2019 PINAL MODEL

AND

100-YEAR ASSURED WATER SUPPLY PROJECTION TECHNICAL MEMORANDUM

OCTOBER 11, 2019

2019 Pinal Model and 100-Year Assured Water Supply Projection

Technical Memorandum

October 11, 2019

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List of Acronyms

AAWS	Analysis of Assured Water Supply
ACM	Alternative Conceptual Models
ADWR	Arizona Department of Water Resources
AF	Acre-Feet
AFA	Acre-Feet per Year (Annually)
AMA	Active Management Area
ASTM	American Society for Testing and Materials
AWC	Arizona Water Company
AWS	Assured Water Supply
AZGS	Arizona Geological Survey
BC	Boundary Condition
CAGRD	Central Arizona Groundwater Replenishment District
CAIDD	Central Arizona Irrigation and Drainage District
CAM	Central Arizona Model
CAP	Central Arizona Project
CAWS	Certificate of Water Supply
CDL	Cropland Data Layer
CFD	Cubic Feet per Day
DAWS	Designation of Water Supply
ESRV	East Salt River Valley
FLTSC	Future Long-Term Storage Credit
GFR	Grandfathered Right
GRIC	Gila River Indian Community
GSF	Groundwater Savings Facility
GW	Groundwater
GWSI	Groundwater Site Inventory
HARN	High Accuracy Reference Network
HIDD	Hohokam Irrigation and Drainage District
HLTSC	Historic Long-Term Storage Credit
HOB	Head Observations
ITD	Information Technology Department
Kx	Horizontal Hydraulic Conductivity
LCU	Lower Conglomerate Unit
LTSC	Long-Term Storage Credit
MSIDD	Maricopa-Stanfield Irrigation and Drainage District
NAD	North American Datum
PCC	Program, Certificate and Conveyance
QC	Quality Control
RoGR	Registry of Grandfathered Rights
RRA	Replenishment Reserve Account
SCIDD	San Carlos Irrigation and Drainage District
SRP	Salt River Project
SRV	Salt River Valley
SVD	Singular Value Decomposition
USF	Underground Storage Facility
USGS	United States Geological Survey

Background

The Pinal AMA (Active Management Area) groundwater flow model was originally developed by the Arizona Department of Water Resources (ADWR) in 1990 as a two-layer, finite-difference groundwater flow model using the USGS MODFLOW code (Corkhill and Hill, 1990). A major update was performed in 2014 by ADWR which included a steady state (circa 1923) and transient (1923 – 2009) calibration with several other improvements listed in the published model report (Liu, et.al, 2014). The 2014 Pinal model used MODFLOW-2005 (Harbaugh, 2005). Since 2014, ADWR has updated the model with annual pumping and recharge data from 2010 through 2015 and made other modifications.

This report documents ADWR's 2019 Pinal Model, which includes annual updates, structural and other modifications to the 2014 Pinal groundwater flow model, and results from a 100-year Assured Water Supply (AWS) projection. The recent structural modifications to the 2019 Pinal AMA groundwater flow model were made mainly to address differences found between the simulated thickness of the aquifer materials and the thickness described in numerous well drillers' logs. The structural modifications required adjustments to maintain a comparably low amount of model error.

The 100-year AWS projection, and corresponding results, presented in this report were conducted using the 2019 Pinal Model. Results of the 100-year AWS projection are generally indicative of future groundwater conditions based on current estimates of locations and volumes of future pumping and recharge.

Modifications to the Pinal AMA Groundwater Flow Model

Since publication of the 2014 Pinal model update (Liu, et.al, 2014) several updates and improvements have been made, including:

1. Updated pumping information 2010 – 2015,
2. Updated recharge estimates 2010 -2015,
3. Improvements to the Numerical Solver Settings and Layer Property Flow (LPF) packages,
4. Revisions to the Central Arizona Model (CAM) grid,
5. More comprehensive head targets and use of the head observation (HOB) package,
6. Conversion of three out of four boundary conditions from specified head to specified flux,
7. Structural modifications to the model geology, increasing model thickness in several areas.

The first six modifications are summarized in Appendix A.

The most significant update to the Pinal model is the structural modifications, summarized below. A more detailed description of the structural modifications is provided as **Appendix B.**

Structural Modifications to the Pinal AMA Groundwater Flow Model

Modifications were made to the model layer thicknesses based on information in ADWR databases, numerous well drillers logs, and sediment thicknesses mapped by the Arizona Geological Survey (AZGS). The areas where differences between modeled and observed layer thickness were noted were primarily in areas of shallow depth to bedrock. In these areas, log descriptions often report semi-consolidated to consolidated materials such as conglomerates, decomposed granite, volcanics and bedrock that have uncertain water bearing properties. In many areas it was found that numerous water-producing wells were drilled below the bottom depth of the 2014 Pinal model, and it was therefore appropriate to increase the thickness of the lowermost model layer (Layer 3) that represents the Lower Conglomerate Unit (LCU).

Other structural modifications to the 2014 Pinal model were made in the Florence area to recognize new geologic information and interpretations provided from a joint geologic study by the AZGS and the Salt River Project (SRP) of the Superstition Vistas Planning Area, Maricopa and Pinal Counties (Gootee et.al, 2017). Changes were also made in the East Salt River Valley (SRV) portion of the SRV model based on these data. Limited structural changes were also made within the Pinal model domain near the northeastern boundary of the Gila River Indian Community (GRIC) and within the SRV model domain near the northwestern boundary of the GRIC to improve the correspondence and transition between Pinal and SRV model geology in those areas. This resulted in some areas where sediment thickness was reduced. These structural modifications were made so that the geologic contacts between the two models would be seamless. **Figure 1** maps the change in total sediment thickness simulated by the 2019 Pinal Model after structural modifications were made and the basis for the changes. Further details on provided as **Appendix B.**

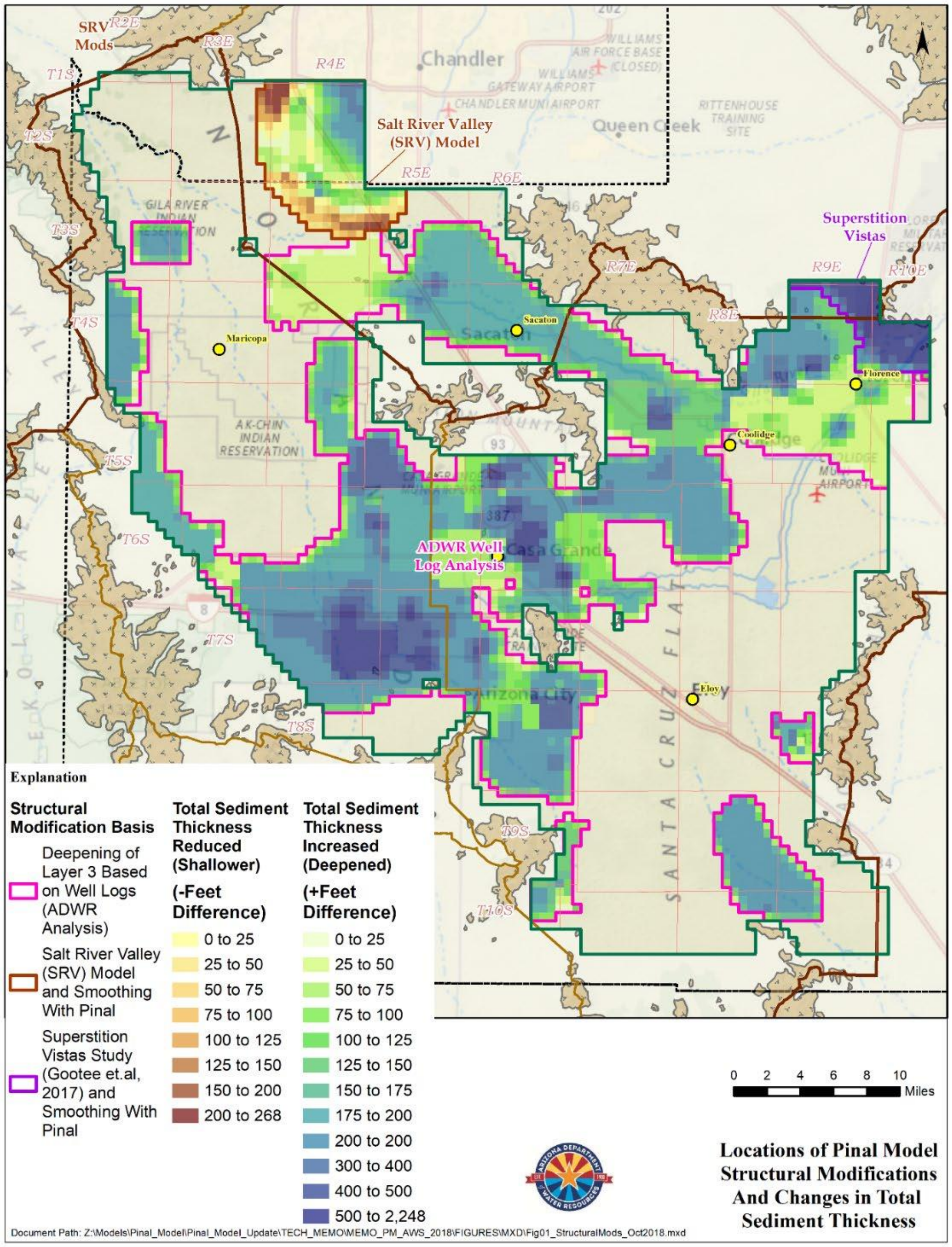

Figure 1. Locations of Structural Modifications and Changes in Total Sediment Thickness

The model incorporates modified geologic contact elevations that required adjusted horizontal hydraulic conductivity values in areas where structural modifications were made. Horizontal hydraulic conductivity was adjusted in model cells within all three model layers to maintain the Pinal model's original transmissivity distribution. Since the structural adjustments to the top and bottom elevations of each layer did not coincide with Kx zone boundaries, the adjusted Kx values are slightly different than the original published values. **Figures 2 and 3** show the Kx values before and after structural modifications.

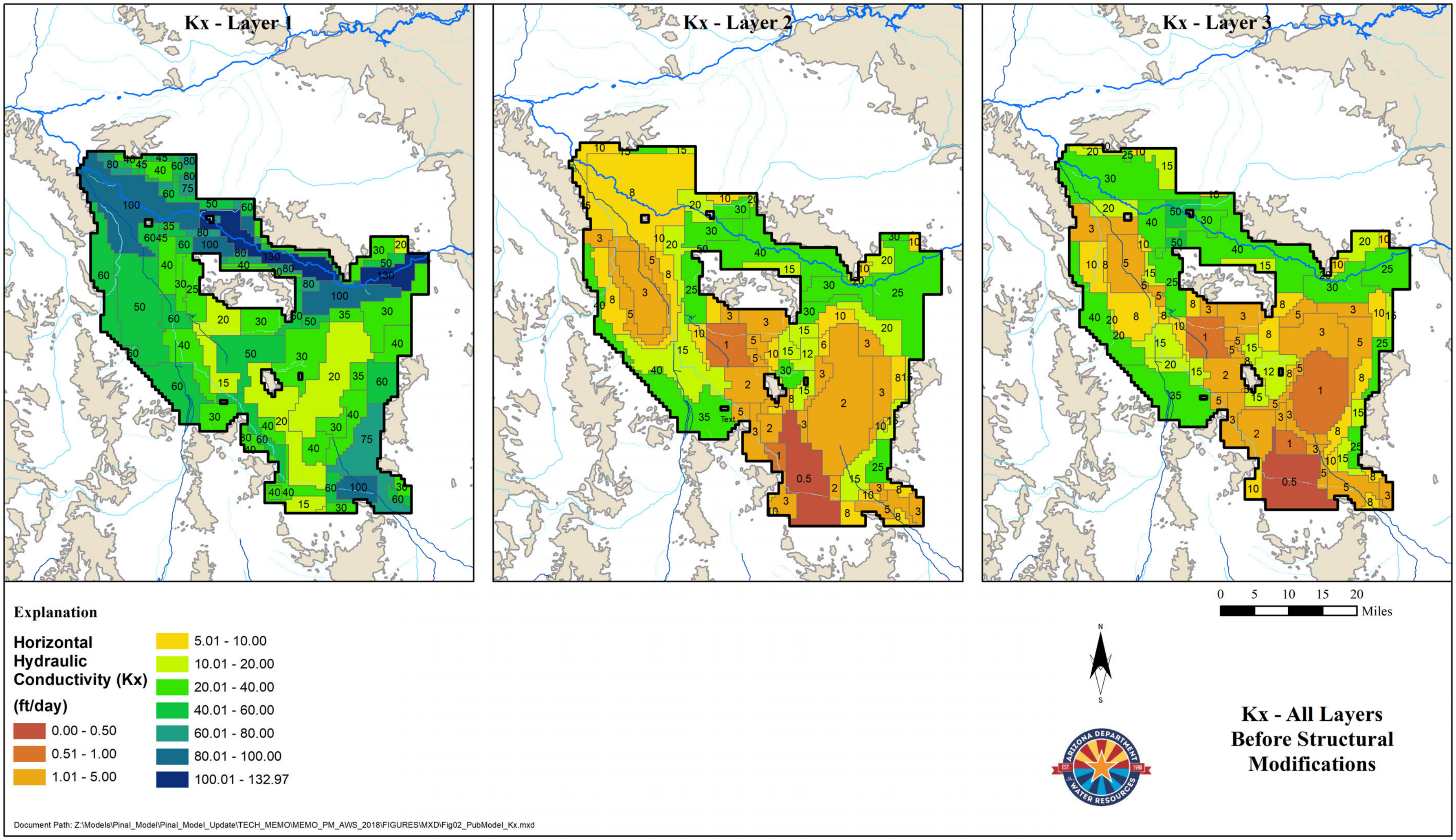

Figure 2. Horizontal Hydraulic Conductivity (Kx) Before Structural Modifications

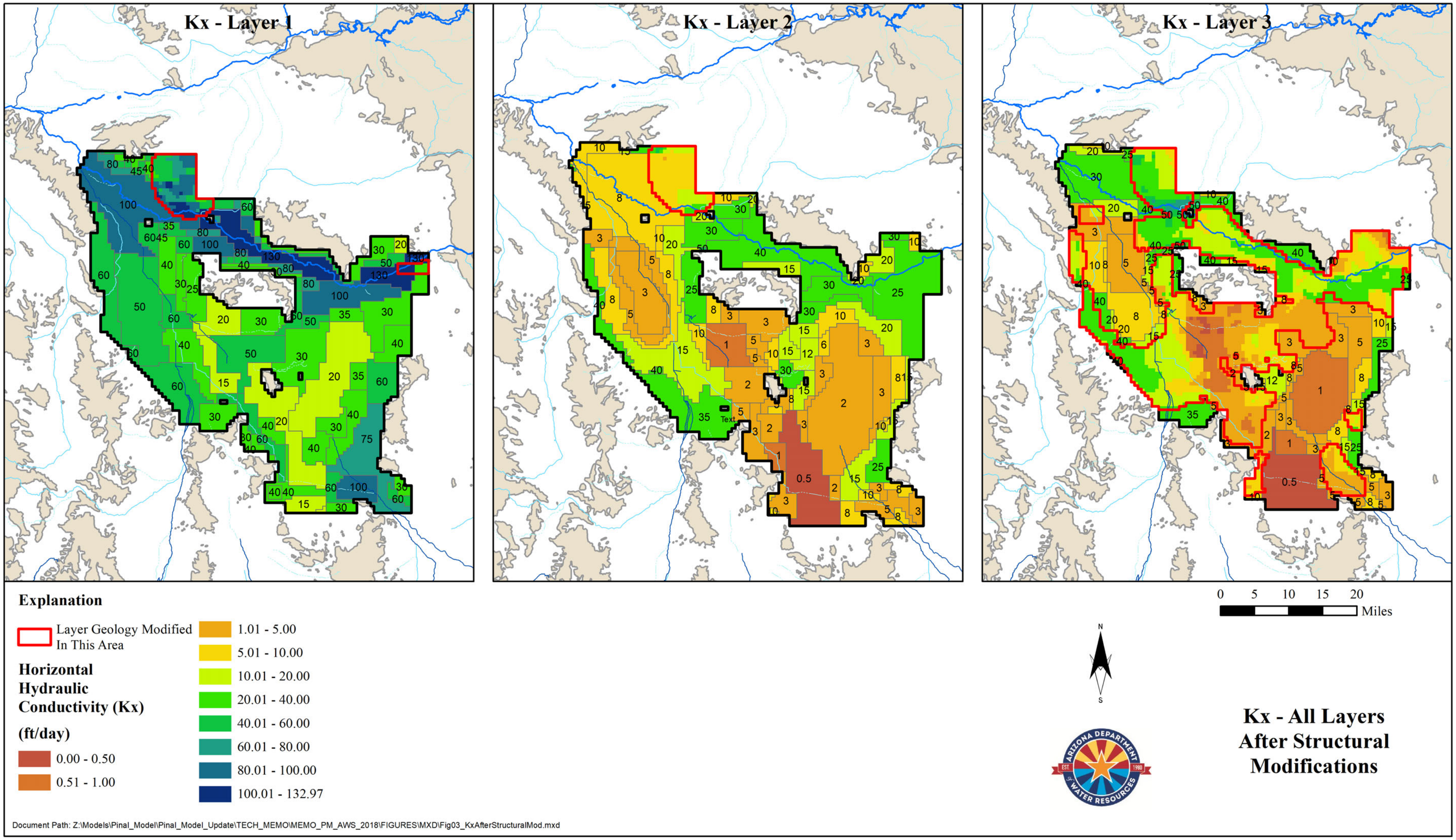

Figure 3. Horizontal Hydraulic Conductivity (Kx) After Structural Modifications

Comparative Residuals

Head residuals, in units of feet above mean sea level (amsl), were calculated by subtracting the simulated head from the measured head for the model before and after structural modifications and hydraulic conductivity adjustments (**Table 1**). These statistics are based on head observations alone, with each observation given the same weight. **Figures 4 and 5** display the simulated vs. observed values and residuals over time before and after the modifications. These comparisons indicate that model error before and after structural modifications and adjustments to the Kx values is very similar. Note that the residual count is slightly different because when the same set of head targets were used on the model prior to structural modifications, 99 heads were simulated to be dry. Summary statistics based on a dataset with dry simulated heads cannot be used. The comparison indicates that the mean residual is slightly better (closer to zero), while the absolute mean residual is slightly worse (further from zero) after the structural modification.

Table 1. Head Residual Statistics (in feet) Before and After Structural and Kx Modifications

	Pinal Model Steady-State - 2015 Before Structural Modifications and Original Kx	**Pinal Model Steady-State - 2015 After Structural Modifications and Adjusted Kx**
Residual Count:	21,057	21,156
Mean:	**-1.3**	**-0.9**
Median:	-5.8	-6.2
Count Pos	9,265	9,222
Count Neg	11,792	11,933
Percent Pos	44%	44%
Percent Neg	56%	56%
Count Sim Dry	0	0
StDev:	52.70	53.06
Max:	439.4	430.3
Min:	-353.0	-351.8
Range:	792.4	782.0
Model Error:	4.22%	4.24%
Abs Mean	**36.38**	**36.78**
SumSq	**58,507,646.91**	**59,584,339.30**
Max ob Elev	1,761.50	1,761.50
Min Ob Elev	511.30	511.30
Ob Elev Range	1,250.20	1,250.20

Positive = Obs > Sim (Model is under simulating

Negative = Obs < Sim (Model is oversimulating)

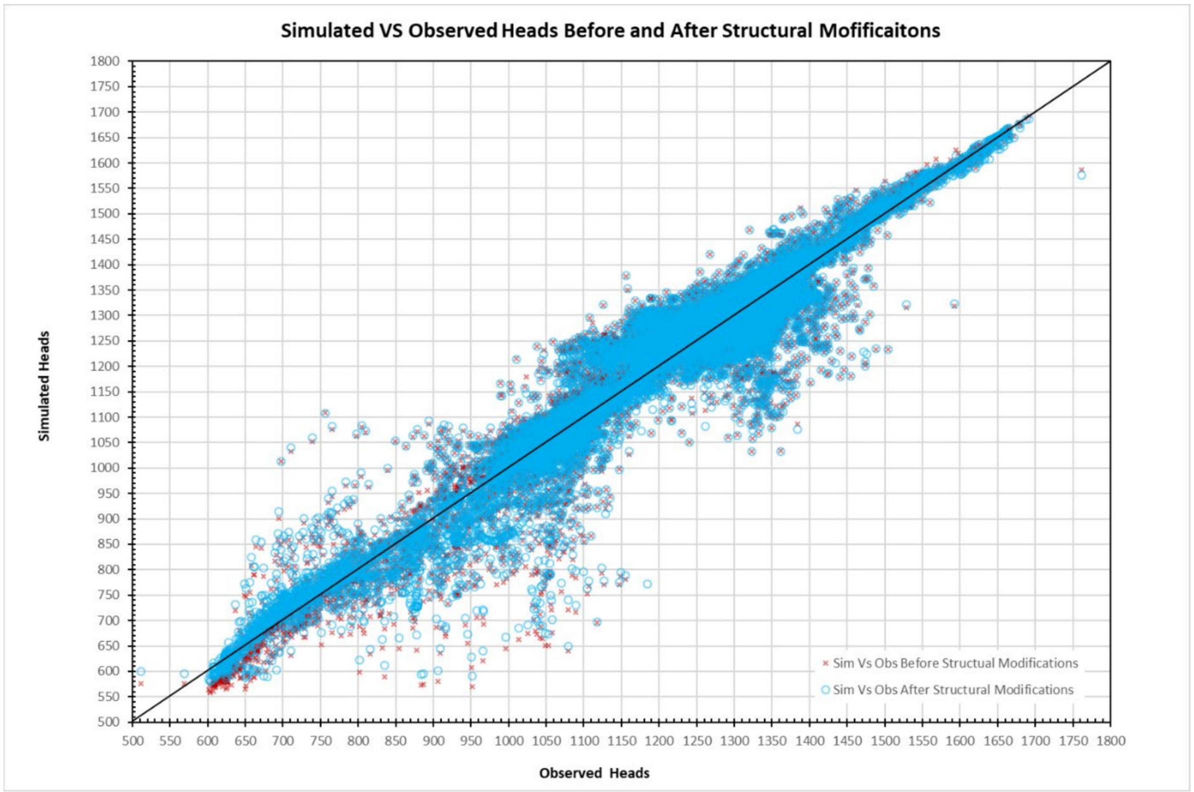

Figure 4. Simulated Vs. Observed Residuals

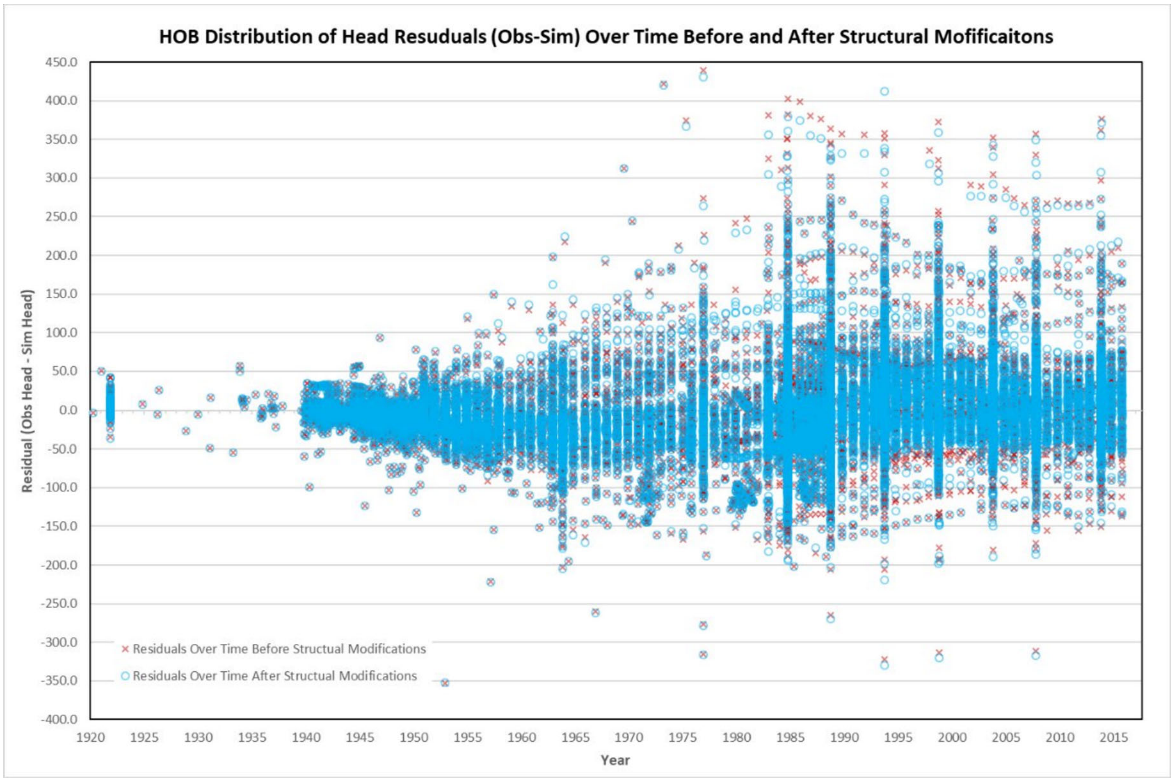

Figure 5. Residuals Over Time

Appendix C includes maps of groundwater elevation residuals and timeseries of observed vs simulated water levels at 12 locations throughout the basin over the course of 12 basin "sweep years", simulated before and after structural modifications to the model. Water level measurements recorded during a "basin sweep" form part of the single largest available dataset of nearly-simultaneous observations and provide a more complete snapshot of groundwater conditions on a regional scale. The spatial distribution of residuals remains largely unchanged between model simulations performed pre- and post- structural modifications.

Model Sensitivity and Calibration

A manual sensitivity analysis was conducted on the 2014 Pinal model. Additional sensitivity analysis and inverse model testing was conducted on the 2019 Pinal Model using the latest available calibration target data and a model-independent parameter estimation and uncertainty analysis utility (PEST) (Doherty, 2015). Inverse modeling is a commonly used method for evaluating a model's performance relative to an observed period of record and determining its ability to forecast (Anderson et. al., 2015).

Results of the 2019 Pinal Model sensitivity analysis indicate that the model provides an acceptable representation of the groundwater flow system in the Pinal AMA with respect to the sensitivity, correlation, and confidence intervals of key parameter values included in the non-linear regression, based on available calibration data. With respect to the 2019 Pinal Model's ability to forecast, the values of invariant aquifer parameters estimated during the calibration period are shown to be valid for future projections. Furthermore, the 2019 Pinal Model generally provides a solution that, overall, minimizes model error in a regional-scale context. Although the 2019 Pinal Model represents regional-scale processes and annualized stress periods, this model may be used for site specific analysis. Additional information on model sensitivity and calibration testing and results is presented in **Appendix D**.

100-year AWS Projection

Introduction

A 100-year AWS projection was completed using the 2019 Pinal Model described above which included all issued AWS demands for analyses, certificates and designations. Demands for pending AWS applications were not included in this projection.

The purpose of this projection was to model existing and projected future groundwater use and recharge over the 100-year projection period, quantify any unmet demands by sector and well within the model domain, and provide the spatial extent of the depth to water after 100 years of pumping.

The 2019 Pinal Model with 100-year AWS projection was completed using the MODFLOW-2005 version of MODFLOW. Datasets were pre- and post-processed using ArcMap, Access databases, Python scripts, Excel and Groundwater Vistas.

Major Assumptions For the 100-Year AWS Projection

The 100-year AWS projection is based on several assumptions related to existing and future groundwater water use and recharge in the Pinal AMA, which include:

1. Municipal and Industrial Groundwater Uses

    a. Existing (current) municipal and industrial groundwater withdrawals are based on reported 2015 well-specific Registry of Grandfathered Rights (RoGR) pumping data.
    b. Some of the existing municipal groundwater pumping is serving built-out lots within AWS developments.
    c. Existing municipal and DAWS demands are simulated in the location of existing wells.
    d. Agricultural lands with AWS development overlays/footprints are assumed to urbanize at the beginning of the projection period (2016).
    e. For partially built-out certificates, any issued, but currently unserved, AWS demands are calculated by subtracting the reported 2016 groundwater uses for existing AWS developments from their full issued AWS volumes and are simulated to begin pumping in 2016.
    f. For fully built-out certificates, current demands are assumed to be represented in the existing municipal pumping and no new demands were created, although current demands were generally less than the original issued volume.
    g. For designations, rates are increased to the full issued volumes beginning in 2016 and pumping assigned to existing wells.
    h. Projected future pumping to serve unbuilt lots within AWS developments is simulated only within the footprints of AWS developments.
    i. Pumping associated with exempt wells is not included.

2. Agricultural Groundwater Uses

    a. Existing agricultural groundwater withdrawals are based on reported 2015 well-specific RoGR pumping data.
    b. Future agricultural water use is projected for the Central Arizona Irrigation and Drainage District (CAIDD), the Maricopa-Stanfield Irrigation and Drainage District (MSIDD), the Hohokam Irrigation and Drainage District (HIDD), the San Carlos Irrigation and Drainage District (SCIDD), non-ID IGFRs, the Gila River Indian Community (GRIC), the Ak-Chin Indian Community (Ak-Chin). **Appendix E** provides more detail on the projection of agricultural water use and incidental recharge.

c. Future agricultural acreage and water demand (consisting of a combination of groundwater and Central Arizona Project (CAP) surface water) is projected for CAIDD and MSIDD based on information supplied by the two irrigation districts and estimates developed by ADWR.
d. Future agricultural water demand (consisting of a combination of groundwater and CAP) is projected for HIDD based on estimates developed by ADWR.
e. Future agricultural water demand (consisting of a combination of groundwater, CAP and Gila River surface water) is projected for SCIDD based on estimates developed by ADWR.
f. Future agricultural water demand (consisting of a combination of groundwater, CAP surface water, and Gila River surface water) for the GRIC is based on estimates developed by ADWR.
g. Future agricultural water demand (consisting of CAP surface water) for the Ak-Chin is based on estimates developed by ADWR.
h. Future agricultural water demand (consisting of groundwater) for non-Indian, non-irrigation district IGFRs is based on estimates developed by ADWR.
i. Within the Analysis of Assured Water Supply (AAWS) and Certificate of Assured Water Supply (CAWS) development footprints, agricultural wells that were active in 2015 are not assigned any further pumping during the 2016 – 2115 projection period.

3. Projected Recovery of Long-Term Storage Credits and Groundwater Replenishment

   a. All existing Central Arizona Groundwater Replenishment District (CAGRD) replenishment obligations accrued in the Pinal AMA will be met by using previously accrued Central Arizona Water Conservation District (CAWCD)/CAGRD Long-term Storage Credits (LTSCs), excluding a small volume set aside as Replenishment Reserve Account (RRA) credits.
   b. Future CAGRD replenishment obligations will be met through storage of CAP water in Groundwater Savings Facilities (GSFs) located near the AWS developments where the replenishment obligations were incurred.
   c. Total Pinal AMA Replenishment obligations are limited to a maximum annual rate of 15,500 AFA based on the CAGRD 2015 Plan of Operation (CAGRD, 2015).
   d. Non-CAGRD LTSCs accrued as of the end of 2015 at 8 Underground Storage Facilities (USFs) and four GSFs were removed at a rate of 1/100th of the total for each location over the next 100 years.

4. Recharge

   a. Non-CAGRD CAP GSF water making up a portion of three irrigation district supplies are treated as accruing FLTSCs. However, these credits will be removed in the same year, at a rate of 95%, thereby leaving 5% of the recharged volume in the aquifer ("cut to the aquifer").
   b. Future agricultural incidental recharge will be applied evenly on remaining active irrigable acres without AWS development overlays at a 34% rate based on current dominant use of flood irrigation in Pinal and will not be subjected to any lagging.
   c. Within GRIC and Ak-Chin lands agricultural incidental recharge is based on estimates developed by ADWR and are estimated to be 26% and 33.4%, respectively.
   d. Stream and canal recharge follow the previous pattern estimated from 1995 – 2010 that is repeated every 16 years through the projection period.
   e. All other types of recharge (Urban, Mountain Front, Picacho Reservoir) remain at 2014 rates.
   f. No recharge is simulated at USFs for accrual of future long-term storage credits (FLTSCs) because they cannot be relied upon by non-storing entities. In addition, the potential volume of future recharge at USFs is considered insignificant over the 100-year projection based on the minimal volume of storage historically at USFs.

5. Groundwater underflows at model boundaries are held constant at 2009 published model rates from 2010 – 2115 as described in **Appendix A**.

Model Assigned Pumping Demands

Assured Water Supply Demands

Information on current water use per lot, including aerial photography and CAGRD reports, was reviewed by ADWR to determine current demand for the partially or fully built-out developments. Current demand is included in existing withdrawal data from RoGR. **Appendix F** includes detailed demand information for the analyses, certificates and designations included in this model projection.

Table 2 summarizes the type, number and annual volume of issued AWS demands. There are two developments, one CAWS and one AAWS, located within the Pinal AMA but outside the model domain. Demands associated with these two developments, totaling 326 AFA, were not included in this model projection. The locations of the AWS developments are shown on **Figure 6.**

Table 2. Summary of Pinal Model Area Issued, Developed and Baseline Model Assigned Adequate and Assured Water Supply (AWS) Volumes

Adequate and Assured Water Supply (AAWS) Type	Analyses (AAWS)	Certificates (CAWS)	Designations (DAWS)	Totals
Total Count in Pinal AMA	41	210	6	**257**
Originally Issued Demand (AFA)	127,287	55,775	48,865	**231,927**
Count Outside Model Area (Demand Not Simulated)	1	1	0	**2**
Issued Demands Outside Model Area	314	12	0	**326**
Certificates Issued from Original Analysis (AFA)	10,101	0	0	**10,101**
Summary of Demands Within Model Area				
Count In Model Area (Demand Simulated)	40	209	6	**255**
Remaining Issued Demand (AFA)[1]	116,872	55,763	48,865	**221,500**
Subdivisions Enrolled in CAGRD	0	135	0	**135**
Currently Developed Demand (AFA)	0	5,991	10,611	**16,602**
Committed Demand Based on Remaining Lots (AFA)[2]	116,872	48,754	38,254	**203,880**
Model Projected GW Demand (AFA)	116,872	48,754	48,865	**214,491**
100-Year Cumulative Demands (AF)	11,687,181	4,875,410	4,886,490	**21,449,081**
Extinguishment Credits (AFA)	0	4,288	0	**4,288**
GW Allowance (AFA)	0	29,877	0	**29,877**
Replenishment Obligation (AFA)	0	15,500	0	**15,500**
Cumulative 100-Year Replenishment Obligation (AF)	0	1,550,000	0	**1,550,000**
CAGRD Credits Used First 20.66 Years (2016 - 2035)[3]	0	320,279	0	**320,279**
Remaining Replenishment Occurring 2035-2115[4]	0	1,229,721	0	**1,229,721**

1. The remaining issued demand reflects the original issued volumes minus volumes issued outside the model domain and minus the 10,101 acre-feet per year of Certificate demands issued on Analyses.
2. Currently developed lots are estimated to be using less water than the issued demand for those lots. Therefore, Committed Demand Based on Remaining Lots does not equal Issued Demand minus Currently Developed Demand.
3. 320,279 non-RRA CAGRD Credits/15,500 Years = 20.66 Years. 5,220.75 AF Obligation for partial year 2035.
4. 5,220.75 in 2035 + 15,600 Year 2036 - 2115 (79 Years)

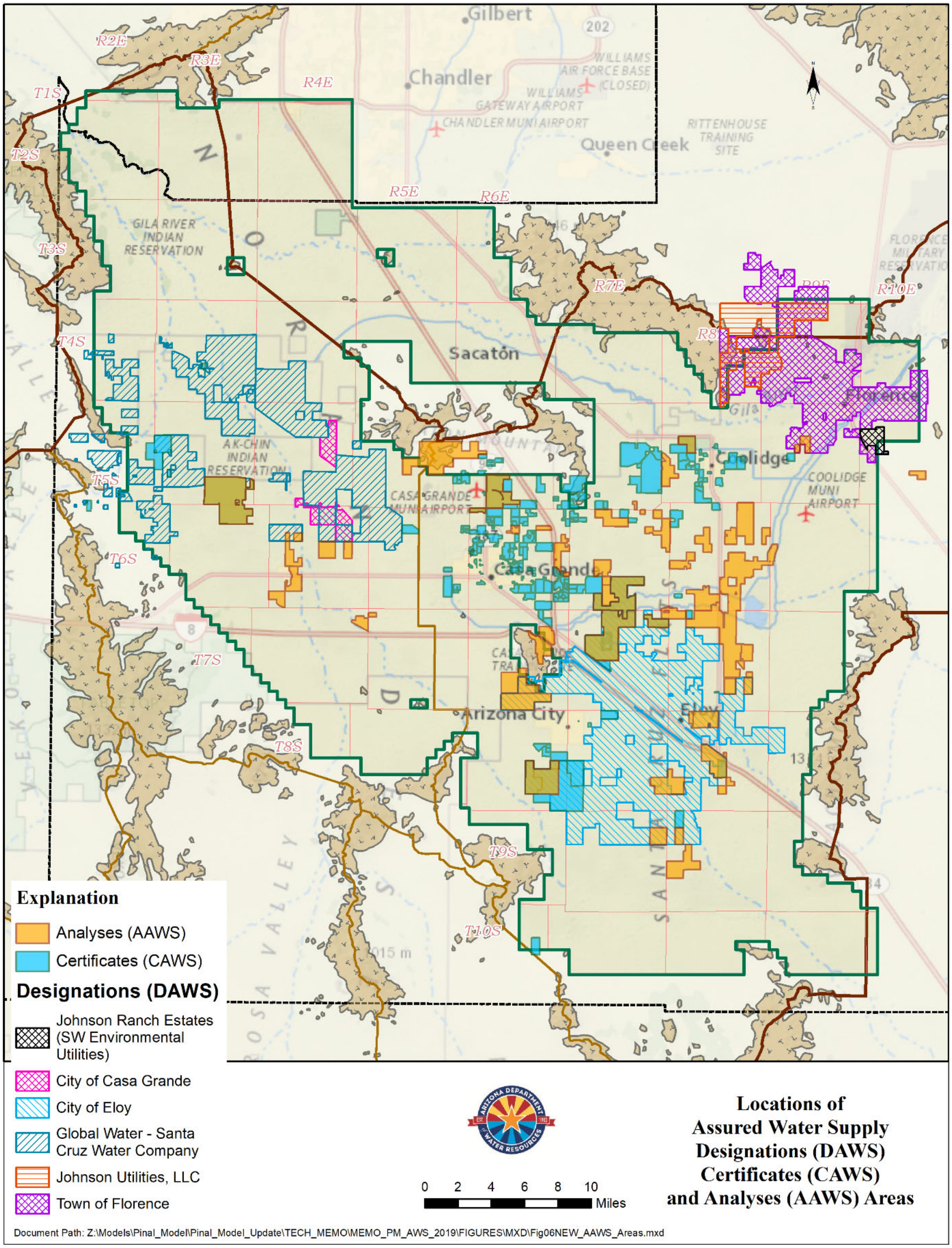

Figure 6. Locations of Designations, Certificates and Analyses Areas in the Pinal Model Area

Certificates of Assured Water Supply

There are 209 issued CAWS for developments within the model domain. Each CAWS falls into one of three categories:

- Fully Built Out: There are 49 issued CAWS developments with zero remaining lots to be built out. No new pumping was assigned in the 100-year projection for these CAWS developments. The total current demand is estimated to be 1,967 AFA for this category of certificates. The total current demand is accounted for at 2015 RoGR pumping data.

- Partially Built Out: There are 75 issued CAWS developments that are partially built out. Within this category of certificates, approximately 23% of the lots (7,334 of 31,598 lots) have been built. The current demand within these developments is estimated to be 4,024 AFA. The current demand is accounted for in 2015 RoGR pumping data. The remaining issued, but unserved, demand is included in the 100-year projection.

- Not Yet Built: There are 85 issued CAWS developments that have no developed/built lots and the fully issued demand of 32,097 AFA is included in 100-year projection for these CAWS developments.

Appendix F provides detailed information on CAWS developments.

Analyses of Assured Water Supply

There are 40 issued AAWS within the model domain that have a total net issued demand of 116,872 AFA. Any issued demands for issued CAWS that rely on an AAWS for physical availability were subtracted from the gross issued AAWS total demand to produce the net AAWS demand. The net issued AAWS demand of 116,872 AFA was included in the 100-year projection.

Appendix F provides detailed information on AAWS developments.

Designations of Assured Water Supply

The Designations of Assured Water Supply (DAWS) were simulated at fully issued rates. However, based on the City of Eloy's request for modification of their DAWS, the total for the City was reduced significantly from the originally issued volume of 49,159 AFA to 3,101 AFA for their groundwater portion. The reduced volume request of 3,101 AFA was included in this model projection.

Appendix F provides detailed information on DAWS developments.

Existing Sector Demands

Municipal and Industrial Demands

Withdrawals for existing non-DAWS municipal and industrial demands were kept at 2015 rates and locations. Demands for exempt wells were not included in this projection due to the minimal demand associated with exempt wells. ADWR estimated that exempt well pumping would represent less than 2% of all current pumping in the Pinal AMA.

Appendix F provides detailed information on municipal and industrial demands.

Agricultural Demands

Over the 100-year projection period, groundwater demand for non-Indian irrigation districts was projected to increase corresponding to reductions in the CAP Ag Pool supplies but decrease corresponding to reduction in farm acres due to urbanization. Agricultural lands with AWS development overlays/footprints are assumed to urbanize (taken out of agricultural production) at the beginning of the 100-year projection period (2016). Agricultural lands without AWS overlays/footprints were assumed to remain in production at the beginning of the 100-year projection and the associated water demand was applied to these remaining lands. Adjustments to the number of irrigated acres and associated water demand were made to some agricultural lands as described below.

This 100-year projection assumes full Ag Pool deliveries through 2030. CAP GSF water is projected to be available to the CAIDD, MSIDD and HID over the 100-year projection period and groundwater pumping by irrigation districts is limited to maximum permitted volumes. **Appendix E, Table E-1** provides the projected water supplies for agriculture by entity used in this 100-year projection.

CAIDD and MSIDD provided farmed acres and water use information to calculate an estimated district total demand on an annual basis through the 100-year projection period. ADWR's draft Pinal 4th Management Plan (4MP) projections include total demand estimates for each district. Demands for CAIDD and MSIDD were updated for this 100-year projection based on the averaging of projections from ADWR's draft Pinal 4MP and those provided by the MSIDD and CAIDD. ADWR and district-provided estimates of the future total active acres and water sources per district were different. However, estimates from the two irrigation districts and ADWR displayed a trend of decreasing water use through the projection period. CAP Ag Pool water and GSF water were incorporated into the total demand projections, with groundwater assumed to make up the balance of the total demand.

Demand estimates for SCIDD were based projections from ADWR's draft Pinal 4MP.

ADWR reviewed the total demand in the draft Pinal 4MP for HIDD. After accounting for significant urbanization, the total demand for HIDD was adjusted (reduced) based on historical irrigation rates within HIDD.

Demand estimates on the GRIC Reservation were based on ADWR's draft Pinal 4MP with an estimated incidental agricultural recharge rate of 26%.

The Ak-Chin Indian Community uses only CAP supplies and is projected to continue to use the same 72,000 AFA of CAP water with 24,048 AFA (33.4%) of incidental agricultural recharge evenly spread over the Ak -Chin Community lands.

Agricultural demand for non-Indian, non-irrigation district IGFRs is assumed to be met with groundwater and was based on the proportion of acres remaining after consideration of immediate urbanization by AWS development footprints.

Long-Term Storage Credit Removal

Pumping locations were added for eight USFs that have accumulated 14,556 AF of LTSCs as of the end of 2015. This volume was simulated to be removed at a uniform annual rate over 100 years at those locations. This projection assumes that no FLTSCs would be accrued at USFs during the 100-year projection period because entities may not rely (benefit) from LTSCs accrued by others. **Table 3** lists the USFs and the accumulated volumes of LTSCs.

This projection includes the removal of existing LTSCs accrued at GSFs as of the end of 2015, except for 320,279 AF of CAGRD credits which are not removed but extinguished for replenishment purposes in the early years of the projection to meet replenishment obligations. These CAGRD LTSCs were extinguished for replenishment purposes at a rate of 15,550 AFA as included in the approved 2015 CAGRD Plan of Operation. As a result, these existing LTSCs will cover the CAGRD replenishment obligation for the first 20.66 years (320,279/15,500) of the 100-year projection period.

The remaining balance of LTSCs accrued by other entities (1,155,437 AF) were removed from the model at a uniform annual rate over the 100-year projection period. These credits would not contribute to annual agricultural water use nor contribute to estimated agricultural incidental recharge over the 100-year projection period. **Appendix E** provides additional information on the LTSCs.

A small volume of CAGRD replenishment reserve account credits (3,823 AF) is not removed or extinguished for replenishment purposes.

FLTSCs projected to be accrued over the 100-year projection period from the storage of CAP water at GSFs are removed in the same year they were accrued with a residual 5% cut to the aquifer.

Additionally, GSF LTSCs were removed from existing wells within CAIDD, MSIDD and HID and on the GRIC. FLTSCs were assigned at the same locations on the CAIDD, MSIDD and HID and removed in the same year, with a residual 5% cut to the aquifer.

Table 3. Long-Term Storage Facilities and Credits (AF) Simulated Removal Between 2016 – 2115

Type	Facility Name	Facility Permit	LTSC Credits (As of the End of 2015)	Future Long-Term Storage Credits (FLTSC)
Underground Storage Facilities (USFs)	ARIZONA CITY SANITARY DISTRICT USF	71-209000	652	Note: Future long-term storage credits at USFs are not simulated in the model because they cannot be relied upon by non-storing entities.
	ANTHEM AT MERRILL RANCH RECHARGE FACILITY	71-211290	2,672	
	ELOY DETENTION CENTER USF	71-220045	3,220	
	TOWN OF FLORENCE	71-519876	565	
	HOHOKAM RECHARGE FACILITY #1	71-588559	1,145	
	ELOY RECLAIMED WATER RECHARGE PROJECT	71-591932	5,736	
	GRIC OLBERG DAM PILOT SCALE USF	71-224500	423	
	SUN LAKES AT CASA GRANDE EFFLUENT RECHARGE FACILITY	71-591938	143	
	USF Subtotal		**14,556**	

Table 3. (Cont.)

	Facility Name	Facility Permit	LTSCs (as of the End of 2015)	CAGRD Credits Used to Meet Replenishment Obligation	CAGRD RRA Credits Not Removed[1]	Remainder of LTSCs (as of the end of 2015) To Remove	Non-CAGRD CAP GSF FLTSC (2016 - 2115)	Non-CAGRD GSF 5% Cut to Aquifer	Remainder FLTSC To Remove (2016-2115)
Groundwater Savings Facilities (GSFs)	GILA RIVER INDIAN IRRIGATION & DRAINAGE DISTRICT GSF	72-211277	17,077			17,077	NA	NA	NA
	MARICOPA STANFIELD IIRRIGATION & DRAINAGE DISTRICT GSF	72-531381	725,835	122,010	3,823	600,001	1,609,048	80,452	1,528,596
	CENTRAL ARIZONA IRRIGATION & DRAINAGE DISTRICT GSF	72-531382	469,052	121,178	0	347,874	1,994,618	99,731	1,894,887
	HOHOKAM IRRIGATION AND DRAINAGE DISTRICT GSF	72-534489	267,576	77,091	0	190,485	1,013,482	50,674	962,808
	GSF Subtotal		**1,479,540**	**320,279**	**3,823**	**1,155,437**	**4,617,148**	**230,857**	**4,386,291**
Long-Term Storage Credit Totals			**1,494,096**	**320,279**	**3,823**	**1,155,437**	**4,617,148**	**230,857**	**4,386,291**

1. RRA = Replenishment Reserve Account

Well Locations for 2016 – 2115 Projection

Existing wells

Existing wells that were active in 2015 are used as locations to simulate demands for non-AWS sectors for the 100-year projection. However, agricultural wells located within AAWS/CAWS development footprints are removed from pumping during the 100-year projection period. Pumping to meet demands for the remaining agricultural lands is assigned to wells located on agricultural lands outside of AAWS/CAWS development footprints. **Figure 7** depicts the locations of existing wells active in 2015 and **Figure 8** shows those wells in relation to AAWS and CAWS footprints and which agricultural wells are removed from the pumping projection.

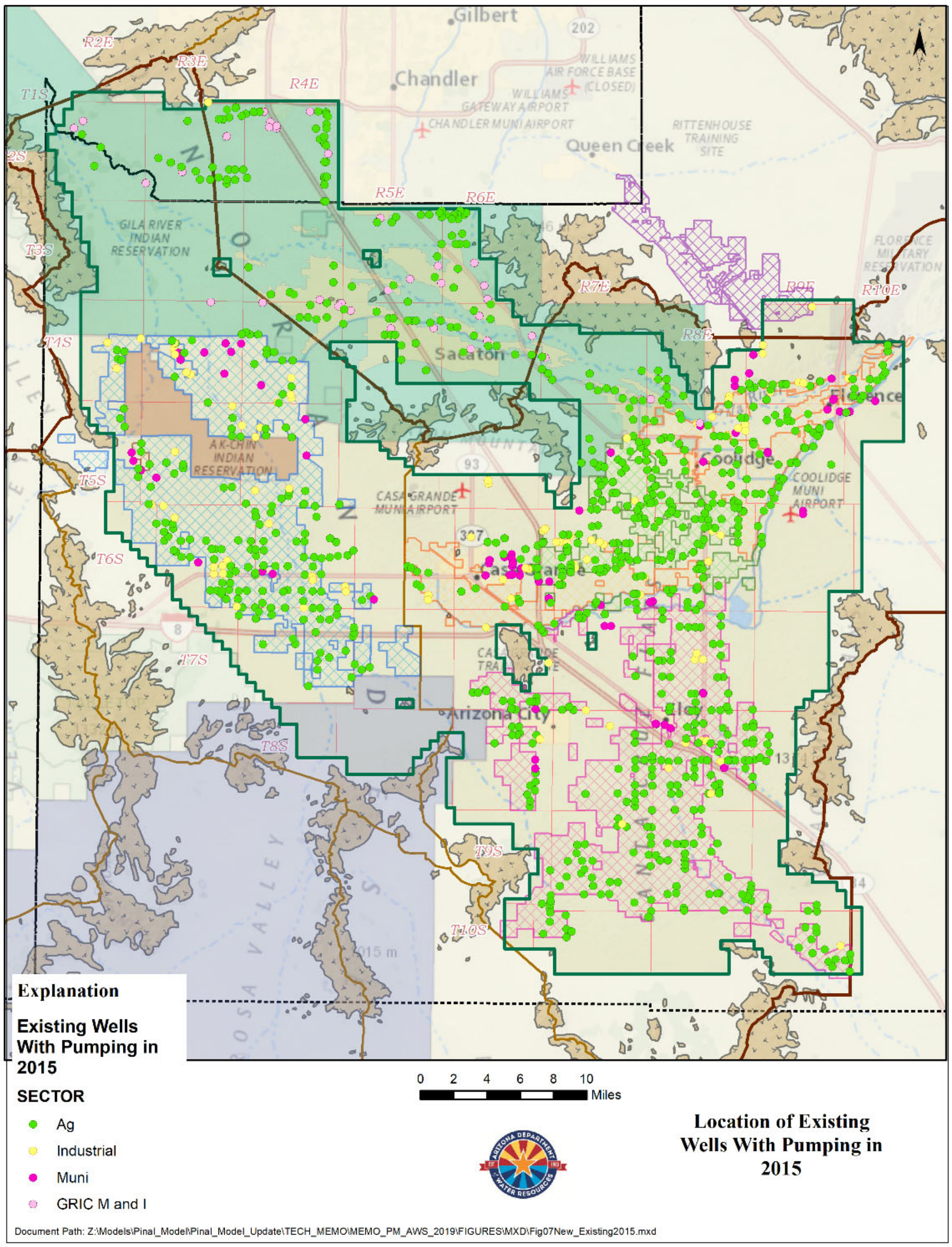

Figure 7. Existing Wells with Pumping in 2015

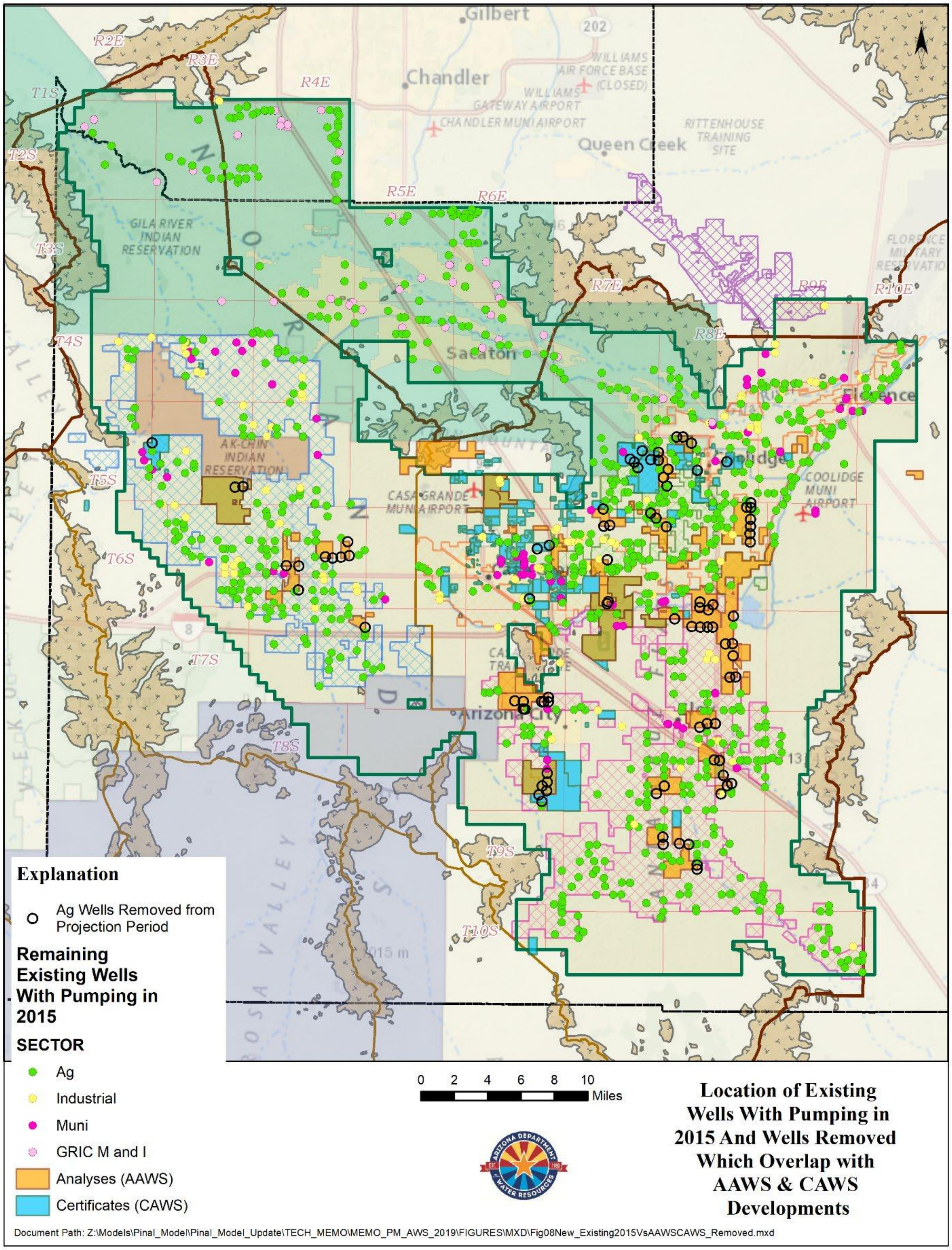

Figure 8. Existing Wells Removed from Projection Due to Overlap with AWS Development Footprints

Proposed New Wells

For the issued but unserved AAWS and CAWS demands, new wells were created and placed within each AWS determination's development footprint. Point locations were named by the most recent Program, Certificate and Conveyance (PCC) number.

There are 12 developments located inside the AMA but outside the active model boundary. Two of these developments (Hacienda Acres Certificate #53-500768.0000) and (Pinebrooke and Diffin Analysis #28-700313.0000) are expected to obtain their supply from outside the model domain and so they were removed from this analysis. Although located within a few miles of the active domain, the projected demands for these two developments are small and the impact in the model domain is considered negligible. The other 10 developments are expected to receive water from water providers located inside the model domain. For these 10 developments, the pumping locations are simulated within close proximity of the developments (generally up to a few miles), and inside the model domain. The Copper Mountain Ranch (Analysis #28-700805.0000) development footprint is located mostly outside the model boundary and has an annual demand of 6,314 AFA that was distributed to eight locations shown on a map submitted with their application. For larger developments covering multiple model cells, pumping was simulated from multiple pumping locations, with demands distributed evenly among the locations. **Figure 9** shows the locations of proposed AAWS, CAWS, and existing DAWS wells used for the projections.

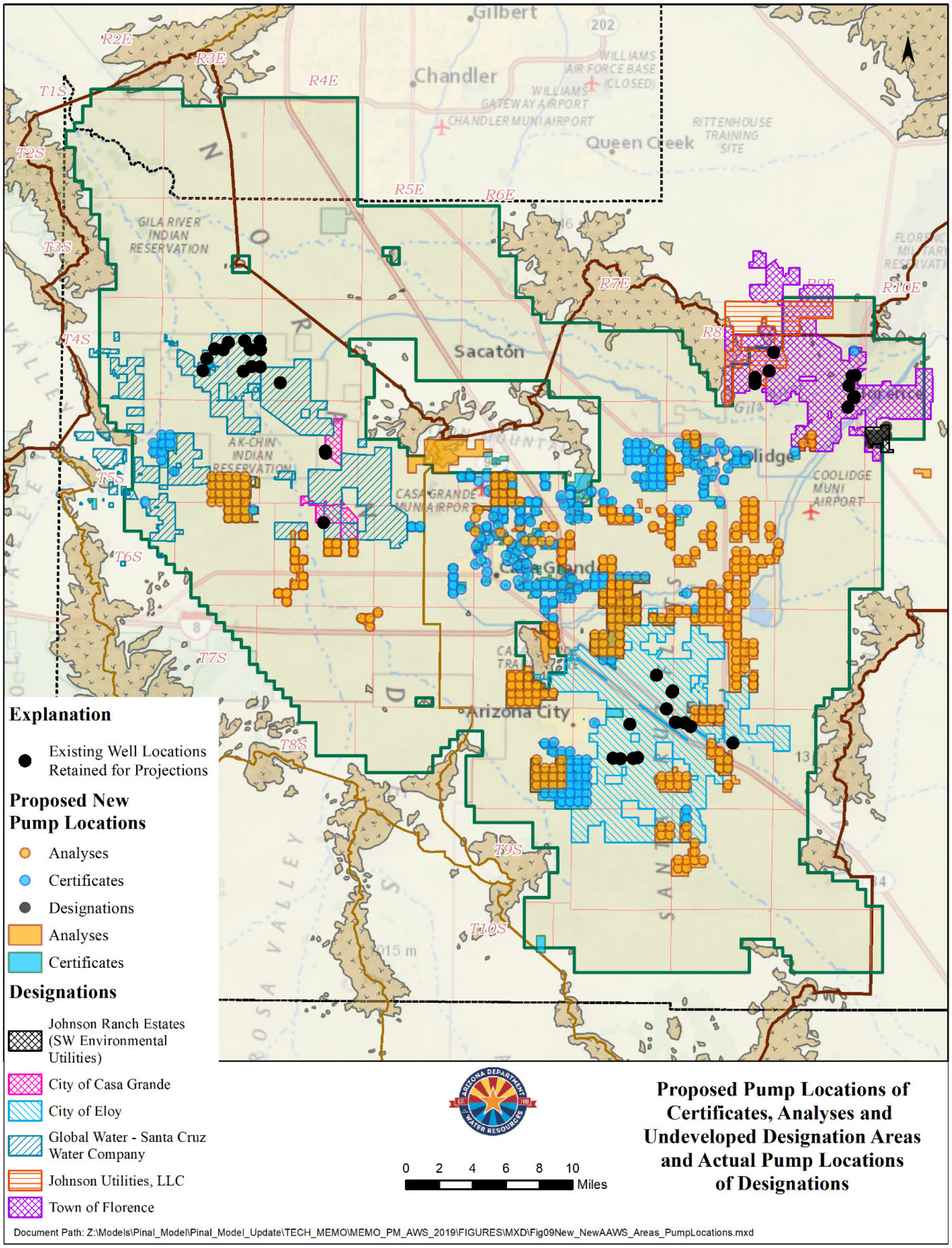

Figure 9. Proposed and Actual Pump Locations Simulated for Certificates, Analyses Areas Designations

LTSC Removal Wells

Pumping well locations were also created for the removal of long-term storage credits. **Figure 10** shows the location of LTSC removal wells. There is one well location for each of eight Underground Storage Facility (USF) sites, while there are several well locations for the removal of water from GSF sites which correspond to the location of existing, active agricultural wells.

Note: some well locations in the original model were located on boundary conditions including both constant head and specified flux cells, making the model unable to properly simulate their demands. In those cases, wells were relocated to the nearest non-boundary model cell.

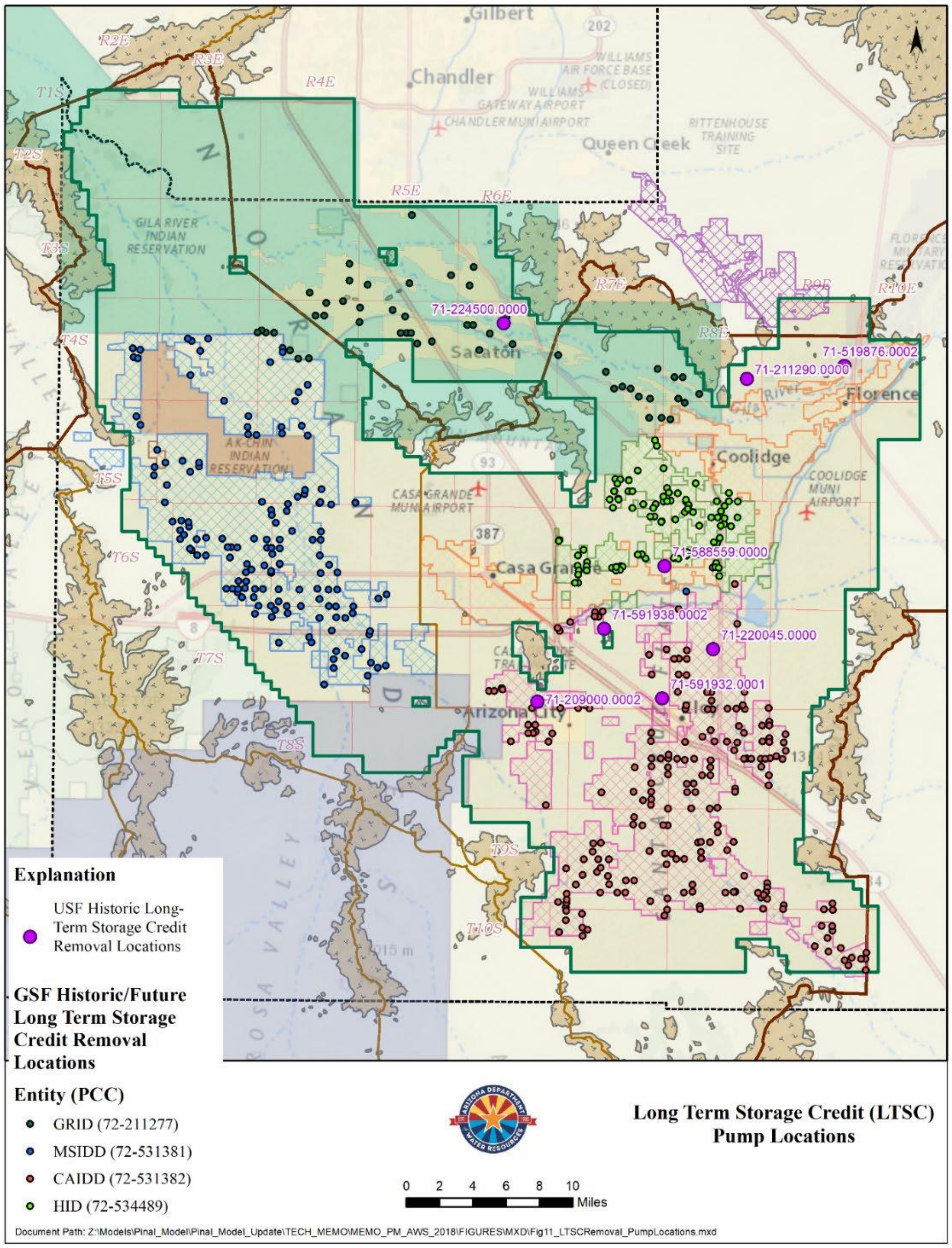

Figure 10. Long-Term Storage Credit Removal Pump Locations

Total 100-year Pumping Demand

All future cumulative projected demand over the next 100 years are shown in **Figure 11** by sectors, including existing and proposed AAWS/CAWS/DAWS wells, existing ag and municipal & industrial (M&I) wells, and LTSC removal locations. Altogether, the 100-year future cumulative projected demand is over 80.6 MAF. **Figure 12** provides a chart of demand by type over time as compared to total recharge.

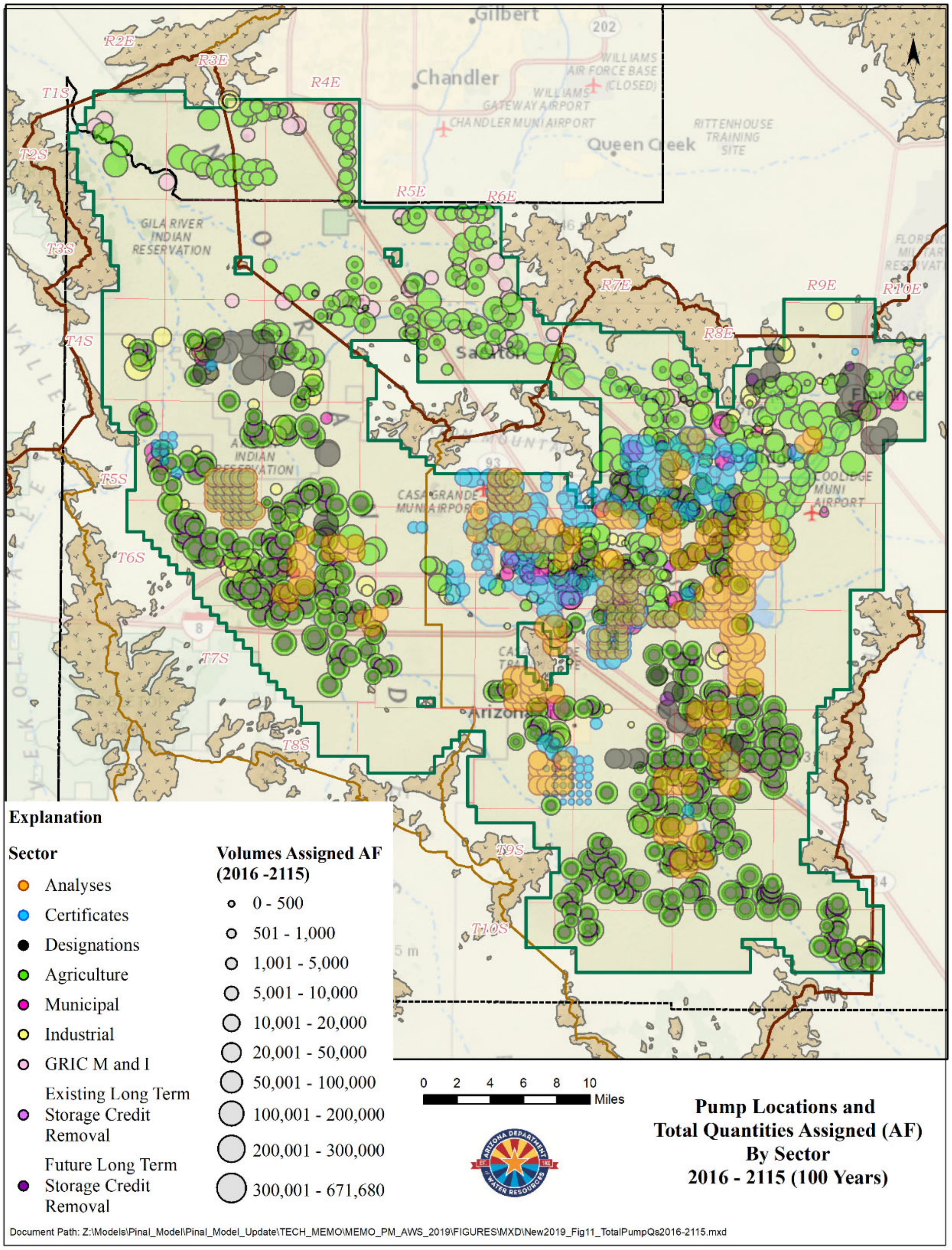

Figure 11. Pump Locations and Total Quantities Assigned 2016 - 2115

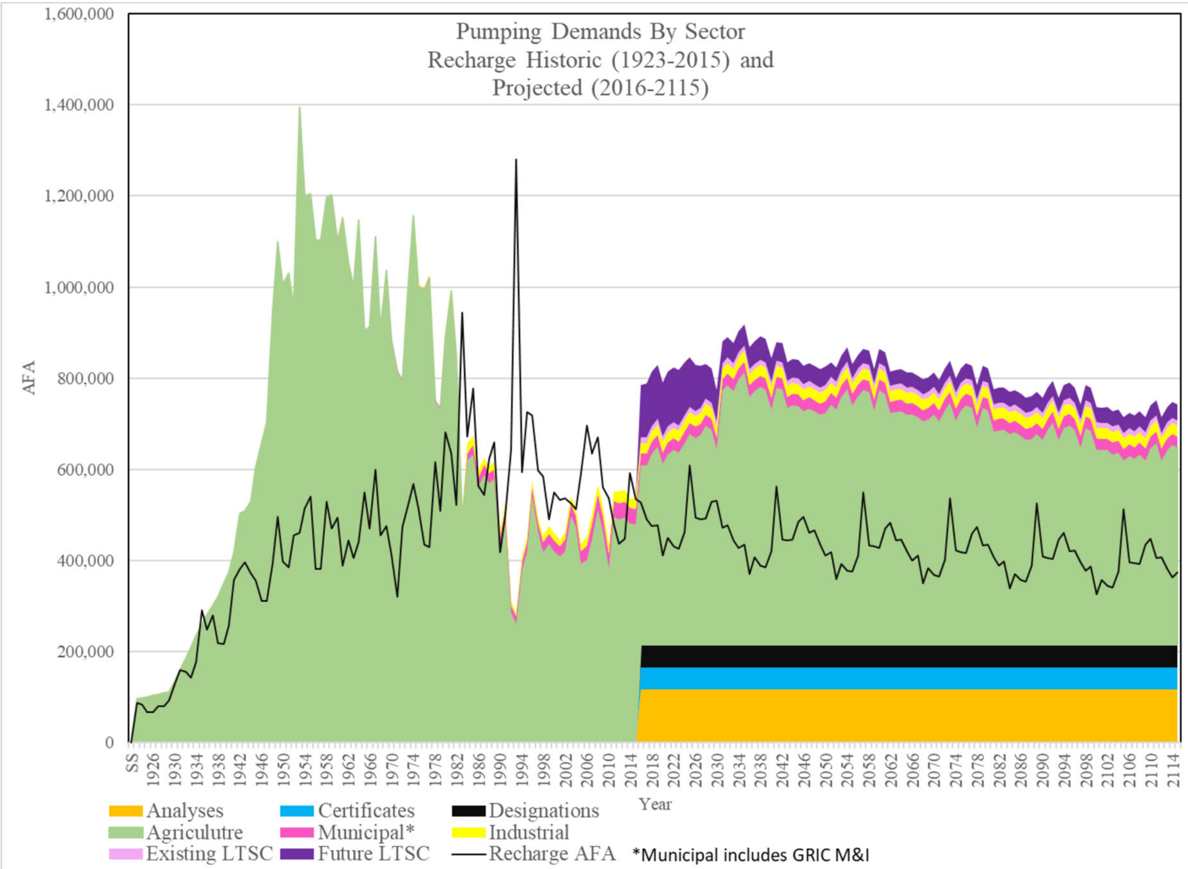

Figure 12. Pump Demands by Sector vs. Total Recharge 1923 - 2115

Vertical Distribution of Pumping Demands and Use of the Multi-Node Well Package

The traditional MODFLOW well pumping (WEL) package was used in the historic period (through 2015). The model 100-year projection (2016-2115) utilized the Multi Node Well (MNW) package. The MODFLOW WEL package was used to simulate historical pumping because it was found that introducing the MNW in the historic period resulted in less agreement between observed and model simulated water levels.

The MNW includes well construction information on depths, diameters and the elevation of perforated intervals, where available, for the existing wells. Where well construction information was not available, wells were assigned between 1 and 3 vertical nodes to withdraw water from the 3-layer model. For proposed new well locations created to represent pumping for issued, but unserved demands related to AAWS, CAWS, and DAWS, each location was assigned 3 vertical nodes. The use of the MNW package allows for dynamic lowering of the pumping distribution as the upper layers are dewatered, maximizing simulated pumping more realistically, and eliminates the need to manually lower pumping to deeper layers. The use of the MNW package helps eliminate wet-dry solver oscillations. Another advantage of the MNW package is the resulting output files that provide information on the net pump rates per stress period per well, allowing for the calculation of simulated unmet demand and percentage unmet demand over time. Because sectors are associated with each well, unmet demand results can be aggregated by sector, entity or sub-area.

Demands are unmet when the model assigned pumping rate cannot be achieved and therefore the simulated pumping rate is less than assigned pumping rate for a specific well. This occurs not only when model layers become dewatered as was the case with the WEL package, but also with the decrease in the saturated thickness and corresponding aquifer transmissivity.

Recharge Projections

Gross recharge is simulated to fluctuate between 327,000 AFA and 609,000 AFA per year over the 100-year projection period with an average of 428,000 AFA. Agricultural incidental recharge was based on a percentage of total agricultural demand. Stream recharge is simulated to fluctuate consistent with the 16-year historical pattern between 1995-2010. Other types of recharge (Urban, Mountain Front, Picacho Reservoir) are simulated to remain at 2014 levels.

CAP supplies include Ag Pool water that is available only until 2030 pursuant to the Arizona Water Settlement Agreement. CAP water, the likely future source of the CAGRD replenishment obligation water, is applied within the nearest GSF of each participating CAGRD member. This projection included the removal of 95% of the non-CAGRD CAP GSF water in the same year it was projected to be stored, leaving 5% in the aquifer.

Non-Indian IGFR acres that overlapped CAWS or AAWS footprints were immediately removed from all agricultural activities at the beginning of the 100-year AWS projection period. Agricultural incidental recharge for non-Indian IGFR acres during the 100-year projection period was estimated to be 34% of the total agricultural water supply, including: groundwater, Gila River surface water, and CAP water. Any estimated agricultural incidental recharge was applied uniformly over the remaining IGFR acres within each model cell associated with each agricultural entity (irrigation district or non-ID IGFR). The 66% irrigation efficiency used to estimate future agricultural incidental recharge was based analyses of USGS crop survey data from 2013 and 2014 that indicated approximately 90% of fields in the Pinal AMA are irrigated using flood irrigation. This efficiency was used as a baseline percentage for the Pinal model's historical calibration. Projected agricultural incidental recharge was not lagged for the 100-year AWS projection period.

For the Ak-Chin Community, a constant agricultural incidental recharge rate of 24,048 AFA of the 72,000 AFA of the CAP water used for agricultural purposes (33.4%) was spread evenly across the Ak-Chin Community lands. This recharge rate is based on the average estimated from a recent mix of crops and irrigation methods used.

For the GRIC, agricultural incidental recharge was based on a percentage of total agricultural demand, prorated based on the number of acres located inside the model domain. Approximately 11.3% of GRIC ag lands are located outside the model domain. Therefore, 88.7% of the total demand was applied and generated agricultural incidental recharge within the model domain. The percentage assumed to be recharged was 26% of the total demand, based on an overall 74% irrigation efficiency. **Appendix G** provides more details on how the agricultural incidental recharge on the GRIC was calculated for this projection.

Figure 13 provides projected recharge by sector for the period 2016-2116. No assumption was made for possible future efficiencies changes related to agricultural water use and irrigation systems yet to be installed. **Appendix E** provides more detail on agricultural supply and incidental recharge assumptions.

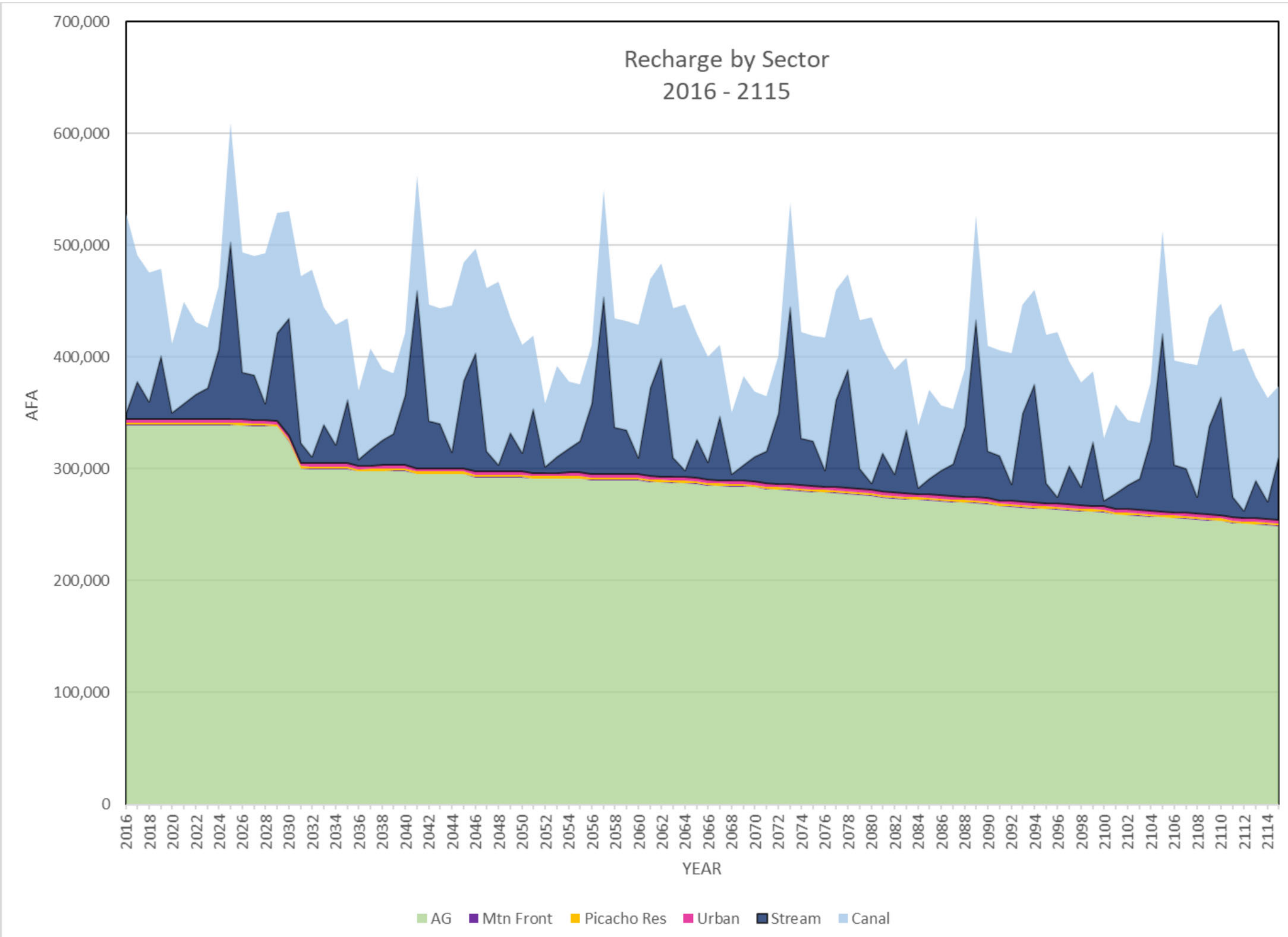

Figure 13. Recharge Projections by Sector 2016 - 2115

100-Year Projection Model Results

Total Unmet Demands

Demands are unmet when the model assigned pumping rate cannot be achieved and therefore the simulated pumping rate is less than assigned pumping rate for a specific well. The 2019 Pinal Model 100-year AWS projection resulted in approximately 8.1 MAF of total unmet demand, comprising just over 10% of cumulative total projected 100-year demand (80.6 MAF). Approximately 2.0 MAF of the total 8.1 MAF of unmet demand is within the AWS sector. **Table 4** shows the assigned model-wide pumping vs. simulated and unmet portions at the end of the 100-year projection. **Figure 14** is a graph comparing the total assigned and total simulated pumping for the 100-year projection period.

Table 4. Model-Wide Pumping Assigned vs. Simulated and Unmet Portions

2019 Pinal Model 100 Year Cumulative Projections 2016 - 2115	
Model Assigned Demands (AF) vs. Simulated Pumping (AF)	
Model Assigned Demand	**80,648,525**
Simulated Demand	72,560,695
Total Simulated Unmet (Model Assigned minus Simulated)	8,087,830
Assured Water Supply (AWS) Portion of Unmet Demands	1,969,950
Percent of Model Assigned Unmet	10.03%

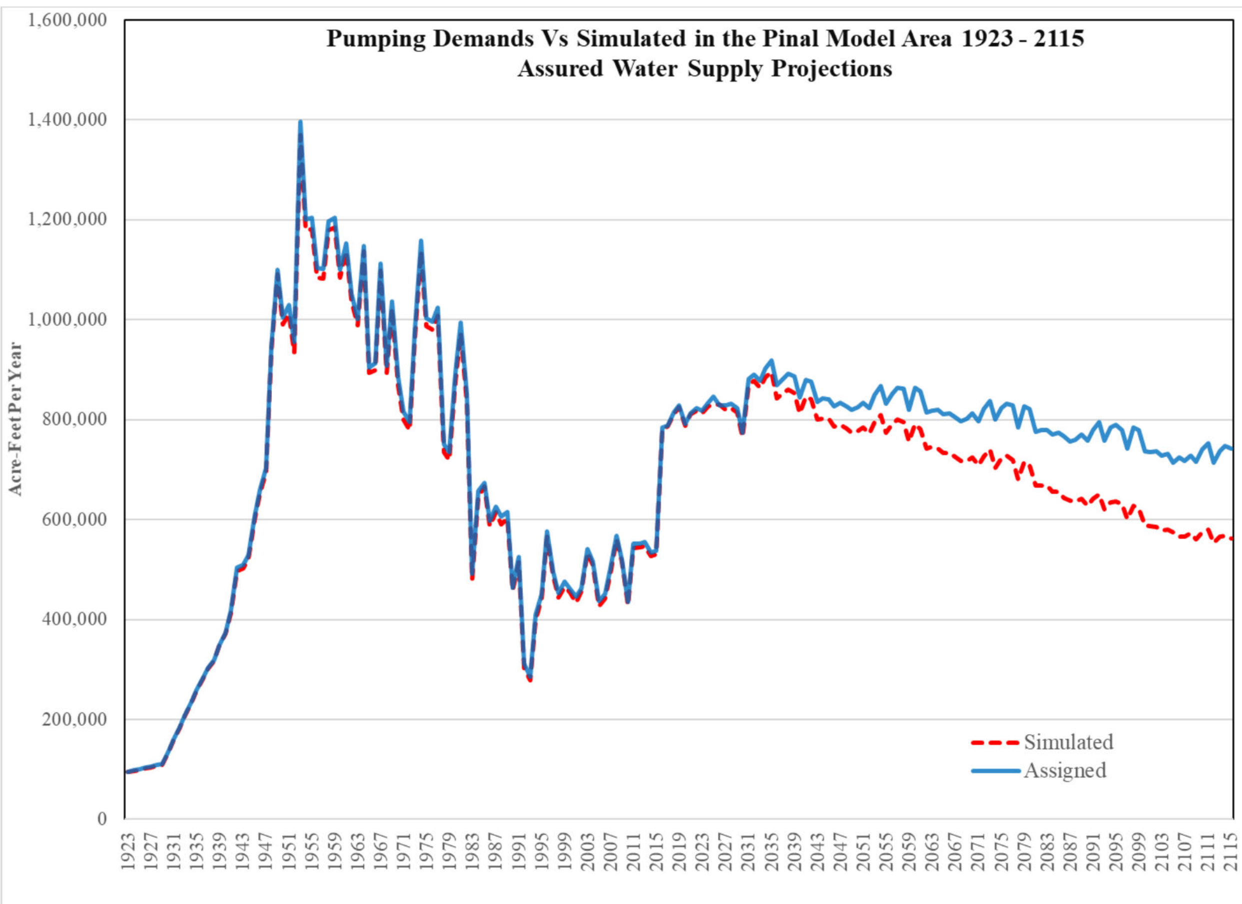

Figure 14. Pumping Demands Assigned vs. Simulated

As stated above, approximately 2.0 MAF of the nearly 8.1 MAF of unmet demand is associated with issued AWS determinations. The remaining unmet demand of approximately 6.1 MAF is associated with agriculture, M&I, and LTSC removal. Approximately 5.8 MAF of the total 6.1 MAF is associated with agriculture and M&I uses, with agricultural uses comprising the largest share, approximately 5.1 MAF. Most of the LTSC demand was successfully simulated. However, approximately 0.27 MAF of LTSC sector demand is not met. Annual unmet demand increased later in the projection period due to cell dewatering. **Table 5** lists the unmet demands by sector in the 100-year projected period.

Although there may have been some small volume of unmet pumping in the historic period due to dry cells, that was not quantified nor is the focus of this study.

Table 5. Summary of Cumulative Demands and Simulated Pumping by Sector

2016 - 2115 100-Year Projected Demands, Simulated and Unmet Percentages								
Sectors	**Total Well Count**	**Count Wells with Unmet Demands**	**Demands (AF)**	**Percent of Total Demands**	**Simulated (AF)**	**Unmet (AF)**	**Percent of Sector Demands Unmet**	**Sector's Proportion of Total Unmet Demands**
Analysis (AAWS)	293	53	11,687,181	14.49%	10,616,411	1,070,770	9.16%	13.24%
Certificates (CAWS)	321	47	4,875,410	6.05%	4,609,484	265,926	5.45%	3.29%
Designations (DAWS)	45	16	4,886,490	6.06%	4,253,237	633,253	12.96%	7.83%
AWS Subtotal	***659***	***116***	***21,449,081***	**26.60%**	***19,479,131***	***1,969,950***	***9.18%***	***24.36%***
Agriculture	758	222	48,573,365	60.23%	43,514,309	5,059,056	10.42%	62.55%
Municipal	51	13	2,005,524	2.49%	1,952,338	53,187	2.65%	0.66%
GRIC M&I	41	0	500,342	0.62%	500,339	3	0.00%	0.00%
Industrial	103	29	2,329,255	2.89%	1,600,332	728,922	31.29%	9.01%
Existing Uses Subtotal	**953**	**264**	**53,408,486**	**66.22%**	**47,567,318**	**5,841,168**	***10.94%***	***72.22%***
Existing LTSC	498	54	1,169,993	1.45%	1,131,929	38,064	3.25%	0.47%
Future LTSC	437	102	4,620,964	5.73%	4,382,316	238,648	5.16%	2.95%
LTSC Subtotal	***935***	***156***	***5,790,958***	**7.18%**	***5,514,245***	***276,712***	***4.78%***	***3.42%***
TOTAL (ALL SECTORS)	**2,547**	**536**	**80,648,525**	**100.00%**	**72,560,695**	***8,087,830***	***10.03%***	**100.00%**

Identification of AWS Unmet Demands

Comparing model assigned pumping rates to simulated rates, unmet demand was calculated annually for each well simulated in the model. Any well with cumulative unmet demands exceeding 1 acre-foot over 100 years, or unmet demand exceeding 1% of total demand, was flagged as having unmet demands. In this 100-year projection, unmet demands were identified in 116 wells associated with 9 Analysis, 32 Certificates and 4 Designations. Most of the fully built out developments are supplied by Arizona Water Company which operated 28 wells in 2015, 8 of which were projected to have unmet demands in this projection. Others list a different provider or no provider.

The unmet portion of the existing municipal sector demands was associated with 13 out of 92 existing municipal supply wells. Because many of the developments with issued CAWS that are fully built out are supplied by AWC, this unmet demand could impact existing developments.

Locations of wells with unmet demands are shown in **Figure 15**. As previously mentioned, structural modifications to the model geology (increasing model thickness in some areas) more accurately represented the productive thickness of basin-fill deposits in the model domain, including in the Casa Grande ridge area.

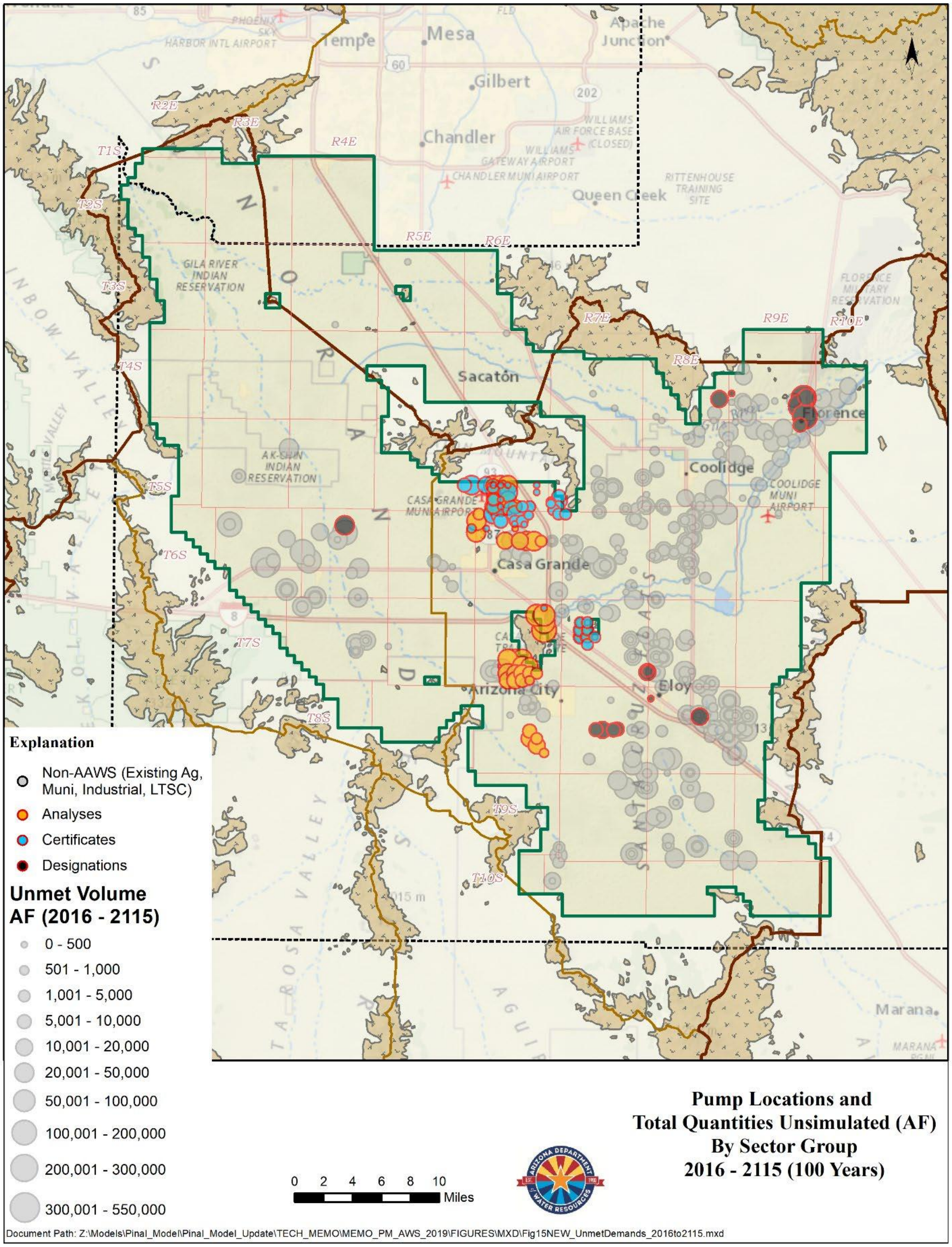

Figure 15. Location of Wells with Unmet Demands 2016 – 2115

Appendix F includes several tables presenting detailed results of the 100-year pumping projection and information on associated entities, issued demands, current demands, and counts of pumping locations associated with the issued, but un-developed demands simulated in this projection.

Tables F-1, F-2, and F3 include results for AWS Analyses, Certificates and Designations, respectively. The list includes fully built out developments that have no new pumping locations.

Tables F-4, F-5, and F-6 includes results for existing non-DAWS municipal, industrial and agriculture, demands. All non-AWS sectors have some unmet demands simulated in the next 100 years.

Table F-7 includes a summary of LTSC entities and their cumulative assigned vs. simulated demands. There were no unmet demands simulated among the eight USFs but there was 276,712 AF of unmet demand associated with existing and future long-term storage credit removal at the three non-Indian GSFs. Since those credits were simulated to be removed (pumped) at the same location as other agricultural pumping demands, the locations correspond to well locations where wells also experience diminished capacity to meet demands in this 100-year projection.

Increased Depths to Water and Perched Water Table

The results of the 100-year projection reveal a substantial lowering of water levels and greater depths to water model-wide. The model simulates water level elevations for each of the three model layers. Calculations are made from those data to derive estimates of depths to water in the regional aquifer based on land surface elevation. In addition, the saturated thickness of each layer within the model domain and the saturated thickness above 1,100 feet was determined.

Appendix H shows the observed water elevations and simulated water elevations through the 100-year projection period for the same 12 hydrographs identified in **Appendix C**. Ten (10) of the 12 hydrographs indicate significant water level declines at the end of the 100-year projection period. The remaining two hydrographs indicate stable or slightly increased water levels at the end of the 100-year projection period. These two wells are located on the GRIC Reservation and near the Gila River. The other 10 wells with significant simulated water level declines are located outside of the GRIC Reservation and cover the remaining area within the model domain.

In some areas thin, isolated perched water tables were simulated to develop in portions of upper two model layers during the 100-year projection period as the regional water table dropped due to projected pumping and the downward flow of deep percolating agricultural incidental recharge was impeded by fine-grained materials in the vadose zone. Although these remnant, or "perched," water tables have depths to water that are shallower than the AWS regulatory limit of 1,100 feet BLS, the perched zones generally have limited thickness and do not represent a viable source of water supply. These perched zones are not considered when evaluating AWS applications for compliance with the 1,100-foot static depth to water pumping limit.

Perched groundwater is defined as a localized body of unconfined groundwater above and separated from the main body of groundwater by a groundwater barrier immediately below which lies unsaturated material. (ASTM D653-14). Unsaturated soil or rock within the simulation was identified by comparing the total thickness of each model cell and layer with the saturated thickness. Within any model cell, if there was a saturated zone above an unsaturated zone with a thickness of greater than 1 foot, the upper saturated zone was identified as hydrologically disconnected or perched. Perched water is located within either layer 1 or layer 2, or in bother layers, with unsaturated thickness underlying it in layers 2 and/or 3. In some areas, layers 2 and 3 are hydrologically connected but water in layer 1 is not connected and identified as perched. In other areas water in layers 1 and 2 are in connection yet perched and separated from the regional aquifer within layer 3. In some areas, layer 3 is completely unsaturated with perched water above.

Table 6 includes a summary of perched water conditions in addition to the model-wide elevations, depths to water, saturated thickness and saturated thickness above 1,100 feet below ground surface (bgs) for the regional aquifer at the start and end of the 100-year projection period. Each cell represents 0.25 square miles, with the entire 6,052-cell active domain covering 1,513 square miles. When perched water is excluded from the regional aquifer, and the 1,100-foot static depth to water limit is imposed, the remaining saturated thickness is significantly less than the total saturated thickness above the model bottom, and there are more cells with no regional aquifer supplies within that zone.

Table 6. Summary of Model-Wide Heads, Depths to Water, and Saturated Thicknesses

Perched Water					
	min	max	ave	Count Perched Cells	Sq. Mi With Perched Water
Thickness of Perched Water in 2015	0.001	385	99	1,108	277.00
Thickness of Perched Water in 2015	0.001	354	33	3,009	752.25
Regional Aquifer (Excludes Perched Water)					
End of 2015 (Pre-Projection Period)					
	min	max	ave	Count Dry Cells	Sq Mi. Dewatered
Head	727	1,635	1,185	18	4.50
Depth to Water	7	728	217	18	4.50
Saturated Thickness Above 1,100 BGS	0	1,081	712	18	4.50
Saturated Thickness Above Model Bottom	0	3,203	1,343	18	4.50
End of 2115 (After 100 Year Projection Period)					
	min	max	ave	Count Dry Cells	Sq Mi. Dewatered
Head	359	1,569	874	103	25.75
Depth to Water	7	1,258	525	103	25.75
Saturated Thickness Above 1,100 BGS	0	1,084	404	307	76.75
Saturated Thickness Above Model Bottom	0	2,894	1,032	103	25.75
Summary of Change Between 2015 - 2115					
	min	max	ave	Additional Dry Cells	Additional Sq Mi. Dewatered
Head	-994	51	-310	+85	+21.25
Depth to Water	-50	968	319	+87	+21.75
Saturated Thickness Above 1,100 BGS	-886	50	-316	+304	+76
Saturated Thickness Above Model Bottom	-994	50	-318	+87	+21.75

Figure 16 shows the depth to water in the regional aquifer before the 100-year projection period (2015) and after (2115). In addition, the change in depth to water over the projection period is provided. In general, the greatest depths to water at the end of the 100-year projection are observed in the Eloy sub-basin. Depth to water in this area exceeds the 100-year projection regulatory depth to water limit in the Pinal AMA of 1,100 feet bgs. The projected maximum depth to water at the end of the 100-year projection was 1,258 feet bgs. In the area south of the City of Maricopa, depth to water at the end of the projection is approaching 1,000 feet bgs. The 100-year projection simulated the first exceedance of the regulatory depth to water to occur in 2074, 59 years into the 100-year projection period.

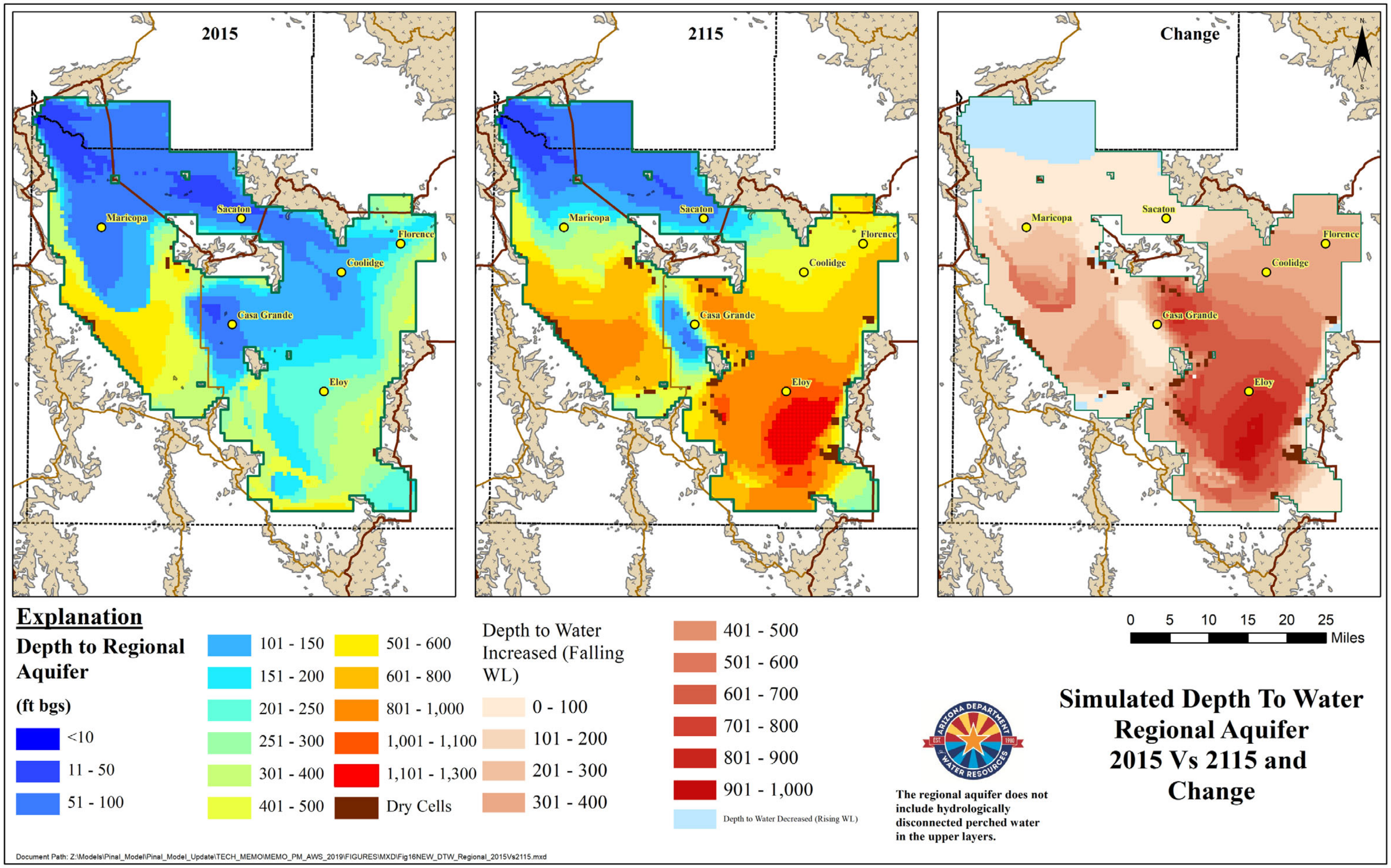

Figure 16. Simulated Depth to Water 2015 and 2115 and Change in Depth to Water

Figure 17 shows the saturated thickness of the regional aquifer, which excludes any perched water zones, above 1,100 feet bgs and "dry cells" at the end of the projection period. When all three model layers within a model cell become dewatered due to pumping, that cell is identified as a "dry cell." In addition, the figure shows cells (light brown with label 0*) that have no saturated thickness above 1,100 feet bgs. Dry cells and cells lacking saturated thickness contribute to unmet demands as the well(s) within these cells cannot support the assigned pumping volumes. Dry cells are typically found along model boundaries due to shallower bedrock. The are 18 dry cells simulated 2015. That number increases to 103 in 2115, with 307 cells being either dry or lacking any regional aquifer above 1,100 feet bgs (**Table 6**).

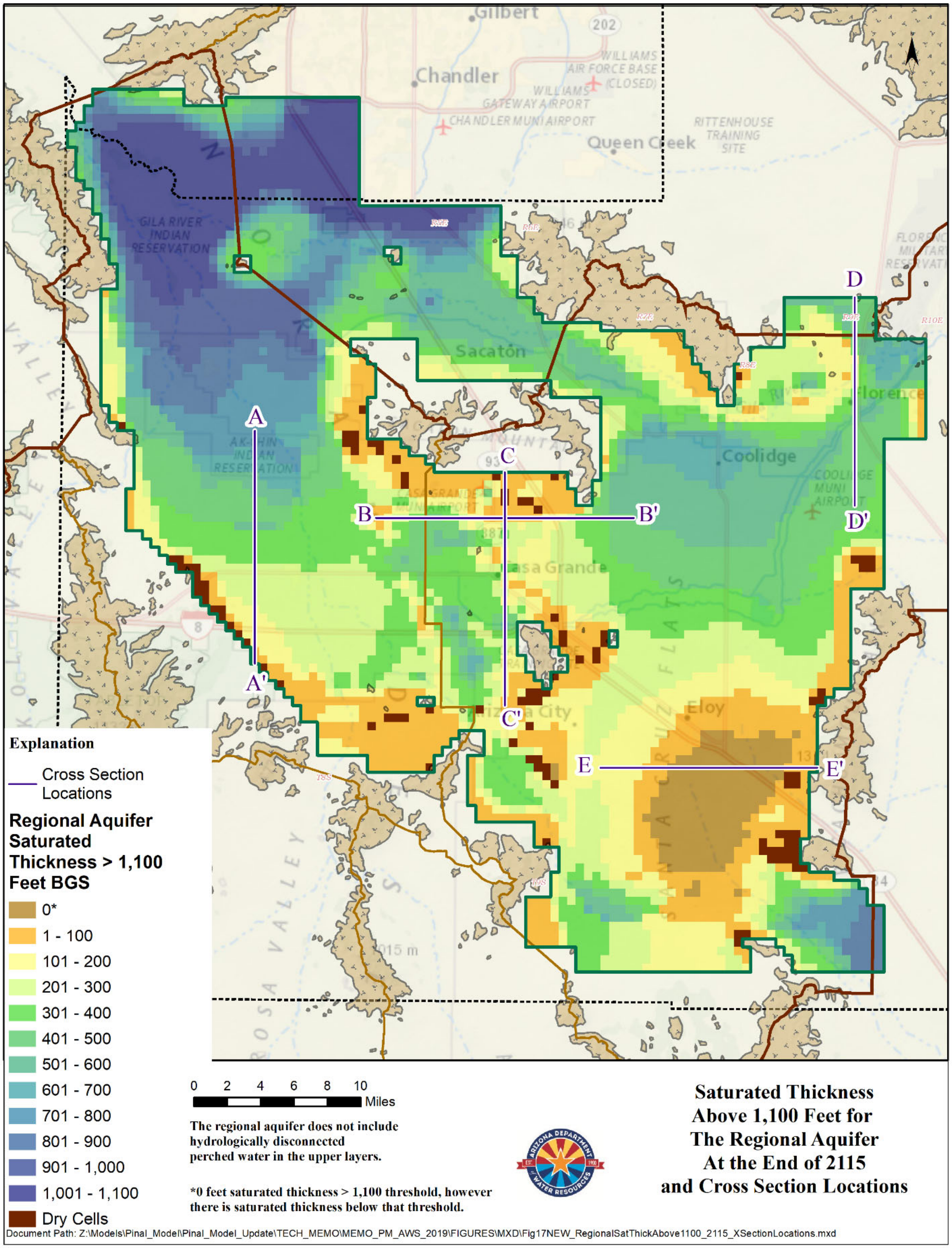

Figure 17. Water Level Cross Section Location Map

To better illustrate the situation described above, cross sectional views of the model geometry and regional and perched water levels are presented. The locations of cross sections are shown as **Figure 17** and **Figures 18 – 22** provide cross sectional views of A-A’, B-B’, C-C’, D-D’ and E-E’.

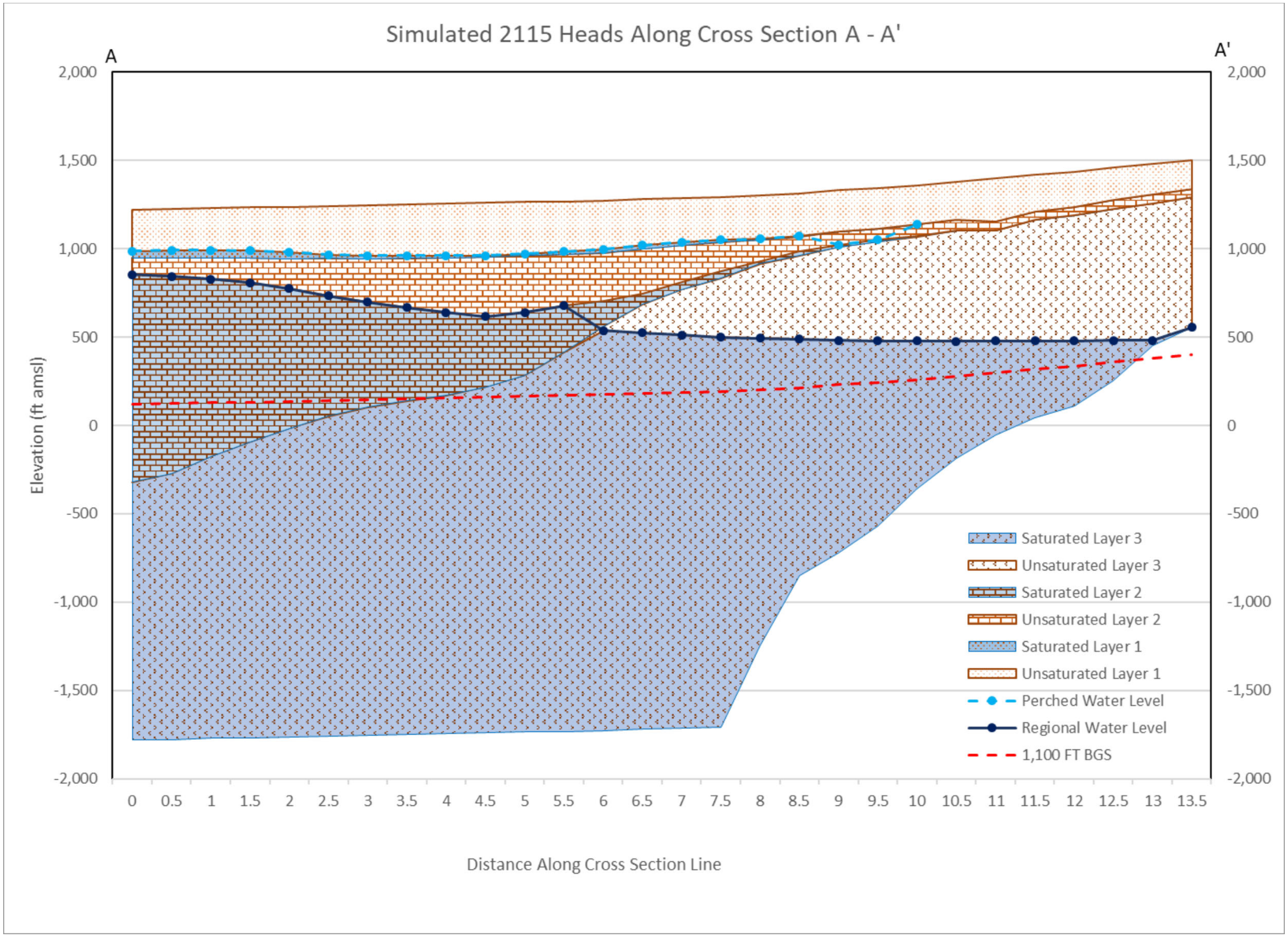

Figure 18. Cross Section A -A'

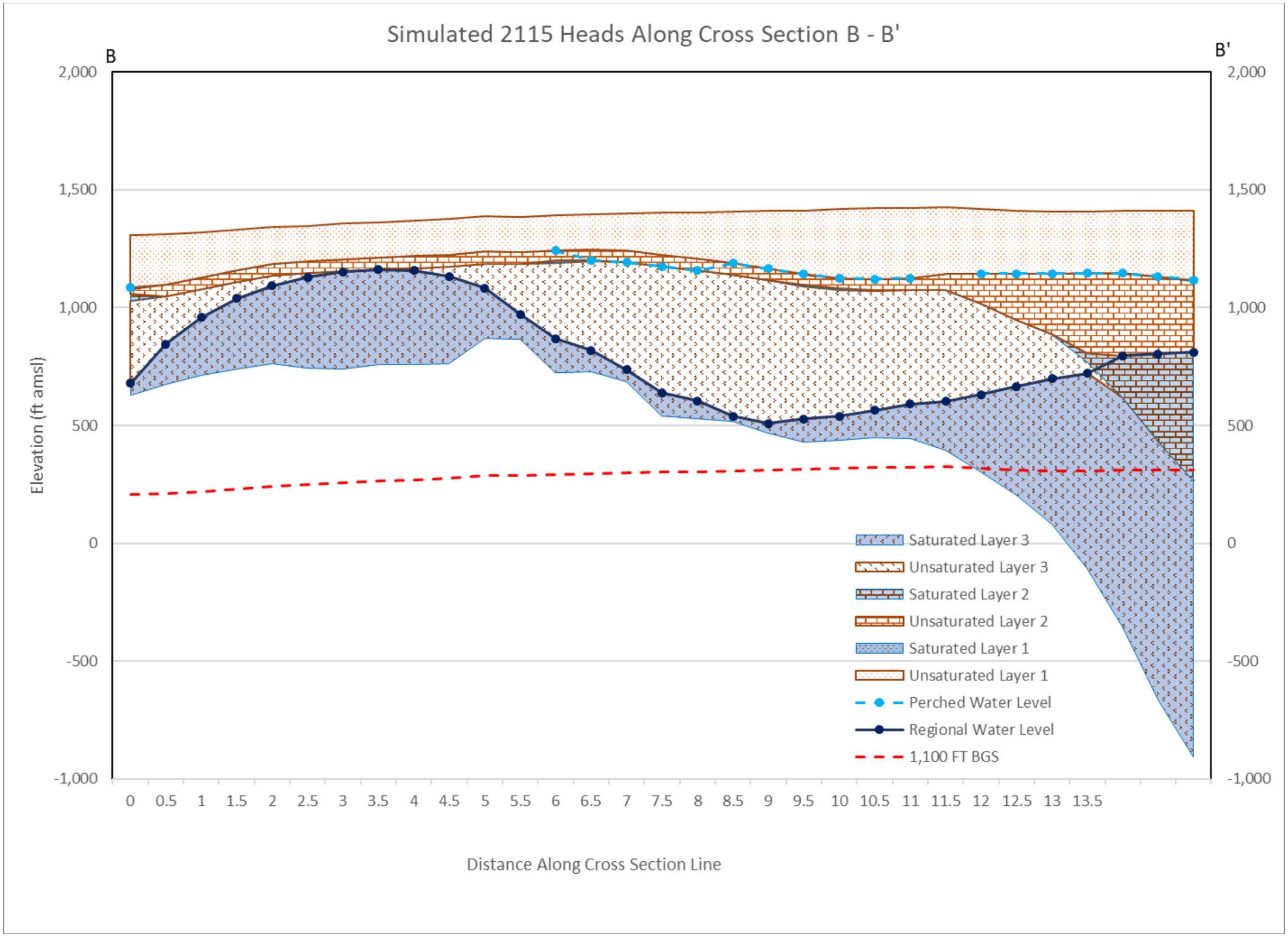

Figure 19. Cross Section B-B'

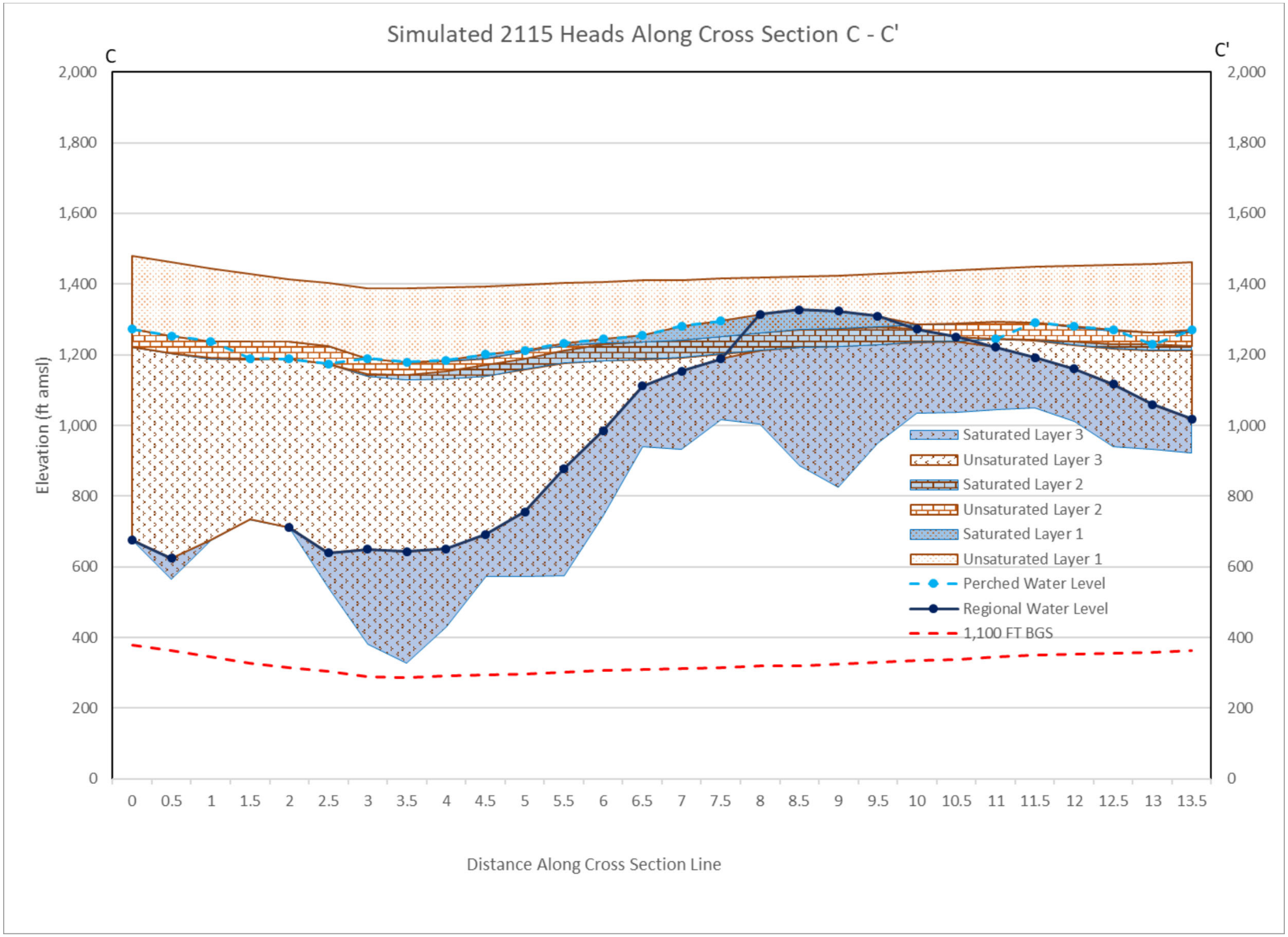

Figure 20. Cross Section C-C'

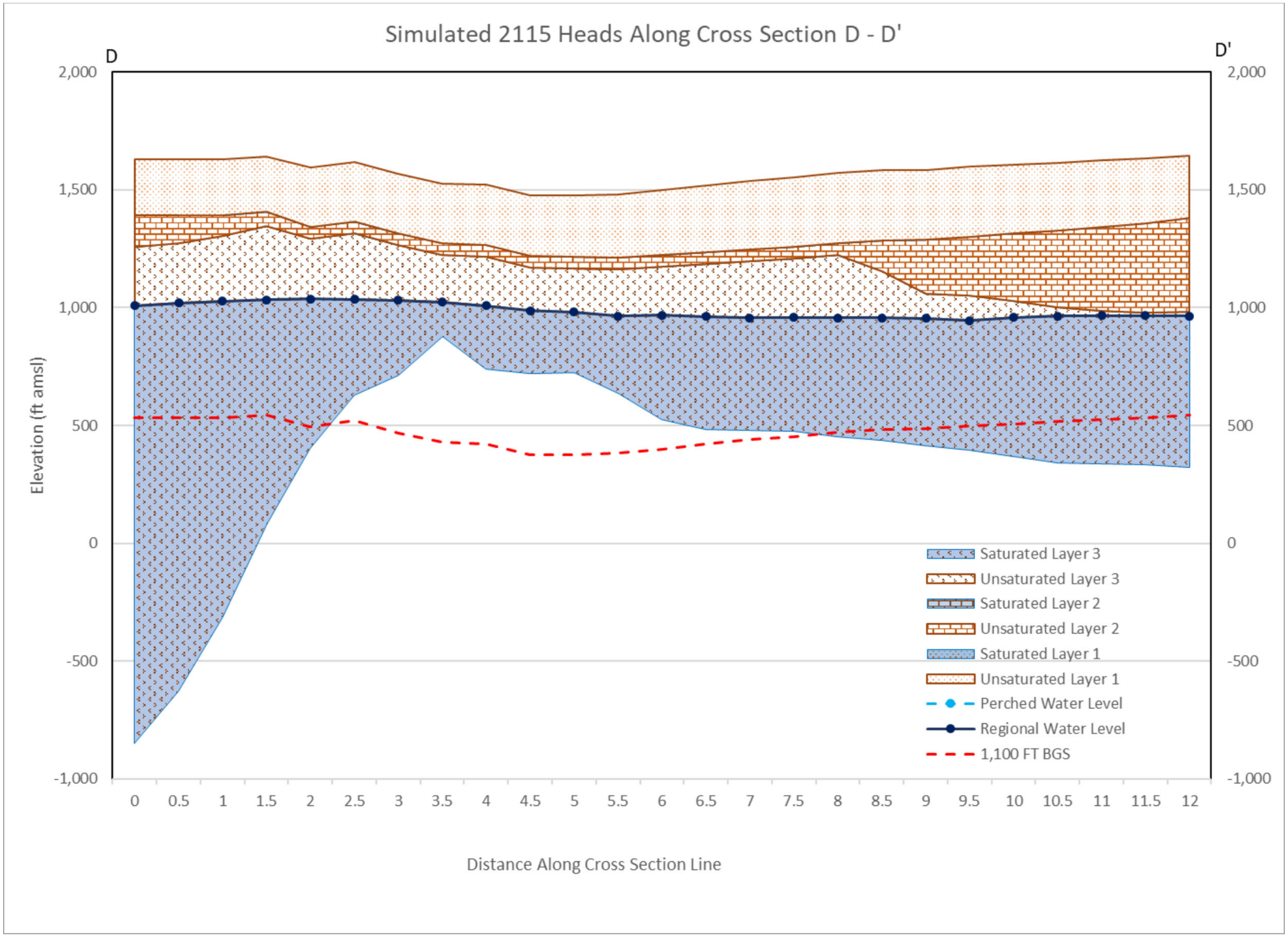

Figure 21. Cross Section D-D'

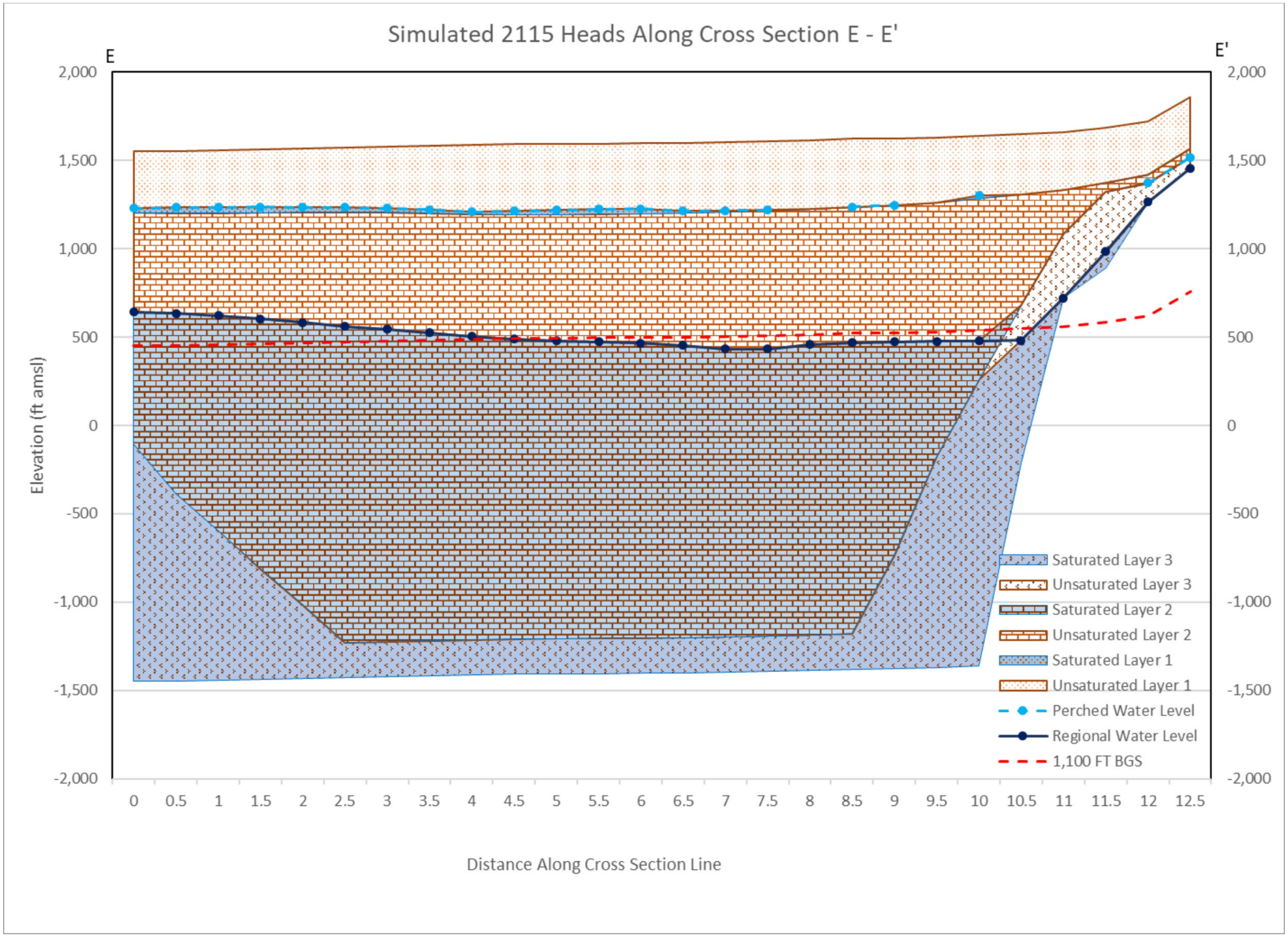

Figure 22. Cross Section E - E'

Change in Storage

Projected groundwater pumping over the 100-year projection period is higher, approximately 72.4 MAF, than the historic period (1920s to 2015) which totaled approximately 59 MAF. Non-agricultural uses increase over the 100-year projection period while there is a gradual decrease in overall pumping related to agricultural uses over the same time period. The projected reduction in agricultural activity also caused total incidental recharge projections to decrease. Historically, and in this 100-year AWS projection, pumping is greater than recharge, thus resulting in the continued loss of groundwater storage. The projected future decrease in groundwater storage also caused additional projected land subsidence.

The simulated cumulative loss in groundwater storage from predevelopment to 2115 was over 44.8 MAF, with 17.3 MAF occurring before 2016 and the remaining 27.5 MAF occurring between 2016 and 2115. About 38.3 MAF of storage loss was from the drainage of pore space and the release of water due to the elastic compression of inter-granular pore space. The remaining 6.5 MAF of storage loss was from the release of water due to the permanent, inelastic compaction of fine-grained interbed materials. **Table 7** provides a water budget summary of inflows, outflows and changes in storage during steady state, historic transient, and the projected periods.

Table 7. Water Budget Summary

	Budget Term	Cumulative Acre Feet				Average Rates (Acre-Feet Per Year)			
		Steady State (1 Day)	1923 - 2015 (93 Years)	2016 - 2115 (100 Years)	Total	Steady State (1 Day)	1923 - 2015 (93 Years)	2016 - 2115 (100 Years)	Overall
IN	UNDERFLOW	108	3,944,133	4,585,959	8,530,200	39,288	42,410	45,860	44,197
	RECHARGE	1	41,960,311	42,503,302	84,463,614	483	451,186	425,033	437,629
	STREAM LEAKAGE	252	98,731	78,802	177,786	92,174	1,062	788	921
	INTERBED STORAGE	0	2,704,378	4,421,181	7,125,559	0	29,079	44,212	36,919
	STORAGE	0	23,750,338	25,549,038	49,299,376	0	255,380	255,490	255,434
	Total IN	**361**	**72,457,890**	**77,138,282**	**149,596,534**	131,946	779,117	771,383	775,101
OUT	UNDERFLOW	40	2,156,004	1,694,399	3,850,442	14,691	23,183	16,944	19,950
	ET	265	1,233,308	221,890	1,455,463	96,648	13,261	2,219	7,541
	STREAM LEAKAGE	56	1,011,544	362,933	1,374,533	20,606	10,877	3,629	7,122
	NET PUMPING	0	58,965,012	72,475,107	131,440,119	0	634,032	724,751	681,027
	INTERBED STORAGE	0	488,832	114,130	602,962	0	5,256	1,141	3,124
	STORAGE	0	8,603,500	2,338,329	10,941,829	0	92,511	23,383	56,693
	Total OUT	**361**	**72,458,200**	**77,206,787**	**149,665,348**	131,945	779,120	772,068	775,457
Stats	In - Out	0	-310	-68,505	-68,814	0	-3	-685	-357
	Mass Balance % Error	0.00%	0.00%	-0.09%	-0.05%	0.00%	0	0	0
	Net Loss in Aquifer Storage (Out - In)					**Average Rate of Storage Loss (AFA)**			
	Interbed	0	-2,215,546	-4,307,052	-6,522,597	0	-23,823	-43,071	-33,795
	Non-Interbed	0	-15,146,838	-23,210,709	-38,357,547	0	-162,869	-232,107	-198,741
	Total	0	-17,362,384	-27,517,760	-44,880,144	0	-186,692	-275,178	-232,536

Summary

This report documents ADWR's 2019 Pinal Model, which includes recent updates and structural modifications to the 2014 Pinal groundwater flow model, and results of a 100-year AWS projection. ADWR's updates include:

- Updated pumping information 2010 – 2015
- Updated Recharge Estimates 2010 -2015
- Improvements to the Numerical Solver Settings and Layer Property Flow (LPF) packages
- Revisions to the Central Arizona Model (CAM) grid
- More comprehensive head targets and use of the head observation (HOB) package
- Conversion of three out of four boundary conditions form specified head to specified flux
- Structural modifications to the model geology, increasing model thickness in several areas.

The recent structural modifications to the 2014 Pinal groundwater flow model included increasing the model thickness in several areas to address differences found between the model simulated thickness of the aquifer materials and the thickness described in numerous well drillers' logs.

The purpose of this 100-year AWS projection was to model existing and future groundwater use and recharge, quantify unmet demands by sector and location within the model domain, and present the resulting depth-to-water.

Results of the 100-year AWS model projection indicate that there is significant unmet demand within multiple sectors throughout the modeled area of the Pinal AMA at the end of the 100-year projection period. Demands are unmet when the model assigned pumping rate cannot be achieved and therefore the simulated pumping rate is less than assigned pumping rate for a specific well. The 2019 Pinal Model 100-year AWS projection resulted in almost 8.1 MAF of total unmet demand, comprising just over 10% of total projected 100-year groundwater demand (80.6 MAF). Approximately 2.0 MAF of the total 8.1 MAF of unmet demand is related to issued AWS determinations. Water demand associated with agriculture, municipal, industrial and GRIC M&I uses total approximately 5.8 MAF. Of this 5.8 MAF volume, agricultural uses comprise the largest share, approximately 5.1 MAF. Approximately 0.27 MAF of LTSC sector demands were not met.

The results of the 100-year AWS projection reveal a substantial lowering of water levels model-wide. In general, the greatest depths to water at the end of the 100-year projection are observed in the Eloy sub-basin area. Depth to water in this area exceeds the 100-year projection regulatory depth to water limit in the Pinal AMA of 1,100 feet below ground surface (bgs). The projected maximum depth to water at the end of the 100-year projection was 1,258 feet bgs. In the area south of Maricopa, depth to water at the end of the projection is approaching 1,000 feet bgs.

In some areas perched water tables were simulated in portions of upper model layers during the 100-year AWS projection period as the regional water table dropped due to projected pumping, and the downward flow of deep percolating agricultural incidental recharge was impeded by fine-grained materials in the vadose zone. These isolated perched zones do not represent a developable or viable source of water to wells and are not considered when evaluating AWS applications for compliance with the 1,100-foot static depth to water pumping limit in the Pinal AMA.

The simulated cumulative loss in groundwater storage from predevelopment until 2115 was over 44.8 MAF, with 17.3 MAF occurring before 2016 and the remaining 27.5 MAF occurring between 2016 and 2115. About 38.3 MAF of storage loss was from the drainage of pore space and the release of water due to the elastic compression of intergranular pore space. The remaining 6.5 MAF of storage loss was from the release of water due to the permanent, inelastic compaction of fine-grained interbed materials.

The 2019 Pinal Model presented in this report represents the best available tool for understanding the groundwater flow system and projecting simulated regional groundwater levels into the future. The 2014 Pinal model was extensively reviewed both internally and externally, including three external professional peer reviews.

Results of the 2019 Pinal Model sensitivity analysis indicate that the model provides an acceptable representation of the groundwater flow system in the Pinal AMA with respect to the sensitivity, correlation, and confidence intervals of key parameter values included in the non-linear regression based on available calibration data. With respect to the 2019 Pinal Model's ability to forecast, the values of invariant aquifer parameters estimated during the calibration period are shown to be valid for future projections. Furthermore, the 2019 Pinal Model generally provides a solution that, overall, minimizes model error in a regional-scale context. Although the 2019 Pinal Model represents regional-scale processes and annualized stress periods, this model may be used for site specific analysis.

References

Anderson M.P., Woessner W.W., Hunt R., J. 2015. Applied Groundwater Modeling: Simulation of Flow and Advective Transport, Second Edition. Academic Press Inc., Elsevier Publishing.

ASTM D653-14, Standard Terminology Relating to Soil, Rock, and Contained Fluids, ASTM International, West Conshohocken, PA, 2014, www.astm.org

Central Arizona Groundwater Replenishment District (CAGRD), 2015. 2015 Plan of Operation. Available online: https://www.cagrd.com/documents/plan-of-operations/2015-CAGRD-Plan-of-Operation.pdf

Corkhill, E.F. and Hill, B.M., 1990. Pinal Active Management Area Regional Groundwater Flow Model Phase Two: Numerical Model, Calibration, Sensitivity and Recommendations. Arizona Department of Water Resources Modeling Report No. 2.

Doherty, J., 2014. PEST, Model-independent parameter estimation-user manual (6th ed., with slight additions): Brisbane, Australia, Watermark Numerical Computing.

Doherty, J., 2015. Calibration and Uncertainty Analysis for Complex Environmental Models. Watermark Numerical Computing, Brisbane, Australia, ISBN: 978-0-9943786-0-6.

Gootee, B.F., Cook J.P., Young, J.J. Pearthree, P.A., 2017. Subsurface Hydrogeologic Investigation of the Superstition Vistas Planning Area, Maricopa and Pinal Counties, Arizona. Arizona Geological Survey Special Paper 11.

Harbaugh, A.W., 2005. MODFLOW-2005, the U.S. Geological Survey modular ground-water model -- the Ground-Water Flow Process: U.S. Geological Survey Techniques and Methods 6-A16.

Liu, S., Nelson, K., Yunker, D., Hipke, W., and Corkhill, E.F., 2014. Regional Groundwater Flow Model of the Pinal Active Management Area. Arizona Department of Water Resources Modeling Report No. 26.