Santa Ana River Water Right Applications for Supplemental Water Supply

Testimony of Dr. Dennis E. Williams

California State Water Resource Control Board

May 2 - 4, 2007

Muni/Western Ex. 6-389

Testimony Summary

The Project Will Result In Significant Benefits Related To Groundwater In The SBBA Including:

- ♦ Development of up to 200,000 acre-ft that would otherwise flow out of the area without being put to beneficial use
- ♦ Additional water conservation will provide drought protection and less reliance on imported water

Testimony Summary

- Reduce liquefaction potential by keeping groundwater levels > 50 ft below the land surface
  - highly urbanized SBBA
  - area is particularly susceptible to liquefaction
  - adjacent to the San Andreas, San Jacinto and Cucamonga faults
  - new evidence indicates that there is a build-up of strain on the southern San Andreas fault that will ultimately result in a large earthquake on both the San Andreas and San Jacinto faults

Testimony Summary

- Assist in improving the water quality of the SBBA:
  - accelerate cleanup of the contaminant plumes
  - expected that Scenario A will clean up the Newmark and Muscoy PCE plumes three years faster than if there was no project
  - expected that Scenario A will clean up the Norton/Redlands-Crafton TCE plume five years faster than if there was no project

Testimony Summary

- The diverted water will have overall benefits with respect to TDS and nitrate concentrations:
  - for TDS, there would be beneficial impacts under the project scenarios in the Bunker Hill A management zone
  - less than significant TDS impacts expected in the Bunker Hill B and Lytle management zones
  - With respect to nitrate concentration, beneficial impacts would be anticipated for all management zones

Testimony Summary

- The findings of my work was based on using six model scenarios that were developed and tested with an integrated groundwater and streamflow model, as well as a solute transport model
  - The ground water flow model simulates groundwater levels, quantities, directions and rates of groundwater flow
  - The solute transport model simulates water quality concentrations (e.g. TDS, nitrate, perchlorate, PCE and TCE)

Testimony Summary

- The six model scenarios simulated the following conditions:
  - No Project
  - Maximum capture (1,500 cfs)
  - Minimum capture (500 cfs)
  - Most likely scenario (1,500 cfs, which takes into account the Seven Oaks Accord and the settlement agreement with the Conservation District)

Testimony Summary

- A subsidence model was developed to evaluate project impacts
- Analytical models were developed to examine impacts of artificial recharge (i.e. spreading) in areas outside of the SBBA

Overview of Groundwater Models

- ♦ Brief Review of Groundwater Modeling Tasks
- ♦ Results of Groundwater Model Runs
- ♦ Discussion of Subsidence Modeling
- ♦ Impacts of Spreading Outside the Model Area

Overview of Groundwater Models

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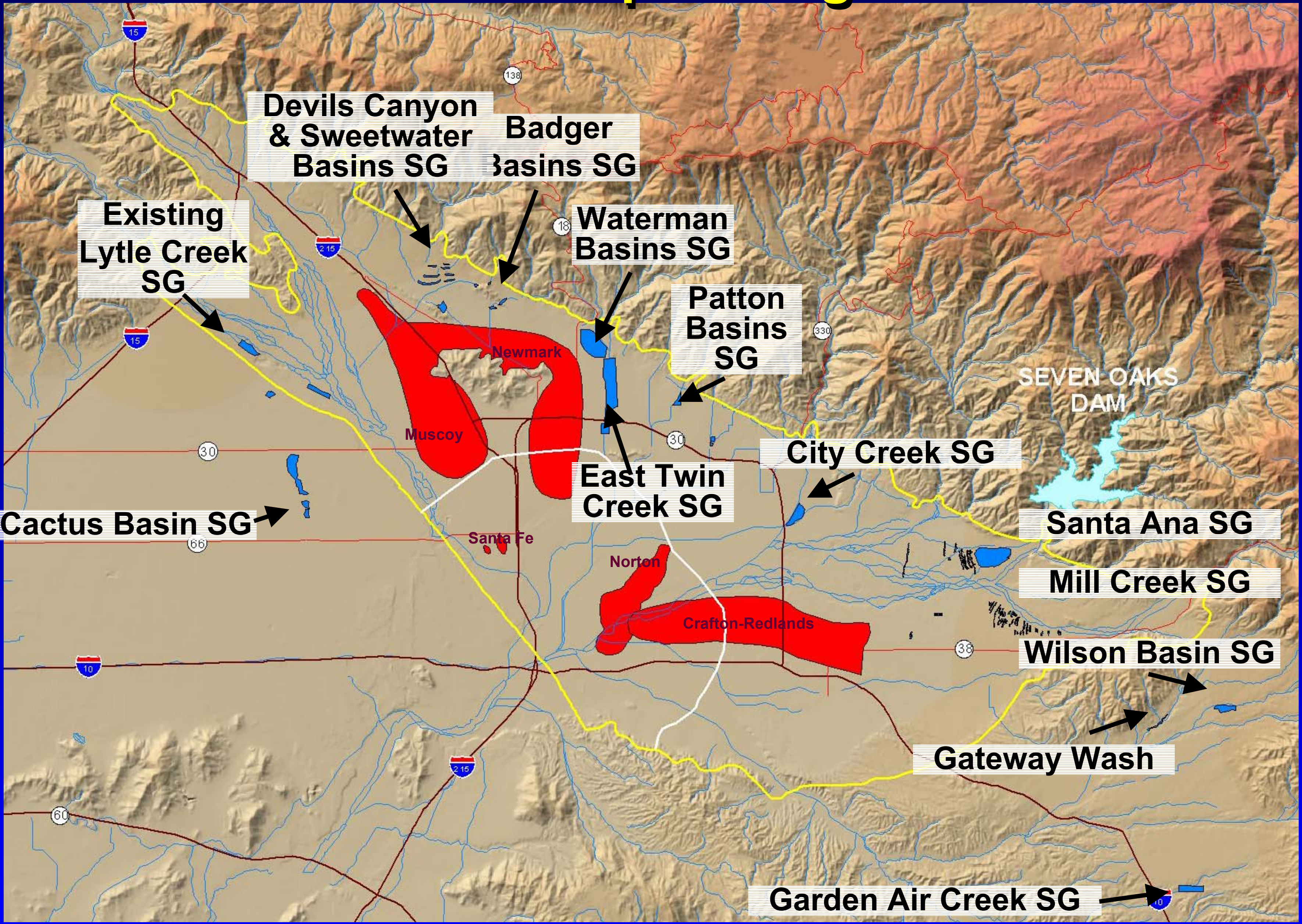
Brief Review of Groundwater Modeling Tasks

- Purpose:
  - To Evaluate Potential Impacts on Groundwater Levels and
  - Quality in the San Bernardino Basin Area Due to Various
  - Proposed Seven Oaks Reservoir Water Diversion Scenarios
- Types of Models:
  - MODFLOW - Flow
  - MODPATH - Particle Tracking
  - MT3DMS - Solute Transport
- Model Calibration and Verification
- Model Scenarios

Location of Spreading Basins



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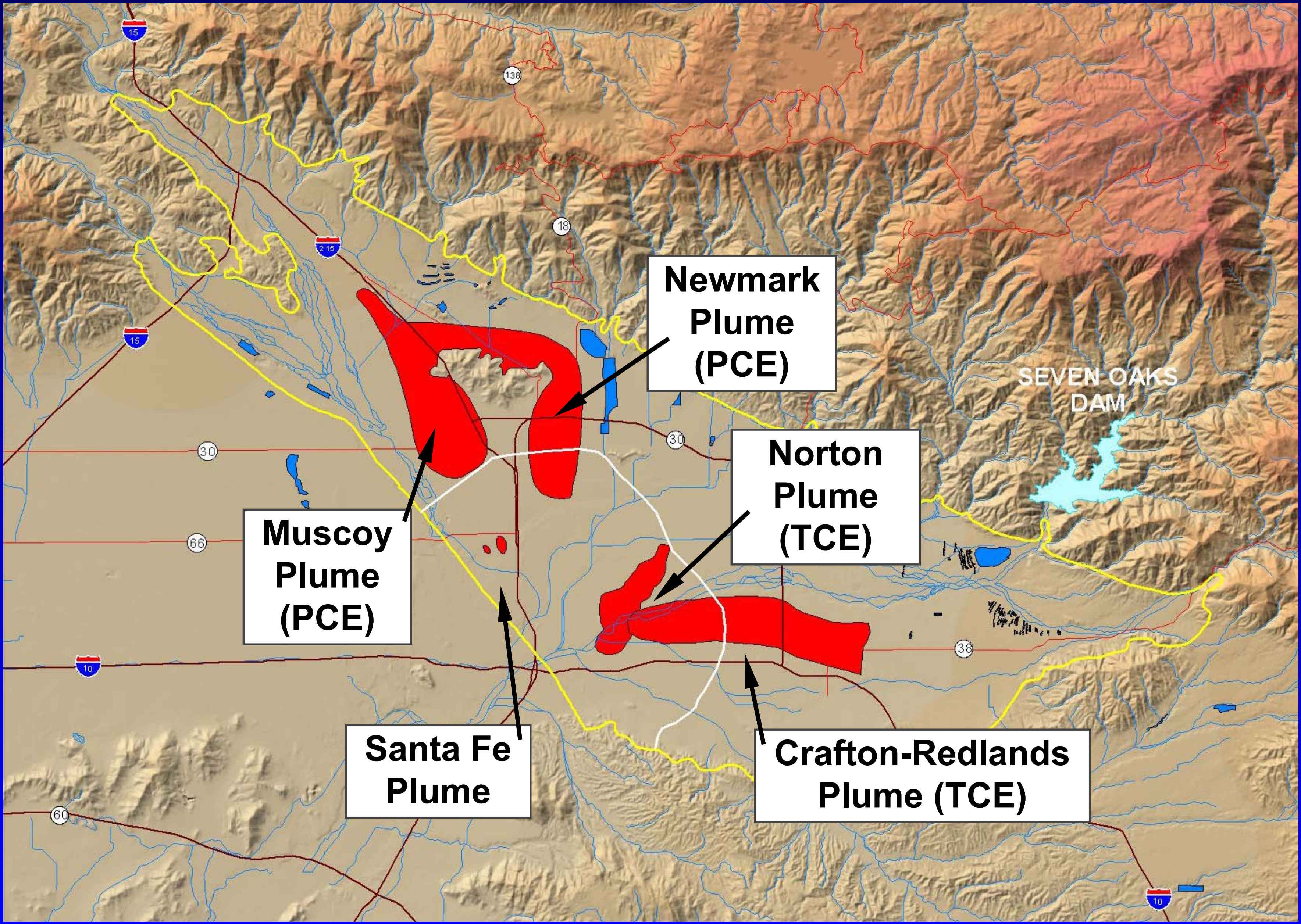
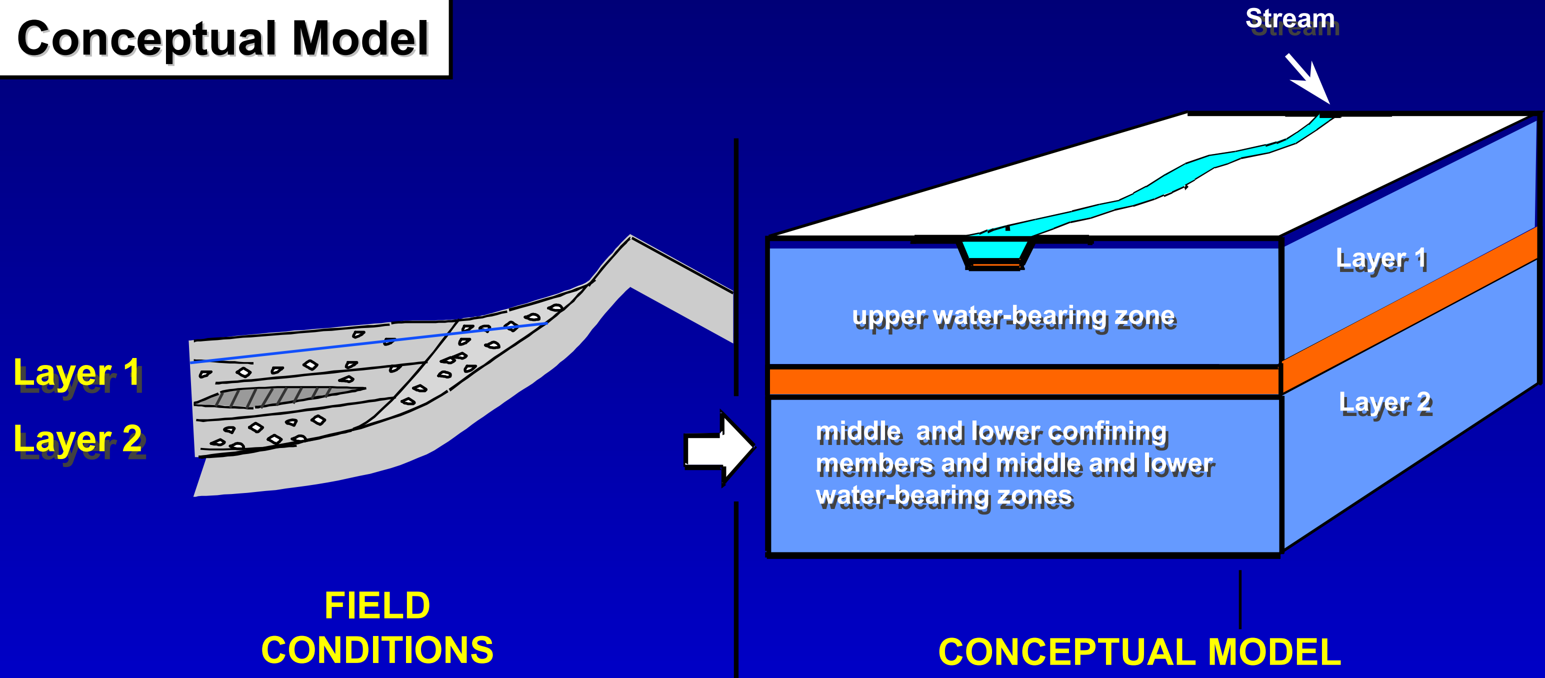
Contaminant Plumes in the Bunker Hill Basin



Description of the USGS Model

Conceptual Model

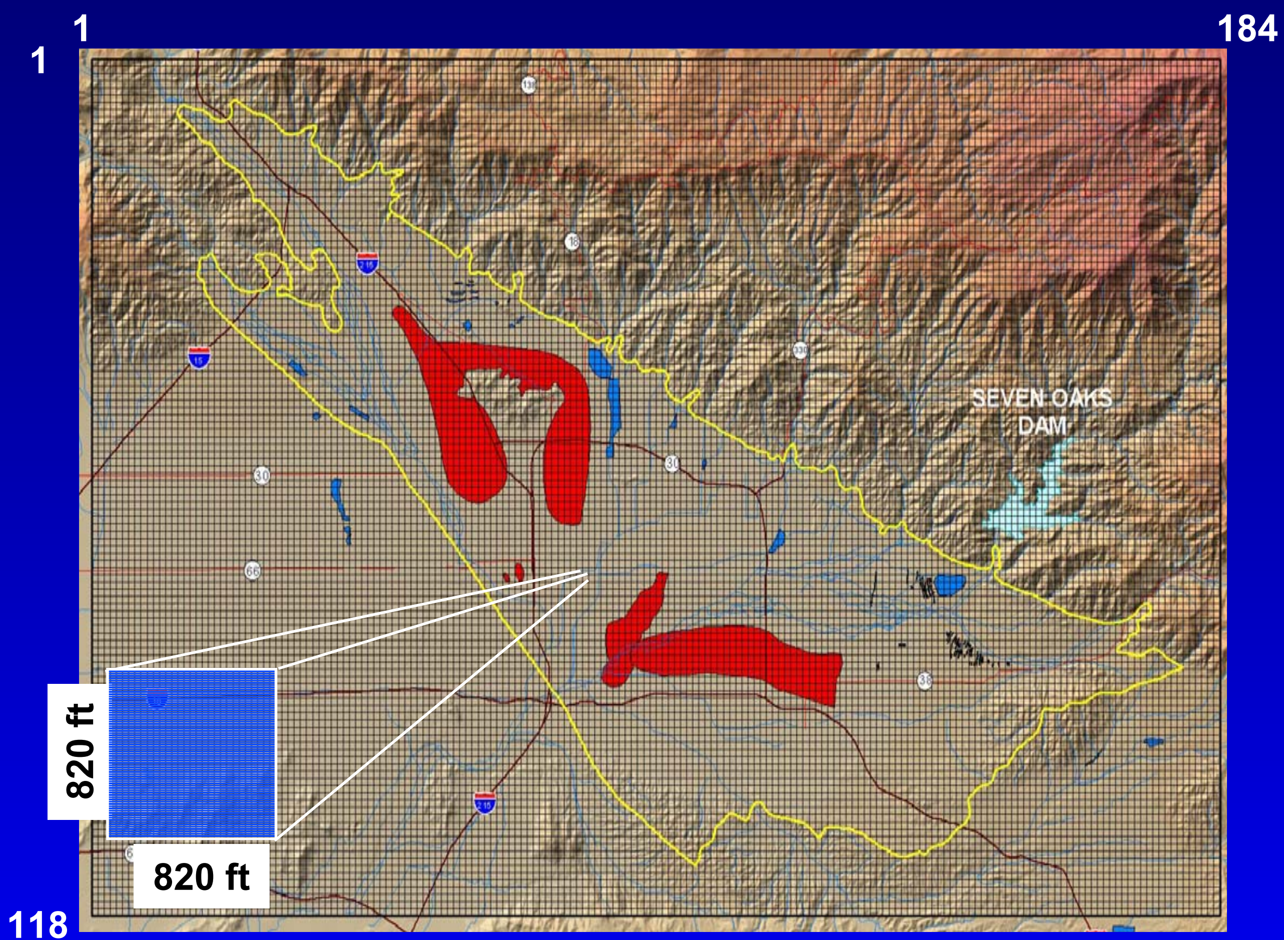


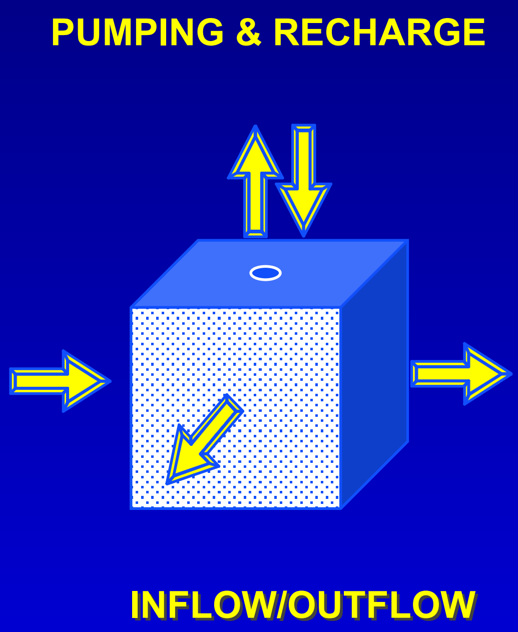
The groundwater flow model was developed for the valley-fill aquifer (1,500 ft deep) and includes both unconsolidated and partly consolidated deposits.

Consolidated rocks underlying and surrounding the valley-fill aquifer are assumed to be non-water bearing

Two Layered Groundwater Model

Model Area and Grid Layout





118 x 184 Cells/Layer
X 2 layers
(43,424 cells in total)

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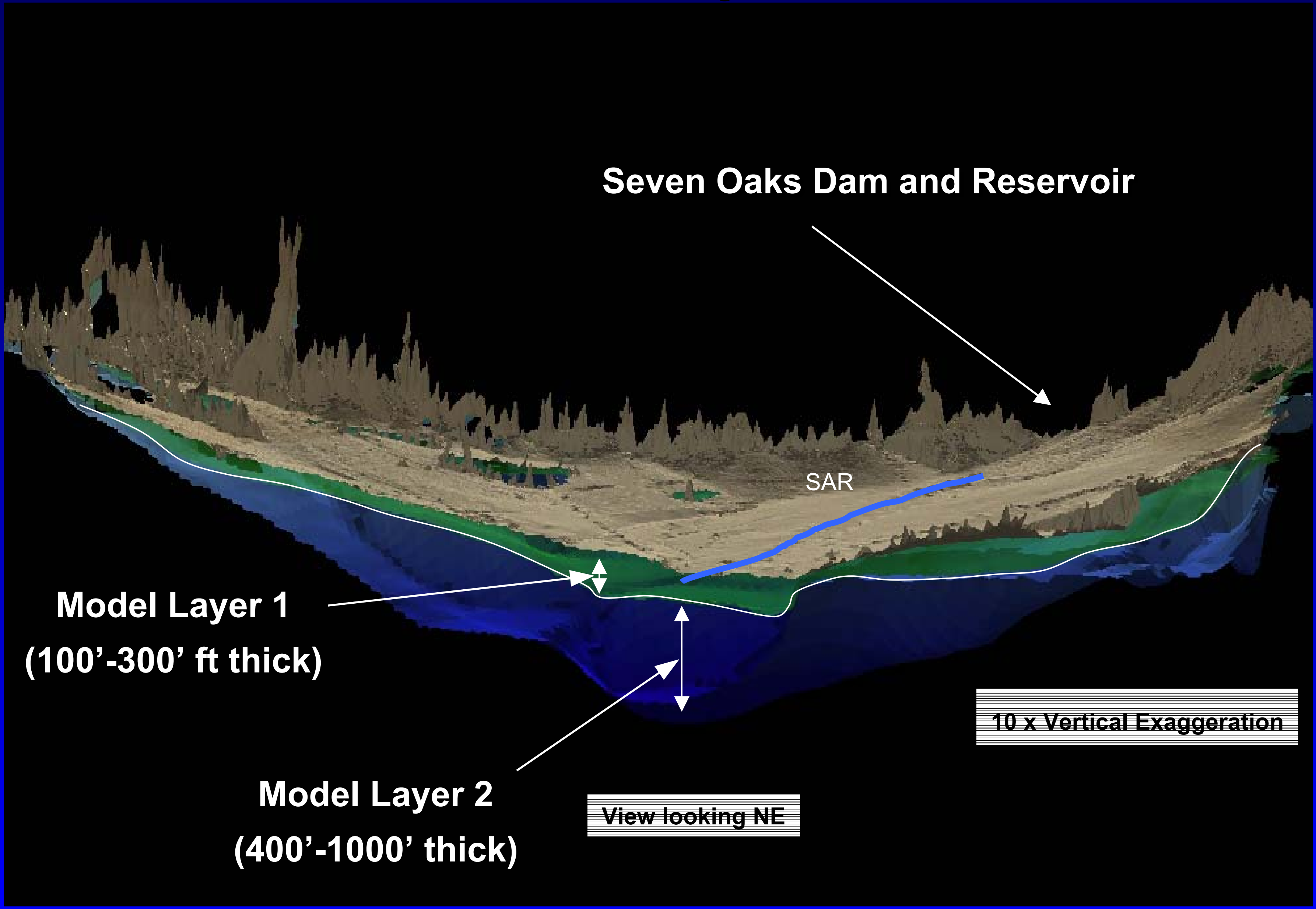
Model Layers



Update of USGS Model

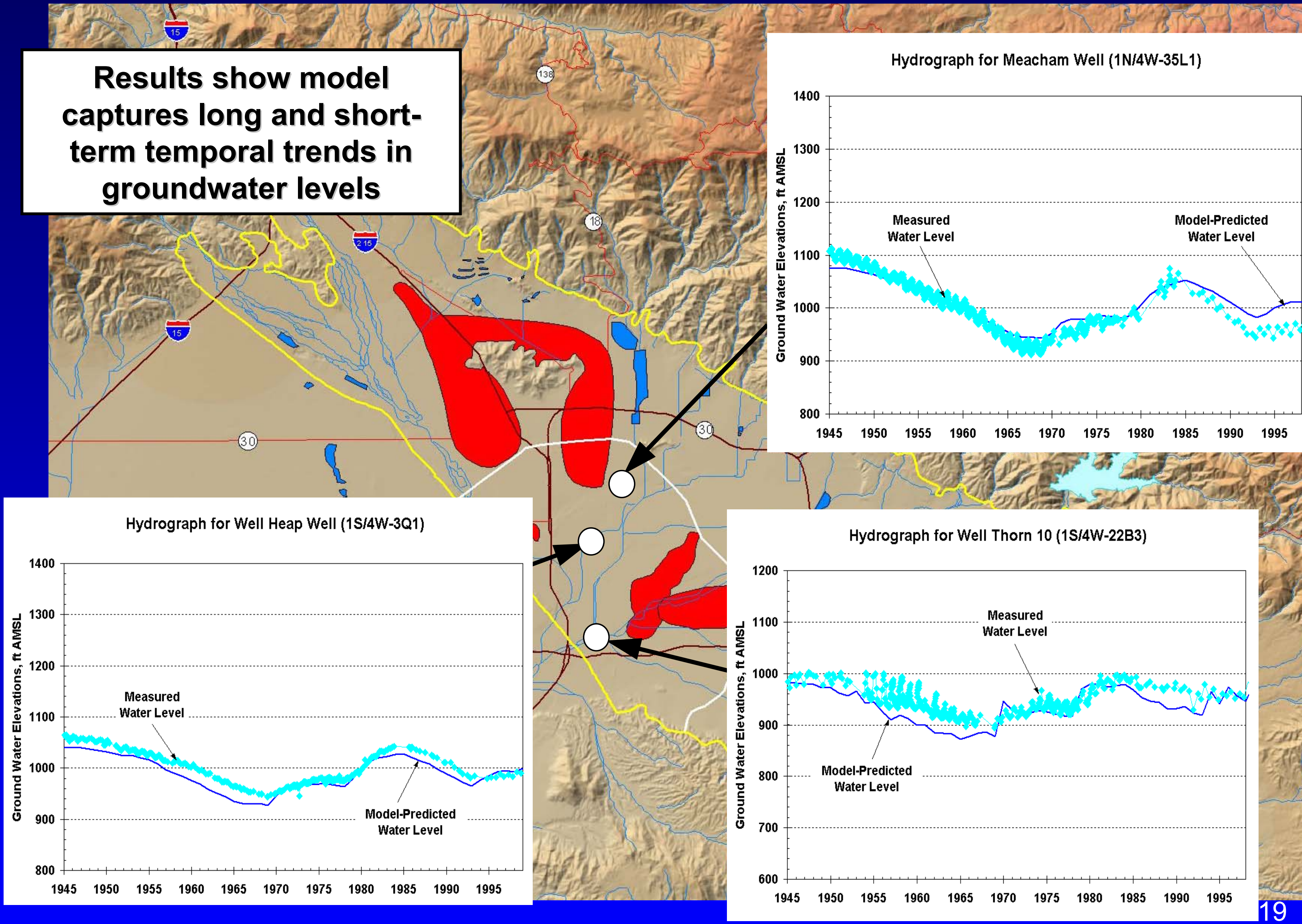
GROUNDWATER FLOW MODEL		
Item	***Original USGS Model***	***USGS Model (Updated)***
Model Package	MODFLOW	same
Areal Extent	All of the valley-fill within the Bunker Hill and Lytle Creek basins (approximately 524 sq. miles)	same
Size	21,712 cells per layer	same
Cell Size	820 ft x 820 ft (uniform)	same
Model Grid	118 (i-direction) and 184 (j-direction)	same
Number of Layers	2	same
Length of Stress Period	1 year	same
Number of Time Steps per Stress Period	100	same
Time Step Multiplier	1.2	same
Steady-State Calibration Year	1945	same
Transient Calibration Period	1945 - 1998	1945 - 2000
Relative Error[1]	4.92 percent	4.93 percent

Particle Tracking and Solute Transport Models

Item	*Original USGS Model*	*USGS Model (Updated)*
PARTICLE TRACKING MODEL		
Model Package	NA	MODPATH
Number of Scenarios	NA	5
Beginning Model Year	NA	2001
SOLUTE TRANSPORT MODEL		
Model Package	NA	MT3DMS
Calibration Period	NA	1986 – 2000 (for PCE and TCE)
Relative Error	NA	8% for PCE and 9% for TCE
Dispersivity - Longitudinal [ft]	NA	300
Dispersivity - Transverse [ft]	NA	100
Dispersivity - Vertical [ft]	NA	1
Bulk Density [g/cm^3]	NA	1.9
Sorption Distribution Coefficient [cm^3/g]	NA	0.0947 (PCE), 0.054 (TCE)
Chemical Constituents Modeled	NA	PCE, TCE, TDS, NO_3, and Perchlorate
Groundwater Plumes Modeled	NA	Muscoy, Newmark, Norton, and Redlands-Crafton

Model Calibration Hydrographs

Results show model captures long and short-term temporal trends in groundwater levels



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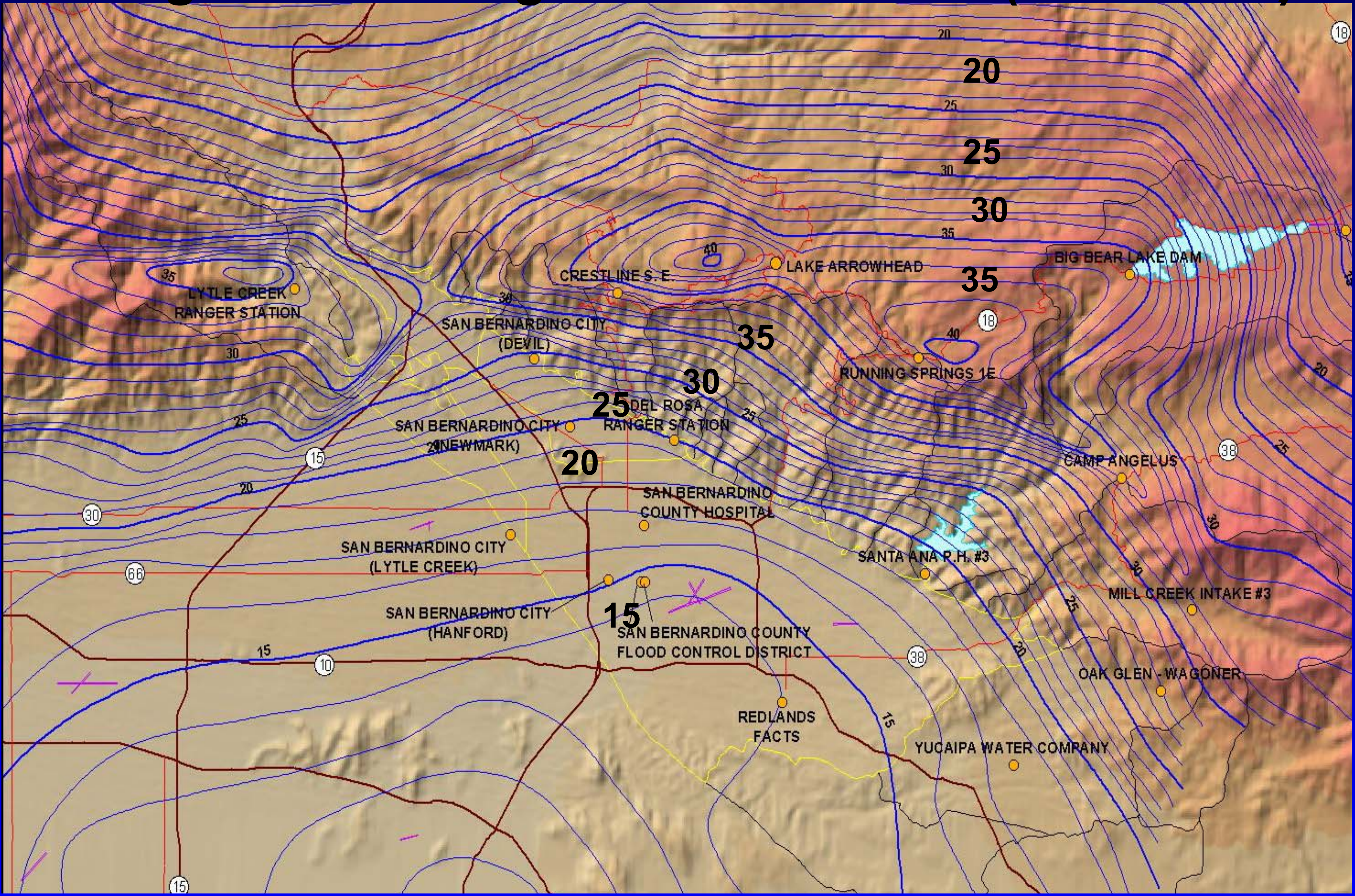
Statistical Measure of Calibration – Relative Error

- Relative Error (RE) = standard deviation of residuals (model water levels – observed) divided by the range of observed values
- An industry standard method commonly used to measure the degree of model calibration
- An acceptable RE is 10% or less
  - Flow Model RE = 5%
  - Solute Transport Models RE = 8%-9%
- Sources: Spitz and Moreno, 1996; Environmental Simulations, Inc., 1999

Hydrologic Base Period

- The Hydrologic "Base Period" was selected as the 39-year period from October 1961 through September 2000 (water years 1961/1962 – 1999/2000)
- The Hydrologic Base Period includes both wet and dry hydrologic cycles with an average hydrologic condition approximately the same as the long-term average

Long-Term Average Annual Rainfall (1870-1970)



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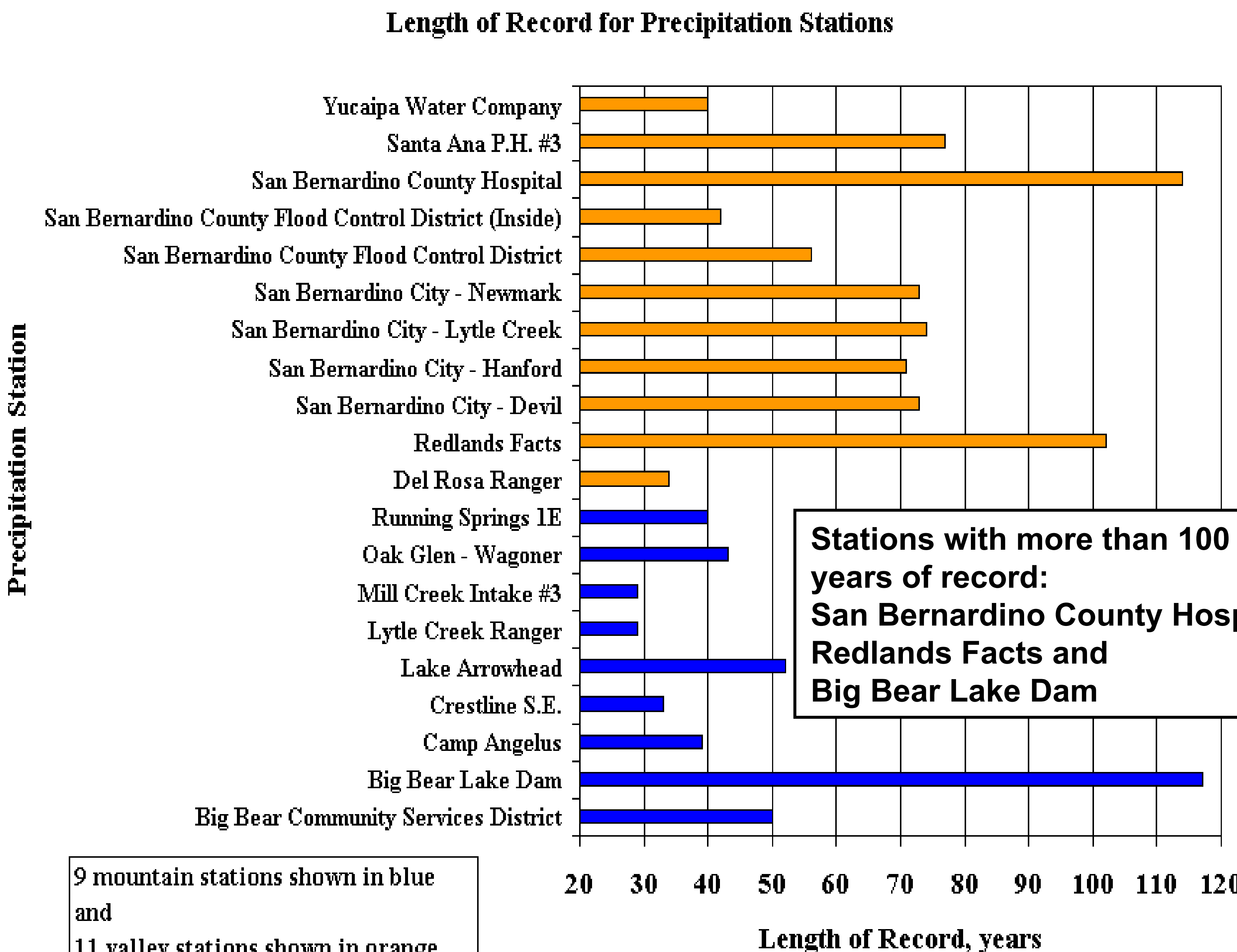
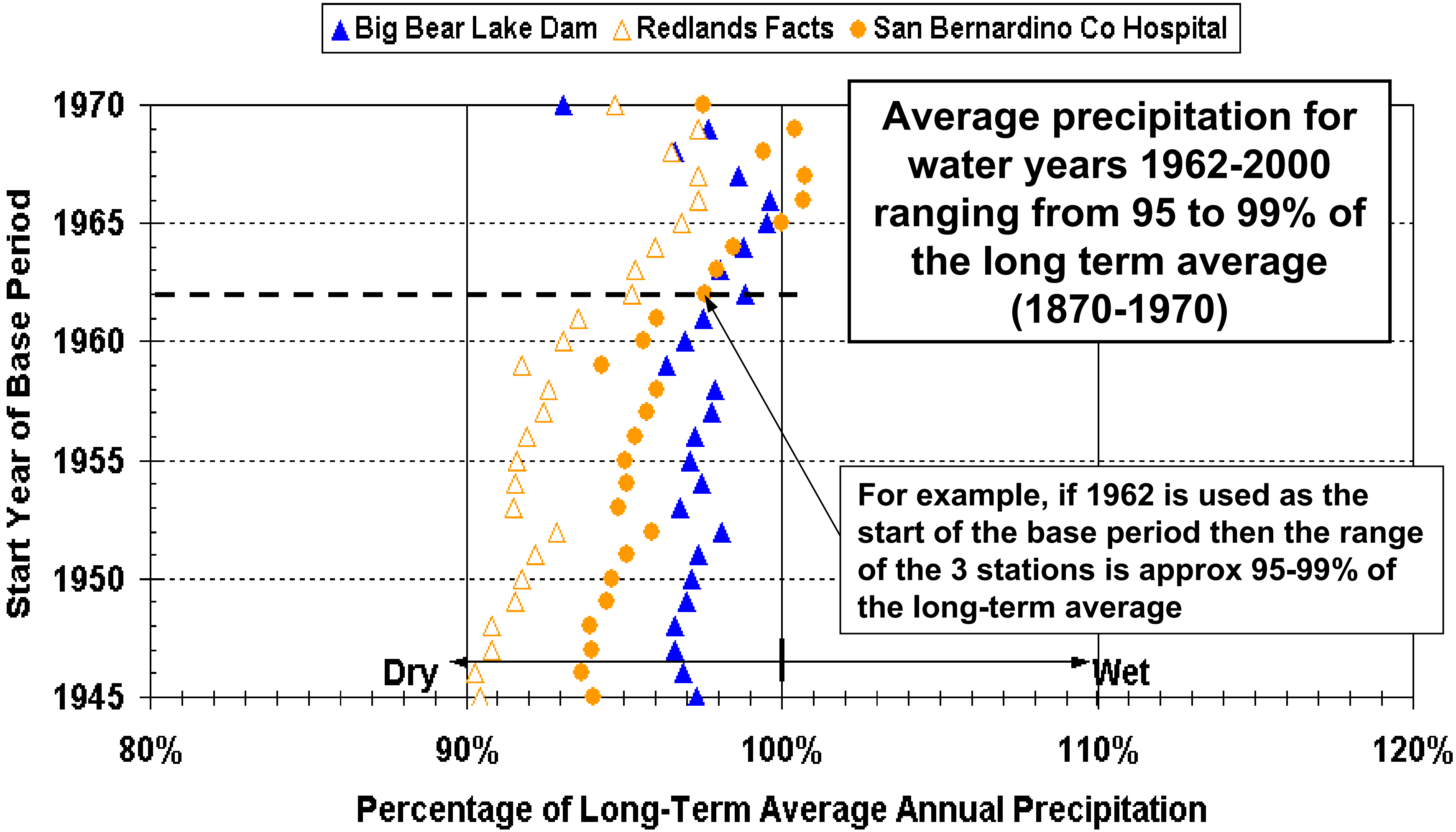


Stations with more than 100 years of record:
San Bernardino County Hospital, Redlands Facts and Big Bear Lake Dam

9 mountain stations shown in blue
and
11 valley stations shown in orange

Station Base Period vs. Percentage of San Bernardino County Flood Control District Long-Term Average Annual Precipitation* (1870-1970)
(All Years are Water Years, Oct 1 - Sep 30)

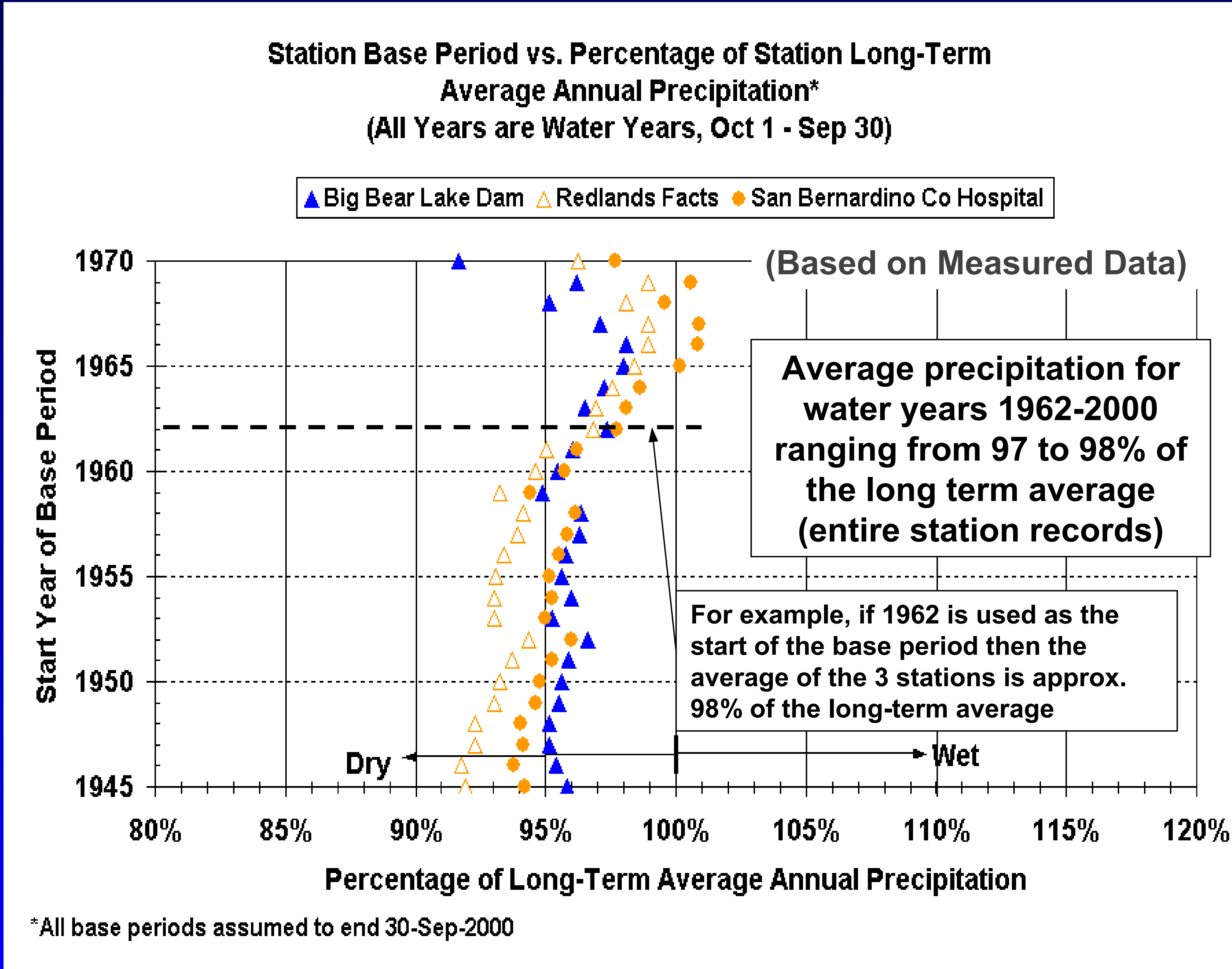
(Based on Isohyetal Map)



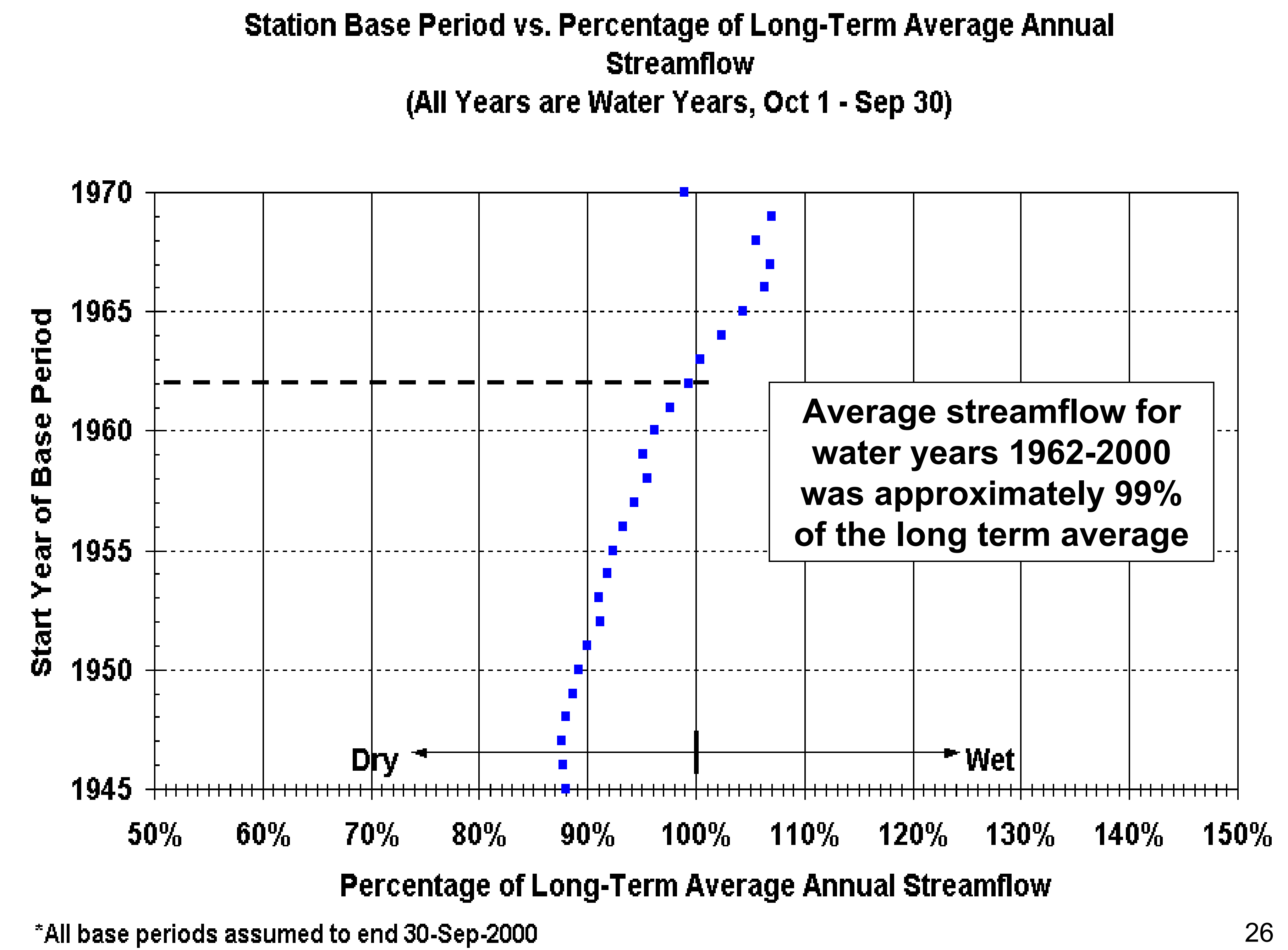
Average precipitation for water years 1962-2000 ranging from 95 to 99% of the long term average (1870-1970)

For example, if 1962 is used as the start of the base period then the range of the 3 stations is approx 95-99% of the long-term average

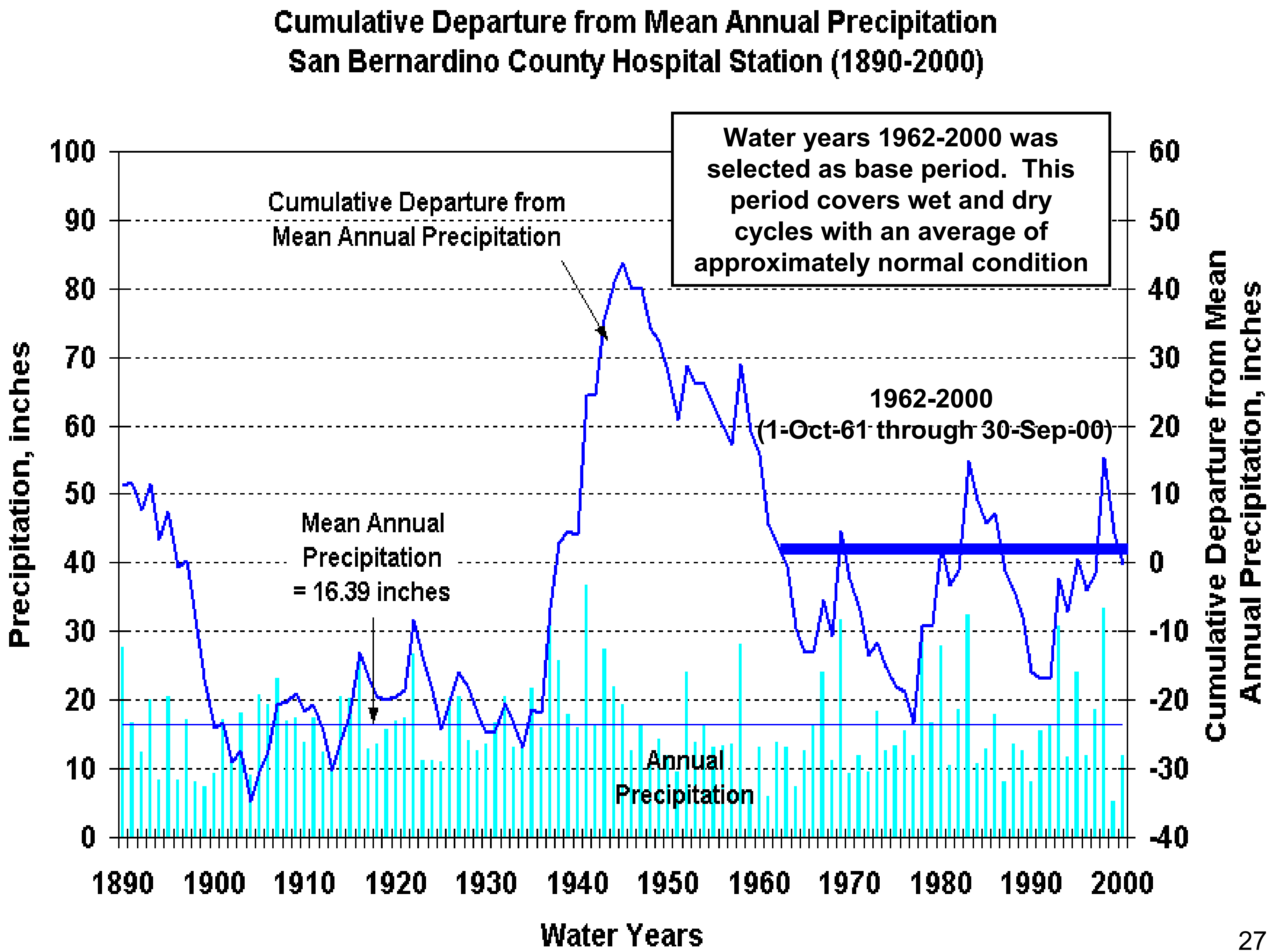
*All base periods assumed to end 30-Sep-2000



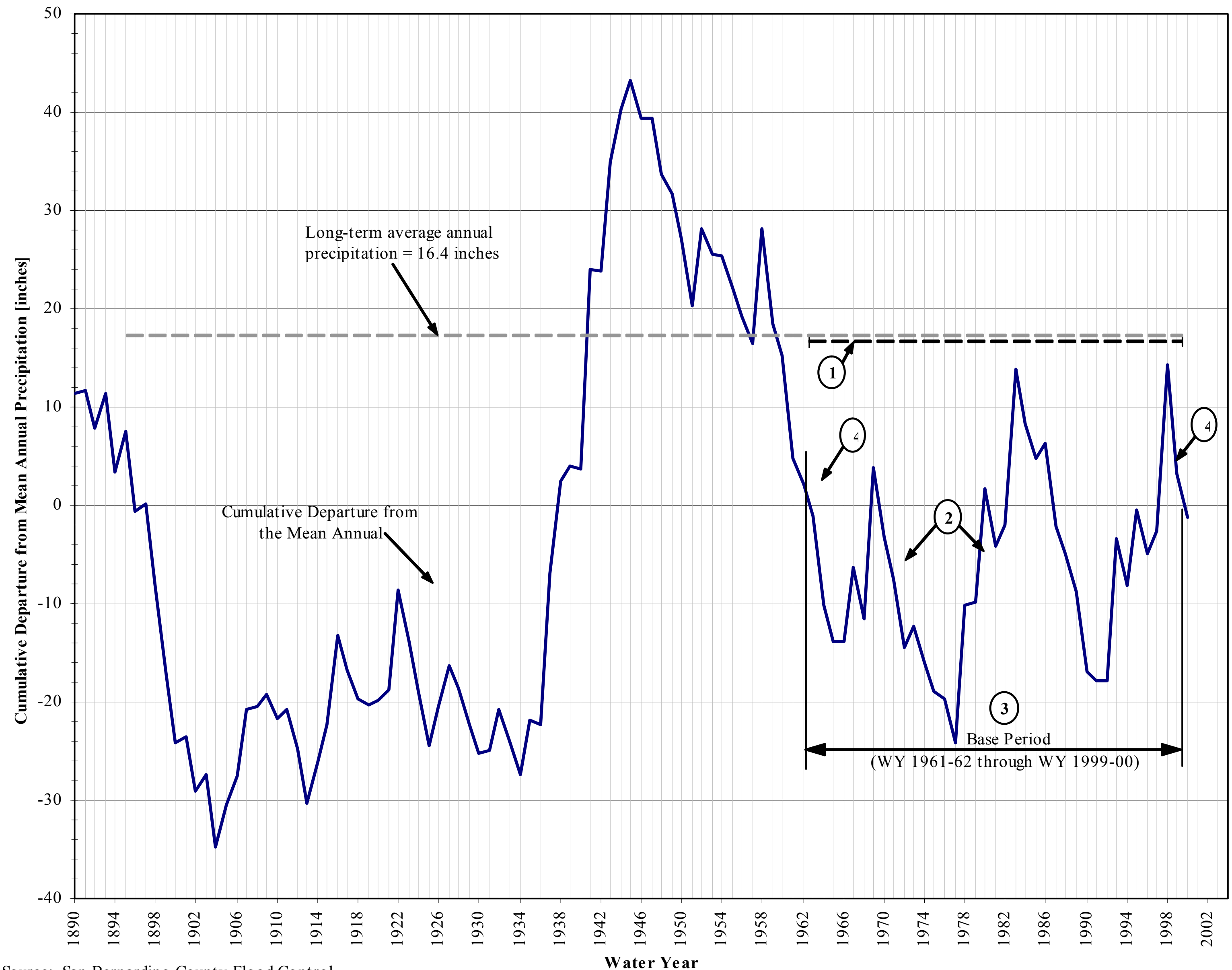
Station Base Period vs. Percentage of Station Long-Term
Average Annual Precipitation*
(All Years are Water Years, Oct 1 - Sep 30)
Big Bear Lake Dam
Redlands Facts
San Bernardino Co Hospital
(Based on Measured Data)
Average precipitation for water years 1962-2000 ranging from 97 to 98% of the long term average (entire station records)
For example, if 1962 is used as the start of the base period then the average of the 3 stations is approx. 98% of the long-term average
Dry
Wet
Start Year of Base Period
1970
1965
1960
1955
1950
1945
80%
85%
90%
95%
100%
105%
110%
115%
120%
Percentage of Long-Term Average Annual Precipitation
*All base periods assumed to end 30-Sep-2000



Station Base Period vs. Percentage of Long-Term Average Annual Streamflow
(All Years are Water Years, Oct 1 - Sep 30)
Start Year of Base Period
1970
1965
1960
1955
1950
1945
Average streamflow for water years 1962-2000 was approximately 99% of the long term average
Dry
Wet
50%
60%
70%
80%
90%
100%
110%
120%
130%
140%
150%
Percentage of Long-Term Average Annual Streamflow
*All base periods assumed to end 30-Sep-2000


Cumulative Departure from Mean Annual Precipitation
San Bernardino County Hospital Station (1890-2000)
Water years 1962-2000 was selected as base period. This period covers wet and dry cycles with an average of approximately normal condition
Cumulative Departure from Mean Annual Precipitation
Mean Annual Precipitation = 16.39 inches
Annual Precipitation
1962-2000
(1-Oct-61 through 30-Sep-00)
Precipitation, inches
Cumulative Departure from Mean Annual Precipitation, inches
Water Years
100
90
80
70
60
50
40
30
20
10
0
60
50
40
30
20
10
0
-10
-20
-30
-40
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

Hydrologic Base Period Meets All Criteria



Source: San Bernardino County Flood Control

1 Average precipitation of the base period (16 in.) is approximately equal to the average precipitation of the long-term (1890-2000) record of 16.4 inches.

2 Base period contains periods of wet, dry and average hydrologic conditions.

3 Base period is sufficiently long (39 years) to contain data representative of the averages, deviations from the averages, and extreme values of the historical period from 1890 to 2000.

Base period is representative of recent and cultural conditions (e.g., land use, urbanization, etc.) for the purpose of using the base period in forecasting models.

4 Base period contains a dry trend at both the beginning and end of the period.

Groundwater Model Scenarios

	WCD Spreading			*Senior Water Right Diversion*		*Habitat Release*		*Muni/Western Diversion*			*Seasonal Water Conservation Storage*
Model Scenario	*Historical*	*Licensed*	*Settlement with Conservation District*	*Historical*	*88 cfs*	*Habitat Release*	*Other Habitat Treatment**	*Plunge Pool 1500 cfs Diversion Rate*	*Cuttle Weir 500 cfs Diversion Rate*	*No*	*Yes*
No Project Condition	X			X		X				X	
Scenario A		X		X			X	X			X
Scenario B		X		X			X		X		X
Scenario C	X				X	X		X			
Scenario D	X				X	X			X		
Most Likely Scenario			X	X		X		X			X

***Less than 100 acre-ft in the 39-year period**

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- Brief Review of Groundwater Modeling Tasks
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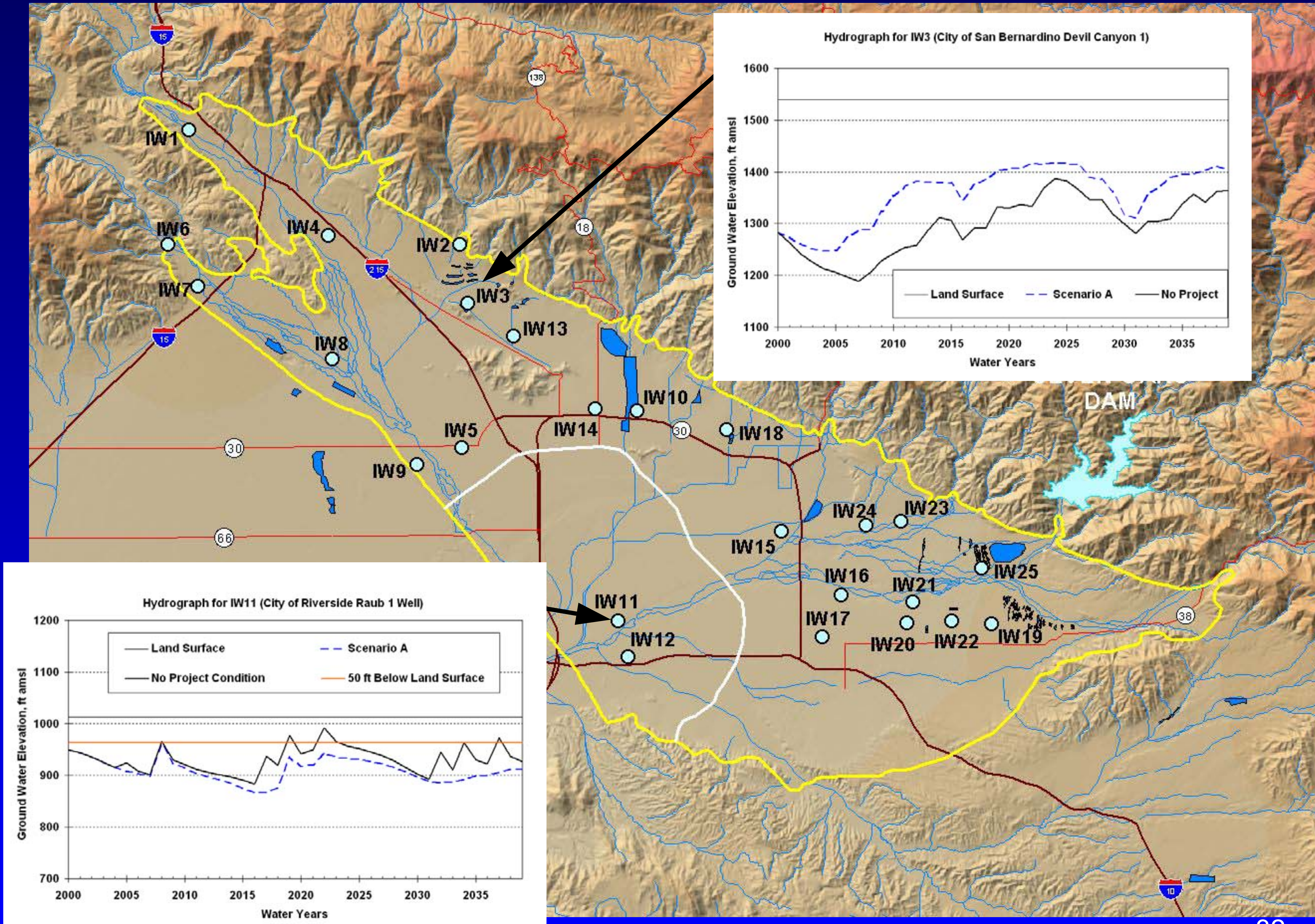
Results of Groundwater Model Runs

- Groundwater Elevations
- Areas of Potential Liquefaction
- Groundwater Budgets
- Groundwater Quality and Contamination

Groundwater Elevations



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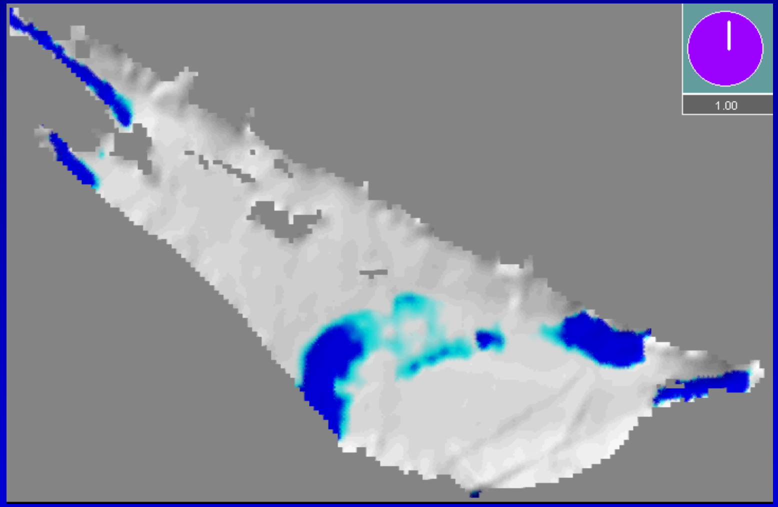
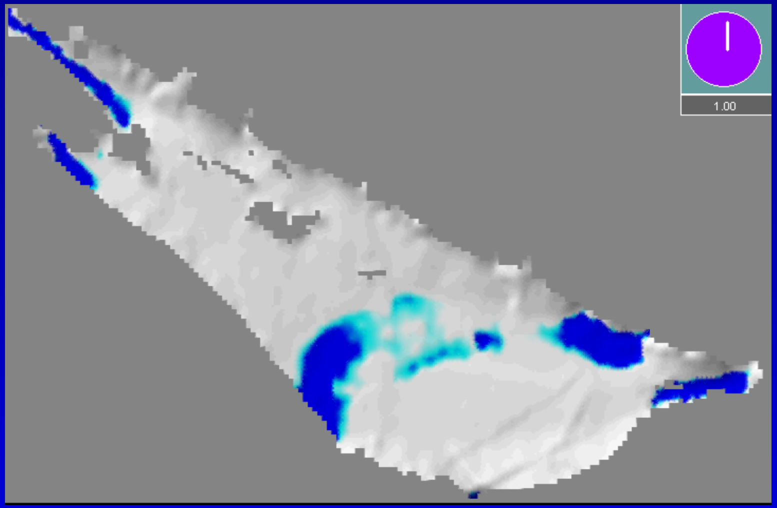
Areas of Potential Liquefaction

<u>Depth to Water</u>
Dark Blue: <50 ft
Light Blue: 50-70 ft
Light Gray: >70 ft

No Project Condition



Scenario A (Max Capture)



2001-2039

Cumulative Area of Potential Liquefaction 2001-2039

Model Scenario	Cumulative Area Susceptible to Liquefaction in the Pressure Zone [acres]	Changes as Compared to No Project [acres]	Comments
No Project	32,184	-	-
Scenario A	7,533	-24,651	Reduction of 77%
Scenario D	16,825	-15,359	Reduction of 48%
Most Likely Scenario	10,728	-21,456	Reduction of 67%

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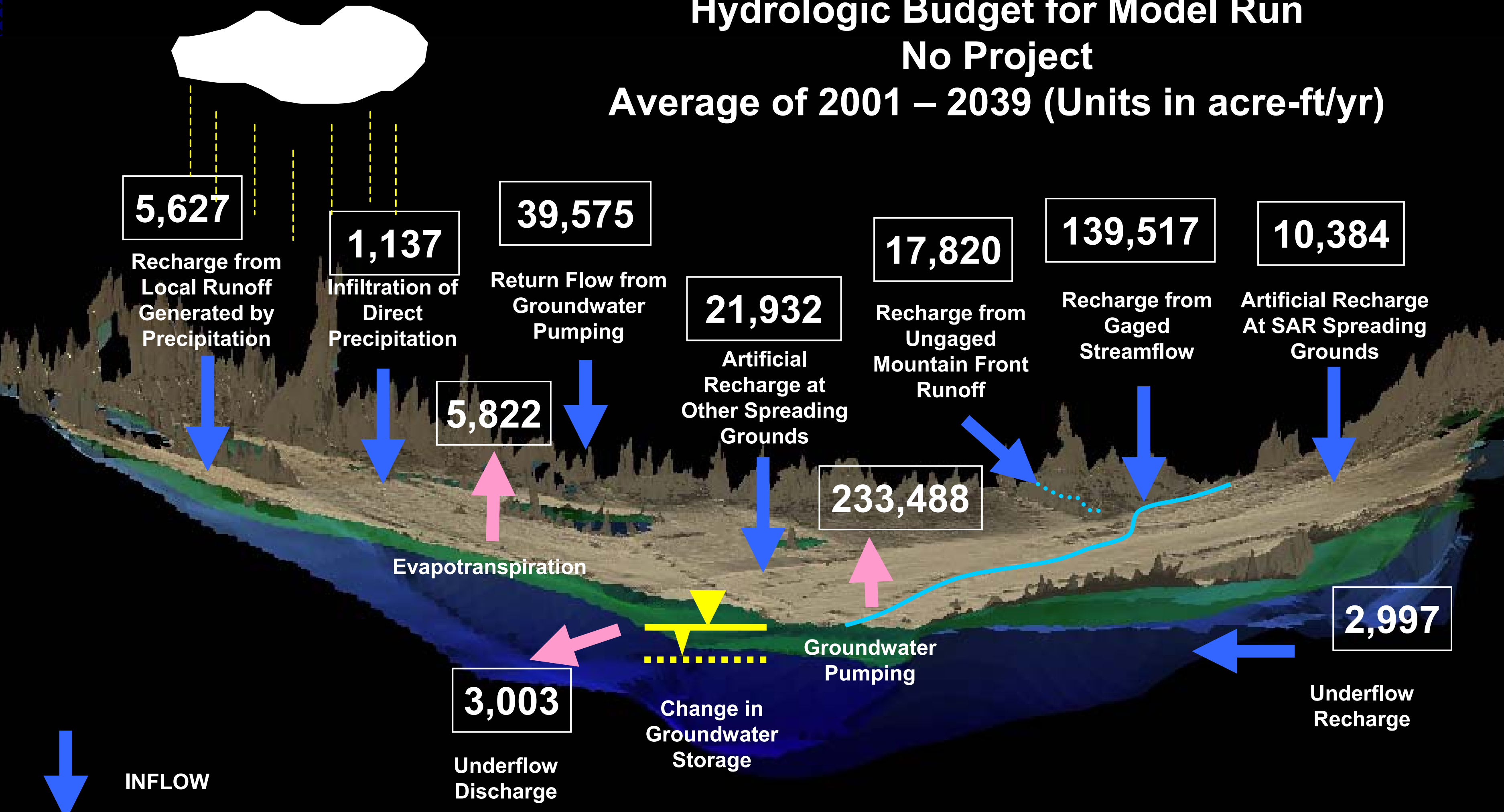
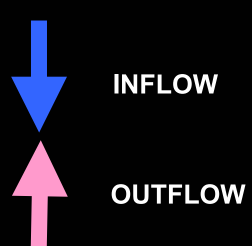
Hydrologic Budget for Model Run
No Project
Average of 2001 – 2039 (Units in acre-ft/yr)

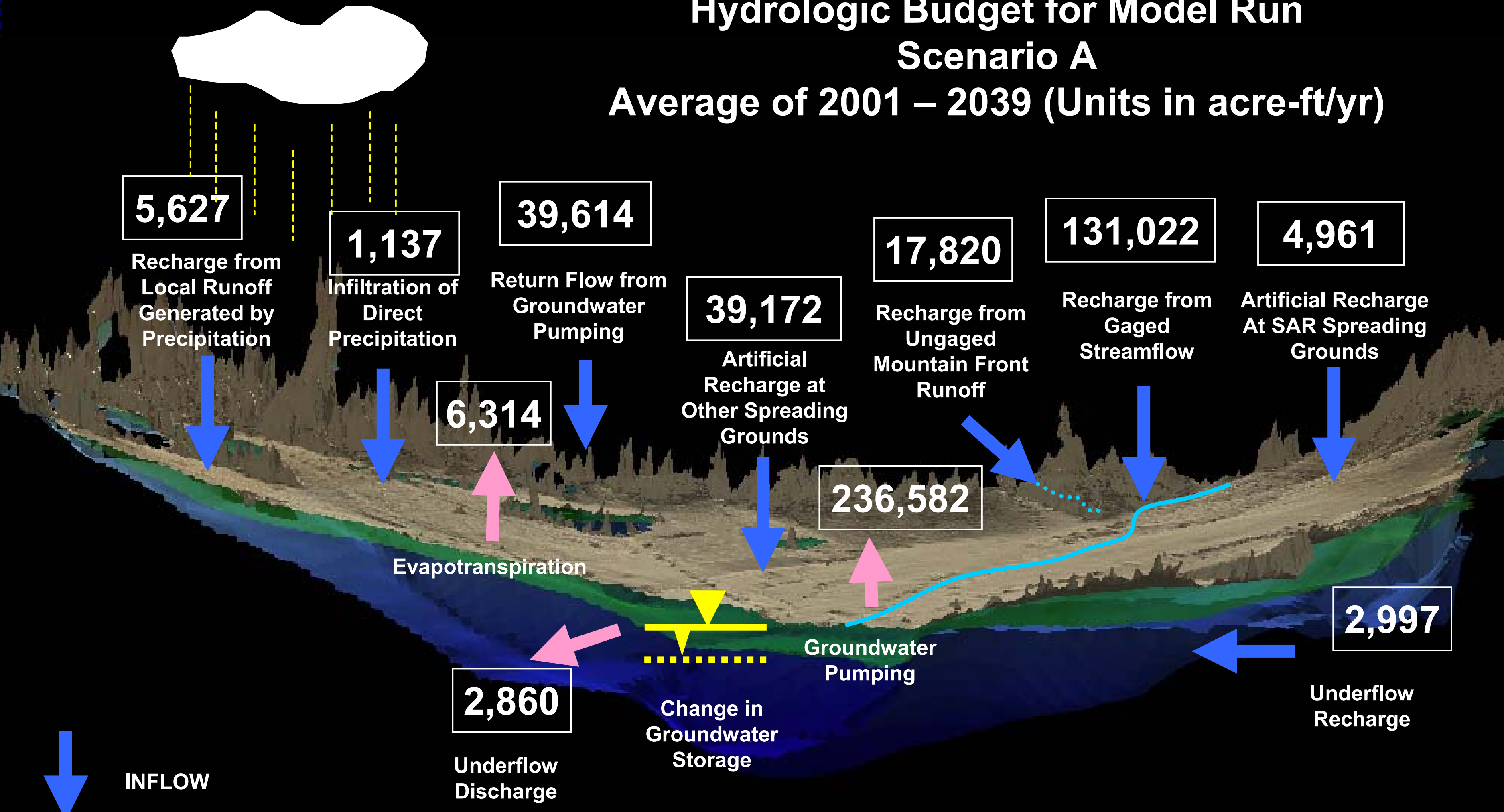




EQUATION OF HYDROLOGIC EQUILIBRIUM
INFLOW = OUTFLOW +/- CHANGE IN GROUNDWATER STORAGE

CHANGE IN GROUNDWATER STORAGE = -3,324 ACRE-FT/YR

Hydrologic Budget for Model Run
Scenario A
Average of 2001 – 2039 (Units in acre-ft/yr)



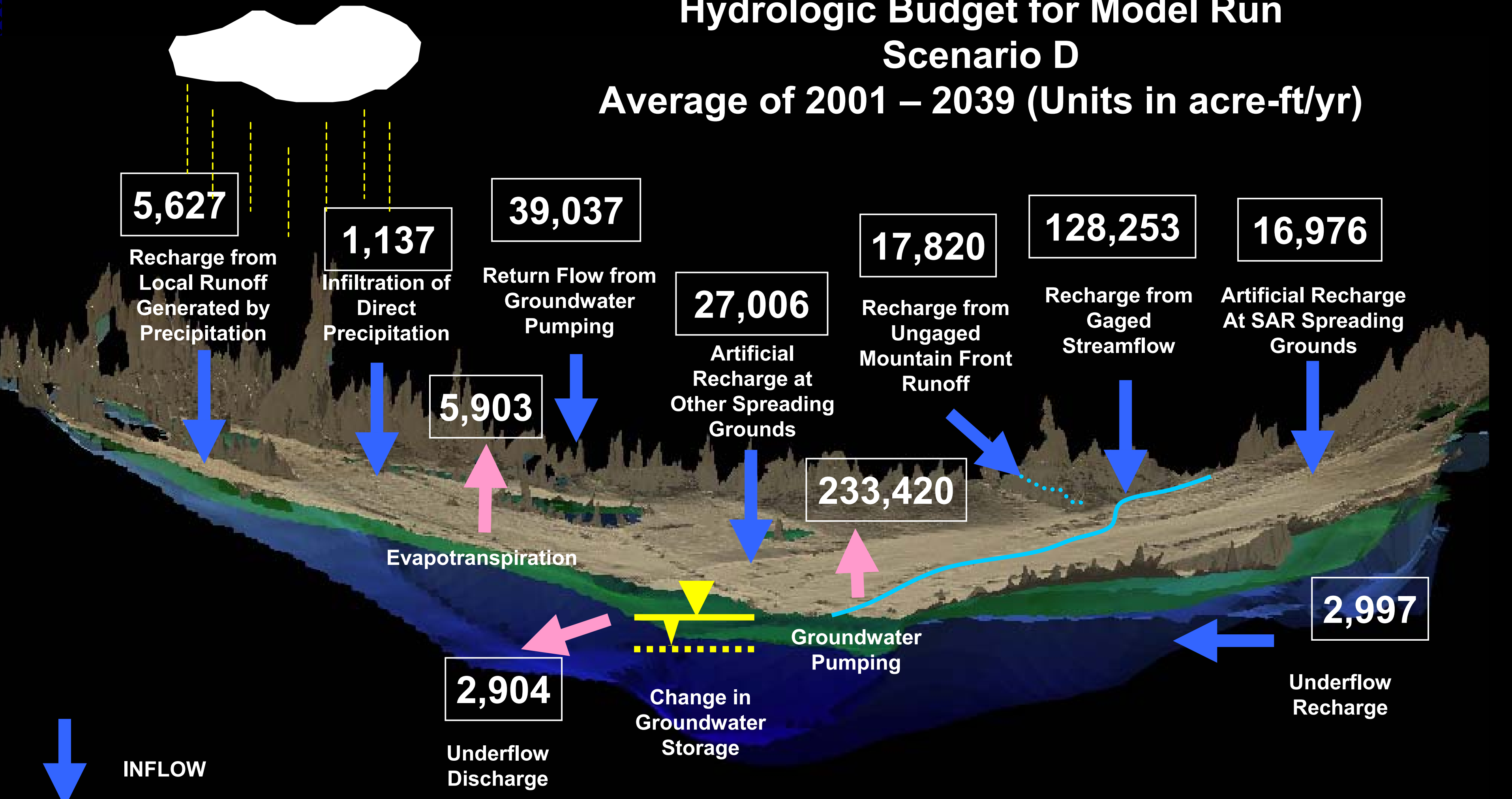
INFLOW

OUTFLOW

EQUATION OF HYDROLOGIC EQUILIBRIUM
INFLOW = OUTFLOW +/- CHANGE IN GROUNDWATER STORAGE

CHANGE IN GROUNDWATER STORAGE = -3,406 ACRE-FT/YR

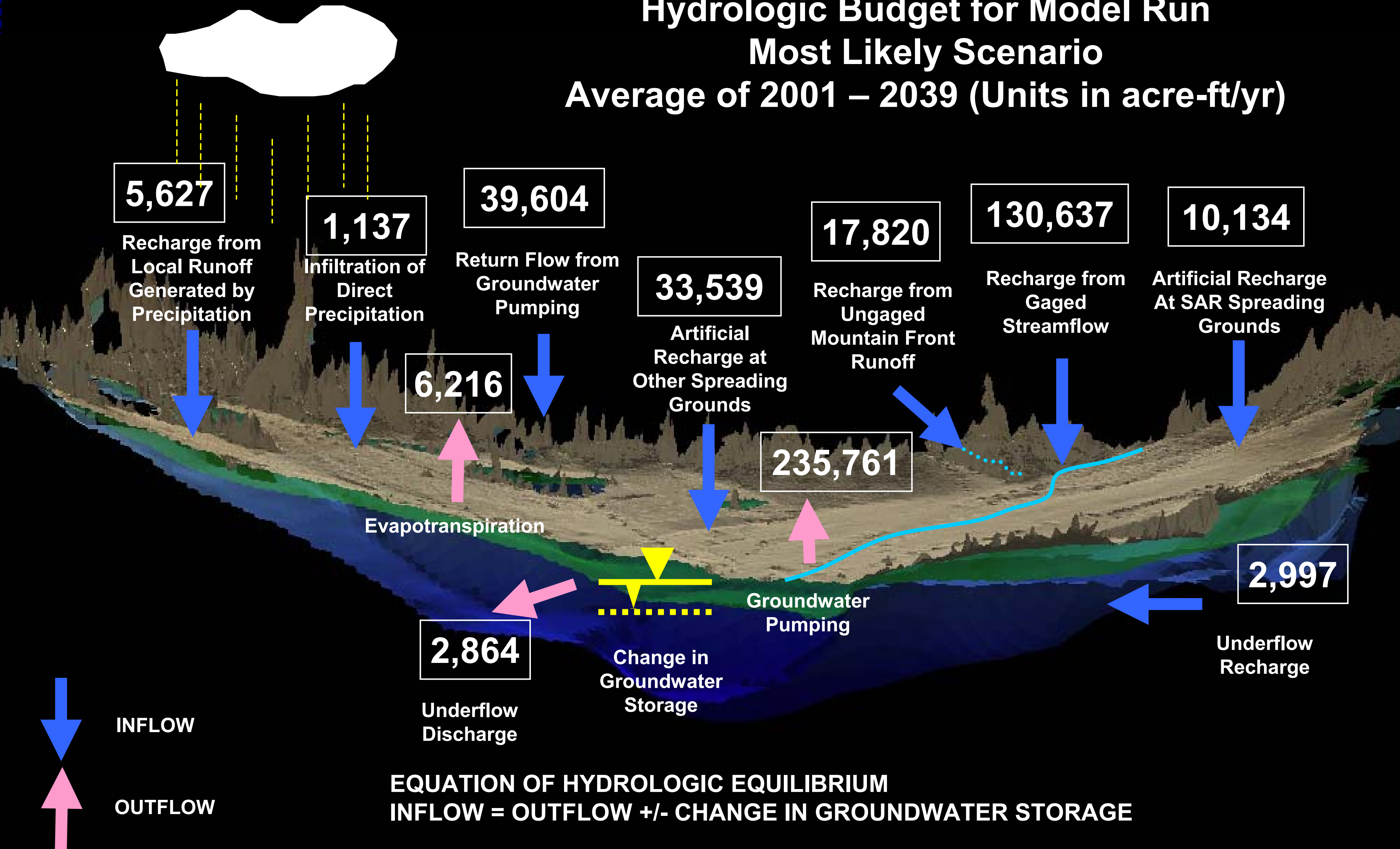
Hydrologic Budget for Model Run
Scenario D
Average of 2001 – 2039 (Units in acre-ft/yr)



EQUATION OF HYDROLOGIC EQUILIBRIUM
INFLOW = OUTFLOW +/- CHANGE IN GROUNDWATER STORAGE

CHANGE IN GROUNDWATER STORAGE = -3,374 ACRE-FT/YR

Hydrologic Budget for Model Run
Most Likely Scenario
Average of 2001 – 2039 (Units in acre-ft/yr)



EQUATION OF HYDROLOGIC EQUILIBRIUM
INFLOW = OUTFLOW +/- CHANGE IN GROUNDWATER STORAGE

CHANGE IN GROUNDWATER STORAGE = -3,346 ACRE-FT/YR

SBBA Groundwater Budgets 2001-2039

Model Scenario	Change in Groundwater Storage [acre-ft/yr]	Changes as Compared to No Project [acre-ft/yr]
No Project	-3,324	-
Scenario A	-3,406	-82
Scenario D	-3,374	-50
Most Likely Scenario	-3,346	-22

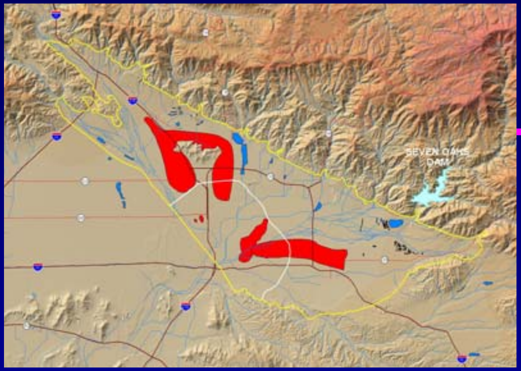
As can be seen, the change in storage under project scenarios are minimal compared to the No Project Condition.

Note: Total groundwater in storage in SBBA is approximately 6 Million Acre-ft (DWR Bulletin 118, 2003)

TDS and Nitrate Concentrations

Model Scenario	Difference from No Project in 2039 (Average of SBBA)	
	TDS [mg/L]	Nitrate (as NO_3) [mg/L]
Scenario A	+0.75	-0.49
Scenario D	-0.21	-0.19

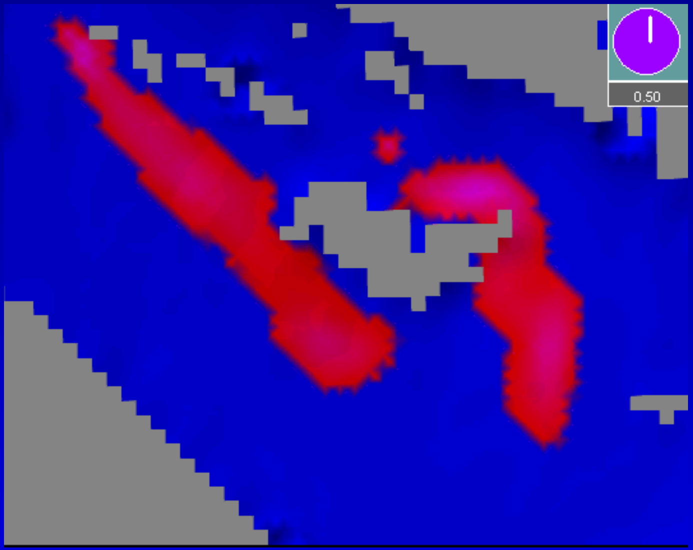
The Project only minimally changes (less than 1 mg/L) the average TDS and NO_3 concentrations for the SBBA.

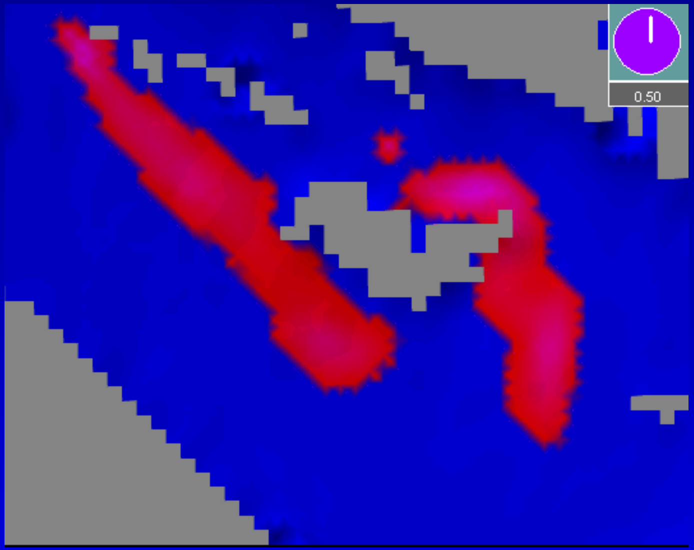


PCE Plume

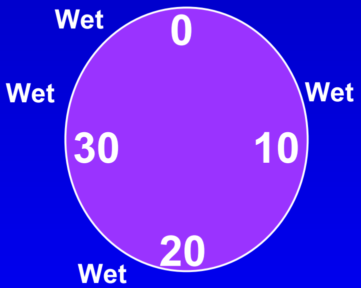
No Project Condition

Scenario A





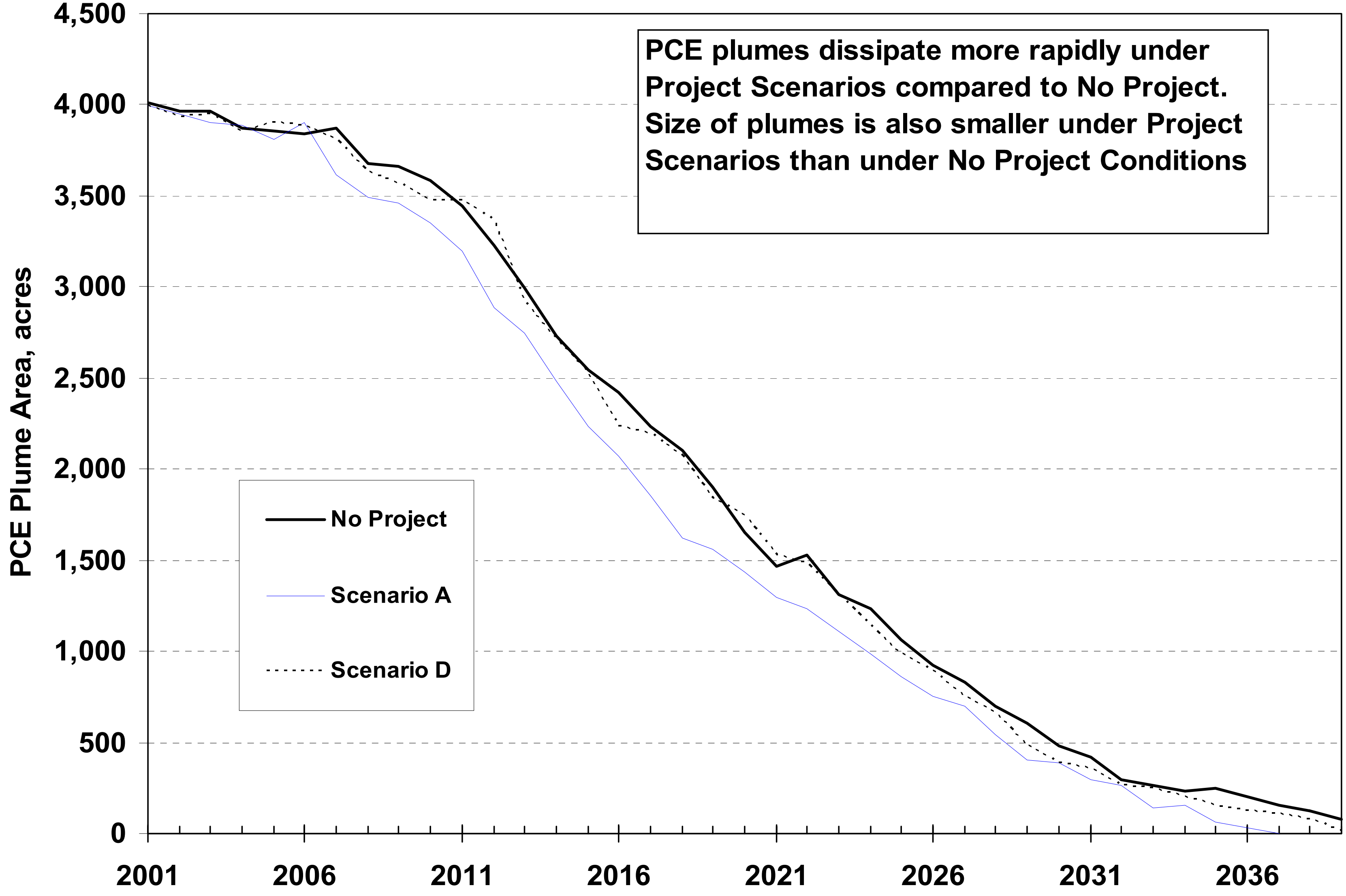
39 yrs



2001-2039

PCE Concentration
Red: >= 5 ug/L
Dark Blue: < 5 ug/L

PCE Plume Areas 2001 -2039



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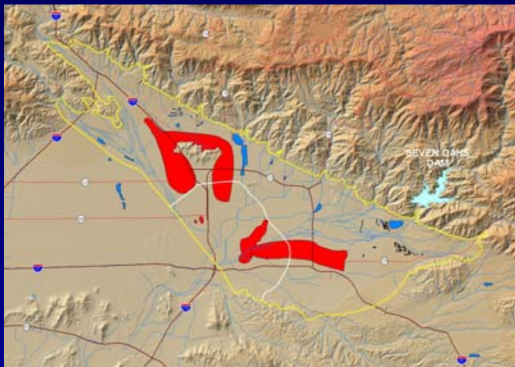
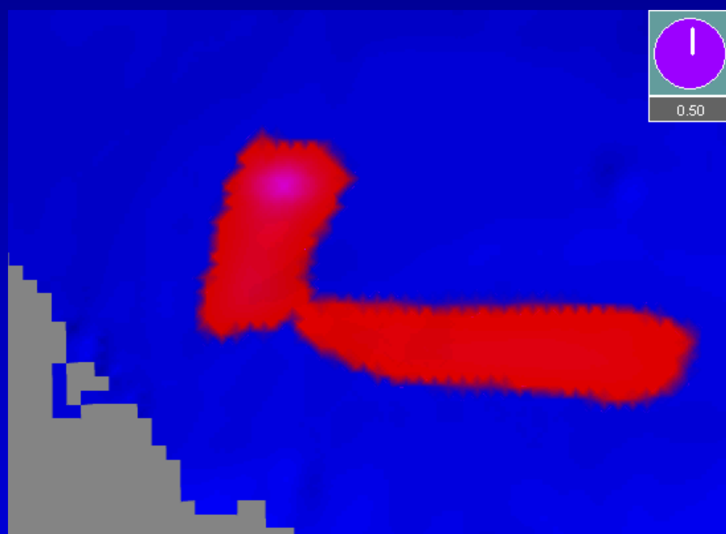
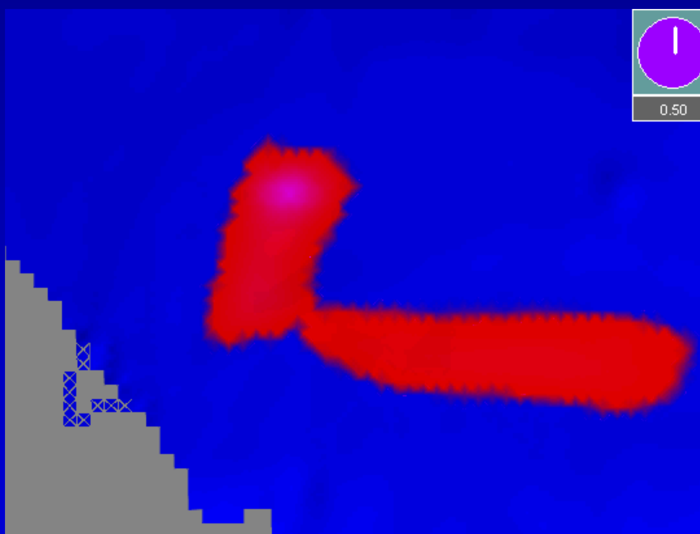


TCE Plume

No Project Condition

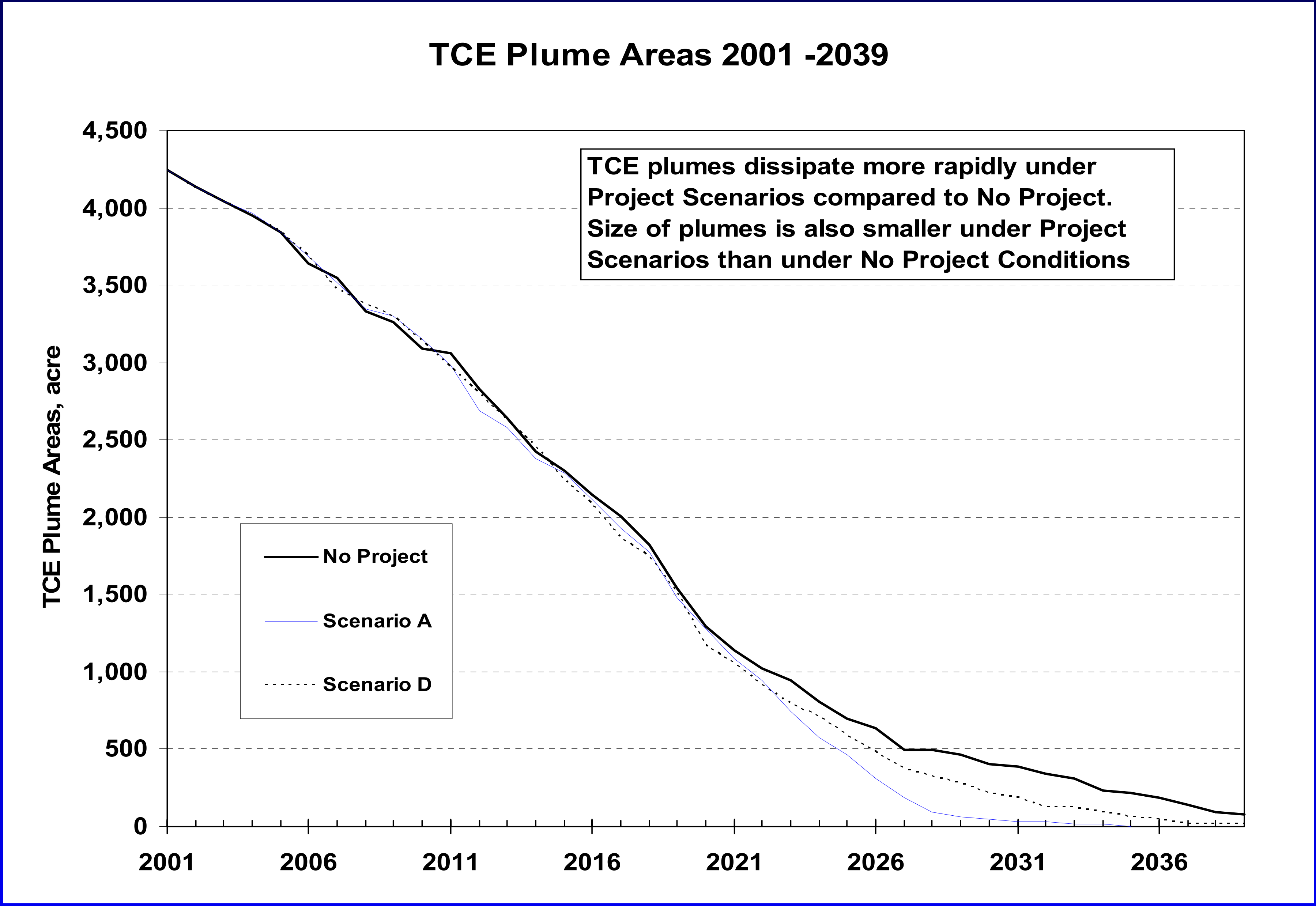


Scenario A



2001-2039

<u>TCE Concentration</u>
Red: >= 5 ug/L
Dark Blue: < 5 ug/L



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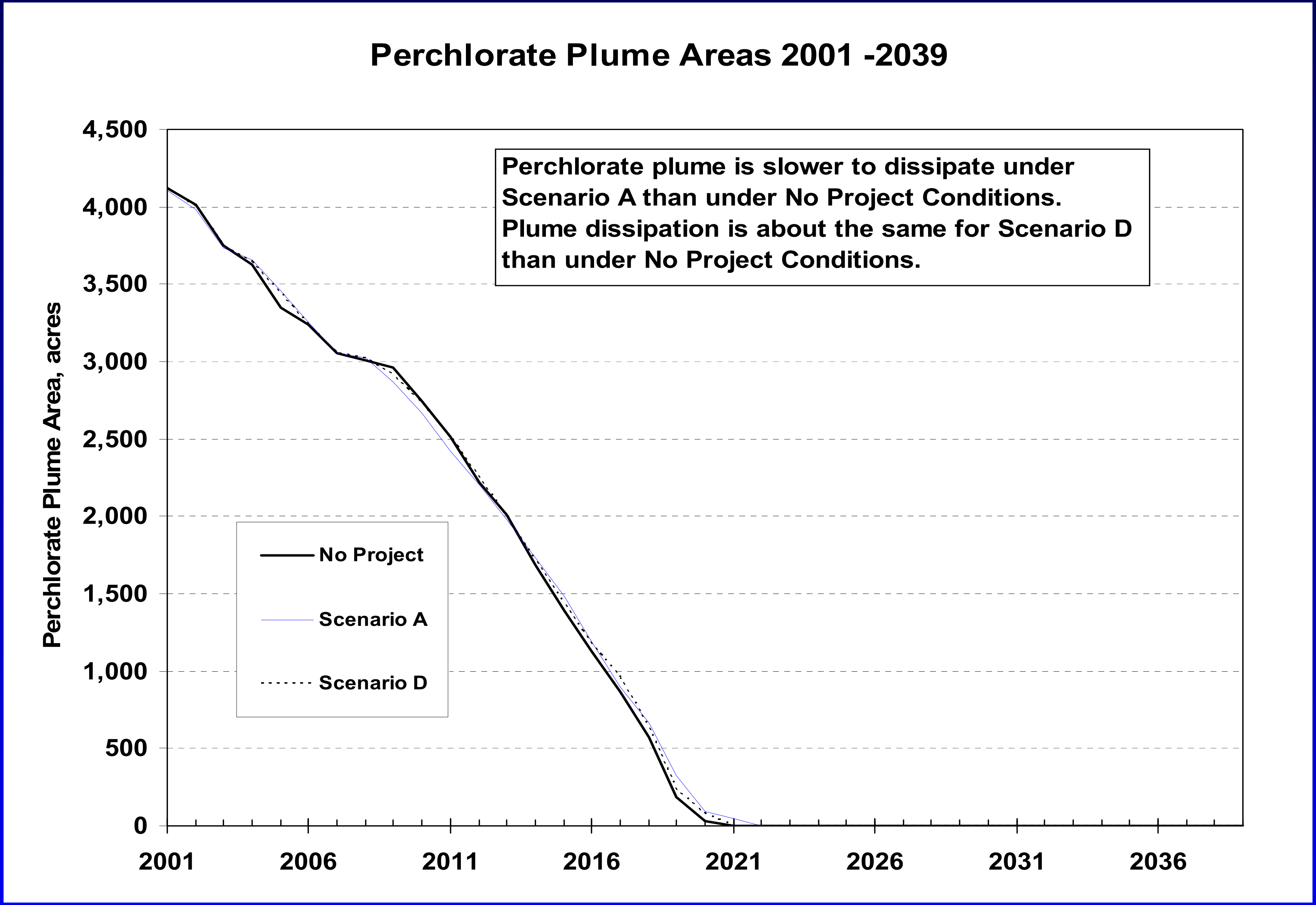

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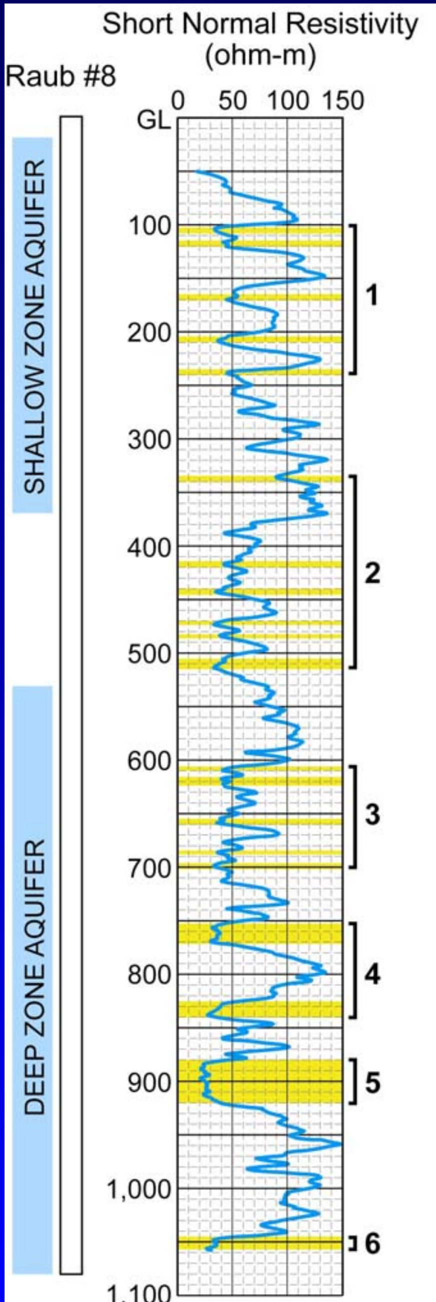
Overview of Groundwater Models

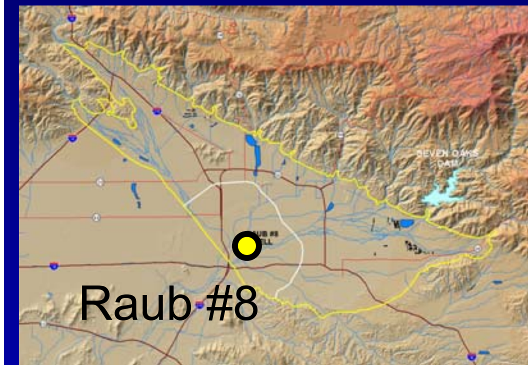
- ♦ Brief Review of Groundwater Modeling Tasks
- ♦ Results of Groundwater Model Runs
- ♦ Discussion of Subsidence Modeling
- ♦ Impacts of Spreading Outside the Model Area

Subsidence Modeling

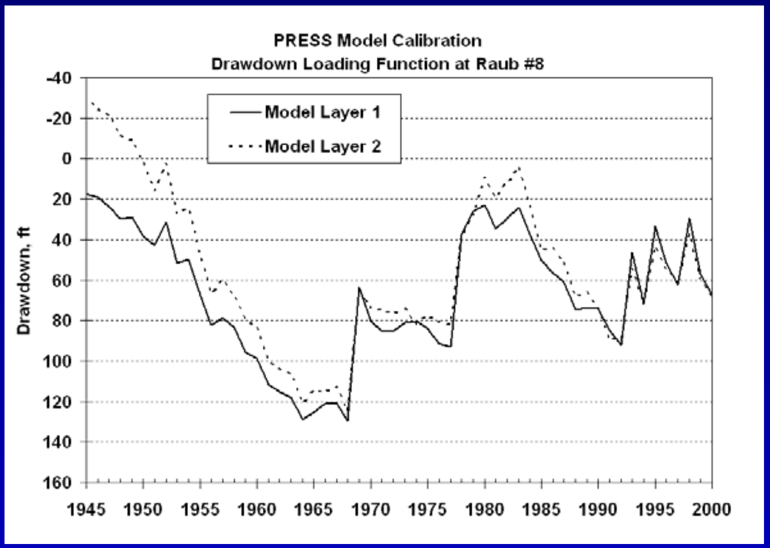
- PRESS (Predictions Relating Effective Stress and Subsidence)
- Developed by Helm (1975)
- Widely Used by Harris-Galveston Coastal Subsidence District
- Based on one-dimensional Terzaghi consolidation theory
- Input includes changes in water levels from groundwater flow model and properties of compaction layers such as virgin compressibility, elastic compressibility, pre-consolidation stress and thickness of compaction layers
- Predicts non-recoverable compaction

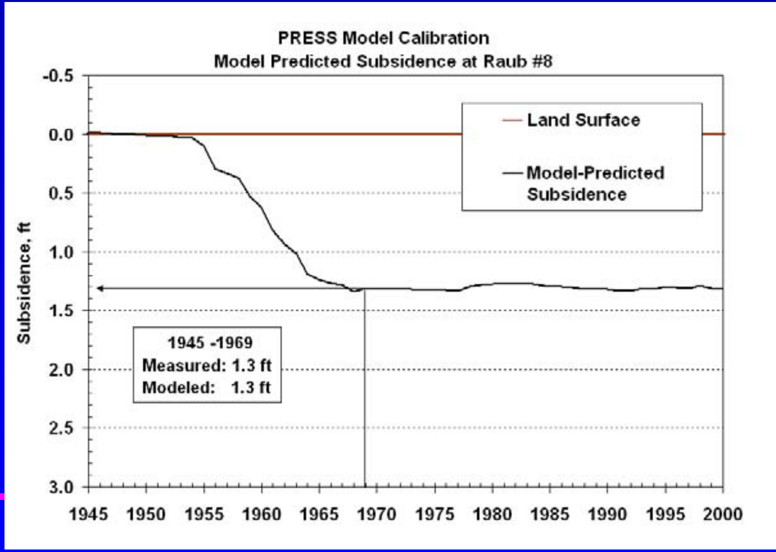
Subsidence Modeling
PRESS Model Calibration Well Raub #8





Well Raub #8 was selected because it is located in the Pressure Zone nearest to the maximum historical subsidence and it has geophysical borehole logs.





Subsidence at Location of Well Raub #8 (2001-2039)

Model Scenario	Total Subsidence [ft]	Average Subsidence Rate [ft/yr]
No Project	0.35	0.0083
Scenario A	0.62	0.0158
Scenario D	0.43	0.0108

The maximum subsidence rate is approximately 1 ft / 100 years for all scenarios. This is within the generally accepted subsidence criteria.

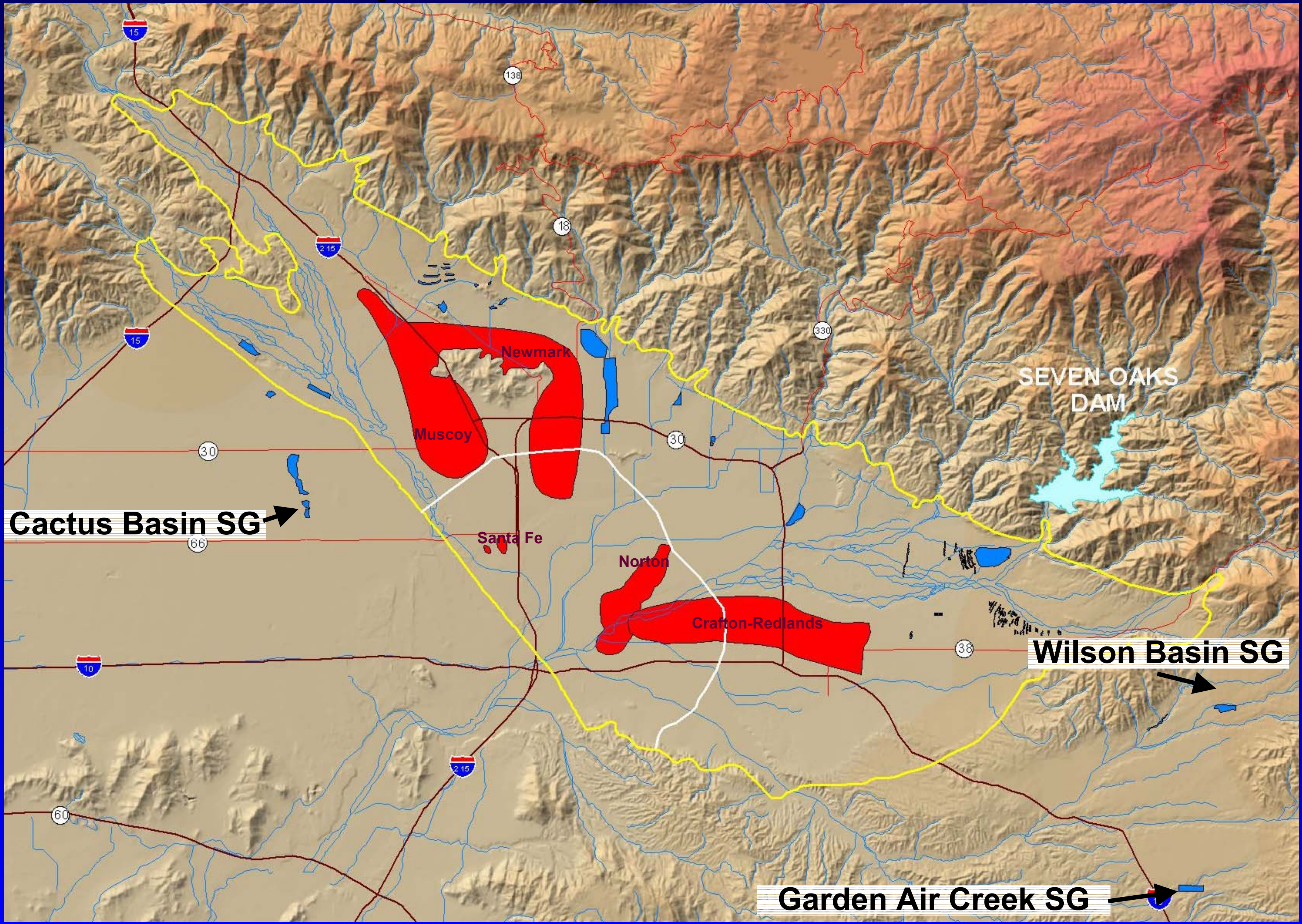
Overview of Groundwater Models

- Brief Review of Groundwater Modeling Tasks
- Results of Groundwater Model Runs
- Discussion of Subsidence Modeling
- Impacts of Spreading Outside the Model Area

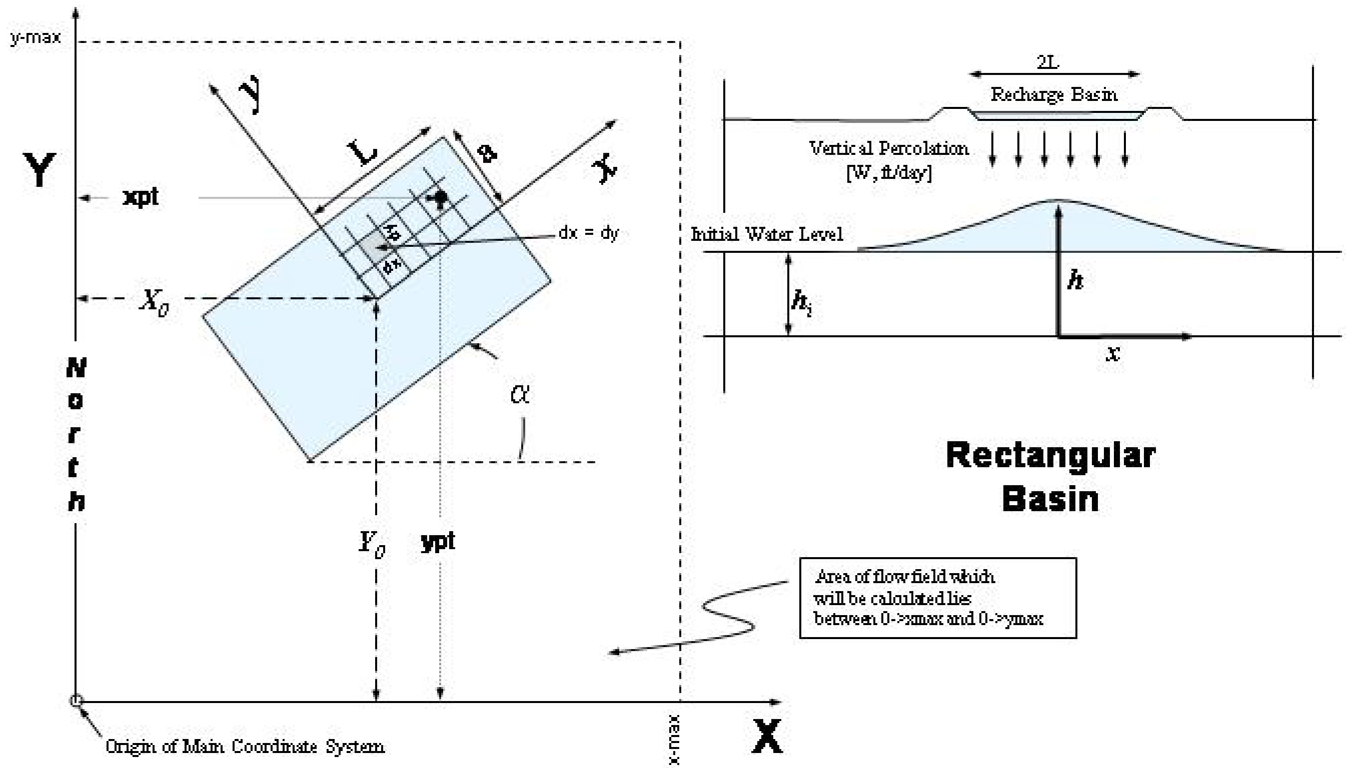
Impacts of Spreading Outside of Model Area

- Analytical method used to evaluate impacts of artificial recharge in areas outside of the model area (due to surface spreading)
- Hantush Equation which estimates the growth and decay of groundwater mounds in response to uniform percolation
- Applied to three artificial recharge areas designated by the Allocation Model :
  - Cactus Spreading Ground (in Rialto-Colton Basin)
  - Wilson Spreading Ground (in Yucaipa Basin)
  - Garden Air Creek Spreading Ground (in San Timoteo Basin)

Location of Spreading Basins Outside the SBBA



Analytical Method – Hantush Equation



Hantush equation predicts rise and fall of groundwater mounds in response to uniform percolation

Impacts of Spreading Outside of Model Area

Model Scenario	Cactus Spreading Ground (Rialto-Colton Basin)	Wilson Spreading Ground (Yucaipa Basin)	Garden Air Spreading Grounds (San Timoteo Basin)
Scenario A	18,953 AF 48 ft mound 152 ft below land surface	2,154 AF 76 ft mound 74 ft below land surface	5,745 AF 38 ft mound 122 ft below land surface
Scenario D	13,317 AF 45 ft mound 155 ft below land surface		

Summary of Comparisons
Project Scenarios to No Project – 39 yr Period

Scenario	Potential Liquefaction	PCE Plume	TCE Plume	Perchlorate Plume	Basin Water Quality (TDS &NO_3)	Potential Subsidence	Change in Basin Storage	Impacts of Spreading Outside SBBA
Scenario A (Max Cap 1500 cfs)	77% Less Than NP	Dissipates More Rapidly	Dissipates More Rapidly	Dissipates Slightly Slower	Minimal Change (<1 mg/L)	Slightly More Than NP	Minimal Change	GW Levels do not rise within 50 ft of surface
Scenario D (Min Cap 500 cfs)	48% Less Than NP	Dissipates More Rapidly	Dissipates More Rapidly	Dissipates Approx the Same	Minimal Change (< 1mg/L)	Slightly More Than NP	Minimal Change	GW Levels do not rise within 50 ft of surface
Most Likely Scenario (1500 cfs, Conserv. District Settlement & Senior Water Rights)	67% Less Than NP	NA	NA	NA	NA	Slightly More Than NP	Minimal Change	GW Levels do not rise within 50 ft of surface