300
250
200
150
100
50
0
2000
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
2033
2036
2039
Water Year
LEGEND
Current WQO
Proposed WQO
No Project Conditions
Scenario A
Scenario B
Scenario C
Scenario D

Figure B 74s. TDS Concentrations for IW-19.

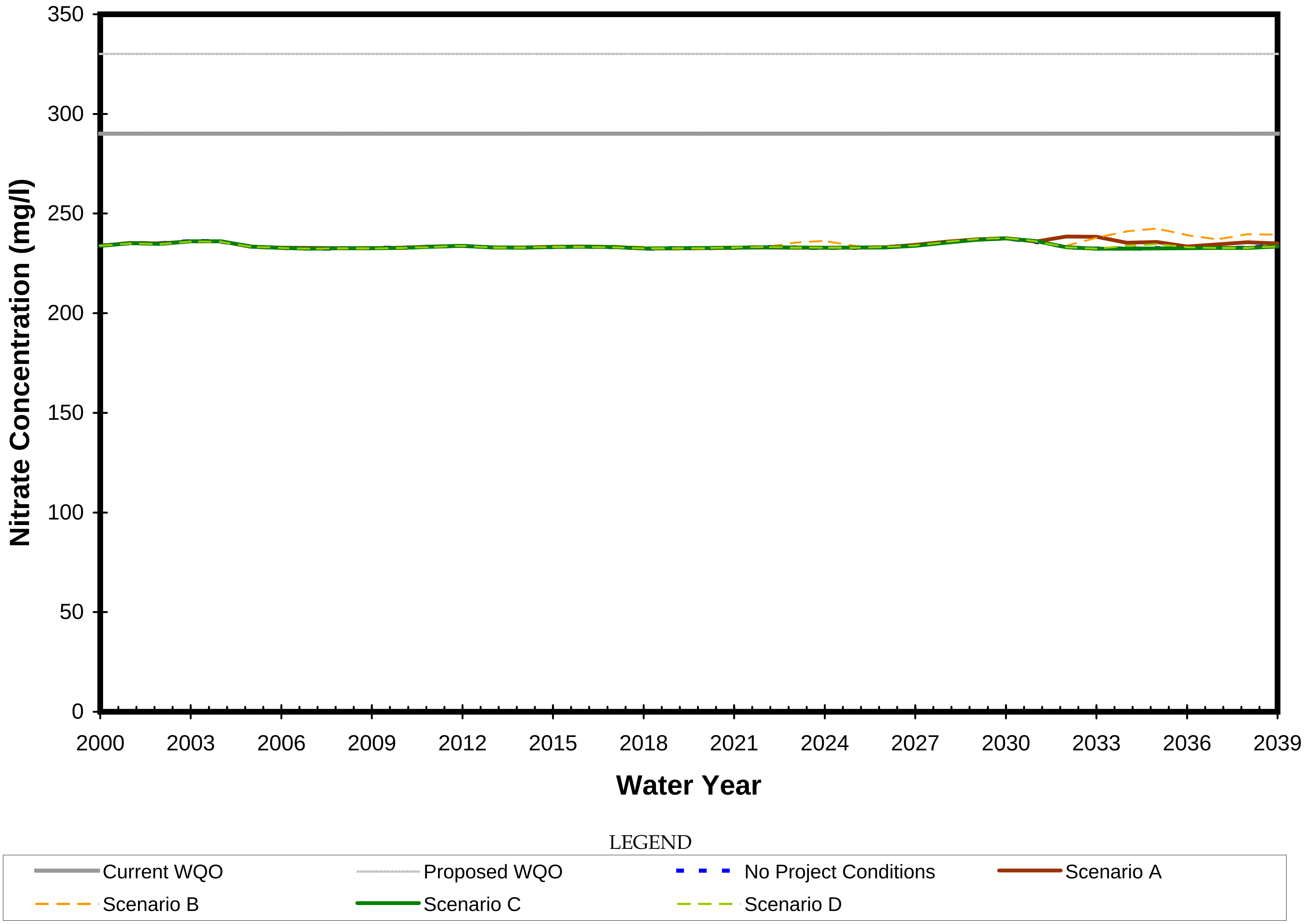


Figure B 74t. TDS Concentrations for IW-20.

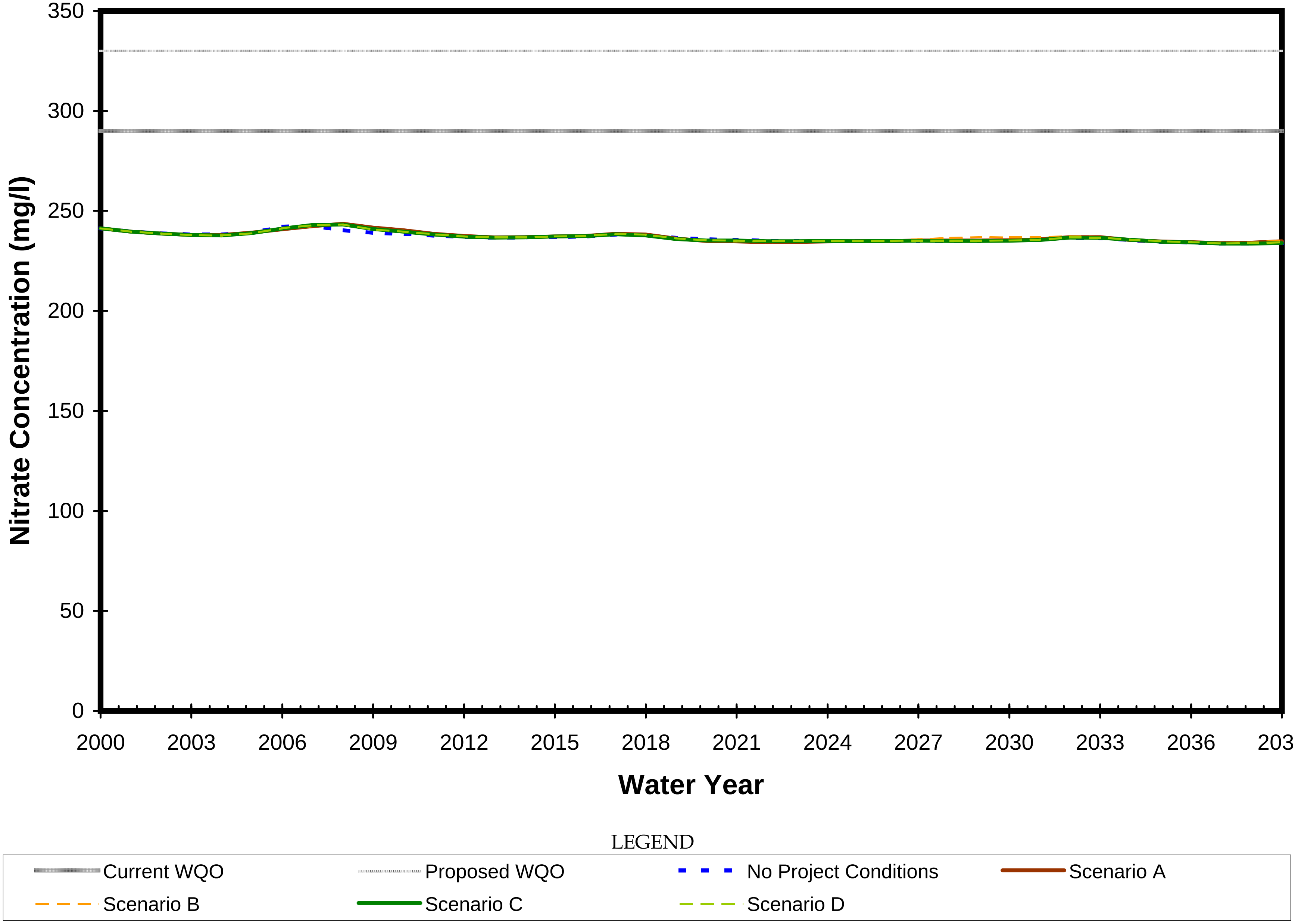
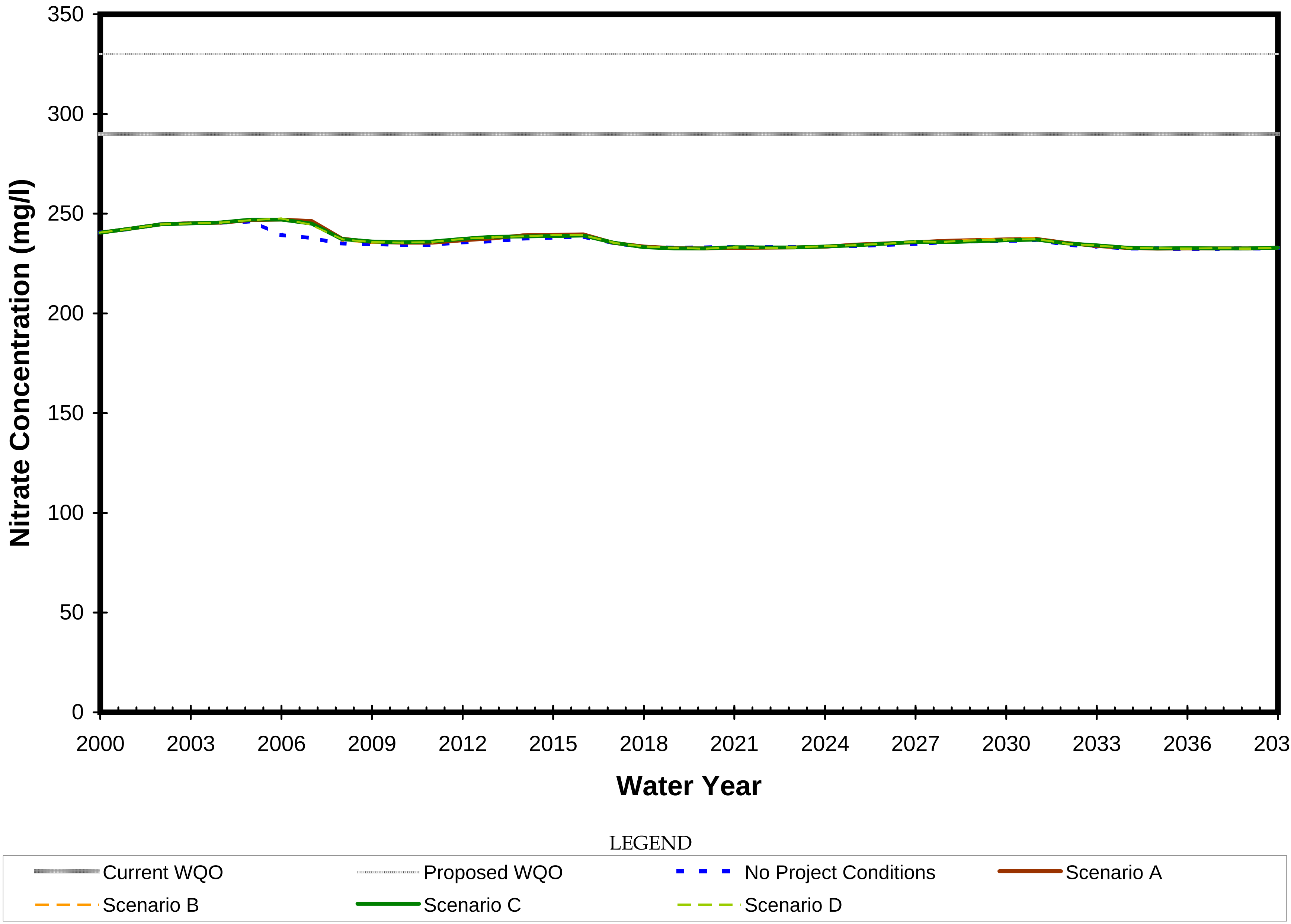


Figure B 74u. TDS Concentrations for IW-21.



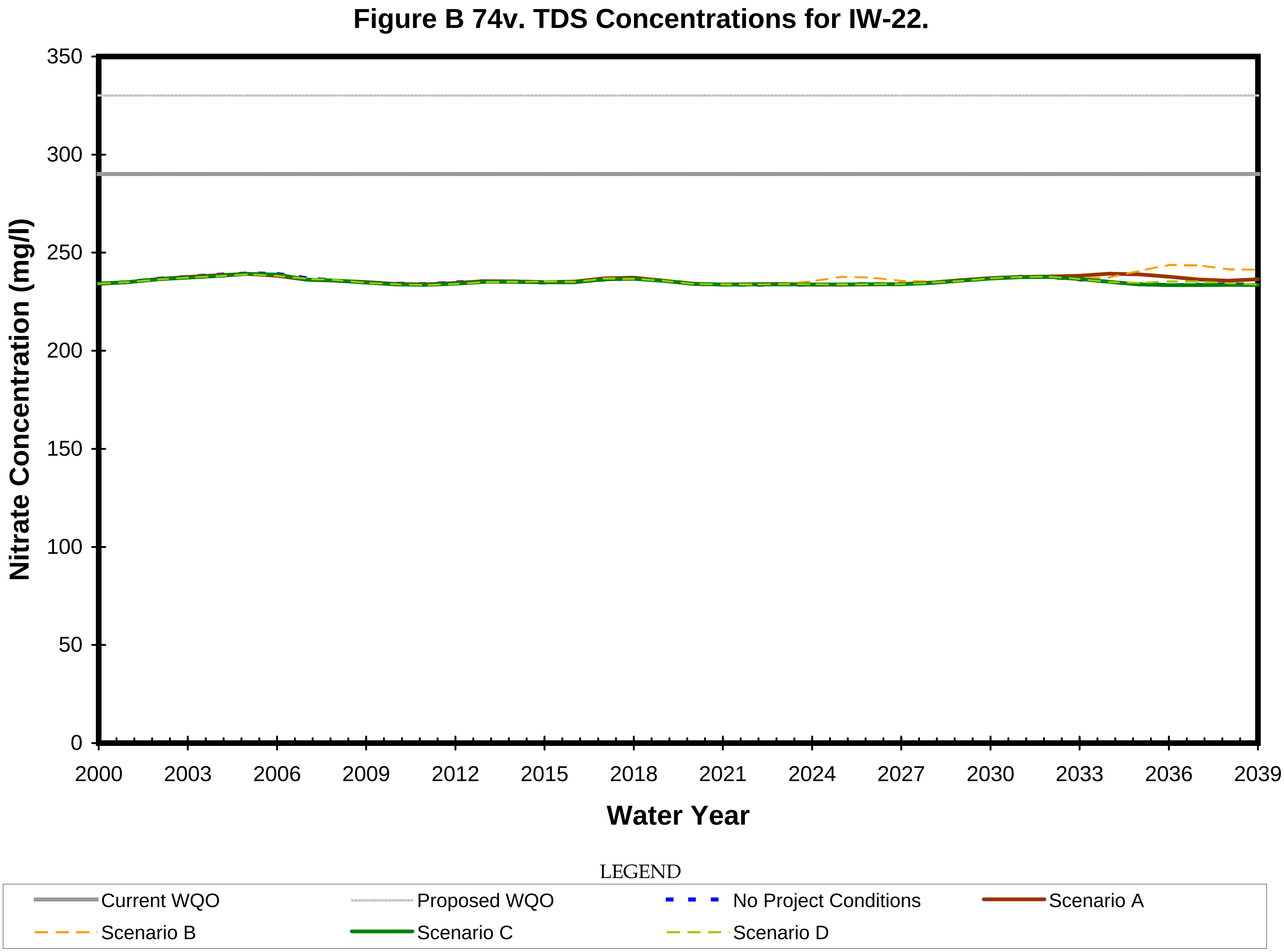


Figure B 74v. TDS Concentrations for IW-22.
Nitrate Concentration (mg/l)
350
300
250
200
150
100
50
0
2000
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
2033
2036
2039
Water Year
LEGEND
Current WQO
Proposed WQO
No Project Conditions
Scenario A
Scenario B
Scenario C
Scenario D

Figure B 74w. TDS Concentrations for IW-23.

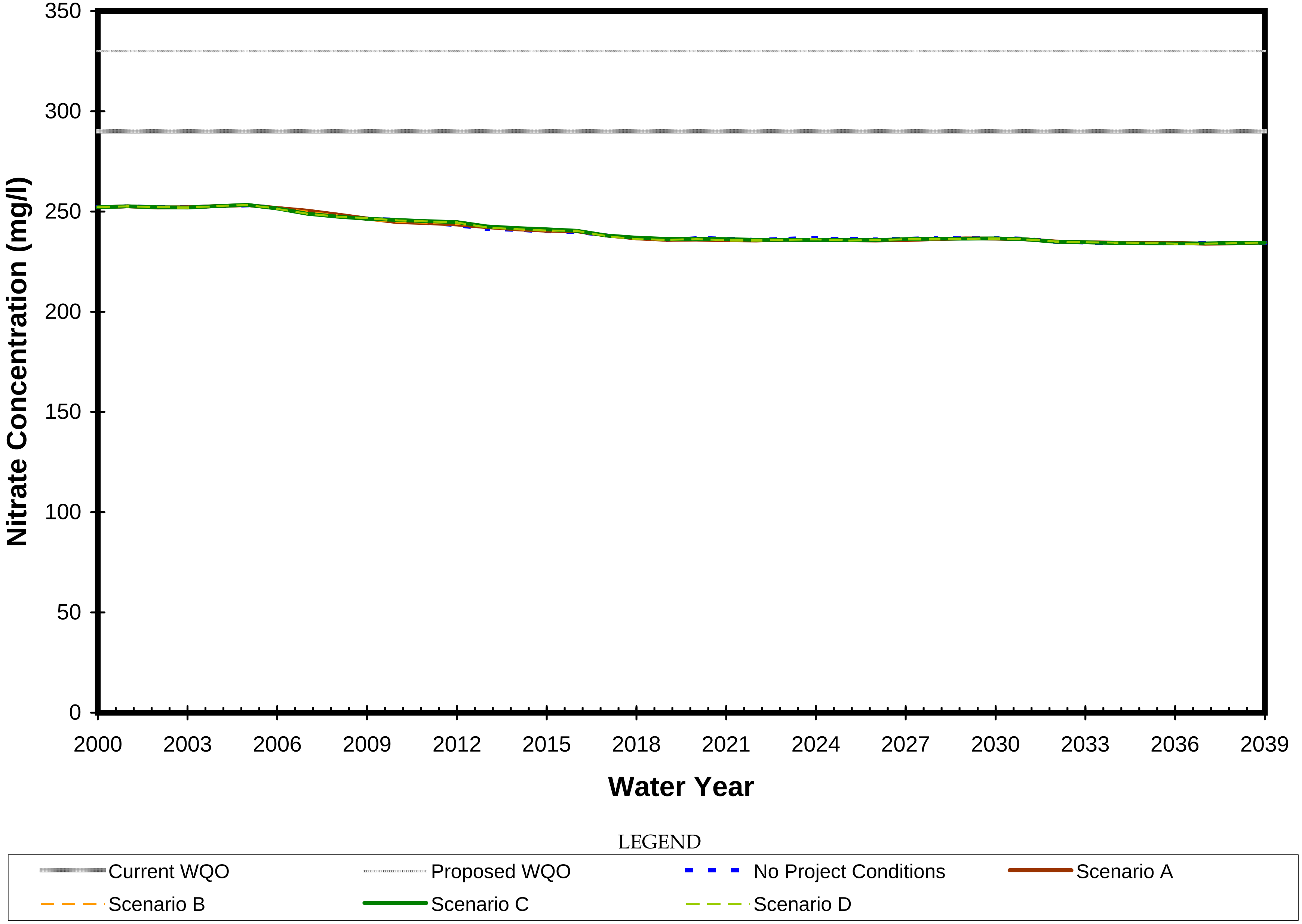


Figure B 74x. TDS Concentrations for IW-24.

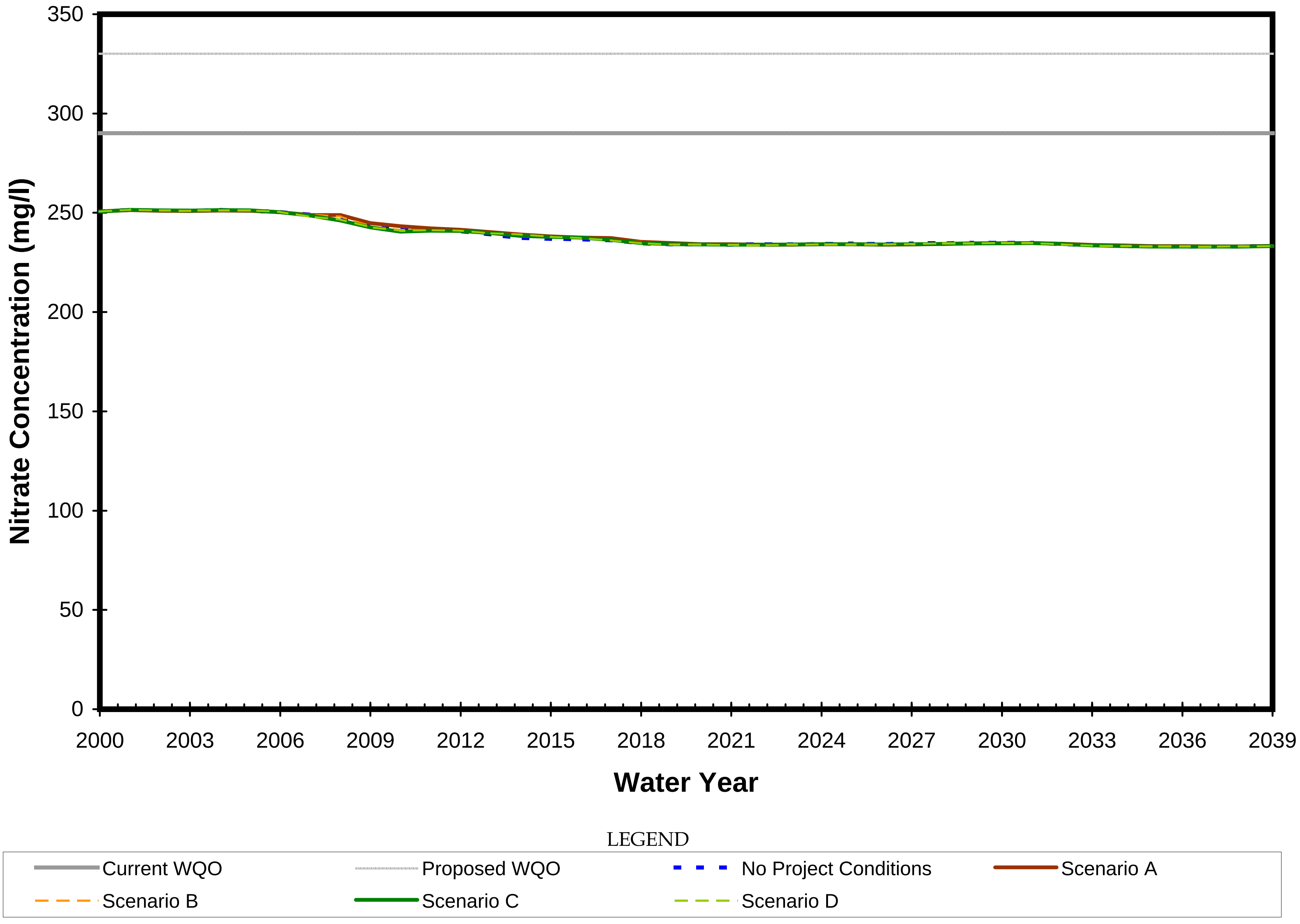


Figure B 74y. TDS Concentrations for IW-25.

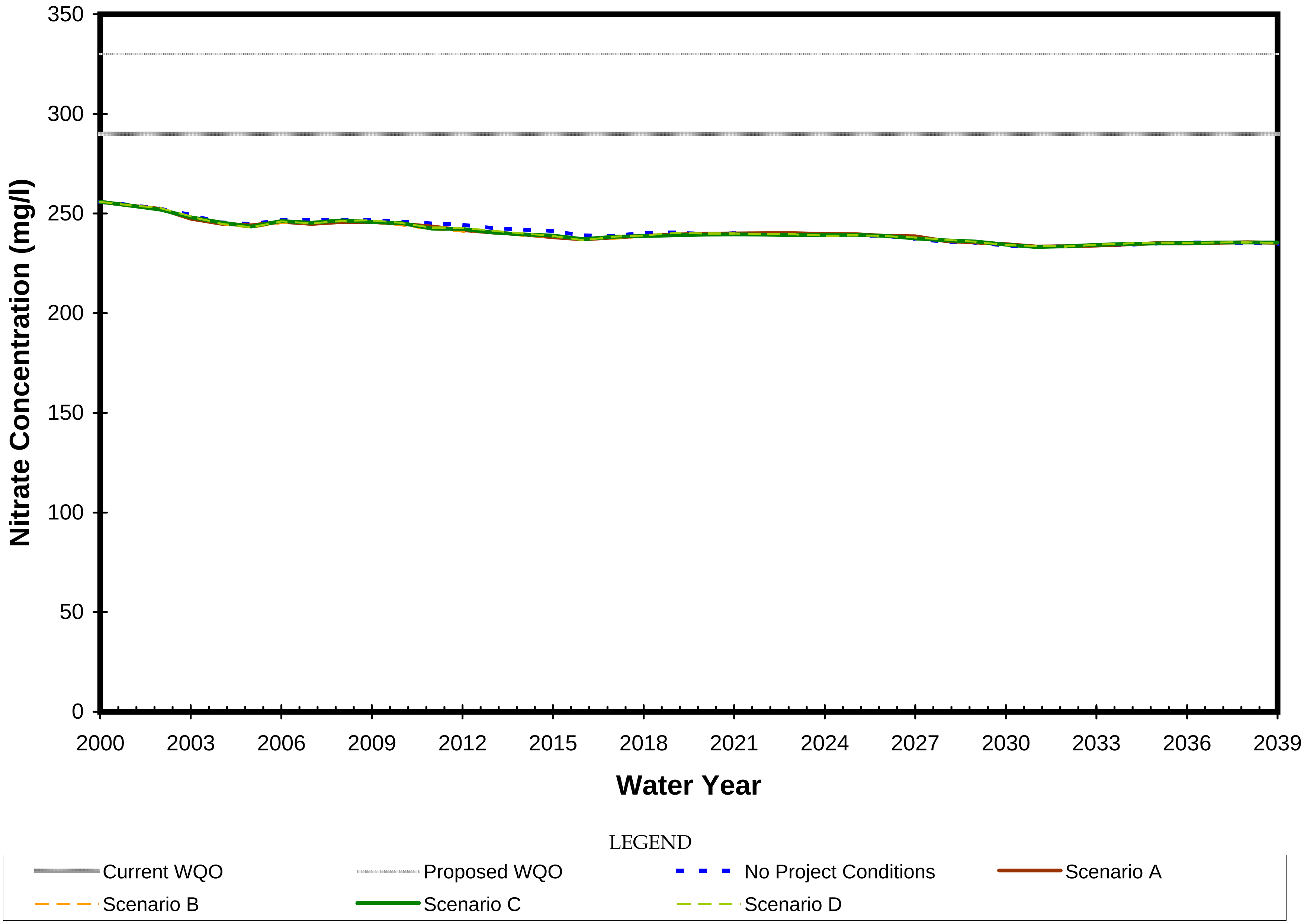


Figure B 74z. TDS Concentrations for SG-1 Devil Canyon / Sweetwater SG.

Figure B 74aa. TDS Concentrations for SG-2 Santa Ana River SG

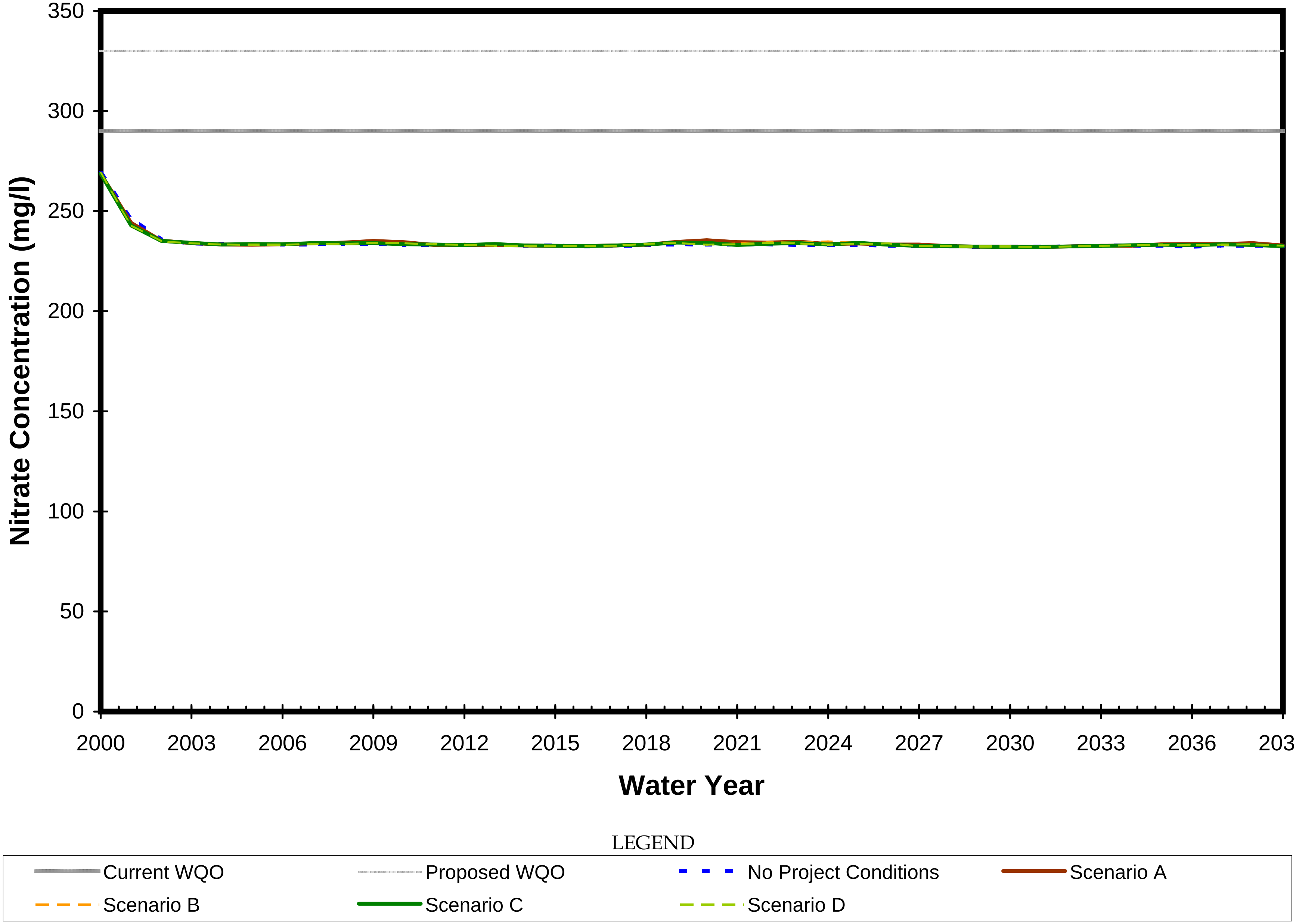


Figure B 74ab. TDS Concentrations for SG-3 Waterman SG.

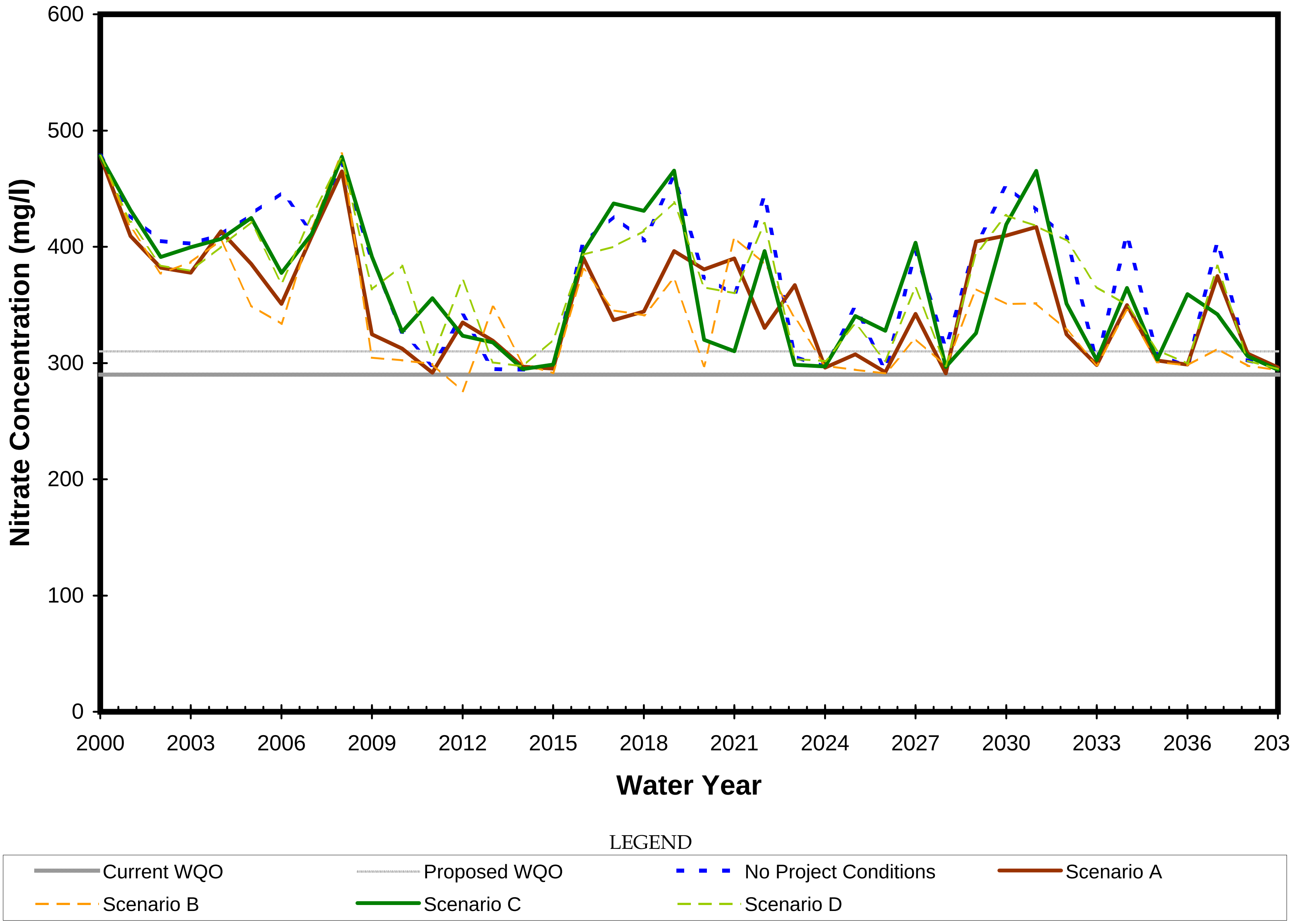


Figure B 74ac. TDS Concentrations for SG-4 Badger SG.

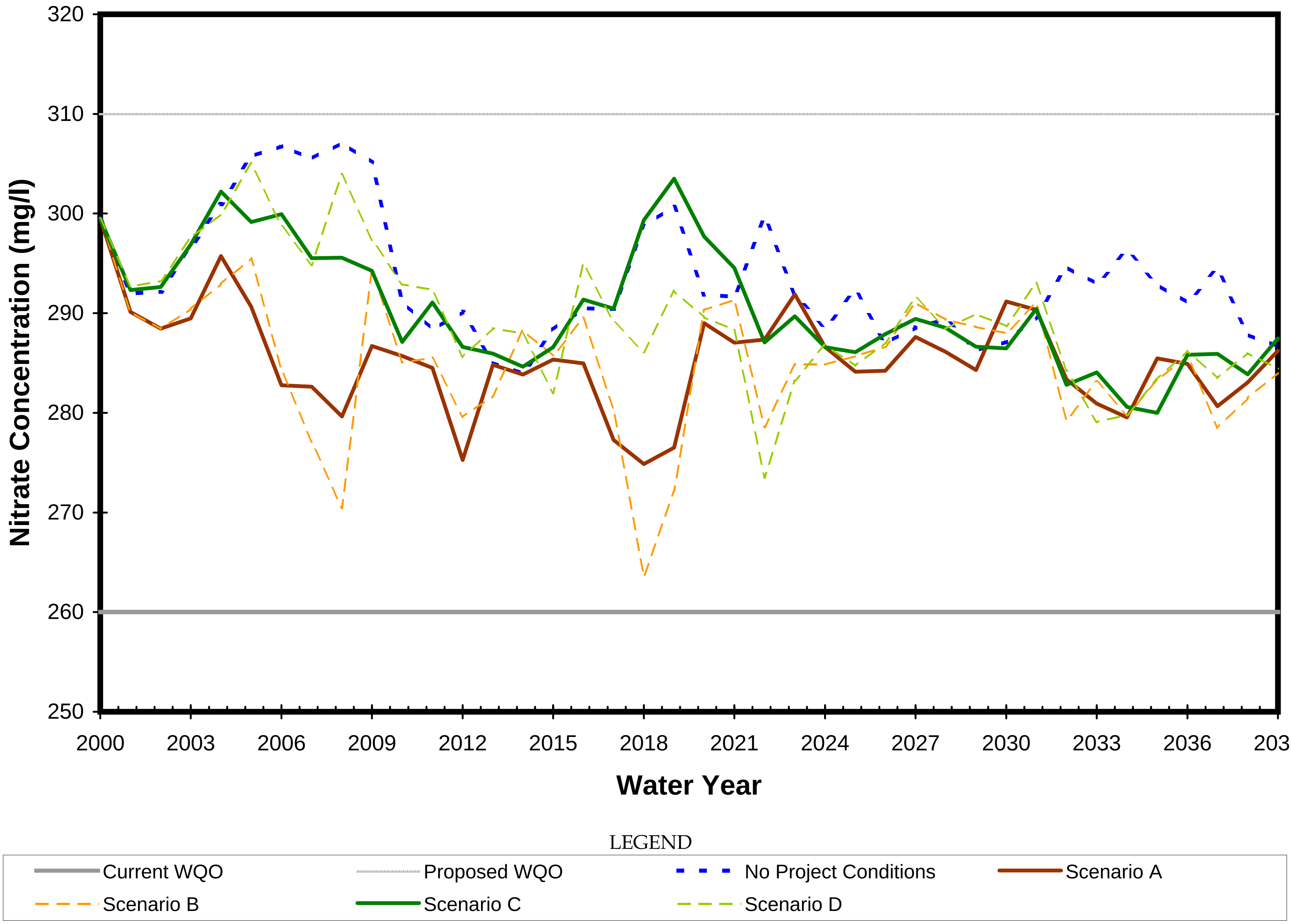


Figure B 74ad. TDS Concentrations for SG-5 Patton SG.

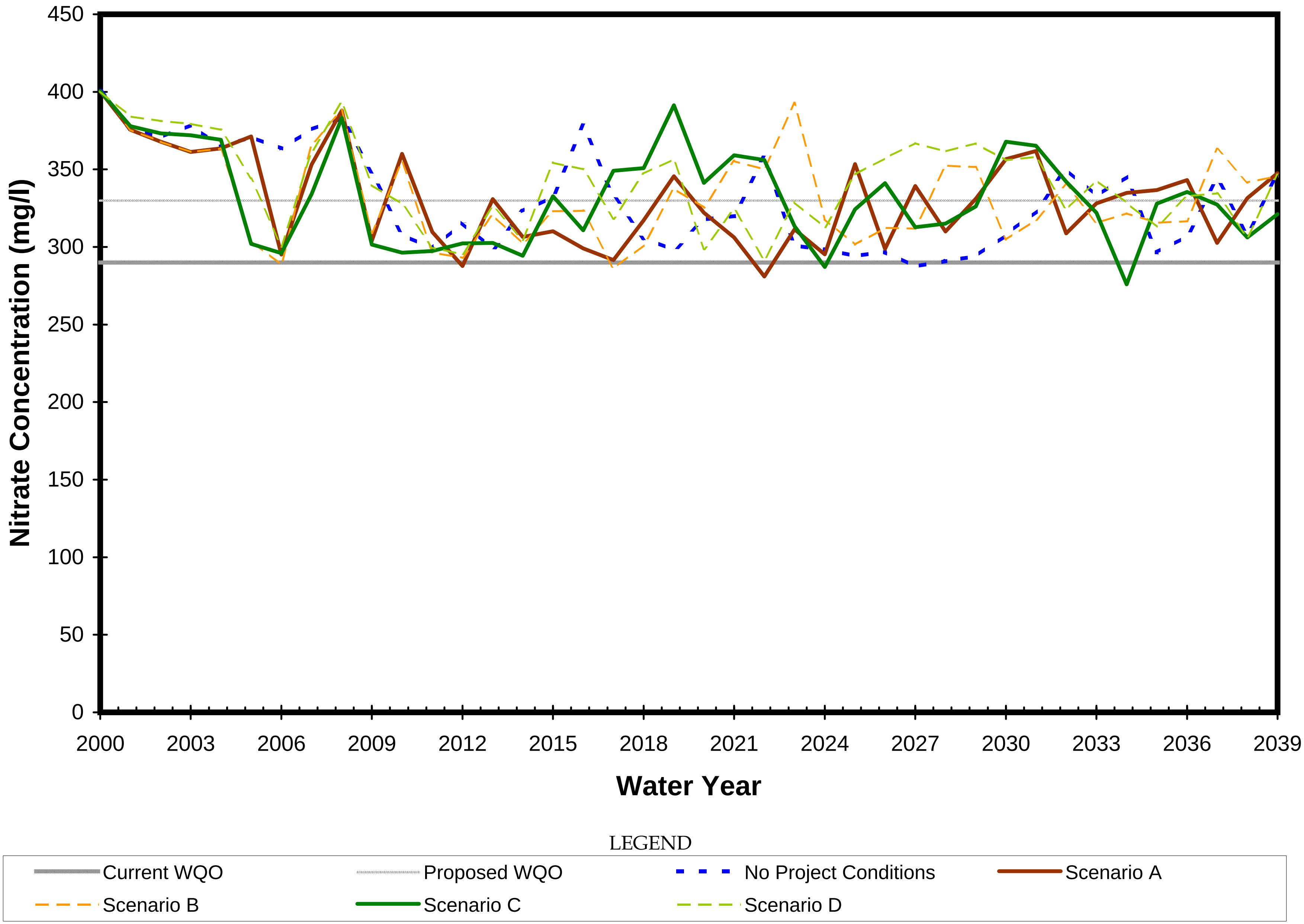


Figure B 74ae. TDS Concentrations for SG-6 Mill Creek SG.

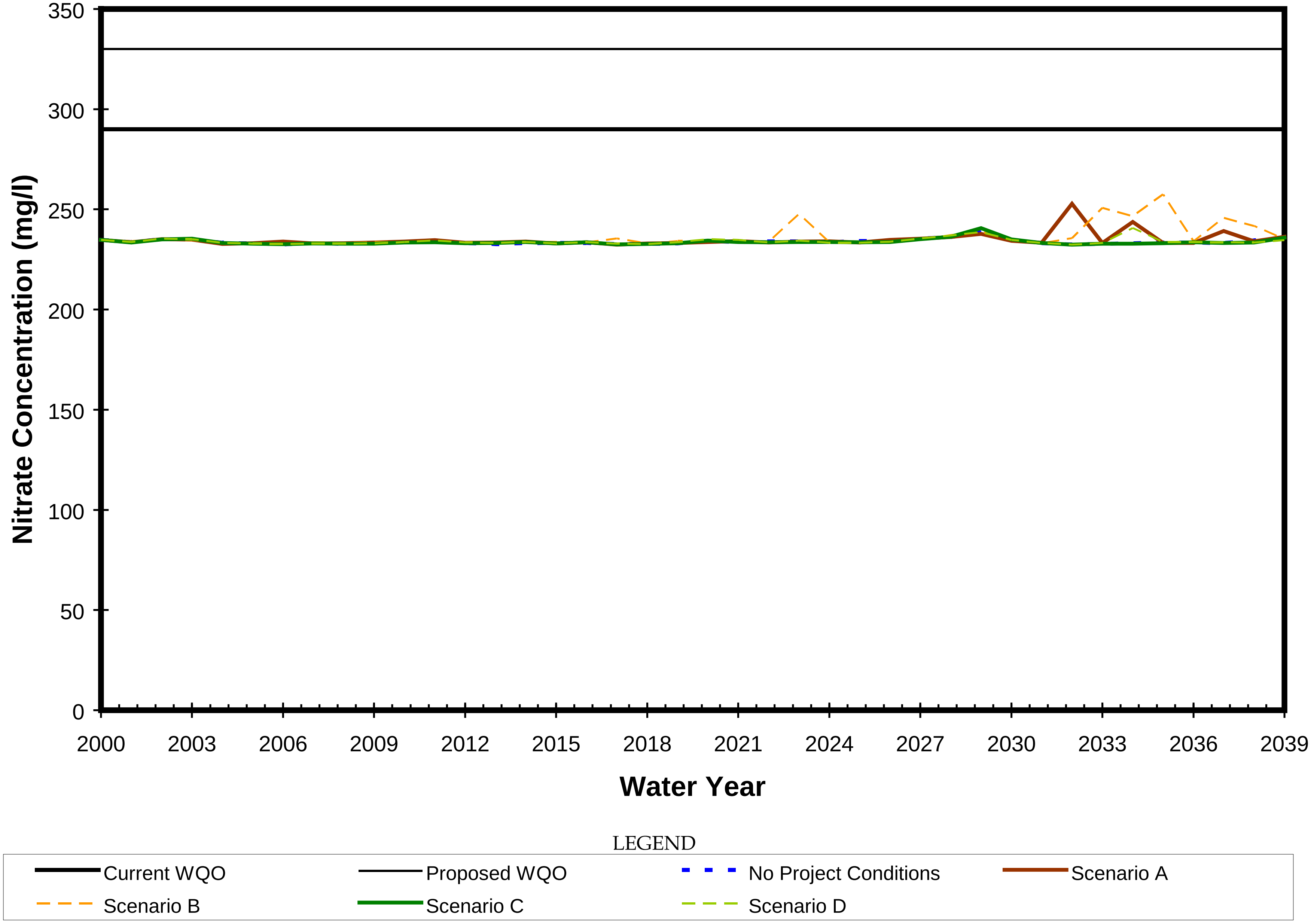


Figure B 74af. TDS Concentrations for SG-7 City Creek SG.

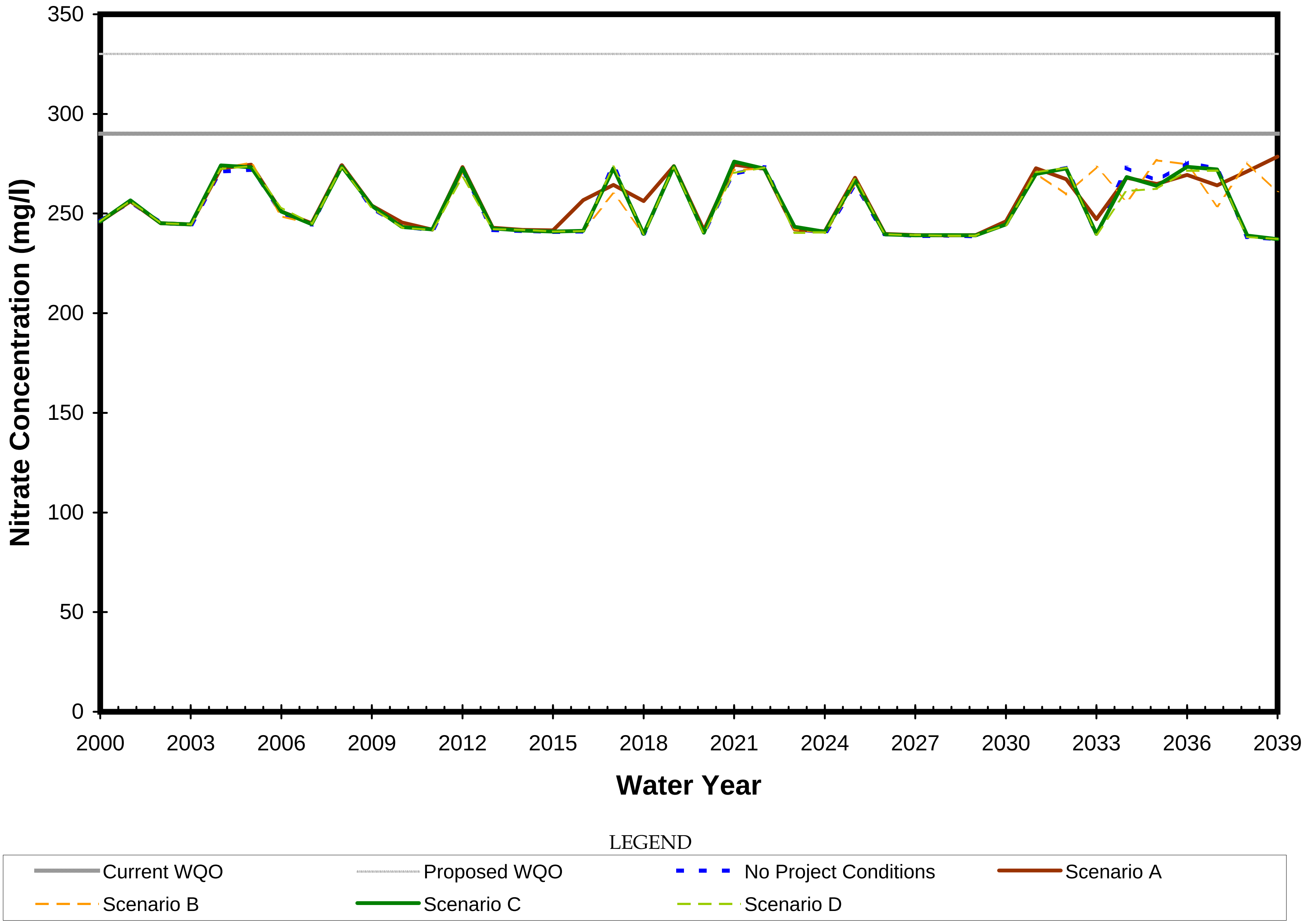


Figure B 74ag. TDS Concentrations for SG-8 East Twin Creek SG.

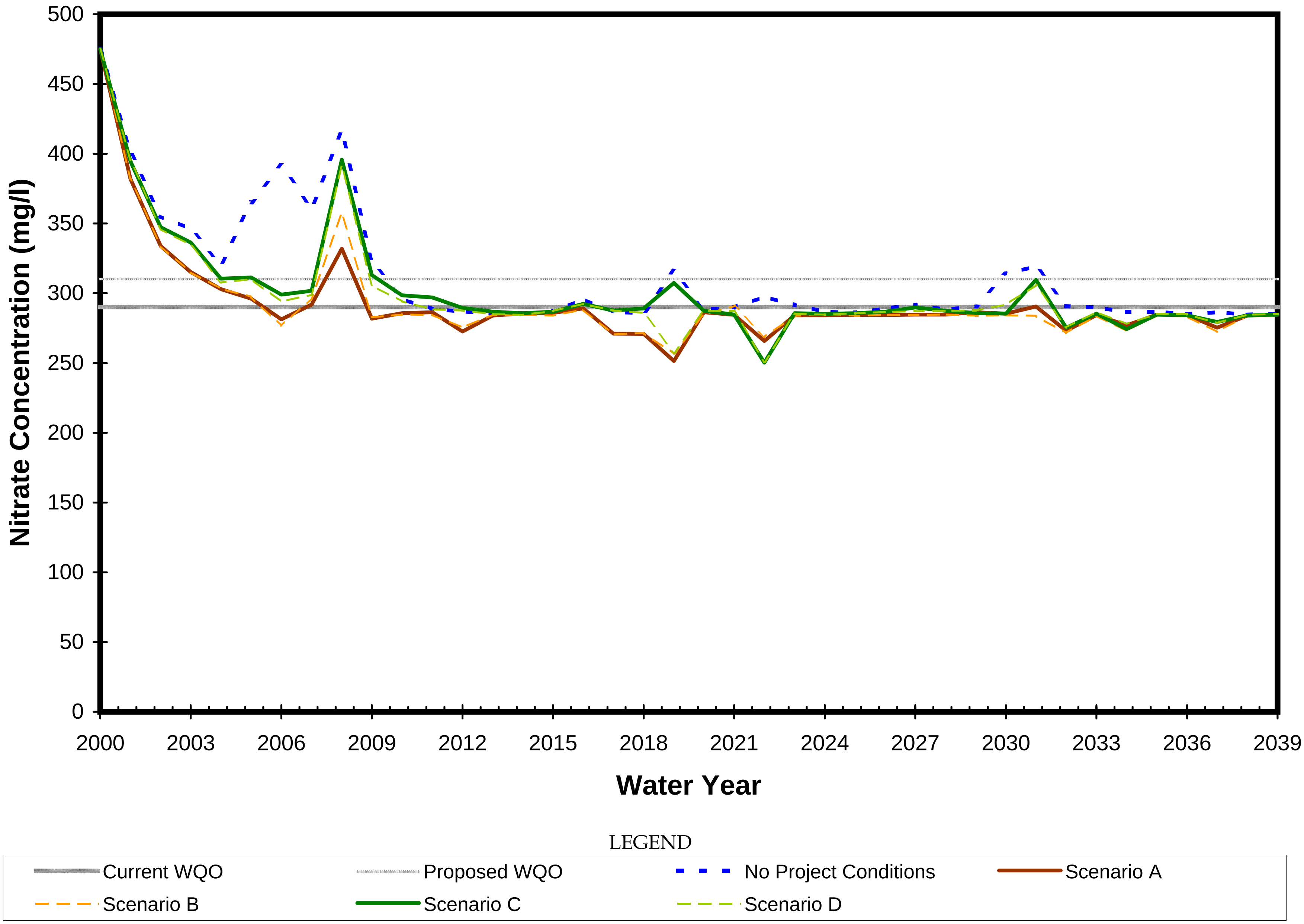


Figure B 74ah. TDS Concentrations for SG-9 Lytle Creek SG.

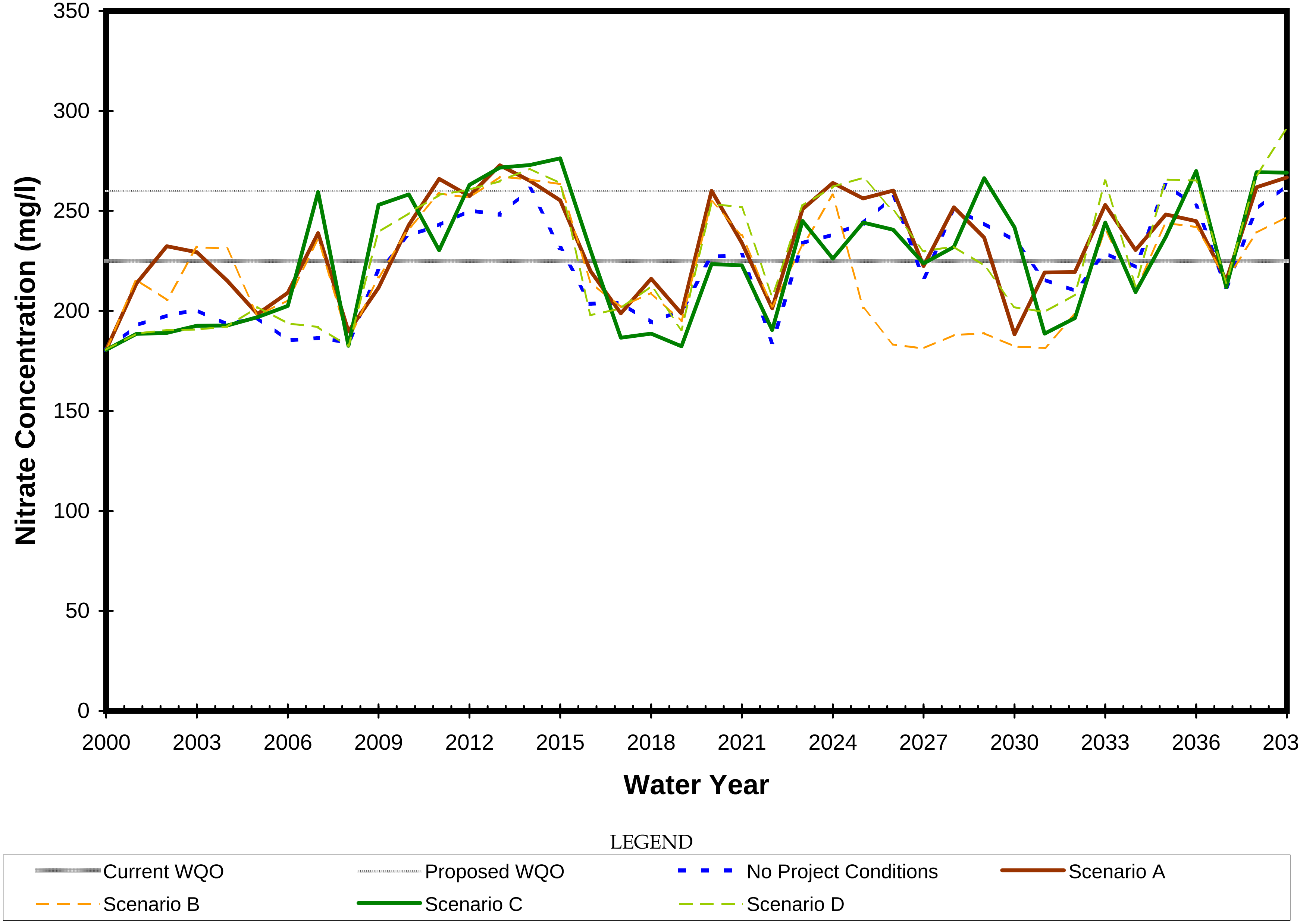


Figure B 75a. Nitrate Concentrations for IW-01.

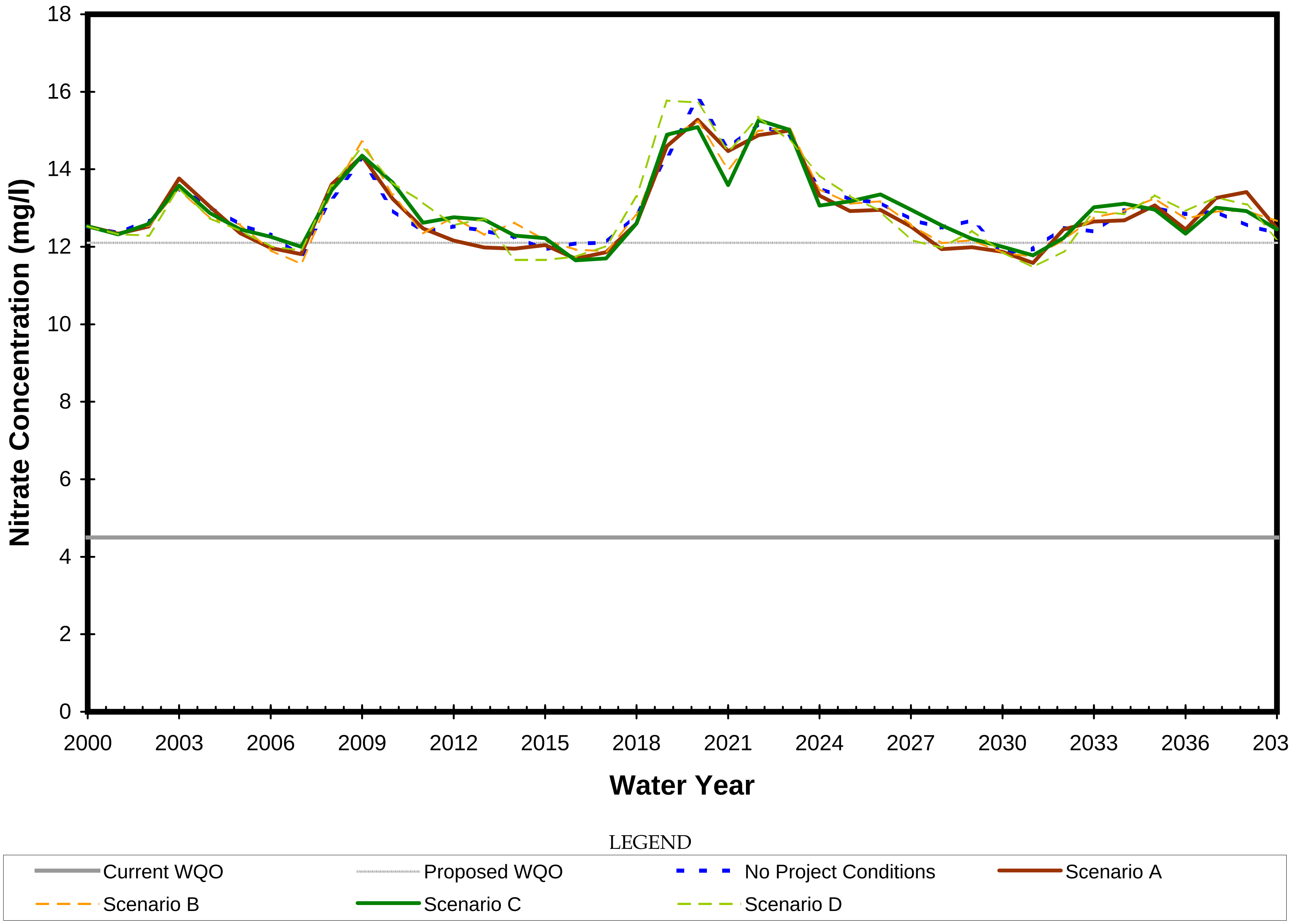


Figure B 75b. Nitrate Concentrations for IW-02.

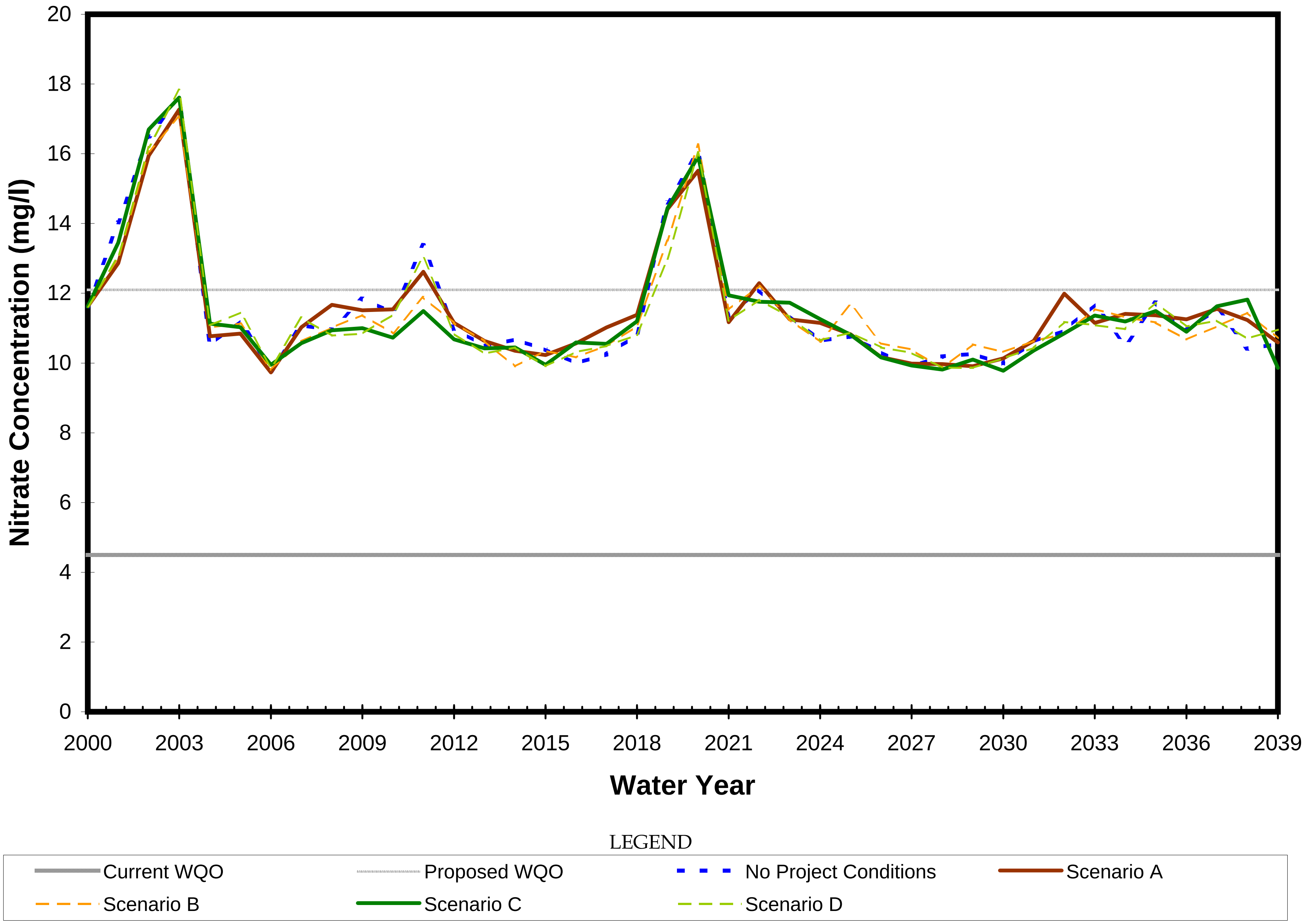


Figure B 75c. Nitrate Concentrations for IW-03.

Figure B 75d. Nitrate Concentrations for IW-04.

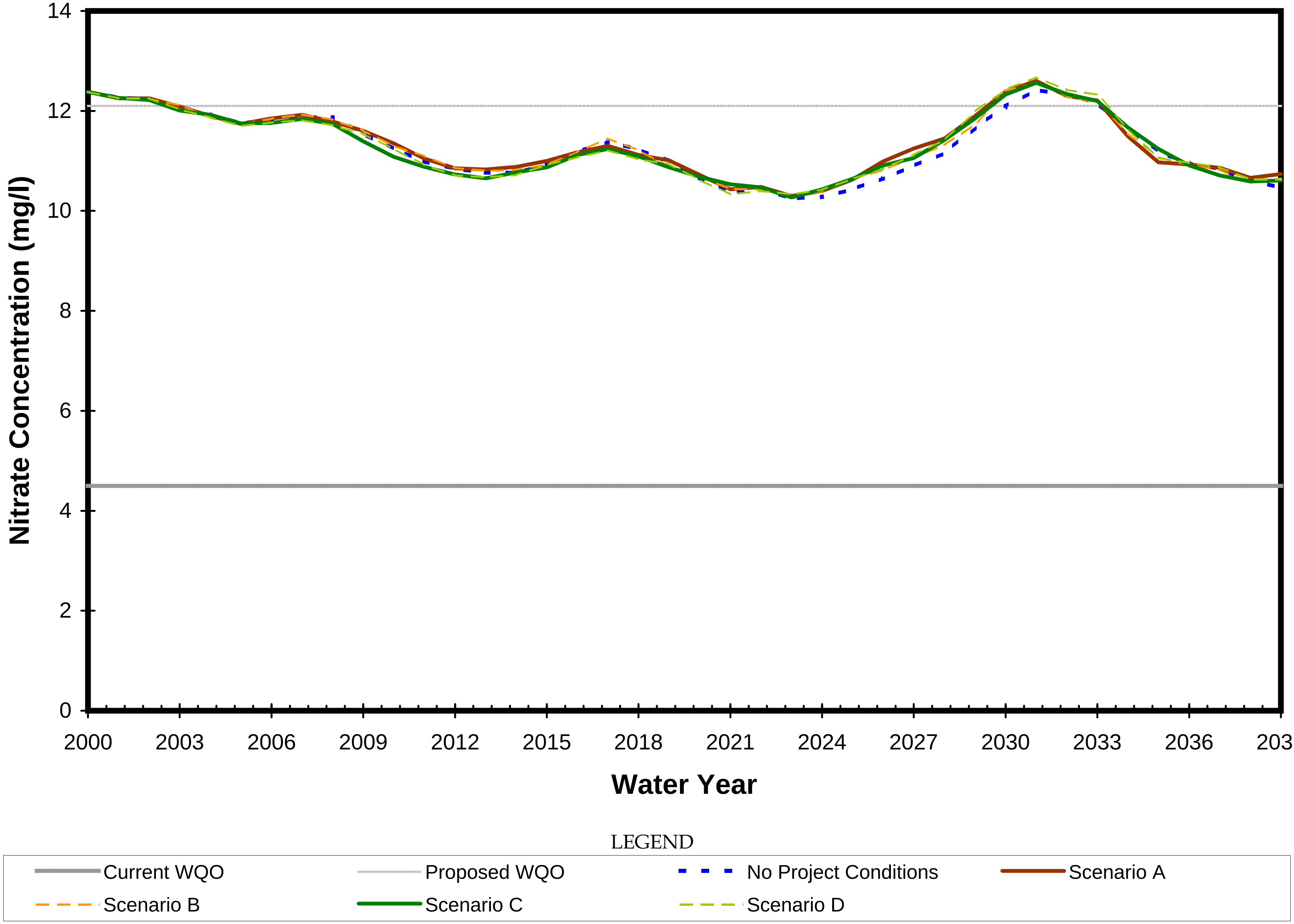


Figure B 75e. Nitrate Concentrations for IW-05.

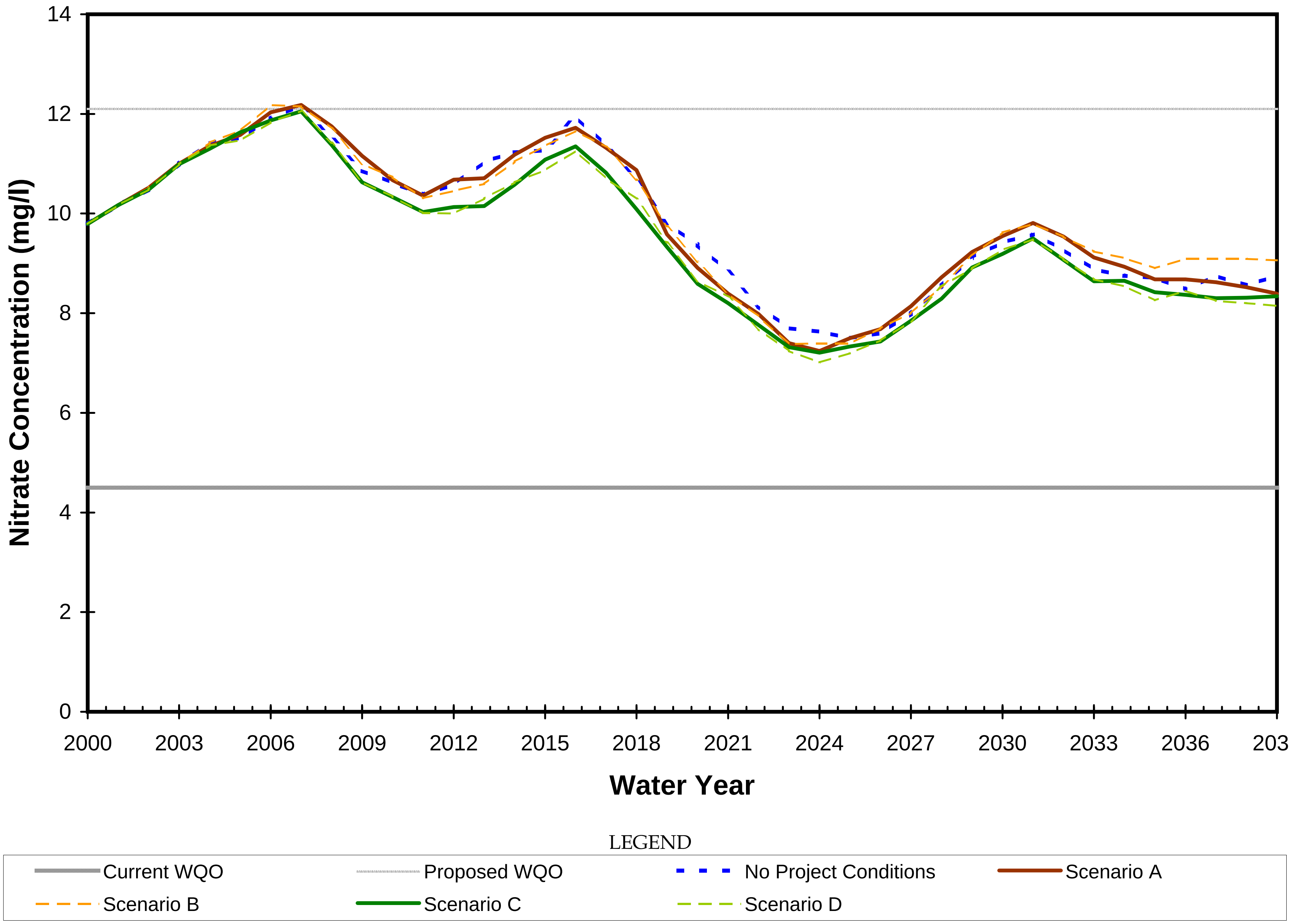
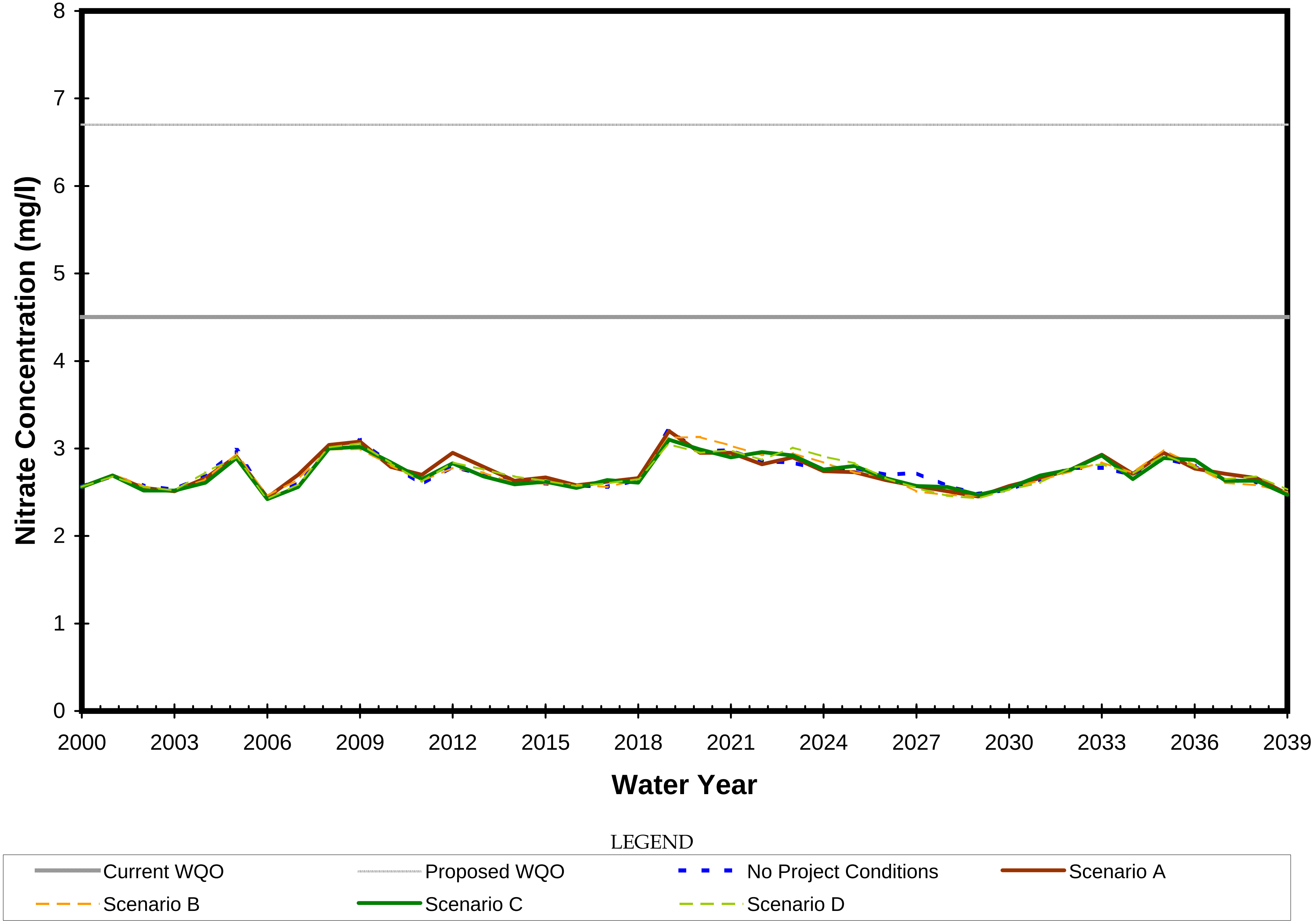


Figure B 75f. Nitrate Concentrations for IW-06.



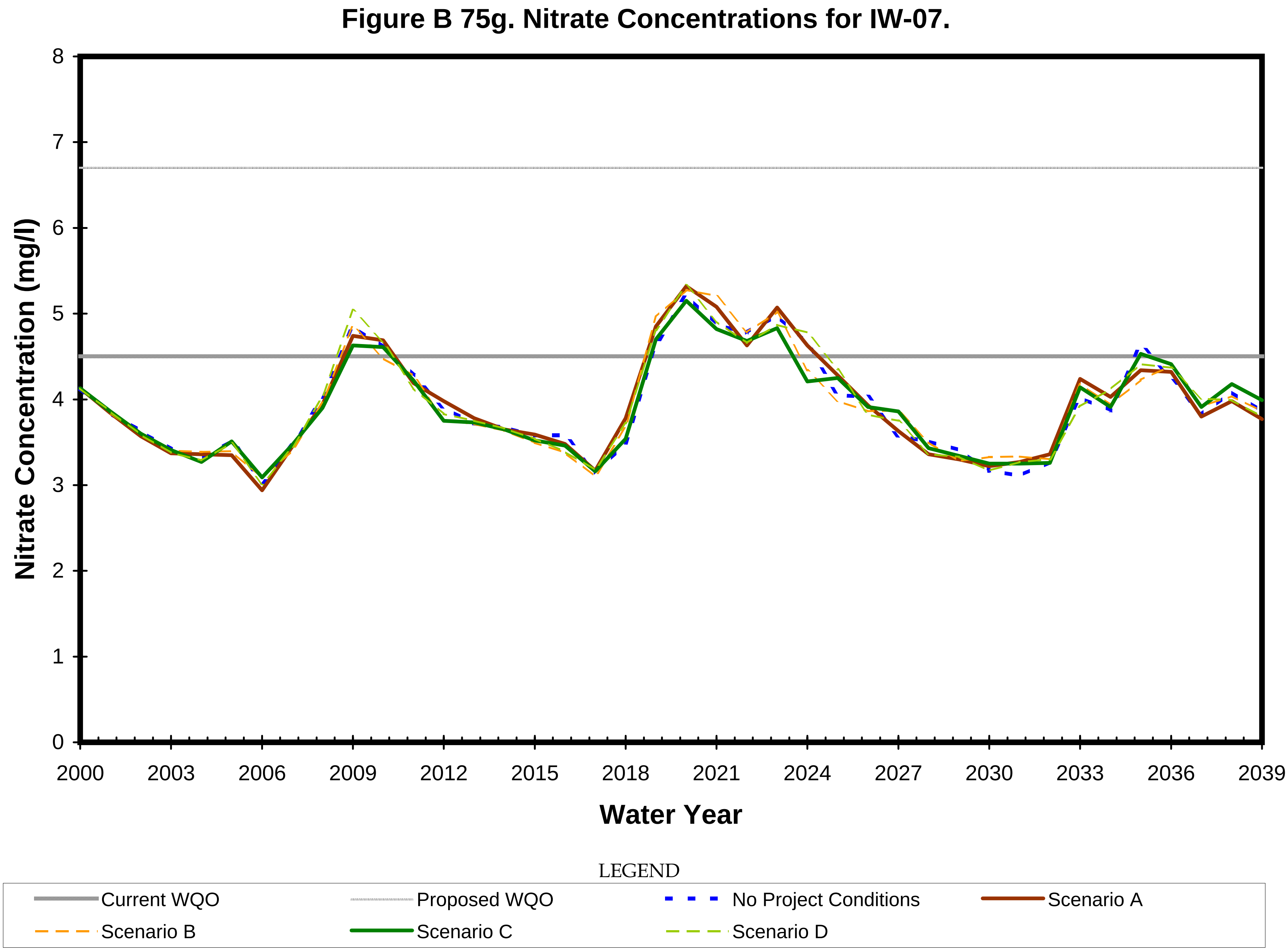


Figure B 75g. Nitrate Concentrations for IW-07.
Nitrate Concentration (mg/l)
8
7
6
5
4
3
2
1
0
2000
2003
2006
2009
2012
2015
2018
2021
2024
2027
2030
2033
2036
2039
Water Year
LEGEND
Current WQO
Proposed WQO
No Project Conditions
Scenario A
Scenario B
Scenario C
Scenario D

Figure B 75h. Nitrate Concentrations for IW-08.

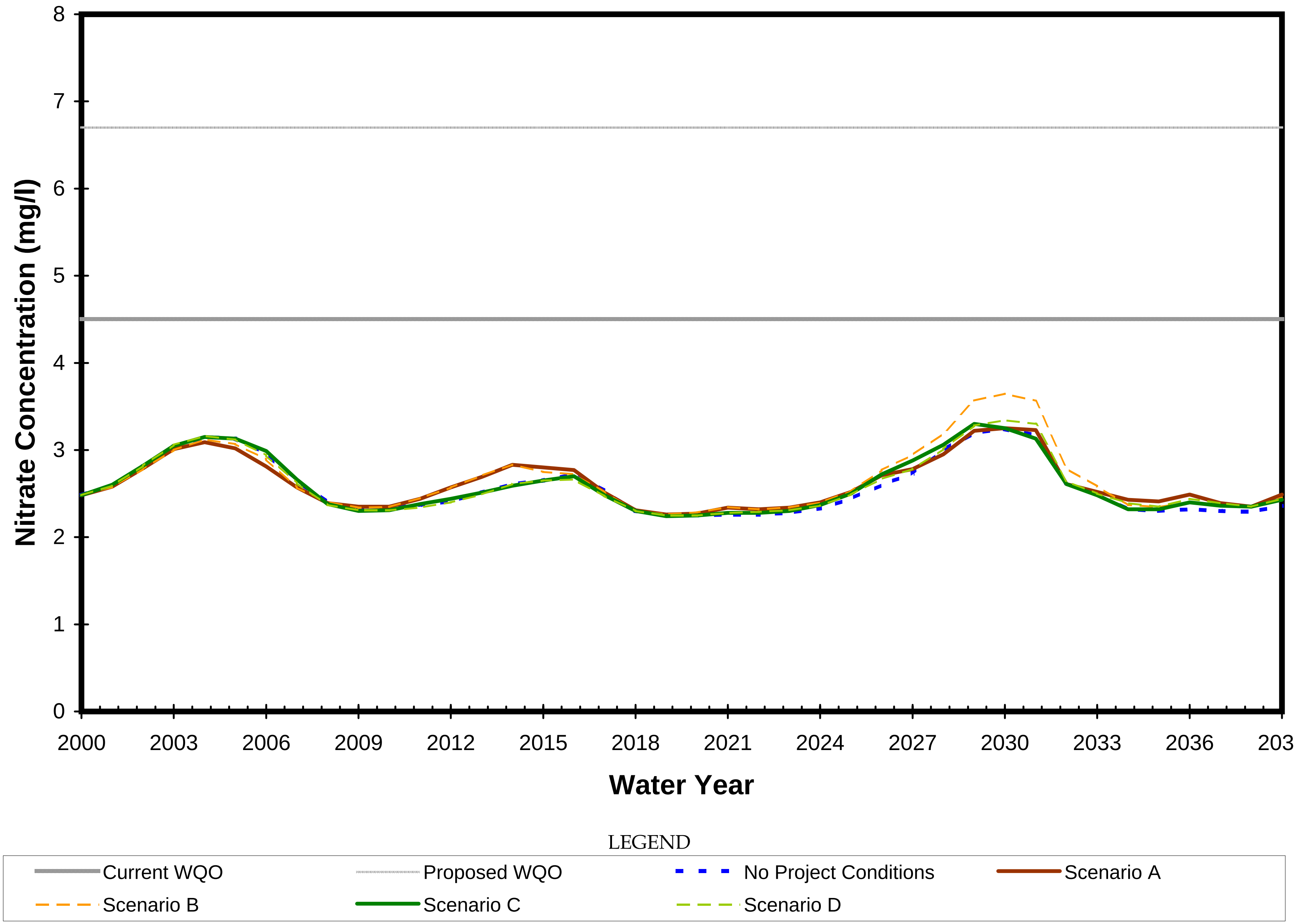


Figure B 75i. Nitrate Concentrations for IW-09.

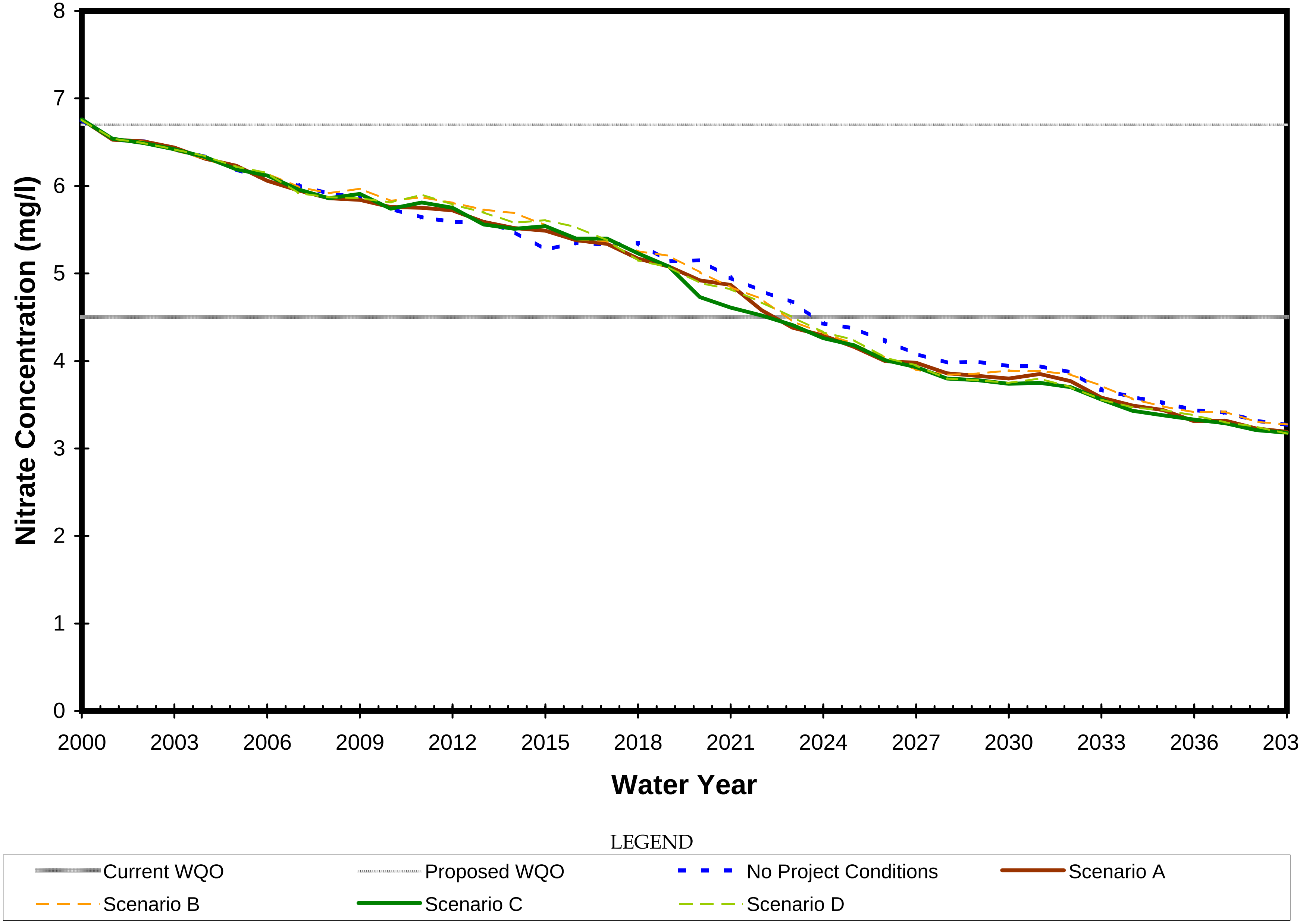
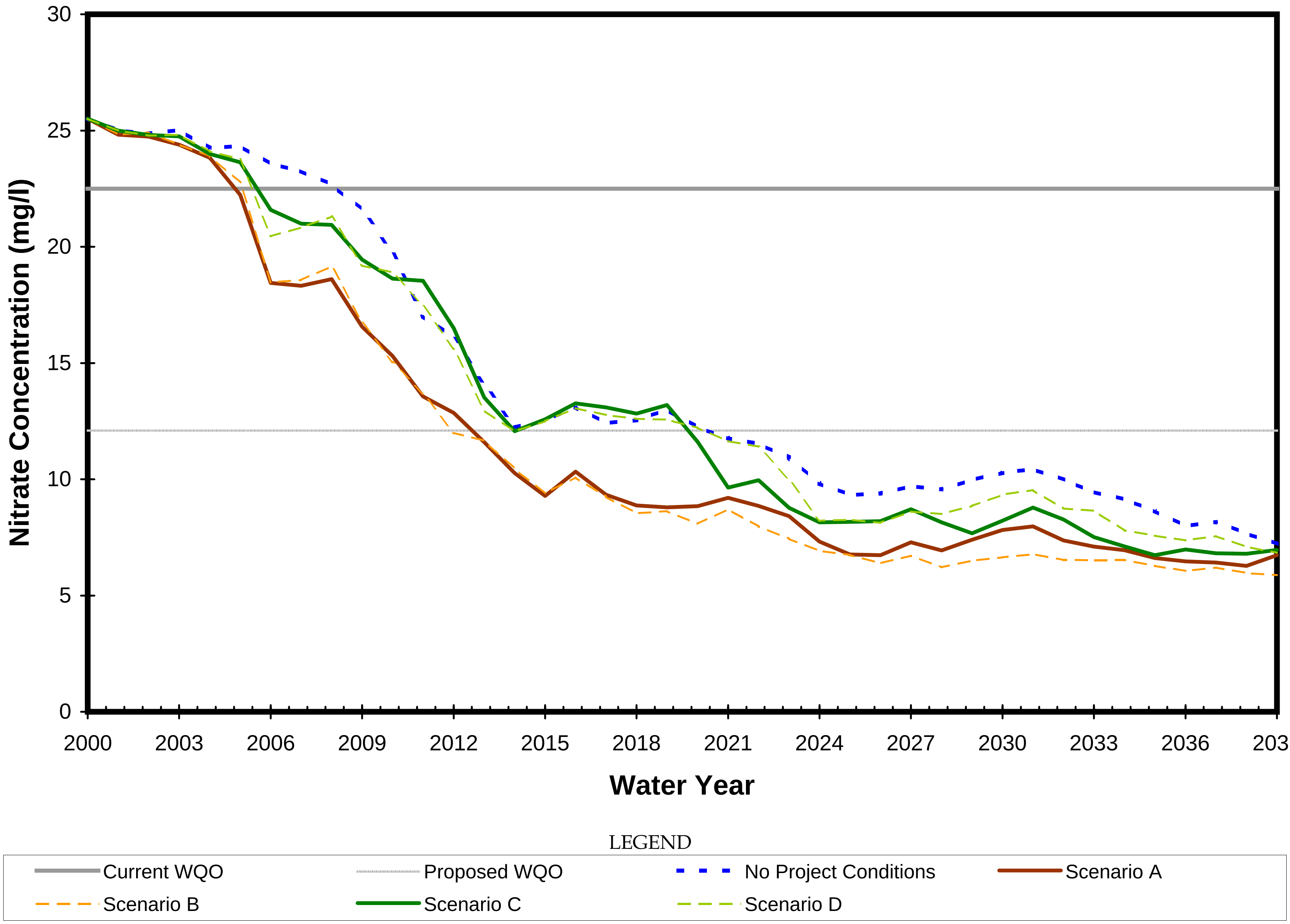


Figure B 75j. Nitrate Concentrations for IW-10.



FigureB 75k. Nitrate Concentrations for IW-11.

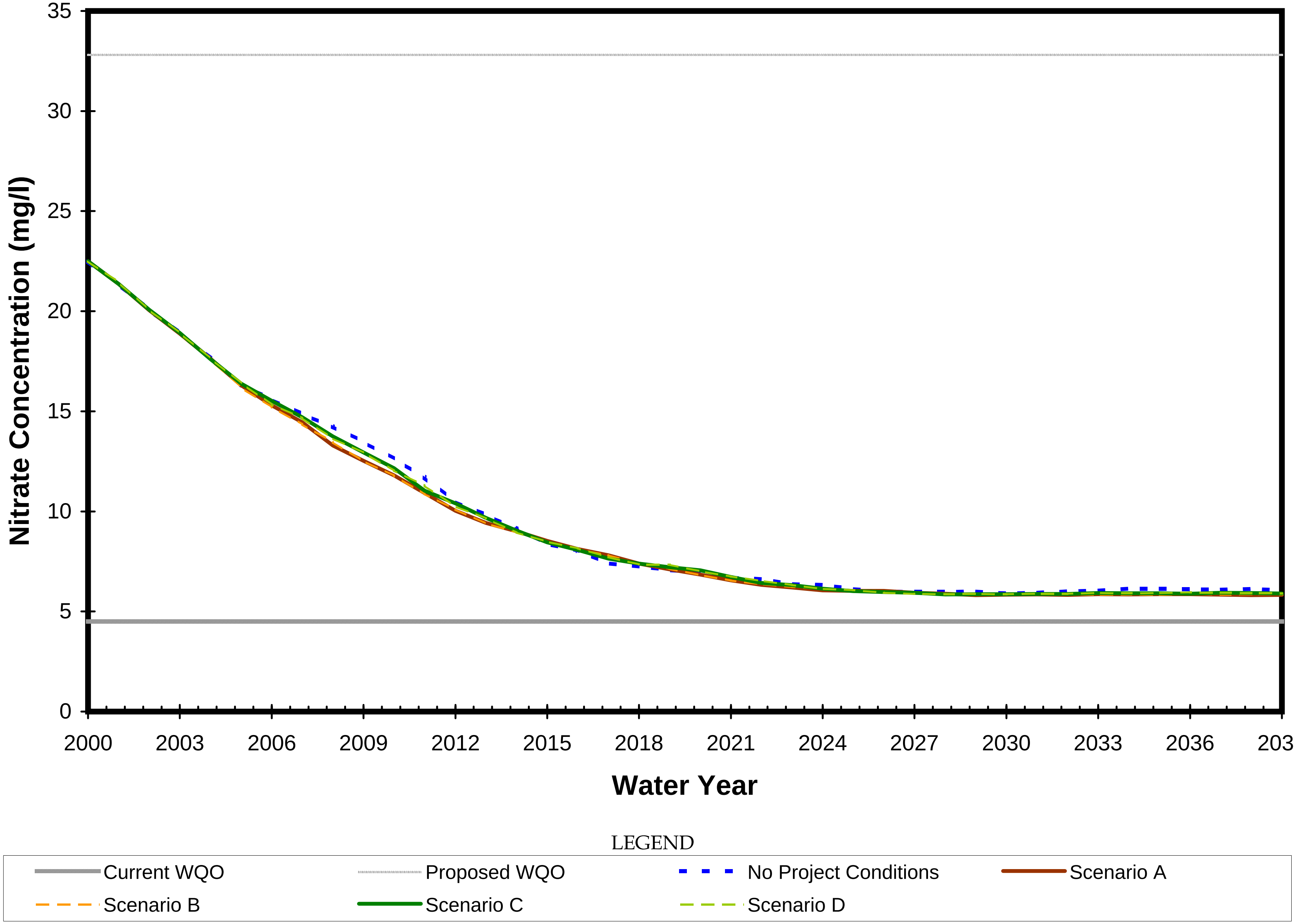


Figure B 75l. Nitrate Concentrations for IW-12.

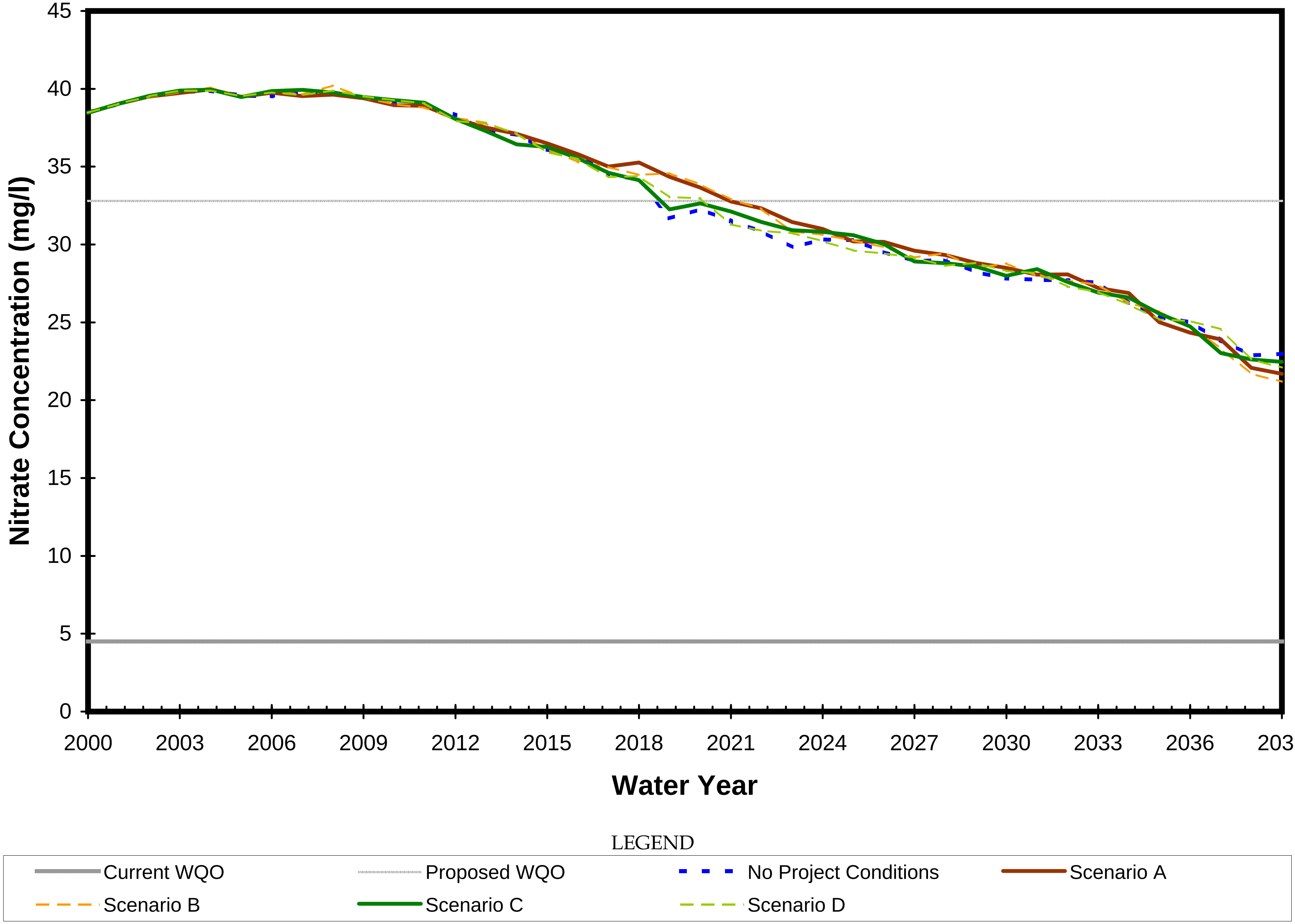


Figure B 75m. Nitrate Concentrations for IW-13.

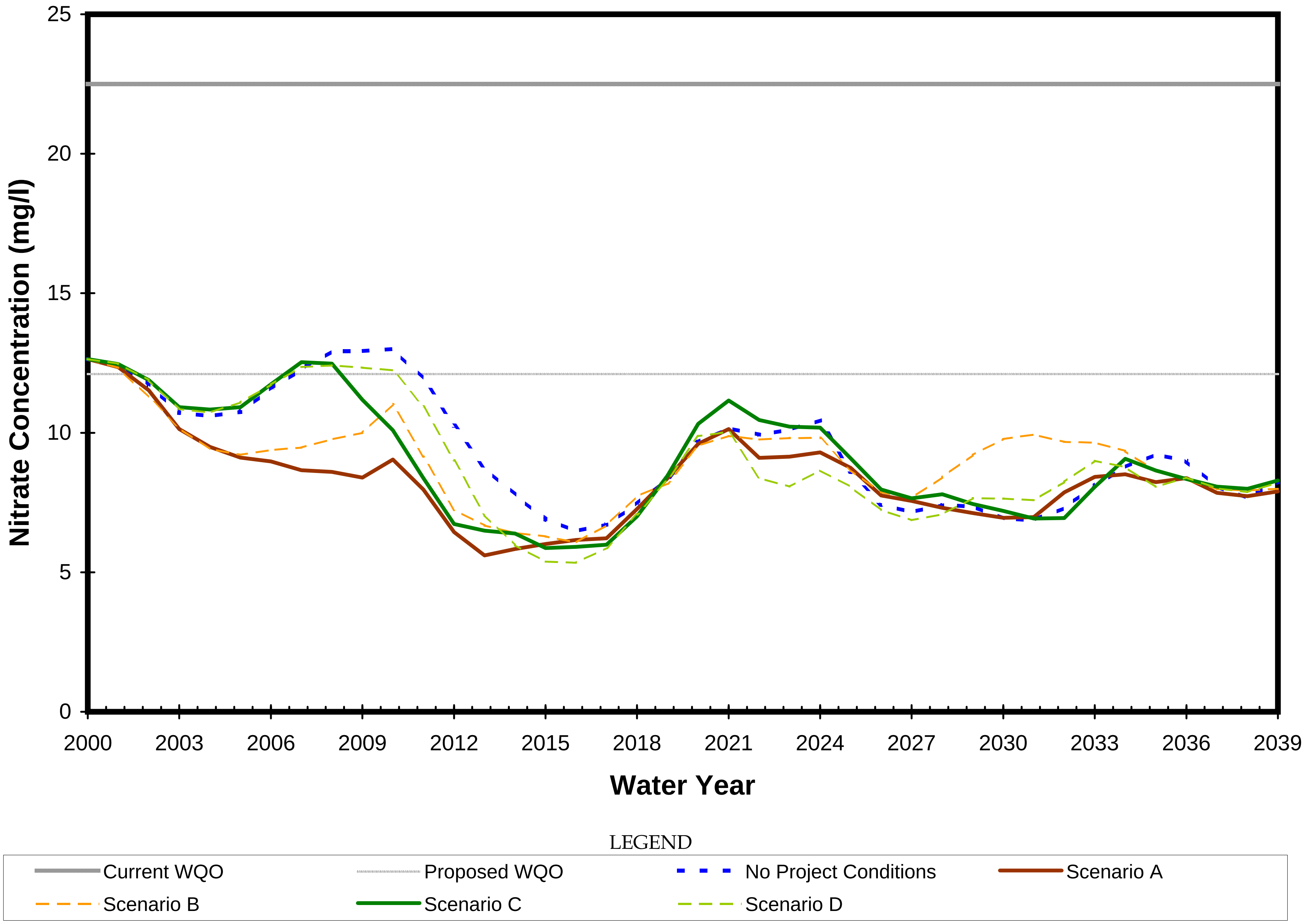


Figure B 75n. Nitrate Concentrations for IW-14.

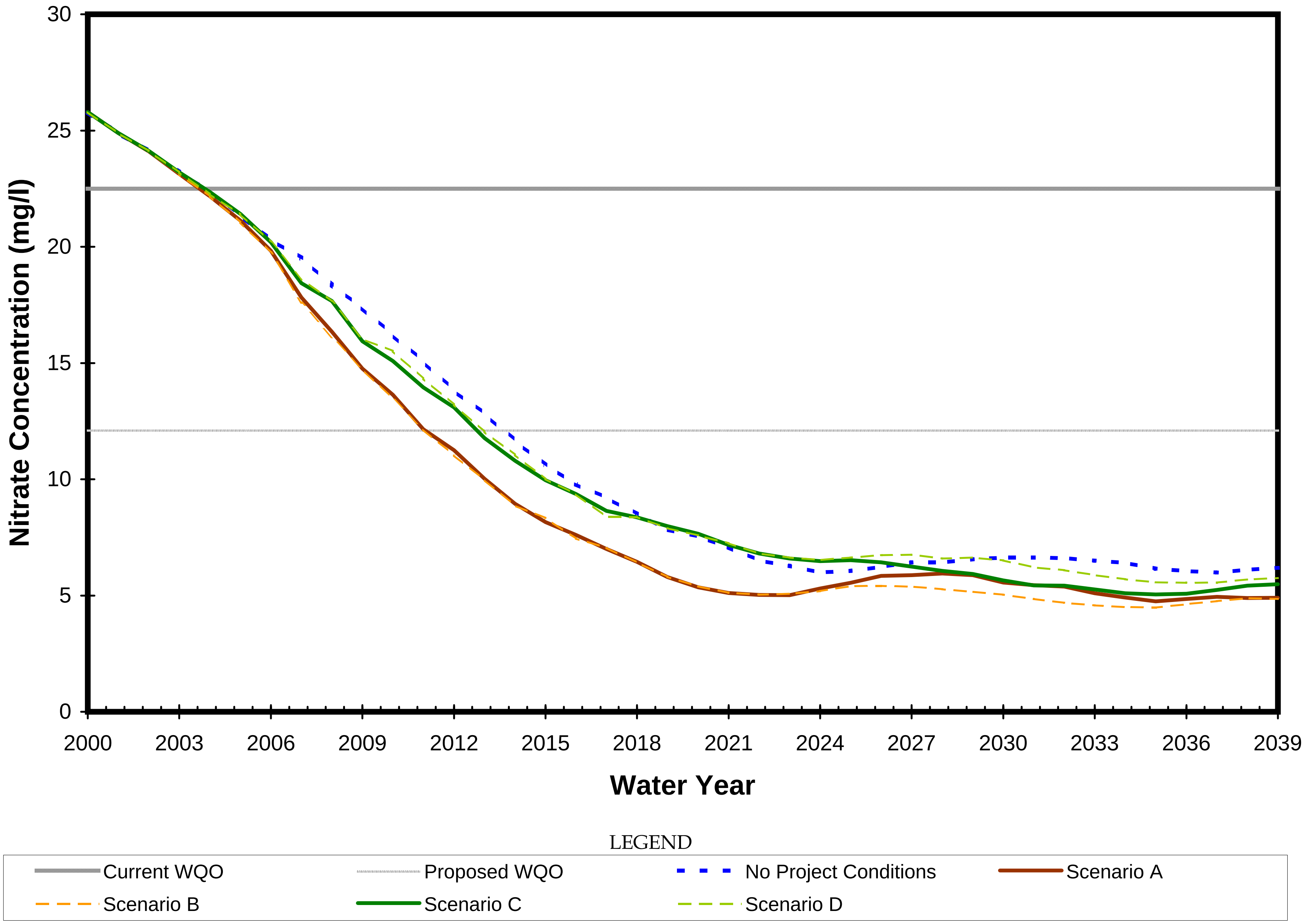


Figure B 75o. Nitrate Concentrations for IW-15.

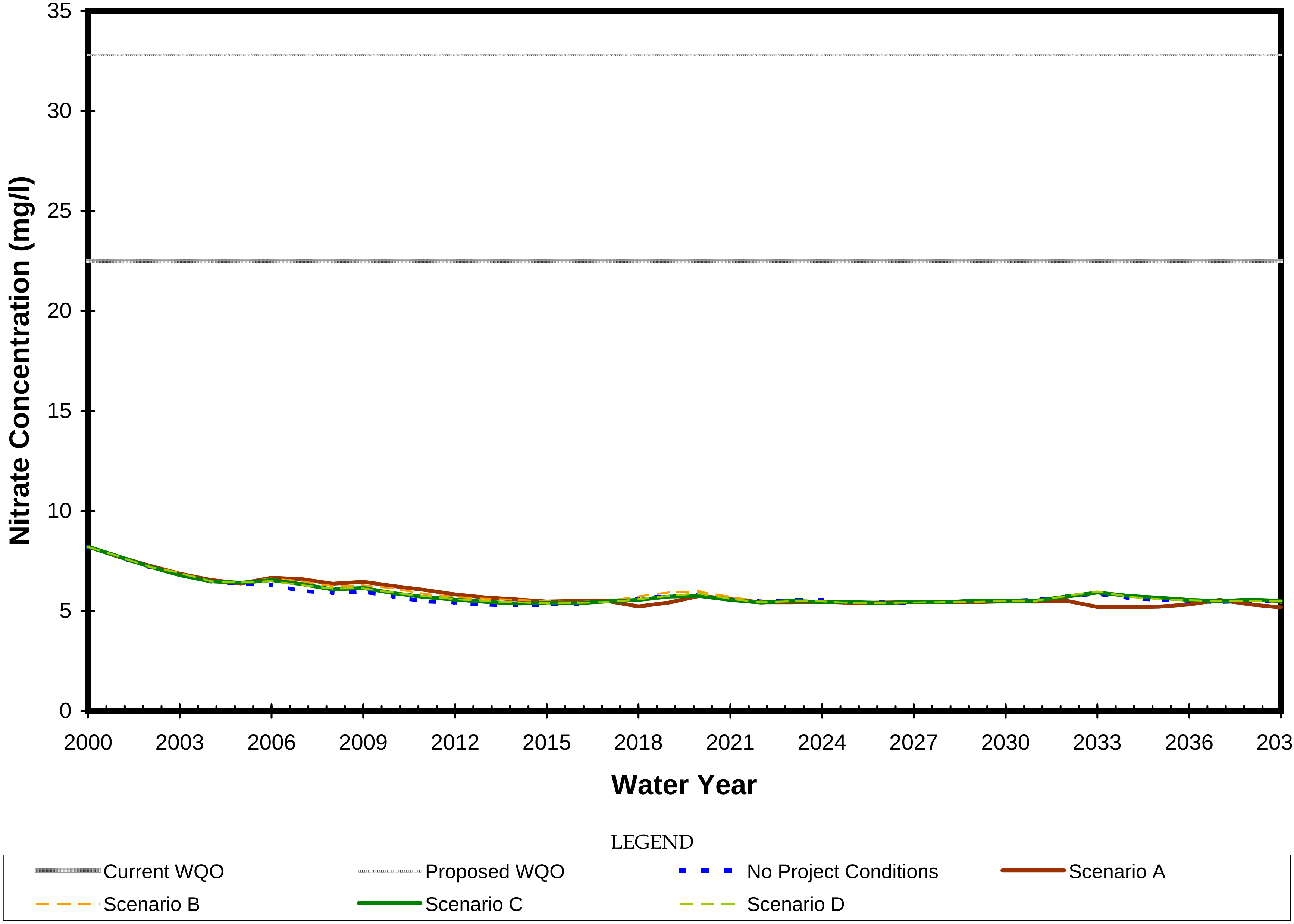


Figure B 75p. Nitrate Concentrations for IW-16.

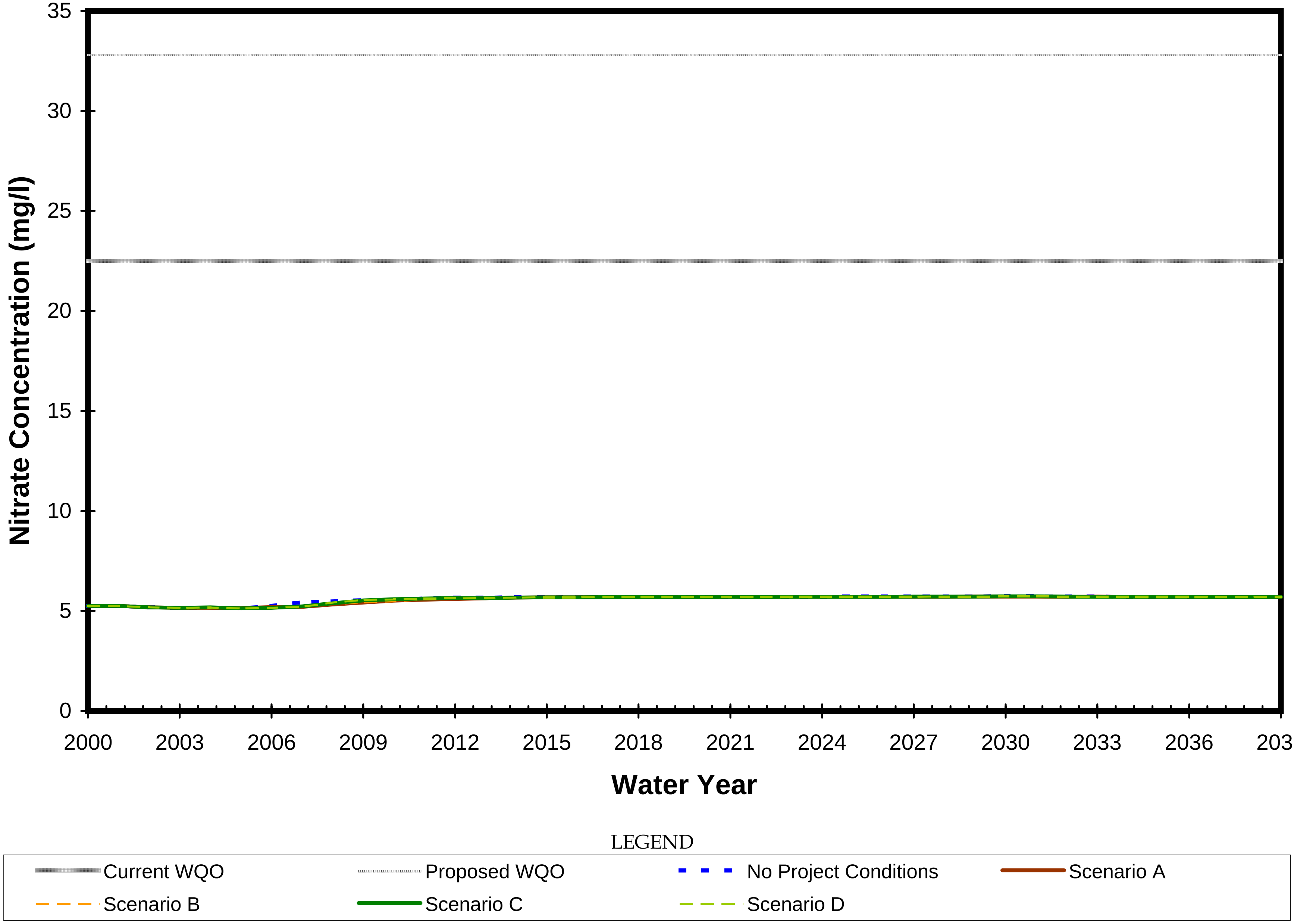


Figure B 75q. Nitrate Concentrations for IW-17.

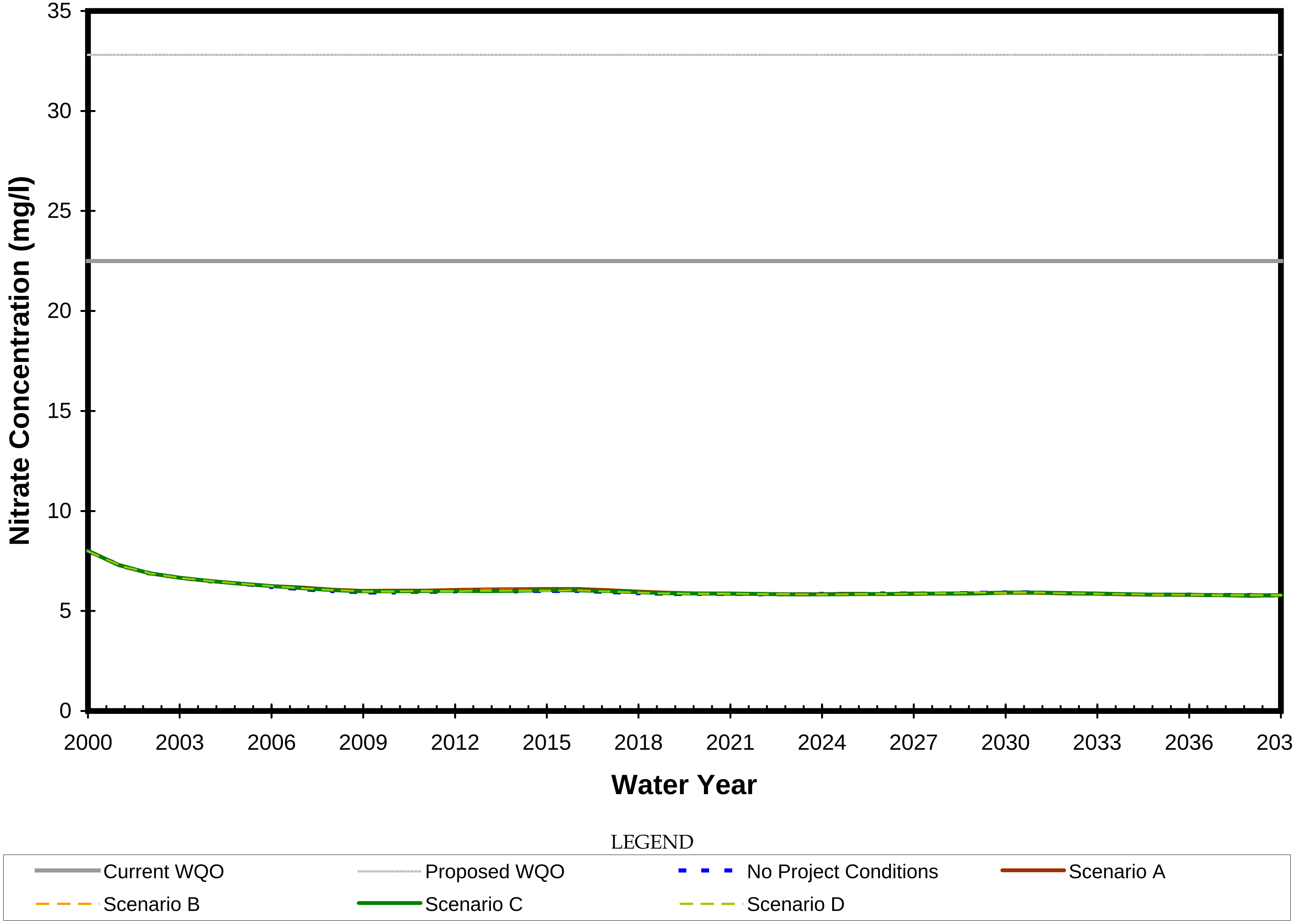


Figure B 75r. Nitrate Concentrations for IW-18.

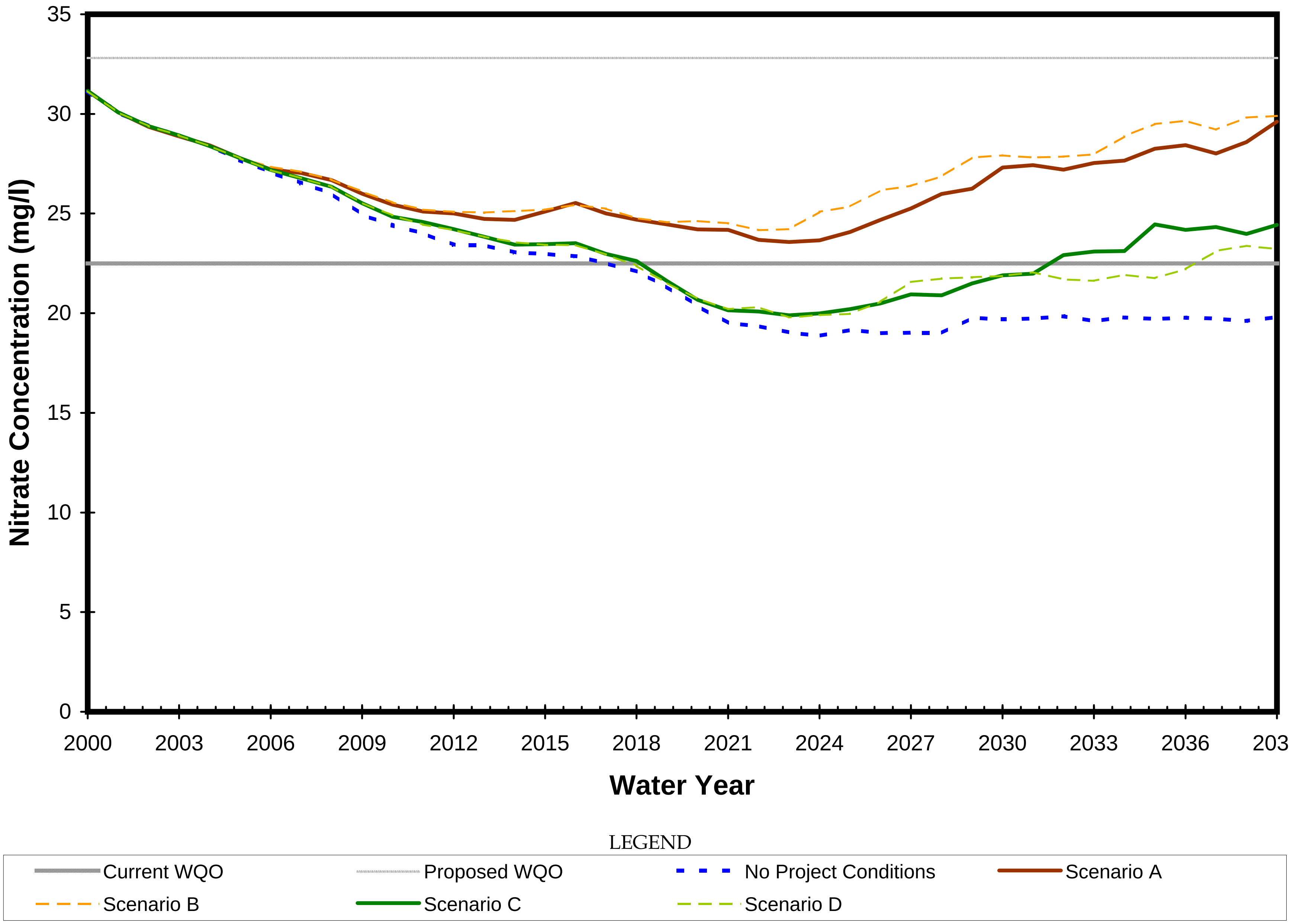


Figure B 75s. Nitrate Concentrations for IW-19.

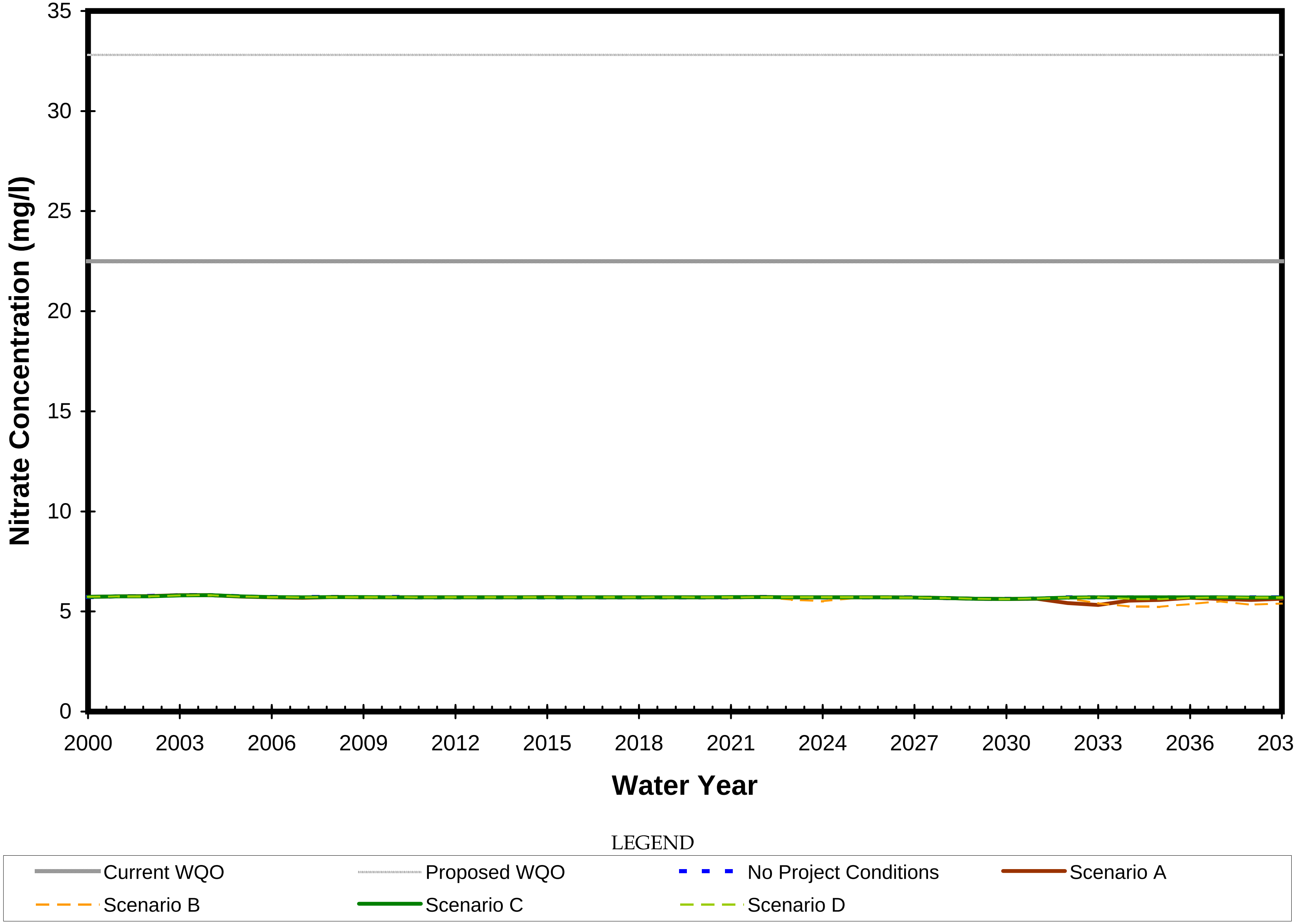


Figure B 75t. Nitrate Concentrations for IW-20.

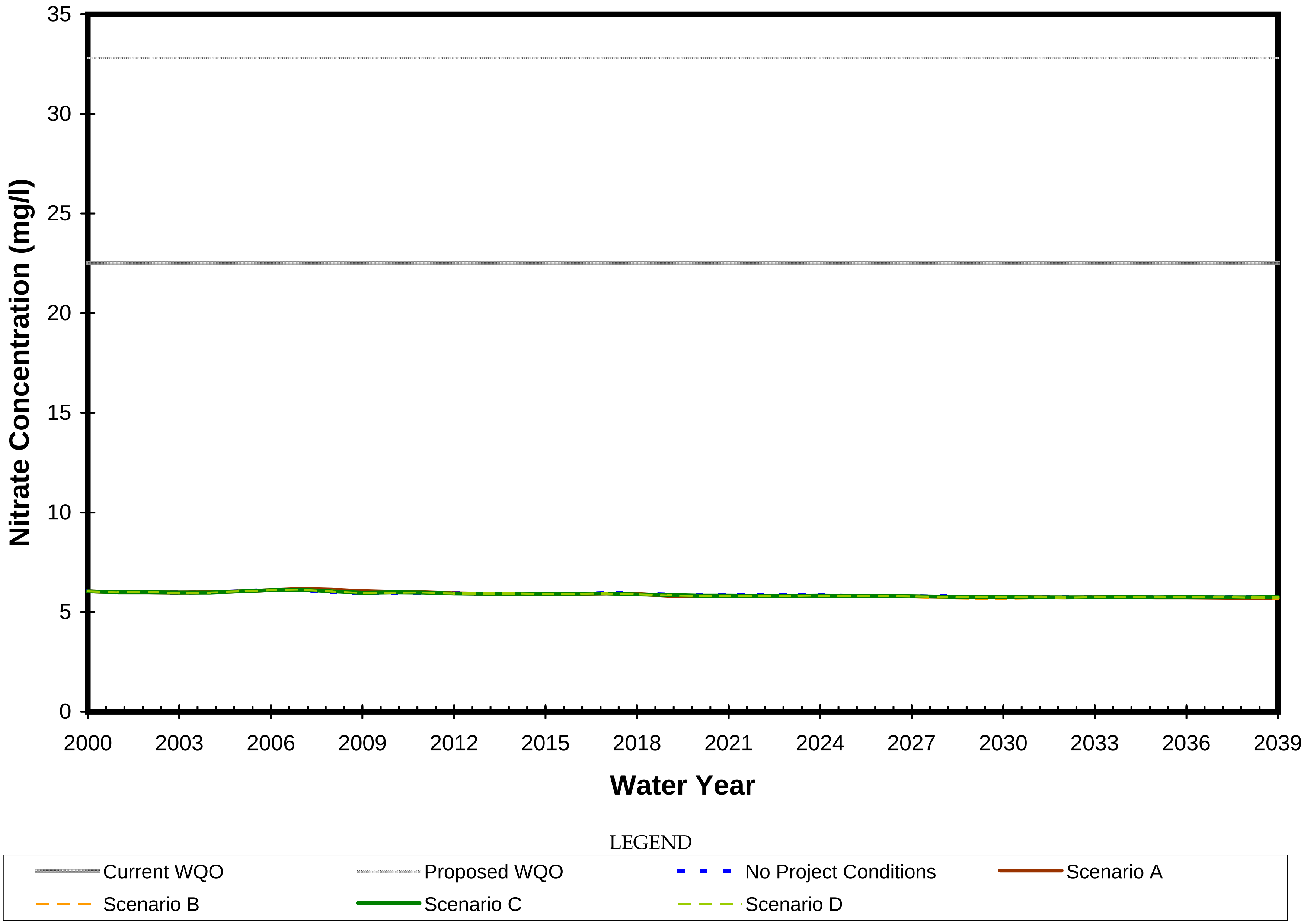


Figure B 75u. Nitrate Concentrations for IW-21.

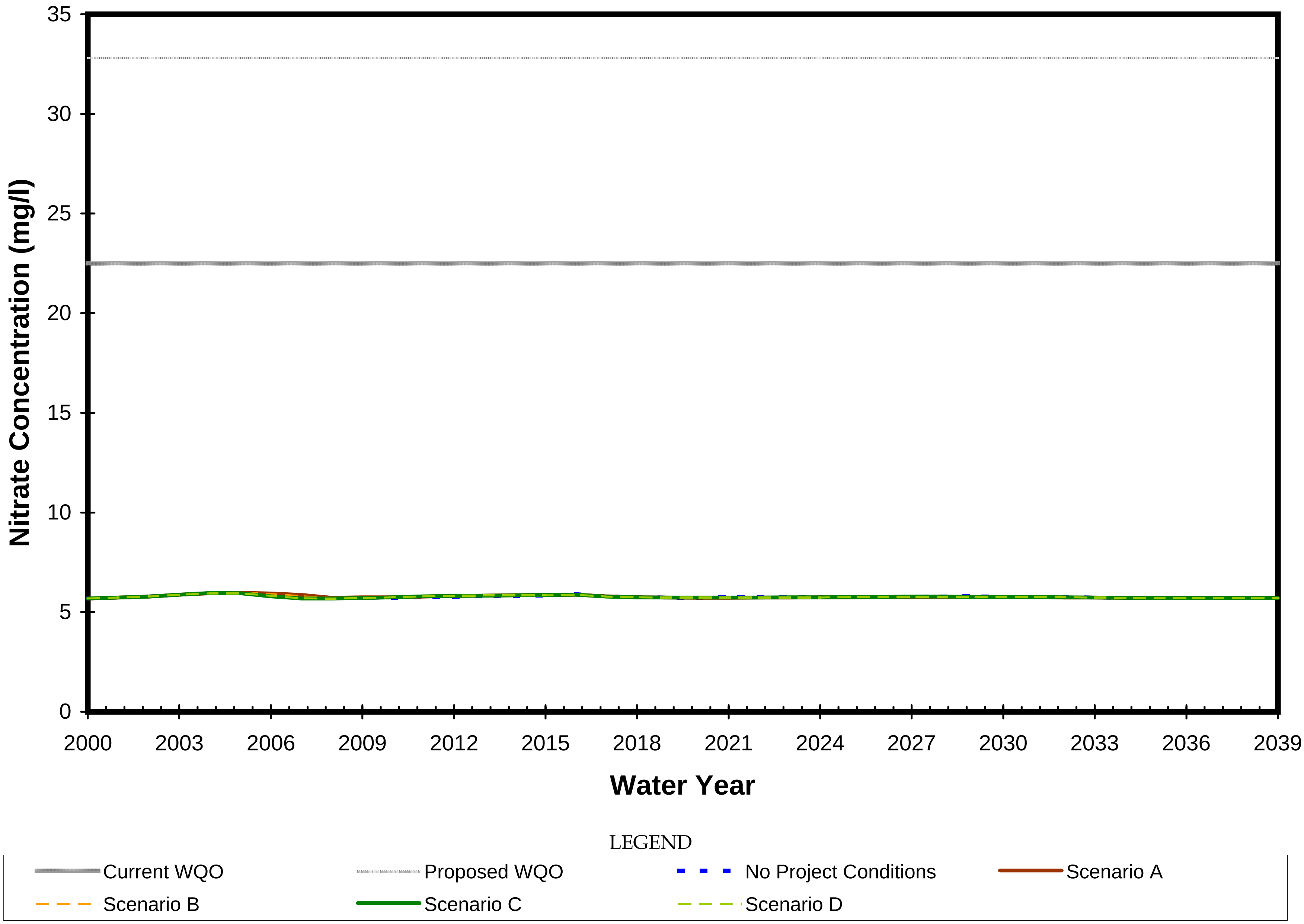


Figure B 75v. Nitrate Concentrations for IW-22.

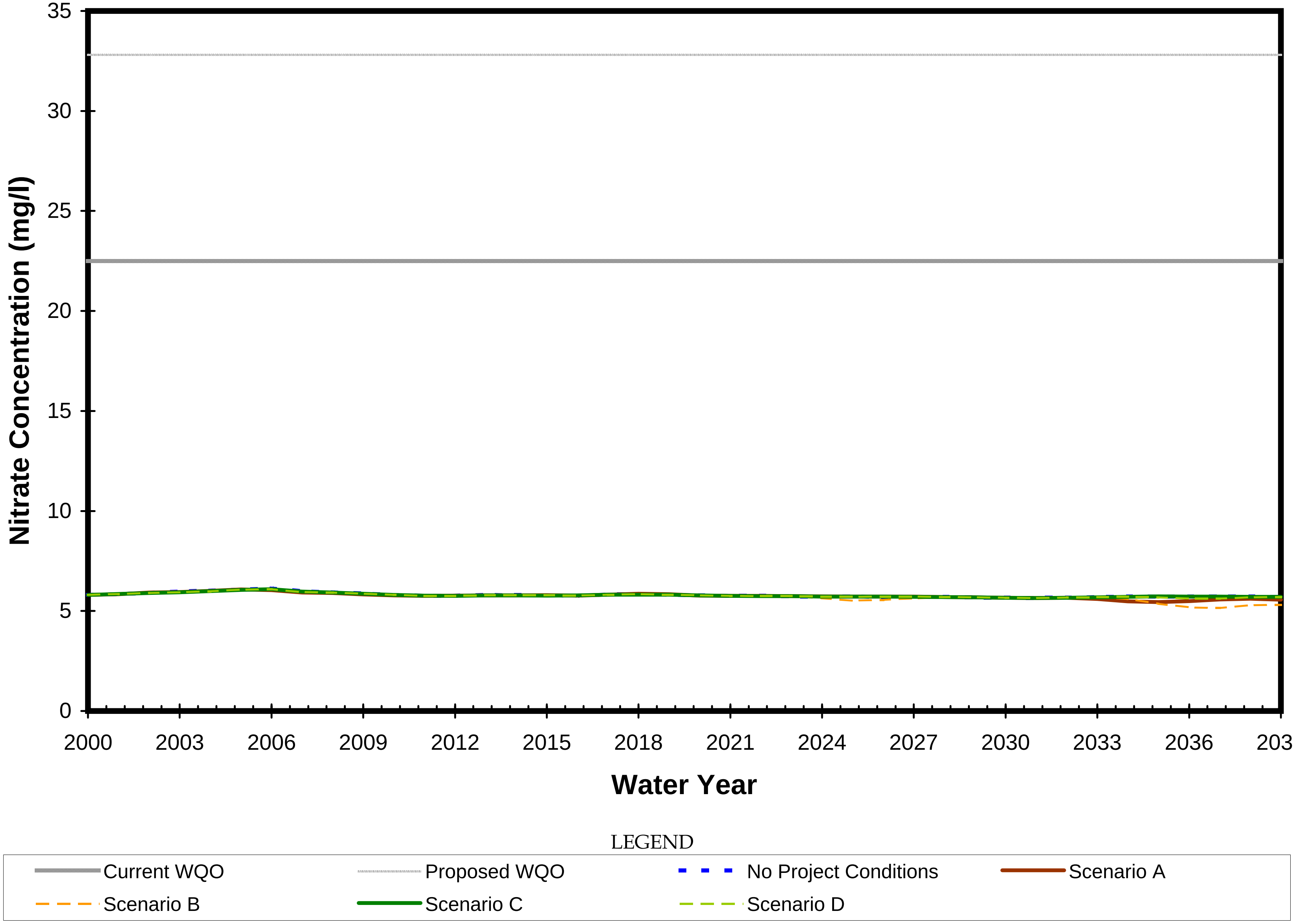


Figure B 75w. Nitrate Concentrations for IW-23.

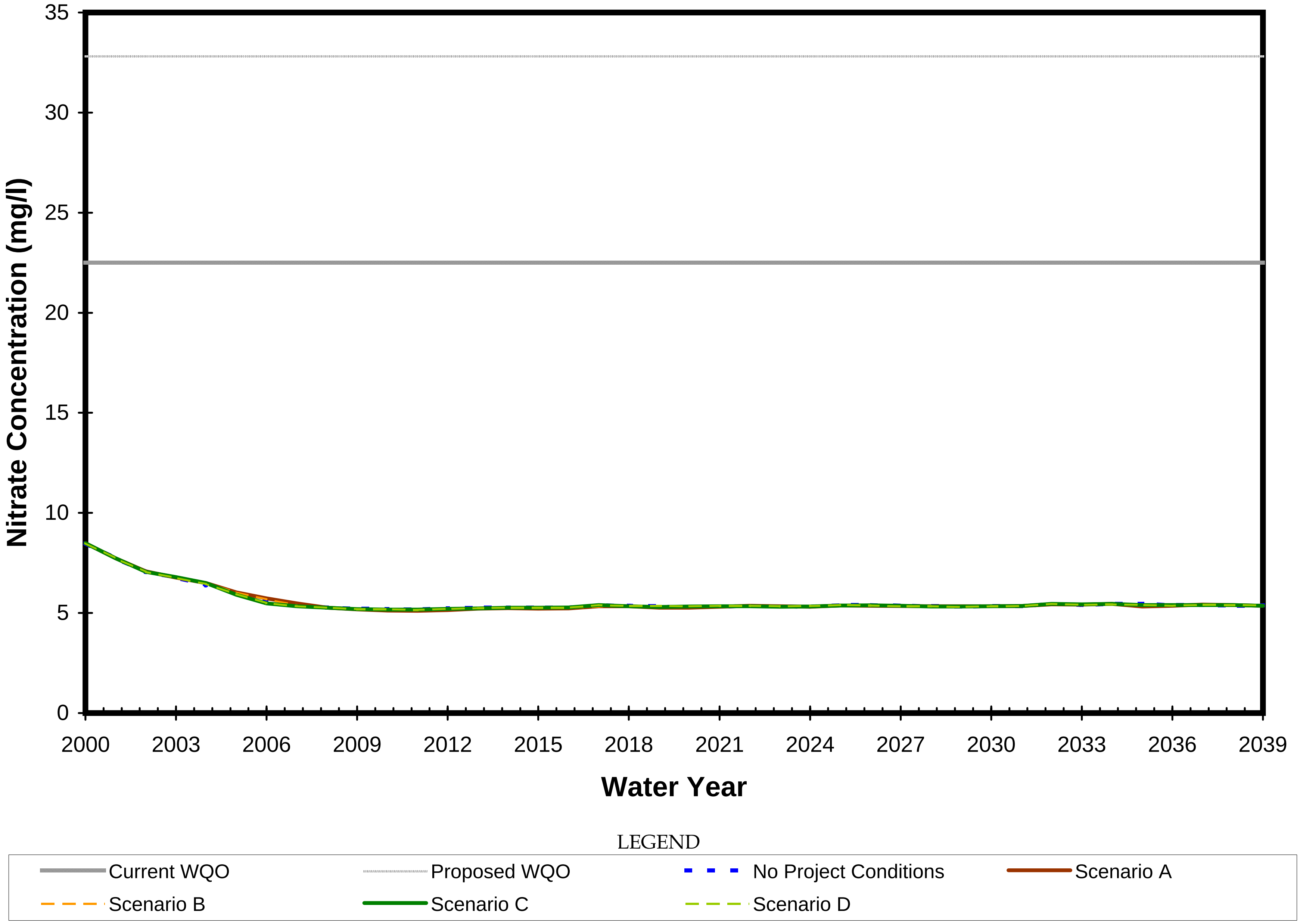


Figure B 75x. Nitrate Concentrations for IW-24.

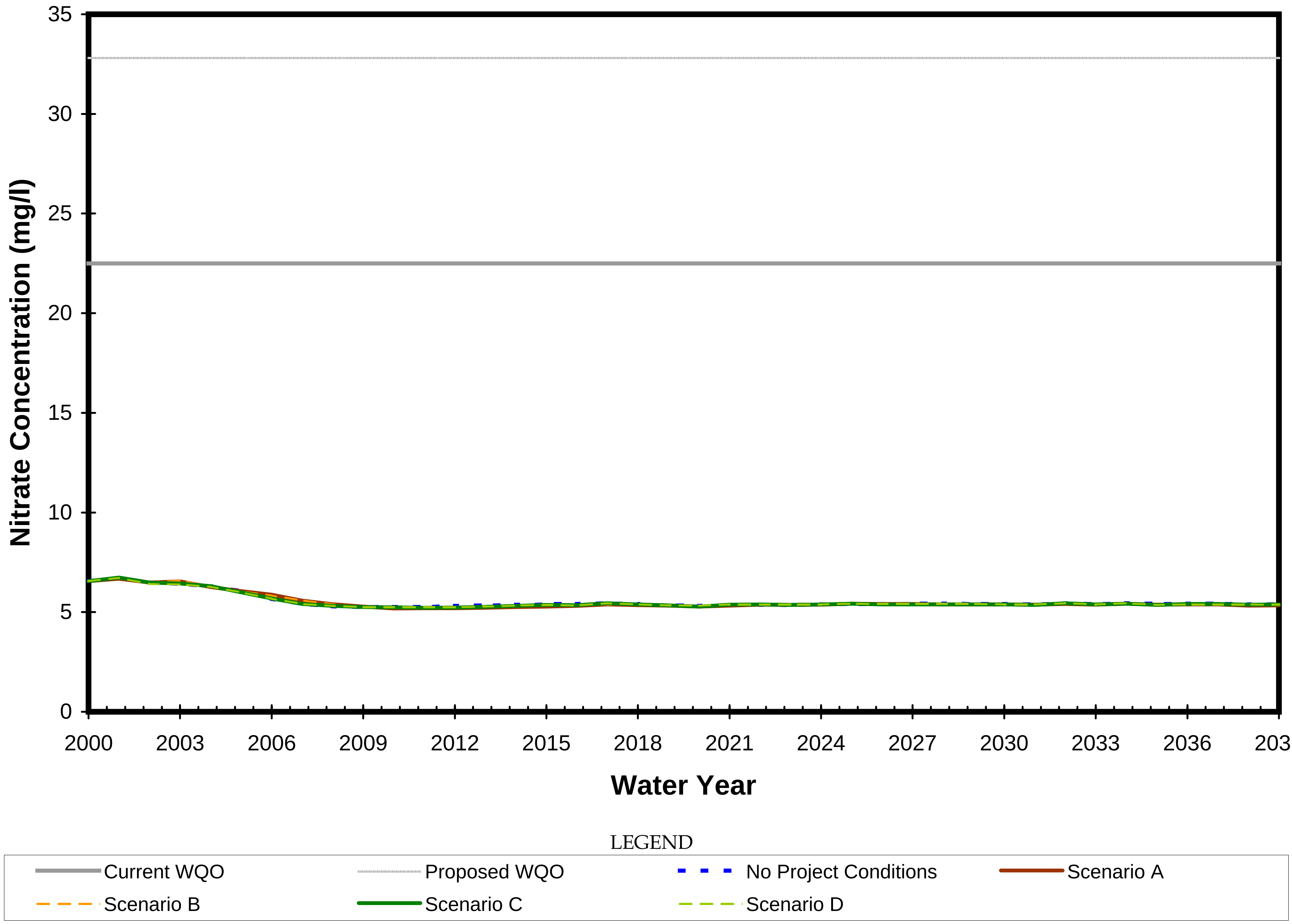


Figure B 75y. Nitrate Concentrations for IW-25.

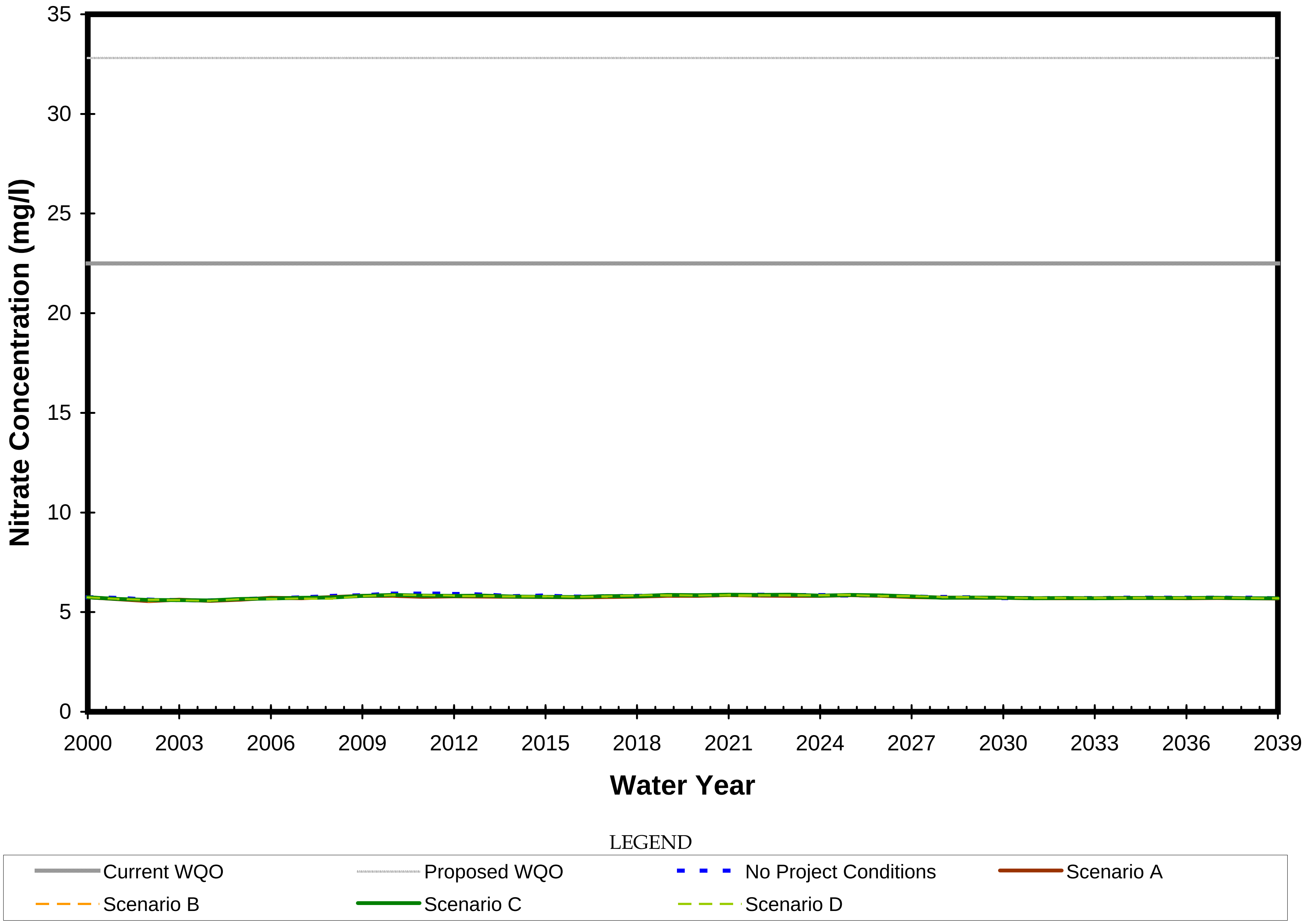


Figure B 75z. Nitrate Concentrations for SG-1 Devil Canyon / Sweetwater SG.

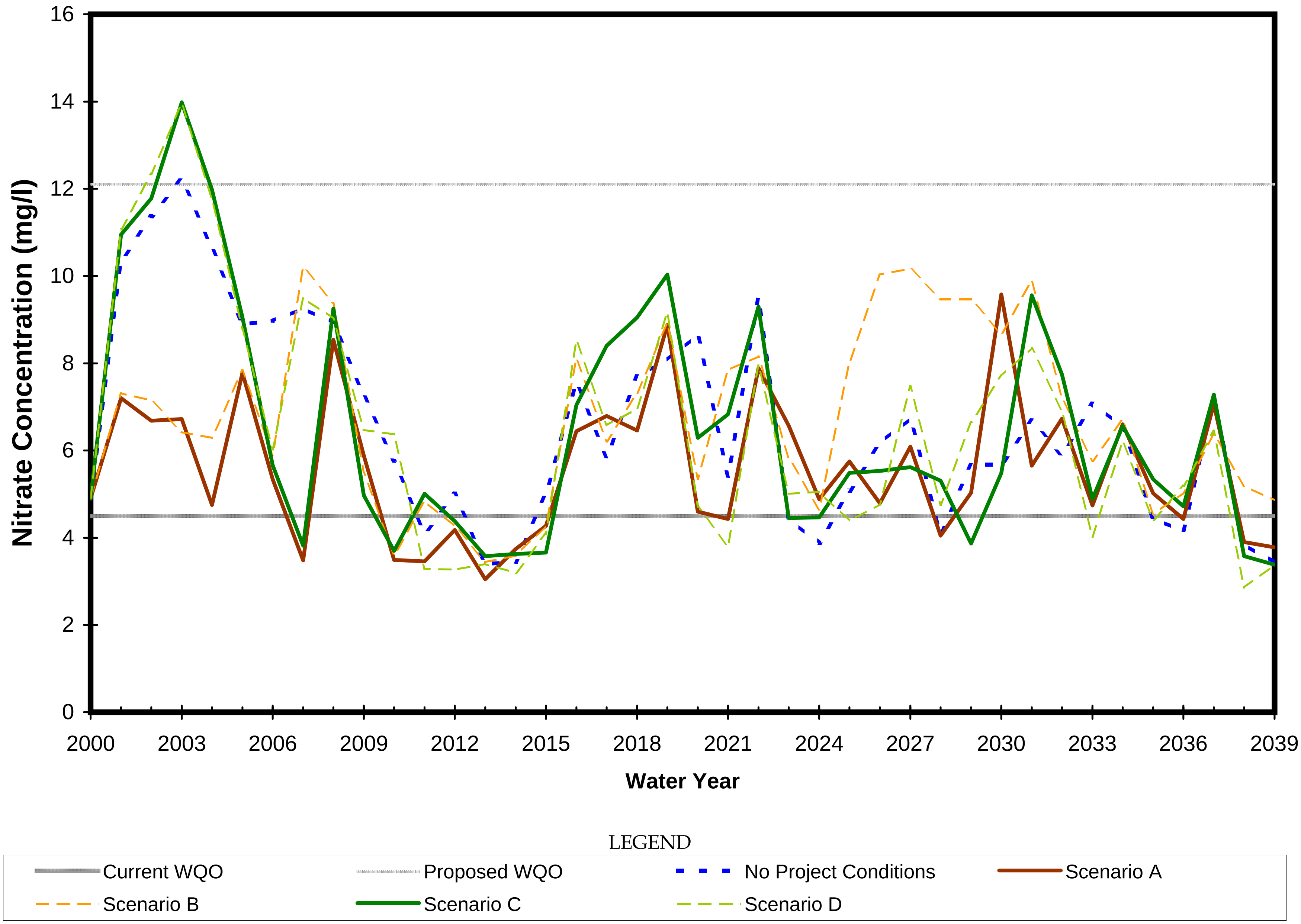


Figure B 75aa. Nitrate Concentrations for SG-2 Santa Ana River SG

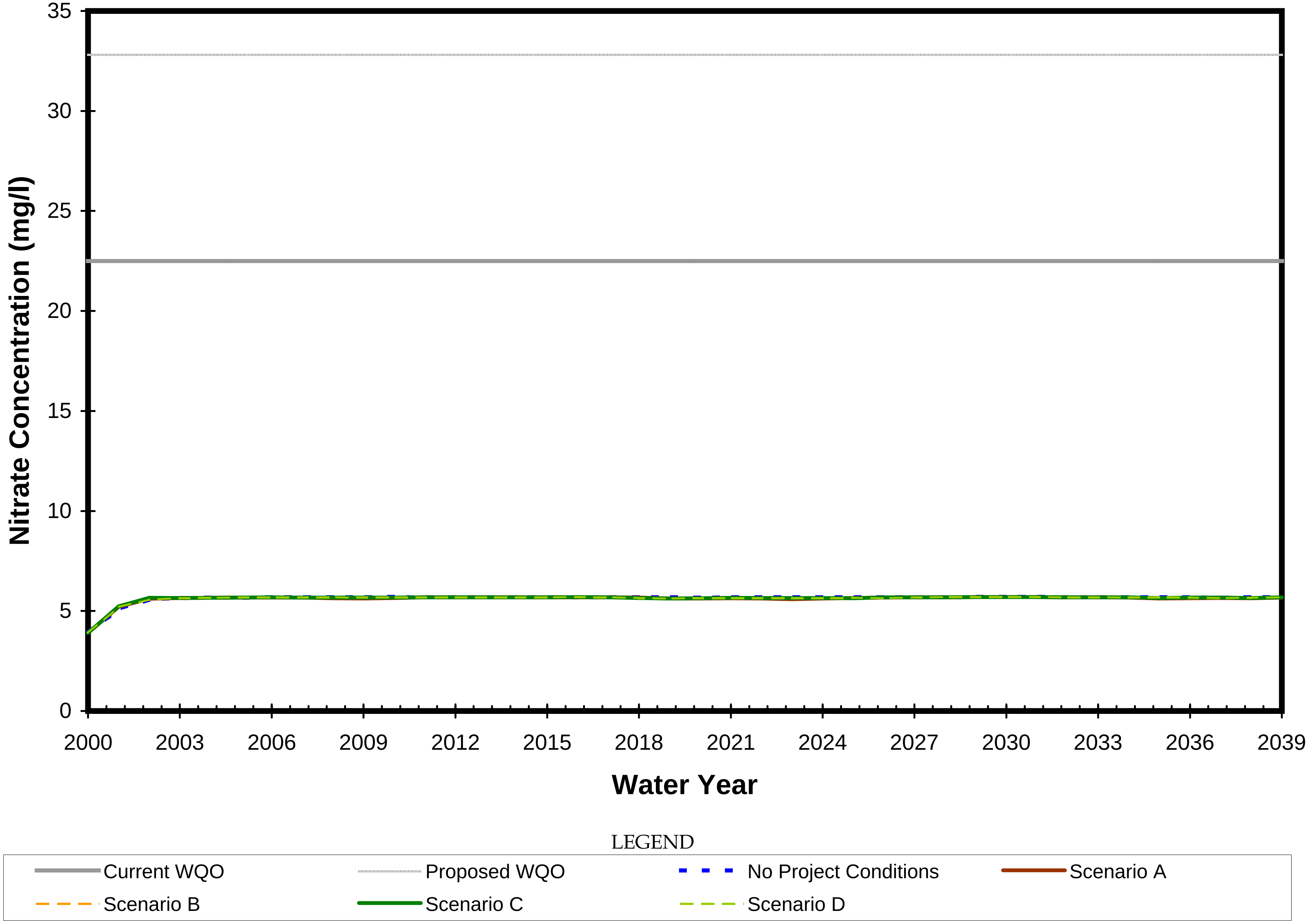


Figure B 75ab. Nitrate Concentrations for SG-3 Waterman SG.

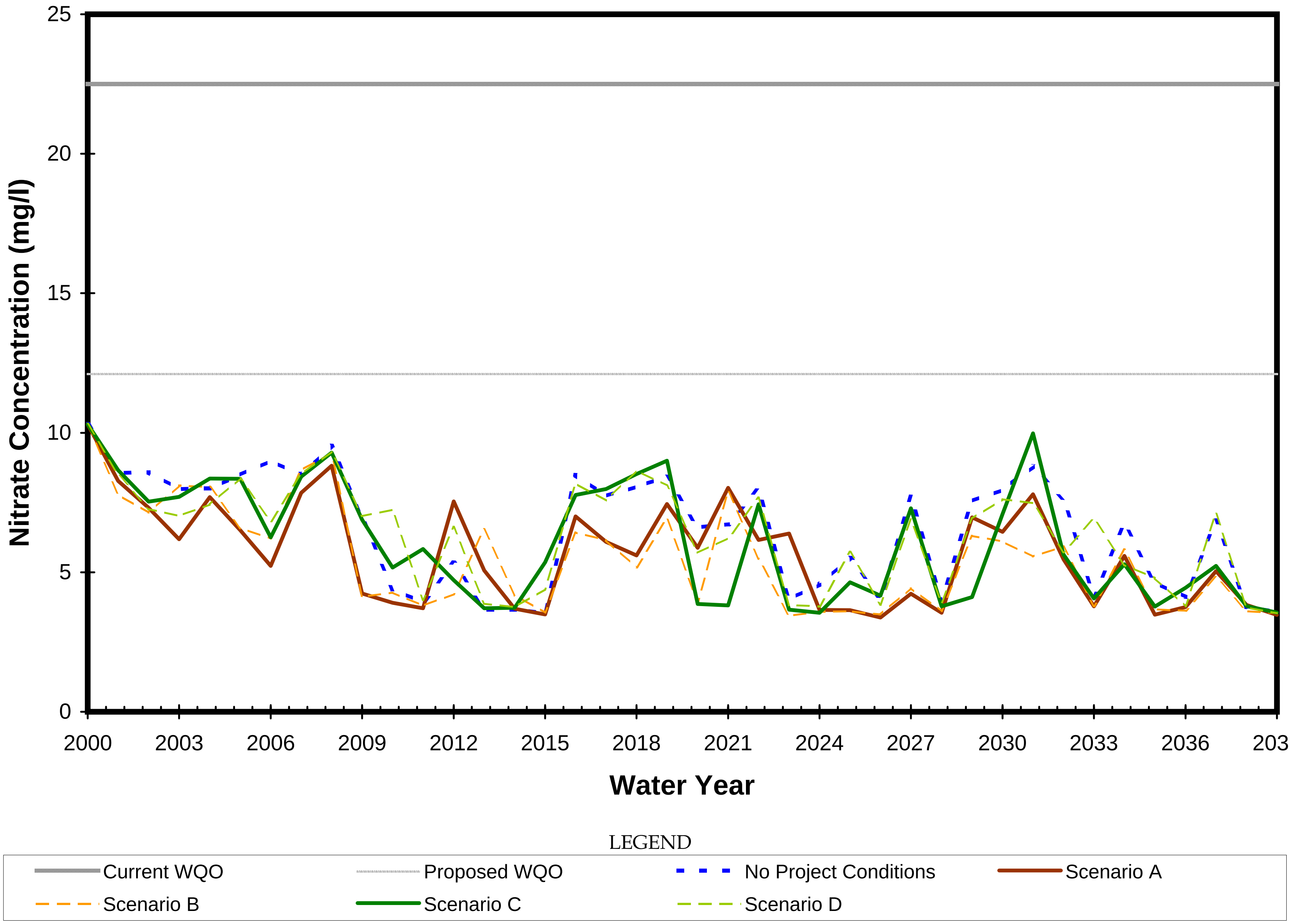


Figure B 75ac. Nitrate Concentrations for SG-4 Badger SG.

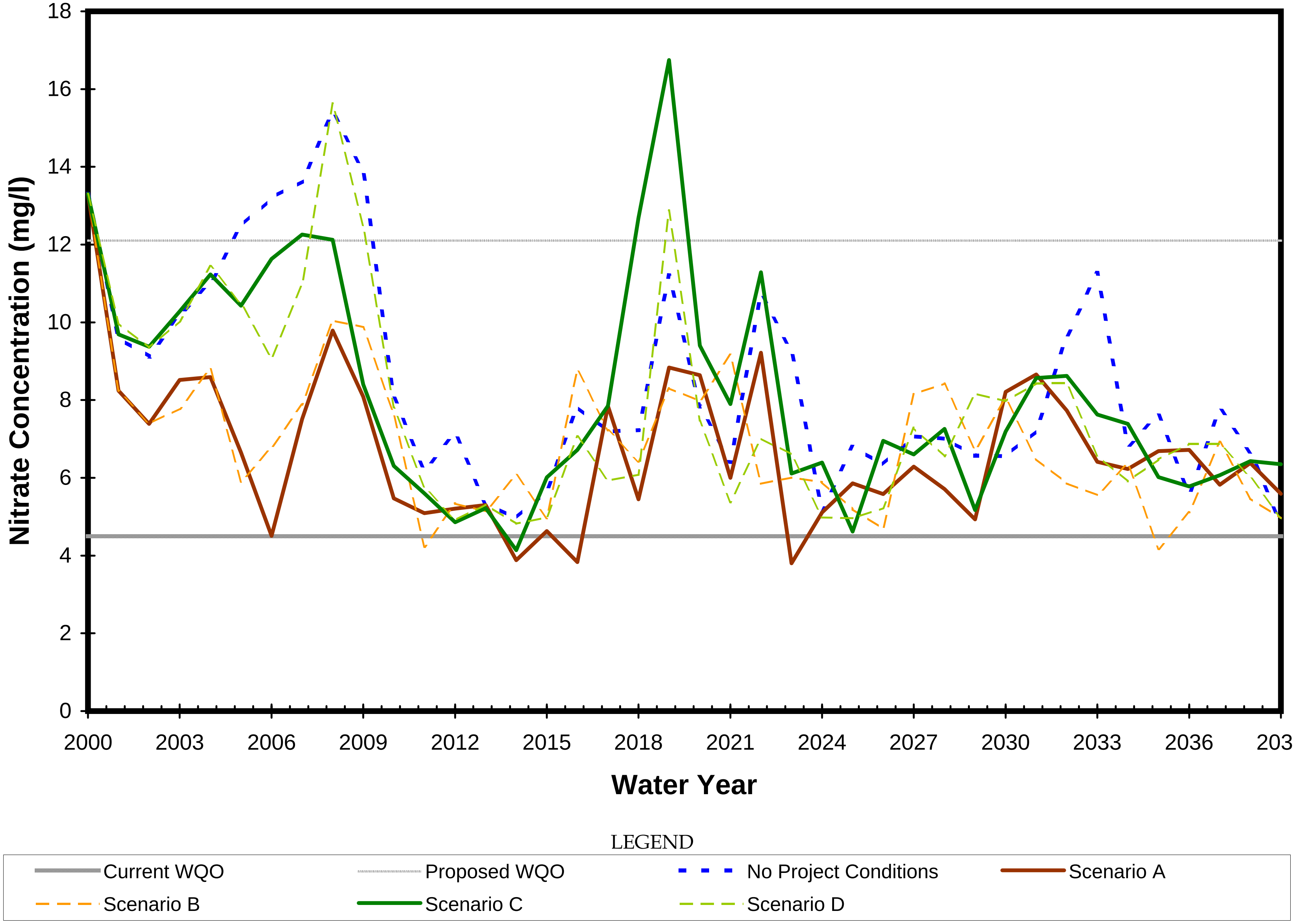


Figure B 75ad. Nitrate Concentrations for SG-5 Patton SG.

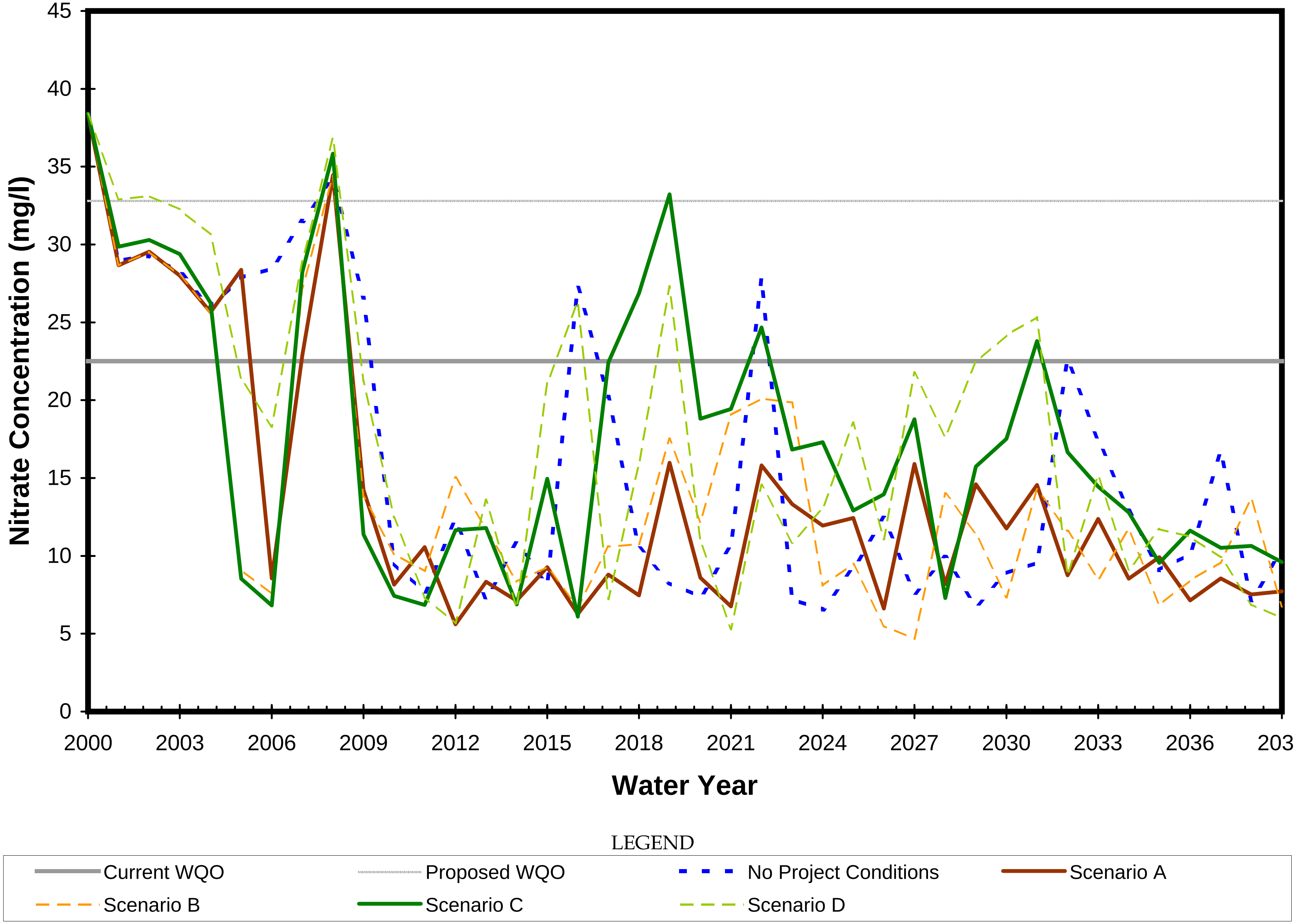


Figure B 75ae. Nitrate Concentrations for SG-6 Mill Creek SG.

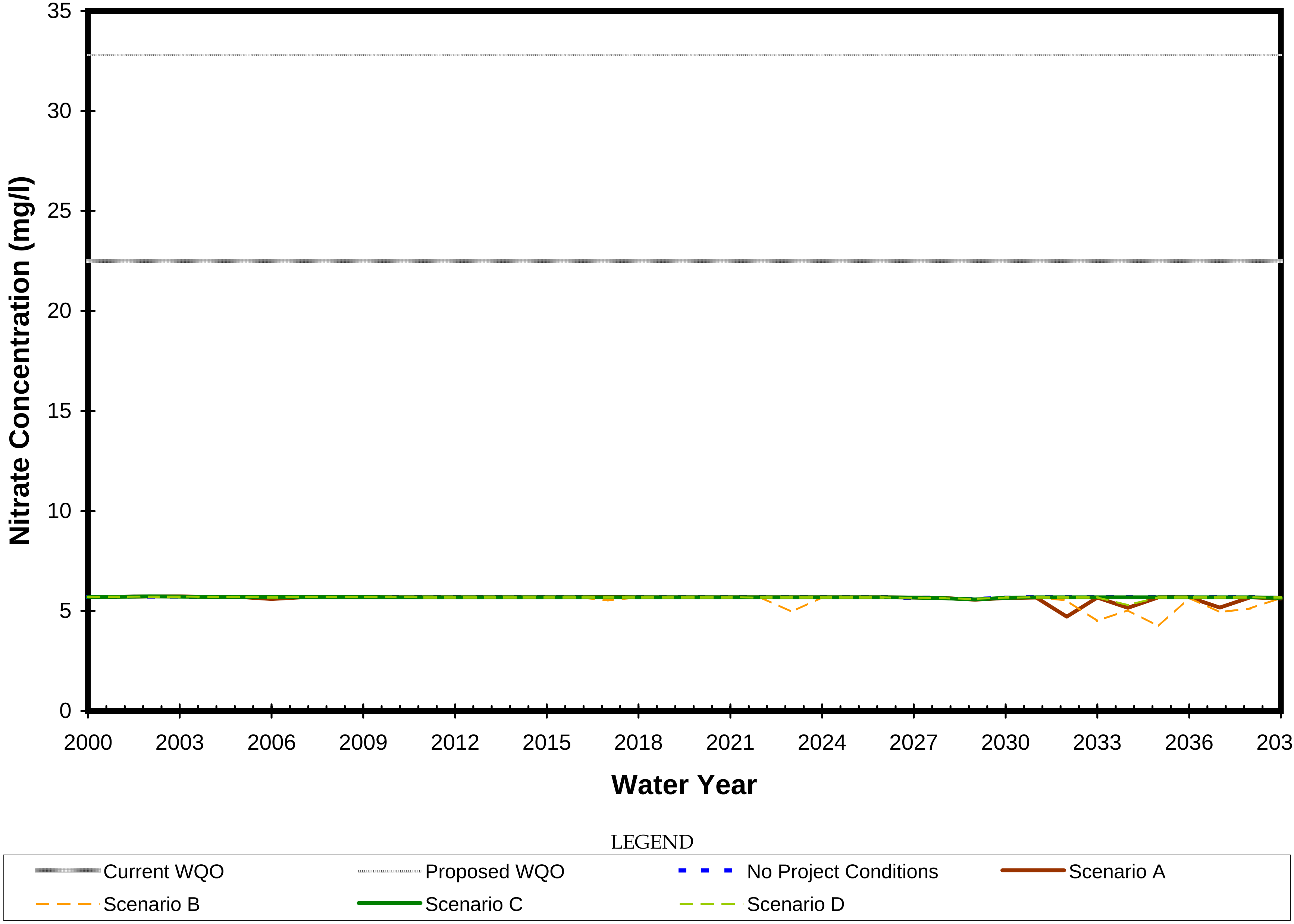


Figure B 75af. Nitrate Concentrations for SG-7 City Creek SG.

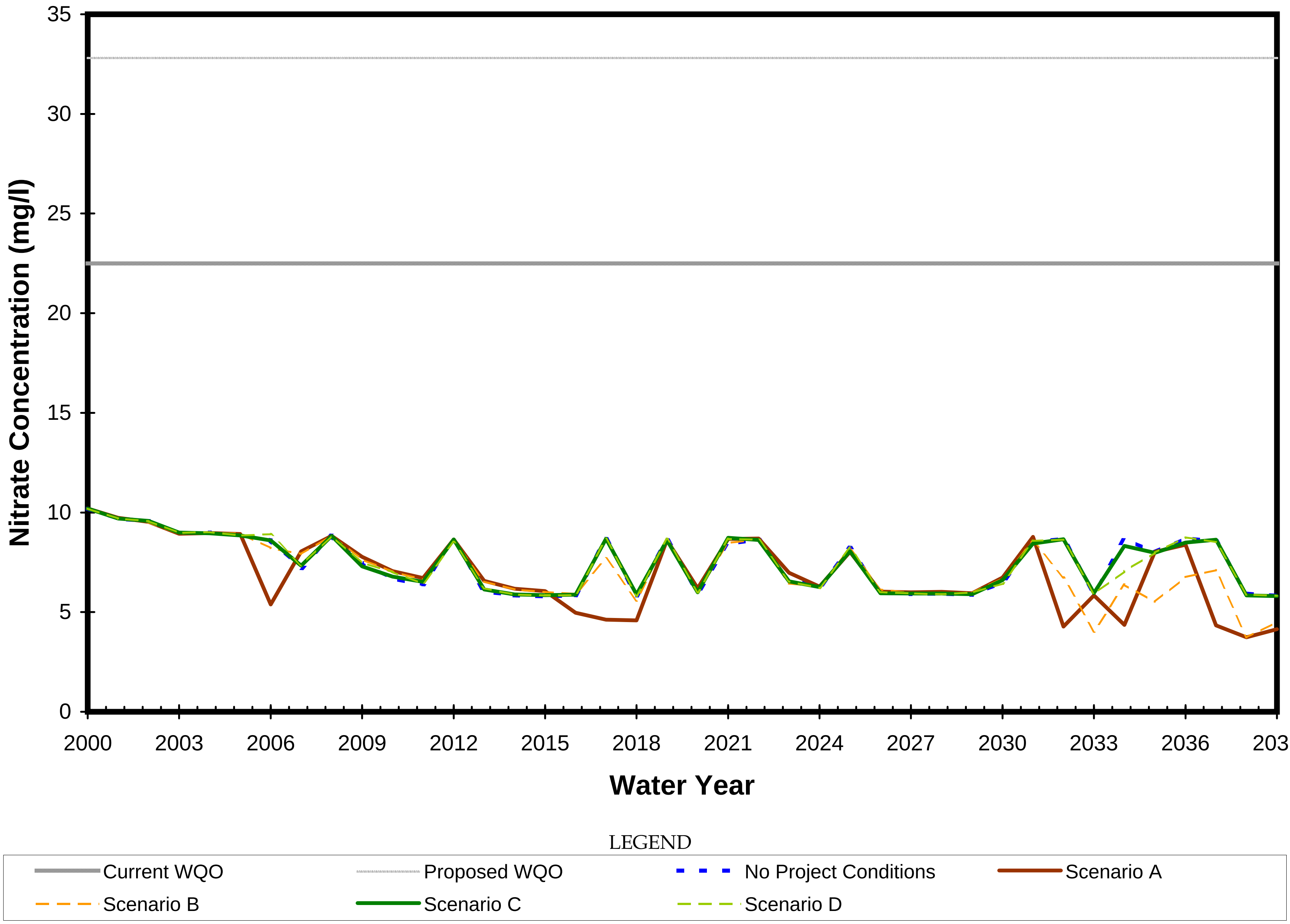


Figure B 75ag. Nitrate Concentrations for SG-8 East Twin Creek SG.

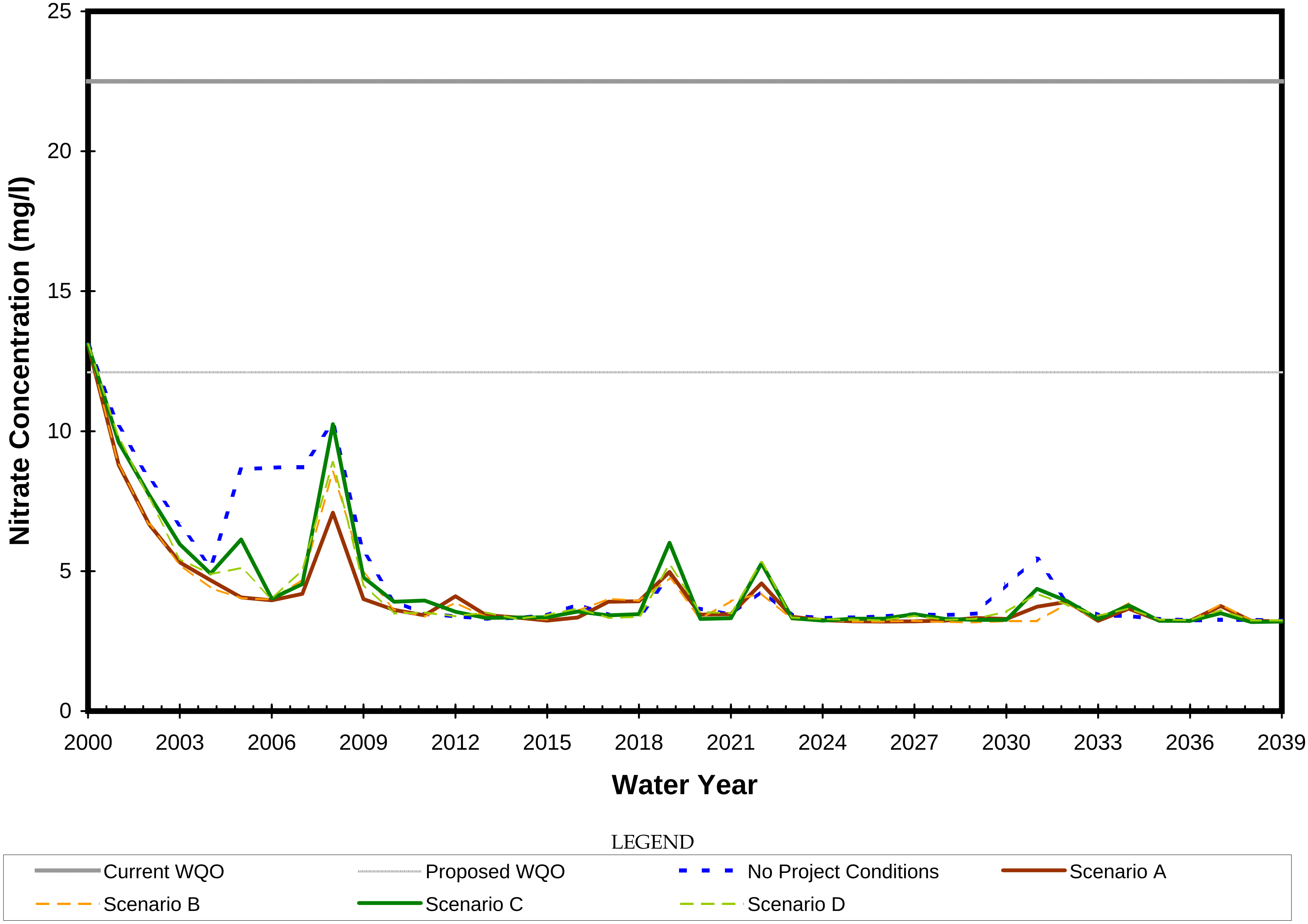
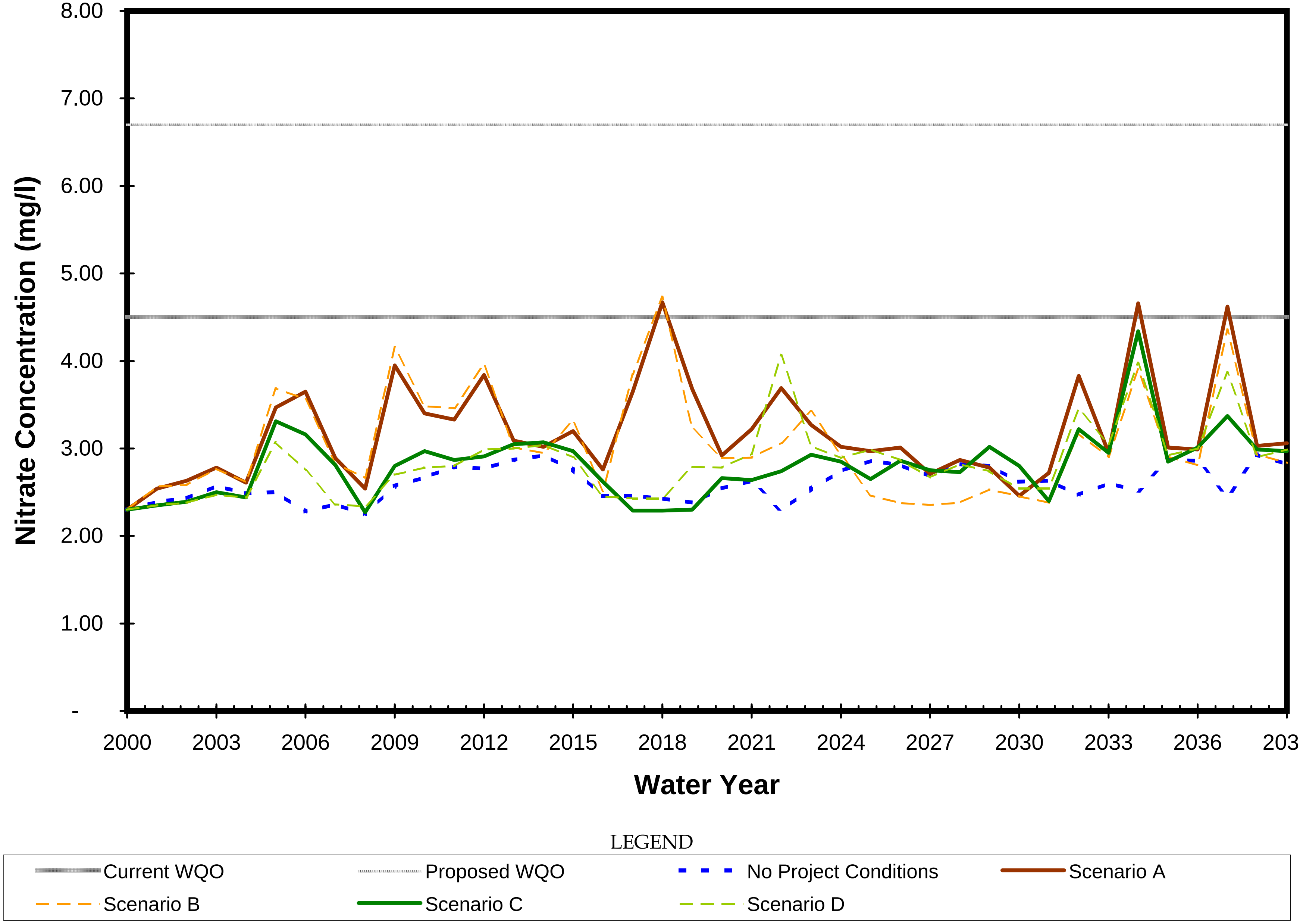
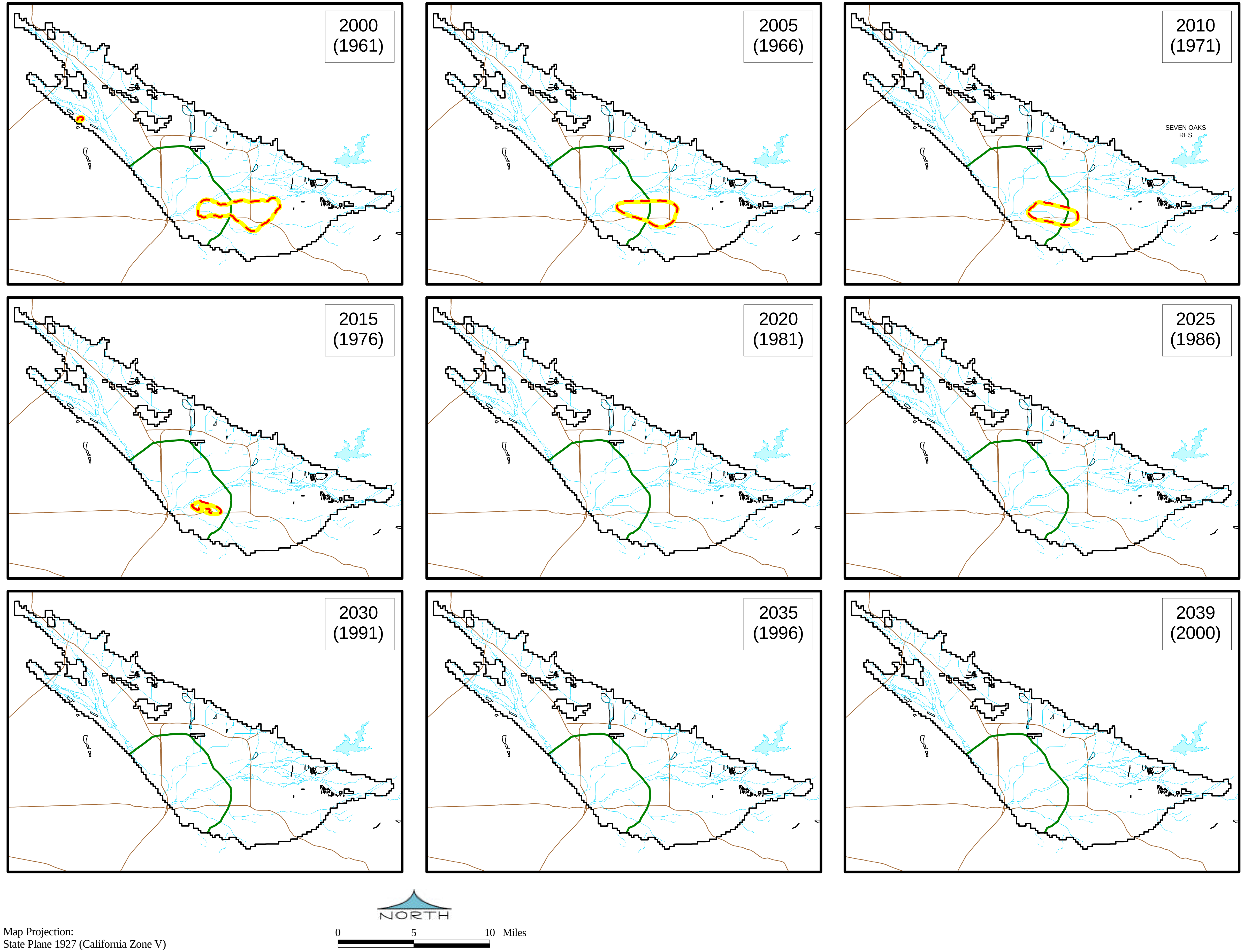


Figure B 75ah. Nitrate Concentrations for SG-9 Lytle Creek SG.



SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PERCHLORATE PLUME BOUNDARY
LAYER 1
NO PROJECT CONDITION VERSUS SCENARIO C

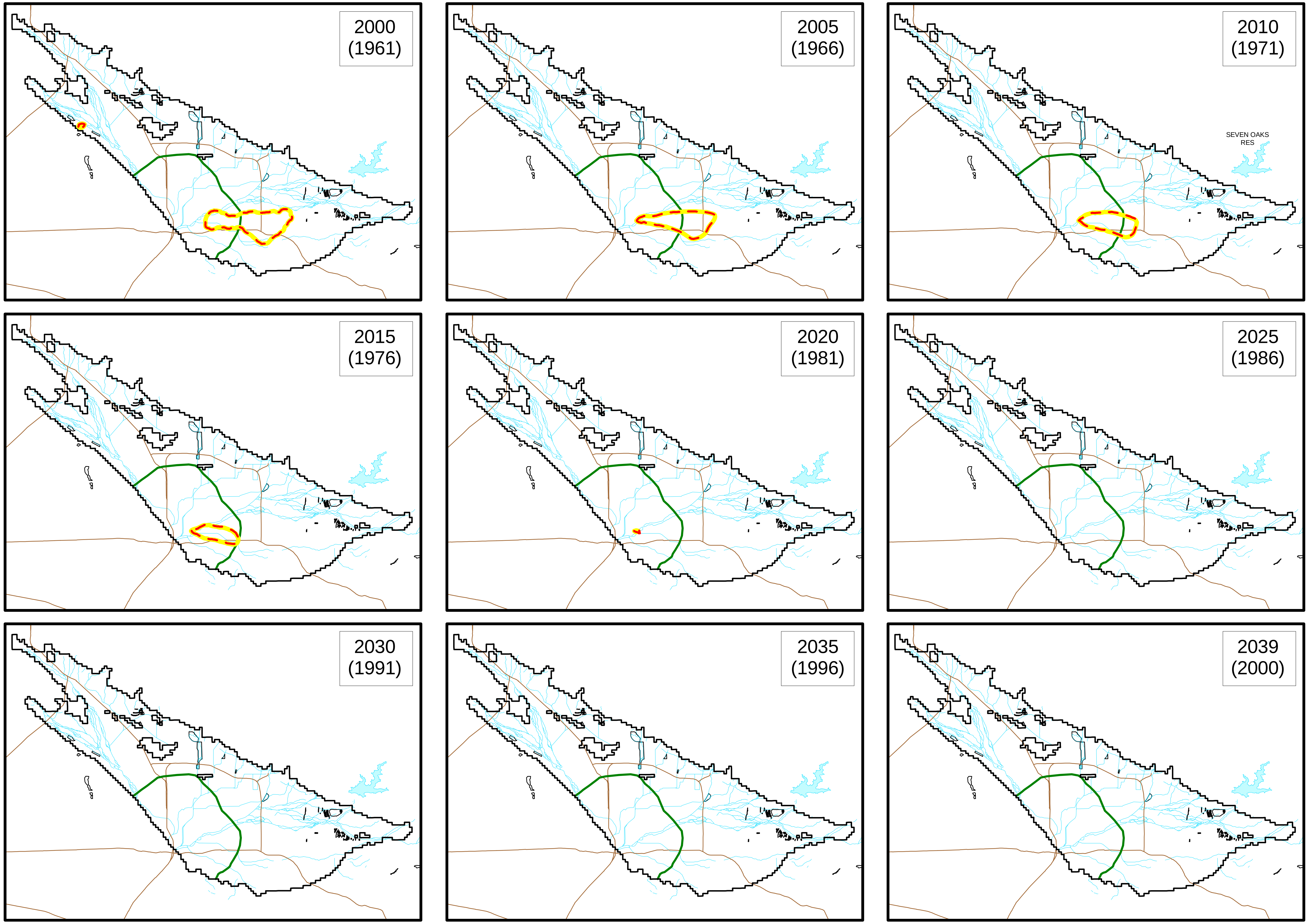


Map Projection:
State Plane 1927 (California Zone V)

Figure B 76

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PERCHLORATE PLUME BOUNDARY
LAYER 2
NO PROJECT CONDITION VERSUS SCENARIO C



EXPLANATION

Yellow Line 🟨	Perchlorate Plume Boundary (6 ug/L) Layer 2, No Project Condition
🟥 🟥 🟥	Perchlorate Plume Boundary (6 ug/L) Layer 2, Scenario C
2000 (1961)	Model Year (Assumed Hydrological Year)
🟩	Pressure Zone
☐	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

NORTH

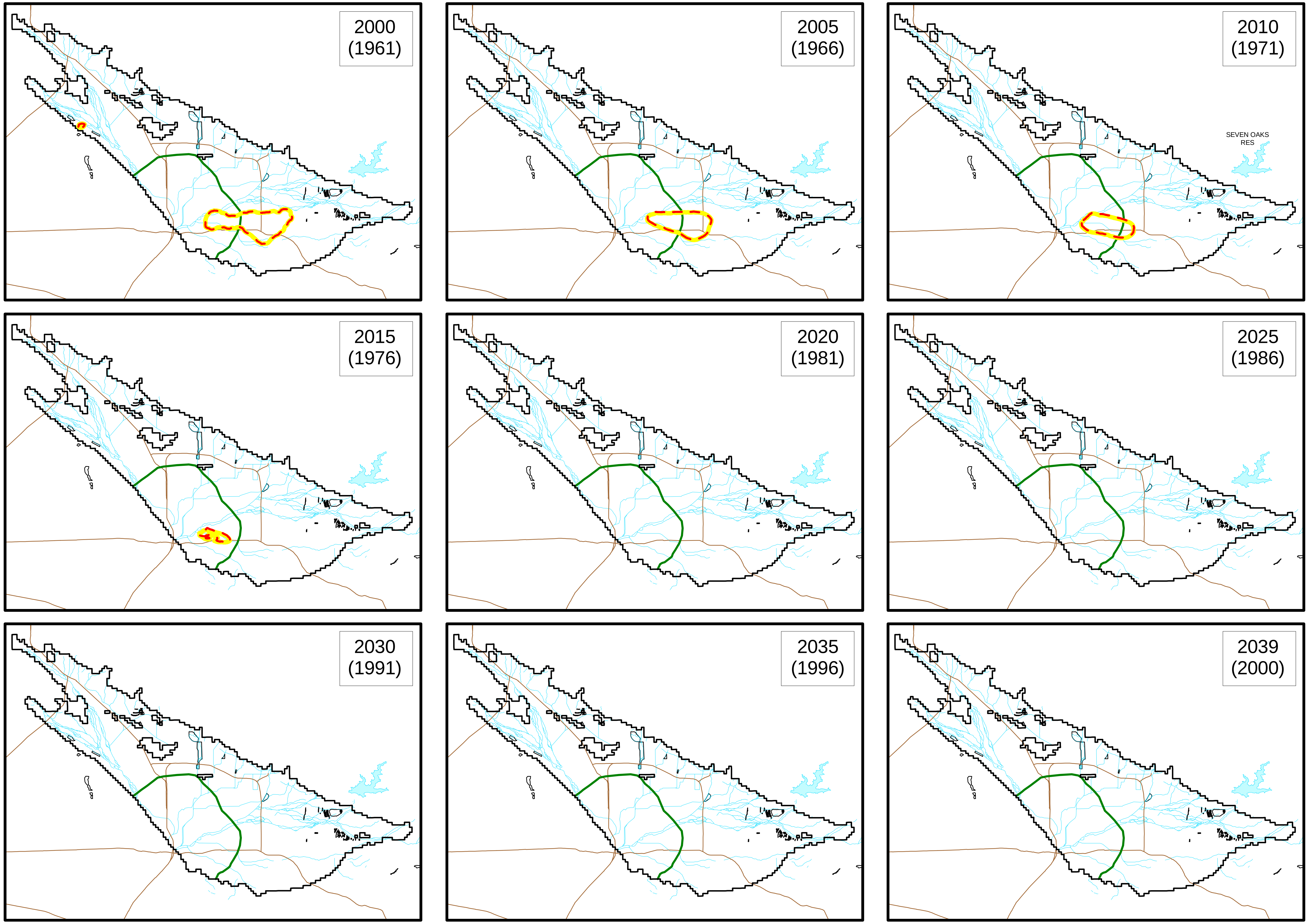
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 77

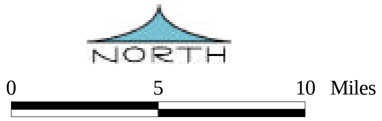
SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PERCHLORATE PLUME BOUNDARY
LAYER 1
NO PROJECT CONDITION VERSUS SCENARIO D



EXPLANATION

Yellow Line	Perchlorate Plume Boundary (6 ug/L) Layer 1, No Project Condition
— —	Perchlorate Plume Boundary (6 ug/L) Layer 1, Scenario D
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

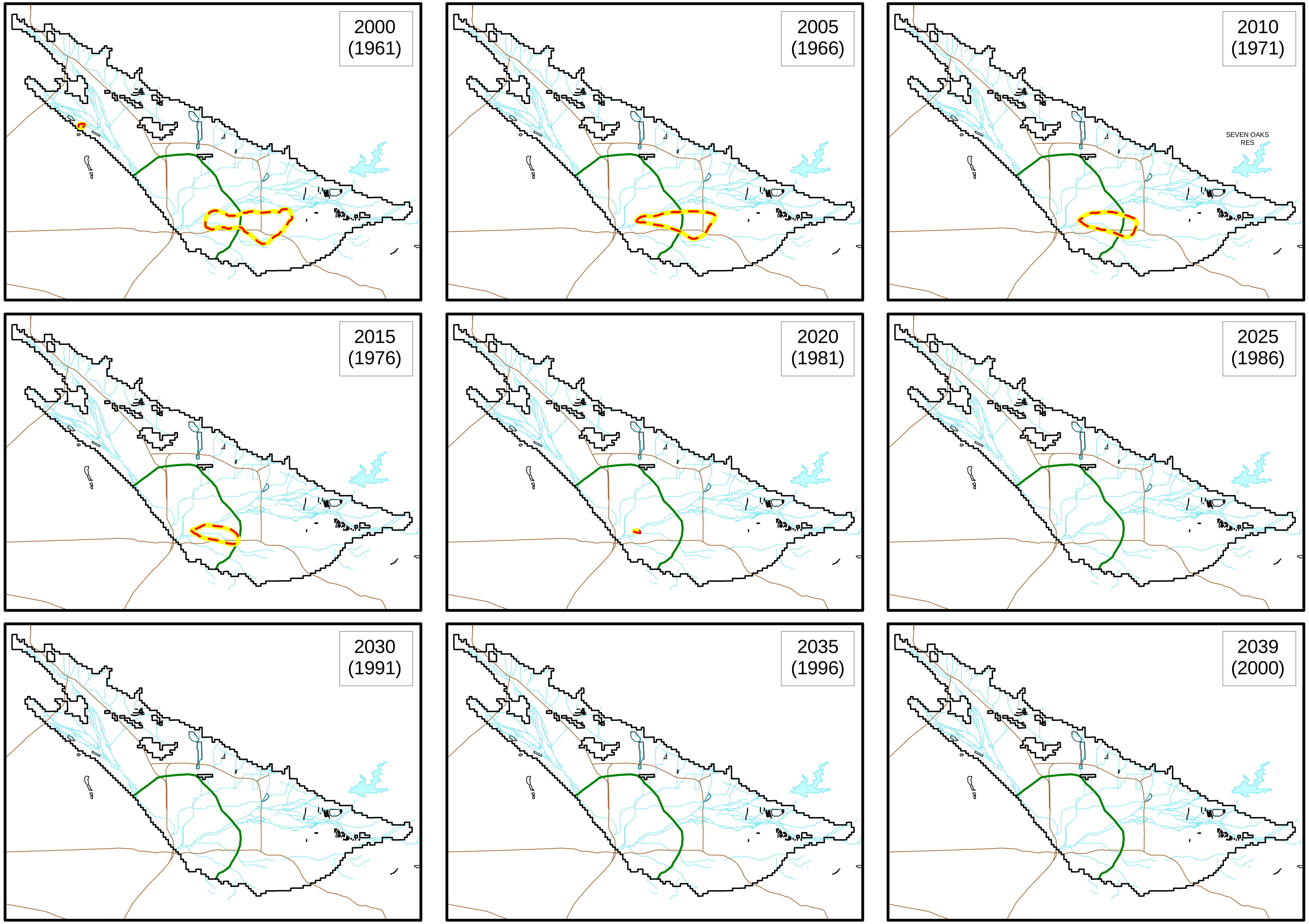


Map Projection:
State Plane 1927 (California Zone V)

Figure B 78

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PERCHLORATE PLUME BOUNDARY
LAYER 2
NO PROJECT CONDITION VERSUS SCENARIO D



EXPLANATION

Yellow Line	Perchlorate Plume Boundary (6 ug/L) Layer 2, No Project Condition
– – –	Perchlorate Plume Boundary (6 ug/L) Layer 2, Scenario D
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

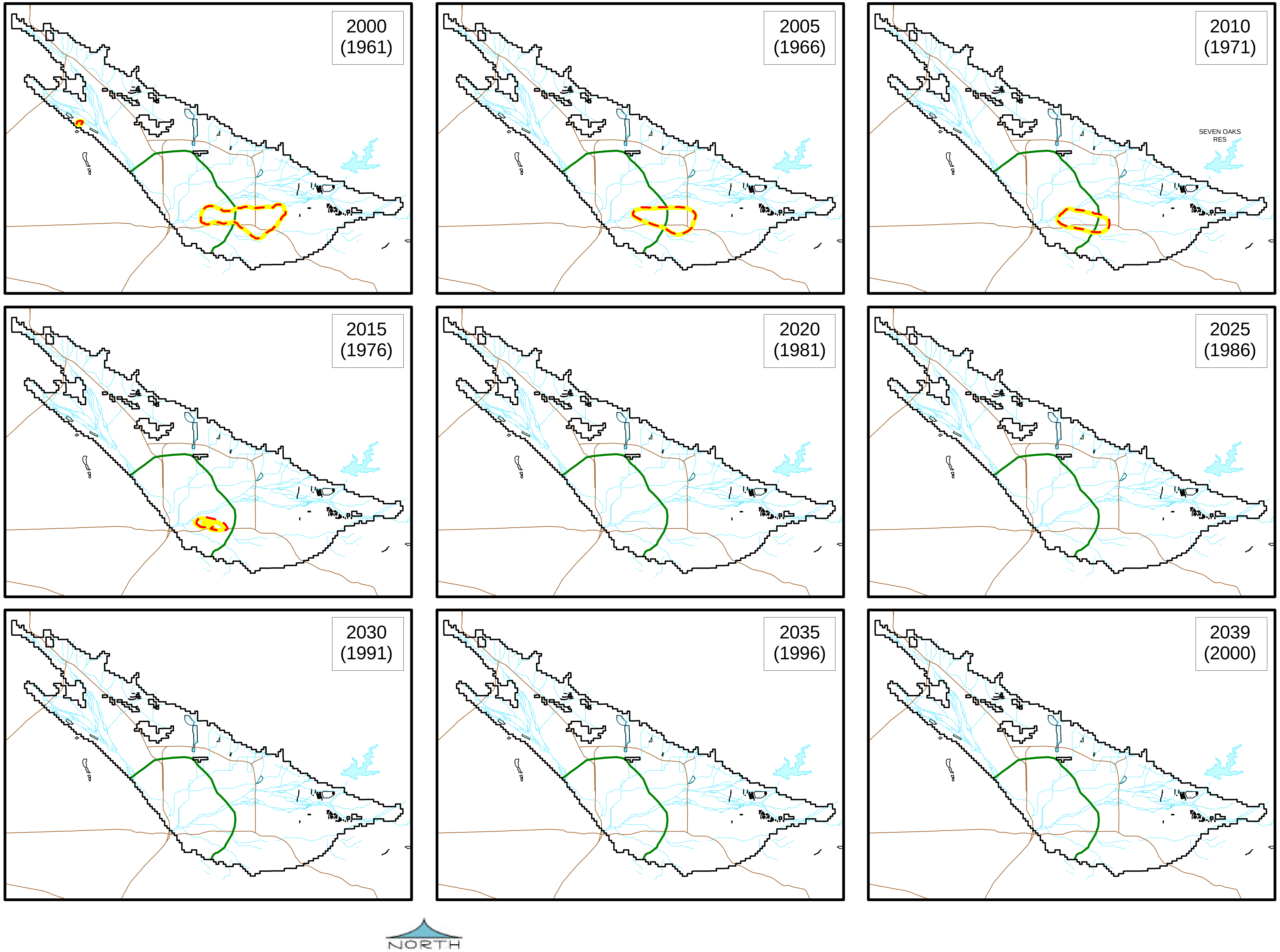
NORTH

0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 79

PERCHLORATE PLUME BOUNDARY LAYER 1 NO PROJECT CONDITION VERSUS SCENARIO A



EXPLANATION

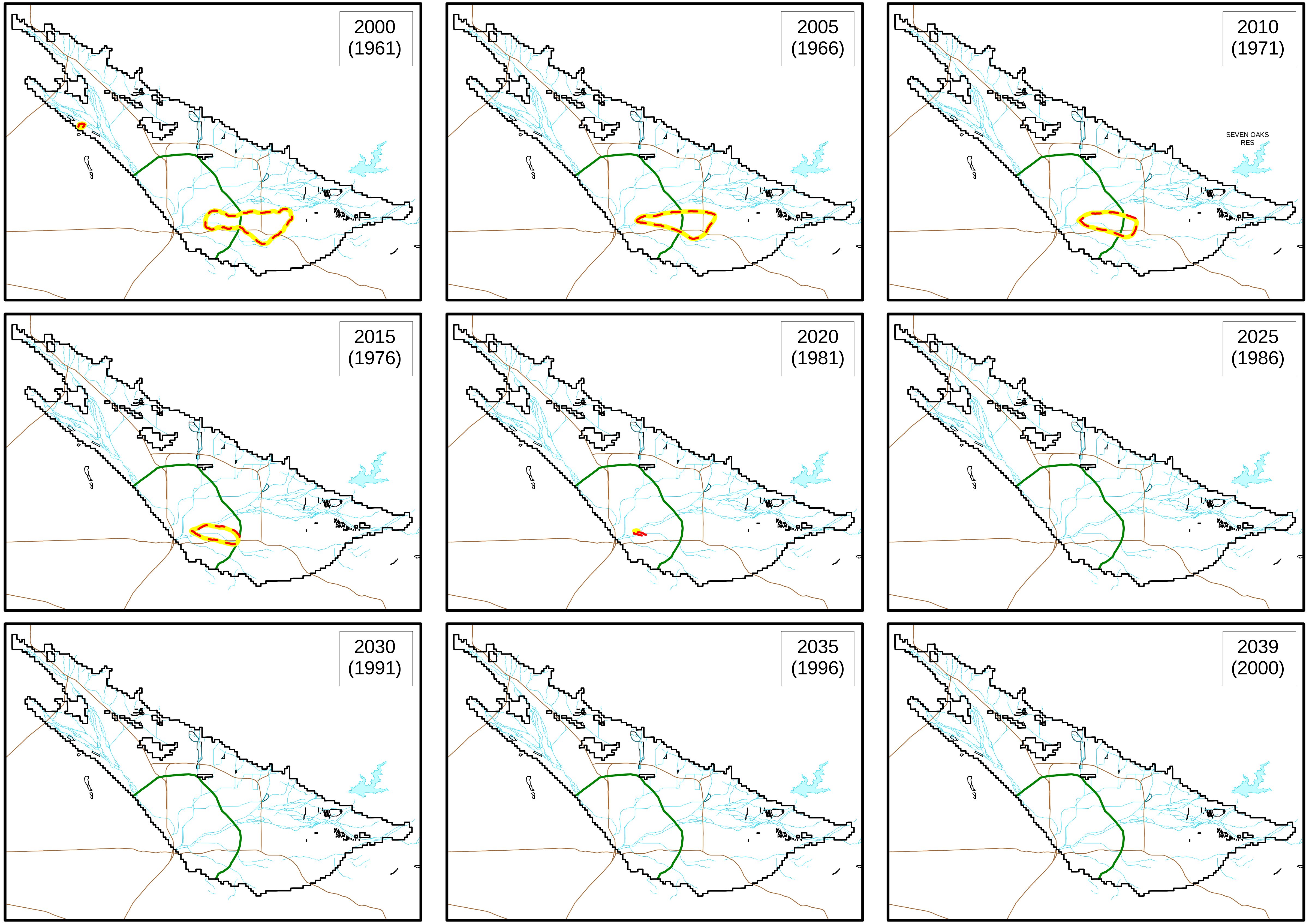
Yellow Line	Perchlorate Plume Boundary (6 ug/L) Layer 1, No Project Condition
– – –	Perchlorate Plume Boundary (6 ug/L) Layer 1, Scenario A
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

Map Projection:
State Plane 1927 (California Zone V)

Figure B 80

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PERCHLORATE PLUME BOUNDARY LAYER 2 NO PROJECT CONDITION VERSUS SCENARIO A



EXPLANATION

Yellow Line	Perchlorate Plume Boundary (6 ug/L) Layer 2, No Project Condition
- - -	Perchlorate Plume Boundary (6 ug/L) Layer 2, Scenario A
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
☐	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

NORTH

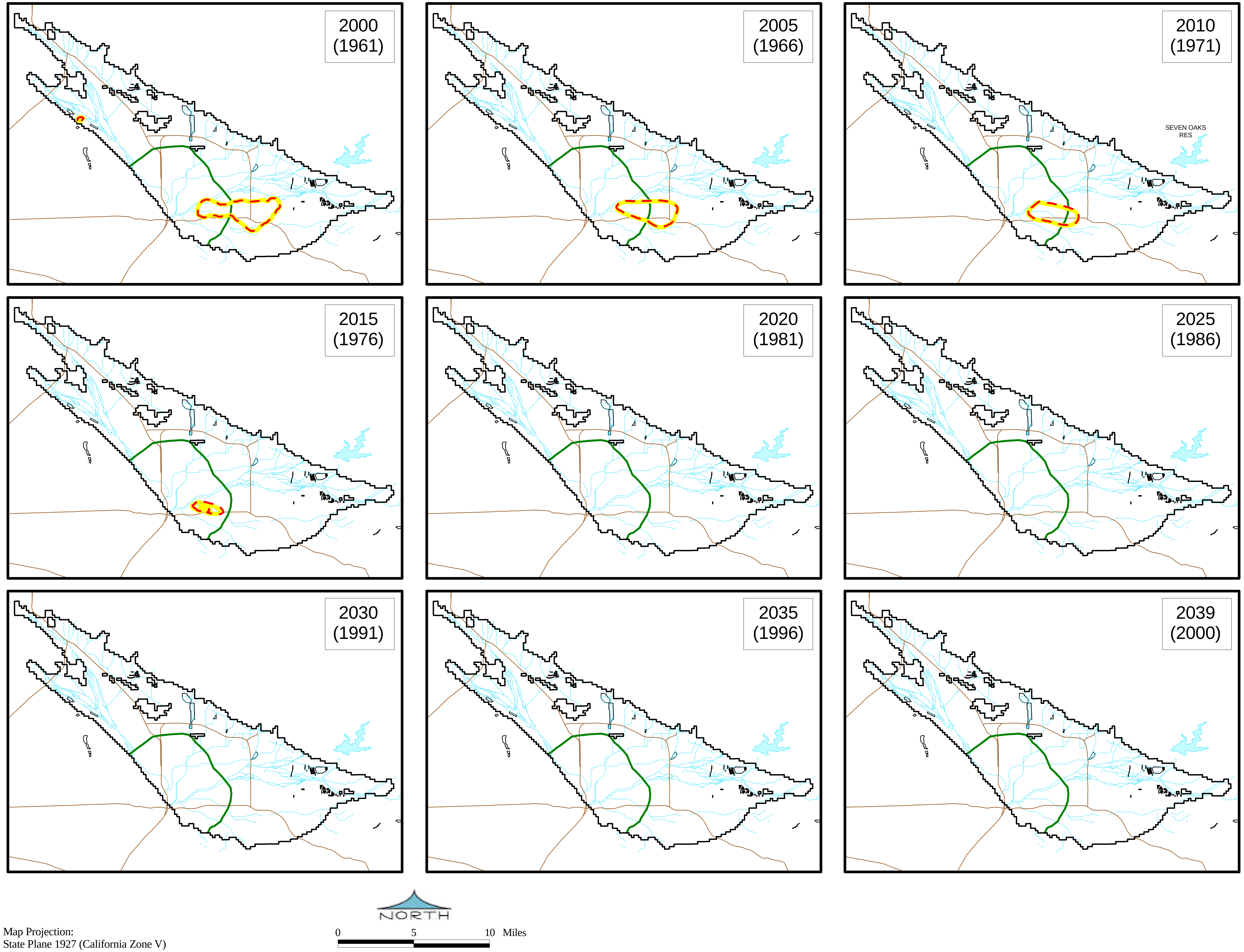
0 5 10 Miles

Map Projection:
State Plane 1927 (California Zone V)

Figure B 81

SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

PERCHLORATE PLUME BOUNDARY LAYER 1 NO PROJECT CONDITION VERSUS SCENARIO B



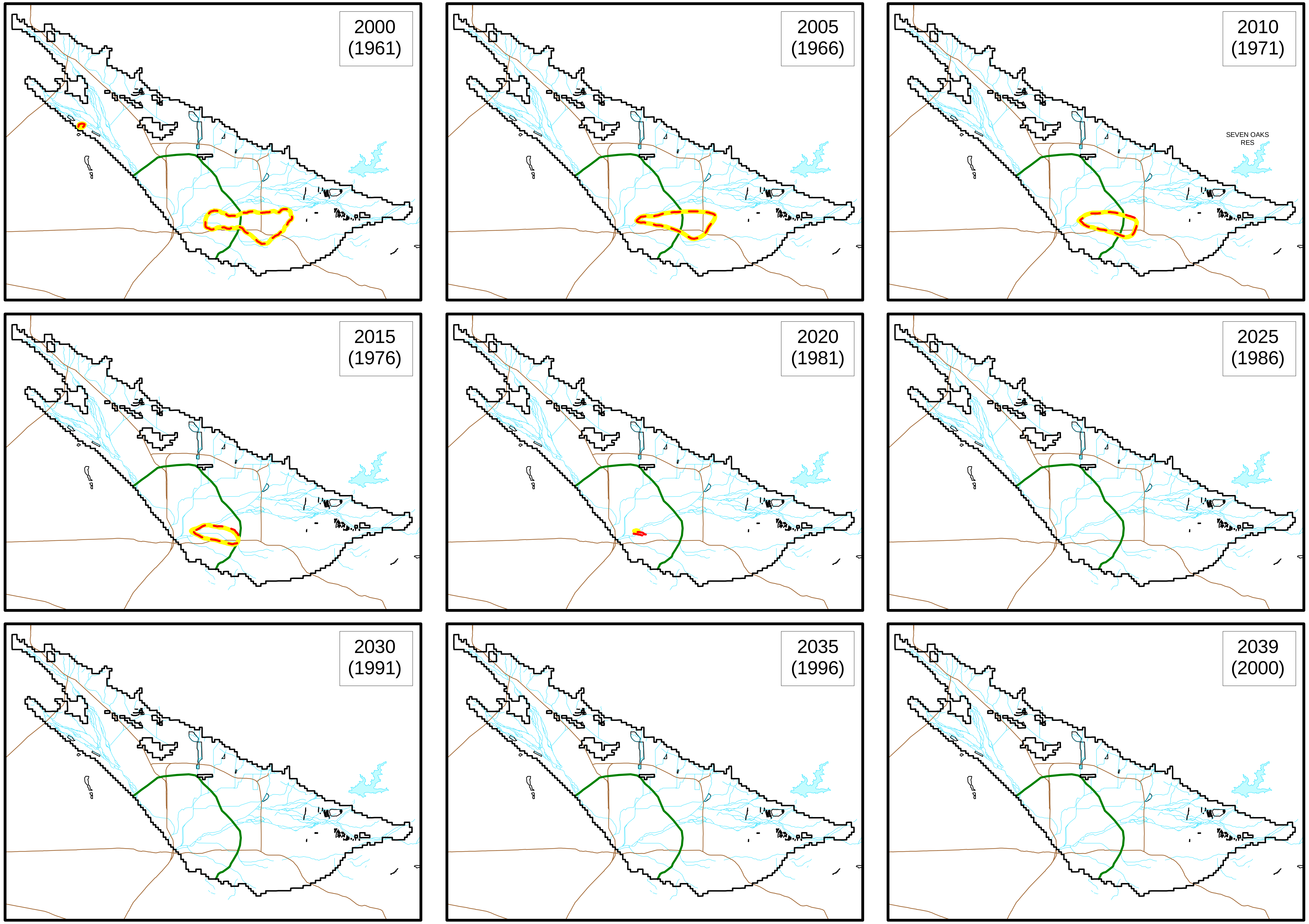
EXPLANATION

Yellow Line	Perchlorate Plume Boundary (6 ug/L) Layer 1, No Project Condition
- - -	Perchlorate Plume Boundary (6 ug/L) Layer 1, Scenario B
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway

Map Projection:
State Plane 1927 (California Zone V)

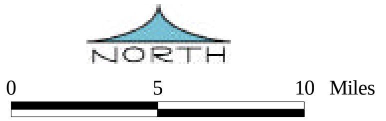
Figure B 82

PERCHLORATE PLUME BOUNDARY LAYER 2 NO PROJECT CONDITION VERSUS SCENARIO B



EXPLANATION

Yellow Line	Perchlorate Plume Boundary (6 ug/L) Layer 2, No Project Condition
— — —	Perchlorate Plume Boundary (6 ug/L) Layer 2, Scenario B
2000 (1961)	Model Year (Assumed Hydrological Year)
—	Pressure Zone
▭	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway



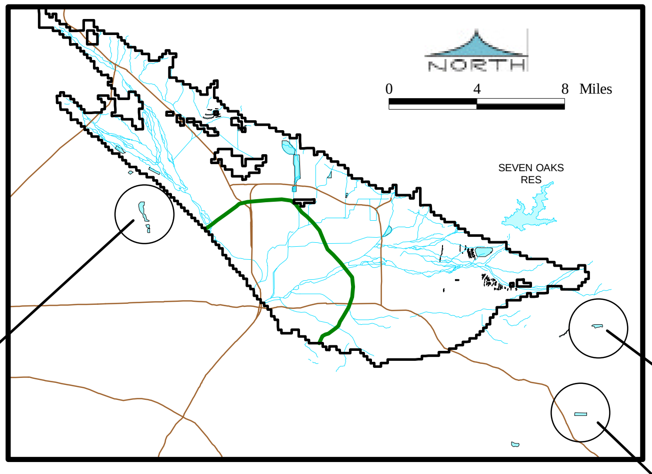
Map Projection:
State Plane 1927 (California Zone V)

Figure B 83

GROUNDWATER MOUNDS RESULTING FROM ARTIFICIAL RECHARGE AT CACTUS, GARDEN AIR CREEK AND WILSON SPREADING GROUNDS SCENARIO C

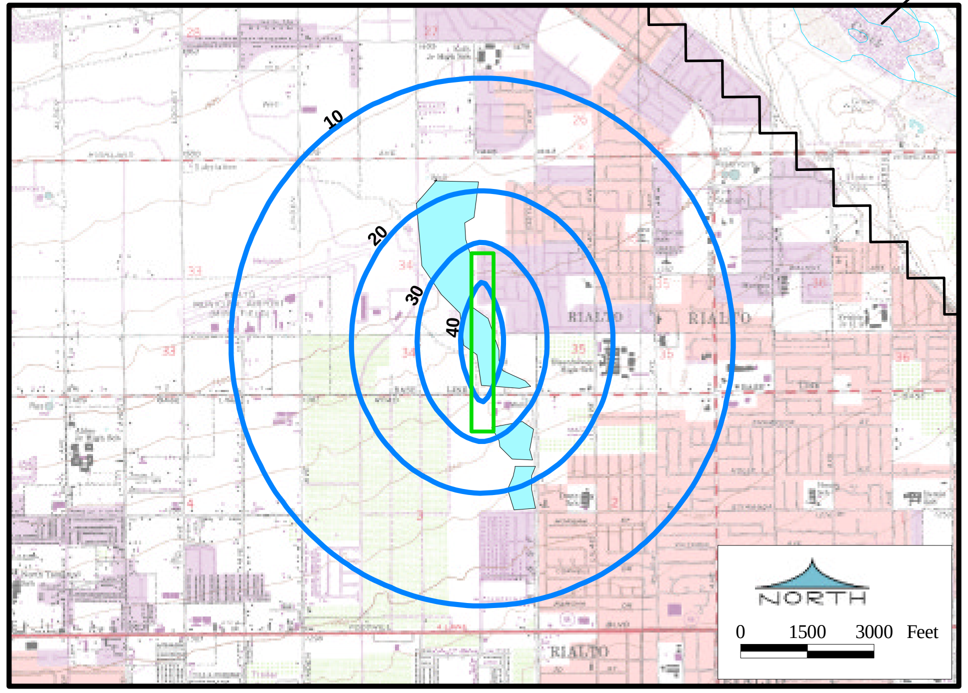
EXPLANATION

- 20 Calculated Groundwater Mound Height, ft
- 🟩 Equivalent Rectangular Spreading Basin Used by Hantush Equation
- Model Grid of the San Bernardino Basin Area Groundwater Model
- Streams or Rivers Within Groundwater Basin Boundary
- Spreading Grounds or Basins
- Freeway



No Artificial Recharge Occurs at These Spreading Grounds in the No Project Scenario

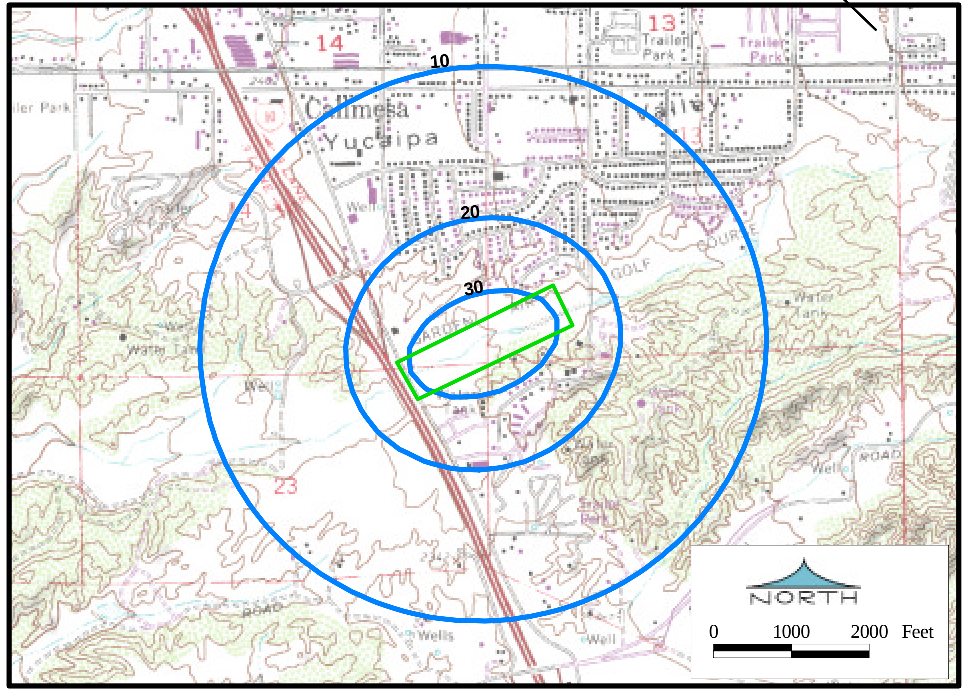
CACTUS SPREADING GROUNDS



Total Recharge Volume = 13,217 acre-ft
Maximum Groundwater Elevation = 1,245 ft amsl

Length = 4,000 ft
Width = 500 ft
Total Area = 46 acres
Land Surface Elevation = 1,400 ft amsl
Basement Complex Elevation = 550 ft amsl
Initial Groundwater Elevation = 1,200 ft amsl
Effective Porosity = 0.15
Hydraulic Conductivity = 374 gpd/ft ^{2}
Recharge Rate = 2 ft/day

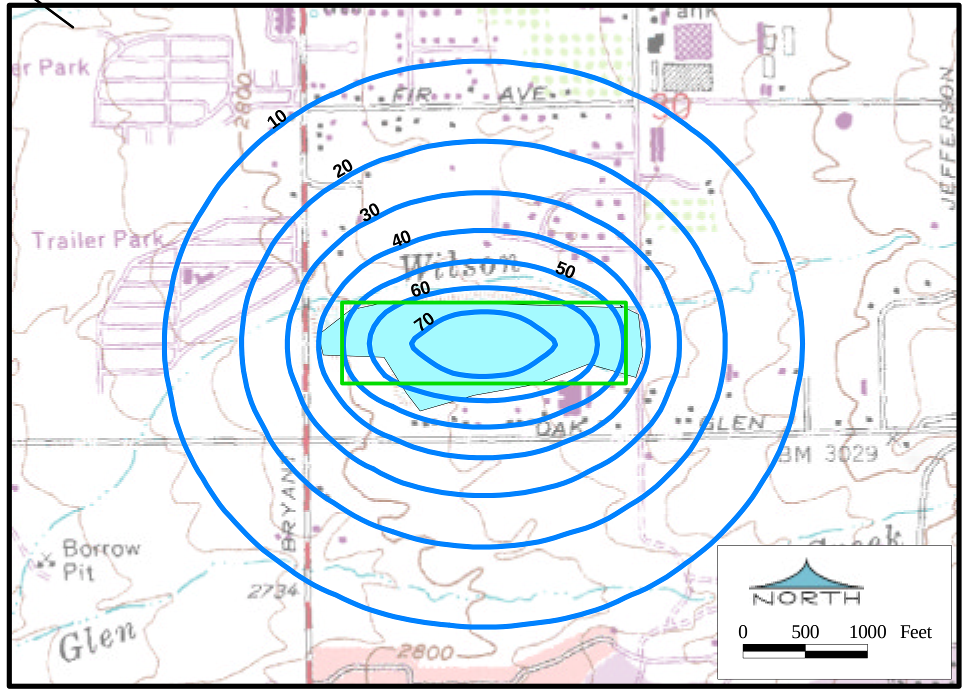
GARDEN AIR CREEK SPREADING GROUNDS



Total Recharge Volume = 5,745 acre-ft
Maximum Groundwater Elevation = 2,238 ft amsl

Length = 2,000 ft
Width = 566 ft
Total Area = 26 acres
Land Surface Elevation = 2,360 ft amsl
Basement Complex Elevation = 1,800 ft amsl
Initial Groundwater Elevation = 2,200 ft amsl
Effective Porosity = 0.15
Hydraulic Conductivity = 224 gpd/ft ^{2}
Recharge Rate = 1 ft/day

WILSON SPREADING GROUNDS



Total Recharge Volume = 2,154 acre-ft
Maximum Groundwater Elevation = 2,776 ft amsl

Length = 2,275 ft
Width = 650 ft
Total Area = 34 acres
Land Surface Elevation = 2,850 ft amsl
Basement Complex Elevation = 2,250 ft amsl
Initial Groundwater Elevation = 2,700 ft amsl
Effective Porosity = 0.15
Hydraulic Conductivity = 66 gpd/ft ^{2}
Recharge Rate = 1 ft/day

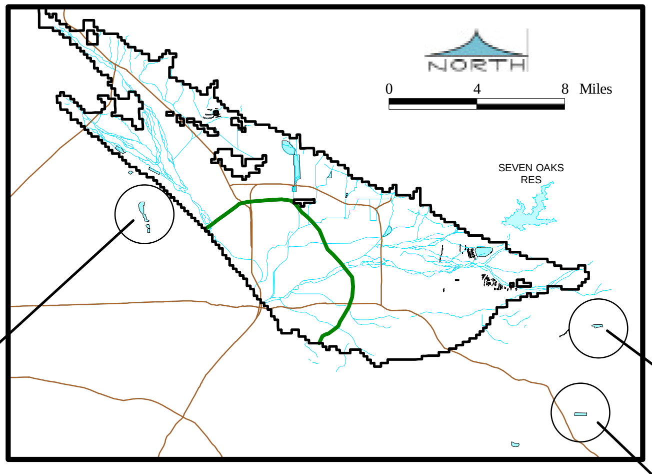
Map Projection:
State Plane 1927 (California Zone V)

Figure B 84

GROUNDWATER MOUNDS RESULTING FROM ARTIFICIAL RECHARGE AT CACTUS, GARDEN AIR CREEK AND WILSON SPREADING GROUNDS SCENARIO D

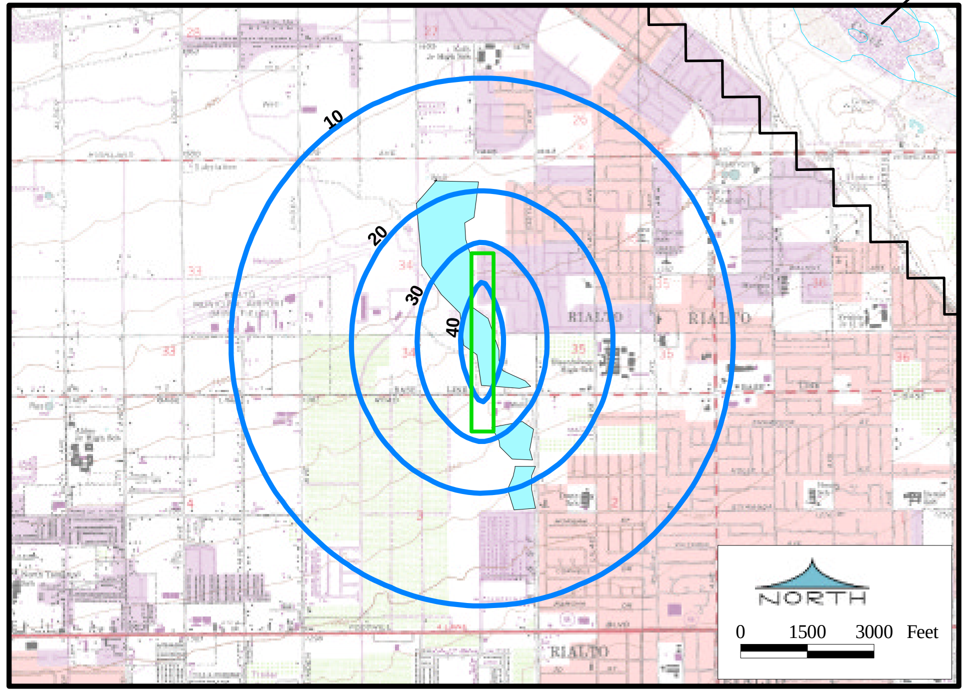
EXPLANATION

- 20 — Calculated Groundwater Mound Height, ft
- ▭ Equivalent Rectangular Spreading Basin Used by Hantush Equation
- Model Grid of the San Bernardino Basin Area Groundwater Model
- Streams or Rivers Within Groundwater Basin Boundary
- Spreading Grounds or Basins
- Freeway



No Artificial Recharge Occurs at These Spreading Grounds in the No Project Scenario

CACTUS SPREADING GROUNDS

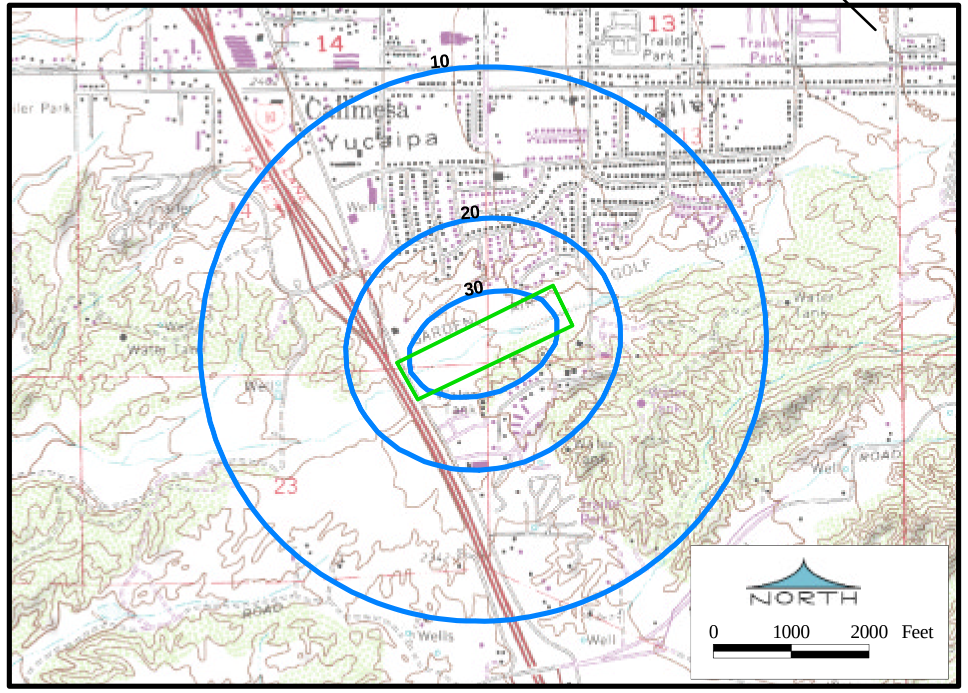


Total Recharge Volume = 13,217 acre-ft

Maximum Groundwater Elevation = 1,245 ft amsl

Length =	4,000 ft
Width =	500 ft
Total Area =	46 acres
Land Surface Elevation =	1,400 ft amsl
Basement Complex Elevation =	550 ft amsl
Initial Groundwater Elevation =	1,200 ft amsl
Effective Porosity =	0.15
Hydraulic Conductivity =	374 gpd/ft ^{2}
Recharge Rate =	2 ft/day

GARDEN AIR CREEK SPREADING GROUNDS

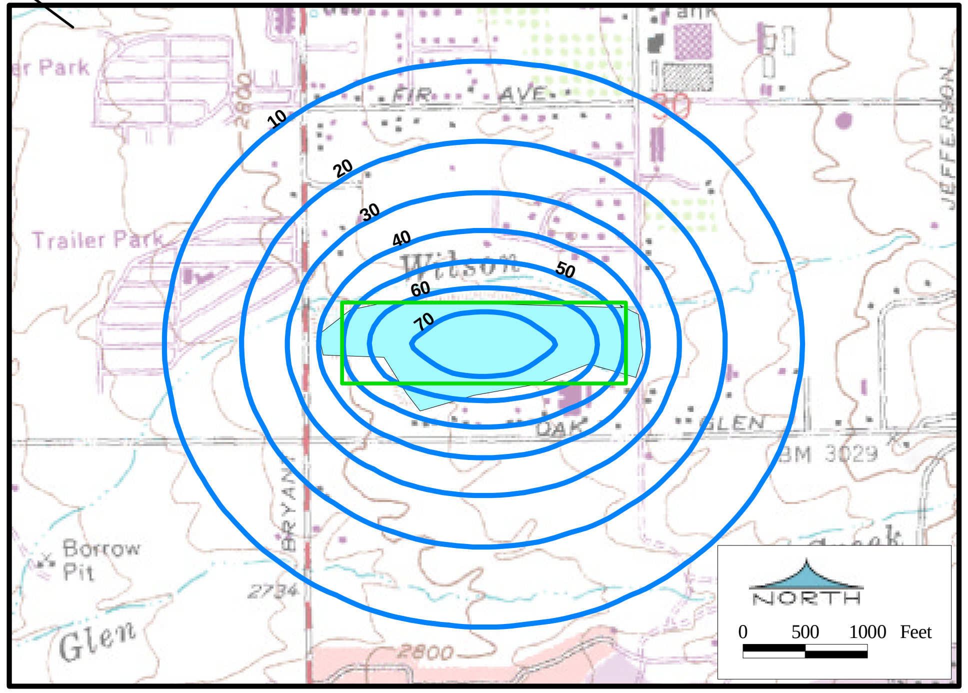


Total Recharge Volume = 5,745 acre-ft

Maximum Groundwater Elevation = 2,238 ft amsl

Length =	2,000 ft
Width =	566 ft
Total Area =	26 acres
Land Surface Elevation =	2,360 ft amsl
Basement Complex Elevation =	1,800 ft amsl
Initial Groundwater Elevation =	2,200 ft amsl
Effective Porosity =	0.15
Hydraulic Conductivity =	224 gpd/ft ^{2}
Recharge Rate =	1 ft/day

WILSON SPREADING GROUNDS



Total Recharge Volume = 2,154 acre-ft

Maximum Groundwater Elevation = 2,776 ft amsl

Length =	2,275 ft
Width =	650 ft
Total Area =	34 acres
Land Surface Elevation =	2,850 ft amsl
Basement Complex Elevation =	2,250 ft amsl
Initial Groundwater Elevation =	2,700 ft amsl
Effective Porosity =	0.15
Hydraulic Conductivity =	66 gpd/ft ^{2}
Recharge Rate =	1 ft/day

Map Projection:
State Plane 1927 (California Zone V)

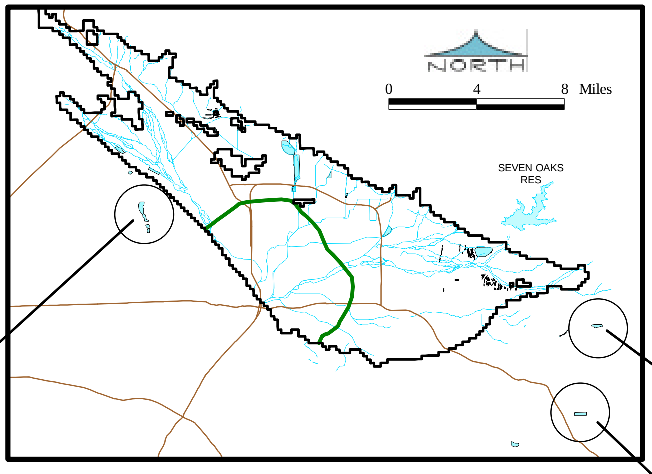
Figure B 85

GROUNDWATER TECHNICAL APPENDIX
SAR WATER RIGHT APPLICATIONS FOR SUPPLEMENTAL WATER SUPPLY EIR

GROUNDWATER MOUNDS RESULTING FROM ARTIFICIAL RECHARGE AT CACTUS, GARDEN AIR CREEK AND WILSON SPREADING GROUNDS SCENARIO A

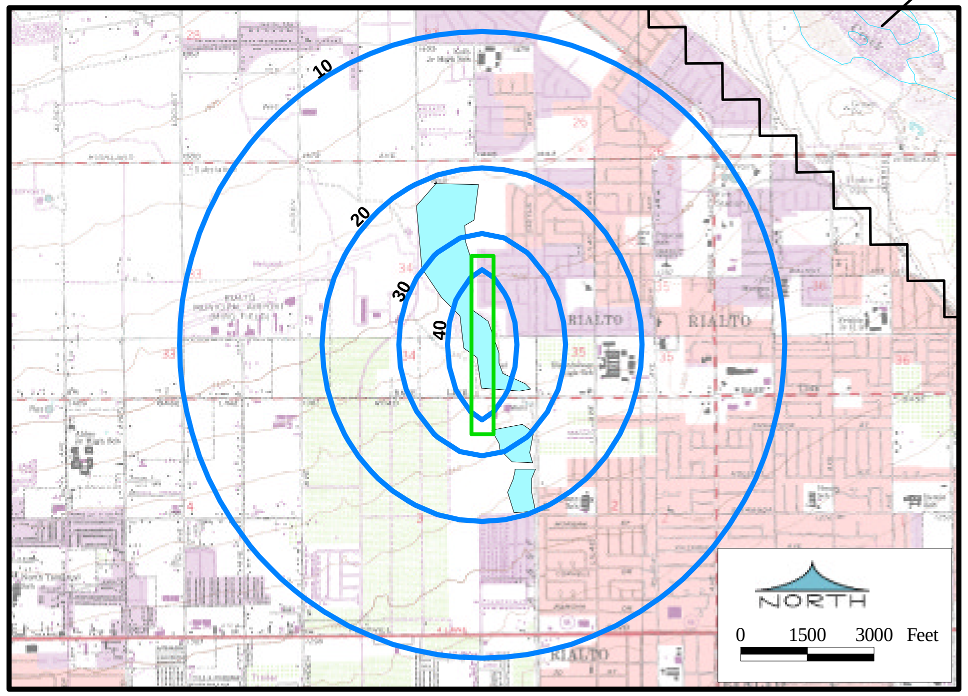
EXPLANATION

- 20 Calculated Groundwater Mound Height, ft
- 🟩 Equivalent Rectangular Spreading Basin Used by Hantush Equation
- Model Grid of the San Bernardino Basin Area Groundwater Model
- Streams or Rivers Within Groundwater Basin Boundary
- Spreading Grounds or Basins
- Freeway



No Artificial Recharge Occurs at These Spreading Grounds in the No Project Scenario

CACTUS SPREADING GROUNDS

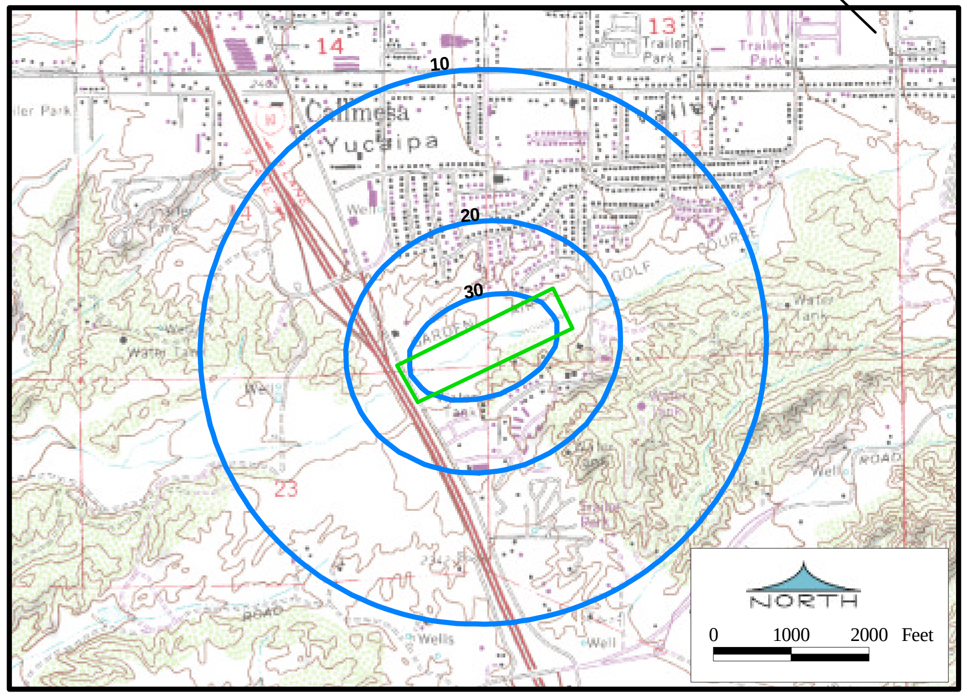


Total Recharge Volume = 18,953 acre-ft

Maximum Groundwater Elevation = 1,248 ft amsl

Length = 4,000 ft
Width = 500 ft
Total Area = 46 acres
Land Surface Elevation = 1,400 ft amsl
Basement Complex Elevation = 550 ft amsl
Initial Groundwater Elevation = 1,200 ft amsl
Effective Porosity = 0.15
Hydraulic Conductivity = 374 gpd/ft^2
Recharge Rate = 2 ft/day

GARDEN AIR CREEK SPREADING GROUNDS

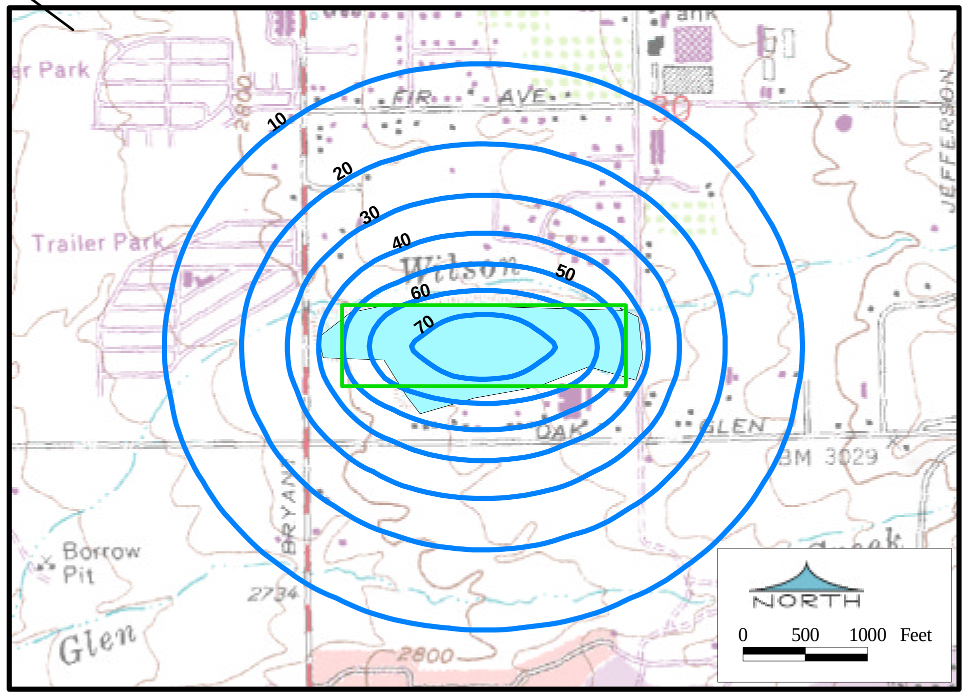


Total Recharge Volume = 5,745 acre-ft

Maximum Groundwater Elevation = 2,238 ft amsl

Length = 2,000 ft
Width = 566 ft
Total Area = 26 acres
Land Surface Elevation = 2,360 ft amsl
Basement Complex Elevation = 1,800 ft amsl
Initial Groundwater Elevation = 2,200 ft amsl
Effective Porosity = 0.15
Hydraulic Conductivity = 224 gpd/ft^2
Recharge Rate = 1 ft/day

WILSON SPREADING GROUNDS



Total Recharge Volume = 2,154 acre-ft

Maximum Groundwater Elevation = 2,776 ft amsl

Length = 2,275 ft
Width = 650 ft
Total Area = 34 acres
Land Surface Elevation = 2,850 ft amsl
Basement Complex Elevation = 2,250 ft amsl
Initial Groundwater Elevation = 2,700 ft amsl
Effective Porosity = 0.15
Hydraulic Conductivity = 66 gpd/ft^2
Recharge Rate = 1 ft/day

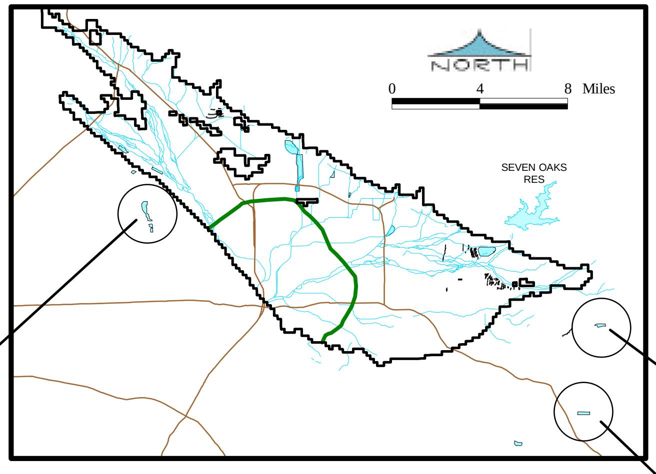
Map Projection:
State Plane 1927 (California Zone V)

Figure B 86

GROUNDWATER MOUNDS RESULTING FROM ARTIFICIAL RECHARGE AT CACTUS, GARDEN AIR CREEK AND WILSON SPREADING GROUNDS SCENARIO B

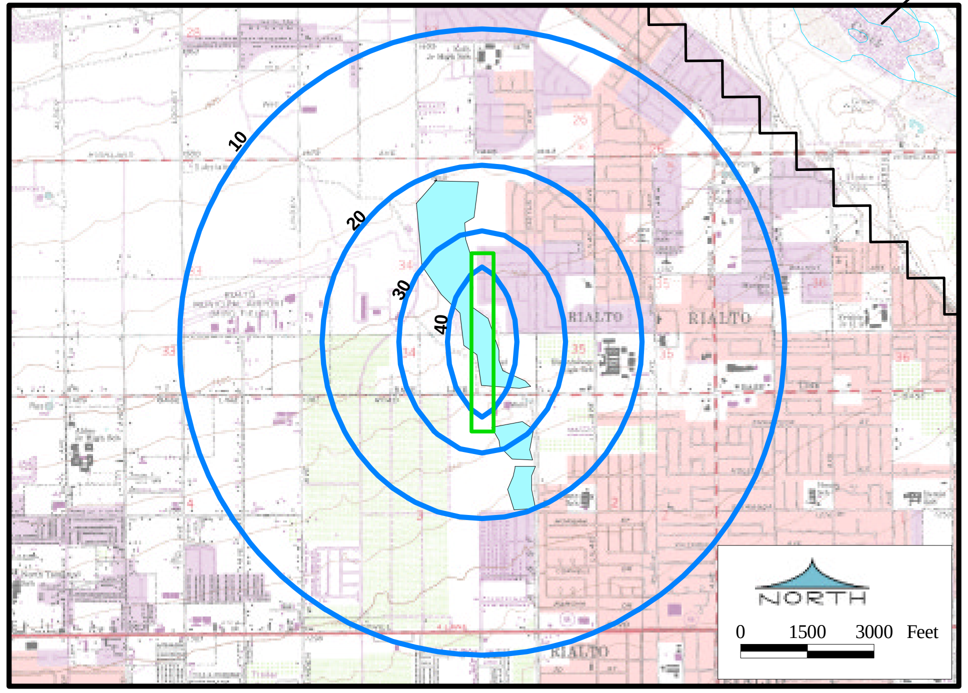
EXPLANATION

20	Calculated Groundwater Mound Height, ft
🟩	Equivalent Rectangular Spreading Basin Used by Hantush Equation
┐	Model Grid of the San Bernardino Basin Area Groundwater Model
—	Streams or Rivers Within Groundwater Basin Boundary
⬭	Spreading Grounds or Basins
—	Freeway



No Artificial Recharge Occurs at These Spreading Grounds in the No Project Scenario

CACTUS SPREADING GROUNDS

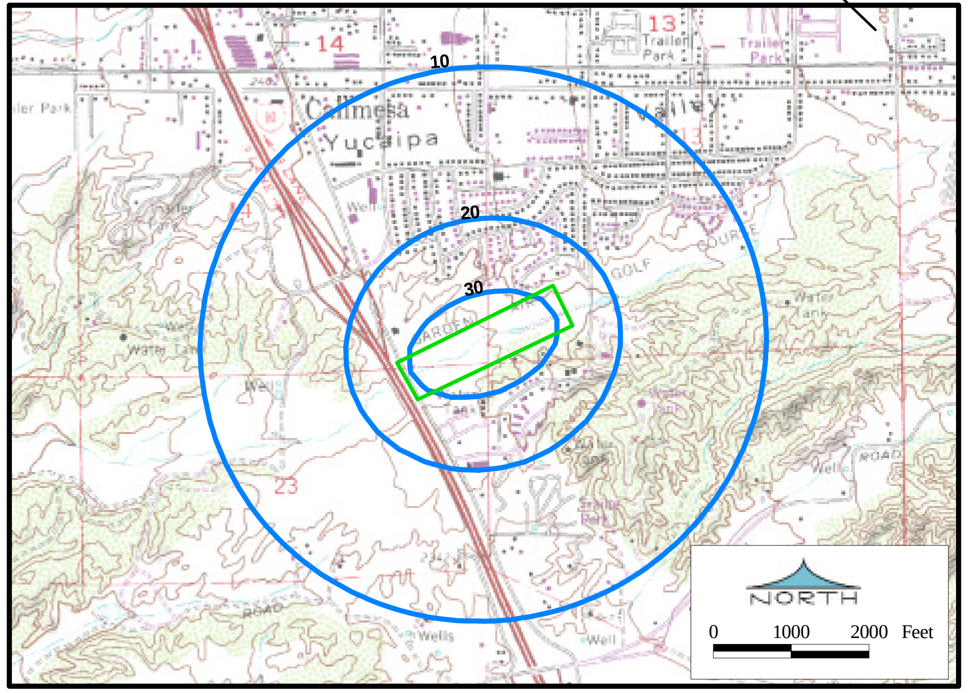


Total Recharge Volume = 18,953 acre-ft

Maximum Groundwater Elevation = 1,248 ft amsl

Length = 4,000 ft
Width = 500 ft
Total Area = 46 acres
Land Surface Elevation = 1,400 ft amsl
Basement Complex Elevation = 550 ft amsl
Initial Groundwater Elevation = 1,200 ft amsl
Effective Porosity = 0.15
Hydraulic Conductivity = 374 gpd/ft ^{2}
Recharge Rate = 2 ft/day

GARDEN AIR CREEK SPREADING GROUNDS

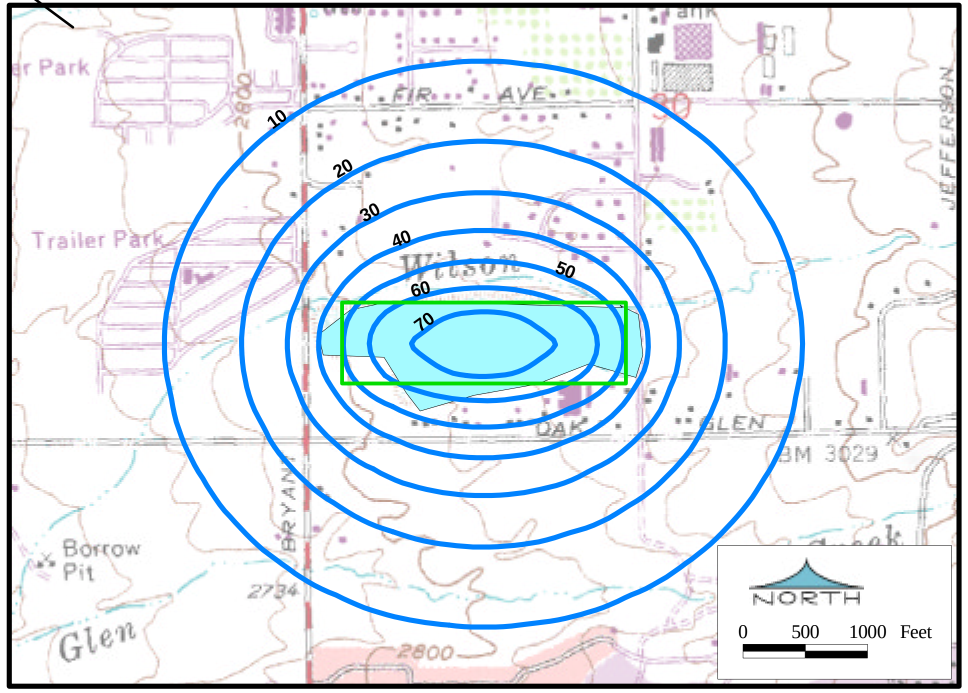


Total Recharge Volume = 5,745 acre-ft

Maximum Groundwater Elevation = 2,238 ft amsl

Length = 2,000 ft
Width = 566 ft
Total Area = 26 acres
Land Surface Elevation = 2,360 ft amsl
Basement Complex Elevation = 1,800 ft amsl
Initial Groundwater Elevation = 2,200 ft amsl
Effective Porosity = 0.15
Hydraulic Conductivity = 224 gpd/ft ^{2}
Recharge Rate = 1 ft/day

WILSON SPREADING GROUNDS



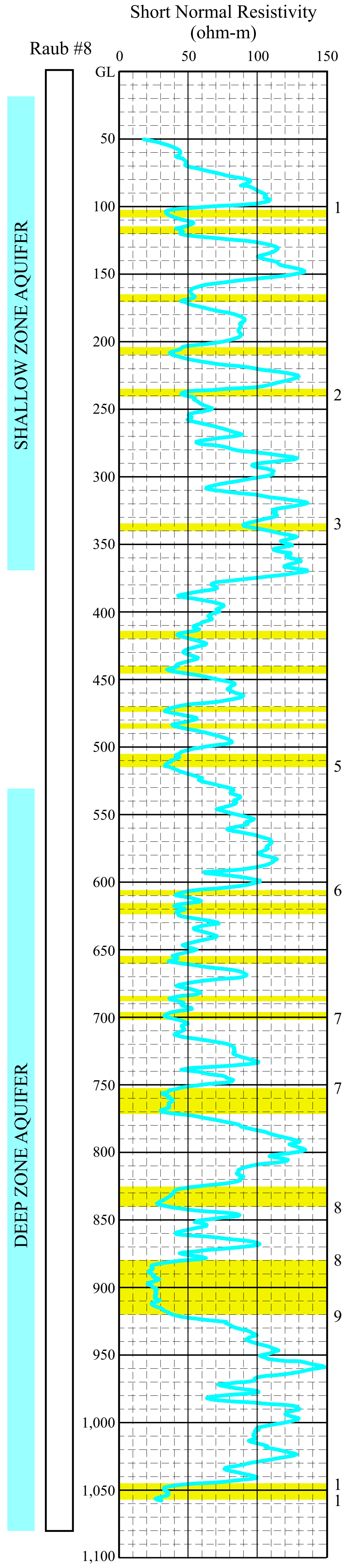
Total Recharge Volume = 2,154 acre-ft

Maximum Groundwater Elevation = 2,776 ft amsl

Length = 2,275 ft
Width = 650 ft
Total Area = 34 acres
Land Surface Elevation = 2,850 ft amsl
Basement Complex Elevation = 2,250 ft amsl
Initial Groundwater Elevation = 2,700 ft amsl
Effective Porosity = 0.15
Hydraulic Conductivity = 66 gpd/ft ^{2}
Recharge Rate = 1 ft/day

Map Projection:
State Plane 1927 (California Zone V)

Figure B 87



Compaction Interval	Depth (ft)	Total Thickness of Clay Layers (ft)	Thickness of Equivalent Clay Layer (ft)	Vertical Hydraulic Conductivity (ft/yr)	Virgin Compressibility (1/ft)	Elastic Compressibility (1/ft)
1	102–240	27	5.5	1.16×10^{-3}	1.24×10^{-4}	5.59×10^{-6}
2	336–516	30	5.6			
3	607–702	24	5.2			
4	752–840	34	17.3			
5	880–920	40	40			
6	1,046–1,058	12	12			

▨ Clay Layer

IDEALIZED LITHOLOGIC LOG
FOR WELL RAUB #8

Figure
B 88

Drawdown Loading Function at Raub #8 in Model Layer 1

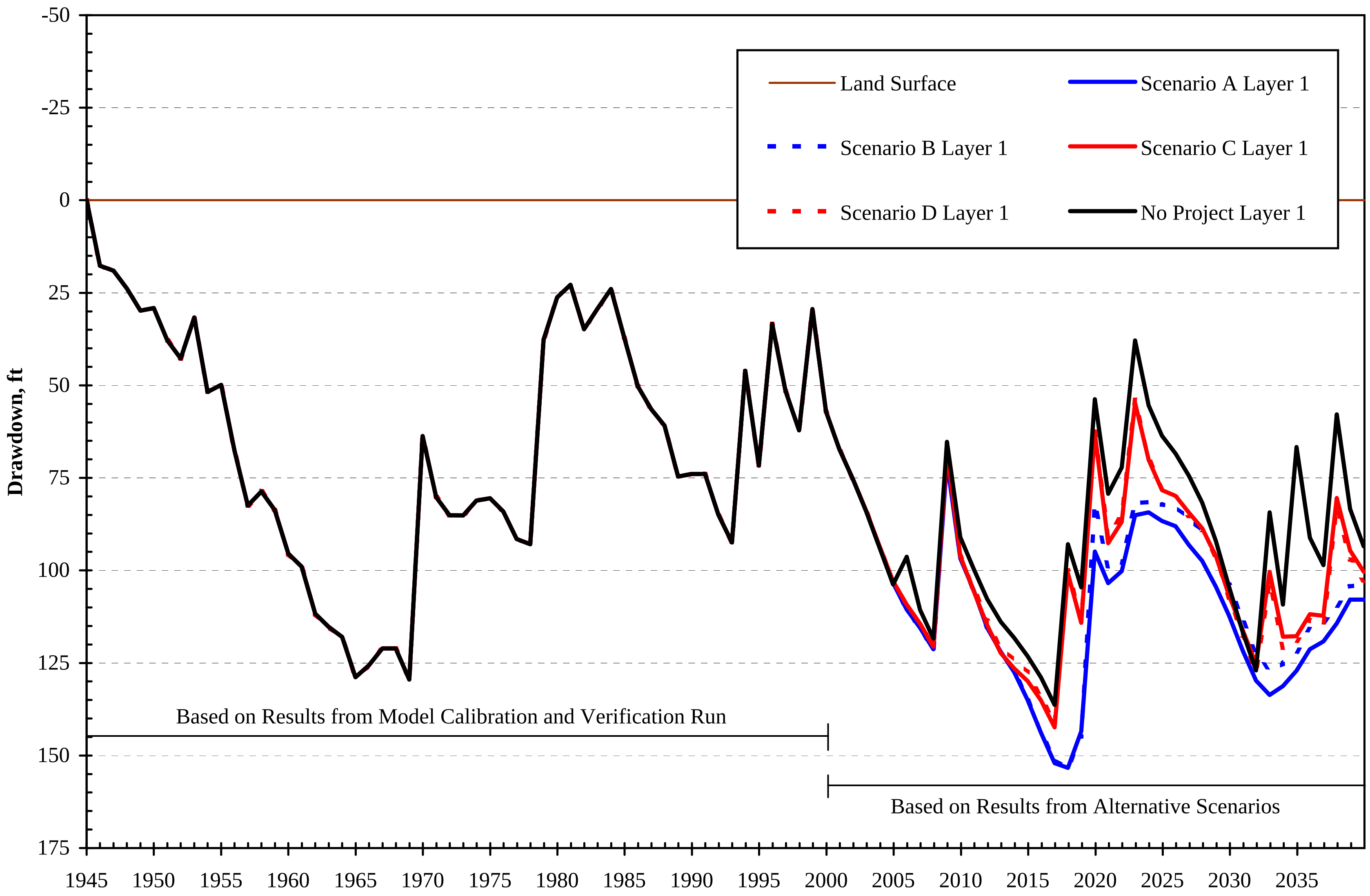


Figure B 89

Drawdown Loading Function at Raub #8 in Model Layer 2

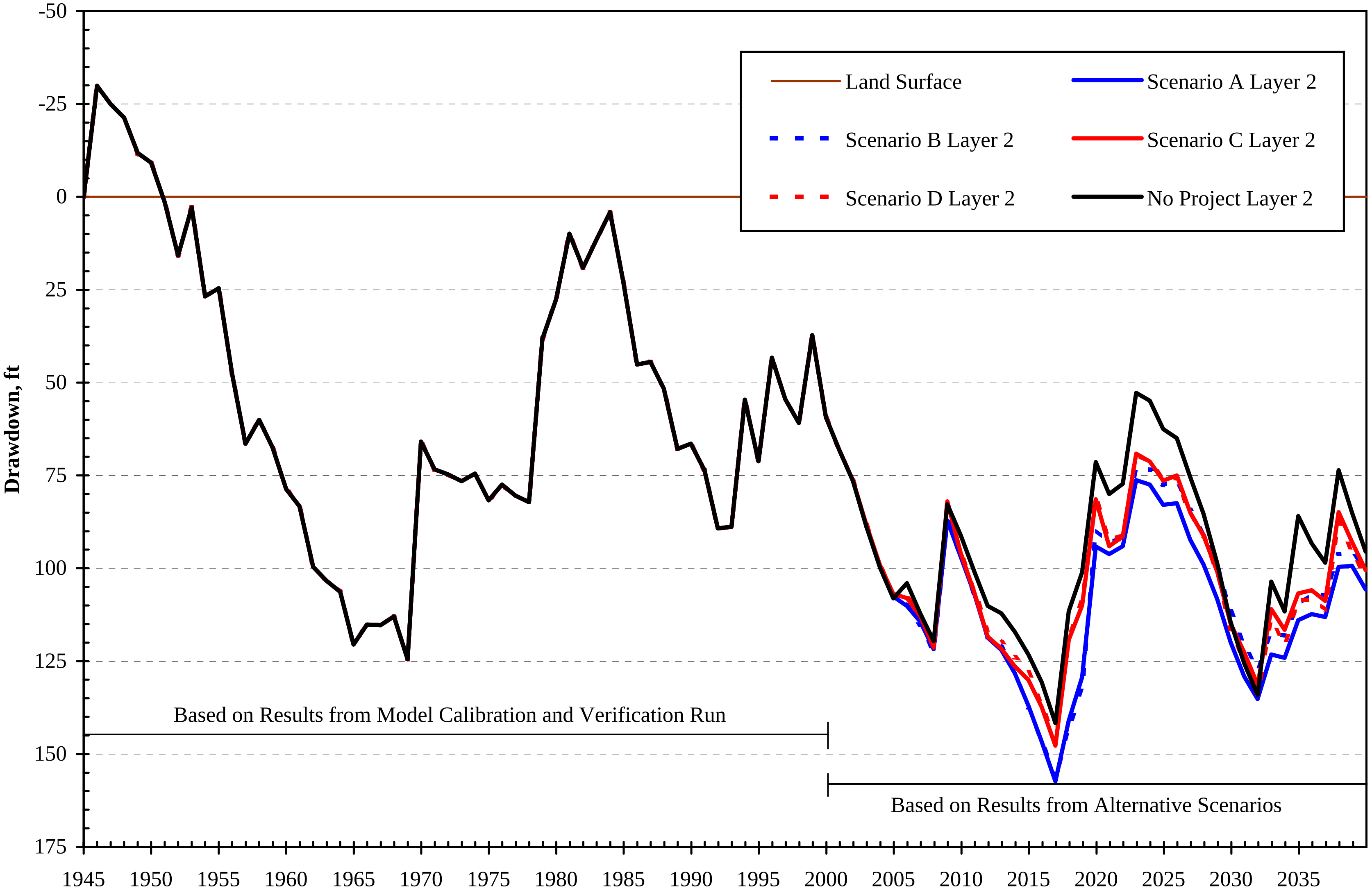
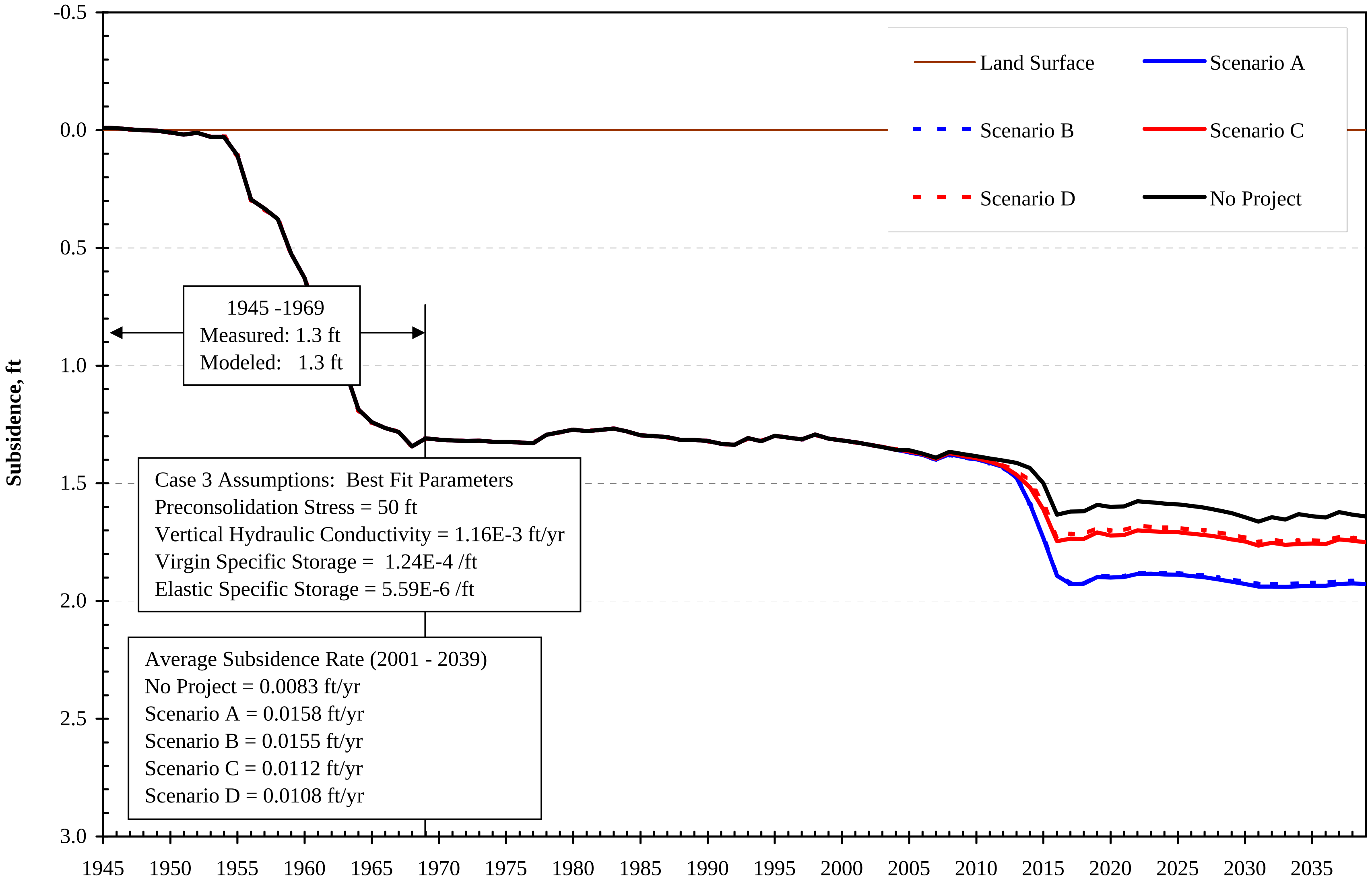


Figure B 90

Model Predicted Subsidence at Raub #8



1945 -1969
Measured: 1.3 ft
Modeled: 1.3 ft

Case 3 Assumptions: Best Fit Parameters
Preconsolidation Stress = 50 ft
Vertical Hydraulic Conductivity = 1.16E-3 ft/yr
Virgin Specific Storage = 1.24E-4 /ft
Elastic Specific Storage = 5.59E-6 /ft

Average Subsidence Rate (2001 - 2039)
No Project = 0.0083 ft/yr
Scenario A = 0.0158 ft/yr
Scenario B = 0.0155 ft/yr
Scenario C = 0.0112 ft/yr
Scenario D = 0.0108 ft/yr

Figure B 91

Annual Releases to SAR from the Seven Oaks Reservoir for Model Scenarios - 2001 to 2039 (Units in acre-ft)

Water Years	No Project Condition				Scenario A				Scenario B				Scenario C				Scenario D			
	Undiverted	Habitat Release	Turnback to SAR	Total	Undiverted	Habitat Release	Turnback to SAR	Total	Undiverted	Habitat Release	Turnback to SAR	Total	Undiverted	Habitat Release	Turnback to SAR	Total	Undiverted	Habitat Release	Turnback to SAR	Total
2001	4,127	0	0	4,127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	573	0	0	573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	111	0	0	111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	249	0	0	249	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	24,756	0	0	24,756	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	55,436	3,967	0	59,403	0	0	0	0	0	0	3,572	3,572	0	3,967	0	3,967	0	3,967	0	3,967
2007	1,175	0	0	1,175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	171,389	3,967	0	175,356	0	0	0	0	18,216	0	6,317	24,533	0	3,967	0	3,967	11,149	3,967	5,583	20,699
2009	17,846	0	0	17,846	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	13,001	0	0	13,001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	8,888	0	0	8,888	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	13,480	0	0	13,480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	535	0	0	535	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	642	0	0	642	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	2,581	0	0	2,581	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	575	0	0	575	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	25,157	3,967	0	29,124	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	24,803	3,967	0	28,770	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	141,416	3,967	0	145,383	0	0	0	0	33,129	0	5,253	38,382	0	3,967	0	3,967	17,469	3,967	11,036	32,472
2020	252	0	0	252	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	5,001	0	0	5,001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	94,456	3,967	0	98,423	0	0	0	0	0	0	0	0	0	3,967	0	3,967	0	3,967	0	3,967
2023	5,082	0	0	5,082	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2024	4,944	0	0	4,944	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2025	5,596	0	0	5,596	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2026	1,428	0	0	1,428	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2027	183	0	0	183	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2028	902	0	0	902	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2030	87	0	0	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2031	628	0	0	628	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2032	82,618	3,967	0	86,585	0	0	0	0	0	0	5,761	5,761	0	3,967	0	3,967	0	3,967	0	3,967
2033	103	0	0	103	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2034	63,262	3,967	0	67,229	0	0	0	0	0	0	0	0	0	3,967	0	3,967	0	3,967	0	3,967
2035	2,296	0	0	2,296	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2036	1,967	0	0	1,967	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2037	30,895	3,967	0	34,862	0	0	0	0	0	0	0	0	0	3,967	0	3,967	0	3,967	0	3,967
2038	1,008	0	0	1,008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2039	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	**20,704**	**915**	**0**	**21,619**	**0**	**0**	**0**	**0**	**1,317**	**0**	**536**	**1,853**	**0**	**712**	**0**	**712**	**734**	**712**	**426**	**1,872**

Source: SAIC (2004)

SAR: Santa Ana River

Annual Artificial Recharge for No Project Condition - 2001 to 2039 (Units in acre-ft)

Water Years	**Mill Creek SG (Airport)**		**Santa Ana River SG**		**Devil Canyon/ Sweetwater SG**		**Lytle Creek SG**		**City Creek SG**		**Patton SG**		**Waterman SG**		**East Twin Creek SG**		**Badger SG**		**Mill Creek SG**		**Total**
	Includes Senior Deliveries SAR	**SWP**	**Includes Senior & WCD Deliveries SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**Includes Senior Deliveries SAR**	**SWP**	
2001	0	0	3,922	0	0	571	0	516	0	0	0	73	0	1,720	0	1,284	0	314	0	0	**8,399**
2002	0	0	412	0	0	606	0	547	0	0	0	77	0	1,825	0	1,362	0	334	0	0	**5,163**
2003	0	0	407	0	0	650	0	587	0	0	0	83	0	1,957	0	1,461	0	358	0	0	**5,503**
2004	0	0	1,754	0	0	833	0	753	0	0	0	107	0	2,511	0	1,874	0	459	0	0	**8,291**
2005	0	0	5,766	0	0	762	0	689	0	0	0	97	0	2,296	0	1,715	0	420	0	0	**11,745**
2006	0	0	9,406	0	0	592	0	535	0	0	0	76	0	1,784	0	1,332	0	326	0	0	**14,050**
2007	0	0	4,232	0	0	553	0	500	0	0	0	71	0	1,668	0	1,245	0	305	0	0	**8,574**
2008	0	0	31,262	0	0	229	0	207	0	0	0	29	0	691	0	516	0	126	0	0	**33,062**
2009	0	0	10,330	0	0	1,885	0	1,704	0	0	0	241	0	5,682	0	4,242	0	1,039	0	0	**25,124**
2010	0	0	5,587	0	0	3,373	0	3,048	0	0	0	431	0	10,165	0	7,589	0	1,859	0	0	**32,053**
2011	0	0	2,192	0	0	4,500	0	3,800	0	0	0	473	0	11,141	0	8,318	0	2,038	0	0	**32,461**
2012	0	0	18,169	0	0	3,900	0	4,200	0	0	0	339	0	13,000	0	11,000	0	1,462	0	0	**52,070**
2013	0	0	5,310	0	0	7,500	0	6,000	0	0	0	700	0	16,000	0	13,500	0	2,890	0	0	**51,900**
2014	0	0	3,834	0	0	8,000	0	6,800	0	0	0	523	0	18,000	0	13,000	0	2,890	0	0	**53,047**
2015	0	0	3,771	0	0	4,105	0	3,710	0	0	0	525	0	12,371	0	9,236	0	2,143	0	0	**35,861**
2016	0	0	1,918	0	0	934	0	934	0	0	0	0	0	934	0	934	0	373	0	0	**6,026**
2017	0	0	48,152	0	0	4,100	0	2,600	0	0	0	254	0	7,500	0	5,800	0	1,600	0	0	**70,006**
2018	0	0	34,614	0	0	2,000	0	931	0	0	0	500	0	5,000	0	4,500	0	1,200	0	0	**48,745**
2019	0	0	33,310	0	0	1,500	0	800	0	0	0	650	0	2,500	0	2,300	0	1,300	0	0	**42,360**
2020	0	0	6,426	0	0	2,400	0	2,553	0	0	0	600	0	8,513	0	6,356	0	2,500	0	0	**29,347**
2021	0	0	9,963	0	0	4,200	0	2,256	0	0	0	319	0	8,600	0	6,500	0	2,500	0	0	**34,339**
2022	0	0	11,516	0	0	0	0	0	0	0	0	152	0	3,590	0	2,680	0	657	0	0	**18,595**
2023	0	0	6,381	0	0	5,500	0	2,320	0	0	0	650	0	14,700	0	12,500	0	2,800	0	0	**44,851**
2024	0	0	186	0	0	6,367	0	3,624	0	0	0	686	0	14,203	0	11,264	0	2,155	0	0	**38,484**
2025	0	0	6,755	0	0	3,940	0	4,641	0	0	0	689	0	12,312	0	7,880	0	1,333	0	0	**37,551**
2026	0	0	0	0	0	3,088	0	4,747	0	0	0	399	0	9,400	0	7,018	0	1,719	0	0	**26,372**
2027	0	0	1,402	0	0	1,942	0	1,942	0	0	0	486	0	1,942	0	1,942	0	1,457	0	0	**11,113**
2028	0	0	2,096	0	0	5,675	0	5,675	0	0	0	386	0	7,785	0	5,813	0	1,424	0	0	**28,854**
2029	0	0	357	0	0	2,455	0	2,160	0	0	0	491	0	2,062	0	1,964	0	1,375	0	0	**10,863**
2030	0	0	5,321	0	0	2,612	0	2,177	0	0	0	348	0	1,306	0	1,306	0	784	0	0	**13,853**
2031	0	0	7,941	0	0	1,770	0	1,573	0	0	0	295	0	1,475	0	1,475	0	983	0	0	**15,513**
2032	0	0	38,877	0	0	3,904	0	3,528	0	0	0	200	0	7,300	0	6,400	0	1,000	0	0	**61,209**
2033	0	0	5,493	0	0	2,672	0	2,415	0	0	0	275	0	12,668	0	10,134	0	1,098	0	0	**34,755**
2034	0	0	17,369	0	0	3,246	0	2,933	0	0	0	415	0	9,500	0	8,400	0	700	0	0	**42,563**
2035	0	0	8,265	0	0	6,200	0	6,800	0	0	0	720	0	14,800	0	13,200	0	2,850	0	0	**52,835**
2036	0	0	9,061	0	0	6,900	0	5,428	0	0	0	720	0	16,300	0	14,600	0	2,700	0	0	**55,709**
2037	0	0	35,337	0	0	2,242	0	2,003	0	0	0	287	0	8,400	0	8,000	0	792	0	0	**57,060**
2038	0	0	3,736	0	0	7,269	0	6,771	0	0	0	697	0	17,425	0	15,334	0	2,688	0	0	**53,921**
2039	0	0	4,150	0	0	6,878	0	6,190	0	0	0	441	0	15,699	0	12,989	0	1,765	0	0	**48,113**
Average	**0**	**0**	**10,384**	**0**	**0**	**3,227**	**0**	**2,785**	**0**	**0**	**0**	**372**	**0**	**7,813**	**0**	**6,332**	**0**	**1,403**	**0**	**0**	**32,316**

Source: SAIC (2004)
SAR: Santa Ana River Water
SWP: State Water Project Water
SG: Spreading Ground

Annual Artificial Recharge for Scenario A - 2001 to 2039 (Units in acre-ft)

Water Years	Mill Creek SG (Airport)		Santa Ana River SG		Devil Canyon/ Sweetwater SG		Lytle Creek SG		City Creek SG		Patton SG		Waterman SG		East Twin Creek SG		Badger SG		Mill Creek SG		Total
	Includes Senior Deliveries SAR	SWP	Includes Senior & WCD Deliveries SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	Includes Senior Deliveries SAR	SWP	
2001	0	0	5,121	0	0	2,000	0	1,600	0	0	0	76	0	2,276	0	1,821	0	800	0	0	**13,695**
2002	0	0	0	0	37	2,163	47	1,713	0	0	0	80	0	2,416	0	1,933	0	800	0	0	**9,189**
2003	0	0	0	0	0	2,300	0	1,840	0	0	0	86	0	2,591	0	2,073	0	800	0	0	**9,691**
2004	0	0	0	0	0	3,000	0	2,500	0	0	0	94	0	2,815	0	2,252	0	800	0	0	**11,462**
2005	0	0	9,911	0	2,000	0	1,600	0	0	0	0	94	0	6,663	0	7,000	0	2,890	0	0	**30,158**
2006	0	0	10,400	0	4,592	1,273	5,278	363	5,274	3,018	93	627	2,775	18,225	2,221	14,779	369	2,521	1,413	213	**73,434**
2007	0	0	2,332	0	0	6,500	0	5,200	0	0	0	112	0	2,000	0	2,000	0	600	0	0	**18,745**
2008	0	0	8,301	0	1,200	0	700	0	0	0	0	0	800	0	800	0	400	0	0	0	**12,201**
2009	0	0	10,400	0	2,844	3,156	3,354	646	0	0	58	363	1,733	10,904	1,387	8,723	231	1,454	0	0	**45,253**
2010	0	0	10,400	0	1,188	8,032	1,553	3,972	0	0	0	422	0	11,050	0	7,650	0	1,690	0	0	**45,957**
2011	0	0	4,539	0	892	8,908	1,166	7,634	0	0	0	497	0	14,903	0	10,260	0	1,988	0	0	**50,786**
2012	0	0	8,479	0	2,817	5,983	3,683	6,036	0	0	123	453	3,674	6,326	2,938	7,062	490	1,812	0	0	**49,875**
2013	0	0	2,783	0	0	7,200	0	10,000	0	0	0	521	0	12,000	0	12,000	0	2,890	0	0	**47,394**
2014	0	0	1,061	0	0	6,900	0	9,000	0	0	0	590	0	15,000	0	15,000	0	2,890	0	0	**50,441**
2015	0	0	371	0	717	5,583	938	8,616	0	0	0	529	0	19,719	0	15,775	0	2,624	0	0	**54,872**
2016	0	0	204	0	0	2,185	0	2,039	0	1,200	0	720	0	2,327	0	2,466	0	2,889	0	0	**14,029**
2017	0	0	8,300	0	5,045	0	3,784	1	11,345	19,833	200	524	5,972	15,747	4,776	12,599	796	2,100	1,354	0	**92,375**
2018	0	0	8,637	0	4,197	1,450	4,144	0	10,402	9,598	182	542	5,475	16,244	4,380	12,995	730	2,166	0	0	**81,142**
2019	0	0	10,126	0	2,600	0	1,260	0	0	0	251	123	7,556	1,264	6,045	2,145	1,007	1,889	0	0	**34,266**
2020	0	0	3,470	0	0	5,324	0	4,867	0	0	0	720	0	10,000	0	10,000	0	2,890	0	0	**37,271**
2021	0	0	8,322	0	227	4,477	297	5,482	0	0	10	710	296	4,704	237	4,763	39	2,851	0	0	**32,415**
2022	0	0	10,261	0	2,600	0	1,430	0	0	0	261	459	7,825	6,684	6,260	6,740	1,043	1,457	0	0	**45,020**
2023	0	0	4,674	0	762	2,338	996	3,204	0	0	0	720	0	10,000	0	10,000	0	2,890	0	0	**35,584**
2024	0	0	2,285	0	0	4,500	0	6,700	0	0	0	720	0	21,719	0	17,375	0	2,890	0	0	**56,189**
2025	0	0	8,300	0	0	3,726	0	6,148	0	0	0	456	0	20,231	0	16,185	0	2,692	0	0	**57,737**
2026	0	0	1	0	0	4,736	0	6,705	0	0	0	631	0	18,915	0	15,132	0	2,517	0	0	**48,636**
2027	0	0	214	0	0	2,417	0	2,071	0	0	0	345	0	6,974	0	5,978	0	1,236	0	0	**19,235**
2028	0	0	162	0	0	4,933	0	5,117	0	0	0	589	0	17,686	0	14,149	0	2,358	0	0	**44,994**
2029	0	0	0	0	0	2,904	0	2,447	0	0	0	184	0	2,447	0	2,500	0	2,466	0	0	**12,947**
2030	0	0	2,368	0	0	0	0	0	0	0	0	200	0	3,999	0	3,909	0	0	0	0	**10,476**
2031	0	0	5,304	0	0	2,916	0	2,366	0	0	0	139	0	2,506	0	2,227	0	718	0	0	**16,177**
2032	0	0	8,501	0	5,919	126	8,593	407	10,206	24,794	179	545	5,371	16,348	4,296	13,079	716	2,180	3,292	3,884	**108,436**
2033	0	0	2,548	0	0	5,000	0	5,000	0	0	0	724	0	21,719	0	17,375	0	2,896	0	0	**55,262**
2034	0	0	8,387	0	4,267	762	5,580	904	7,412	18,588	129	595	3,901	17,818	3,121	14,254	520	2,376	2,600	1,544	**92,757**
2035	0	0	7,685	0	0	5,200	0	6,000	0	0	0	724	0	20,356	0	16,618	0	2,896	0	0	**59,479**
2036	0	0	8,115	0	0	5,100	0	6,000	0	0	0	655	0	19,650	0	15,850	0	2,890	0	0	**58,260**
2037	0	0	8,316	0	4,217	4	5,069	0	8,664	15,336	152	572	4,561	17,158	3,648	13,727	607	2,289	2,598	1,270	**88,188**
2038	0	0	1,848	0	0	6,545	0	8,676	0	3,600	0	696	0	16,000	0	16,000	0	2,777	0	0	**56,142**
2039	0	0	1,357	0	0	6,468	0	6,348	0	5,000	0	388	0	13,200	0	6,200	0	1,994	0	68	**41,024**
Average	**0**	**0**	**4,961**	**0**	**1,183**	**3,439**	**1,269**	**3,580**	**1,367**	**2,589**	**42**	**442**	**1,280**	**11,041**	**1,028**	**9,246**	**178**	**2,022**	**289**	**179**	**44,133**

Source: SAIC (2004)
SAR: Santa Ana River Water

SWP: State Water Project Water
SG: Spreading Ground

Annual Artificial Recharge for Scenario B - 2001 to 2039 (Units in acre-ft)

Water Years	Mill Creek SG (Airport)		Santa Ana River SG		Devil Canyon/ Sweetwater SG		Lytle Creek SG		City Creek SG		Patton SG		Waterman SG		East Twin Creek SG		Badger SG		Mill Creek SG		Total
	Includes Senior Deliveries SAR	SWP	Includes Senior & WCD Deliveries SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	Includes Senior Deliveries SAR	SWP	
2001	0	0	5,121	0	0	2,000	0	1,600	0	0	0	76	0	2,276	0	1,821	0	800	0	0	**13,695**
2002	0	0	0	0	37	2,163	47	1,713	0	0	0	80	0	2,416	0	1,933	0	800	0	0	**9,189**
2003	0	0	0	0	0	2,300	0	1,840	0	0	0	86	0	2,591	0	2,073	0	800	0	0	**9,691**
2004	0	0	0	0	0	2,500	0	2,000	0	0	0	94	0	2,815	0	2,252	0	800	0	0	**10,462**
2005	0	0	9,911	0	2,000	0	1,600	0	0	0	0	500	0	10,000	0	6,000	0	900	0	0	**30,911**
2006	0	0	13,474	0	5,984	516	6,075	75	1,292	0	143	577	4,263	15,737	3,411	13,589	569	1,431	0	0	**67,136**
2007	0	0	2,332	0	0	0	0	4,000	0	0	0	112	0	2,000	0	2,000	0	600	0	0	**11,045**
2008	0	0	14,152	0	0	0	700	0	0	0	0	0	0	0	0	0	1,000	0	0	0	**15,852**
2009	0	0	10,400	0	2,844	3,156	3,354	646	0	0	58	363	1,733	10,904	1,387	8,723	231	1,454	0	0	**45,253**
2010	0	0	10,400	0	1,188	8,032	1,553	3,972	0	0	0	422	0	11,050	0	7,650	0	1,690	0	0	**45,957**
2011	0	0	4,539	0	892	4,108	1,166	7,634	0	0	0	497	0	14,903	0	10,260	0	1,988	0	0	**45,986**
2012	0	0	8,479	0	2,817	5,183	3,683	6,036	0	0	123	453	3,674	12,785	2,938	10,876	490	1,812	0	0	**59,348**
2013	0	0	2,783	0	0	7,200	0	9,000	0	0	0	521	0	8,000	0	7,195	0	2,084	0	0	**36,783**
2014	0	0	1,061	0	0	6,900	0	8,000	0	0	0	590	0	11,871	0	11,000	0	2,364	0	0	**41,786**
2015	0	0	371	0	717	4,979	938	9,046	0	0	0	497	0	20,998	0	16,999	0	2,890	0	0	**57,434**
2016	0	0	204	0	0	938	0	938	0	0	0	477	0	2,353	0	1,557	0	625	0	0	**7,092**
2017	0	0	8,300	0	5,962	598	5,999	1	7,802	0	211	513	6,322	15,395	5,056	12,319	843	2,053	3,514	486	**75,374**
2018	0	0	8,637	0	4,197	103	3,533	0	10,402	1,598	182	542	5,475	16,240	4,380	12,995	730	2,166	0	0	**71,180**
2019	0	0	12,903	0	2,600	0	1,260	0	0	0	303	71	9,105	5,895	7,284	4,716	1,214	1,682	0	0	**47,033**
2020	0	0	3,470	0	0	5,324	0	4,867	0	0	0	652	0	21,000	0	17,375	0	2,890	0	0	**55,577**
2021	0	0	8,322	0	227	1,685	297	2,063	0	0	10	214	296	3,652	237	3,674	39	1,073	0	0	**21,787**
2022	0	0	10,261	0	2,250	0	1,446	0	118	0	253	26	7,829	13,888	6,263	10,737	1,044	1,846	0	0	**55,961**
2023	0	0	4,674	0	762	2,783	996	3,202	0	0	0	121	0	16,000	0	15,000	0	2,896	0	2,000	**48,434**
2024	0	0	2,285	0	0	4,040	0	5,281	0	0	0	720	0	20,000	0	16,000	0	2,890	0	0	**51,216**
2025	0	0	8,300	0	0	899	0	0	0	0	0	720	0	19,000	0	15,000	0	2,890	0	0	**46,809**
2026	0	0	1	0	0	172	0	0	0	0	0	720	0	18,000	0	17,000	0	2,890	0	0	**38,783**
2027	0	0	214	0	0	0	0	0	0	0	0	720	0	8,000	0	6,822	0	252	0	0	**16,008**
2028	0	0	162	0	0	209	0	252	0	0	0	199	0	13,720	0	13,720	0	1,495	0	0	**29,756**
2029	0	0	0	0	0	260	0	260	0	0	0	187	0	4,297	0	4,512	0	750	0	0	**10,265**
2030	0	0	2,368	0	0	458	0	0	0	0	0	700	0	8,000	0	7,138	0	978	0	0	**19,641**
2031	0	0	5,304	0	0	0	0	0	0	0	0	357	0	10,421	0	7,148	0	1,434	0	0	**24,665**
2032	0	0	14,352	0	3,999	1	4,000	0	11,006	3,994	193	529	5,792	15,673	4,634	12,549	773	2,120	3,543	474	**83,632**
2033	0	0	2,548	0	0	4,000	0	4,000	0	4,000	0	720	0	21,000	0	17,000	0	2,890	0	3,000	**59,158**
2034	0	0	8,387	0	5,430	0	5,000	0	10,402	3,598	182	538	5,475	15,525	4,380	12,620	730	2,160	3,650	2,350	**80,427**
2035	0	0	7,685	0	0	5,139	0	4,362	0	8,600	0	720	0	21,500	0	17,000	0	2,890	0	3,000	**70,896**
2036	0	0	8,115	0	0	3,859	0	3,900	0	3,600	0	679	0	21,500	0	17,000	0	2,717	0	0	**61,369**
2037	0	0	8,316	0	5,330	670	5,910	90	8,156	144	180	540	5,412	15,588	4,329	12,671	721	1,997	2,598	2,302	**74,954**
2038	0	0	1,848	0	0	4,761	0	4,761	0	6,000	0	695	0	21,000	0	17,000	0	2,890	0	1,077	**60,032**
2039	0	0	1,357	0	0	4,887	0	4,887	0	1,800	0	720	0	17,105	0	15,000	0	2,354	0	0	**48,110**
Average	**0**	**0**	**5,411**	**0**	**1,211**	**2,303**	**1,219**	**2,421**	**1,261**	**855**	**47**	**435**	**1,420**	**12,131**	**1,136**	**9,972**	**215**	**1,775**	**341**	**377**	**42,530**

Source: SAIC (2004)
SAR: Santa Ana River Water

SWP: State Water Project Water
SG: Spreading Ground

Annual Artificial Recharge for Scenario C - 2001 to 2039 (Units in acre-ft)

Water Years	**Mill Creek SG (Airport)**		**Santa Ana River SG**		**Devil Canyon/ Sweetwater SG**		**Lytle Creek SG**		**City Creek SG**		**Patton SG**		**Waterman SG**		**East Twin Creek SG**		**Badger SG**		**Mill Creek SG**		**Total**
	Includes Senior Deliveries SAR	**SWP**	**Includes Senior & WCD Deliveries SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**SAR**	**SWP**	**Includes Senior Deliveries SAR**	**SWP**	
2001	1,114	0	5,842	0	0	342	0	302	0	0	0	63	0	1,837	0	1,464	0	265	1,114	0	**12,345**
2002	0	0	0	0	0	363	0	321	0	0	0	67	0	1,950	0	1,554	0	282	0	0	**4,536**
2003	0	0	0	0	0	390	0	344	0	0	0	71	0	2,092	0	1,667	0	302	0	0	**4,866**
2004	0	0	24	0	0	500	0	441	0	0	0	84	0	2,454	0	1,955	0	357	0	0	**5,815**
2005	0	0	17,769	0	1,266	0	1,223	0	0	0	0	650	0	2,400	0	2,100	0	900	0	0	**26,308**
2006	0	0	27,137	0	1,605	1,932	1,849	942	0	0	16	436	468	14,532	374	8,326	62	784	0	0	**58,463**
2007	0	0	5,540	0	0	5,202	0	4,405	0	0	0	78	0	1,689	0	1,525	0	327	0	0	**18,766**
2008	259	0	58,149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	0	**58,667**
2009	1,604	0	12,176	0	0	6,000	0	5,700	0	0	0	523	0	6,000	0	5,000	0	1,500	1,604	0	**40,107**
2010	795	0	4,262	0	0	8,700	0	7,200	0	0	0	533	0	9,450	0	5,400	0	2,214	795	0	**39,350**
2011	263	0	3,172	0	0	3,000	0	3,000	0	0	0	433	0	4,000	0	2,000	0	1,788	263	0	**17,920**
2012	0	0	24,490	0	0	7,600	0	7,900	0	0	0	280	0	13,000	0	12,000	0	2,800	0	0	**68,070**
2013	0	0	5,978	0	0	7,900	0	9,800	0	0	0	359	0	12,600	0	10,800	0	2,800	0	0	**50,237**
2014	0	0	4,605	0	0	7,335	0	11,678	0	0	0	720	0	15,000	0	13,500	0	2,800	0	0	**55,638**
2015	1,299	0	3,923	0	0	6,243	0	9,074	0	0	0	306	0	8,324	0	6,581	0	1,561	1,299	0	**38,611**
2016	0	0	0	0	0	1,558	0	1,348	0	0	0	481	0	1,444	0	1,444	0	481	0	0	**6,756**
2017	0	0	77,260	0	0	546	0	315	0	0	0	151	0	5,322	0	6,000	0	1,500	0	0	**91,094**
2018	0	0	62,537	0	0	883	0	353	0	0	0	157	0	3,300	0	2,880	0	780	0	0	**70,891**
2019	0	0	63,571	0	156	0	63	0	0	0	19	0	1,050	0	1,200	0	181	0	0	0	**66,240**
2020	0	0	6,819	0	0	4,300	0	3,144	0	0	0	362	0	17,000	0	13,000	0	1,448	0	0	**46,073**
2021	0	0	14,903	0	0	3,075	0	2,863	0	0	0	237	0	18,000	0	15,000	0	1,407	0	0	**55,485**
2022	0	0	31,259	0	806	0	500	0	0	0	141	0	6,470	530	5,380	620	443	0	0	0	**46,149**
2023	0	0	10,694	0	0	5,200	0	4,000	0	0	0	720	0	21,719	0	17,375	0	2,890	0	0	**62,598**
2024	507	0	2,662	0	0	5,656	0	3,828	0	0	0	626	0	18,898	0	15,118	0	2,515	507	0	**50,317**
2025	0	0	12,381	0	0	3,230	0	3,784	0	0	0	471	0	11,852	0	9,572	0	1,886	0	0	**43,177**
2026	762	0	0	0	0	3,400	0	5,015	0	0	0	279	0	8,329	0	7,649	0	1,700	762	0	**27,895**
2027	0	0	0	0	0	2,942	0	2,447	0	0	0	489	0	2,547	0	2,153	0	979	0	0	**11,556**
2028	0	0	0	0	0	2,908	0	3,042	0	0	0	324	0	13,892	0	9,377	0	1,360	0	0	**30,905**
2029	0	0	0	0	0	6,196	0	6,885	0	0	0	334	0	9,294	0	8,881	0	1,928	0	0	**33,517**
2030	0	0	1,319	0	0	3,739	0	3,739	0	0	0	216	0	6,076	0	5,819	0	648	0	0	**21,557**
2031	0	0	8,295	0	0	8	0	8	0	0	0	1	0	62	0	65	0	4	0	0	**8,443**
2032	0	0	68,884	0	2,550	0	2,550	0	0	0	140	291	4,209	10,791	3,367	10,333	561	1,896	0	0	**105,571**
2033	0	0	5,682	0	0	5,000	0	5,000	0	0	0	390	0	15,000	0	14,000	0	2,246	0	0	**47,319**
2034	0	0	34,591	0	3,968	1,032	4,873	127	1,750	0	172	548	5,176	16,543	4,141	13,234	690	2,200	0	0	**89,045**
2035	0	0	10,611	0	0	4,000	0	4,000	0	0	0	709	0	20,000	0	17,375	0	2,844	0	0	**59,539**
2036	0	0	11,049	0	0	5,591	0	7,897	0	0	0	576	0	12,000	0	14,000	0	2,890	0	0	**54,003**
2037	0	0	53,078	0	1,414	1,086	1,849	1,373	0	0	61	439	1,845	12,155	1,476	10,824	246	1,386	0	0	**87,232**
2038	1,307	0	2,277	0	0	7,439	0	7,427	0	0	0	714	0	16,000	0	15,000	0	2,866	1,307	0	**54,337**
2039	0	0	0	0	0	7,570	0	8,566	0	0	0	392	0	14,190	0	11,352	0	1,892	0	0	**43,963**
Average	**203**	**0**	**16,691**	**0**	**302**	**3,356**	**331**	**3,494**	**45**	**0**	**14**	**347**	**493**	**8,981**	**409**	**7,563**	**56**	**1,447**	**203**	**0**	**43,933**

Source: SAIC (2004)
SAR: Santa Ana River Water

SWP: State Water Project Water
SG: Spreading Ground

Table B 6

Annual Artificial Recharge for Scenario D - 2001 to 2039 (Units in acre-ft)

Water Years	Mill Creek SG (Airport)		Santa Ana River SG		Devil Canyon/ Sweetwater SG		Lytle Creek SG		City Creek SG		Patton SG		Waterman SG		East Twin Creek SG		Badger SG		Mill Creek SG		Total
	Includes Senior Deliveries SAR	SWP	Includes Senior & WCD Deliveries SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	SAR	SWP	Includes Senior Deliveries SAR	SWP	
2001	1,114	0	5,842	0	0	297	0	310	0	0	0	40	0	1,797	0	1,435	0	195	1,114	0	**12,144**
2002	0	0	0	0	0	322	0	354	0	0	0	40	0	2,071	0	1,655	0	210	0	0	**4,653**
2003	0	0	0	0	0	298	0	265	0	0	0	44	0	2,229	0	1,781	0	364	0	0	**4,981**
2004	0	0	24	0	0	502	0	538	0	0	0	57	0	2,801	0	2,239	0	359	0	0	**6,519**
2005	0	0	17,769	0	1,215	165	1,441	197	0	0	0	228	0	2,357	0	1,934	0	520	0	0	**25,825**
2006	0	0	27,137	0	1,563	1,783	1,849	1,651	0	0	16	381	489	11,787	391	10,550	65	1,596	0	0	**59,258**
2007	0	0	5,540	0	0	284	0	360	0	0	0	47	0	1,485	0	1,273	0	214	0	0	**9,203**
2008	259	0	60,926	0	229	0	207	0	0	0	0	0	0	0	0	0	0	0	259	0	**61,880**
2009	1,604	0	12,176	0	0	2,800	0	2,900	0	0	0	303	0	9,123	0	7,284	0	1,214	1,604	0	**39,007**
2010	795	0	4,262	0	0	3,329	0	3,329	0	0	0	333	0	3,995	0	3,329	0	1,665	795	0	**21,832**
2011	263	0	3,172	0	0	7,796	0	7,338	0	0	0	607	0	9,283	0	8,794	0	2,568	263	0	**40,085**
2012	0	0	24,490	0	0	8,486	0	8,958	0	0	0	566	0	9,712	0	9,316	0	2,640	0	0	**64,168**
2013	0	0	5,978	0	0	8,239	0	8,724	0	0	0	285	0	15,489	0	12,635	0	2,132	0	0	**53,482**
2014	0	0	4,605	0	0	9,158	0	10,604	0	0	0	653	0	12,532	0	11,444	0	2,786	0	0	**51,783**
2015	1,299	0	3,923	0	0	6,178	0	6,565	0	0	0	319	0	7,723	0	7,337	0	2,600	1,299	0	**37,243**
2016	0	0	0	0	0	420	0	480	0	0	0	68	0	1,512	0	1,225	0	264	0	0	**3,970**
2017	0	0	77,260	0	0	2,545	0	2,121	0	0	0	597	0	7,755	0	6,959	0	2,873	0	0	**100,109**
2018	0	0	62,537	0	0	2,841	0	1,420	0	0	0	213	0	4,617	0	4,261	0	2,695	0	0	**78,585**
2019	0	0	69,422	0	1,500	0	800	0	0	0	182	0	4,000	0	4,300	0	730	0	0	0	**80,934**
2020	0	0	6,819	0	0	6,395	0	4,573	0	0	0	589	0	8,306	0	7,362	0	2,735	0	0	**36,779**
2021	0	0	14,903	0	0	6,795	0	5,339	0	0	0	582	0	8,376	0	7,280	0	2,882	0	0	**46,157**
2022	0	0	31,259	0	2,800	0	2,000	0	0	0	240	309	6,121	237	5,440	408	961	1,799	0	0	**51,575**
2023	0	0	10,694	0	0	4,469	0	3,977	0	0	0	709	0	20,295	0	17,200	0	2,830	0	0	**60,174**
2024	507	0	2,662	0	0	5,479	0	6,460	0	0	0	511	0	16,437	0	14,943	0	2,879	507	0	**50,385**
2025	0	0	12,381	0	0	4,974	0	6,422	0	0	0	465	0	11,450	0	9,947	0	2,875	0	0	**48,513**
2026	762	0	0	0	0	3,707	0	4,118	0	0	0	304	0	11,142	0	9,410	0	2,306	762	0	**32,511**
2027	0	0	0	0	0	1,272	0	1,653	0	0	0	96	0	4,400	0	3,520	0	490	0	0	**11,430**
2028	0	0	0	0	0	4,072	0	4,072	0	0	0	136	0	9,505	0	7,412	0	1,435	0	0	**26,632**
2029	0	0	0	0	0	1,522	0	1,522	0	0	0	97	0	3,727	0	3,065	0	609	0	0	**10,542**
2030	0	0	1,319	0	0	1,003	0	1,003	0	0	0	65	0	3,070	0	2,456	0	511	0	0	**9,426**
2031	0	0	8,295	0	0	652	0	696	0	0	0	67	0	2,778	0	2,268	0	587	0	0	**15,342**
2032	0	0	68,884	0	5,482	18	5,600	0	0	0	140	546	4,204	13,505	3,364	10,992	561	2,200	0	0	**115,497**
2033	0	0	5,682	0	0	7,414	0	8,585	0	0	0	356	0	6,631	0	6,966	0	1,994	0	0	**37,628**
2034	0	0	37,077	0	2,901	1,795	3,702	798	7,190	2,726	125	599	3,784	17,935	3,027	14,348	505	2,385	2,523	1,116	**102,535**
2035	0	0	10,611	0	0	5,378	0	8,605	0	0	0	655	0	16,041	0	15,156	0	2,826	0	0	**59,271**
2036	0	0	11,049	0	0	5,303	0	8,533	0	0	0	546	0	18,607	0	14,462	0	2,786	0	0	**61,286**
2037	0	0	53,078	0	1,414	1,729	1,849	921	0	0	61	450	1,845	7,895	1,476	7,672	246	2,560	0	0	**81,195**
2038	1,307	0	2,277	0	0	7,098	0	8,252	0	0	0	689	0	17,475	0	15,534	0	2,889	1,307	0	**56,829**
2039	0	0	0	0	0	7,374	0	9,487	0	0	0	598	0	13,640	0	11,958	0	2,880	0	0	**45,937**
Average	**203**	**0**	**16,976**	**0**	**439**	**3,382**	**447**	**3,619**	**184**	**70**	**20**	**337**	**524**	**8,147**	**461**	**7,072**	**79**	**1,727**	**268**	**29**	**43,982**

Source: SAIC (2004)	SWP: State Water Project Water
SAR: Santa Ana River Water	SG: Spreading Ground

Table B 7

Groundwater Budgets for No Project Condition - 2001 to 2039 (Units in acre-ft)

Water Years	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
	INFLOW									OUTFLOW				
	Recharge from Gaged Streamflow	Artificial Recharge at SAR Spreading Grounds	Artificial Recharge at Other Spreading Grounds	Recharge from Local Runoff Generated by Precipitation	Infiltration from Direct Precipitation	Return Flow from Groundwater Pumping	Recharge from Ungaged Mountain Front Runoff	Underflow Recharge	Total Inflow	Evapo-transpiration	Groundwater Pumping	Underflow Discharge	Total Outflow	CHANGE IN GROUNDWATER STORAGE
2001	85,964	3,922	4,477	3,611	1,137	34,131	10,291	3,780	147,312	2,929	213,577	3,687	220,193	**-72,881**
2002	46,333	412	4,751	5,948	1,137	36,833	5,348	3,726	104,488	2,314	226,198	3,350	231,861	**-127,374**
2003	42,718	407	5,096	3,388	1,137	37,795	5,467	3,690	99,699	1,845	223,541	3,015	228,401	**-128,702**
2004	114,427	1,754	6,537	7,446	1,137	36,908	12,653	3,654	184,516	1,947	219,247	2,801	223,994	**-39,478**
2005	152,284	5,766	5,979	5,060	1,137	34,171	20,139	3,609	228,145	2,919	206,346	2,742	212,007	**16,139**
2006	198,295	9,406	4,644	5,876	1,137	36,892	18,871	3,563	278,683	6,407	219,373	2,650	228,430	**50,253**
2007	80,503	4,232	4,342	2,572	1,137	36,379	9,173	3,534	141,871	4,583	217,068	2,538	224,189	**-82,318**
2008	403,245	31,262	1,800	10,958	1,137	36,263	66,749	3,482	554,895	9,532	217,493	2,699	229,725	**325,171**
2009	94,234	10,330	14,794	4,988	1,137	37,211	11,583	3,453	177,729	6,812	222,244	2,879	231,935	**-54,206**
2010	74,103	5,587	26,466	4,616	1,137	39,615	9,605	3,415	164,542	5,074	233,592	2,822	241,489	**-76,947**
2011	63,788	2,192	30,269	2,349	1,137	40,269	7,170	3,364	150,539	4,484	236,459	2,712	243,655	**-93,116**
2012	120,816	18,169	33,901	4,975	1,137	37,068	17,518	3,328	236,912	4,879	221,775	2,640	229,294	**7,617**
2013	92,732	5,310	46,590	5,163	1,137	38,619	11,448	3,292	204,291	5,270	228,285	2,592	236,147	**-31,857**
2014	73,218	3,834	49,213	4,091	1,137	39,754	9,605	3,238	184,090	4,970	233,440	2,538	240,948	**-56,858**
2015	76,009	3,771	32,090	5,167	1,137	40,542	9,480	3,211	171,406	4,029	237,104	2,473	243,606	**-72,199**
2016	61,392	1,918	4,108	5,114	1,137	41,868	7,170	3,166	125,872	2,125	243,362	2,384	247,871	**-121,999**
2017	425,220	48,152	21,854	10,573	1,137	40,384	33,981	3,121	584,422	7,548	237,296	2,430	247,275	**337,147**
2018	208,058	34,614	14,131	5,643	1,137	37,851	31,634	3,078	336,145	10,002	226,252	2,577	238,831	**97,314**
2019	338,405	33,310	9,050	9,110	1,137	38,462	67,712	3,049	500,234	13,531	230,070	2,936	246,536	**253,698**
2020	89,740	6,426	22,921	3,947	1,137	40,082	10,291	2,995	177,539	8,118	237,805	3,230	249,154	**-71,614**
2021	136,442	9,963	24,376	7,859	1,137	39,587	18,943	2,959	241,265	6,322	235,723	3,341	245,385	**-4,120**
2022	333,415	11,516	7,079	11,788	1,137	38,985	50,284	2,923	457,126	13,164	231,722	3,857	248,744	**208,383**
2023	106,962	6,381	38,470	3,062	1,137	39,086	11,986	2,871	209,954	9,789	231,310	4,314	245,413	**-35,458**
2024	82,778	186	38,298	3,738	1,137	40,696	9,480	2,833	179,146	6,603	237,872	4,281	248,756	**-69,610**
2025	114,260	6,755	30,796	5,324	1,137	37,970	13,304	2,805	212,351	5,817	225,004	4,129	234,949	**-22,598**
2026	64,199	0	26,372	4,469	1,137	41,968	7,495	2,745	148,384	4,636	243,576	3,853	252,065	**-103,681**
2027	59,562	1,402	9,711	4,177	1,137	41,651	6,474	2,716	126,829	2,735	241,762	3,512	248,009	**-121,180**
2028	47,528	2,096	26,758	2,479	1,137	43,576	5,467	2,671	131,712	3,055	250,721	3,151	256,927	**-125,215**
2029	36,353	357	10,506	2,808	1,137	45,526	3,977	2,627	103,292	1,721	259,938	2,833	264,493	**-161,201**
2030	75,505	5,321	8,532	6,118	1,137	42,852	8,175	2,590	150,230	1,609	247,257	2,609	251,475	**-101,245**
2031	111,338	7,941	7,572	6,894	1,137	40,738	12,181	2,553	190,354	1,728	237,522	2,472	241,723	**-51,369**
2032	434,599	38,877	22,332	9,016	1,137	40,128	52,483	2,501	601,072	7,402	235,822	2,529	245,753	**355,319**
2033	86,408	5,493	29,262	4,755	1,137	40,400	11,042	2,467	180,963	5,660	237,214	2,638	245,512	**-64,549**
2034	308,150	17,369	25,194	7,419	1,137	40,110	38,408	2,417	440,204	10,064	236,378	2,783	249,225	**190,979**
2035	111,526	8,265	44,570	6,414	1,137	41,686	14,265	2,372	230,236	8,055	243,919	2,906	254,880	**-24,645**
2036	95,677	9,061	46,648	5,952	1,137	41,747	11,042	2,329	213,593	6,274	244,242	2,885	253,401	**-39,808**
2037	278,042	35,337	21,723	9,945	1,137	40,199	35,918	2,300	424,600	10,880	236,816	3,057	250,753	**173,848**
2038	63,821	3,736	50,185	2,332	1,137	42,436	4,315	2,239	170,201	7,603	247,332	3,182	258,117	**-87,916**
2039	53,125	4,150	43,963	4,318	1,137	42,992	3,836	2,212	155,732	4,620	251,375	3,092	259,087	**-103,356**
Average	**139,517**	**10,384**	**21,932**	**5,627**	**1,137**	**39,575**	**17,820**	**2,997**	**238,989**	**5,822**	**233,488**	**3,003**	**242,313**	**-3,324**

Note:
[1] Model-Calculated
[2] Model input data from Allocation Model
[3] Model input data from Allocation Model
[4] Model input based on historical conditions
[5] Model input based on historical conditions
[6] Model input data from Allocation Model
[7] Model input based on historical conditions
[8] Model input based on historical conditions
[9] = sum of [1] through [8]
[10] Model-Calculated
[11] Model input data from Allocation Model
[12] Model input based on historical conditions and model-calculated water level in Heap Well
[13] = sum of [10] through [12]
[14] = [9]-[13]

Groundwater Budgets for Scenario A - 2001 to 2039 (Units in acre-ft)

Water Years	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
	INFLOW									OUTFLOW				CHANGE IN GROUNDWATER STORAGE
	Recharge from Gaged Streamflow	Artificial Recharge at SAR Spreading Grounds	Artificial Recharge at Other Spreading Grounds	Recharge from Local Runoff Generated by Precipitation	Infiltration from Direct Precipitation	Return Flow from Groundwater Pumping	Recharge from Ungaged Mountain Front Runoff	Underflow Recharge	Total Inflow	Evapo-transpiration	Groundwater Pumping	Underflow Discharge	Total Outflow	
2001	81,836	5,121	8,574	3,611	1,137	34,132	10,291	3,780	148,481	2,707	213,617	3,690	220,014	**-71,533**
2002	45,760	0	9,189	5,948	1,137	36,833	5,348	3,726	107,941	2,331	226,224	3,358	231,913	**-123,972**
2003	42,608	0	9,691	3,388	1,137	37,796	5,467	3,690	103,776	2,004	223,554	3,019	228,576	**-124,800**
2004	114,178	0	11,462	7,446	1,137	36,907	12,653	3,654	187,437	2,116	219,201	2,806	224,123	**-36,687**
2005	130,622	9,911	20,247	5,060	1,137	34,175	20,139	3,609	224,900	3,225	206,612	2,707	212,543	**12,357**
2006	138,883	10,400	63,034	5,876	1,137	36,884	18,871	3,563	278,647	8,561	218,702	2,647	229,909	**48,738**
2007	79,336	2,332	16,413	2,572	1,137	36,384	9,173	3,534	150,880	4,654	217,466	2,573	224,693	**-73,814**
2008	429,665	8,301	3,900	10,958	1,137	36,294	66,749	3,482	560,485	7,475	219,990	2,726	230,191	**330,295**
2009	76,623	10,400	34,853	4,988	1,137	37,245	11,583	3,453	180,281	7,046	224,891	2,903	234,839	**-54,558**
2010	61,078	10,400	35,557	4,616	1,137	39,649	9,605	3,415	165,457	5,040	236,317	2,840	244,197	**-78,740**
2011	54,908	4,539	46,247	2,349	1,137	40,335	7,170	3,364	160,049	4,620	241,657	2,707	248,984	**-88,935**
2012	107,341	8,479	41,396	4,975	1,137	37,120	17,518	3,328	221,292	4,641	225,842	2,620	233,103	**-11,810**
2013	92,185	2,783	44,611	5,163	1,137	38,663	11,448	3,292	199,281	4,648	231,764	2,547	238,959	**-39,678**
2014	72,587	1,061	49,380	4,091	1,137	39,816	9,605	3,238	180,915	4,496	238,333	2,470	245,300	**-64,385**
2015	73,421	371	54,501	5,167	1,137	40,627	9,480	3,211	187,916	4,532	243,878	2,399	250,809	**-62,892**
2016	60,829	204	13,825	5,114	1,137	41,941	7,170	3,166	133,385	2,250	249,116	2,321	253,688	**-120,302**
2017	408,654	8,300	84,075	10,573	1,137	40,444	33,981	3,121	590,284	10,023	242,079	2,309	254,411	**335,873**
2018	179,122	8,637	72,505	5,643	1,137	37,880	31,634	3,078	339,635	12,404	228,571	2,397	243,371	**96,264**
2019	358,283	10,126	24,140	9,110	1,137	38,504	67,712	3,049	512,060	13,803	233,380	2,611	249,795	**262,266**
2020	89,893	3,470	33,801	3,947	1,137	40,115	10,291	2,995	185,649	8,772	240,485	2,935	252,192	**-66,543**
2021	132,693	8,322	24,093	7,859	1,137	39,619	18,943	2,959	235,625	6,209	238,261	3,060	247,530	**-11,905**
2022	310,960	10,261	34,759	11,788	1,137	39,055	50,284	2,923	461,167	13,822	237,297	3,287	254,406	**206,760**
2023	104,047	4,674	30,910	3,062	1,137	39,190	11,986	2,871	197,877	9,029	239,545	3,677	252,252	**-54,375**
2024	77,779	2,285	53,904	3,738	1,137	40,807	9,480	2,833	191,963	7,163	246,623	3,708	257,493	**-65,531**
2025	108,456	8,300	49,437	5,324	1,137	38,066	13,304	2,805	226,829	6,496	232,573	3,695	242,764	**-15,935**
2026	62,931	1	48,635	4,469	1,137	42,081	7,495	2,745	169,493	5,402	252,531	3,553	261,487	**-91,994**
2027	59,178	214	19,021	4,177	1,137	41,739	6,474	2,716	134,654	2,983	248,684	3,332	254,999	**-120,344**
2028	46,714	162	44,832	2,479	1,137	43,641	5,467	2,671	147,103	3,736	255,877	3,072	262,685	**-115,582**
2029	36,263	0	12,947	2,808	1,137	45,553	3,977	2,627	105,312	1,754	262,077	2,824	266,655	**-161,343**
2030	75,711	2,368	8,108	6,118	1,137	42,872	8,175	2,590	147,078	1,507	248,841	2,621	252,969	**-105,891**
2031	110,541	5,304	10,873	6,894	1,137	40,734	12,181	2,553	190,217	1,813	237,207	2,496	241,516	**-51,299**
2032	379,323	8,501	99,935	9,016	1,137	40,124	52,483	2,501	593,019	10,786	235,493	2,469	248,749	**344,270**
2033	86,267	2,548	52,714	4,755	1,137	40,426	11,042	2,467	201,355	6,591	239,256	2,547	248,395	**-47,040**
2034	249,836	8,387	84,370	7,419	1,137	40,128	38,408	2,417	432,103	13,098	237,874	2,601	253,573	**178,530**
2035	109,344	7,685	51,794	6,414	1,137	41,725	14,265	2,372	234,737	8,430	247,034	2,680	258,144	**-23,407**
2036	93,905	8,115	50,145	5,952	1,137	41,787	11,042	2,329	214,412	6,086	247,428	2,729	256,244	**-41,832**
2037	252,228	8,316	79,872	9,945	1,137	40,229	35,918	2,300	429,944	13,796	239,180	2,796	255,773	**174,171**
2038	62,883	1,848	54,294	2,332	1,137	42,443	4,315	2,239	171,491	7,896	247,826	2,908	258,631	**-87,140**
2039	53,003	1,357	39,667	4,318	1,137	42,993	3,836	2,212	148,520	4,300	251,401	2,909	258,609	**-110,089**
Average	**131,022**	**4,961**	**39,172**	**5,627**	**1,137**	**39,614**	**17,820**	**2,997**	**242,350**	**6,314**	**236,582**	**2,860**	**245,756**	**-3,406**

Note:
[1] Model-Calculated
[2] Model input data from Allocation Model
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[5] Model input based on historical conditions
[6] Model input data from Allocation Model
[7] Model input based on historical conditions
[8] Model input based on historical conditions
[9] = sum of [1] through [8]
[10] Model-Calculated
[11] Model input data from Allocation Model
[12] Model input based on historical conditions and model-calculated water level in Heap Well
[13] = sum of [10] through [12]
[14] = [9]-[13]

Table B 9

Groundwater Budgets for Scenario B - 2001 to 2039 (Units in acre-ft)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
	INFLOW									**OUTFLOW**				
Water Years	**Recharge from Gaged Streamflow**	**Artificial Recharge at SAR Spreading Grounds**	**Artificial Recharge at Other Spreading Grounds**	**Recharge from Local Runoff Generated by Precipitation**	**Infiltration from Direct Precipitation**	**Return Flow from Groundwater Pumping**	**Recharge from Ungaged Mountain Front Runoff**	**Underflow Recharge**	**Total Inflow**	**Evapo-transpiration**	**Groundwater Pumping**	**Underflow Discharge**	**Total Outflow**	**CHANGE IN GROUNDWATER STORAGE**
2001	81,836	5,121	8,574	3,611	1,137	34,132	10,291	3,780	148,481	2,707	213,617	3,690	220,014	**-71,533**
2002	45,760	0	9,189	5,948	1,137	36,833	5,348	3,726	107,941	2,331	226,224	3,358	231,913	**-123,971**
2003	42,608	0	9,691	3,388	1,137	37,796	5,467	3,690	103,776	2,004	223,554	3,019	228,576	**-124,800**
2004	114,178	0	10,462	7,446	1,137	36,907	12,653	3,654	186,437	2,066	219,201	2,806	224,073	**-37,637**
2005	130,622	9,911	21,000	5,060	1,137	34,175	20,139	3,609	225,653	3,262	206,612	2,707	212,581	**13,072**
2006	142,461	13,474	53,662	5,876	1,137	36,888	18,871	3,563	275,931	8,080	219,054	2,646	229,779	**46,152**
2007	79,338	2,332	8,713	2,572	1,137	36,384	9,173	3,534	143,182	4,282	217,448	2,570	224,300	**-81,118**
2008	432,752	14,152	1,700	10,958	1,137	36,297	66,749	3,482	567,226	8,306	220,176	2,727	231,209	**336,016**
2009	76,639	10,400	34,853	4,988	1,137	37,247	11,583	3,453	180,299	7,326	225,079	2,898	235,302	**-55,003**
2010	61,067	10,400	35,557	4,616	1,137	39,651	9,605	3,415	165,447	5,079	236,503	2,833	244,415	**-78,968**
2011	54,905	4,539	41,447	2,349	1,137	40,333	7,170	3,364	155,245	4,405	241,491	2,702	248,598	**-93,353**
2012	107,354	8,479	50,869	4,975	1,137	37,122	17,518	3,328	230,782	5,117	226,047	2,623	233,787	**-3,006**
2013	92,201	2,783	34,000	5,163	1,137	38,663	11,448	3,292	188,687	4,133	231,764	2,554	238,451	**-49,765**
2014	72,564	1,061	40,725	4,091	1,137	39,816	9,605	3,238	172,237	4,079	238,333	2,464	244,877	**-72,640**
2015	73,421	371	57,063	5,167	1,137	40,615	9,480	3,211	190,466	4,632	242,906	2,389	249,927	**-59,462**
2016	60,827	204	6,888	5,114	1,137	41,921	7,170	3,166	126,426	1,910	247,529	2,315	251,755	**-125,329**
2017	409,127	8,300	67,074	10,573	1,137	40,426	33,981	3,121	573,738	9,054	240,621	2,301	251,975	**321,762**
2018	179,217	8,637	62,543	5,643	1,137	37,862	31,634	3,078	329,749	11,506	227,113	2,375	240,994	**88,755**
2019	381,578	12,903	34,130	9,110	1,137	38,493	67,712	3,049	548,112	13,807	232,531	2,648	248,986	**299,126**
2020	89,847	3,470	52,107	3,947	1,137	40,117	10,291	2,995	203,912	9,534	240,596	3,018	253,148	**-49,236**
2021	133,131	8,322	13,465	7,859	1,137	39,628	18,943	2,959	225,445	5,533	238,999	3,165	247,698	**-22,253**
2022	314,023	10,261	45,700	11,788	1,137	39,064	50,284	2,923	475,179	14,144	237,964	3,416	255,525	**219,654**
2023	103,790	4,674	43,760	3,062	1,137	39,200	11,986	2,871	210,479	9,674	240,318	3,895	253,887	**-43,408**
2024	77,710	2,285	48,931	3,738	1,137	40,799	9,480	2,833	186,913	6,822	246,035	3,970	256,828	**-69,914**
2025	108,654	8,300	38,509	5,324	1,137	38,054	13,304	2,805	216,086	5,851	231,604	3,945	241,400	**-25,314**
2026	62,924	1	38,782	4,469	1,137	42,046	7,495	2,745	159,598	4,857	249,745	3,796	258,398	**-98,801**
2027	59,407	214	15,794	4,177	1,137	41,703	6,474	2,716	131,621	2,824	245,844	3,559	252,227	**-120,606**
2028	46,482	162	29,594	2,479	1,137	43,604	5,467	2,671	131,596	2,983	252,932	3,262	259,177	**-127,581**
2029	36,263	0	10,265	2,808	1,137	45,526	3,977	2,627	102,603	1,622	259,883	2,966	264,471	**-161,869**
2030	75,711	2,368	17,273	6,118	1,137	42,849	8,175	2,590	156,220	1,972	247,029	2,735	251,736	**-95,516**
2031	110,541	5,304	19,361	6,894	1,137	40,734	12,181	2,553	198,705	2,244	237,213	2,597	242,054	**-43,349**
2032	387,473	14,352	69,280	9,016	1,137	40,125	52,483	2,501	576,366	8,990	235,592	2,560	247,142	**329,225**
2033	86,178	2,548	56,610	4,755	1,137	40,423	11,042	2,467	205,159	6,928	239,035	2,634	248,598	**-43,439**
2034	249,793	8,387	72,040	7,419	1,137	40,132	38,408	2,417	419,733	12,222	238,166	2,680	253,069	**166,664**
2035	109,177	7,685	63,211	6,414	1,137	41,721	14,265	2,372	245,983	8,950	246,732	2,756	258,437	**-12,455**
2036	93,802	8,115	53,254	5,952	1,137	41,783	11,042	2,329	217,414	6,350	247,116	2,809	256,274	**-38,860**
2037	252,428	8,316	66,638	9,945	1,137	40,225	35,918	2,300	416,906	12,930	238,924	2,877	254,731	**162,175**
2038	62,860	1,848	58,184	2,332	1,137	42,441	4,315	2,239	175,357	7,804	247,734	2,975	258,513	**-83,156**
2039	53,211	1,357	46,753	4,318	1,137	42,983	3,836	2,212	155,806	4,686	250,636	3,001	258,324	**-102,518**
Average	**132,099**	**5,411**	**37,119**	**5,627**	**1,137**	**39,608**	**17,820**	**2,997**	**241,818**	**6,180**	**236,100**	**2,929**	**245,209**	**-3,391**

Note:
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Groundwater Budgets for Scenario C - 2001 to 2039 (Units in acre-ft)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
	INFLOW									**OUTFLOW**				
Water Years	**Recharge from Gaged Streamflow**	**Artificial Recharge at SAR Spreading Grounds**	**Artificial Recharge at Other Spreading Grounds**	**Recharge from Local Runoff Generated by Precipitation**	**Infiltration from Direct Precipitation**	**Return Flow from Groundwater Pumping**	**Recharge from Ungaged Mountain Front Runoff**	**Underflow Recharge**	**Total Inflow**	**Evapo-transpiration**	**Groundwater Pumping**	**Underflow Discharge**	**Total Outflow**	**CHANGE IN GROUNDWATER STORAGE**
2001	81,836	5,842	6,503	3,611	1,137	34,130	10,291	3,780	147,129	2,635	213,518	3,689	219,842	**-72,712**
2002	45,760	0	4,536	5,948	1,137	36,623	5,348	3,726	103,078	2,152	225,085	3,357	230,594	**-127,516**
2003	42,607	0	4,866	3,388	1,137	37,684	5,467	3,690	98,838	1,785	222,853	3,017	227,655	**-128,816**
2004	114,182	24	5,791	7,446	1,137	36,471	12,653	3,654	181,358	1,852	216,864	2,807	221,523	**-40,165**
2005	130,615	17,769	8,539	5,060	1,137	32,278	20,139	3,609	219,145	2,702	197,153	2,711	202,566	**16,579**
2006	142,855	27,137	31,326	5,876	1,137	33,907	18,871	3,563	264,672	7,667	204,899	2,640	215,207	**49,465**
2007	79,327	5,540	13,226	2,572	1,137	36,375	9,173	3,534	150,883	4,785	216,787	2,549	224,121	**-73,238**
2008	381,307	58,149	518	10,958	1,137	31,674	66,749	3,482	553,973	9,306	198,342	2,730	210,378	**343,596**
2009	76,630	12,176	27,931	4,988	1,137	34,540	11,583	3,453	172,438	7,487	214,906	2,903	225,296	**-52,858**
2010	61,075	4,262	35,088	4,616	1,137	36,963	9,605	3,415	156,161	5,329	226,573	2,825	234,727	**-78,565**
2011	54,907	3,172	14,748	2,349	1,137	38,774	7,170	3,364	125,621	3,253	234,696	2,680	240,629	**-115,008**
2012	107,333	24,490	43,580	4,975	1,137	35,616	17,518	3,328	237,976	4,934	219,996	2,584	227,513	**10,462**
2013	92,197	5,978	44,259	5,163	1,137	38,651	11,448	3,292	202,125	4,842	230,784	2,523	238,149	**-36,024**
2014	72,590	4,605	51,033	4,091	1,137	39,751	9,605	3,238	186,050	4,758	233,210	2,470	240,437	**-54,387**
2015	73,419	3,923	34,688	5,167	1,137	40,533	9,480	3,211	171,558	3,665	236,425	2,410	242,500	**-70,942**
2016	60,833	0	6,756	5,114	1,137	41,319	7,170	3,166	125,495	2,043	240,322	2,333	244,698	**-119,204**
2017	393,197	77,260	13,834	10,573	1,137	40,390	33,981	3,121	573,492	6,849	237,796	2,370	247,014	**326,478**
2018	179,336	62,537	8,354	5,643	1,137	37,868	31,634	3,078	329,586	9,183	227,634	2,494	239,311	**90,276**
2019	312,260	63,571	2,669	9,110	1,137	38,517	67,712	3,049	498,025	13,058	234,466	2,780	250,304	**247,721**
2020	89,630	6,819	39,254	3,947	1,137	40,188	10,291	2,995	194,261	8,978	246,224	3,017	258,220	**-63,959**
2021	132,103	14,903	40,582	7,859	1,137	39,702	18,943	2,959	258,188	7,043	244,834	3,129	255,006	**3,182**
2022	311,578	31,259	14,890	11,788	1,137	39,130	50,284	2,923	462,989	13,008	243,221	3,492	259,721	**203,268**
2023	102,256	10,694	51,904	3,062	1,137	39,240	11,986	2,871	223,150	10,063	243,525	3,962	257,550	**-34,400**
2024	77,779	2,662	47,655	3,738	1,137	40,811	9,480	2,833	186,095	6,772	246,976	3,986	257,733	**-71,639**
2025	108,650	12,381	30,796	5,324	1,137	38,038	13,304	2,805	212,435	5,534	230,405	3,904	239,843	**-27,408**
2026	62,865	0	27,895	4,469	1,137	42,029	7,495	2,745	148,634	4,400	248,401	3,669	256,470	**-107,836**
2027	59,387	0	11,556	4,177	1,137	41,314	6,474	2,716	126,761	2,690	241,607	3,381	247,679	**-120,918**
2028	46,637	0	30,905	2,479	1,137	42,915	5,467	2,671	132,211	3,083	247,276	3,091	253,450	**-121,240**
2029	36,253	0	33,517	2,808	1,137	45,449	3,977	2,627	125,769	2,803	259,296	2,834	264,934	**-139,165**
2030	75,607	1,319	20,238	6,118	1,137	41,871	8,175	2,590	157,055	2,128	241,824	2,655	246,607	**-89,552**
2031	110,527	8,295	148	6,894	1,137	40,728	12,181	2,553	182,464	1,295	236,746	2,524	240,566	**-58,102**
2032	383,471	68,884	36,687	9,016	1,137	40,153	52,483	2,501	594,332	7,890	237,771	2,520	248,182	**346,150**
2033	86,017	5,682	41,637	4,755	1,137	40,430	11,042	2,467	193,166	6,154	239,609	2,633	248,397	**-55,231**
2034	253,836	34,591	54,454	7,419	1,137	40,151	38,408	2,417	432,413	11,403	239,646	2,662	253,711	**178,702**
2035	109,102	10,611	48,928	6,414	1,137	41,736	14,265	2,372	234,565	8,101	247,854	2,758	258,713	**-24,148**
2036	93,698	11,049	42,954	5,952	1,137	41,798	11,042	2,329	209,959	5,745	248,256	2,787	256,788	**-46,830**
2037	256,261	53,078	34,154	9,945	1,137	40,230	35,918	2,300	433,022	11,171	239,280	2,903	253,353	**179,669**
2038	62,895	2,277	52,060	2,332	1,137	42,463	4,315	2,239	169,718	7,546	249,417	3,047	260,010	**-90,293**
2039	52,945	0	43,963	4,318	1,137	42,108	3,836	2,212	150,517	4,590	248,090	3,006	255,687	**-105,169**
Average	**128,558**	**16,691**	**27,242**	**5,627**	**1,137**	**39,040**	**17,820**	**2,997**	**239,112**	**5,864**	**233,655**	**2,919**	**242,438**	**-3,326**

Note:
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Groundwater Budgets for Scenario D - 2001 to 2039 (Units in acre-ft)

Water Years	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
	INFLOW									OUTFLOW				
	Recharge from Gaged Streamflow	Artificial Recharge at SAR Spreading Grounds	Artificial Recharge at Other Spreading Grounds	Recharge from Local Runoff Generated by Precipitation	Infiltration from Direct Precipitation	Return Flow from Groundwater Pumping	Recharge from Ungaged Mountain Front Runoff	Underflow Recharge	Total Inflow	Evapo-transpiration	Groundwater Pumping	Underflow Discharge	Total Outflow	CHANGE IN GROUNDWATER STORAGE
2001	81,836	5,842	6,302	3,611	1,137	34,130	10,291	3,780	146,929	2,625	213,518	3,688	219,831	**-72,903**
2002	45,760	0	4,653	5,948	1,137	36,623	5,348	3,726	103,194	2,157	225,085	3,357	230,600	**-127,405**
2003	42,607	0	4,981	3,388	1,137	37,684	5,467	3,690	98,953	1,790	222,853	3,018	227,661	**-128,708**
2004	114,182	24	6,495	7,446	1,137	36,471	12,653	3,654	182,061	1,887	216,864	2,809	221,560	**-39,499**
2005	130,615	17,769	8,056	5,060	1,137	32,278	20,139	3,609	218,663	2,678	197,153	2,713	202,544	**16,119**
2006	142,860	27,137	32,122	5,876	1,137	33,907	18,871	3,563	265,472	7,711	204,899	2,644	215,254	**50,218**
2007	79,327	5,540	3,663	2,572	1,137	36,375	9,173	3,534	141,320	4,308	216,787	2,551	223,645	**-82,325**
2008	379,807	60,926	954	10,958	1,137	31,677	66,749	3,482	555,690	9,323	198,646	2,732	210,701	**344,989**
2009	76,630	12,176	26,831	4,988	1,137	34,544	11,583	3,453	171,341	7,425	215,175	2,907	225,508	**-54,166**
2010	61,075	4,262	17,570	4,616	1,137	36,953	9,605	3,415	138,633	4,435	225,762	2,833	233,030	**-94,397**
2011	54,907	3,172	36,913	2,349	1,137	38,764	7,170	3,364	147,776	4,359	233,886	2,694	240,940	**-93,164**
2012	107,356	24,490	39,679	4,975	1,137	35,605	17,518	3,328	234,087	4,736	219,185	2,603	226,525	**7,562**
2013	92,174	5,978	47,504	5,163	1,137	38,637	11,448	3,292	205,333	5,001	229,669	2,542	237,212	**-31,879**
2014	72,590	4,605	47,178	4,091	1,137	39,738	9,605	3,238	182,181	4,567	232,129	2,488	239,184	**-57,003**
2015	73,419	3,923	33,320	5,167	1,137	40,533	9,480	3,211	170,190	3,599	236,424	2,421	242,443	**-72,254**
2016	60,833	0	3,970	5,114	1,137	41,319	7,170	3,166	122,708	1,904	240,319	2,339	244,562	**-121,854**
2017	393,989	77,260	22,849	10,573	1,137	40,390	33,981	3,121	583,299	7,283	237,787	2,376	247,446	**335,853**
2018	179,334	62,537	16,048	5,643	1,137	37,868	31,634	3,078	337,278	9,574	227,619	2,507	239,700	**97,577**
2019	304,995	69,422	11,512	9,110	1,137	38,531	67,712	3,049	505,467	13,558	235,519	2,810	251,887	**253,580**
2020	89,632	6,819	29,960	3,947	1,137	40,175	10,291	2,995	184,956	8,587	245,185	3,059	256,831	**-71,875**
2021	131,642	14,903	31,254	7,859	1,137	39,685	18,943	2,959	248,381	6,675	243,474	3,128	253,277	**-4,895**
2022	308,107	31,259	20,316	11,788	1,137	39,117	50,284	2,923	464,931	13,617	242,215	3,444	259,276	**205,655**
2023	102,244	10,694	49,480	3,062	1,137	39,225	11,986	2,871	220,699	10,158	242,314	3,887	256,358	**-35,659**
2024	77,797	2,662	47,723	3,738	1,137	40,783	9,480	2,833	186,152	6,991	244,709	3,929	255,629	**-69,477**
2025	108,643	12,381	36,132	5,324	1,137	38,036	13,304	2,805	217,762	6,012	230,230	3,850	240,092	**-22,330**
2026	62,865	0	32,511	4,469	1,137	42,031	7,495	2,745	153,252	4,667	248,563	3,635	256,865	**-103,613**
2027	59,157	0	11,430	4,177	1,137	41,312	6,474	2,716	126,403	2,684	241,408	3,380	247,472	**-121,069**
2028	46,637	0	26,632	2,479	1,137	42,915	5,467	2,671	127,938	2,870	247,289	3,097	253,256	**-125,318**
2029	36,256	0	10,542	2,808	1,137	45,449	3,977	2,627	102,796	1,654	259,297	2,818	263,769	**-160,973**
2030	75,607	1,319	8,107	6,118	1,137	41,871	8,175	2,590	144,924	1,521	241,825	2,618	245,964	**-101,040**
2031	110,757	8,295	7,047	6,894	1,137	40,728	12,181	2,553	189,592	1,638	236,746	2,488	240,872	**-51,280**
2032	383,237	68,884	46,613	9,016	1,137	40,157	52,483	2,501	604,027	8,375	238,091	2,486	248,953	**355,074**
2033	86,019	5,682	31,946	4,755	1,137	40,432	11,042	2,467	183,478	5,663	239,730	2,583	247,976	**-64,498**
2034	253,935	37,077	65,458	7,419	1,137	40,155	38,408	2,417	446,007	12,226	239,999	2,603	254,828	**191,179**
2035	109,061	10,611	48,660	6,414	1,137	41,737	14,265	2,372	234,258	8,298	247,984	2,700	258,982	**-24,724**
2036	93,678	11,049	50,237	5,952	1,137	41,799	11,042	2,329	217,223	6,153	248,374	2,727	257,254	**-40,032**
2037	256,254	53,078	28,117	9,945	1,137	40,228	35,918	2,300	426,976	10,954	239,137	2,841	252,932	**174,044**
2038	62,879	2,277	54,552	2,332	1,137	42,463	4,315	2,239	172,195	7,810	249,476	2,979	260,265	**-88,071**
2039	53,175	0	45,937	4,318	1,137	42,108	3,836	2,212	152,721	4,758	248,086	2,951	255,795	**-103,074**
Average	**128,253**	**16,976**	**27,006**	**5,627**	**1,137**	**39,037**	**17,820**	**2,997**	**238,853**	**5,903**	**233,420**	**2,904**	**242,227**	**-3,374**

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Annual Artificial Recharge at Cactus, Garden Air Creek and Wilson Spreading Grounds for Model Scenarios (Years 2001 to 2039)
(Units in acre-ft)

Water Years	No Project Condition			Scenario A			Scenario B			Scenario C			Scenario D		
	Cactus	Wilson	Garden Air Creek	Cactus	Wilson	Garden Air Creek	Cactus	Wilson	Garden Air Creek	Cactus	Wilson	Garden Air Creek	Cactus	Wilson	Garden Air Creek
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	4,235	726	1,936	4,235	726	1,936	167	0	0	0	0	0
2006	0	0	0	2,152	369	984	2,431	369	984	4,235	726	1,233	4,132	369	984
2007	0	0	0	2,083	357	952	2,083	357	709	0	0	0	0	0	0
2008	0	0	0	18,953	2,154	5,745	18,953	2,154	5,745	13,217	2,154	5,745	13,217	2,154	5,745
2009	0	0	0	0	0	0	0	0	0	12,705	1,083	2,888	12,705	1,083	2,888
2010	0	0	0	0	0	0	0	0	0	2,083	357	952	0	0	0
2011	0	0	0	4,235	726	1,936	4,235	726	1,936	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	4,235	726	1,936	4,235	726	1,936	0	0	0	0	0	0
2014	0	0	0	4,235	726	1,936	4,235	726	1,936	0	0	0	0	0	0
2015	0	0	0	6,318	726	1,936	2,083	357	952	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	6,179	1,059	2,016	5,936	1,059	2,139	0	0	0	0	0	0
2018	0	0	0	5,215	726	1,936	5,827	726	1,936	0	0	0	0	0	0
2019	0	0	0	10,483	1,797	4,793	13,800	1,797	4,793	10,414	1,785	4,761	10,414	1,785	4,761
2020	0	0	0	4,235	726	1,936	4,235	726	1,936	12,705	1,083	2,888	4,235	726	1,936
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	9,402	1,428	3,809	10,414	1,428	3,809	8,470	1,452	3,872	8,470	1,452	3,872
2023	0	0	0	4,235	726	1,936	4,235	726	1,376	2,083	357	952	2,083	357	952
2024	0	0	0	8,401	1,083	2,888	4,235	726	1,936	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2026	0	0	0	4,235	726	1,721	0	0	0	0	0	0	0	0	0
2027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2028	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2031	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2032	0	0	0	7,838	1,428	2,609	8,331	1,428	2,609	10,414	1,785	3,640	9,383	1,428	2,425
2033	0	0	0	6,318	1,083	2,442	2,520	357	183	0	0	0	0	0	0
2034	0	0	0	3,846	702	1,311	6,474	1,059	1,462	4,235	726	1,426	3,112	369	422
2035	0	0	0	2,083	357	952	0	0	0	0	0	0	0	0	0
2036	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2037	0	0	0	2,152	0	0	1,902	0	0	235	0	0	235	0	0
2038	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2039	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	**0**	**0**	**0**	**3,104**	**471**	**1,172**	**2,831**	**415**	**5,257**	**2,076**	**295**	**727**	**1,743**	**249**	**615**

Source: SAIC Allocation Model, 2004