

## Executive Summary

# State of the Salinas River Groundwater Basin Report

An examination of the state of the Salinas River Groundwater Basin (Basin) was conducted in the last half of 2014 as part of the larger Basin Investigation. This Executive Summary of the State of the Basin Report addresses the ramifications of prolonged drought by considering likely changes in groundwater head elevations, groundwater storage, and seawater intrusion in the event that the current drought continues. In addition, some steps are presented that could be taken to help alleviate the consequences of further depleting groundwater storage.

This study was conducted for Monterey County under County Professional Agreement 14-714, dated 1 July 2014, in response to the Monterey County Board of Supervisors Referral No. 2014.01. The work was carried out with oversight provided by the Monterey County Water Resources Agency (MCWRA).

## Study Area

The study area for this report is MCWRA Benefit Zone 2C (Zone 2C), which largely straddles the Salinas River within Monterey County (Figure ES-1). Zone 2C consists of 7 subareas named as follows: Above Dam, Below Dam, Upper Valley, Arroyo Seco, Forebay, East Side, and Pressure. The analyses detailed in this report cover the four primary water-producing subareas, the Pressure, East Side, Forebay (including the Arroyo Seco), and Upper Valley Subareas. These four subareas include most of the land area and account for nearly all of the groundwater usage within Zone 2C.

The Salinas River Groundwater Basin is the largest coastal groundwater basin in Central California. It lies within the southern Coast Ranges between the San Joaquin Valley and the Pacific Ocean, and is drained by the Salinas River. The valley extends approximately 150 miles from the La Panza Range north-northwest to its mouth at Monterey Bay, draining approximately 5,000 square miles in Monterey and San Luis Obispo Counties. The valley is bounded on the west by the Santa Lucia Range and Sierra de Salinas, and on the east by the Gabilan and Diablo Ranges. The Monterey Bay acts as the northwestern boundary of the Basin.

The Salinas Valley has a Mediterranean climate. Summers are generally mild, and winters are cool. Precipitation is almost entirely rain, with approximately 90% falling during the six-month period from November to April. Rainfall is highest on the Santa Lucia Range (ranging from 30 to 60 inches per year) and lowest on the valley floor (about 14 inches per year). Very dry years are common and droughts can extend over several years, such as the eight-year drought of Water Years (WY) 1984 to 1991.

Major land uses in the Salinas Valley include agriculture, rangeland, forest, and urban development. Mixed forest and chaparral shrub cover the mountain upland areas surrounding the valley, while the rolling hills are covered with coastal scrub and rangeland. Agricultural and urban land uses are predominant on the valley floor.

Historically, irrigated agriculture began with surface water diversions in 1773 on Mission Creek, and diversions from the Salinas River were first recorded in 1797. Groundwater pumping began as early as 1890, and expanded greatly through about 1920 as enabled by several developments such as widespread electrical lines, the development of better well pumps, and the replacement of grain crops with vegetable crops. Groundwater is currently the source of nearly all agricultural and

municipal water demands in the Salinas Valley, and agricultural use represents approximately 90% of all water used in the Basin. In addition to groundwater, other sources of water for agricultural production include surface water diverted from the Arroyo Seco, recycled municipal waste water supplied by the Monterey County Water Recycling Projects, and surface water diverted from the Salinas River north of Marina as part of the Salinas Valley Water Project).

By 1944, groundwater pumping in the entire valley was estimated to total about 350,000 acre-feet per year (afy), with about 30% of the pumping occurring within the Pressure Subarea, 10% in the East Side Subarea, 35% in the Forebay Subarea, and 25% in the Upper Valley Subarea.

Groundwater use in the Salinas Valley peaked in the early 1970's and then started declining, due primarily to changes in crop patterns, continued improvements in irrigation efficiency, and some conversion of agricultural lands to urban land uses.

Seawater intrusion was detected in coastal wells as early as the 1930's, resulting from declining groundwater head elevations in the Pressure and East Side Subareas. Seawater intrusion has continued so that it now reaches as far as 8 miles inland within the Pressure Subarea. The declining head and intruding seawater helped lead to the construction of the Nacimiento and San Antonio Dams (releases beginning in 1957 and 1965, respectively), which are used for flood control, maintenance of groundwater head elevations, multi-year storage, and recreation.

Today, as urbanization increases in the valley, alternative sources of urban water supplies and relocation of groundwater pumping are being evaluated and implemented by the Marina Coast Water District and various communities in the northern Salinas Valley.

## Hydrogeology

The Salinas Valley Groundwater Basin is a structural basin (i.e., formed by tectonic processes) consisting of up to 10,000 to 15,000 feet of terrigenous and marine sediments overlying a basement of crystalline bedrock. The sediments are a combination of gravels, sands, silts, and clays that are organized into sequences of relatively coarse-grained and fine-grained materials. When layers within these sequences are spatially extensive and continuous, they form aquifers, which are relatively coarse-grained and are able to transmit significant quantities of groundwater to wells, and aquitards, which are relatively fine-grained and act to slow the movement of groundwater. Figure ES-2 is a schematic cross-section across the Pressure Subarea showing its general hydrostratigraphy.

Groundwater flow in the Basin is generally down the valley, from the southern end of the Upper Valley Subarea toward Monterey Bay, up to about Chualar (Figure ES-3). North of Chualar, groundwater flows in a north to east direction toward a trough of depressed groundwater head on the northeastern side of Salinas. This trough is especially pronounced in August, the approximate time of the seasonal peak groundwater pumping.

## Water Balance

A water balance is a quantitative accounting of the various components of flow entering and leaving a groundwater system. Typical outflows include evapotranspiration, surface runoff that leaves the system, groundwater pumping, and groundwater outflow to a neighboring groundwater system. Typical inflows include recharge from infiltration of precipitation, releases from reservoirs (which receive runoff from precipitation), recharge from leaky aquitards, and groundwater inflow. The difference between inflows and outflows represents the change in groundwater storage. Because precipitation constitutes the major input of water to the Basin, rainfall records from the Salinas Municipal Airport gauge from 1873 to the present were analyzed. Based on the mean precipitation



of 13.4 inches and standard deviation of 4.8 inches, each year’s precipitation total was assigned to one of seven, “wetness levels,” as follows: Extremely Dry, Very Dry, Dry, Normal, Wet, Very Wet, or Extremely Wet. In general, dry years are more common than wet years, but Extremely Dry years are less common than Extremely Wet years. The drought period from WY 1984 to 1991 included three Very Dry years, four Dry years, and one Normal year; this period was used in this study as a comparative period for predicting future changes in groundwater head and storage. Based on provisional data, the WY 2014 precipitation of about 5.9 inches represents a Very Dry year and the third-driest water year on record. The current drought of WY 2012 to 2014 includes two Dry years and one Very Dry year; over this three-year period, the total rainfall was about 15 inches below the period of record average.

This study emphasizes the importance of cumulative precipitation surplus, which quantifies precipitation on timescales longer than a year to examine the impacts of multi-year dry and wet periods. The cumulative precipitation surplus reached a high of about 41 inches at the end of WY 1958, and declined to zero by the end of WY 2013. During the extended drought from WY 1984 to 1991, the cumulative precipitation surplus declined by about 36 inches, an average of about 4.5 inches per year. The major declines in cumulative precipitation surplus had and continue to have negative effects on groundwater storage in Basin aquifers (see Storage Change discussion below). Figure ES-4 shows a time series of annual and cumulative precipitation surplus.

## Inflows

Out of an estimated total of about 504,000 afy of inflow to the Basin, about 50% occurs as stream recharge, 44% occurs as deep percolation from agricultural return flows and precipitation, and 6% occurs as subsurface inflow from adjacent groundwater basins (MW, 1998). Table ES-1 summarizes the inflow components of the water budget, as reported by MW (1998).

**Table ES-1 Water Budget Components by Subarea**

Subarea	Representative of 1994 Conditions (from MW, 1998)				2013 Groundwater Pumping (reported by MCWRA) <sup>3</sup>
	Inflow		Outflow		
	Natural Recharge <sup>1</sup>	Subsurface Inflow	Groundwater Pumping <sup>2</sup>	Subsurface Outflow	
Pressure	117,000	17,000	130,000	8,000	118,000
East Side	41,000	17,000	86,000	0	98,000
Forebay	154,000	31,000	160,000	20,000	148,000
Upper Valley	165,000	7,000	153,000	17,000	145,000

Note: All estimates in acre-feet per year (afy).

Note 1: Includes agricultural return flow, stream recharge, and precipitation.

Note 2: Groundwater pumping as reported by MW(1998) are presented to provide a complete water budget.

Note 3: The 2013 groundwater pumping totals are provided for comparison.

Within the Pressure Subarea, inflow is largely made up of subsurface inflow from the Forebay Subarea; prior to development, additional subsurface inflow occurred from the East Side Subarea, but this flow had been reversed by declining groundwater head elevations in the East Side Subarea. An additional inflow to the Pressure Subarea is seawater intrusion, which could account for between about 11,000 and 18,000 afy.

Inflow to the East Side Subarea is made up of a combination of infiltration along the small streams on the west side of the Gabilan Range, direct recharge of precipitation on the valley floor, and subsurface inflow from the Pressure and Forebay Subareas.

Inflow to the Forebay Subarea is made up of infiltration along Arroyo Seco, Reliz Creek, and the Salinas River as well as agricultural return flow, direct recharge of precipitation on the valley floor, subsurface inflow from the Upper Valley Subarea, and mountain front recharge along the eastern and western Subarea boundaries.

Inflow to the Upper Valley Subarea is made up of infiltration along the Salinas River and its tributaries, with lesser amounts entering the subarea via direct recharge of precipitation on the valley floor and agricultural return flow, plus minor quantities entering via subsurface inflow from the Panch Rico Formation to the east and along drainages tributary to the Salinas River.

## Outflows

Groundwater pumping is, by far, the largest component of outflow from the Basin. Of an estimated total of 555,000 afy of outflow, about 90% is groundwater pumping, with the remainder occurring as evapotranspiration along riparian corridors (Ferriz, 2001). Table ES-1 summarizes the outflow components of the water budget, as reported by MW (1998).

In general, groundwater pumping in the study area increased over the first 14 years of the available period of record (1949 to 2013), from about 380,000 afy in 1949 to about 620,000 afy in 1962, the highest pumping year on record. Pumping began to decline after about 1972, when pumping was about 530,000 afy, and fell to about 430,000 afy by 1982 before averaging about 500,000 afy over the rest of the period of record. Reported pumping for 2013 totaled about 509,000, acre-feet (af).

While annual pumping totals were relatively steady in the Pressure and East Side Subareas after about 1962, pumping in the Forebay and Upper Valley Subareas continued to increase until the early 1970's, then decreased slightly through the mid-1980's. On average, from 1949 to 2013, about 25% of basinwide pumping occurred in the Pressure Subarea, 17% in the East Side Subarea, 30% in the Forebay Subarea, and 28% in the Upper Valley Subarea.

Within the Pressure Subarea, outflow occurs as a combination of groundwater pumping and subsurface outflow to the East Side Subarea. In the East Side Subarea, outflow is made up entirely of groundwater pumping, since the reversal of the groundwater head gradient curtailed the natural subsurface outflow to the Pressure Subarea. In the Forebay Subarea, outflow is dominated by groundwater pumping, with a small amount of subsurface outflow to the Pressure and East Side Subareas. Outflow from the Upper Valley Subarea is largely made up of groundwater pumping, with a small amount of subsurface outflow to the Forebay Subarea.

## Groundwater Storage

Estimated Basin groundwater storage is summarized in Table ES-2. The total stored volume of groundwater in the Basin is about 16.4 million af, and the aquifer storage capacity is approximately 19.8 million af (DWR, 2003); this suggests that there is an unfilled storage capacity of about 3.3 million af.

## Storage Change

The estimation of groundwater storage changes in the Basin is more important than determining absolute storage because storage changes are measures of aquifer response to the natural hydrologic cycle (e.g. precipitation) and human-induced effects (e.g. pumping). The analysis of storage change was accomplished by considering subarea-averaged annual groundwater head elevation changes reported by MCWRA from 1944 to 2013. The accuracy of this analysis relies directly on the accuracy of the estimates of head change and of the values of storage coefficient and

land area used. For this analysis, the storage coefficients reported by DWR (2003) were used<sup>1</sup>. Figure ES-5 shows a time series of calculated storage change for the Basin, color-coded by subarea. When compared with Figure ES-4, it is clear that there is a strong correlation between the pattern of the cumulative precipitation surplus and that of storage change. The storage change analysis included a statistical comparison between subarea storage change and annual precipitation surplus, reservoir releases, streamflow (at the Salinas River gauge near Bradley), and groundwater pumping. In all four subareas, annual storage change was correlated most strongly to annual precipitation surplus. The results of the storage change analysis are summarized in Table ES-3.

**Table ES-2 Groundwater Storage**

Subarea	Storage Coefficient (ft <sup>3</sup> /ft <sup>3</sup> ) <sup>1</sup>	Land Area (acres) <sup>2</sup>	Storage Capacity (acre-feet) <sup>1</sup>	Groundwater in Storage (acre-feet) <sup>1</sup>	Available Storage (acre-feet)
Pressure	0.036	126,000	7,240,000	6,860,000	380,000
East Side	0.08	75,000	3,690,000	2,560,000	1,130,000
Forebay	0.12	87,000	5,720,000	4,530,000	1,190,000
Upper Valley	0.10	92,000	3,100,000	2,460,000	640,000
Total	--	380,000	19,750,000	16,410,000	3,340,000

Note 1: From DWR (2003).

Note 2: From the Salinas Valley Integrated Ground and Surface Water Model (SVIGSM).

**Table ES-3 Calculated Storage<sup>1</sup> Change by Subarea, 1944 to 2013**

Subarea	Minimum Annual (af)	Maximum Annual (af)	Annual Average (afy)	Minimum Cumulative (af)	2013 Cumulative (af)	Predicted Change If Drought Continues (afy)
Pressure	-35,000	+44,000	-2,000	-144,000 (1991)	-110,000	-10,000 to -20,000
East Side	-58,000	+83,000	-5,000	-398,000 (1991)	-333,000	-25,000 to -35,000
Forebay <sup>1</sup>	-93,000	+98,000	-2,000	-192,000 (1991)	-105,000	-10,000 to -15,000
Forebay <sup>2</sup>	-93,000	+98,000	-2,000	-192,000 (1991)	-105,000	-80,000 to -90,000
Upper Valley <sup>1</sup>	-70,000	+65,000	-200	-88,000 (1990)	-12,000	-5,000 to -15,000
Upper Valley <sup>2</sup>	-70,000	+65,000	-200	-88,000 (1990)	-12,000	-50,000 to -70,000
Zone 2C <sup>1</sup>	-256,000	+217,000	-8,000	-786,000 (1990)	-559,000	-50,000 to -85,000
Zone 2C <sup>2</sup>	-256,000	+217,000	-8,000	-786,000 (1990)	-559,000	-165,000 to -215,000

Note: af = acre-feet; afy = acre-feet per year

Note 1: Based on calculated storage changes over the extended drought of WY 1984 to 1991

Note 2: Based on calculated storage changes for years with very low reservoir release (WYs 1961 and 1990)

<sup>1</sup> The storage calculation presented in this Executive Summary is based on the storage coefficients published in DWR (2003). In the main body of the Report, the storage calculation is based on the DWR (2003) data and an additional and smaller storage coefficient that could be representative of the confined portions of the Pressure Subarea aquifer system.

### **Pressure Subarea**

Using the storage coefficient value of 0.036, as reported by DWR (2003), calculated storage change in the Pressure Subarea from 1944 to 2013 was about -110,000 af, averaging about -2,000 afy. Based on storage changes during the extended drought of WY 1984 to 1991, storage in the Pressure Subarea could be expected to decline by about 10,000 to 20,000 afy under continued dry conditions.

### **East Side Subarea**

Calculated storage change in the East Side Subarea from 1944 to 2013 was about -333,000 af, averaging about -5,000 afy. Based on storage changes during the extended drought of WY 1984 to 1991, storage in the East Side Subarea could be expected to decline by about 25,000 to 35,000 afy under continued dry conditions.

### **Forebay Subarea**

Calculated storage change in the Forebay Subarea from 1944 to 2013 was about -105,000 af, averaging about -2,000 afy. The pattern of storage change in the Forebay Subarea is quite dissimilar to that in the Pressure and East Side Subareas, being much closer to zero storage change over much of the period of record and appearing to be strongly affected by years of very low reservoir releases, which lead to very large storage declines in this Subarea. Based on storage changes during the extended drought of WY 1984 to 1991, storage in the Forebay Subarea could be expected to decline by about 10,000 to 15,000 afy under continued drought conditions. However, if reservoir releases are severely curtailed (as occurred in WYs 1961 and 1990), storage changes may be much greater in magnitude, on the order of 80,000 to 90,000 afy, or about 50 to 60% of annual pumping in the Forebay Subarea.

### **Upper Valley Subarea**

Calculated storage change in the Upper Valley Subarea from 1944 to 2013 was about -12,000 af, averaging about -200 afy. The pattern of storage change is similar to that of the Forebay Subarea, with a similar apparent reliance on reservoir releases. Based on storage changes during the extended drought of WY 1984 to 1991, storage in the Upper Valley Subarea could be expected to decline by about 5,000 to 15,000 afy under continued drought conditions. However, if reservoir releases are severely curtailed, storage losses may be much larger, on the order of about 50,000 to 70,000 afy, or about 30 to 50% of annual pumping in the Upper Valley Subarea.

### **Zone 2C**

Based on the numbers presented above, calculated storage change from 1944 to 2013 in all of Zone 2C was about -559,000 af, averaging about -8,000 afy. The pattern of storage change follows the pattern of the precipitation surplus, but is also affected by reservoir releases, which typically replenish approximately 35% of annual pumping as aquifer recharge. During years of exceptionally low reservoir releases, such as 1991, drought-related aquifer storage depletion is amplified.

Storage under continued dry conditions can be expected to decline by about 50,000 to 85,000 afy, comparable to past dry years. However, if reservoir releases are severely curtailed, as occurred in WYs 1961 and 1990, storage losses can be expected to be much larger, on the order of about 165,000 to 215,000 afy.

Over the period from 1959 to 2013 (the period for which groundwater pumping data are available and the reservoirs have been operating), the average annual pumping in Zone 2C was about 523,000 afy. During this same time period, the average annual storage change (calculated using



groundwater head changes) was about -6,000 afy. An additional loss of storage due to seawater intrusion has occurred, and has been estimated at between 11,000 and 18,000 afy. This suggests that, overall, Zone 2C is out of groundwater balance by about 17,000 to 24,000 afy. The total calculated storage change over this period (not including seawater intrusion) was about -349,000 af, about 50% more than the storage change experienced prior to the beginning of operations of the reservoirs (about -210,000 af from 1944 to 1958), indicating that the reservoirs have greatly slowed storage losses in the Basin. However, the existing storage deficit has continued to grow over the period of record, and must be remedied before the deleterious effects of storage declines, such as seawater intrusion and the drying of wells, can be reversed. In addition, the volume of storage lost due to seawater intrusion must be better quantified.

## State of the Basin - Water Supply in Zone 2C

The Basin is currently out of hydrologic balance by approximately 17,000 to 24,000 afy. However, the estimated volume of groundwater in reserve (i.e. storage) is about 6.8 million acre-feet in the aquifers of the Pressure Subarea (Table ES-2), and the total volume of groundwater stored in Zone 2C is about 16.4 million acre-feet.

The goal of the water supply analyses presented in this report was to provide a postulation of how groundwater supply may change in the future should the current drought conditions continue. This was accomplished by understanding how and why groundwater head elevations and groundwater storage have changed in the past. Independent hydrologic variables (precipitation, groundwater pumping, reservoir releases, and streamflow) were compared with the groundwater head and storage changes to provide insight (or correlations) into which of these factors is driving these changes. Lastly, this study then provides professional opinions on the consequences of using more groundwater than the estimated yield on both the short-term Basin conditions and long-term sustainability.

An analysis of historical groundwater head elevation at a selected set of 25 locations indicated that, overall, groundwater head changes are correlated most strongly to the annual precipitation surplus in the Pressure, East Side, and Forebay Subareas. Head changes in the Upper Valley Subarea are not well-correlated to any independent variable; whereas, the storage changes discussed above are statistically correlated to annual precipitation surplus.

Based on statistical correlations and comparison with the extended drought from WY 1984 to WY 1991, representative head changes at the Subarea scale are expected to range from:

- -5.3 to -1.1 feet per year in the Pressure Subarea (for all three aquifers),
- -9.6 to -3.0 feet per year in the East Side Subarea,
- -5.6 to -1.8 feet per year in the Forebay Subarea, and
- -2.0 to +0.2 feet per year<sup>2</sup> in the Upper Valley Subarea.

Storage changes are also strongly affected by the occurrence of very low reservoir releases, which have historically resulted in storage declines. The cumulative storage loss over the period from 1944 to 2013, not including storage volume lost to seawater intrusion, was about 559,000 af for all of Zone 2C. About 40% of the storage loss occurred in the 14 years before Nacimiento Reservoir

---

<sup>2</sup> Positive head changes in individual wells are reflective of increases in head that occurred in select wells during the WY 1984 to 1991 drought, and are not reflective of the average head change in the Upper Valley Subarea during the same period. It is considered unlikely that continued drought conditions will result in an overall increase in head in the Upper Valley Subarea, although individual wells may see head increases, depending on local conditions.

began releasing water, while about 60% occurred over the 55 years from 1959 to 2013. Estimates of storage decline in future dry years range from about 50,000 to 215,000 afy (Table ES-3), depending on the level of reservoir releases that occur. This storage loss, added to the existing storage deficit built up over the history of groundwater development in the study area, will exacerbate the problem of seawater intrusion in the Pressure Subarea.

## State of the Basin - Seawater Intrusion

The water quality analysis in this study was undertaken to determine the extent of seawater intrusion into the coastal aquifers in 2013 and to analyze how it is likely to evolve in the future, should the current dry conditions continue into the coming years. The extent of seawater intrusion into the Pressure 180-Foot and Pressure 400-Foot Aquifers (Figures ES-6 and ES-7, respectively) in 2013 was not different from the extents mapped in 2011, indicating that the first two years of current drought did not have an apparent effect on the movement of the seawater intrusion front.

In assessing other markers of seawater intrusion, the sodium to chloride (Na/Cl) ratios<sup>3</sup> indicate that numerous wells on the landward side of the seawater intrusion front have likely been affected by seawater intrusion, even though the chloride concentration has not increased to the 500 mg/L level used by MCWRA to delineate seawater intrusion. Wells screened in the Pressure 400-Foot Aquifer that are several miles landward of the mapped seawater intrusion extent may have been impacted by seawater intrusion in the past. The landward seawater mixing with deeper groundwater can possibly be attributed to the vertical movement of groundwater from the Pressure 180-Foot Aquifer into the lower Pressure 400-Foot zone. Possible mechanisms include: a) natural leakage through areas of thin or absent aquitard between the two aquifers, b) via wells screened across both aquifers, and c) along faulty or compromised well casings acting as conduits.

The accelerated rate of seawater intrusion in 1984 can be attributed to the seven-year drought that started in 1984, the extent of which is depicted in Figures ES-6 and ES-7. The apparent rate of seawater intrusion in the period peaked from 1997 to 1999, despite the fact that the groundwater head elevations began to recover before this time from the declines experienced during the WY 1984 to 1991 drought. If this latent response to an extended drought is repeated in the Basin, water quality impacts stemming from the current drought may not manifest for several years. Chloride concentrations in affected wells increased by up to 100 mg/L from the beginning of the extended drought to 1999, and similar concentration changes may be expected in wells near the seawater intrusion front over the coming years.

## Options to Address Water Supply under Continued Drought Conditions

Based on the analyses discussed above, the Basin is out of hydrologic balance. The average annual groundwater extraction for the four primary water-producing subareas that compose Zone 2C was about 523,000 afy from 1959 to 2013. The average annual change in storage was about -17,000 to -24,000 afy, including seawater intrusion. This implies that the yield for Zone 2C is on the order of about 501,000 to 508,000 afy; the deficit is essentially the storage change (loss) stated above. It is important to note that the Basin does have an estimated volume of groundwater in storage of about 16 million af (Table ES-2), which could represent a significant groundwater reserve – as compared to the current estimated storage loss of 17,000 to 24,000 afy – and could be used to offset temporary overdraft conditions in the future.

---

<sup>3</sup> Calculated from historical water quality data at selected monitoring wells



Based on the continued large storage declines in the East Side and Pressure Subareas (and resulting groundwater head declines and seawater intrusion), the current distribution of groundwater extractions is not sustainable. Seawater intrusion can account for up to 18,000 afy of the total storage loss of 24,000 afy. Sustainable use of groundwater can only be achieved by aggressive and cooperative water resources planning to mitigate seawater intrusion and groundwater head declines.

The consequences of no-action under continued drought conditions will be the imminent advancement of seawater intrusion within the next few years and the continued decline of groundwater head. Both of these conditions would necessitate the drilling of deeper groundwater wells to produce the quantity and quality of water needed for consumptive use and irrigation. The installation of deeper wells may not be feasible in some areas because of lower groundwater yield and water quality in the Pressure Deep Aquifer. A more sustainable and long term management practice would encourage a Basin-wide redistribution and reduction of groundwater pumping, which would require cooperative and aggressive resource management. The unsustainability of the current distribution of groundwater extractions has long been recognized by various investigators, and Basin-wide redistribution and reduction of pumping have been recommended previously (e.g. DWR, 1946).

### **Management Option 1**

The large storage declines that have occurred in the Basin in the past, especially in the East Side Subarea, have created a significant landward groundwater head gradient that must be reversed before seawater intrusion can be halted. Reduction of pumping in the Pressure and East Side Subareas could help mitigate some of the anticipated effects of extended drought on groundwater storage and water quality in the study area. Shifting of pumping to areas farther away from the coast would also be helpful, as long as it is shifted south of the current head trough (Figure ES-3) that exists in the East Side Subarea. While not currently consistent with County Policy, shifting pumping to areas that are both south of the seawater intrusion zone and hydraulically connected to the Salinas River does represent a physical option for addressing seawater intrusion.

DWR (1946) recommended that pumping be curtailed in the Pressure and East Side Subareas and substituted with extraction in the Forebay and Upper Valley Subareas, which are strongly connected to (and interact with) the Salinas River. Yates (1988) performed a numerical modeling analysis of the Basin, with a specific focus on the effect of pumping changes on seawater intrusion, and found that seawater intrusion could be cut by more than half (from about 18,000 to 8,000 afy) over a 20-year period by decreasing pumping in the Pressure and East Side Subareas by 30%<sup>4</sup>; whereas, reducing pumping in the Forebay and Upper Valley Subareas had minimal to no effect on seawater intrusion.

### **Management Option 2**

The shifting of some pumping from the Pressure 180-Foot and Pressure 400-Foot Aquifers to the Pressure Deep Aquifer would reduce the storage deficit in the shallower aquifers; however, this would necessarily lead to head declines in the Pressure Deep Aquifer. Unlike the Pressure 180-Foot and Pressure 400-Foot Aquifers, it is uncertain if the Pressure Deep Aquifer is hydraulically connected to the ocean in Monterey Bay, so it is not known whether this pumping shift would lead to the onset of seawater intrusion into the Pressure Deep Aquifer. Also unknown is the likelihood of localized interaquifer seawater mixing between the Pressure 400-Foot Aquifer and the Pressure

---

<sup>4</sup> Note that Yates (1988) assumed an agricultural pumping rate of 512,200 afy, based on the results of a land use survey performed in the Salinas Valley in 1976. Recent pumping rates are slightly lower (around 500,000 afy), in part due to the operation of the Monterey County Water Recycling Projects.



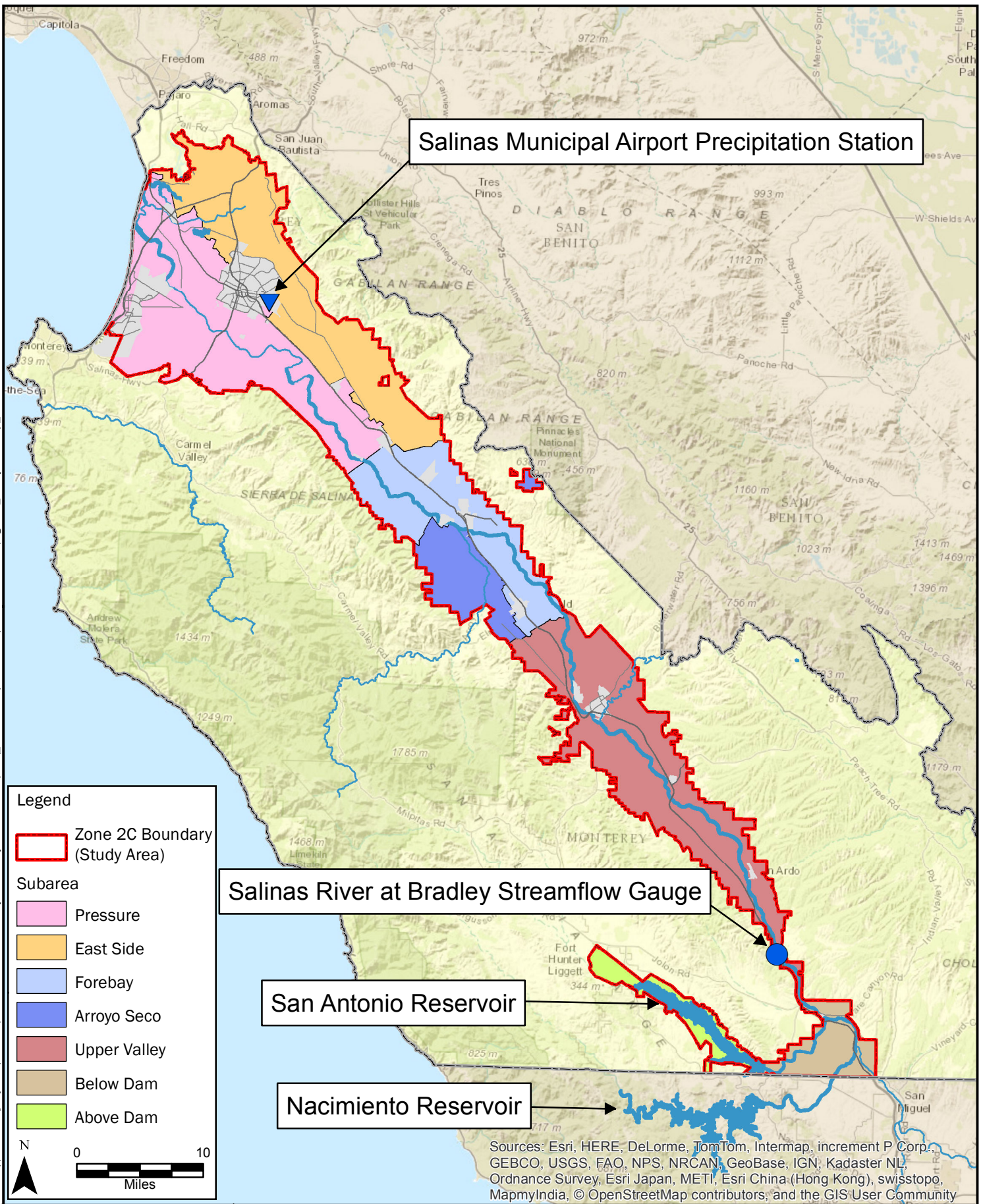
Deep Aquifer. Hence, this Management Option requires more investigation to determine its feasibility.

### **Evaluation of Potential Solutions**

The numerical modeling analysis to be performed as the second part of this Basin Investigation will consider the effects of various management decisions on the water supply and water quality in the study area. The primary questions to be answered for each scenario are 1) what will be the rate of groundwater head decline and 2) what will be the rate of increase in acreage with impaired water quality due to the advancement of the seawater intrusion front. We can then determine the economic effects of 1) and 2) due to water supply wells becoming inoperable (i.e. dry), and the further loss of aquifer storage capacity due to the advancement of seawater intrusion.

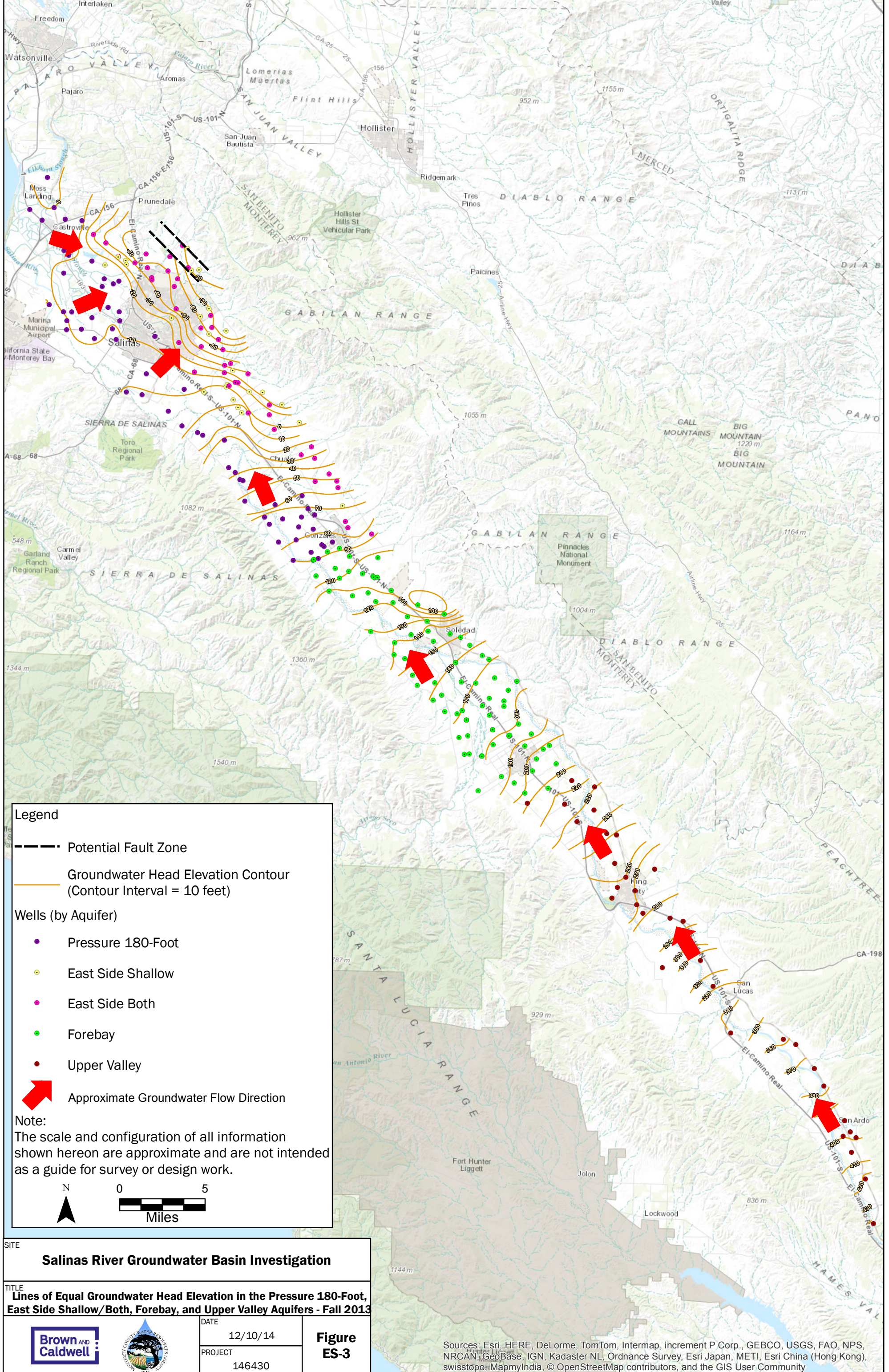
The numerical model should be used to predict groundwater head declines under different management scenarios, including implementing targeted pumping rates and optimizing the distribution of pumping. Future declines in groundwater head must be evaluated by simulated groundwater conditions so that “trigger (groundwater) head levels” can be used as a measure of safe yield and an early alert system as part of Basin Management Objectives. That analysis will extend the discussions and conclusions presented in this report.

Document Path: BCSACFP01\projects\46000\146430 - Salinas Valley GW Study - Simulation\GIS\_MAPDOCS\WORKING\StateoftheBasin\FigES-1\_StudyAreaMap\_20141203.mxd



DATE 12/03/14	PROJECT 146430	SITE <b>Salinas River Groundwater Basin Investigation</b>	<b>Figure ES-1</b>
		TITLE <b>Study Area Map</b>	





**Legend**

- Potential Fault Zone
- Groundwater Head Elevation Contour (Contour Interval = 10 feet)

**Wells (by Aquifer)**

- Pressure 180-Foot
- East Side Shallow
- East Side Both
- Forebay
- Upper Valley
- Approximate Groundwater Flow Direction

**Note:**  
The scale and configuration of all information shown hereon are approximate and are not intended as a guide for survey or design work.

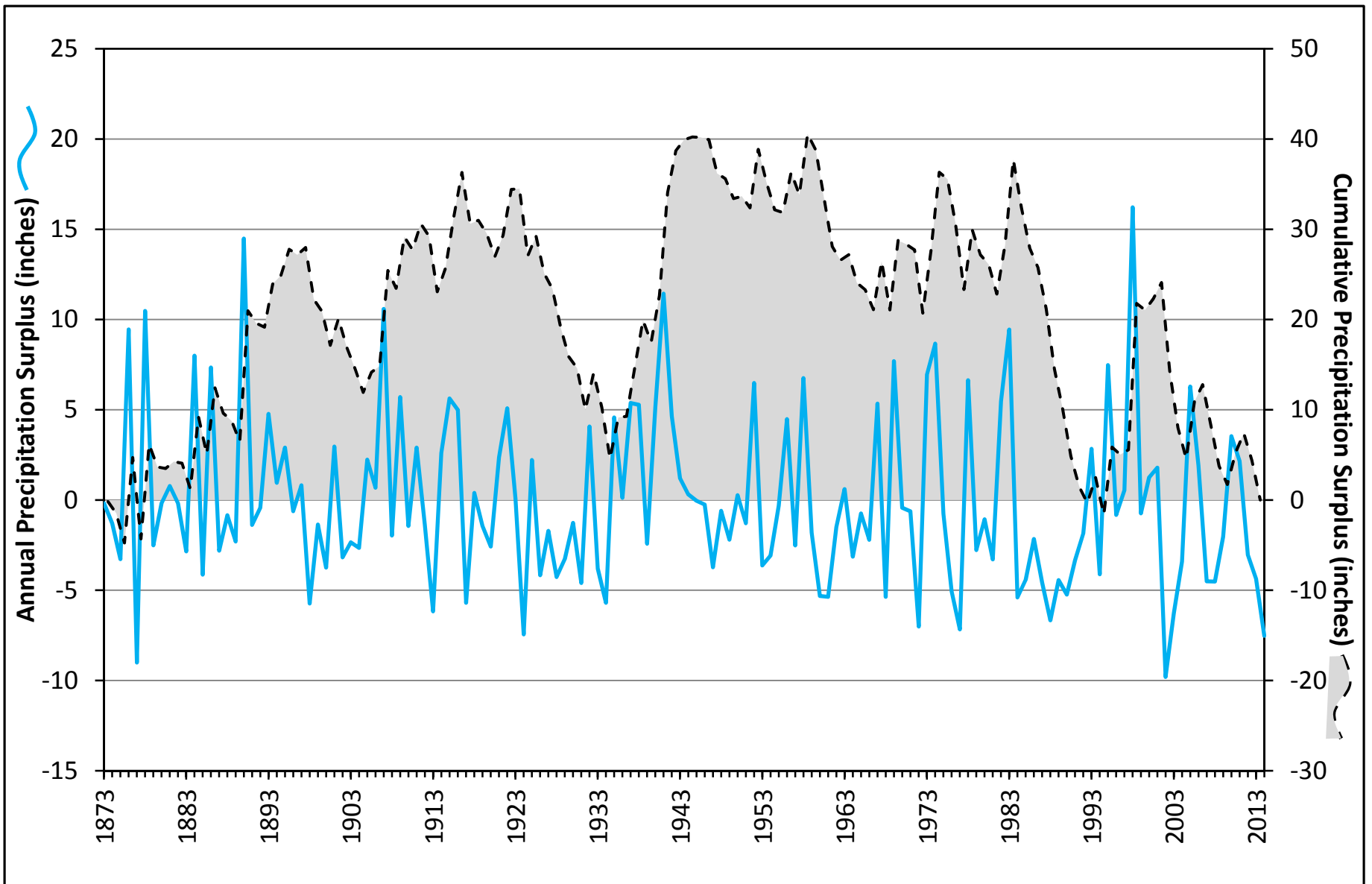
N  
0 5  
Miles

**SITE**  
**Salinas River Groundwater Basin Investigation**

**TITLE**  
**Lines of Equal Groundwater Head Elevation in the Pressure 180-Foot, East Side Shallow/Both, Forebay, and Upper Valley Aquifers - Fall 2013**

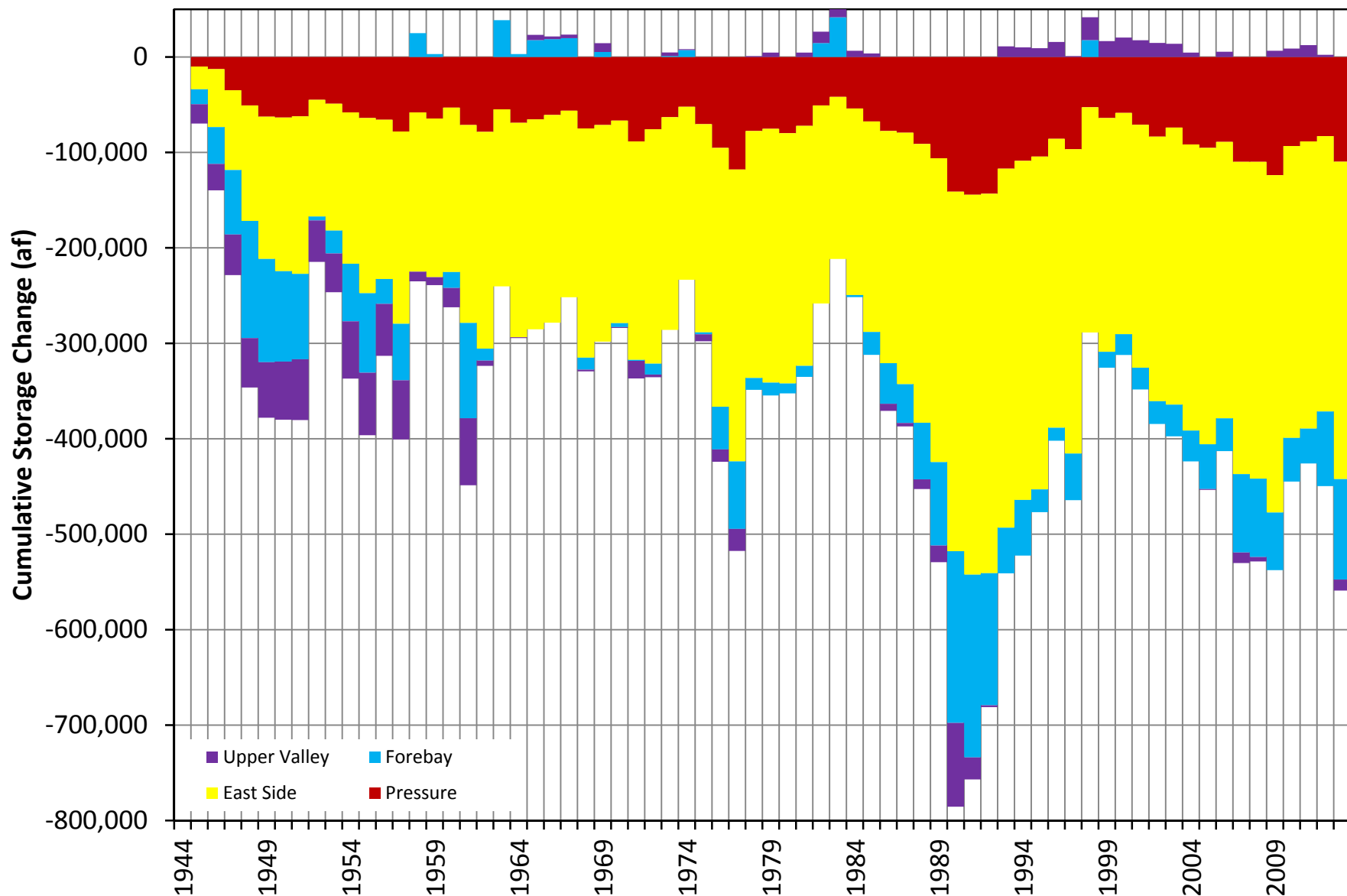
	DATE	12/10/14	<b>Figure ES-3</b>
	PROJECT	146430	

Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Note: The annual precipitation surplus represents the difference between the annual precipitation and the long-term mean.

	DATE	12/03/14	SITE	Salinas River Groundwater Basin Investigation	<b>Figure ES-4</b>
	PROJECT	146430	TITLE	Annual and Cumulative Precipitation Surplus at Salinas Municipal Airport	



DATE  
12/03/14  
PROJECT  
146430

SITE  
Salinas River Groundwater Basin Investigation  
TITLE  
Cumulative Storage Change by Subarea

Figure  
ES-5

