East Valley Water Forum Hydrologic Groundwater Modeling Water Budget, Model Results, and Conclusions:

Groundwater Resource

Although groundwater is pumped throughout the entire East Valley, the East Valley draws most of its water supplies from surface water sources. Large recharge facilities, such as the Granite Reef Underground Storage Project (GRUSP), divert both CAP and Salt and Verde River water into large spreading basins. These spreading basins allow surface water to rapidly percolate into the ground and thus "recharge" the groundwater aquifer. Recharge at GRUSP, and the planned Superstition Mountains Recharge Project, will replace the groundwater being pumped. Smaller volumes of recharge, which are widely distributed throughout the East Valley, also occur through other mechanisms (such as natural recharge from rainfall, percolation from outside watering, percolation from irrigating lawns and farms, and individual municipal recharge projects). The following explains complex interaction between recharge and pumping and how water moves through an aquifer.

Mountains eroding over millions of years created the "basin fill" sediments (silts, clays, sands and gravels) that make up the East Valley's aquifer. The various climatic conditions in which the mountains eroded caused the materials to be deposited in three geological units (or layers). Two semi-impermeable layers separate the three units and restrict the downward movement of water. The mixture of basin fill sediments determines the aquifer's ability to move groundwater. Hydrologists refer to the aquifer's ability to move and hold groundwater as the aquifer "parameters". Aquifer parameters vary horizontally and vertically throughout the aquifer. A computer program, known as MODFLOW, is a tool used to predict future groundwater levels. MODFLOW uses the aquifer parameter, recharge, and pumping to predict future groundwater levels.

Groundwater levels respond to natural conditions, dams and pumping. If more water is being pumped than is being recharged, water levels in the aquifer will fall, and vise versa. Groundwater moves very slowly and pumping and recharge can take decades to affect regional groundwater levels. Prior to dams on the Salt and Verde Rivers and large scale groundwater pumping, the groundwater levels interacted with the Salt and Gila Rivers. Depth to groundwater[1] in the East Valley ranged from land surface to 50-feet in the Maricopa County Area[2] and 200 to 300 feet in the Pinal County Area[3]. Groundwater generally flowed from the east (Superstition Mountains) to the west (South Mountain).

With the completion of the dams on the Salt, Verde and Gila Rivers and the advent of the well pump in the 1940's, the aquifer levels began to fall. From the early 1900's to the 1980's, groundwater levels in the East Valley declined 100 to 150 feet in the Maricopa County Area and 200 feet in the Pinal County Area. In 1983, depth to groundwater[4] ranged from 150 to 250 feet

[1] 1986, Geoffrey W.Freethey and T.W. Anderson, "Predevelopment Hydrologic Conditions in the Alluvial Basins of Arizona and Adjacent Parts of California and New Mexico"
[2] Maricopa County Area is that area in the East Salt River Valley that is west of Higley Road.
[3] Pinal County Area is that area in the East Salt River Valley that is east of Higley Road.
[4] ADWR Hydrologic Map Series Report Number 12

in the Maricopa County Area and 300 to 500 feet in the Pinal County Area. Cones of depression occurred in areas where the wells were clustered[5].

Since the 1980's groundwater levels have been rising, but have not risen to the 1900's levels. From 1983 to 2003 the entire East Valley groundwater levels rose two to three feet/year (except near the recharge and cone of depression areas). In 2003 the depth to groundwater[6], except near the recharge and cone of depression areas, ranged from 100 to 200 feet in the Maricopa County Area and 300 to 400 feet in the Pinal County Area. The general east to west groundwater flow is altered by the North Meridian Road and Santan cones of depression capturing some of the natural east to west flow. The depth to groundwater in the North Meridian Road cone of depression ranges from 500 to 600 feet. The depth to groundwater in the Santan cone of depression is about 400 feet. Figure 1 shows the general flow and cones of depression. Note that some of the GRUSP recharge is flowing towards the North Meridian Road cone of depression. Just west of the Santan cone of depression, the historic groundwater flow direction is reversed.

<u>Scenario Development.</u> The water providers, with technical assistance from ADWR, developed future pumping and recharge projections/estimates, while ADWR's aquifer parameters and minor recharge quantities were used as input data for the East Valley groundwater model. Three scenarios were examined. The two "book end" scenarios help narrow the wide range of possible future scenarios. Scenario 1 (S1), or the base case scenario, envisions "business as usual" and, other than the Groundwater Code, there is no coordinated groundwater management effort. The S1 water budgets in Table 1 show approximately 100,000 acre-feet per year overdraft (or mined from the East Valley). Scenario 2 (S2) is the other "book end". S2 places the East Valley Water Forum planning area in safe-yield by prohibiting new pumping after 2020.

The EVWF, using its ADWR grant funds and BOR funds, contracted with ASU's Decision Theater to display the groundwater model's complex output. The Decision Theater is pioneering new technology that visualizes technical information in a three-dimensional format, similar to the concept of the "IMAX" Theater. Using the Decision Theater's 3-D visualizations of Scenarios S1 and S2, the EVWF developed Scenarios S3A, S3B, and S3C. These three scenarios present alternatives to manage the North Meridian Road cone of depression but allow groundwater mining. Safe-yield in the East Valley is not achieved in the S3 alternatives. S3 alternatives allow 30,000 (S3C) to 50,000 (S3A and S3B) acre-feet per year to be mined from the aquifer.

<u>Groundwater Model Results</u>. Groundwater models are only as good as the input data. For many of the model parameters, data is not available and assumptions must be made. The largest assumption is future pumping. While water providers developed annual pumping schedules through the year 2030, these schedules are only estimates and depend upon many other factors. The East Valley groundwater model shows groundwater trends and should be used only as a regional planning tool. The groundwater model cannot precisely predict future

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[5] A Cone of Depression is where the groundwater levels in the aquifer are dropping at a significantly higher rate than the surrounding aquifer.
[6] ADWR Hydrologic Map Series Report Number 35

groundwater levels for specific locations and at a specific time. Furthermore, the model's groundwater level predictions close to the mountains (or the model boundaries) are less reliable than areas towards the center of the East Valley. For instance, the model may show the groundwater levels declining 25 feet (between the years 2005 to 2030) at the intersection of the Superstition and Price Road Freeways. A better way to describe future water levels near the intersection of the Superstition and Price Road Freeways is to say groundwater levels have a tendency to slowly decline, about one foot per year.

Groundwater level projections for the Maricopa County area depend upon wells pumping in Chandler, Tempe, Salt River Project (SRP) and the Gila River Indian Community (GRIC) service areas. The model pumping quantities assumed GRIC (one of the largest groundwater pumpers in the Maricopa County area) would pump their full groundwater allotment (identified in the GRIC Settlement). Furthermore, pumping by GRIC was equally distributed throughout the farm areas on the Community. It is recognized the GRIC will have an integrated surface water and groundwater delivery system and the GRIC pumping assumptions will need to be updated after the GRIC Settlement is final and the GRIC Master Plan completed. Groundwater level predictions in Maricopa County should be used carefully.

For S1, groundwater levels throughout the East Valley drop approximately one-foot per year and large cones of depression around North Meridian Road and the Queen Creek Wash develop. S2's model results reveal the aquifer near the Superstition Mountains rises about two-feet per year and the aquifer near South Mountain falls about one-foot per year. In addition, there is a large cone of depression around North Meridian Road. The three S3 scenarios reduced the North Meridian Road cone of depression's severity to varying degrees, but none of the scenarios eliminated the cone of depression. Apache Junction found the S2 results helpful and actively participated in developing the S3 Scenarios. Table 1 summarizes the results.

The following conclusions, covering the East Valley, can be reached from the scenario analysis.

General Conclusion for all Scenarios and the Base Case

1. Regional groundwater problems manifest themselves after 2020. There is time to resolve regional groundwater problems before they become critical. Resolving regional groundwater problems after 2020 will be more expensive and difficult.
2. The existing GRUSP (operated by SRP) and future Superstition Mountains Recharge Project (to be constructed and operated by CAP) are critical to the East Valley. These recharge projects must operate indefinitely.
3. To achieve safe-yield, development after the year 2020 must replace (recharge) any new pumped water close to where the pumping occurs. Current regulations allow recharge (replacement) to occur independent of pumping.
4. Reaching safe-yield does not mean all wells in the East Valley can continue to pump. Unless there is regional cooperation, cones of depression will occur in the North Meridian Road and Queen Creek Wash areas.

Base Case (S1) Observations for year 2100 (see Figure 2):

1. Groundwater level trends (for years 2003 to 2100): Groundwater levels will decline approximately one foot/year throughout the entire East Valley (except near the recharge and cone of depression areas).

2. Depth to groundwater: Except near the recharge and cone of depression areas, depth to groundwater ranges:
    a. Maricopa County Area: 200 to 300 feet
    b. Pinal County Area: 200 to 600 feet
3. Groundwater flow direction: Along Higley Road there is a groundwater divide and the groundwater flows east and west of the groundwater divide. The North Meridian Road and Queen Creek Wash cones of depression alter the general flow directions.
4. Cones of depression: Two large cones of depression have developed:
    a. North Meridian Road – From years 2002 to 2100 decline rates average about three feet/year and depth to groundwater in this area is about 800 feet.
    b. Queen Creek Wash (east and south of the Superstition Mountains Recharge Project) – From years 2002 to 2100 decline rates averaged about 3 feet/year and depth to groundwater in this area is about 700 feet.
5. Groundwater recharge projects:
    a. Granite Reef Underground Storage Project helps fill in the North Meridian Road cone of depression and reduce the groundwater decline rates.
    b. Superstition Mountains Recharge Project helps reduce the North Meridian Road and Queen Creek Wash cones of depression decline rates.

Scenario 2 Observations for year 2100 (see Figure 3):

1. Groundwater level trends for years 2002 to 2100:
    a. Groundwater levels will decline about one foot/year in the Maricopa County Area.
    b. Groundwater levels will rise about two feet/year in the Pinal County Area.
2. Depth to groundwater ranges from 100 to 300 feet (except near the recharge and the North Meridian Road cone of depression areas).
3. Groundwater flow direction: Groundwater flows generally from the east (Superstition Mountains) to the west (South Mountain). In the northeast area, the North Meridian Road cone of depression alters the general east to west groundwater flow.
4. Cones of depression:
    a. North Meridian Road – From years 2002 to 2100 decline rates averaged about three feet/year and depth to groundwater in this area is about 700 feet.
5. The groundwater recharge projects:
    a. Granite Reef Underground Storage Project helps reduce the North Meridian Road cone of depression decline rates.
    b. Superstition Mountains Recharge Project helps reduce the North Meridian Road cone of depression decline rates.

Scenario 3 (See Figure 4)

The purpose of Scenario 3 was to reduce the severity of the North Meridian Road cone of depression. After considering various options, the Forum conceptually agreed to relocating pumping from two major water providers in the North Meridian Road cone of depression and decreasing some new post year 2020 pumping. Options 3A and 3B relocate the 75% of the municipal pumping to another portion of the aquifer. Option 3A relocates 75% of the municipal pumping thereby reducing new post year 2020 pumping by 14,000 acre-feet. The table below summarizes the pumping relocation and reduction for the S3 scenarios.

Scenario 3 Pumping Relocation and Reduction Assumptions:

Scenario	Pumping Reduction in North Meridian Road Cone of Depression	Increased Pumping	Superstition Vistas Pumping
3A	14,000 af/year	14,000 af/year moved South of Apache Junction	56,500 af/year
3B	14,000 af/year	14,000 af/year moved to North Mesa area	56,500 af/year
3C	14,000 af/year	14,000 af/year moved South of Apache Junction	42,500 af/year

Scenario 3 Observations for year 2100

1. Groundwater level trends (from years 2002 to 2100, except near cones of depression)

Scenario	Maricopa County Area	Pinal County Area
3A	1 ft/year decline	1 ft/year decline
3B	1 ft/year decline	0.5 ft/year rise
3C	1 ft/year decline	1 ft/year rise

2. Depth to groundwater:
   a. Maricopa County Area: 200 to 300 feet
   b. Pinal County Area: 300 to 600 feet
3. Groundwater flow direction: Groundwater flows generally from the east (Superstition Mountains) to the west (South Mountain).
4. Cones of depression:

North Meridian Road Cone of Depression

Scenario	Depth to Groundwater	Additional Decline Rate (from years 2002 to 2100)
3A	700 feet	2 ft/year
3B	600 feet	1 ft/year
3C	600 feet	1 ft/year

5. The groundwater recharge projects:
   a. Granite Reef Underground Storage Project helps reduce the North Meridian Road cone of depression decline rates.
   b. Superstition Mountains Recharge Project helps reduce the North Meridian Road cone of depression decline rates.

Table 1 Simulated Water Budget for the **East Salt River Valley (values rounded to nearest 100 acre-feet per year)**

Base Case:

	2005	**2010**	**2015**	**2020**	**2025**	**2030**	**2060**	**2100**
Inflows	Acre-feet/year							
Recharge	440,000	514,000	510,500	563,300	564,300	527,600	527,600	527,600
Underflow & Mt. Front Recharge	22,800	22,800	22,800	22,800	22,800	22,800	22,800	22,800
Total Inflow	**462,800**	**536,800**	**533,300**	**586,100**	**587,100**	**550,400**	**550,400**	**550,400**
Outflows								
Pumpage	415,500	467,100	524,300	586,800	612,800	630,000	641,500	641,400
WSRV Underflow	15,900	17,700	18,200	18,000	18,900	20,000	20,300	20,500
Evapotranspiration	1,000	0	0	0	0	0	0	0
Total Outflow	**432,400**	**484,800**	**542,500**	**604,800**	**631,700**	**650,000**	**661,800**	**661,900**
Inflow-Outflow	**30,400**	**52,000**	**-9,200**	**-18,700**	**-44,600**	**-99,600**	**-111,400**	**-111,500**

Scenario 2:

	2005	**2010**	**2015**	**2020**	**2025**	**2030**	**2060**	**2100**
Inflows	Acre-feet/year							
Recharge	440,000	514,000	510,500	563,300	563,300	563,300	563,300	563,300
Underflow & Mt. FrontRecharge	22,800	22,800	22,800	22,800	22,800	22,800	22,800	22,800
Total Inflow	**462,800**	**536,800**	**533,300**	**586,100**	**586,100**	**586,100**	**586,100**	**586,100**
Outflows								
Pumpage	415,500	467,100	524,300	586,800	586,400	586,400	586,300	586,000
WSRV Underflow	15,900	17,700	18,200	18,000	18,800	19,400	19,600	19,700
Evapotranspiration	1,000	0	0	0	0	0	0	0
Total Outflow	**432,400**	**484,800**	**542,500**	**604,800**	**605,200**	**605,800**	**605,900**	**605,700**
Inflow-Outflow	**30,400**	**52,000**	**-9,200**	**-18,700**	**-19,100**	**-19,700**	**-19,800**	**-19,600**

Table 2

Recharge Water Budget for the East Salt River Valley[1]
Base Case (Acre-feet/year)

Recharge	2005	2010	2015	2020	2025	2030 - 2100
Turf	10,913	10,913	10,913	10,913	10,913	10,913
Urban	9,962	9,965	9,965	9,965	9,965	9,965
Lake	8,274	8,274	8,274	8,274	8,274	8,274
Canals	22,659	22,659	22,659	22,659	22,659	22,659
SCIP	38,731	38,731	38,731	38,731	38,731	38,731
Salt River	40,891	40,891	40,891	40,891	40,891	40,891
Gila River	37,155	37,155	37,155	37,155	37,155	37,155
USF	69,824	153,832	157,928	155,351	162,369	163,869
AG	205,940	198,272	192,864	252,007	246,170	207,776
Total Recharge	**444,349**	**520,692**	**519,377**	**575,943**	**577,124**	**540,230**

Scenario 2 (Acre-feet/year)

Recharge	2005	2010	2015	2020	2025	2030 - 2100
Turf	10,913	10,913	10,913	10,913	10,913	10,913
Urban	9,962	9,965	9,965	9,965	9,965	9,965
Lake	8,274	8,274	8,274	8,274	8,274	8,274
Canals	22,659	22,659	22,659	22,659	22,659	22,659
SCIP	38,731	38,731	38,731	38,731	38,731	38,731
Salt River	40,891	40,891	40,891	40,891	40,891	40,891
Gila River	37,155	37,155	37,155	37,155	37,155	37,155
USF	69,824	153,832	157,928	155,351	155,351	155,351
AG	205,940	198,272	192,864	252,007	252,007	252,007
Total Recharge	**444,349**	**520,692**	**519,377**	**575,943**	**575,943**	**575,943**

[1] Data was summed on areas that were active in year 2003 of the model.

Pumping Water Budget for the East Salt River Valley (acre-feet)[1]
Base Case

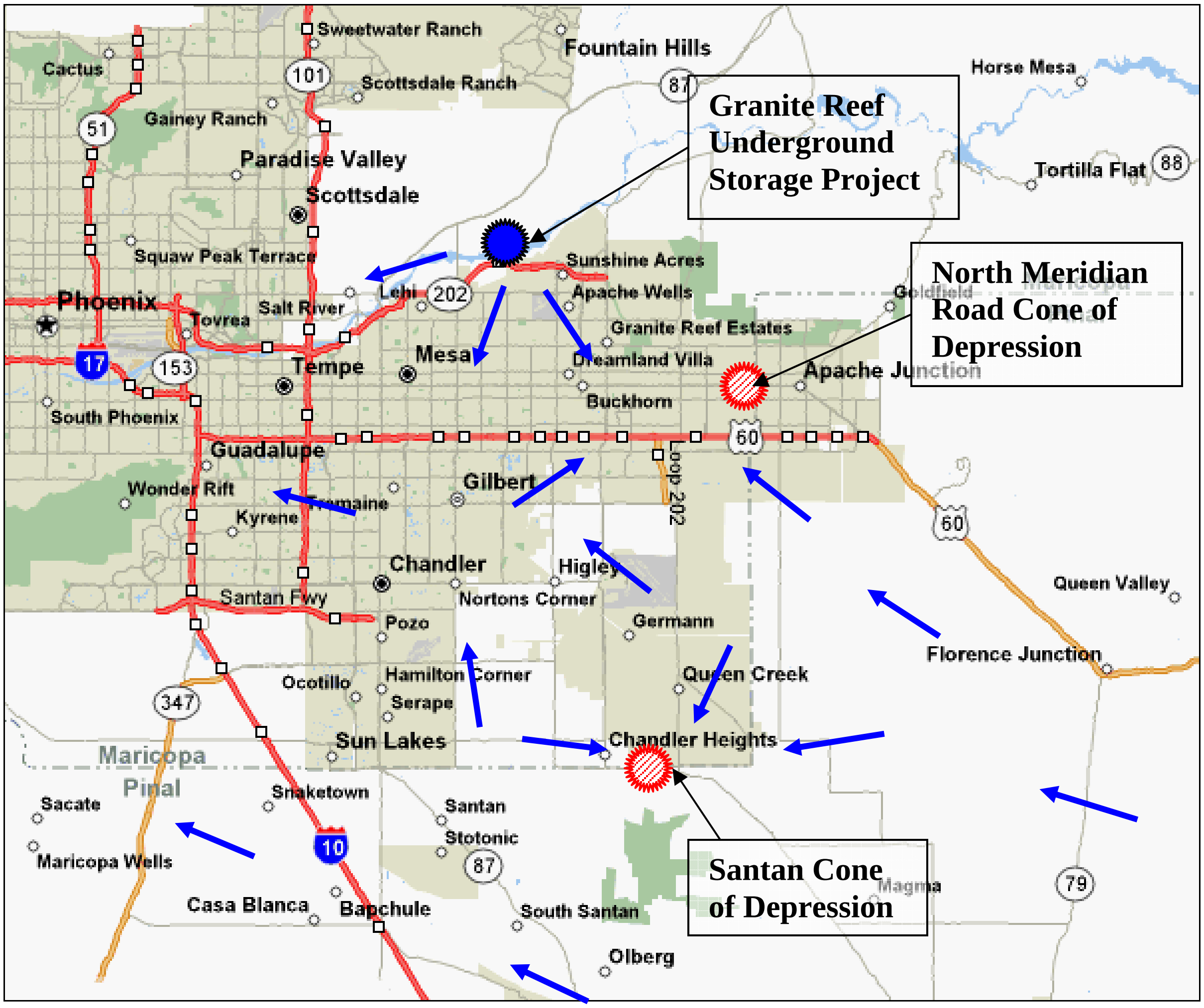
Pumping	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2040 - 2100**
Domestic	2,642	2,642	2,642	2,642	2,642	2,642	2,642
Municipal	124,233	144,892	178,177	217,384	249,643	272,097	282,097
Irrigation Districts	104,161	105,470	107,046	106,350	104,257	104,257	104,257
Agricultural[2]	48,997	48,074	43,056	42,341	40,218	36,653	36,653
San Carlos Project	29,328	36,778	44,133	51,547	51,547	51,547	51,547
GRIC	86,723	106,426	125,881	145,491	145,491	145,491	145,491
Industrial	2,836	2,836	2,836	2,836	2,836	2,836	2,836
Recovery	13,817	16,917	20,317	20,017	19,717	19,717	19,717
Total Pumpage	**412,737**	**464,035**	**524,088**	**588,608**	**616,351**	**635,240**	**645,240**

Scenario 2

Pumping	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2040 - 2100**
Domestic	2,642	2,642	2,642	2,642	2,642	2,642	2,642
Municipal	124,233	144,892	178,177	217,384	217,384	217,384	217,384
Irrigation Districts	104,161	105,470	107,046	106,350	106,350	106,350	106,350
Agricultural[2]	48,997	48,074	43,056	42,341	42,341	42,341	42,341
San Carlos Project	29,328	36,778	44,133	51,547	51,547	51,547	51,547
GRIC	86,723	106,426	125,881	145,491	145,491	145,491	145,491
Industrial	2,836	2,836	2,836	2,836	2,836	2,836	2,836
Recovery	13,817	16,917	20,317	20,017	20,017	20,017	20,017
Total Inflow	**412,737**	**464,035**	**524,088**	**588,608**	**588,608**	**588,608**	**588,608**

[1] Data was summed on areas that were active in year 2003 of the model.
[2] Agricultural pumping includes Type 1 and Type 2 wells.

Figure 1
2003 Conditions

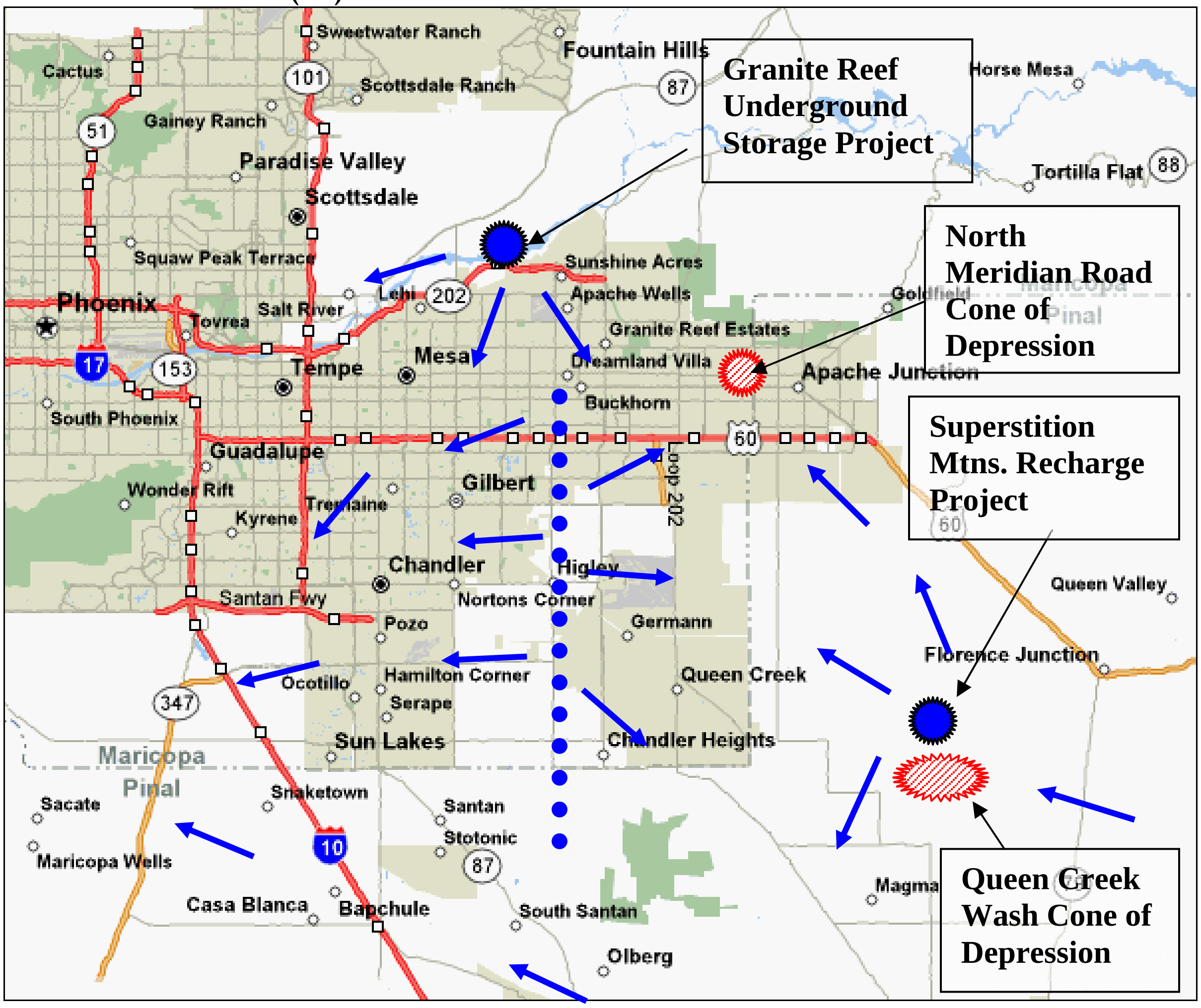


Groundwater Flow Direction

Recharge Project

Cone of Depression

Figure 2
Base Case Scenario (S1)



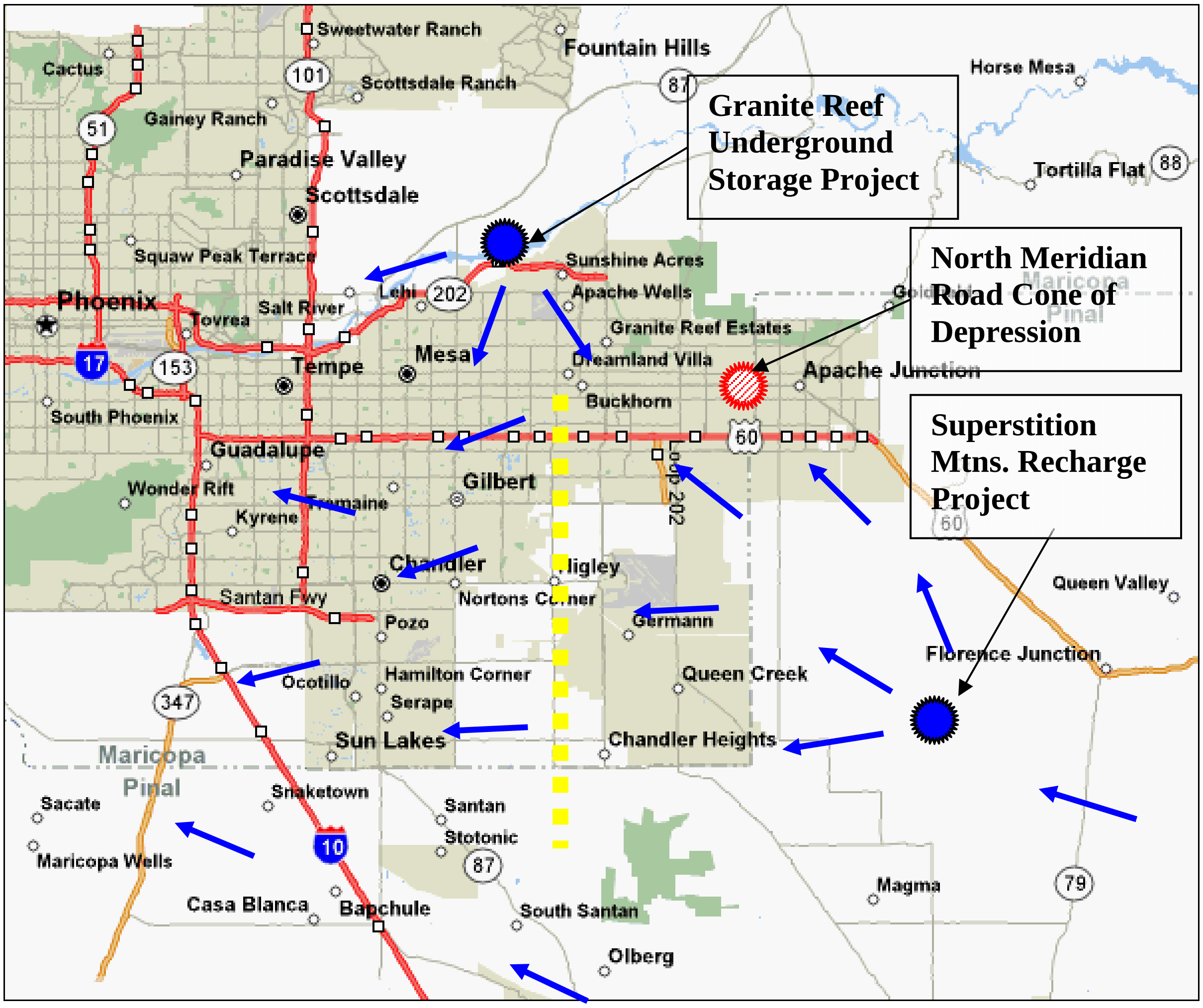
Groundwater Flow Direction

Recharge Project

Cone of Depression

Groundwater divide – groundwater is moving east or west of this line

Figure 3
Scenario S2



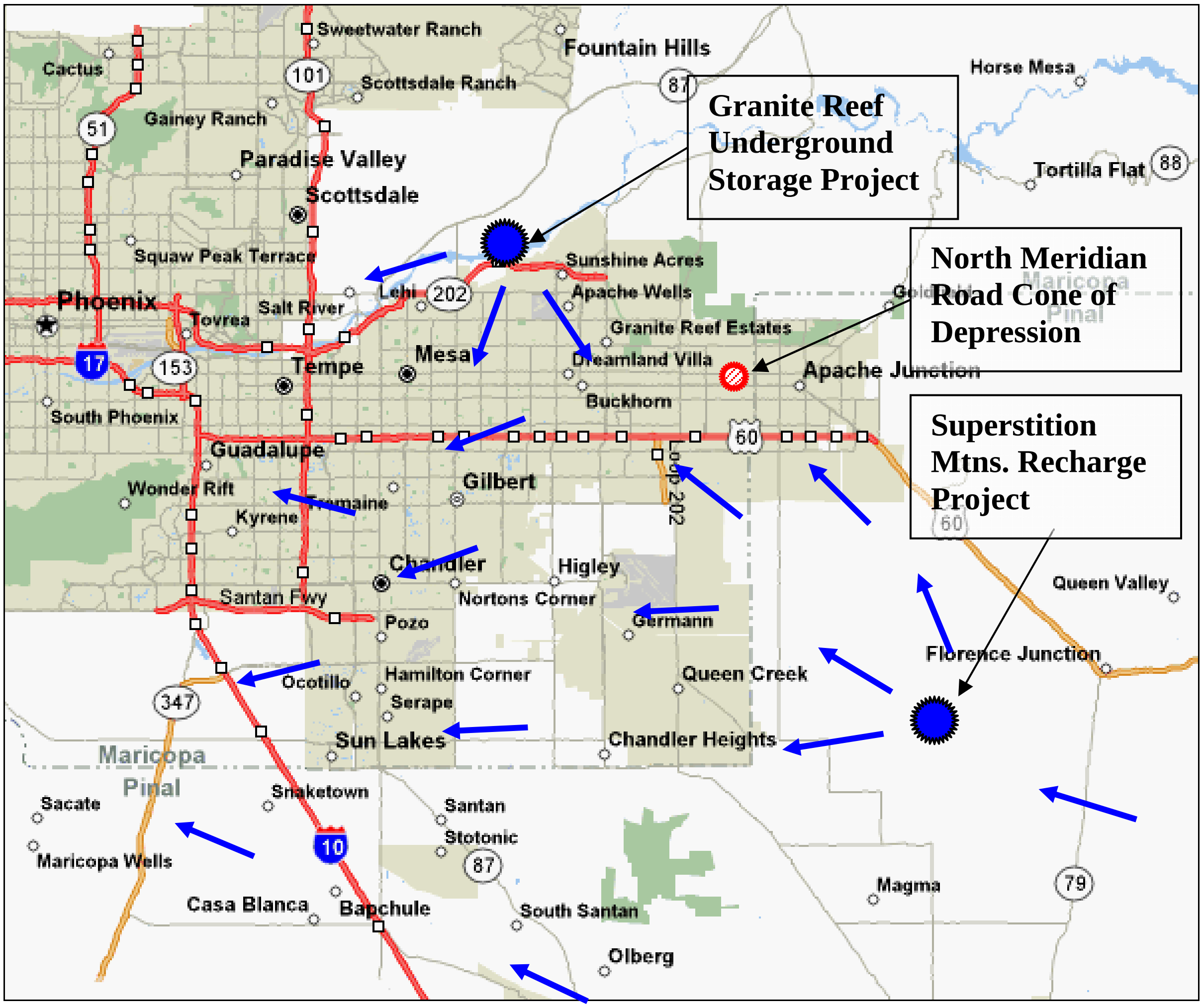
Groundwater Flow Direction

Recharge Project

Cone of Depression

Groundwater inflection line – groundwater to the west is declining; groundwater to the east is rising

Figure 4
Scenario S3



Groundwater Flow Direction

Recharge Project

Cone of Depression

Table 1 - Scenario Summary

Scenario Number	Scenario Description	Purpose of Scenario	**Pumping** Total East Valley Year 2100	**Pumping** North Meridian Road/ Florence Jct - Year 2100	**Cones of Depression** Annual decline rate and depth to groundwater (DTW) Year 2100	**General Groundwater Levels** (Annual decline rate and depth to groundwater (DTW) in year 2100)	
						Maricopa County Area	Pinal County Area
1	Base Case - Business as usual	No Coordinated Planning	645,000 af/yr	103,000 af/yr	**North Meridian Road** 3 ft/year decline 800 ft DTW **Queen Creek Wash** 3 ft/year decline 700 ft DTW	1 ft/year decline 200 to 300 ft DTW	1 ft/year decline 300 to 600 ft DTW
2	No New Pumping after 2020	Pumping equals recharge	588,000 af/yr	59,000 af/yr	**North Meridian Road** 2 ft/year decline 700 ft DTW	1 ft/year decline 200 to 300 ft DTW	2 ft/year rise 100 to 200 ft DTW
3A	Manage Cones of Depression	Mitigate North Meridian Road cone of depression by moving pumping south	622,000 af/yr	80,000 af/yr	**North Meridian Road** 2 ft/year decline 700 ft DTW	1 ft/year decline 200 to 300 ft DTW	1 ft/year decline 300 to 600 ft DTW
3B	Manage Cones of Depression	Mitigate North Meridian Road cone of depression by moving pumping to northwest	622,000 af/yr	80,000 af/yr	**North Meridian Road** 1 ft/year decline 600 ft DTW	1 ft/year decline 200 to 300 ft DTW	0.5 ft/year rise 200 to 400 ft DTW
3C	Manage Cones of Depression	Mitigate North Meridian Road cone of depression by moving pumping south and reducing Superstition Vista's pumping	608,000 af/yr	66,000 af/yr	**North Meridian Road** 1 ft/year decline 600 ft DTW	1 ft/year decline 200 to 300 ft DTW	1 ft/year rise 200 to 400 ft DTW

Notes:

1. DTW: Depth to Groundwater
2. The groundwater model was designed to predict the average groundwater levels in a one-mile grid. Within each square mile grid there may be localized cones of depression or groundwater mounds.
3. Depth to groundwater is reported for the central aquifer region. The groundwater levels near the mountains are much more sensitive to pumping and recharge and are not reported in this Table.
4. The DTW in the cones of depression are reported as the water levels averaged within a square mile. Individual wells may see much greater pumping levels.
5. North Meridian Road/Florence Junction Area is the area east of the Central Arizona Project Canal and includes the following Water Planning Areas: Apache Junction, Arizona Water Company, and Maricopa East.
6. The Maricopa County Area is generally the area west of Higley Road.
7. The Pinal County Area is the area east of Higley Road.

References:

ADWR, 1999. "Third Management Plan for the Phoenix Active Management Area, 2000-2010"

ADWR, 1993. Model Report No. 6. "A Regional Groundwater Flow Model for the Salt River Valley – Phase I, Phoenix Active Management Area, Hydrogeologic Framework and Basic Data Report"

ADWR, 1994. Model Report No. 8. "A Regional Groundwater Flow Model for the Salt River Valley – Phase II, Phoenix Active Management Area, Numerical Model, Calibration, and Recommendations"

ADWR, 1996. "Analysis of Future Water Use and Supply Conditions: Current Trends Alternative 1989-2025". An Application of the Regional Groundwater Flow Model of the Salt River Valley, Arizona.