

Objection of the ITAA, Inc. AMRC, Access Fund, Center for Biological Diversity,
Earthworks, and Sierra Club – Grand Canyon to the Resolution Copper Project
Final Environmental Impact Statement and Draft Record of Decision
(August 4, 2025)

ATTACHMENTS
PART 2

Bureau of Land Management Review of Hydrology Aspects of the Resolution Copper Project

Lisa Dubas¹, James Johnsen², Steve Rice³

June 13, 2022

At the request of the Department of Agriculture – U.S. Forest Service (USFS), the Bureau of Land Management (BLM) provided a targeted technical review of the 2021 Final Environmental Impact Statement for the Resolution Copper (RC) Project and Land Exchange (FEIS) and supporting documents.

For this review, a team of Bureau of Land Management hydrology specialists (BLM reviewers) reviewed the hydrology and water resources aspects of the project and assessed whether the FEIS adequately addressed comments received during the FEIS development. The team focused on comments and questions raised by the Salt River Pima-Maricopa Indian Community (SRPMIC), other Tribes, and governments. All but the targeted list of SRPMIC concerns were in Volume 6 of the FEIS. Due to the substantial number of supplemental studies and amount of analysis conducted to develop the multi-volume FEIS, and the relatively short time in which to evaluate, the BLM reviewers consider this document to be a high-level review which focuses on broader topics that we believe may be deficient, under-developed, or improperly analyzed rather than a point-by-point list of technical comments.

The BLM reviewers would like to acknowledge the extensive amount of time and effort that has gone into developing this FEIS and for the obvious high level of staff and time commitment by the Tonto National Forest on the National Environmental Policy Act (NEPA) process. The NEPA process and the resulting documents in the hydrology focus area were considered sufficient except where highlighted in this summary document.

While not unexpected, the FEIS struggles under the extensive scope of the proposed project and the scale of the studies needed to inform it. Several perceived deficiencies in data analysis and interpretation or in adequacy of describing cumulative effects were later rationalized by searching the enormous number of supplementary reports, studies, and memos to file. By not adequately incorporating this information into the FEIS, the final document often reads as incomplete and subjective in its preferred approaches. As difficult as it is for seasoned technical reviewers to follow the analyses, discussion, and reasoning for the assumptions and conclusions made in this FEIS, it must pose significant difficulty for a lay audience to process the scope and scale of the impacts predicted by this project, and whether they were predicted in an adequate and reasonable way. It is understood that the magnitude of a project such as this is difficult to convey in a single document, even an expansive multi-volume one, but the reviewers felt that excessive time was spent tracking down the source material and studies necessary to understand the information and conclusions that are presented in the FEIS.

This document is structured to provide a general assessment of the FEIS and supporting documentation, followed by more specific topic area discussion containing comments and findings the BLM reviewers felt

¹ Hydrogeologist, Arizona State Office

² Hydrologist, Upper Snake Field Office, Idaho

³ Hydrogeologist, BLM National Operations Center, Colorado

did not meet the analysis standards of NEPA, or suffered from insufficient evaluation or unsupported conclusions.

Table of Contents

Executive Summary.....	3
General comments on the FEIS	6
Summarize Additional Studies within FEIS	6
Additional Figures Would Benefit the Readers	6
Arizona Water Law	7
Review Applicability of New CEQ Regulations	8
General Comments About Report Organization (not related to submitted comments)	9
Technical Comments	9
Introduction.....	9
Detailed Technical Comments.....	13
Baseline Conditions.....	13
Concerns about Native Waters / Tribal Water Supplies	13
Impacts of Climate Change	14
Alternatives Analysis and Climate Change	14
Groundwater Model and Climate Change.....	15
Suggestions for Analysis of Alternatives	16
Characterization of Preferred Alternative Skunk Camp TSF	17
Impacts to Water Sources (springs, seeps, aquifer)	18
Mitigation (water)	20
Limitations of Modeling Effort.....	22
Skunk Camp Model.....	22
The Mine Model	22
The East Salt River Valley Project Model.....	25

Executive Summary

The BLM reviewers believe that all additional studies referenced in the FEIS should be summarized in the FEIS to promote accessibility. These additions would ultimately benefit the FEIS and the public's understanding of the action. These summaries should be sufficiently technical (as to provide the needed information) and approachable (for less technical readers to grasp the concepts). Where feasible, selected public comments could also be referenced in the FEIS in their respective sections, especially when the comment led to additional studies being performed.

The BLM reviewers identified the need for figures, coupled with a short discussion of terminology, to explain how the effects of this project are limited spatially and temporally. An example would be a figure of the geographic limitations on surface and groundwater flow.

The BLM reviewers found a few references to Arizona water law throughout the documents they reviewed but believe there is a need for a consolidated section within the FEIS that gives a brief overview of Arizona water rights related to this project.

The BLM reviewers note that the Council on Environmental Quality (CEQ) Executive Office of the President recently issued new regulations concerning NEPA.⁴ Our understanding of the regulations is that the USFS *may* (but is not required to) apply the new regulations to this FEIS since the NEPA process started before September 14, 2020.⁵ However, we suggest that the USFS consult with their Solicitor's Office or USFS implementation guidance (if available) about the implications of the new regulations.

With literature suggesting a higher likelihood for severe storm events in the future, the BLM reviewers believe alternatives lack sufficient discussion on climate change and the potential for catastrophic events. Climate change predictions should be discussed, and potential impacts of floods greater than the 200-year event should be incorporated into the FEIS analysis and discussion.

The FEIS groundwater model scenarios used to predict water resources impacts into the future did not incorporate any changes over time for precipitation and recharge in transient simulations. The FEIS docket contains a "Climate Change" scenario run that does not appear to be discussed in the FEIS. That scenario indicated that when reductions in recharge were simulated (which is common during drought), there were higher rates of drawdown at wells and springs compared to the static recharge scenarios presented in the FEIS, particularly to the north and east of the model area. The BLM reviewers believe the "Climate Change" scenario model run and the results from the model run should be discussed in the FEIS.

The BLM reviewers believe the potential to store some or all tailings in existing open pits in the area was dismissed too quickly and that this option should be given more than passing consideration and rise to the level of "detailed analysis". To minimize impacts, it may be feasible to place a portion of the tailings in existing pits in the area. If these existing pits cannot accommodate all the tailings from the proposed

⁴ Effective May 20, 2022. See <https://ceq.doe.gov/docs/laws-regulations/NEPA-Implementing-Regulations-Desk-Reference-2022.pdf>

⁵ See § 1506.13 Effective date.

action, a smaller tailings storage facility (TSF) alternative than that which was analyzed could be proposed for the remaining tailings.

The BLM reviewers note that the Global Tailings Review published new guidelines and industry standards for tailings management in August 2020.⁶ If practicable, the FEIS would benefit from TSF breach analysis consistent with the Global Tailings Review guidelines and standards for all alternatives. If breach analysis for all alternative TSF's is impactable, a breach analysis for the preferred alternative is recommended. Based on the changing industry standards for TSFs, it may be feasible to reconsider all alternatives, including those alternatives that were originally dismissed from the analysis.

The BLM reviewers suggest looking at alternate Pyrite Cell locations within the Skunk Camp TSF layout to potentially negate exposure of the highest concentration tailings to stormwater runoff greater than the 200-year flood event. Alternatively, analysis is recommended for the permanent rerouting of Stone Cabin and Skunk Camp Washes to the west of the Skunk Camp TSF. The BLM reviewers believe a more thorough surface water hydrology characterization, as it concerns to climate change, needs to be completed for the Skunk Camp TSF.

Additional geologic cross sections should be developed, expanding beyond the eastern bounds of the groundwater model area to the Cutter Basin to highlight both the distance and the controls to groundwater flow between these two areas. The potential for the Cutter Basin to be viewed as a potential alternate water supply in the future is a plausible indirect effect of the proposed mine.

The BLM reviewers found no mention of a date for steady state in the Skunk Camp groundwater model, other than a statement that average values were used. The reviewers also found no mention within the Skunk Camp model of flood events being incorporated into the groundwater model. It is unclear whether 100, 200, and 500-year flood events factored into the projection runs.

While dewatering of the Resolution graben has been occurring since 2009, the baseline condition for analysis would be set to the start of mining. The BLM reviewers note that baseline monitoring occurred from 2003 to 2017, but dewatering started in 2009. Please explain whether the short time-period between the start of dewatering and the end of monitoring is cause for concern. For example, did the short time-period account for a delay in response between deep dewatering and a near-surface expression of the dewatering?

The BLM reviewers strongly recommend: implementing an adaptive monitoring and mitigation plan until the effects of mining have stabilized; using site photographs, vegetation monitoring, and water levels at the associated primary monitoring well (PMW) where direct measurements of spring discharge are not feasible; obtaining mitigation make up water from outside the project area; and using a threshold for potential effects to springs and GDEs that is more stringent (expanded area of impact) than the threshold used for wells. In addition, the BLM reviewers recommend that control sites be proactively implemented for data collection, a one-mile buffer be added around the modeled extent of mining impacts to the Apache Leap tuff aquifer, and that the wells, springs, and GDEs between the 10-foot

⁶ See "Global Industry Standard on Tailings Management," available at <https://globaltailingsreview.org/global-industry-standard/> (accessed May 10, 2022). The Global Tailings Review was convened by the International Council on Mining and Metals, the United Nations Environment Programme, and the Principles for Responsible Investment. The stated goal is to "establish an international standard for the safer management of tailings storage facilities."

contour and the 1-mile buffer be part of the monitoring and mitigation plan. Finally, the BLM reviewers suggest some of the 'potential future measures' like PF-WR-03 become a required measure.

BLM reviewers do not believe the north, south and east groundwater boundaries of the mine model are sufficient because the boundaries were not extended beyond the area of potential impact. Mineral Creek is defined as a boundary in the mine model, but the Apache Leap tuff aquifer extends past this creek and literature states that Mineral Creek is fed by the Apache Leap tuff aquifer. Additionally, the BLM reviewers suggest a figure be added that shows the spatial distribution of error between measured and simulated water levels of the mine model. How many wells will be impacted by the proposed mining and what could be the potential impacts?

The BLM reviewers note that several comments were directed at the surface water and the potential for contamination. The reviewers believe that the predicted outcome of impacts at 200 years is insufficient to address the true cumulative hydrological impacts of the action. The reviewers believe the surface water time scale should match the groundwater predictions (noting that the groundwater model was run out 1,000 years). Further, with literature pointing to less frequent but larger storms in the future because of climate change, the 1000-year flood event calculated today has the potential to be recalculated soon with a higher possibility of recurrence. A longer view of the impacts would help the public understand what impact a 1000-year stormwater event would have on the preferred alternative TSF and what the final condition of the aquifers in the mine model would be once they have adjusted to the new equilibrium. The BLM reviewers suggest additional cross-sections showing the north, south, and east mine model boundaries with justification for why the model boundaries were chosen.

Other comments from the BLM reviewers address the groundwater models for Skunk Camp and the East Salt River Valley Project.

General comments on the FEIS

Summarize Additional Studies within FEIS

Several perceived deficiencies in data analysis and interpretation or inadequacy of describing cumulative effects were later rationalized by searching the enormous number of supplementary reports, studies, and memos to file. By not adequately incorporating this information into the FEIS, the final document often reads as incomplete and subjective in its preferred approaches. The BLM reviewers believe all additional studies referred to in the FEIS should be summarized in the FEIS to promote accessibility. These comments should be sufficiently technical as to provide the needed information, but also approachable for less technical readers to grasp the concepts. Where feasible, selected comments could also be referenced in the FEIS in their respective sections, especially when the comment led to additional studies being performed.

For example, the BLM reviewers believe the mining methods section does not sufficiently present or discuss why other known mining methods were not appropriate for the project location. In Appendix F of the FEIS under *Post-DEIS Analysis of Alternative Mining Techniques*, where M3 Engineering and Technology Corporation is listed as a source for in-situ mining, the USFS could simply add the following paragraph, which was in the referenced July 13, 2020 M3 report, *Viability of In-Situ Leaching of the Resolution Copper Deposit*: “Expected copper recovery would be approximately 15%, as the Resolution Copper deposit is mostly comprised of chalcopyrite and bornite ore and not copper oxide ore, which is readily leachable.” Instead, the FEIS just states it was reviewed but found not appropriate, with the M3 report listed as a source of that statement. The Reviewers believe that short statements like these, added to the FEIS for all the considered mining methods, would satisfy the comments concerned about why other mining methods were not discussed.

In another example, a comment questioned whether riparian habitats was adequately addressed in the DEIS. The response in Volume 6 of the FEIS was that the commenter was “unaware of the substantial background information, either in the project record or cited as DEIS references, that contributed to the analysis statements contained in the DEIS.” The BLM reviewers believe this comment would likely have not been submitted if previous studies had been summarized within the FEIS,.

Additional Figures Would Benefit the Readers

The BLM reviewers understand hydrologic concepts like model boundaries, boundary conditions and what they represent, cumulative impacts on surface and subsurface waters from stormwater runoff with dilution, and deposition of contaminated sediments later mobilized and transported further downstream, etc. However, some of the comments indicate there are others who do not have this knowledge but are attempting to understand the effects of the proposed project.

The following comments by the BLM reviewers relate to the need for figures, coupled with a short discussion of terminology, to explain how the effects of this project are limited spatially and temporally because of geographic limitations on surface and groundwater flow. The BLM reviewers believe that the FEIS would benefit from at least one figure that shows the various basins/subbasins in the area, with a discussion about what basins/subbasins are and how they contribute to the flow of surface water and groundwater.

For example, one of the comments received by the USFS included a figure that connected the contour lines provided in the East Salt River Valley (ESRV) groundwater model report with the contour lines provided in the mine groundwater model report, and then stated there would be cumulative effects within the mine area from pumping being done in the ESRV area. The aquifer in the ESRV is not connected to the Apache Leap tuff aquifer, which could have been more apparent to the readers if a figure of basins/subbasins had been included in the FEIS and/or the geologic controls delineating these basin boundaries was shown.

The BLM reviewers also noted comments submitted that referenced shortages of water in the Pinal Active Management Area (AMA), with reference to the ESRV model domain and the area of the mine project. ADWR's Pinal AMA groundwater model covers the Maricopa-Stanfield subbasins only, and the estimates provided on depletions within the aquifer are limited to those two subbasins and do not cross into the ESRV area adjacent to the wellfield, or the area of the proposed mining activity. The BLM reviewers believe the above-mentioned figure of basins/subbasins with supporting text could have helped someone who was speculating that the depletion estimates from the Pinal AMA groundwater model could be applied to this study area. A figure of basins/subbasins would have showed that these areas are not connected, and that any reference to a depleted aquifer in the Pinal AMA should not be used to prove depletions today or in the future for the areas referenced in the FEIS.

The BLM reviewers believe there should be a map (or several maps) that show the six alternative locations plus the HUC 12 or HUC 10 outlines from USGS (depending on the circumstances) that show each alternative and how it relates to places like "Cutter Basin", Maricopa-Stanfield, the ESRV area, the Gila River, and Top of the World. The BLM reviewers would also like to see such a map under the discussions for each alternative.

Arizona Water Law

A general discussion of water law in Arizona could be warranted – for example surface water rights not being adjudicated yet and no groundwater water rights in Arizona. Additional topics that could be addressed in this discussion are if there are any Federal or State regulations that prevent destruction of springs, if anything in the basin has been assigned a water right by the Arizona Adjudication Court, if the wells take groundwater out of the Phoenix AMA and if so, what does the law state on taking water out of an AMA? The BLM reviewers found a few references to Arizona water law throughout the documents they reviewed but believe there needs to be a consolidated section within the FEIS that gives a brief overview of Arizona water rights related to this project.

The BLM reviewers believe there needs to be a discussion about the potential for a subflow zone to be established in the project area, and if the project could potentially remove water from any proposed subflow zone. Even though a subflow zone has not been established within the project area, past precedence tells us any future subflow zone will be defined using floodplain alluvial sediments, but not bedrock or older consolidated sediments. This suggestion is not implying that the USFS needs to show where that subflow zone would be drawn, just an acknowledgement that one will be defined and if the project would impact it. The FEIS also needs a discussion about only major rivers and potentially mountain front streams being involved in Arizona Adjudication proceedings, and if there is a potential to impact these rivers. The BLM reviewers would also like to see a list of the Statement of Claimants (39s)

in the study area that would likely lose their ability to claim a water right when the Adjudication Court reaches the area as part of the Adjudication proceedings.

RC is currently dewatering the aquifer and some of the comments that were expressed denote confusion about the purpose and reasoning for the pumping. The BLM reviewers suggest a paragraph be added to the FEIS to tell readers what a mineral extraction withdrawal permit is, what the purpose of such withdrawals are, and how long RC can withdrawal under that permit, even without the new project. This paragraph should also state that permits must be renewed through the State of Arizona and state how often the permits need to be renewed.

Does the General Mining Law of 1872 have a higher priority than state and federal water rights? If the General Mining Law of 1872 is a dominant factor in the water rights at stake in the project area, the BLM reviewers want to see a paragraph stating as such in the FEIS. If the law of 1872 is not a dominant factor, the BLM reviewers want to see a discussion about other Federal rights already given and any state-based water right claims that would have an earlier priority date than RC.

A GIS layer of NHD points obtained by the BLM reviewers shows a lot more springs in the area of interest than are shown in the FEIS. Are the rest of these springs/seeps already dry? Why are they not mentioned? If they are mentioned in other literature available through the FEIS web page the BLM reviewers believe there needs to be a summary in the FEIS where the groundwater dependent ecosystem (GDEs)/springs are discussed. Would it help to tally up the number of springs that would not be impacted by the project versus how many would be impacted? Do they have 39s filed on them?

The BLM reviewers noted the mention of Superstition Vistas within Chapter 4, with the statement that the project is speculative and therefore not included in the analysis. We think it is important to provide more information related to what Superstition Vistas has managed to procure with regards to Assured and Adequate Water Supply permits and what is currently considered speculative. Superstition Vistas has obtained the rights to pump in that area, but only for a fraction of their conceptual project area.

The 39s filed with ADWR as part of the Gila River Adjudication are not mentioned in the FEIS. There are several comments that were submitted about how this project will affect water rights, but only Federal water rights would have been decided to date. Have any Federal water rights been approved within the project area? How many state-based claims have been filed with ADWR within the project area? Are there any surface water claims filed with ADWR in the area? How many parties will not be able to get a state-based water right because the water source no longer exists due to the dewatering of the Apache Leap tuff aquifer? The BLM reviewers found information within the FEIS lacking about water rights in Arizona, but we acknowledge the information could have potentially been included in another report related to the FEIS that was not reviewed by the BLM reviewers. There should also be a paragraph added that state-based rights in the area have not yet gone through the adjudication court.

Review Applicability of New CEQ Regulations

As stated in the Executive Summary, the CEQ issued new regulations concerning NEPA. The BLM reviewers believe that the USFS *may* (but is not required to) apply the new regulations to this FEIS since the NEPA process started before September 14, 2020. This understanding is based on § 1506.13 Effective Date which reads “the regulations in this subchapter apply to any NEPA process begun after

September 14, 2020. An agency may apply the regulations in this subchapter to ongoing activities and environmental documents begun before September 14, 2020.”

We understand that the USFS (or the U.S. Department of Agriculture) may have implementation guidance on how to interpret or comply with the CEQ regulations with respect to the FEIS. Therefore, we suggest that the USFS consult with their Solicitor’s Office or USFS implementation guidance (if available) about the implications of the new regulations.

The BLM reviewers note that if the USFS applies the new CEQ regulations to the FEIS, it could require the addition of information to the FEIS. For example, information might be required related to the proposed or potential smelting operations. Page 58 of the FEIS states the final smelter destination for copper concentrate has not been determined. Though this has not been determined, it will occur somewhere, and smelting is known to have potentially significant effects on the local air and water quality at which it occurs. If the smelter location is beyond the extent of cumulative effects analysis, it still should be acknowledged as an associated environmental consequence of the action. Not currently knowing the location does not preclude a discussion of potential effects.

General Comments About Report Organization (not related to submitted comments)

Volume 1 p. 87 of the FEIS states “This alternative is required by regulation 40 CFR 1502.14(d).” The placement of this statement makes it appear that the mine is required to do these activities because of this regulation. The BLM reviewers looked up this regulation and it stipulates that when a study with alternatives is completed, then a no-action alternative must be considered. The statement in the text is misleading.

If discussions about the alternatives were decided based on information presented in other sections within the FEIS, the BLM reviewers believe those sections should be called out in the FEIS text along with the decision. For example, “For a discussion of the potential impacts to water rights from this alternative see Chapter #, Section #”.

Add the water use number to the summary table given in each alternative. For example, the text earlier in the section says 590,000 acre-feet (AF) so add a line to the table that says 590,000 AF of water will be used for that alternative. Land acreage could also be added to the table as well (private, FS, BLM, State, etc.).

Technical Comments

Introduction

Adequate understanding of the surface water hydrology and hydrogeology of the mine area and proposed TSFs are key to accurately assessing the effects of mining, recovery, and for long-term stability. This includes baseline conditions, dewatering needs, drawdown in the Apache Leap tuff aquifer, impacts to groundwater dependent ecosystems and stream baseflow, seepage and transport of contaminants from the mine workings and tailings facilities, and effects of climate change, among others.

Considering the complex geology and mining-specific changes with time and the spatial and temporal scope of evaluation, all modeling and assumptions resulting from it need to be tempered with the appropriate level of acknowledgement of its limitations and uncertainty. It will be imperative that adequate monitoring be conducted and that observations are fed back into the model on a regular basis to increase the predictive capacity of the models as tools to estimate impacts. The presented extents of modeled impacts provide best estimates with reasonable degrees of certainty, but these extents should not be construed as evidence that impacts are not occurring beyond the boundaries of the presented extents. It will be imperative that adequate monitoring be conducted and that observations are fed back into the model on a regular basis to increase the predictive capacity of the models as tools to estimate impacts.

The RC project has the potential to generate significant tonnage of important ore materials, but as a result will have a significant lasting impact on the landscape that will not be repaired with any level of mitigation. Even after mining and dewatering ceases, and water levels begin to recover, hydrologic features and processes in the project area will be altered forever and, in many cases, destroyed in perpetuity.

Future precipitation and recharge conditions must be adequately addressed to evaluate the cumulative effects of mine dewatering on the impacts and recovery of water levels in wells, spring discharge, and baseflow to streams. Climate predictions of an increase in the severity of convective storm events must be adequately incorporated into assessments of future event magnitude and severity of storms related to the proposed tailings facility at Skunk Camp.

When it comes to surface features and mine waste it is important to ensure that impacts are disclosed well past the life of the mine. This involves identification of potential failure modes and more robust facilities design as these features continue in perpetuity. Because of the episodic nature of stresses like climate, earthquakes, wildfire, and stormwater events, catastrophic failure and rare natural events were not often seen as driving factors in alternative selection or mitigation planning. However, in the last few decades, with increasing news reports of tailings facility failures occurring, the potential impacts of these rare natural events appear to be increasing in importance.

According to Table R-2 in Appendix R of the FEIS, 472 comments were received with the general category of “Water resources” and comments that could touch on water related issues could also be within the general categories of “Alternative-related comments” and “Mitigation-related comments”. The number of comments received on water and water resources alone, speaks to the importance of this issue to the submitters of comments. Table 1 summarizes the topics of interest found within these comments in Volume 6 Appendix R, and those topics of interest served as a guide through the review process and for writing this report.

Table 1. Comments to the DEIS Which Guided the BLM Reviewers Strategy During Their Review

Sub-Topic	Comment/Response Number	Number of Comments
Characterization of Skunk Camp Alternative	30078-34 (WT7), 30078-35 (WT7), 463-3 (MIT3), 28824-1 (MIT1), 314-1 (MIT1), 524-15 (MIT17) lack of 200-yr, 524-18 (WT92), 524-21 (ALT1),	8
Impacts of Climate Change	30078-18 (WT4), 30075-9 (AQ11), 28449-54 (WT4)	3
Environmental Impacts	463-2 (CR12), 8030-12 (ALT22), 30078-1 (NS1), 261-10 (MIT1), 30075-3 (WT8), 30075-4 (DOC1), 30075-6 (DOC1), 30075-29 (WT17), 524-9 (WT76) only median flow used, 28449-54 (WT4)	10
Impacts to Water Sources (springs, seeps, aquifer)	235-2 (CR4), 235-18 (WT30), 235-20 (CR21), 235-23 (WT50), 8030-9 (ALT22), 30078-3 (CR4), 30078-13 (WT4_A), 30078-14 (WT42), 30078-15 (WT4), 30078-24 (WT69), 30078-25 (NS2), 30078-26 (WT19), 30078-29 (MIT3), 30078-30 (MIT1), 30078-31 (MIT1), 30078-32 (MIT1), 30078-36 (WT4), 30078-37 (DOC1), 30078-44 (NEPA-44), 30078-45 (WT54), 30078-51 (WT10), 30079-3 (WT4), 30079-4 (WT4), 322-5 (MIT1), 261-3 (MIT1), 30075-21 (MIT3), 30075-30 (MIT30), 30075-44 (WI3), 30075-46 (MIT1), 562-2 (NS1)?, 562-4 (WT4_G), 562-7 (MIT1), F1 (ALT22, ALT5, NEPA2, NS1, TS2, WT1), F2 (ALT22, ALT5, NEPA2, NS1, TS2, WT1), F3 (NS1), F4 (ALT22, ALT5, NEPA2, NS1, TS2, WT1), F6 (ALT22, NEPA2, NEPA33, NS1, TS2, WT1, WT8), 29449-56 (NEPA54), 28449-55 (WT33), F10 (ALT22, NS1, WT4, WT6)	40
Mitigation	30075-96 (MIT38), 30075-108 (MIT3), 30075-133 (MIT1), 30075-117 (MIT1), 30075-123 (MIT1), 524-6 (MIT27), 524-7 (MIT1)	7
Concerns About Native Waters	30078-17 (WT4), 30079-5 (CR4),	2
Arizona Water Law	30078-19 (WT4_H), 30078-42 (NEPA14), 30078-43 (NEPA14), 30078-44 (NEPA14), 30078-46 (WT21_C), 30078-48 (WT19), 562-6 (NEPA20) jurisdictional waters, 524-2 (MIT27) jurisdictional waters, 524-3 (MIT27), 524-5 (MIT27) jurisdictional waters	10
Baseline Conditions	30078-20 (NEPA19), 30078-21 (NEPA19), 524-1 (ALT22)	3
Basin/Sub-Basin Concerns	30078-23 (WT71), 30078-40 (WT30), 30078-41 (WT30)	3
Alternative Mining Methods	30078-28 (AMT1_B), 30078-38 (AMT1), F5 (AMT1), F6 (ALT22, NEPA2, NEPA33, NS1, TS2, WT1, WT8)	4
Limitations of Modeling Effort	30078-27 (WT61), 30078-33 (WT49), 30075-18 (WT79), 30075-20 (WT79), 30075-22 (WT79), 30075-1 (WT82),	14

Sub-Topic	Comment/Response Number	Number of Comments
	30075-23 (WT79), 30075-25 (WT8), 30075-24 (WT62), 30075-2 (WT16), 30075-26 (WT61), 30075-34 (DOC1), 28449-155 (WT81), 28449-52 (WT7)	
Impacts to Water Sources	235-2 (CR4), 235-18 (WT30), 235-20 (CR21)?, 235-23 (WT50), 8030-9 (ALT22), 30078-3 (CR4), 30078-13 (WT4_A), 30078-14 (WT42), 30078-15 (WT4), 30078-24 (WT69), 30078-25 (NS2), 30078-26 (WT19), 30078-29 (MIT3), 30078-30 (MIT1), 30078-31 (MIT1), 30078-32 (MIT1), 30078-36 (WT4), 30078-37 (DOC1), 30078-44 (NEPA-44), 30078-45 (WT54), 30078-51 (WT10), 30079-3 (WT4), 30079-4 (WT4), 322-5 (MIT1), 261-3 (MIT1), 30075-21 (MIT3), 30075-30 (MIT30), 30075-44 (WI3), 30075-46 (MIT1), 562-2 (NS1)?, 562-4 (WT4_G), 562-7 (MIT1), F1 (ALT22, ALT5, NEPA2, NS1, TS2, WT1), F2 (ALT22, ALT5, NEPA2, NS1, TS2, WT1), F3 (NS1), F4 (ALT22, ALT5, NEPA2, NS1, TS2, WT1), F6 (ALT22, NEPA2, NEPA33, NS1, TS2, WT1, WT8), 29449-56 (NEPA54), 28449-55 (WT33), F10 (ALT22, NS1, WT4, WT6)	40
Contamination/Water Quality	30078-33 (WT49), 30078-52 (TS24), 30078-53 (TS24), 30078-54 (TS24), 30075-31 (WT49), 30075-32 (WT44), 30075-33 (WT48), 30075-35 (WT44), 30075-36 (WT49), 30075-37 (DOC1), 30075-38 (WT44), 30075-42 (WT44), 30075-43 (WT44), 30075-33 (WT48), 30075-41 (WT7), 30075-45 (WT57), 30075-130 (DOC1) is only asking for something to be added to a table, 30075-131 (DOC1) correction to table, 30075-132 (DOC1), correction to table, 28449-5 (DOC1) asks for an add to a sentence, 28449-49 (WT32), 28449-89 (DOC1), 524-1 (ALT22), 524-4 (WT7), 524-8 (WT37), 524-10 (WT84), 524-11 (WT32), 524-12 (WT78), 524-13 (WT47), 524-14 (WT46), 524-16 (WI26), 28449-53 (DOC1),	32

Detailed Technical Comments

Baseline Conditions

In reference to comment response WT31 and WT45, many comments centered on when the baseline condition started, on which impacts due to mining will be compared. The Groundwater Modeling Workgroup also discussed the issue, but no consensus was ever reached on which baseline condition would be most appropriate for groundwater modeling and the NEPA analysis. Concern was expressed in the comments that while dewatering of the Resolution graben has been occurring since 2009, the baseline condition for analysis would be set to the start of mining. The BLM reviewers share this concern because baseline monitoring occurred from 2003 to 2017, but dewatering started in 2009. The short time-period between the start of dewatering and the end of monitoring did not take into consideration a delay in response between deep dewatering and a near-surface expression of the dewatering. The BLM reviewers believe it may be more appropriate to analyze available groundwater level information from wells, between where dewatering is occurring and the four springs in Devils Canyon and the 14 sites on Oak Flat. A study of historical groundwater level information could identify if pre-mining dewatering appears to be expanding towards the locations being monitored, or if impacts are already being realized.

CEQ regulations define cumulative effect as one that “results from the incremental impact of the action when added to other past, present, and reasonably foreseeable actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time” (40 CFR 1508.7) p. 911. By not adequately addressing the importance of regional pre-mining groundwater conditions and the effects of early dewatering associated with the Magma mine, and by including continued dewatering in the analysis of the No Action alternative, the approach to assessing cumulative impacts does not meet the requirements of the above definition.

Concerns about Native Waters / Tribal Water Supplies

The San Carlos Sub-Basin of the Safford Groundwater Basin, otherwise known as the Cutter Basin, is located east of the predicted extent of mining influence but remains a concern to tribal entities who obtain groundwater there. Modeling results and geologic controls, mainly the basement rock complex of the Pinal Mountains, indicate that the likelihood of mining impacts propagating to the Cutter Basin is low. To better address the concerns regarding the Cutter Basin, an additional geologic cross section should be developed, expanding beyond the eastern bounds of the model area to the Cutter Basin, highlighting both the distance and the controls to groundwater flow between these two areas. Comment response WT30 addresses the structural and distance controls between the modeled extent of impact and the Cutter Basin, but the text of the FEIS does not appear to.

However, the BLM reviewers believe that geologic isolation does not preclude indirect effects of mining impacting groundwater resources in the Cutter Basin. Should the effects of mining degrade water availability or water quality in the Superior Basin, the Top-of-the-World area, or potential new areas of population development, especially beyond the boundaries of model-predicted effects that may not be subject to mitigation/compensation for loss, water users may have to go elsewhere for water supply. As

an adjacent basin, the Cutter Basin may be viewed as a potential alternative supply, which could lead to an indirect effect of mining on the water resources within the Cutter Basin.

Impacts of Climate Change

Alternatives Analysis and Climate Change

All alternatives for the tailing facilities have advantages and disadvantages in their location, construction, drainage management, breach control, and other factors. With literature in the last decade pointing to a higher likelihood for severe storm events in the future, the BLM reviewers believe there could be an increase in their recurrence. Examples include:

- "Average air temperatures are rising, and it is likely that continued warming will accentuate the temperature difference between the Southwest and the tropical Pacific Ocean, enhancing the strength of the southwesterly winds that carry moist air from the tropics into the Southwest during the monsoon. This scenario may increase the monsoon's intensity, or its duration, or both, in which case floods will occur with greater frequency. Hurricanes and other tropical cyclones are projected to become more intense in the future. Since Arizona and New Mexico typically receive 10 percent or more of their annual precipitation from tropical storms, it is likely that this change will also increase flooding." <https://climas.arizona.edu/blog/climate-and-floods-southwest>
- "We find that floods generated by convective storms have become more common and more extreme. On the other hand, rain-on-snow floods have become rarer and less extreme." <https://doi.org/10.1029/2021GL097022>
- "A growing body of work suggests that the extreme weather events that drive inland flooding are likely to increase in frequency and magnitude in a warming climate, thus potentially increasing flood damages in the future." <https://doi.org/10.5194/nhess-17-2199-2017>

The BLM reviewers located only brief references to the analysis of flood events at each of the alternative TSF. In addition, discrepancies were noted in discussions of 100-year vs 200-year flood events. Furthermore, no discussion was found of flood events greater than 200 years. We believe each alternative lacks sufficient discussion on climate change and the potential for catastrophic events.

Please incorporate climate change predictions into the stormwater event discussion and analyze the impacts of larger floods (1,000-year flood event has been suggested by the review team) into the analysis of all alternatives. In addition, please provide a summary for each alternative that states the predicted 1,000-year event entering and exiting the TSFs. Please provide the expected spill threshold for all alternatives. This could include buffering and storage based on the TSF pond depth. Also, please provide the expected contaminants and concentrations and their change as the contact water moves downstream and additional waters dilute. Finally, please provide the required mitigation measures if such an event takes place and provide impacts analysis and extent of the contaminants. Results should

be reported in acre feet per day and ft³/s. Results should also be added to the text of the FEIS and provided in simple visual figures and tables for reference.

Groundwater Model and Climate Change

Regarding comment response WT4 on water scarcity and competing water uses, the USFS response states “cumulative effects analysis has been expanded in chapter 4 of the FEIS to quantify the cumulative effects of competing water uses in the region and the ramifications of ongoing drought or climate change” The section in chapter 4 recognizes that temperatures continue to rise and that there is a general agreement that timing and intensity of precipitation events would change, however, the groundwater model scenarios used to predict water resources impacts in the future did not incorporate any changes over time for precipitation and recharge in transient simulations. The BLM reviewers believe this results in an under-representation of the extent and magnitude of drawdown induced by mine operation (recharge was increased during simulations for the subsidence zone), which is supported by the “Climate Change” scenario that was requested to be conducted by the Groundwater Modeling Workgroup. The “Climate Change” scenario run indicated that when reductions in recharge (which is common during drought) were simulated, there were higher rates of drawdown at wells and springs compared to the static recharge scenarios presented in the FEIS, particularly to the north and east of the model area. Examples include a nearly 150-foot increase in projected drawdown between the proposed action scenario and the climate change scenario at well HRES-06 near Top-of-the-World, and significant (greater than 10 feet) additional increases in drawdown at locations such as McGinnel Spring, Rock Horizontal Spring, Queen Creek 17.39, DHRES-16, Devils Canyon 6.1E, 6.6W, and 8.8C, and Mineral Creek 6.9. The examples given are in different areas within the model, and in a variety of lithologies. The BLM reviewers could not find any discussion of the “Climate Change Scenario” within the FEIS and believe the model run and the results from the model run should be discussed within the FEIS.

According to the Arizona State Climate Office, in May 2022 Arizona is in the 27th year of a long-term drought. Data shown on the website azclimate.asu.edu/drought shows drought has affected Arizona many times throughout recorded history. The BLM reviewers are concerned that the FEIS does not adequately account for permitting processes for water use, CAP water availability, partially planned developments, and decreased precipitation (and therefore changes in recharge). The Drought Contingency Plan is mentioned, but with a short comment that the drought contingency plan is ending in 2026 and therefore will not affect the project. The BLM reviewers believe the FEIS treats other water uses as “speculative”, even though there is a high probability that some of these actions will either affect the amount of water available to RC, or the amount of water withdrawn by RC will affect other planned developments. There are many assumptions in the FEIS regarding availability of water to RC, but few assumptions on the availability of water due to an extended drought or other planned projects.

Impacts from climate change will have significant ramifications on hydrologic conditions in the project area during both mine operation and the extended recovery period. Increases in temperature leading to more ET losses to aquifer systems, a reduction in recharge-inducing snowfall, increase in the severity and occurrence interval of convective storm events, and basin-scale drought (reducing not only local water supplies but regional ones including where the Desert Wellfield is proposed), are all factors that influence the cumulative impact of the mining operation and tailings storage on the landscape. The BLM reviewers do not believe factors known to be associated with climate change, such as higher average temperatures, decreased precipitation, higher evapotranspiration, more frequent and potentially more

severe flooding, increase in forest fires due to dry vegetation, increased groundwater pumping due to the reduction of surface flows, and salinity, were thoroughly addressed within the FEIS.

Suggestions for Analysis of Alternatives

Tailings storage facilities continue in perpetuity after mine closure. The potential energy of upper drainage TSFs like Skunk Camp increases the likelihood of TSF failure and increases the potential spatial extent of impacts. Because of the episodic nature of stresses like earthquakes and stormwater events, the chance for catastrophic tailings storage failure during the life of the mine is low. However, for the communities and environment they depend on for resources like water, the chance for catastrophic failure and the associated impacts is an important consideration.

In August of 2020, in response to the increasing number of TSF failures around the world, the Global Industry Standard on Tailings Management was published with the goal “of zero harm to people and the environment with zero tolerance for human fatality. It requires Operators to take responsibility and prioritize the safety of tailings facilities, through all phases of a facility’s lifecycle, including closure and post-closure. It also requires the disclosure of relevant information to support public accountability.”

The BLM reviewers believe TSF breach analysis should be conducted for the preferred alternative following the guidelines and standards put forth by the Global Industry Standard on Tailings Management. Study results should be disclosed in the FEIS to inform alternative selection and support public accountability. This analysis is typically conducted by a qualified third party, and like other external studies, the findings should be summarized in the FEIS and should include maps for the extent of impacts and modeling outputs to inform the public. If practicable, breach analysis or some variance thereof for all alternatives should be included in the alternatives analysis to inform the decision-making process. Results from additional breach analysis will inform other permitting data needs and emergency planning and response.

With the potential for extreme stormwater events on the rise and flows that would be catastrophic to downstream resources if the proposed Skunk Camp impoundment failed, what would be the extent of the damage? Has this potential stress on the TSF been considered in the design and placement of materials? What would the extent of the damage be for all the alternatives (not just Skunk Camp)? The BLM reviewers recommend a detailed analysis of the potential extent and impacts associated with each of the alternative tailing facility locations if a catastrophic failure occurred due to the Global Industry Standard 10,000-year stormwater runoff event.

Owing to the changing standards for TSFs, it may be feasible to reopen alternatives that were originally dismissed from the analysis. An alternative that was discussed in Appendix F (Alternatives considered but dismissed from detailed analysis) was the potential to store tailings in existing open pits in the area. While many of them have legitimate rationale for dismissal, the prospect of splitting the PAG tailings into multiple sites such as Casa Grande, Copperstone, and Tohono Cyprus appears viable. It is unclear how much analysis went into the feasibility of a multi-site disposal plan, but it seems that this option should be given more than passing consideration and rise to the level of “detailed analysis” even if it were ultimately dismissed. Even if a combination of available sites still are not sufficient in storing the PAG tailings, the remainder could potentially be stored in a scaled-down version of one of the other

alternatives that was analyzed. The BLM reviewers believe this should be explored more as continued evaluation of the preferred alternative approach could potentially reveal an increasing number of concerns about its long-term reliability.

The Reviewers found no evidence within the FEIS or supporting materials that forest fires were considered in the analysis for the alternatives presented for the TSF. Due to the decades long drought Arizona is currently experiencing there is a greater chance for wildfires in the state, and the Skunk Camp location is adjacent to several mountain ranges. If a wildfire were to occur upgradient of the tailings pile, the lack of vegetation caused by the fire could have a profound effect on the local hydrology and the BLM reviewers believe this scenario needs to be addressed as an environmental impact, or as part of a climate change discussion.

It is possible the following information has been presented in other documents that were provided as reference, but the BLM reviewers believe the FEIS should state that contamination of the aquifer and rivers/streams is possible during stormwater events. Please indicate in the FEIS under what scenarios this will happen and identify the extent of contamination for each scenario. The BLM reviewers noted 10 comments expressing concern about the environmental impacts of the TSF and 40 comments about impacts to water quality. The BLM Reviewers believe there needs to be a more thorough discussion in the FEIS about this topic.

Water quality modeling results are based on the seepage collection efficiency for each alternative. However, there is little documentation on what the confidence levels are on seepage efficiency of theoretical tailings facilities. If the values presented are average or expected values, but may vary plus/minus 5% for example, how much variability does that introduce into the modeled water quality results? The reviewers believe this deserves further explanation.

Characterization of Preferred Alternative Skunk Camp TSF

BLM reviewers recognize that the alternatives presented in the FEIS are not fully developed and that the purpose of the alternatives analysis is to consider a reasonable range of alternatives that can accomplish the purpose and need of the proposed action. With that in mind the following comments are concerns about the preferred alternative. The layout and positioning of the facilities for the Skunk Camp TSF illustrated in Appendix F of the FEIS shows Pyrite Cell 1 is planned in the path of the two largest drainages entering the Skunk Camp TSF (Stone Cabin and Skunk Camp Wash). The USGS StreamStats calculated 500-year event for the Skunk Camp Wash entering the TSF is 4750 ft³/s (PII 2430 and Plu 9270 ft³/s) while the Stone Cabin Wash for the same recurrence interval is 3760 ft³/s (PII 1910 and Plu 7390 ft³/s) ([StreamStats \(usgs.gov\)](https://streamstats.usgs.gov) accessed on 05/03/2022).

The BLM reviewers suggest looking at alternate Pyrite Cell locations within the Skunk Camp TSF layout to potentially negate exposure of the highest concentration tailings to stormwater runoff greater than the 200-year event. Alternatively, please analyze the feasibility of permanently rerouting Stone Cabin and Skunk Camp Washes around the Skunk Camp TSF to the west. The USGS StreamStats calculated 500-year event for the Skunk Camp Wash at the downstream extent of the TSF is 13,100 ft³/s (PII 5900 and Plu 29,100 ft³/s) ([StreamStats \(usgs.gov\)](https://streamstats.usgs.gov) accessed on 05/03/2022). Diverting all the upstream inflow to the TSF from Skunk Camp and Stone Cabin Washes would reduce the 500-year flood event volume of

water coming into contact with tailings in the Skunk Camp TSF by more than 50%. This has the long-term benefit of rerouting potential peak flows around the tailings facility and potentially generating more robust excavated material for tailings impoundment structures. The new alignment appears to be a paleo alignment of those washes prior to the washes eroding through the bed rock.

Permanent diversion dams for the Stone Wash and Skunk Camp Washes potentially entering the TSF should be of significant size and construction to prevent the suggested 1,000-year stormwater event from gaining contact with the TSF. As mentioned above, the probability of a 1,000-year stormwater event occurring during mining operations is low, but viewed at a longer temporal scale, it is an important consideration.

The BLM reviewers believe a more thorough surface water hydrology characterization as it concerns to climate change needs to be completed for the Skunk Camp TSF. This location has the largest 100-year floodplain footprint when compared to other drainages in the area and BLM reviewers are concerned that more frequent and more severe flood events that could result from climate change have not been addressed. The more severe flood events could cause erosion and breach of the tailings pile, which would lead to contamination and impact the Gila River. This location is mostly surrounded by mountains, and with wildfires more likely due to a drier climate, the risk of flood flows caused by fires in the mountains is also a concern for the reviewers.

The BLM reviewers found no mention of a date for steady state in the Skunk Camp groundwater model, other than a statement that average values were used. Does that mean all historical water levels were averaged and that the data used was not representative of a single moment in time? There needs to be more of a discussion in the FEIS about the steady state heads used in the groundwater model.

The Reviewers found no mention within the Skunk Camp model of flood events being incorporated into the groundwater model. Were 100, 200, 500, etc. flood events factored into the projection runs? The groundwater model seemed to mainly be a tracer type study to show how far contaminants would travel if they got into the aquifer or streambed.

Impacts to Water Sources (springs, seeps, aquifer)

After significant study of the FEIS and supplemental studies the BLM reviewers believe the characterization of GDEs is inadequate. On the United States Department of Agriculture RC Project and Land Exchange Environmental Impact Statement web page under “Baseline Reports” there are inventories of springs, but only a few of those springs were included in the FEIS. The BLM reviewers did not see a discussion in the FEIS about why only a few of these GDEs were included within the study.

One of the questions sent to the USFS was a concern that there could be an impact to the subflow zone along the Salt River, due to pumping associated with the project. Since the project is nowhere near the Salt River, the BLM reviewers wonder if this comment is concerned about pumping near the Gila River. If that is the case, a cross-section showing the general geology from the East Valley wellfield to the Gila River could be used to show that pumping for this project can not impact the Gila River.

The BLM reviewers believe the FEIS does not provide enough information to satisfy the concern that the damage to the aquifer from future subsidence at Oak Flat will impact the water in Mineral Creek. If that

information is available within a supplemental source, a summary of the study should be provided in the FEIS.

In Comment Response WT19, which concerns mitigating lost flows to Queen Creek, the response states that through mitigation (measure FS-WR-04) lost flows would be replaced by direct input of water from existing wells. Since the loss of flows due to subsidence are a permanent feature of the post-mining landscape, are mitigation flows to Queen Creek planned to be permanent, or will this mitigation be like the mitigation planned for springs and GDEs, where after 10 years past active dewatering the mitigation could potentially cease. The BLM reviewers believe the response as written requires additional clarification to be adequate.

The area encompassed by the RC project, within any scenario, consists of lands managed by the USFS, State Land, and BLM, as well as interspersed private ownership. The BLM reviewers wondered if the dewatering of the shallow aquifer will forever prevent any future landowner or development from using the shallow Apache Leap tuff aquifer as a water source, which would force any development or landowner to either drill a more expensive well to a deeper water source, or force them to obtain water from another basin?

In the water budget information presented in Volume 4 Appendix H of the FEIS, there are three periods discussed which include construction, operation, and rampdown, but there is no indication that any water budget analysis was done for the period following year 45 (end of rampdown). Water budget values should be presented for out-years (perhaps 200 years to match the groundwater model) to compare the budget to pre-mining conditions.

The water balance information shown in Volume 4 Appendix H of the FEIS has exact numbers given to represent water use for each aspect of the project and is meant to convey water use between mine years 6-12, mine years 13-36, and mine years 37-46. The BLM reviewers wonder how such specific values can be calculated before the project has even begun. As part of any groundwater modeling process the initial step of creating a water budget always involves coming up with ranges based on available literature. The exact numbers presented in this report could likely change as mining progresses, and therefore should be represented as a range of values instead of exact values. The BLM reviewers would also like to see, built into the FEIS, mitigation efforts by RC if water use ends up higher than the new range of values.

The BLM reviewers believe the cumulative impact to groundwater users in the affected area are not well quantified, which should include costs to deepen or relocate wells and added costs to draw groundwater from deeper depths or treat for degraded quality prior to use. Effects more difficult to directly quantify are the long-term impacts related to loss of basin storage due to irreversible subsidence.

In Volume 2 of the FEIS on page 384 Figure 3.7.1-6 depicts “Apache Leap tuff aquifer water-level elevations and general flow directions”. The BLM reviewers think there should be a similar figure which shows the predicted water level once the upper and lower aquifers become connected through subsidence and new steady state conditions are created.

Mitigation (water)

The BLM reviewers did not find any references within the FEIS to monitoring data being added back into the mine groundwater model to determine if initial predictions were accurate or if more mitigation measures needed to be considered to get the results intended under the mitigation plan. The reviewers also wondered if the data obtained through the mitigation efforts were to be entered back into the model and the results showed mitigation efforts were not moving in the direction intended, what would RC do with the result to ensure mitigation efforts stay on track?

The BLM reviewers do not believe the FEIS does enough to acknowledge that although subsidence will be monitored, there is not much that can be done to mitigate once block caving has started. The BLM reviewers believe there needs to be a discussion within the FEIS about the limitations of mitigating the effects of subsidence and an acknowledgement that subsidence could occur in a way that has not been predicted by the modeling efforts.

According to the FEIS, the groundwater model was based on a 200-year timeframe and effects of the mining project could go on for much longer than 200 years. However, the monitoring plan (2020 Monitoring and Mitigation Plan for Groundwater Ecosystems and Water Wells by Montgomery and Associates) states monitoring will only be done for 10 years after dewatering has ceased. The BLM reviewers believe 10 years is not adequate, considering the effects will be felt for hundreds of years, and that the monitoring and mitigation action should be in place until the effects of mining on those sources have been mitigated from the effects of the mining project.

As stated in Volume 4 of the FEIS on page J-2, "The role of the Tonto National Forest under its primary authorities in the Organic Administration Act, Locatable Regulations (36 Code of Federal Regulations (CFR) 228 Subpart A), and Multiple-Use Mining Act is to ensure that mining activities minimize adverse environmental effects on National Forest System (NFS) surface resources." The BLM reviewers want to know if the contents of this statement inhibit the agency's ability to mitigate impacts to groundwater resources (the Apache Leap tuff aquifer) that provide water to surface resources, like springs fed by water from the Apache Leap tuff aquifer?

In Table 2 of the monitoring plan, the measurement type at the springs is listed as "visual estimate" of flow. The BLM reviewers believe "visual estimate" of flow is a qualitative, subjective, and un-repeatable approach that should not be used in the statistical analysis of discharge trends over time. If spring flow cannot be measured directly (volumetric, weir, etc.) it should not be recorded, and site photographs, vegetation monitoring, and water levels at the associated primary monitoring well (PMW) should be used instead.

Contingent monitoring wells (CMWs) are planned at some of the GDE sites, but the CMWs are only planned to be constructed and monitored once trigger levels are met at a nearby PMW. The BLM reviewers believe, when the compartmentalization by faults and the heterogeneity of the fractured Apache Leap tuff are taken into consideration, it seems plausible that impacts will be realized at some GDE sites without a nearby PMW having reached the threshold necessary to move forward with a site-specific CMW.

Installation of wells, or systems to harvest precipitation or surface water flows to mitigate for spring flow loss is a flawed approach which follows the 'rob Peter to pay Paul' logic (FEIS p.421) and would

more accurately be called ‘passing the buck’ or ‘kicking the can’ than ‘mitigation’. The water captured by a well in the discharging aquifer system of the spring, or capturing rainfall or flow is simply taking water that would have provided another resource further downgradient. From a water budgeting perspective, the only true means of compensating for loss of spring flow is to make up for the loss of system water by augmenting with water from outside that system. Otherwise, it should be acknowledged that the mitigations as proposed have the potential for future negative impacts on other undetermined downgradient resources. The only in-basin alternative that would not impair the collective water resources of the area would be after subsidence connects the Apache Leap aquifer with the deeper aquifer; water could be collected via wells prior to being lost to the lower aquifer and redistributed back on the landscape.

The monitoring plan shows many springs having been historically impounded, diverted, or otherwise influenced. Restoration of these sites may offset the impacts of potential reductions in flow or add habitat to compensate for other areas that may experience significant reductions or total loss of discharge. The reviewers propose that a mitigation for springs and GDEs could be to remove the development structures which inhibit full ecological utilization of the groundwater discharge. However, this is the opposite of what is proposed in the plan, where impacts to flow would trigger more construction of spring boxes. If the springs in question are within a 10-foot drawdown area, only substantial site work could create a spring box that would continue to supply groundwater to the surface.

The potential for a 10-foot water level decline in a well could result in an inconvenience or could make a well non-viable for water production. By contrast, a 1-foot decline in the water table from an aquifer that supplies water to a spring could prevent discharge from occurring at the spring entirely. The BLM reviewers believe the threshold for potential effects to springs and GDEs should be more stringent (expanded area of impact) than the threshold used for wells.

A 10-foot contour line, as stated within the FEIS and provided literature, was the highest accuracy decided upon to represent the effects to the Apache Leap tuff aquifer due to mining activity, and nothing less than 10-feet of drawdown was presented. The 10-foot contour line represents the drawdown limit after 200 years, but it has been acknowledged that drawdown will still be occurring after 200 years. The BLM reviewers suggest a one-mile buffer be added around the modeled extent of mining impacts to the Apache Leap tuff aquifer, and that the wells, springs, and GDEs between the 10-foot contour and the 1-mile buffer be part of the monitoring and mitigation plan.

The BLM reviewers believe the monitoring plan should have control sites outside of the mine project area to study non-mine related impacts such as precipitation patterns, temperature, non-mine pumping, wildfire potential, etc. Control sites were mentioned as a potential in Level 2 trigger, but these control sites should be proactively implemented for data collection, rather than implemented as a reaction to decreasing flows or water levels. The use of control sites would also improve the confidence in the analysis results.

Measure PF-WR-03 is another ‘potential future measure’ that should become a required measure. The EIS states that quality impacts and water level declines are not anticipated due to operation of the Desert Wellfield, it should not be a voluntary potential future mitigation. If no effects are observed, there will be no action necessary, however, the BLM reviewers believe it should be a mandatory

mitigation if in fact negative impacts are observed. The uncertainty in occurrence should not preclude the requirement for action should it occur; as such, this should be a required measure.

Limitations of Modeling Effort

Skunk Camp Model

See earlier discussion of the Skunk Camp model in the “Suggestions for Analysis of Alternatives” section.

The Mine Model

The BLM reviewers do not believe the north, south, and east boundaries of the mine model extend far enough, and that the reasoning given (that only one of the sensitivity runs showed depletion at the boundaries of the model domain and therefore the boundaries are sufficient) is not an adequate justification as the impacts are based on extent of an arbitrarily selected impact threshold, and not the extent of potentially measurable impact.

Model boundaries should extend beyond areas that could potentially be impacted by the project, and since the project will impact the Apache Leap tuff aquifer, and has the potential to impact Mineral Creek, the BLM reviewers believe the FEIS did not adequately explain why Mineral Creek was chosen as a general head boundary (GHB) in the mine model, while a map of the Apache Leap tuff reviewed by the BLM reviewers shows the unit extending beyond Mineral Creek. There is also reference in the literature that states Mineral Creek is fed in places by the Apache Leap tuff aquifer, yet Mineral Creek was chosen as the boundary for the groundwater model.

The BLM reviewers noted that no pumping other than mine related pumping was added to the mine groundwater model, or at least we did not see any evidence that current stresses outside those caused by the RC mine were incorporated into the model. The BLM reviewers believe model boundaries far away from stresses to the aquifer cannot be accurately chosen unless all pumping within the Apache Leap tuff and deeper aquifer are included within the groundwater model.

Many WT comment responses provide the estimated water budget values for varying components of the mine operations, stating that while this is “complex”, values are presented to the single acre-foot. By contrast, model estimates of mine impact are not presented past 10 feet of drawdown because of uncertainty. The BLM reviewers wondered if the values used to calculate the water budget (fracture flow drainage, ore moisture, tailings facility seepage control efficiency, etc.) are so well constrained that this level of precision is justified? A review of Appendix H (Mine water balance and use) does not indicate that the presented values are an average, median, or range of potential values, they are presented as one static value for each component of the overall balance.

Comment response WT36 states “In the DEIS we compared the elevations of the subsidence crater and modeled elevations of groundwater during recovery and found that even after a period of 1,000 years they did not intersect.” The BLM reviewers noted up to a 500 ft error in the water levels for the deeper aquifer in the hydrographs. Did the USFS choose water levels from hydrographs that had a lower error rate? Or did the USFS use water level elevations presented as part of the final scenario run? We are concerned that error prone water levels were used to make this assumption.

A secondary purpose of the mine model is to evaluate the effects of dewatering on the Apache Leap tuff aquifer. The BLM reviewers wondered if the collapse of Oak Flat causes the Apache Leap tuff aquifer to dewater, does the GHB used in the mine model at Mineral Creek permit the stream to dewater if the effects of the dewatering extend to Mineral Creek?

The BLM reviewers suggest a figure that shows the spatial distribution of error between measured and simulated water levels for the Apache Leap tuff aquifer and the deep aquifer are needed with any discussion of model related error in the FEIS. For example, The ADWR Salt River Valley 2009 model report has such a figure (https://new.azwater.gov/sites/default/files/SRV8306_Model_Report_1.pdf) which makes it easy to determine where the groundwater model was under and over simulating water levels in the chosen calibration run of the model.

The BLM reviewers looked at the hydrographs within the February 2019 RC Groundwater Flow Model Report in Appendix C and it appears that the Apache Leap tuff aquifer heads were simulated adequately, but that the deeper aquifer heads had errors up to several hundred feet. Is this an accurate interpretation of the hydrographs? If this is an accurate interpretation, does this error reflect the collapse of the mine over time? If that is the case, then the report needs further explanation so the reader can make the connection. If not, then there needs to be some explanation as to why the error is acceptable for the deep aquifer.

In Section 1.1 of the SWCA Environmental Consultants *Review of Numerical Groundwater Model Construction and Approach (Mining and Subsidence Area) Final* report, the modeling work group stated “Number of known private and public water supply wells within the geographic extent of the water-level impact, and assessment of impact to these water supplies”. The BLM reviewers wonder if this was ever completed. If as part of the groundwater model discussion the results are to be presented using a representative well, so that a real well owned by a private entity is not used in the analysis, the BLM reviewers understand that decision. But the USFS needs to also state how many wells are registered with ADWR that could potentially be impacted given the extent of impact shown in the groundwater model. Exact locations and registry numbers are not required.

On page 410 and 411 of the FEIS the comment about well impacts is misleading. The model presented impacts at a well that was created only to symbolize pumping in a specific area (Top of the World, Superior, Boyce Thompson Arboretum). But as stated in a comment submitted to the draft EIS, all wells produce differently based on varying hydraulic conductivity and depths. The BLM reviewers believe Table 3.7.1-4 is misleading because one well is used to represent Superior, Boyce Thompson Arboretum, and Top-of-the-World. If other wells in those areas have different hydraulic conductivities or are screened in slightly different locations, the drawdown in those wells could be different from the well chosen to represent the area. Table 3.7.1-4 at least needs a statement that these wells were chosen to represent each area and a similar analysis at other wells within the same generalized area could produce different results.

Previous reviewers point to lack of adequate scientific data within the groundwater model (Comment ID 30078-27, 30075-26, 28449-62, 28449-155, BGC Engineering USA Inc, 2020) which made the model a generic representation of the system versus a complex representation of the system. When beginning a groundwater model of this scale, the best approach is to build a model based on a very generic system, get it calibrated, then add complexity as the model progresses. In response to the concerns expressed by past reviewers, a generalized USFS response was given that adding additional complexity could

produce more model uncertainty by requiring additional parameters to be estimated in the absence of value data (SWCA memo 2020). The BLM reviewers looked to ADWR's approach with the complex regional groundwater models that they have built. These models are used by countless entities in support of assured and adequate water supply designations in the State of Arizona. The ADWR models follow proven groundwater methodology, and they take time to calibrate and refine their modeling approach to incorporate more complex data. Examples of data that would improve the mine model are variations of recharge, variations to evapotranspiration rates, and stresses on the aquifer not limited to RC pumping.

Comprehensive reviews of the model had been conducted prior to the release of the FEIS in 2021 by various parties. The BLM reviewers evaluated the model report, and the description of predicted impacts, prior to evaluating past assessments of the model, as well as the Water Resources Workgroup responses and modifications based on these evaluations. Remarkably, many of the same concerns expressed in past assessments of the model were identified by the BLM reviewers, indicating the concerns had never been incorporated into the groundwater model by the time the FEIS was released. According to the October 2020 SWCA report *Evaluation and Response to Public Comments on Groundwater Modeling Analysis*, prepared for the USFS, the various reasons behind not addressing these concerns were listed under "General categories of comments received" which included four categories of comments and an accompanying table (Table 1). The "General categories of comments received" section, and the accompanying table, did not address that there were definite concerns with the mine model. The section only lists reasons why the legitimate concerns should not be addressed.

The FEIS states that the model was run to 1,000 years, as this was likely necessary to bring the model to a point when effects of mine dewatering were no longer expanding, and that water levels at the edges of mine influence begin to recover. Model scenarios indicate that impacts beyond 200 years are predicted in the areas of natural discharge in Queen Creek, Telegraph Canyon, and Arnett Creek, and in water supply wells in Superior and Top of the World for many hundreds of years up to roughly 900 years. (FEIS p.411). The BLM reviewers believe it should be recognized and highlighted within the FEIS that the information presented in the FEIS does not represent the bounds of predicted impacts, merely those which can be reasonably predicted at an arbitrarily determined time step. We also believe that analyzing only three predicted outcomes, no action (with continued dewatering), life of mine, and impacts at 200 years, is insufficient to address the true cumulative effects of the action.

As addressed in comment response WT16, long term trends shown by the groundwater model have been limited to 200 years. While this time period was agreed upon by the Groundwater Modeling Group, there appears to be no reasoning provided as to why it is anything other than an arbitrary value. The BLM reviewers wondered if there were indications that there is an inflection point in predictive capability at 200 years and beyond this point certainty drops off? Without explanations as to why this alternative was chosen, one could assume that a reason 200 years was chosen was because if the spatial extent of the model was beyond this time period (say 300 or 400 years) the groundwater model results would show that mining impacts extend a significant distance past the model boundary, which would warrant an expansion of the model domain and re-analysis. The comment on the use of the 200-year time period has been mentioned multiple times in past reviews, but the response from the USFS has simply been that 200 years was the agreed-on time frame. The use of drawdown at 200 years and 10 feet was not universally agreed upon by the internal Groundwater Modeling Workgroup.

Regarding the potential formation of a pit lake, comment response WT36 states that comments on water levels rebounding and forming a pit lake are inaccurate, because “changes wrought to the aquifer by the block caving fundamentally change the hydrologic and geologic framework of the system. A return to pre-mining conditions is not anticipated, and a return to pre-mining groundwater levels is not inevitable.” Model results have been provided to 200 years and have been qualitatively described as continuing to expand for many hundreds of years, even more than 1,000 years, but there is little description or presentation of what will be the new groundwater condition in this area long into the future. This project is not one where after time, even a very long time, conditions return to an approximate pre-mining condition. The BLM reviewers believe a description of what the new system will look like and how it will behave is warranted. Uncertainty may be high in this assessment, but it should not be avoided.

The WSP (2018) block cave report states that once subsidence connects the Apache Leap aquifer with the lower system (mine year 16), the Apache Leap will be draining nearly 1,600 gallons per minute (gpm) out of the upper aquifer system into the lower workings. This rate will decrease over time, but at mine year 50 it will still be draining nearly 380 gpm (600 acre-feet per year) as the Apache Leap tuff continues to move towards a new equilibrium condition. While these flows will be removed from the lower aquifer via the mine drains during mine operation, once mining is completed these flows will continue to drain from the upper aquifer until another equilibrium condition is reached, either by filling the extent of the workings and subsidence area or draining the Apache Leap aquifer. This drainage likely accounts for the single largest output of groundwater from the Apache Leap aquifer, so what does this do to new equilibrium groundwater flow directions and gradients compared to the pre-mining condition? Will existing drain points for this aquifer ever recover to pre-mining conditions or will the generation of this new base level permanently alter this system, and what is the ultimate drain point for the lower aquifer?

Figure 2.1, Surface Geology Map, within the WSP February 2019 RC Groundwater Flow Model Report, shows the locations of cross-section A-A' and B-B' which are centered on the Oak Flat area of the project. The BLM reviewers noted that neither cross-section can be used to help orient readers as to why the north, south and east groundwater model boundaries were chosen. We would like to see either new cross-sections added to the FEIS, or modifications to these cross-sections, that would help explain to reviewers of the EIS as to why WSP chose those boundary locations for the groundwater model. The BLM reviewers also believe such cross-sections would help to explain the science between basins/sub-basins and surface water/groundwater flow.

The East Salt River Valley Project Model

The BLM reviewers did not see any reference within the FEIS or provided documents to indicate site geology was used to update the 2009 ADWR Salt River Valley groundwater model. A study was published in 2017 by the Arizona Geological Survey, with funding provided by RC, of the Superstition Vistas Planning Area, within the area shown in the FEIS and accompanying documents that would be used by RC for their East Salt River Valley pumping wells. The BLM reviewers did not read this report, but the publication stated, “Depth to bedrock, and saturated thickness, were significantly increased throughout SVPA, especially along bedrock piedmonts adjacent to the Superstition Mountains and Mineral Mountains.” The increased depth to bedrock has not yet been included in a published ADWR

groundwater model of the East Salt River Valley, but the BLM reviewers believe this information should be reviewed and incorporated into the groundwater model that evaluates the pumping wells for the RC project.

The BLM reviewers want more of an explanation into how dry cells were modified within the East Salt River Valley Project Model when cells went dry. The literature stated cells that went dry were modified, but the BLM reviewers did not find anything cited within the literature to indicate what scientific data was used to give the cells a greater depth to bedrock.

The BLM reviewers found, related to the FEIS, that the pumping model within the East Salt River Valley states the groundwater model takes into consideration past stored water credits that RC has in the East Valley. Within a few years other entities that have stored water within the East Salt River Valley will also be removing their stored water credits. BLM reviewers would like to know if the pumping model factors in other entities removing stored credits.

The BLM reviewers noted the location of the modeled 25-foot drawdown contour but found no mention of other water users within that 25-foot drawdown zone. Are there current water users within that 25 ft drawdown zone, and are there any future projects already approved by ADWR within that area?

The BLM reviewers believe change maps should be included in the ESRV model report, in addition to the contour maps provided in the groundwater model report. For example, illustrating how much has depth to water changed between the no-action alternative and the other alternatives.



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

Table of Contents

Background	1
Modifications to the Pinal AMA Groundwater Flow Model	1
Structural Modifications to the Pinal AMA Groundwater Flow Model	1
Comparative Residuals.....	6
Model Sensitivity and Calibration	8
100-year AWS Projection.....	9
Introduction	9
Major Assumptions For the 100-Year AWS Projection	9
Model Assigned Pumping Demands.....	12
Assured Water Supply Demands.....	12
Existing Sector Demands	15
Long-Term Storage Credit Removal	16
Well Locations for 2016 – 2115 Projection	20
Existing wells.....	20
Proposed New Wells.....	22
LTSC Removal Wells.....	24
Total 100-year Pumping Demand.....	25
Vertical Distribution of Pumping Demands and Use of the Multi-Node Well Package.....	26
Recharge Projections	27
100-Year Projection Model Results	28
Total Unmet Demands.....	28
Identification of AWS Unmet Demands.....	32
Increased Depths to Water and Perched Water Table	34
Change in Storage	46
Summary.....	48
References	50



Figures

Figure 1. Locations of Structural Modifications and Changes in Total Sediment Thickness	3
Figure 2. Horizontal Hydraulic Conductivity (Kx) Before Structural Modifications.....	4
Figure 3. Horizontal Hydraulic Conductivity (Kx) After Structural Modifications.....	5
Figure 4. Simulated vs. Observed Residuals.....	7
Figure 5. Residuals Over Time	7
Figure 6. Locations of Designations, Certificates and Analyses Areas in the Pinal Model Area	14
Figure 7. Existing Wells with Pumping in 2015.....	20
Figure 8. Existing Wells Removed from Projection Due to Overlap with AWS Development Footprints.....	21
Figure 9. Proposed and Actual Pump Locations Simulated for Certificates, Analyses Areas Designations	23
Figure 10. Long-Term Storage Credit Removal Pump Locations.....	24
Figure 11. Pump Locations and Total Quantities Assigned 2016 - 2115	25
Figure 12. Pump Demands by Sector vs. Total Recharge 1923 - 2115	26
Figure 13. Recharge Projections by Sector 2016 - 2115.....	28
Figure 14. Pumping Demands Assigned vs. Simulated.....	29
Figure 15. Location of Wells with Unmet Demands 2016 – 2115	33
Figure 16. Simulated Depth to Water 2015 and 2115 and Change in Depth to Water	37
Figure 17. Water Level Cross Section Location Map	39
Figure 18. Cross Section A -A'	41
Figure 19. Cross Section B-B'	42
Figure 20. Cross Section C-C'	43
Figure 21. Cross Section D-D'	44
Figure 22. Cross Section E - E'	45

Tables

Table 1. Head Residual Statistics (in feet) Before and After Structural and Kx Modifications.....	6
Table 2. Summary of Pinal Model Area Issued, Developed and Baseline Model Assigned Adequate and Assured Water Supply (AWS) Volumes	12
Table 3. Long-Term Storage Facilities and Credits (AF) Simulated Removal Between 2016 – 2115	18
Table 4. Model-Wide Pumping Assigned vs. Simulated and Unmet Portions	29
Table 5. Summary of Cumulative Demands and Simulated Pumping by Sector.....	31
Table 6. Summary of Model-Wide Heads, Depths to Water, and Saturated Thicknesses.....	35
Table 7. Water Budget Summary	47

Appendices

Appendix A – Modifications to the Pinal Model Since 2014
Appendix B – Structural Modifications to the Pinal Model
Appendix C – Head Residual Maps and Hydrographs Before and After Structural Modifications
Appendix D – Control Calibration Statistics
Appendix E – 100-Year AWS Projection Agricultural Water Use and Recharge
Appendix F – 100-Year Projection Tables
Appendix G – Gila River Indian Community Agricultural Water Demand and Incidental Recharge
Appendix H – Simulated Hydrographs During 100-Year Projection



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**.



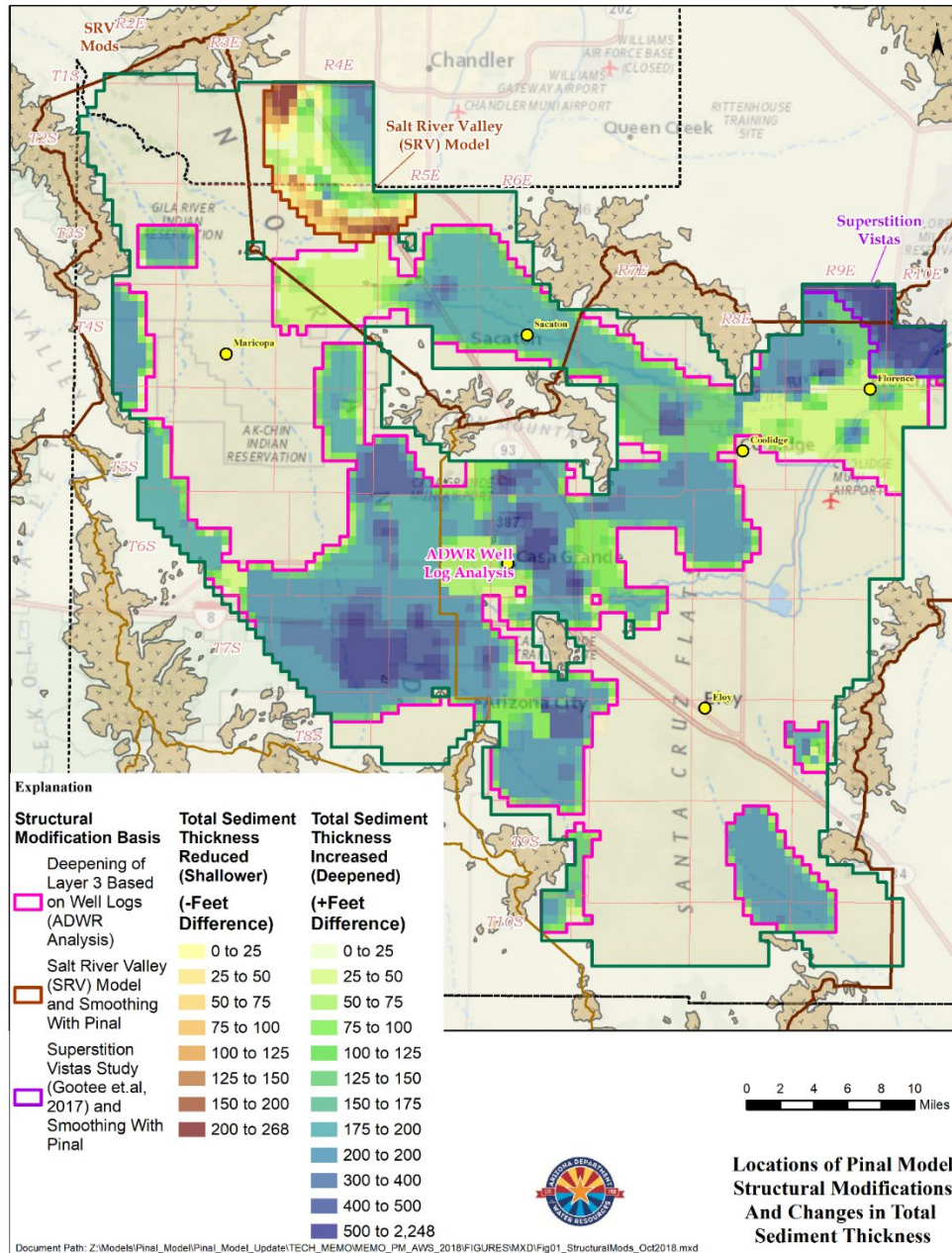


Figure 1. Locations of Structural Modifications and Changes in Total Sediment Thickness

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.

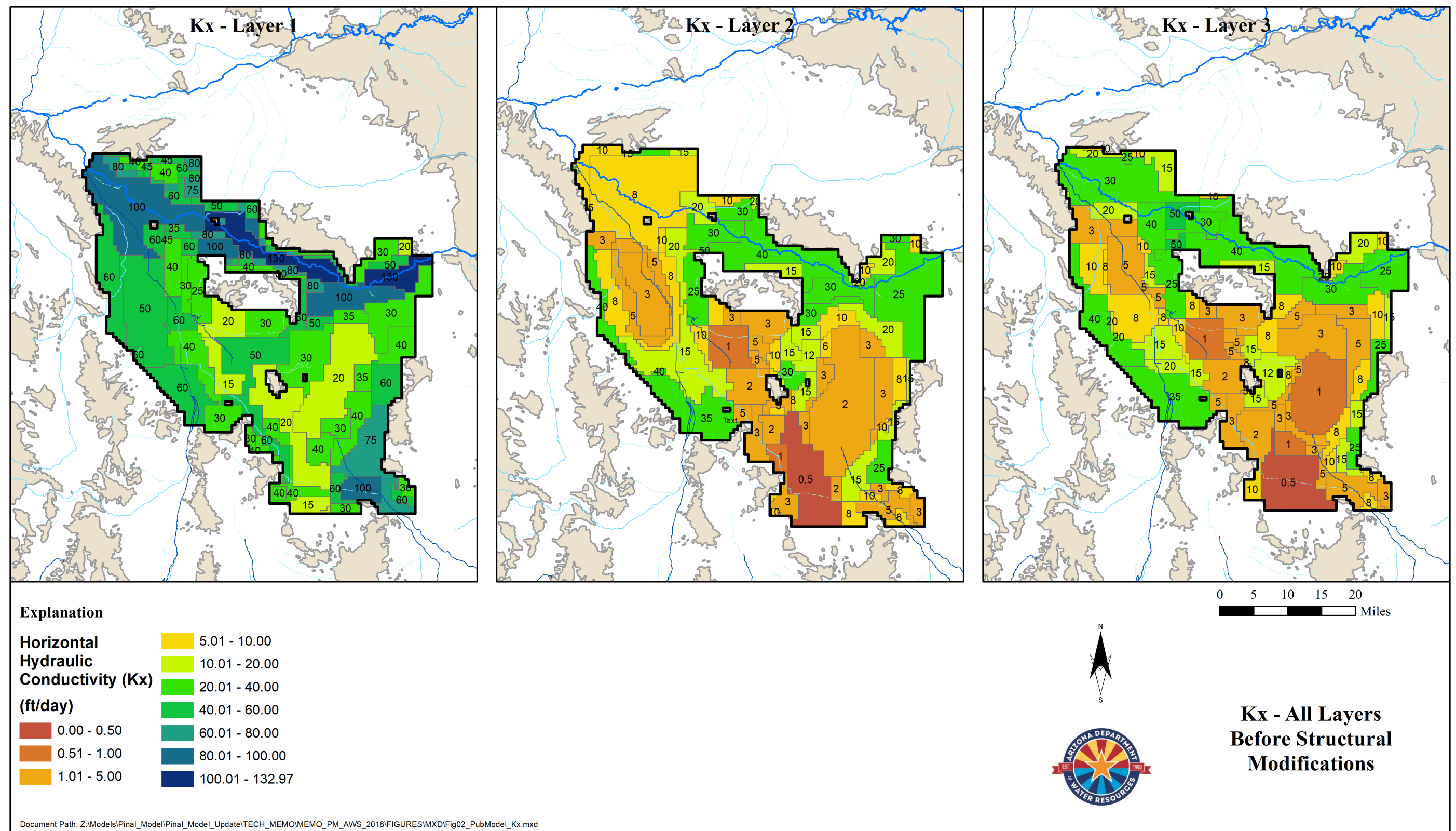


Figure 2. Horizontal Hydraulic Conductivity (Kx) Before Structural Modifications



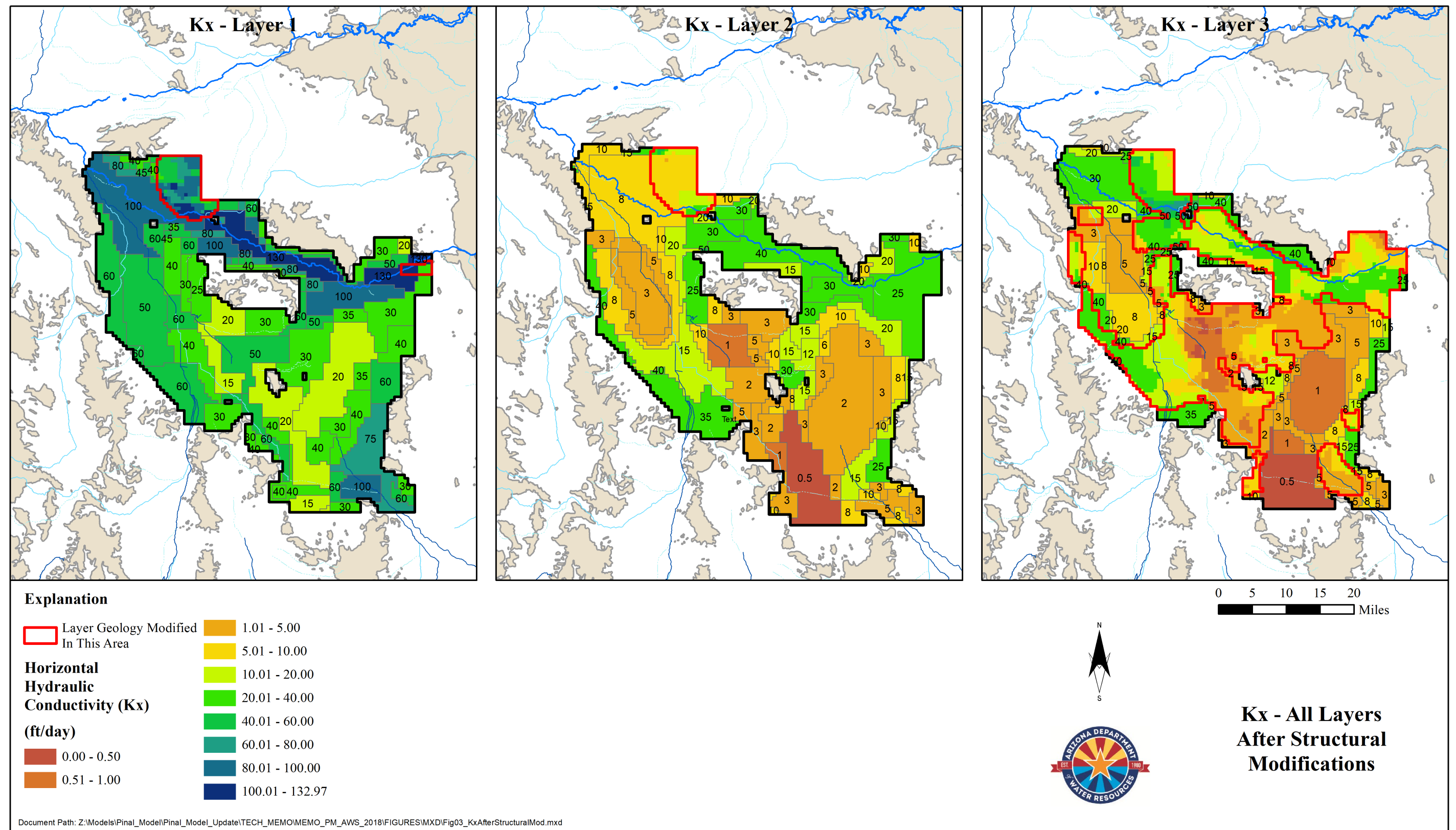


Figure 3. Horizontal Hydraulic Conductivity (Kx) After Structural Modifications



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)



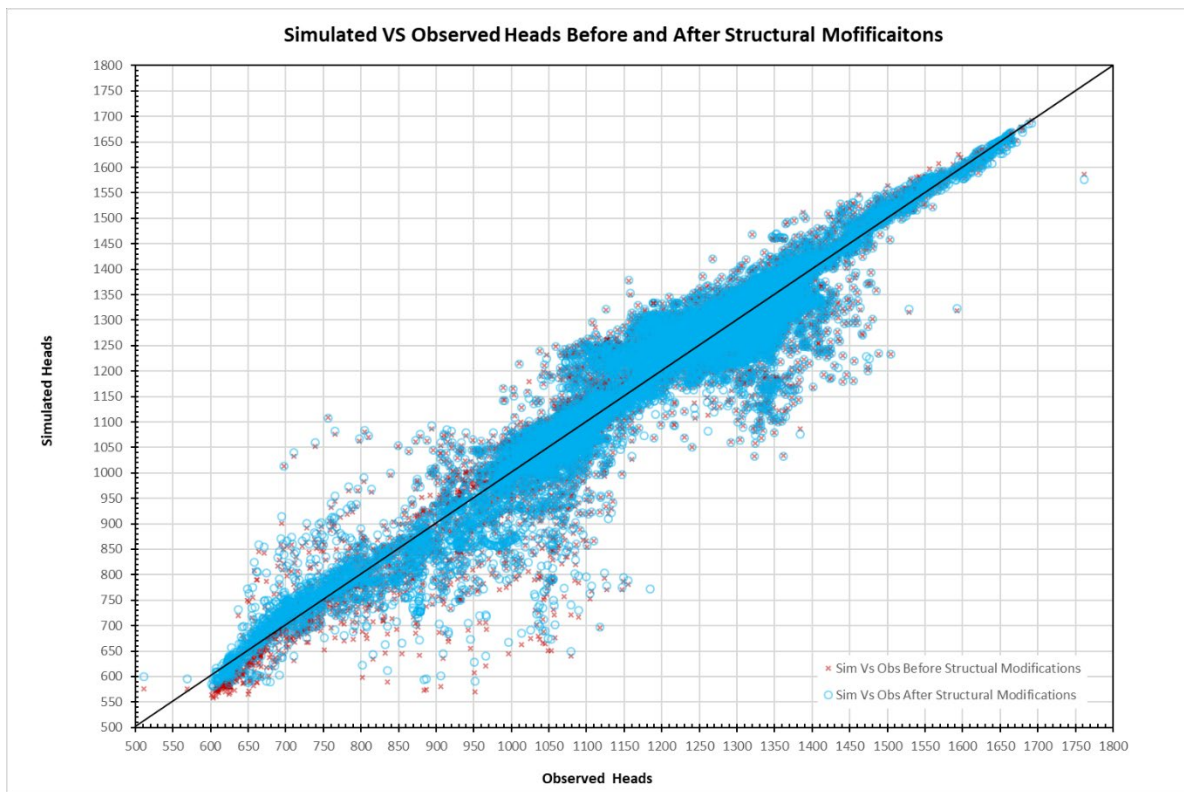


Figure 4. Simulated Vs. Observed Residuals

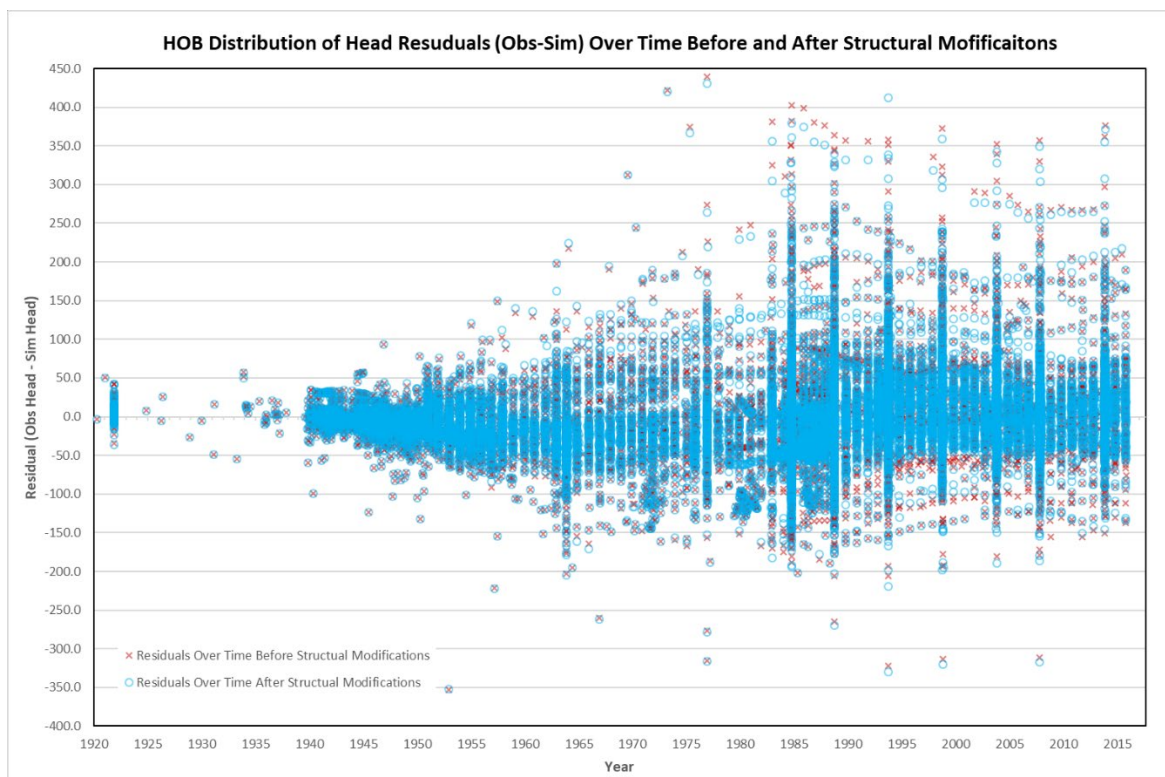


Figure 5. Residuals Over Time

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 CAGR D 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	Certificates	Designations	Totals
	(AAWS)	(CAWS)	(DAWS)	
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 CAGR D	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
CAGR D 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. $320,279 \text{ non-RRA CAGR Credits} / 15,500 \text{ Years} = 20.66 \text{ Years}$. 5,220.75 AF Obligation for partial year 2035.
4. 5,220.75 in 2035 + 15,600 Year 2036 - 2115 (79 Years)



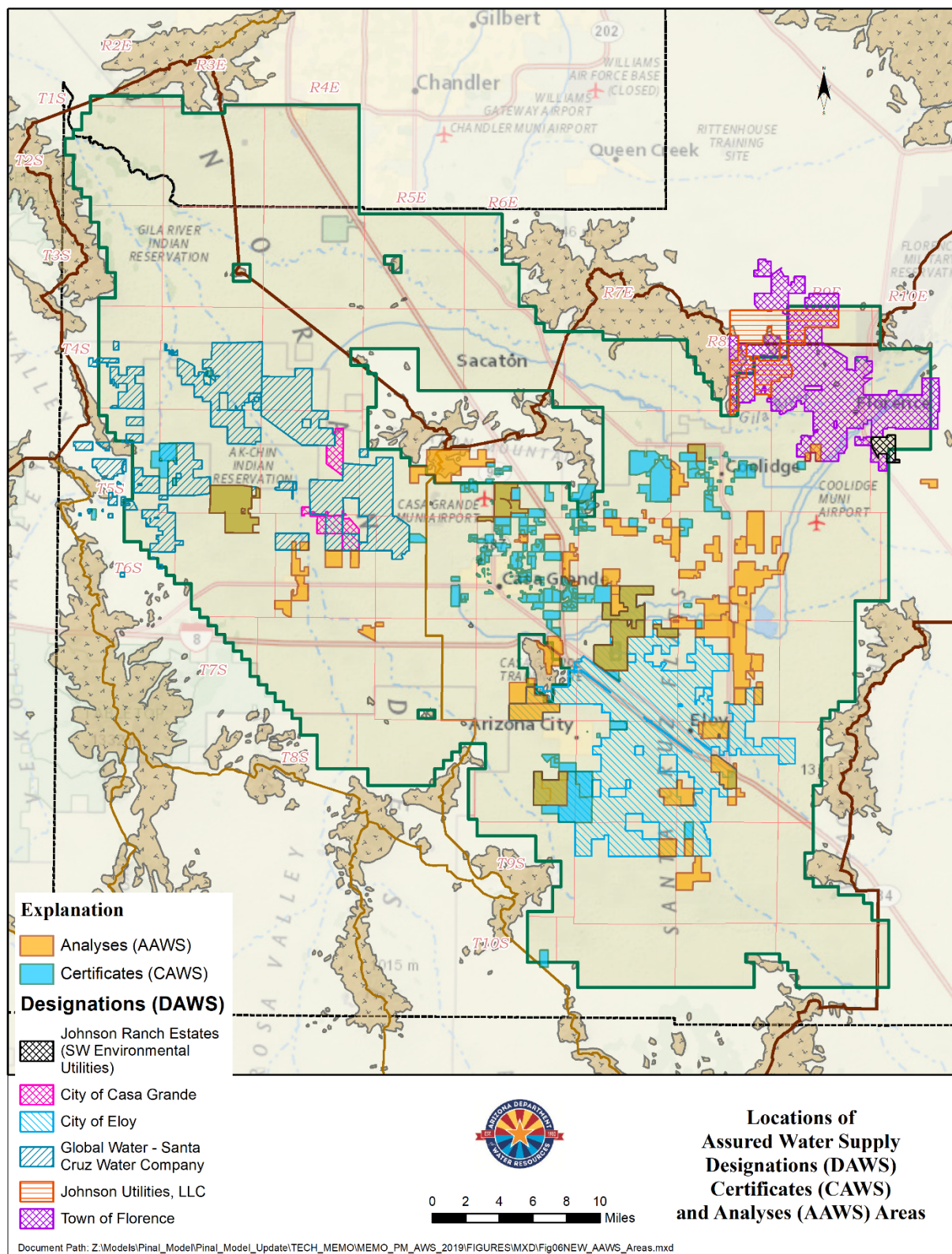


Figure 6. Locations of Designations, Certificates and Analyses Areas in the Pinal Model Area

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 LTSCs 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 CAGRDR credits which are not removed but extinguished for replenishment purposes in the early years of the projection to meet replenishment obligations. These CAGRDR LTSCs were extinguished for replenishment purposes at a rate of 15,550 AFA as included in the approved 2015 CAGRDR Plan of Operation. As a result, these existing LTSCs will cover the CAGRDR 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 CAGRDR 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 IRRIGATION & 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.

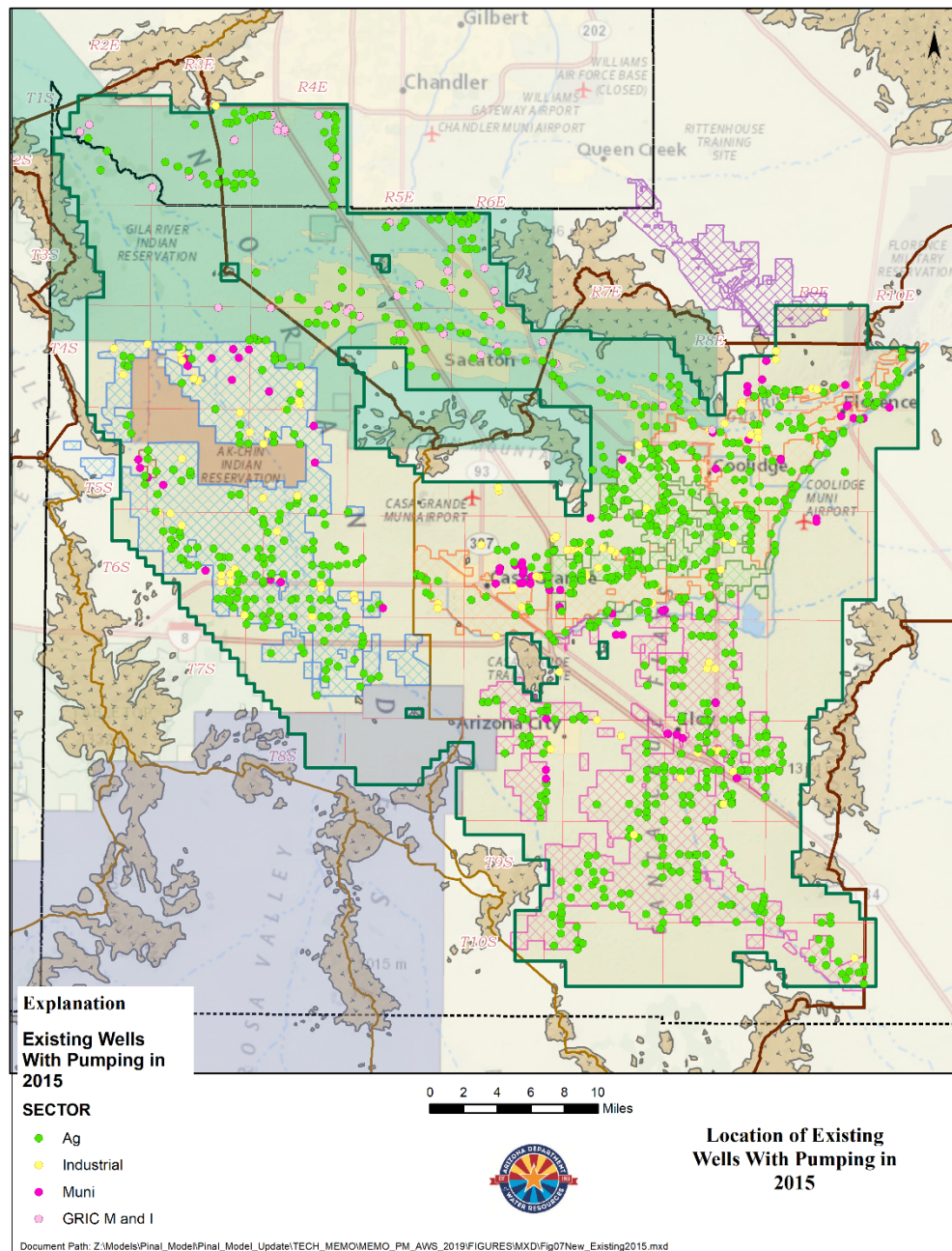


Figure 7. Existing Wells with Pumping in 2015

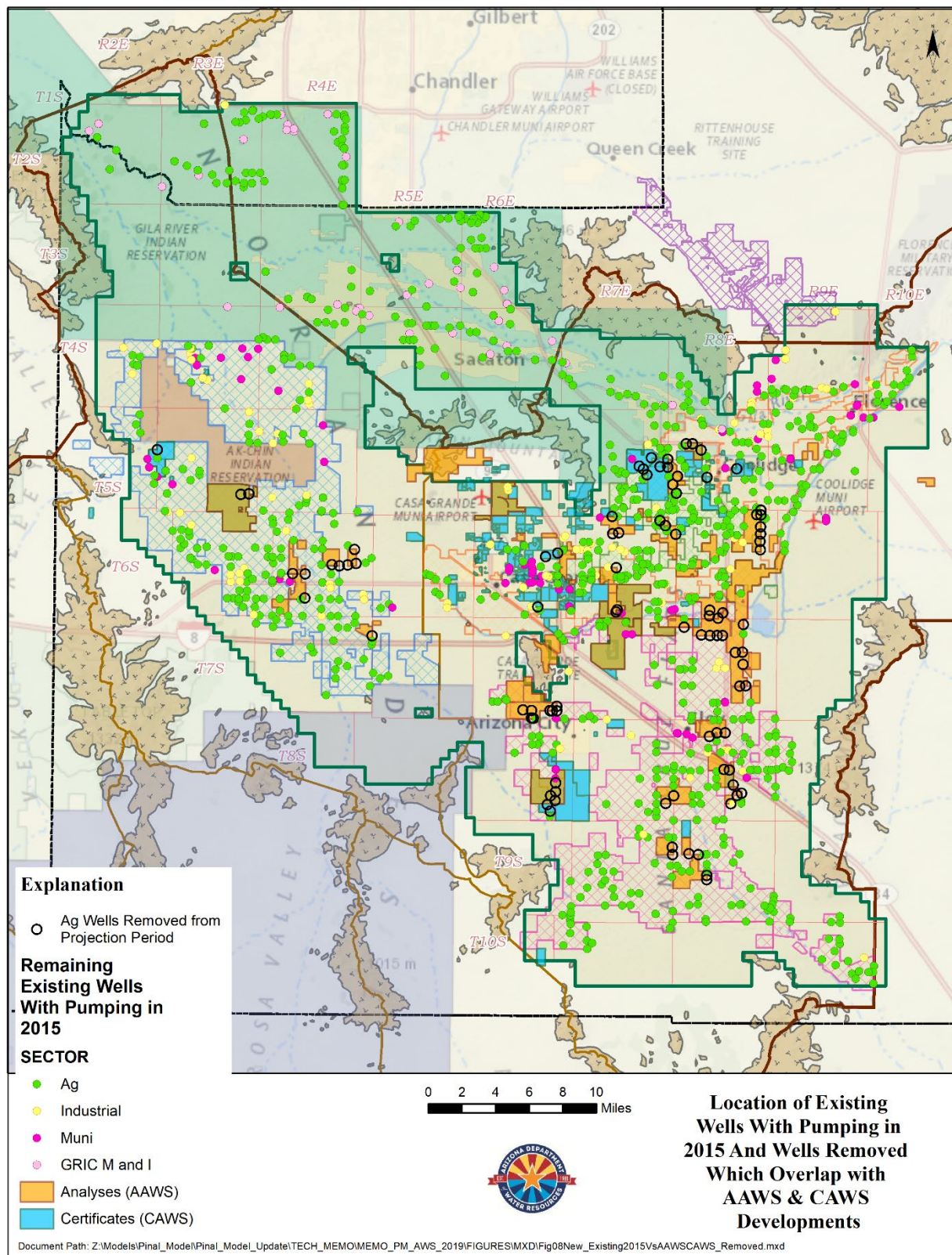


Figure 8. Existing Wells Removed from Projection Due to Overlap with AWS Development Footprints

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.



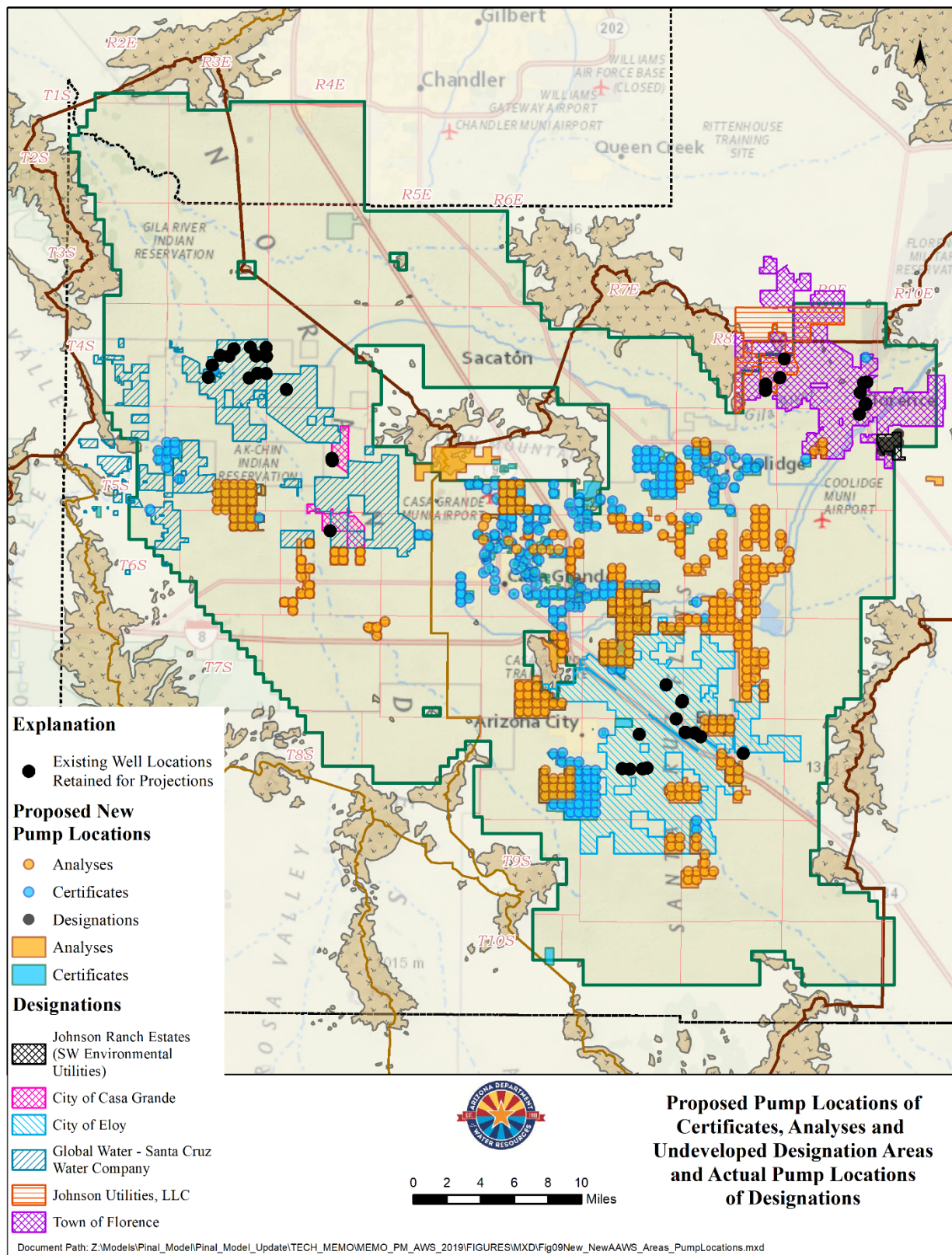


Figure 9. Proposed and Actual Pump Locations Simulated for Certificates, Analyses Areas Designations

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.

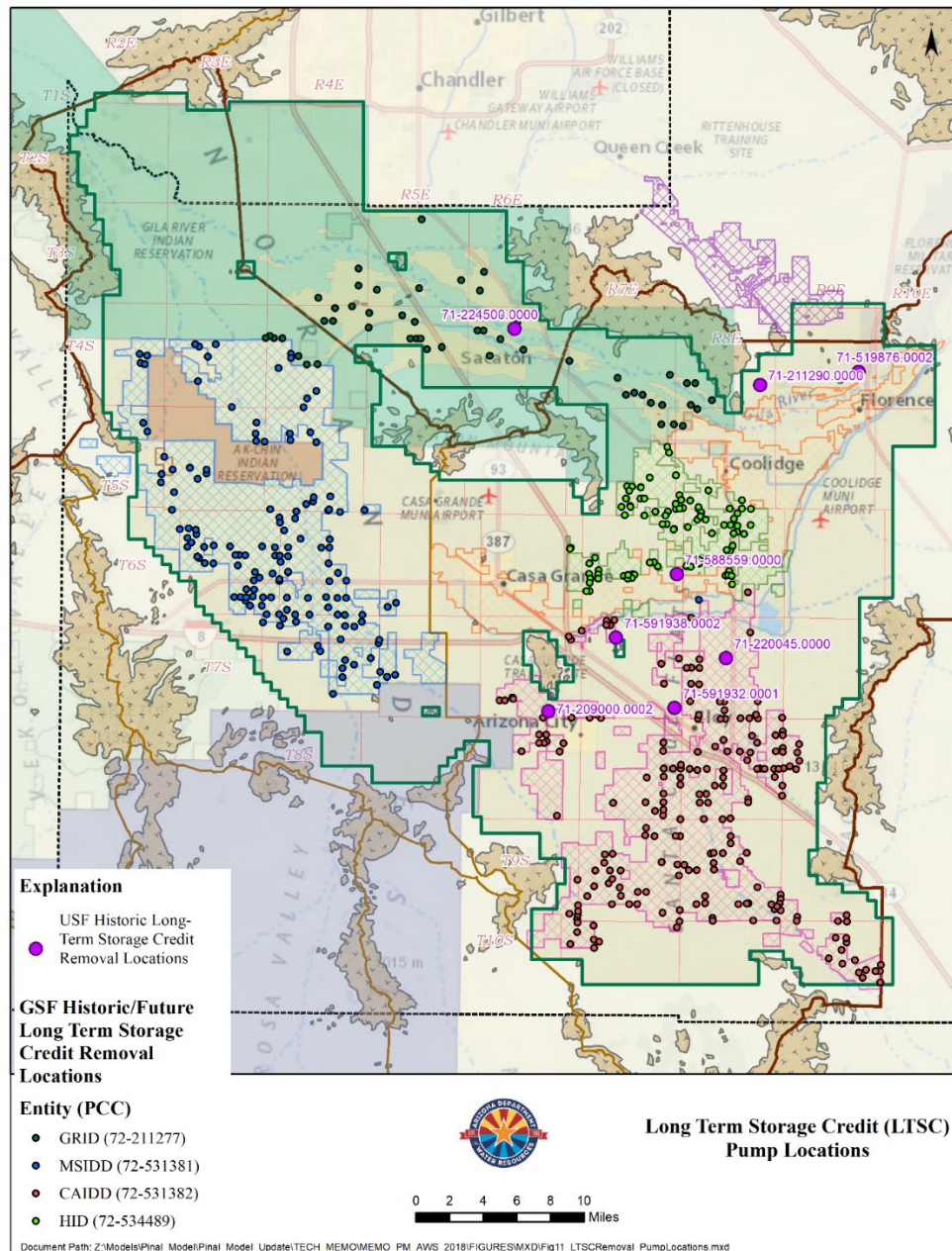


Figure 10. Long-Term Storage Credit Removal Pump Locations

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.

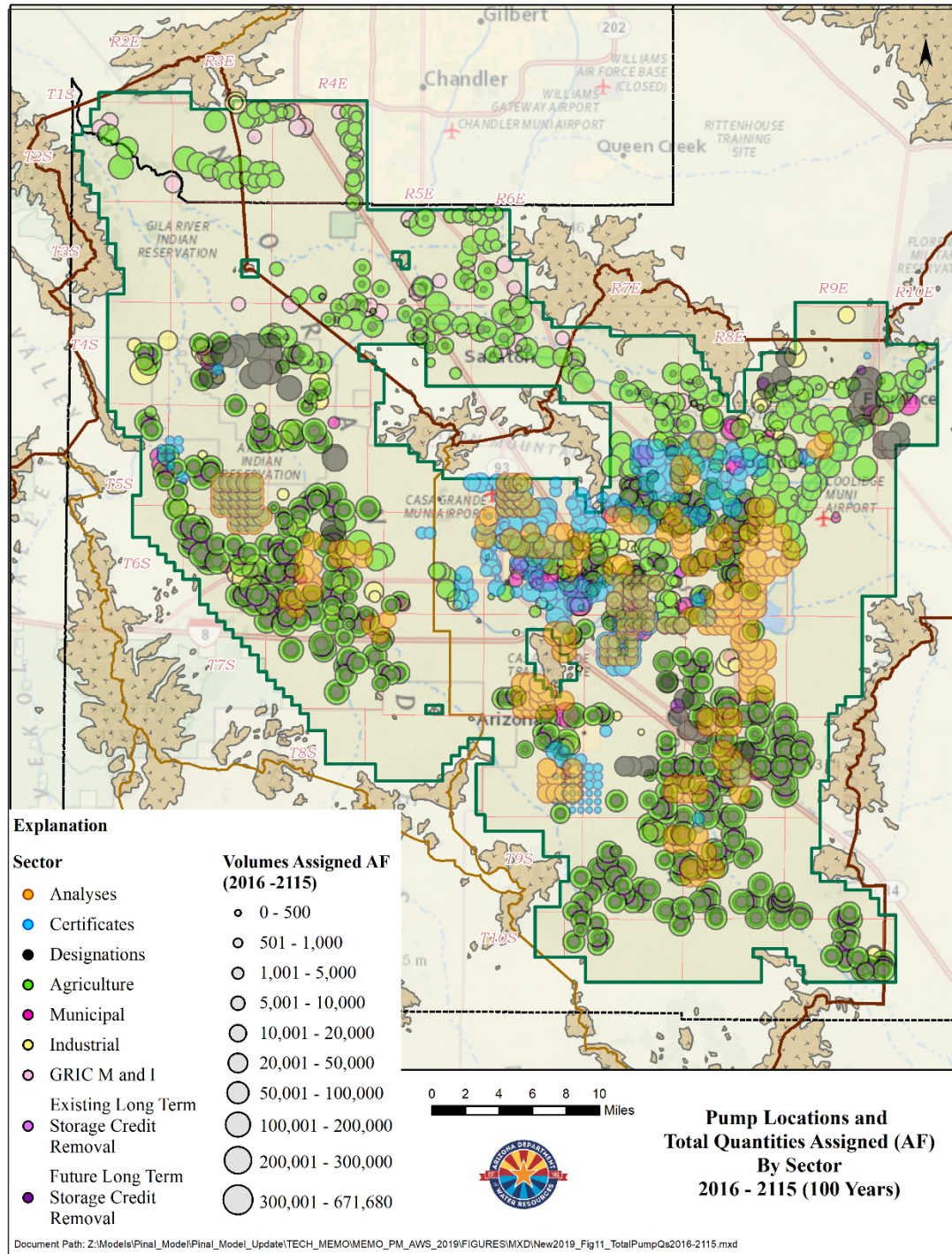


Figure 11. Pump Locations and Total Quantities Assigned 2016 - 2115

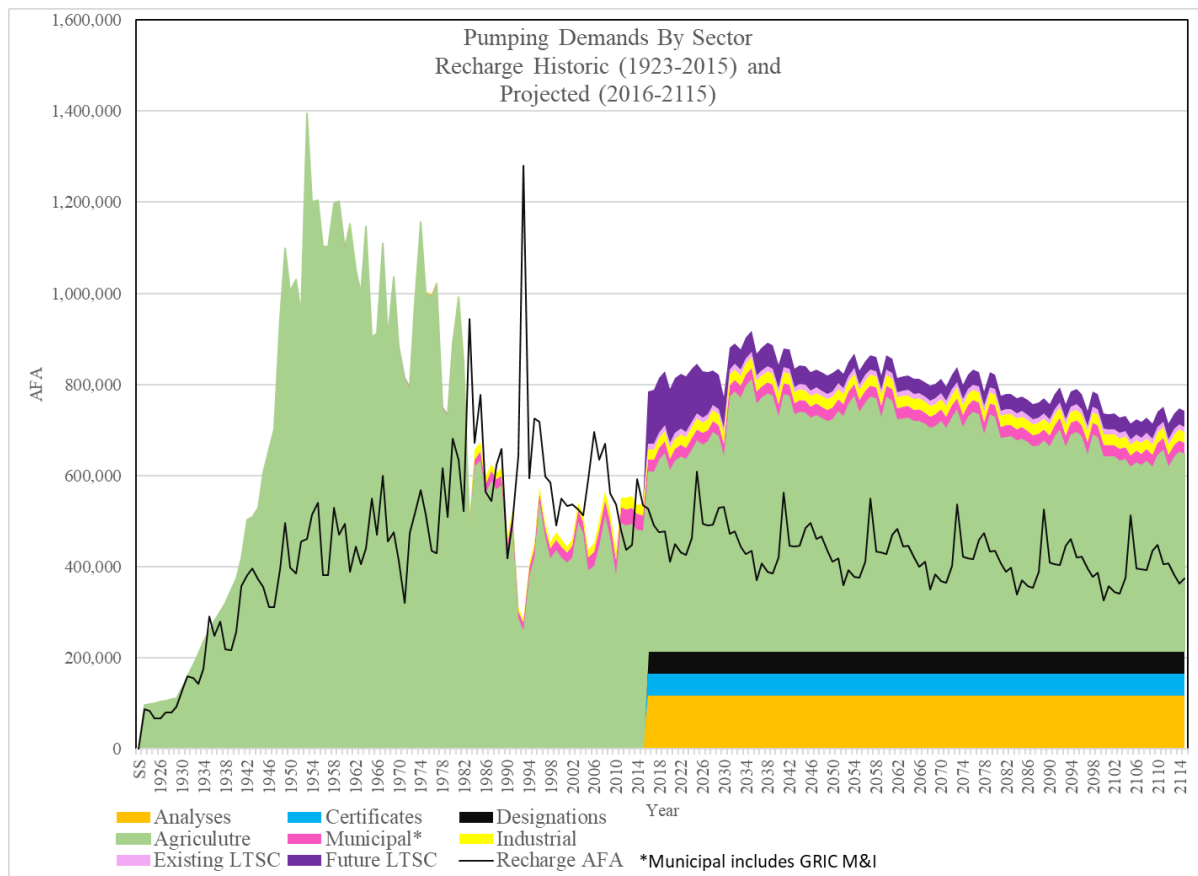


Figure 12. Pump Demands by Sector vs. Total Recharge 1923 - 2115

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 CAGRDR replenishment obligation water, is applied within the nearest GSF of each participating CAGRDR member. This projection included the removal of 95% of the non-CAGRDR 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.



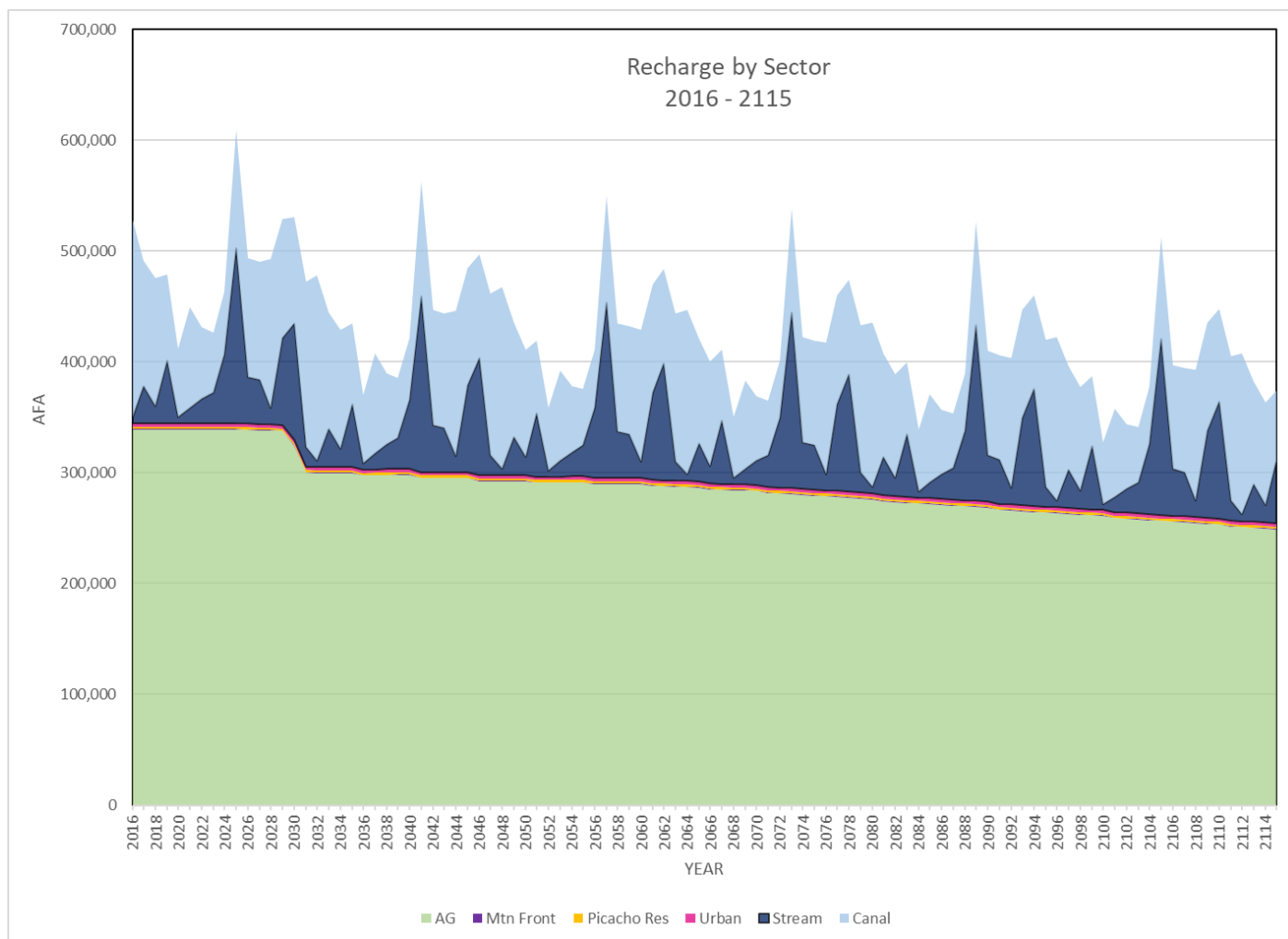


Figure 13. Recharge Projections by Sector 2016 - 2115

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%

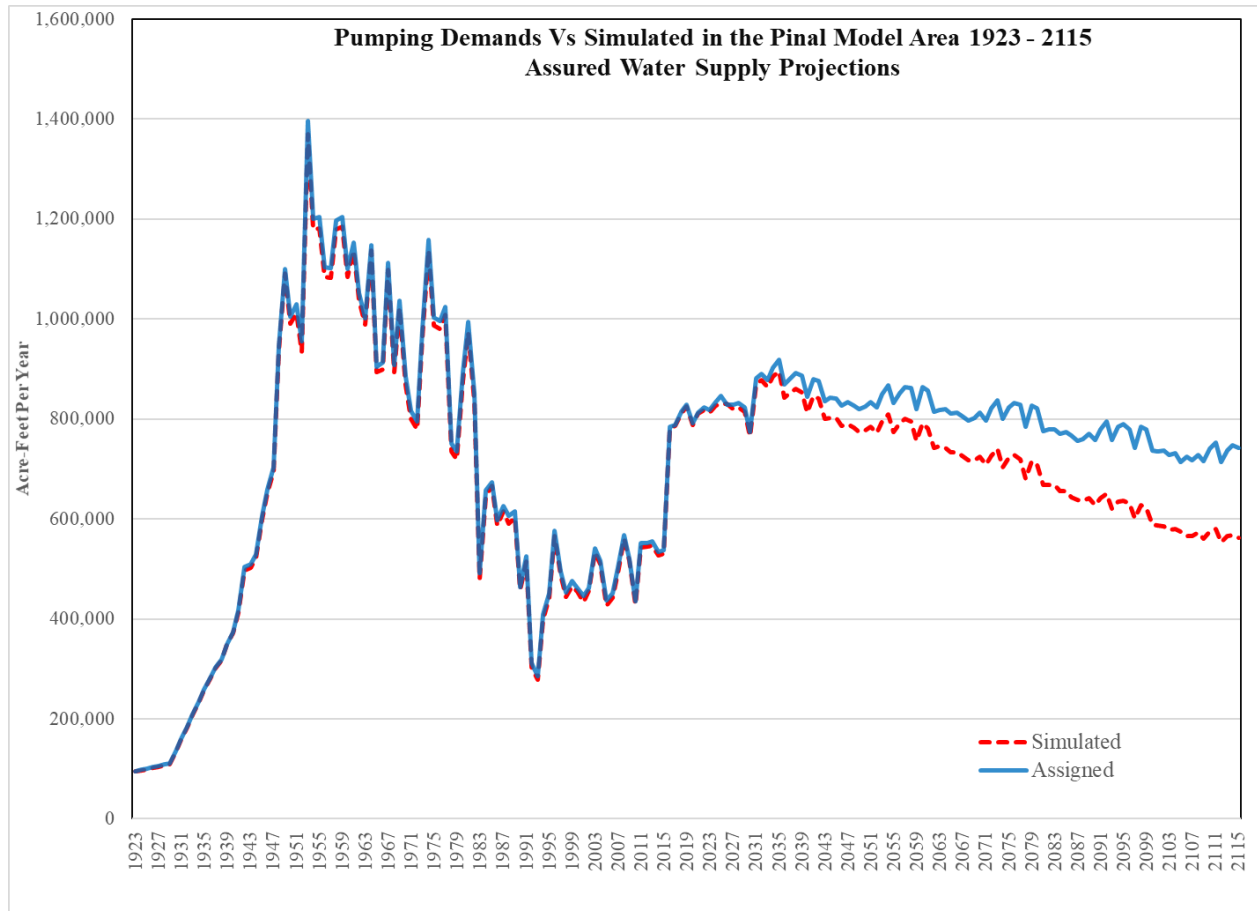


Figure 14. Pumping Demands Assigned vs. Simulated

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.



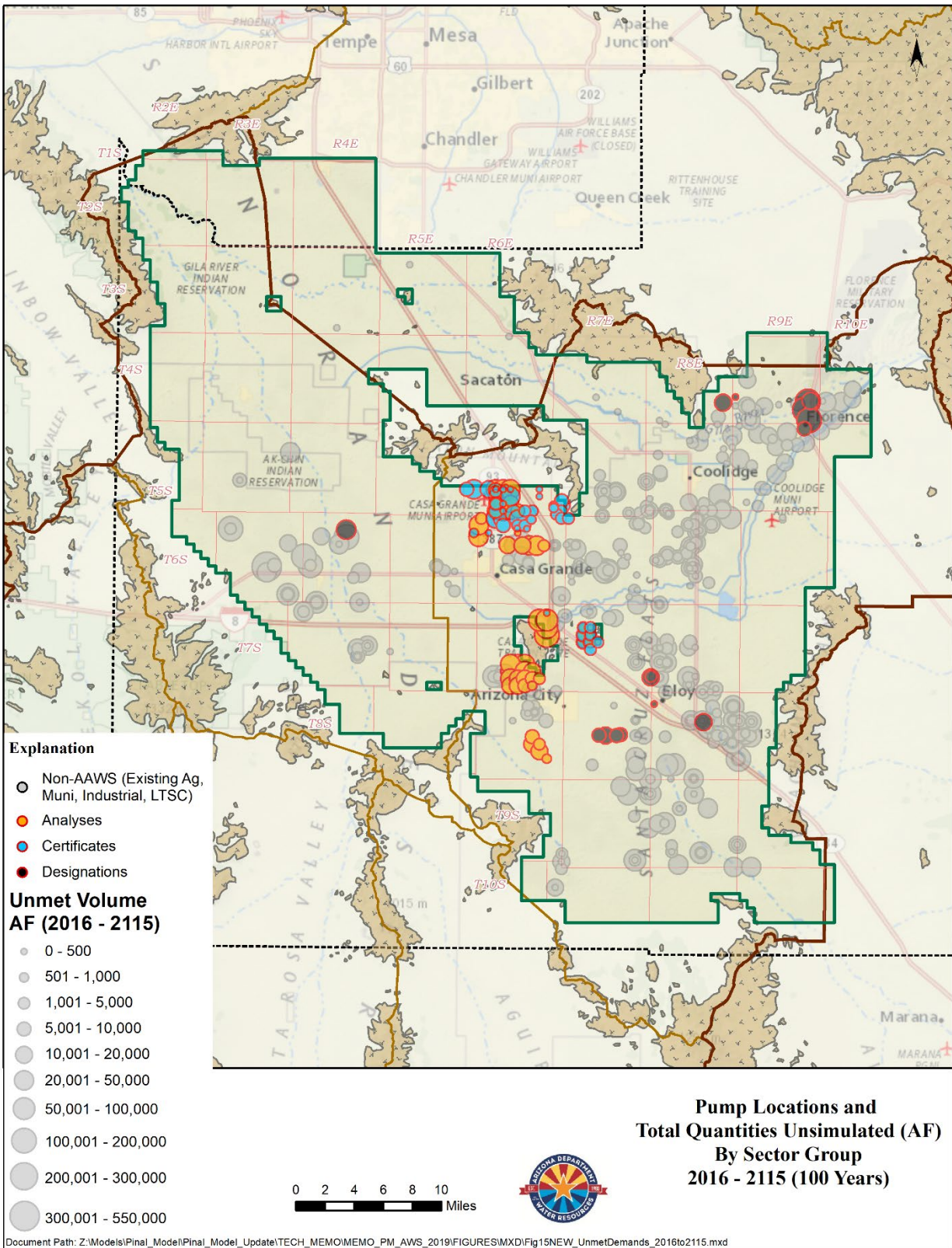


Figure 15. Location of Wells with Unmet Demands 2016 – 2115

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 both 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.



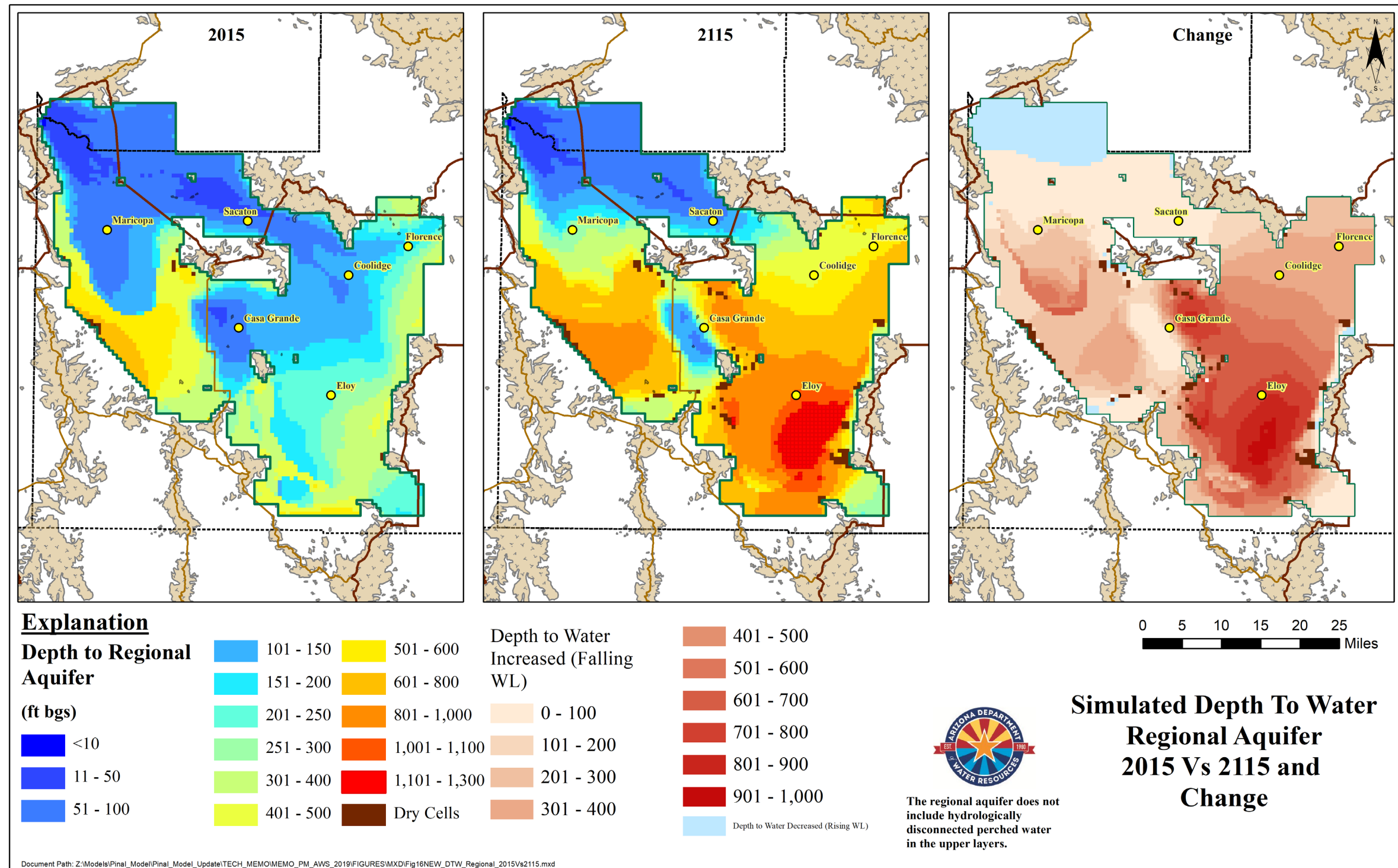


Figure 16. Simulated Depth to Water 2015 and 2115 and Change in Depth to Water

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. There 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**).



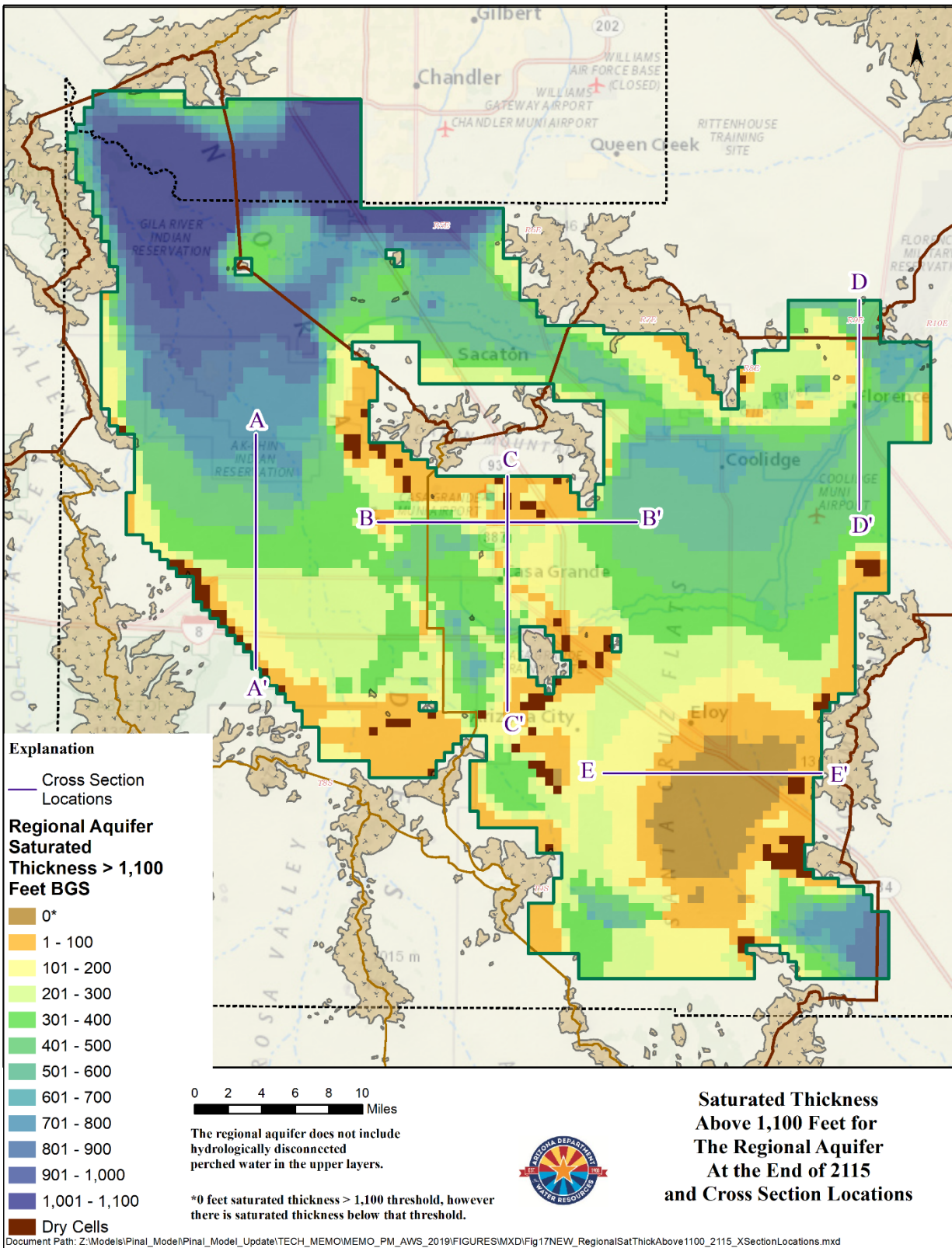


Figure 17. Water Level Cross Section Location Map



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'.



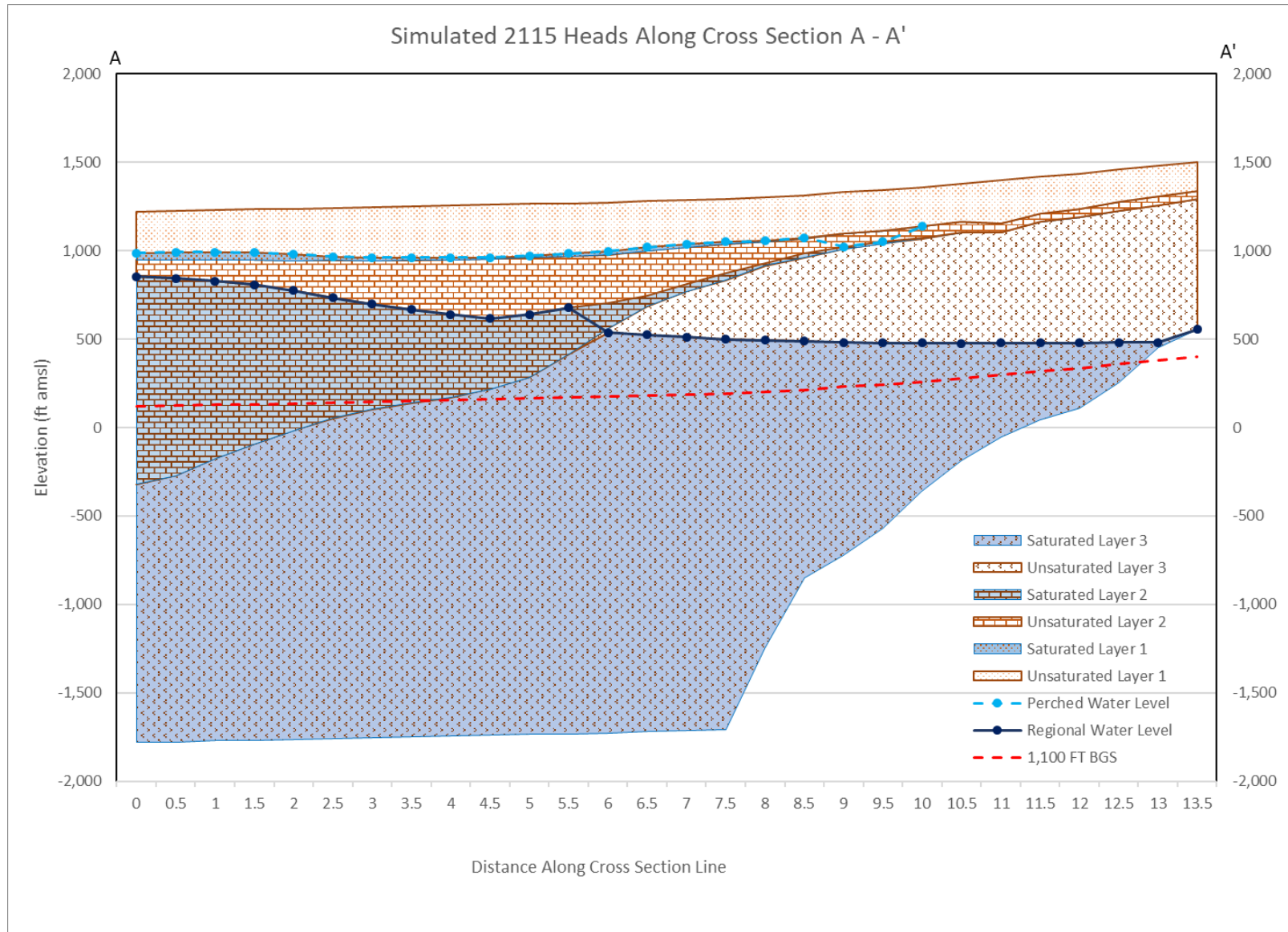


Figure 18. Cross Section A -A'



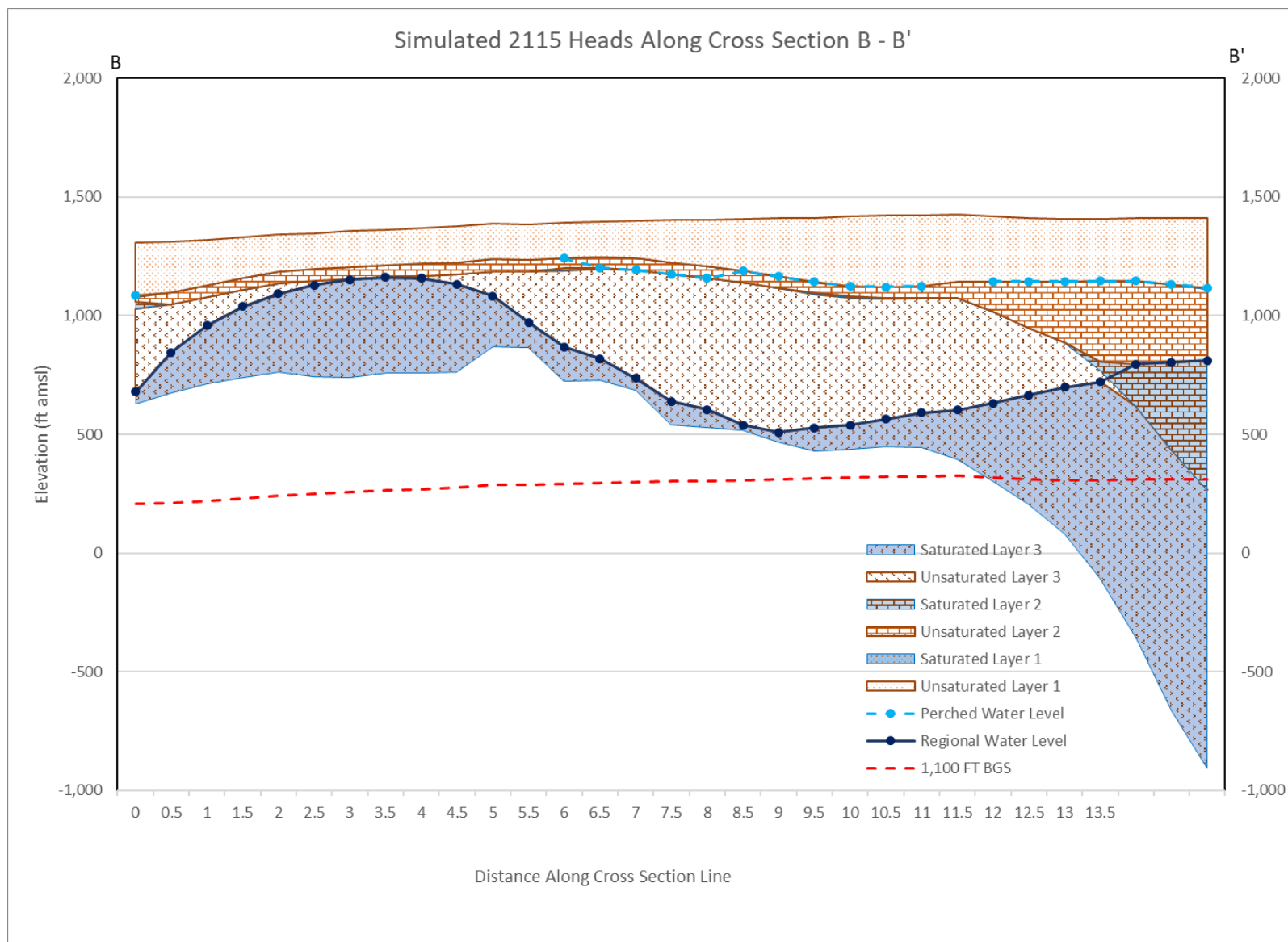


Figure 19. Cross Section B-B'



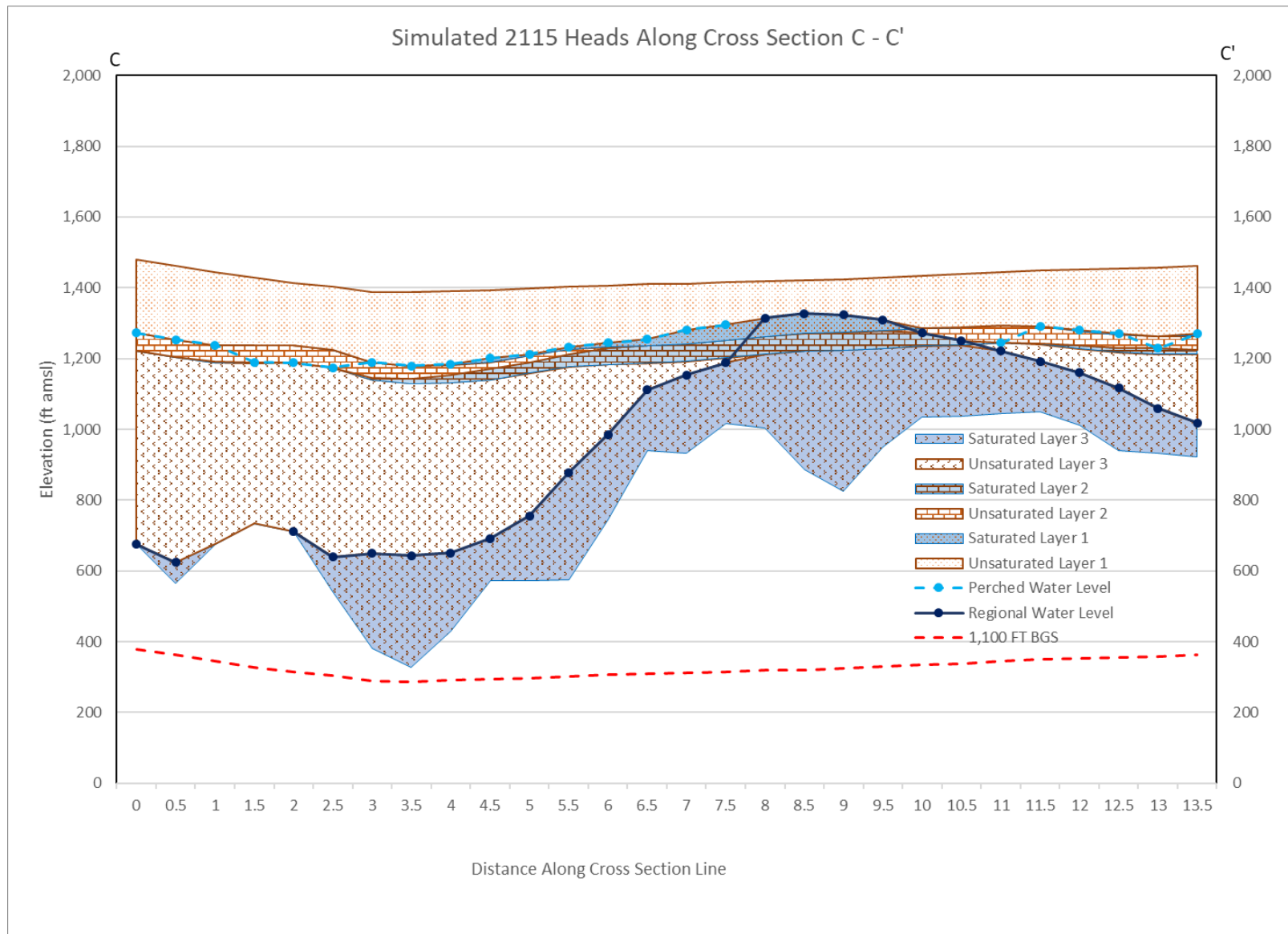


Figure 20. Cross Section C-C'



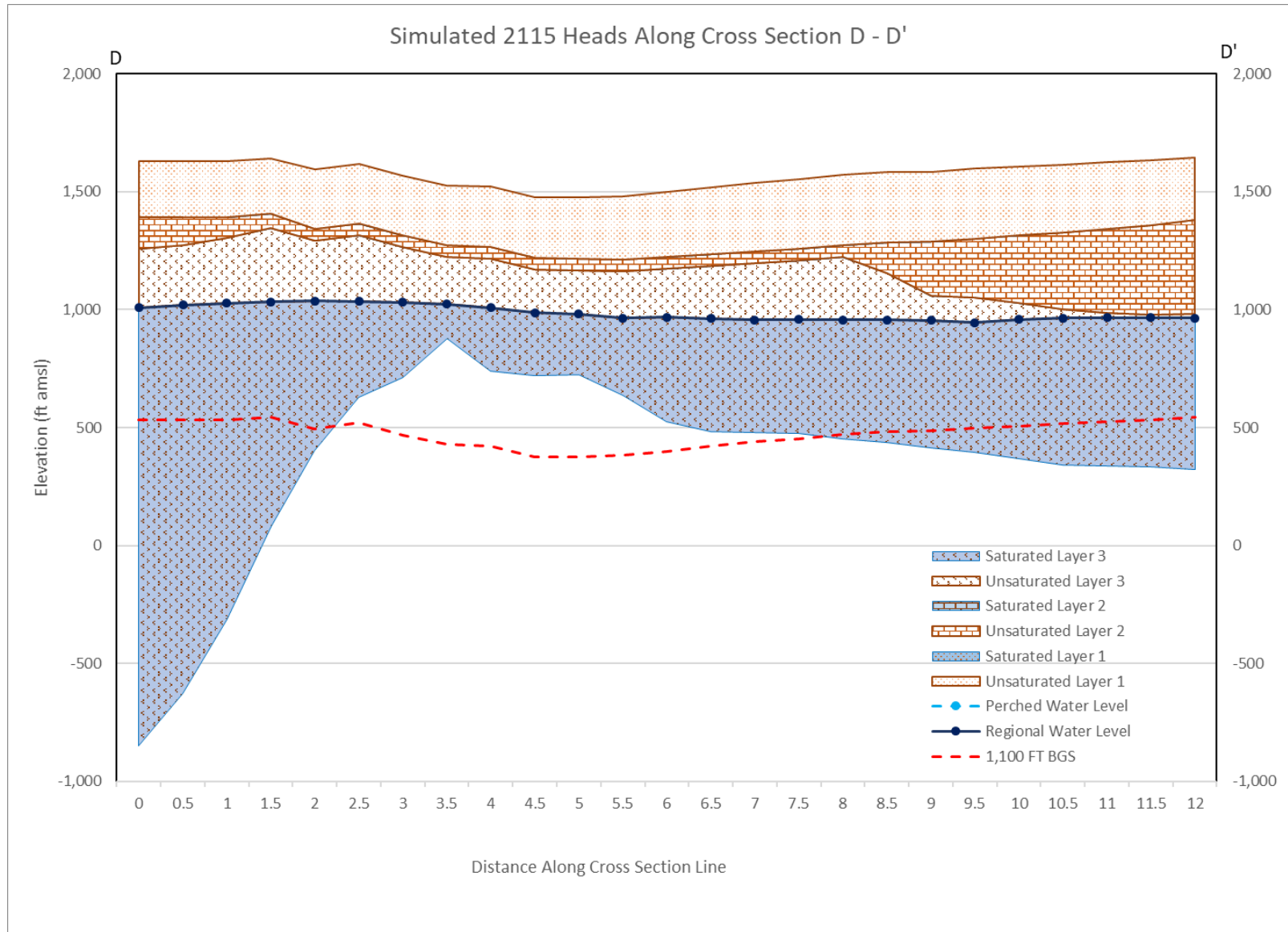


Figure 21. Cross Section D-D'



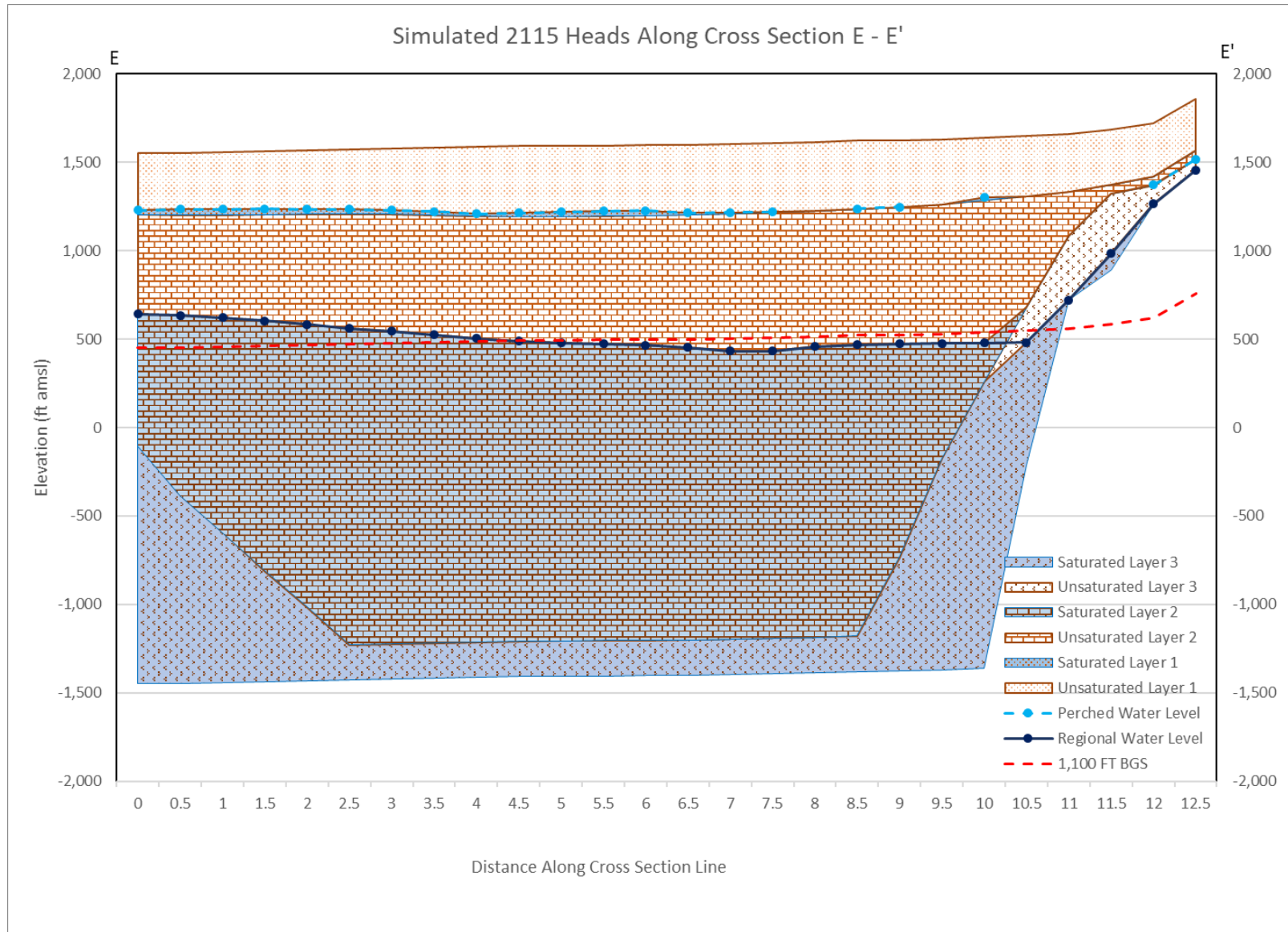


Figure 22. Cross Section E - E'



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	1923 - 2015	2016 - 2115	Total	Steady State	1923 - 2015	2016 - 2115	Overall
		(1 Day)	(93 Years)	(100 Years)		(1 Day)	(93 Years)	(100 Years)	
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	-
	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 from 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.





ARIZONA DEPARTMENT OF WATER RESOURCES

Technical Memorandum

Phoenix AMA

Groundwater Model and 100-Year Assured Water Supply Projection Updated with 2022 Data

Groundwater Modeling Section
Hydrology Division

November 2024

This page intentionally left blank.

Table of Contents

EXECUTIVE SUMMARY	1
1.0 BACKGROUND.....	3
2.0 UPDATE TO THE HISTORICAL GROUNDWATER FLOW MODEL	4
2.1 REVISIONS/RESPONSES BASED ON INFORMATION RECEIVED FROM THE PUBLIC.....	4
2.2 EXTENDING MODEL PACKAGES TO INCLUDE 2022	4
2.3 UPDATED MODEL RESULTS	8
3.0 UPDATE TO THE 100-YEAR ASSURED WATER SUPPLY PROJECTION	9
3.1 REVISIONS BASED ON INFORMATION RECEIVED FROM THE PUBLIC/INTERNAL REVIEW	10
3.2 CHANGES AND ASSUMPTIONS TO MODEL PACKAGES IN THE PROJECTION PERIOD.....	11
3.3 UPDATED PROJECTION AQUIFER CONDITIONS.....	15
4.0 100-YEAR ASSURED WATER SUPPLY PROJECTION MODEL RESULTS	17
4.1 DEPTH TO WATER LEVEL.....	17
4.2 UNMET DEMAND	18
5.0 SUMMARY AND LIMITATIONS.....	19
6.0 REFERENCES.....	22

List of Tables

Table 2-1	Urban Recharge Rate Adjustment
Table 2-2	Underflow Values in Historical Model
Table 2-3	Wells Added to the Phoenix AMA Groundwater Model MNW Package for Stress Period 106 (Year 2022)
Table 2-4	Modeled Recharge by Component
Table 2-5	Simulated Water Budget for Phoenix AMA Groundwater Model, Pre-1900 to 2022
Table 3-1	Summary of Annual CAGR D Replenishment
Table 3-2	Assigned Pumping by Sector
Table 3-3	Changes to Simulated City of Surprise DAWS Wells
Table 3-4	Estimated Discharge from Wastewater Treatment Plants and Release from Reservoirs to Surface Water Bodies during Projection
Table 3-5	Simulated Water Budget for 100-Year AWS Projection, 2023 to 2122
Table 4-1	Simulated Pumping by Sector
Table 4-2	Unmet Demand by Sector
Table 5-1	Assigned, Simulated, and Unmet Demands by Sector for the 100-Year Projection (2023 to 2122)
Table 5-2	Summary of Simulated Groundwater Budget for the Historical and Projection Periods

List of Acronyms

%	percent
ADWR	Arizona Department of Water Resources
AF	Acre-feet
AFY	Acre-feet per year
AMA	Active Management Area
AWS	Assured Water Supply
bls	below land surface
CAGRD	Central Arizona Groundwater Replenishment District
CAP	Central Arizona Project
ET	Evapotranspiration
ft	feet
GIS	Geographic Information System
GMA	Groundwater Management Act
LTSC	Long-term Storage Credit
MFR	Mountain-front Recharge
MNW2	Multi-Node Well (package)
NWT	Newton-Raphson (solver)
RCH	Recharge (package)
RGR	Registry of Grandfathered Rights
SCIP	San Carlos Irrigation Project
SP	Stress Period
SRP	Salt River Project
SRV	Salt River Valley
USF	Underground Storage Facility
WEL	Well (package)

Executive Summary

The Arizona Department of Water Resources (ADWR) Groundwater Modeling Section has updated the Phoenix Active Management Area (AMA) groundwater model to incorporate the most recent pumping and recharge data. Along with this update, ADWR updated the 100-year AWS projection with the new base model, applicant-requested and approved hypothetical well locations, and several other technical improvements. This update is different from the June 2023 release, which was a multi-year overhaul effort to bring the Phoenix AMA model up to speed with advances in groundwater modeling. It simply updates the pumping data with the next reporting year, recharge volumes and locations, and approved well movements from property owners.

The reader is encouraged to download the original groundwater model documentation (ADWR, 2023a) and Technical Memorandum for the 100-year Assured Water Supply (AWS) projection (ADWR, 2023b) for background on the development of the model and projection simulation. This document describes the process of updating the model and the 100-year AWS projection using the most recent data available to ADWR. Model files and an ArcPro GIS geodatabase with cell-specific input and output values are available for download on ADWR's website.

The Phoenix AMA groundwater model ("base model") now runs from pre-1900 to 2022 for a period of 123 years. Inflows to the aquifer include mountain-front recharge, underflow from adjacent basins/subbasins, artificial, incidental, and natural recharge, and stream leakage. Outflows from the aquifer consist of well pumping, underflow to adjacent basins/subbasins, and evapotranspiration (ET) from riparian vegetation. The water budget for the year 2022 was similar to 2021 and appears here, rounded to the nearest 100 or 1,000 acre-feet (AF) for readability. Mountain-front recharge and underflow into the AMA, which sums to 77,000 AF, is constant at rates from the previous year. Underflow out of the AMA to the adjacent Pinal AMA via the Maricopa-Stanfield boundary is also constant from the previous year at 25,000 AF. Simulated stream leakage (water into the aquifer), at 18,800 AF, did not change from the 2021 modeled value. There were slight reductions in simulated ET

and underflow from the AMA into the Gila Bend Basin due to water level changes from 2021 to 2022. The simulated pumping in the active model domain was 842,000 AF, up from 832,000 AF in 2021. The most notable change in the water budget between 2021 and 2022 occurred in the recharge package and was primarily due to updating the footprint of irrigated agriculture (and subsequent incidental recharge). The estimated recharge in 2022 was 622,000 AF compared to 717,000 AF in 2021. For the 100-year AWS projection, recharge carried forward into the projection period is an average of the last five years of the historical period, so this change does not dramatically impact the projection water budget. Finally, the simulated change in storage in 2022 was 217,000 AF removed from the aquifer. The cumulative storage change (decline) for the historical period (1900 to 2022) is 21,470,000 AF. The average water level decline across the active model domain over this same period is 95 feet. The estimated volume of groundwater in storage above 1,000 feet at the end of the historical simulation is 126,750,000 AF.

The 100-year AWS projection was updated to incorporate the 2022 data in the base model, hypothetical well locations requested by applicants to the AWS program, and other minor technical changes. The result of these changes is that unmet demand at the end of the 100-year projection period is estimated to be 3,604,500 AF, which is a reduction from the previous projection estimate of 4,862,000 AF. Of the total unmet demand, 704,400 AF falls into the AWS and Long-Term Storage Credit (LTSC) sectors, which are required to be considered for purposes of the AWS program. The remainder of the unmet demand is within the so-called “unprotected” sectors, which are not part of the AWS program and include agriculture uses, industrial uses, and others.

This technical memorandum summarizes the process of extending the Phoenix AMA groundwater flow model’s historical period by one year and the results of an updated 100-year projection for the Phoenix AMA. This update incorporates information submitted to ADWR since the June 2023 release of the groundwater model and 100-year projection. Unless noted here, the assumptions from the June 2023 release were carried forward as-is to this update.

1.0 Background

The Groundwater Management Act (GMA or the Act) passed by the Arizona Legislature in 1980 requires that developers of new subdivisions within AMAs demonstrate a 100-year AWS. ADWR implements this legislative directive through the AWS Program, which is, at its core, a groundwater management and consumer-protection program applicable within Arizona's six AMAs. Applicants must demonstrate, among other things, that each water supply is physically available for 100 years. Where ADWR has developed a numerical model for a particular AMA or basin, applicants must use ADWR's model.

In the Phoenix AMA, an applicant must demonstrate that the water level decline after 100 years of groundwater withdrawals to satisfy the demands of existing uses, issued AWS determinations, and the applicant's demand will not exceed 1,000 feet below land surface (bls) or bedrock, whichever is shallower.¹ In order to achieve this demonstration, all groundwater pumping associated with long-term storage credits (LTSCs), municipal uses, and AWS determinations must be simulated for the full 100-year projection period.² In other words, unmet groundwater demands associated with LTSCs and AWS determinations over the 100-year projection period are not acceptable.

Unmet groundwater demand occurs when the model cannot simulate pumping for all included demands, creating a pumping shortfall or deficit. This shortfall or deficit occurs when there is insufficient saturated aquifer to satisfy the pumping demand during the 100-year projection period.

ADWR developed the Phoenix AMA groundwater model for regional-scale groundwater analyses and the AWS program. The files in this release represent the most current version of the model.

¹ A.A.C. R12-15-716(B)(2) and ADWR Substantive Policy Statement Hydrologic Studies Demonstrating Physical Availability of Groundwater for Assured and Adequate Water Supply Applications (AWS7).

² A.A.C. R12-15-716(B)(3).

2.0 Update to the Historical Groundwater Flow Model

The update to the groundwater flow model for the Phoenix AMA includes data from the calendar year 2022. The historical period now covers the years from pre-1900 to 2022. The historical update incorporates both reported and estimated data. Examples of reported data include groundwater pumping from wells and stream flows; estimated data includes rates of incidental and natural recharge and underflow from adjacent groundwater basins. The following sections outline the process to complete the update.

2.1 Revisions/Responses Based on Information Received from the Public

Members of the public have reached out to ADWR with questions and comments regarding the Phoenix AMA groundwater model. The questions relate to differences between the Phoenix AMA groundwater model and the previous Salt River Valley (SRV) groundwater model. ADWR made one revision to the Phoenix AMA groundwater model in response to a comment received by the ADWR Recharge & Recovery program:

- Applicants to the ADWR Recharge & Recovery program noted high water levels in the central Phoenix portion of the groundwater model. ADWR reviewed this area (west of Piestewa Peak and Camelback Mountain centered around Row 56, Column 127) and adjusted the urban turf recharge rate in 112 cells by a factor of 0.5. This reduced the amount of recharge going into the model at this location and eliminated the flooded cells in the projection period (see **Table 2-1**).

In response to why the Phoenix AMA groundwater model has higher transmissivity in the ESRV (near Queen Creek and Superstition Vistas) compared to the SRV model, the reason for this is that the groundwater model layer thicknesses were updated based on a 2017 study conducted for the area by the Arizona Geological Survey (Gootee et al., 2017). Recalibration in the area also indicated that hydraulic conductivity may be higher than previously thought.

2.2 Extending Model Packages to Include 2022

ADWR edited the model input files to extend the model by one year. Each package and how it was updated is listed here. If a package is not listed, it was not changed. Bold text indicates there is further explanation regarding the package update.

- **phx_ama.dis** – added stress period (SP) 106 (calendar year 2022).
- **phx_ama.wel** – copied SP 105 (calendar year 2021) to SP 106.
- **phx_ama.ghb** – copied SP 105 to SP 106.
- **phx_ama.mnw** – pumping reported to ADWR for the calendar year 2022 was added to SP 106.
- **phx_ama.mnwi** – updated to reflect the updates to **phx_ama.mnw**.
- **phx_ama.sfr** – copied SP 105 to SP 106 and updated the inflows in the *.dat files.
- **phx_ama.rch** – some recharge components were revised for SP 106.
- **phx_ama.evt** - copied SP 105 to SP 106.
- **phx_ama.oc** – updated to include SP 106.

Details behind these changes are as follows:

- **phx_ama.wel:** The WEL package simulates mountain-front recharge (MFR) and underflow from adjacent basins. MFR is constant over the simulation period (see Tables 6-5 and 6-6 from ADWR, 2023a) and was not changed; values from SP 105 were simply copied over to SP 106. Underflow from adjacent basins varies over the stress periods but has been stable in the model since SP 99 (calendar year 2015); therefore, the SP 105 values were copied over to SP 106. **Table 2-2** summarizes the simulated underflow at each of the boundaries from 1900 to 2022 and shows the following:
 - Florence – varies from 649 to 8,464 AFY into the Phoenix AMA with an average value of 3,729 AFY. Since 2015, the estimated underflow value has been close to the long-term average, at 2,982 AFY.
 - GRIR (aka Santan-Sacaton) – varies from 1,519 to 6,970 AFY into the Phoenix AMA, with an average value of 4,173 AFY. Since 2015, the estimated underflow value has been below the historical average at 3,311 AFY.
 - Hassayampa – constant at 3,002 AFY into the Phoenix AMA.

- Lake Pleasant – except for the steady-state period, underflow into the Phoenix AMA at this boundary is constant at 2,502 AFY.
- Maricopa-Stanfield – varies from 13,919 AFY into the Phoenix AMA to 53,925 AFY out of the Phoenix AMA. Since 2015 the estimated underflow value is 24,018 AFY flowing out of the Phoenix AMA.
- Santa Cruz – constant at 271 AFY into the Phoenix AMA.
- Harquahala – varies from 6 to 1,473 AFY out of the Phoenix AMA. Since 1987 the estimated underflow value is 1,473 AFY flowing out of the Phoenix AMA.
- **phx_ama.ghb**: the GHB package simulates underflow from the Phoenix AMA to the Gila Bend groundwater basin. The reference data for this package is an ADWR index well (GWSI Well 331143112450801). The well was measured in 2021 and 2023 but not in 2022, so the 2021 measurement was carried over into SP 106 for this current update. The 2023 measurement will be incorporated into the next model update.
- **phx_ama.mnw**: the MNW package contains pumping from wells. The data source for this package is the pumping reported on annual reports submitted to ADWR. Reported pumping for calendar year 2022 was downloaded from the ADWR online query center³ and formatted for use in the MNW package. Twenty non-exempt wells were added to the MNW package in SP 106. Exempt wells are not simulated in the Phoenix AMA groundwater model. The owner, right number, right type, well ID, cadastral, reported volume, and well depth (depth to bottom of screen) can be found in **Table 2-3**.
- **phx_ama.sfr**: the SFR package contains measured inflows from the larger waterways in the AMA, namely the Salt, Gila, Agua Fria, and Hassayampa Rivers, diversions from the Buckeye Irrigation Canal (BIC), and discharges from the City of Phoenix 91st Avenue and 23rd Avenue Wastewater Treatment Plants (WWTPs). Gage data for 2022 were obtained from SRP, the USGS website, and San Carlos Irrigation Project (SCIP) reporting for the Salt, Hassayampa, and Gila Rivers, respectively. Diversions from the

³<https://app.azwater.gov/querycenter/query.aspx?qrysessionid=9D766144C04C8E37E0534C64850A58D9>

Gila River to the BIC have been relatively constant over the historical period, so SP 105 was copied to SP 106. The WWTP discharges were copied from SP 105 to SP 106. Flows in the Agua Fria primarily occur due to spills over the New Waddell Dam, which did not occur in 2022.

- **phx_ama.rch**: the RCH package contains 11 recharge components that occur within the AMA. The recharge volume by component is summarized in **Table 2-4**. ADWR's assumptions behind each component update are as follows:
 - **ag.txt** – Contains incidental recharge associated with irrigated agriculture. This file was modified for 2022 based on a review of aerial imagery. Fields that had previously been irrigated but had since been converted to industrial or municipal use were removed from the spatial coverage. As of 2022, there were approximately 108,880 acres of irrigated agriculture in the active model domain. The percentage of irrigated fields in each model cell was recalculated to update the recharge rates. An incidental recharge rate of 25% of 3.7 ft per year was applied to the cells with irrigated agriculture. The rate for SP 106 was then multiplied by the calibrated agricultural zone factor (see Table 6-3 from ADWR, 2023a). The resulting estimated agricultural recharge for 2022 was 225,324 AF, down from 277,558 AF in 2021.
 - **agEarly.txt** – Contains incidental recharge associated with irrigated agriculture prior to the 1920s. Every entry later than that time is zero. To update this file, SP 105 was copied to SP 106.
 - **CAP.txt** – Contains incidental recharge associated with canal seepage from the Central Arizona Project (CAP) canal. This is a constant rate, so SP 105 was copied to SP 106.
 - **ephemeral.txt** – Contains natural recharge associated with precipitation collecting in ephemeral channels. PRISM data (PRISM, 2024) were used to calculate the ratio of 2021 to 2022 precipitation in the AMA. That ratio was 0.8517, indicating less precipitation in 2022 than in 2021. SP 106 rates are equal to the calculated ratio multiplied by SP 105.

- **flood.txt** – Contains natural recharge associated with infrequent, large floods in the channels represented with the SFR package. The last flood in the historical record was 2014. The zero recharge rate from SP 105 was copied to SP 106.
- **IBW.txt** – Contains natural recharge in the Indian Bend Wash in Scottsdale. This is a constant rate, so SP 105 was copied to SP 106.
- **lakes.txt** – Contains incidental recharge associated with ornamental, residential lakes. This value has been constant since 2008 (SP 92) as no new ornamental lakes have been constructed, so SP 105 was copied to SP 106.
- **NonSCIP.txt** – Contains incidental recharge associated with seepage from canals not belonging to the SCIP. This value has been constant since 1983 (SP 67) as no further canal lining activities have occurred, so SP 105 was copied to SP 106.
- **SCIP.txt** – Contains incidental recharge associated with seepage from canals belonging to the SCIP. This value has been constant since 2017 (SP 101) under the assumption that no new canal lining activities have occurred. SP 105 was copied to SP 106.
- **UrbanTurf.txt** – Contains incidental recharge associated with ornamental lawns and recreational fields. The recharge rate at select cells (**Table 2-1**) was reduced by a factor of 0.5 to address flooding occurring in the projection period. The adjustment was applied to all the historical SPs, not just SP 106. No other changes were made.
- **USF.txt** – Contains artificial recharge at permitted underground storage facilities. Recharge values reported to ADWR for 2022 were added to SP 106.

2.3 Updated Model Results

The updated groundwater flow model indicates that, in 2022, the following conditions were present in the AMA (see **Table 2-5**):

- Groundwater pumping from non-exempt wells has increased slightly over the last several years. In 2020, pumping in the model was 819,432 AF; in 2021, it was 831,937 AF; and in 2022, it was 841,656 AF.
- Natural, incidental, and artificial recharge has decreased over the last several years, partly because irrigated land is converted to commercial or residential use. In 2020, recharge in the model was 757,652 AF; in 2021, it was 716,924 AF; and in 2022, it was 621,800 AF.
- Streams in the model domain continue to be primarily losing streams in 2022; however, gains are still present along the lower reaches of the Gila River.
- Riparian vegetation was estimated to consume 47,240 AF of groundwater in 2022, continuing the gradual decline in ET over the historical period.
- An estimated 20,568 AF of underflow exited the Phoenix AMA to the south (Gila Bend basin) in 2022. This is slightly higher than the long-term average outflow of 15,348 AFY.
- The cumulative modeled storage change between 1900 and 2022 shows 21,469,028 AF removed from storage.
- The cumulative modeled pumping between 1900 and 2022 shows 116,558,120 AF pumped.

3.0 Update to the 100-Year AWS Projection

The 100-year projection simulation for the Phoenix AMA is derived from the calibrated historical model by ADWR (ADWR, 2023a), which has been updated to cover the period from pre-1900 to 2022. This section discusses the process to update and revise the previous projection. The process of revising the MODFLOW-NWT packages from the calibrated model to reflect the changes from the historical period to the projection period are documented in ADWR, 2023b.

3.1 Revisions Based on Information Received from the Public/Internal Review

AWS program applicants have submitted proposed changes to the ADWR 100-year AWS projection (ADWR, 2023b). The changes relate to the simulation of dewatering wells, pumping well screen intervals, and pumping well locations. ADWR made the following revisions to the 100-year AWS projection in response to information received from the public, as well as internal review:

- CAGR D replenishment was modified to begin at 100% of the maximum planned volume in Year 1 of the projection, per the 2015 Plan of Operations (CAGR D, 2015), rather than go through a ramp-up period. This is consistent with the assumption that AWS developments start at 100% build-out in Year 1.
- An unintended malfunction with the MNW code resulted in the 13 dewatering wells injecting approximately 1.17 MAF of water into the model during the 100-year projection period rather than ceasing pumping when the depth to water hits 20 feet bls. To address this, the consultant who identified the issue truncated the dewatering wells at 20 ft. ADWR accepted and implemented the correction.
- Several wells appeared to have unmet demand not because of a lack of groundwater but because the simulated water level fluctuated around a layer boundary, resulting in automatic, temporary pumping reductions. By assigning the pumping from the well to occur only in the deepest layer of the model (Layer 3) rather than all three layers, the automatic pumping rate reduction and simulated unmet demand were eliminated. A consultant proposed this modification, and ADWR accepted and implemented it.
- ADWR has stated publicly that applicants to the AWS program (and/or well owners) may tell ADWR where they want their wells to be located, and if the locations are reasonable and consistent with the rules and statutes, then ADWR will accept the proposed locations. In May 2024, an applicant submitted a projection model with preferred well locations for multiple housing developments in the Lower Hassayampa Subbasin. After reviewing these locations, ADWR determined that they were allowable under the requirements of the AWS program.

- ADWR reviewed the locations of all wells with unmet demand to evaluate the starting saturated thickness of the aquifer. Based on this review, two wells associated with a certificate were moved to alternative locations within the footprint of the development.
- An Analysis of Assured Water Supply was approved in May 2023 using the SRV model to demonstrate the physical availability of groundwater. This analysis was added to the updated projection.

3.2 Changes and Assumptions to Model Packages in the Projection Period

The projection period now covers the years from 2023 to 2122. This section outlines ADWR's changes to projection model packages to update the projection. For details on how the projection was initially constructed, please refer to ADWR, 2023b.

Input files for the projection run were edited to incorporate the changes discussed above. Each package and how it was revised is listed here. If a package is not listed, it was not changed. Bold text indicates there is further explanation regarding the package update.

- phx_ama_proj.bas – initial heads were updated to the last stress period of the updated calibrated model.
- phx_ama_proj.dis – shifted the annual stress periods (and corresponding duration in days) by one year, so the projection now starts in 2023 and ends in 2122. The number of stress periods (100) did not change.
- **phx_ama_proj.rch** – recharge volumes were updated.
- **phx_ama_proj.mnw** – pumping well locations and volumes were updated.
- phx_ama_proj.mnwi – updated to reflect the updates to phx_ama.mnw.
- **phx_ama_proj.sfr** – inflows were updated to include 2022 data.

Details behind these changes are as follows:

- **phx_ama_proj.rch**: for all components other than Underground Storage Facilities (USF), recharge is based on the five-year average (2018 to 2022) of the updated calibrated model (see **Table 2-4**). These rates were updated from the previous

projection to incorporate the new year of data (2022) from the historical model. USF recharge is treated differently because water providers and other entities within the Phoenix AMA plan for future recharge, so it is not simply an average of past activities.

USF recharge has two categories in the projection: Central Arizona Groundwater Replenishment District (CAGRD) replenishment and artificial recharge associated with providers with Designations of Assured Water Supply (DAWS).

- CAGRD replenishment was modified to be recharged at 100% of the maximum volume per the 2015 Plan of Operations (CAGRD, 2015) in Year 1. Because water is already stored in master and reserve accounts (see **Table 3-1**), the CAGRD recharge begins in the model after these accounts have been extinguished.
- Artificial recharge related to DAWS Decisions and Orders (D&Os) at USFs was identified initially in Hipke (2010) and has been modified by subsequent applicants to the AWS program since then. ADWR retained these volumes from the previous projection.
- **phx_ama_proj.mnw**: Changes to the pumping package fall into one of three categories: 1) update to existing pumping, 2) location and rate change based on information from applicants, and 3) incorporation of determinations approved since the previous projection cut-off date of late 2022. Assigned pumping by sector is presented in **Table 3-2**.
 - Existing pumping is set at a constant rate for 100 years. The 2022 values from the updated historical model were applied to the wells in the “Existing” sector in the projection model.
 - Information from applicants regarding preferred pumping well locations and rates was submitted to ADWR in May 2024. The information related to the applicants’ wells was accepted and incorporated into this revision. One item of note is that the applicants changed the names of the hypothetical wells belonging to their properties and in doing so erroneously lumped a number of “certificate”

- wells into wells that they coded as “analyses”. Because it doesn’t change the volumes of groundwater being withdrawn or this projection’s results, ADWR has retained the applicants’ grouping and will correct the sector assignment before the next update.
- Incorporation of determinations approved since the previous projection cut-off date involved adding an analysis that was issued on May 5, 2023, and updating pumping associated with the City of Surprise DAWS.
 - The Box Canyon (Trinity) Analysis of Assured Water Supply, file number 28-701281.0000, was approved on May 5, 2023, after ADWR’s internal cut-off date for incorporating changes in the previous projection. A consultant identified this omission, and ADWR incorporated the additional 42.15 AFY of pumping into the revised projection via a hypothetical well at row 99, column 177. This is within the ESRV subbasin.
 - The City of Surprise had a DAWS modification approved in 2022 that was not captured in the 2023 ADWR projection run. The modification increased the groundwater portion of the DAWS from 13,457 AFY to 23,726 AFY. In the D&O of the DAWS modification, the City of Surprise listed how much groundwater would be pumped from each of their Special Planning Areas (SPAs), of which there are four. ADWR used the groundwater model submitted with the 2022 modification (the “DAWS model”) to adjust the projected pumping for the City of Surprise. The adjustment resulted in the addition of 24 simulated wells to the updated model. See **Table 3-3**.
 - SPA1 – the 2023 projection model contained the same number of City of Surprise-owned wells as the DAWS model, but the pumping rates differed. ADWR’s total pumping summed to approximately 13,500 AFY and the DAWS model pumping summed to 10,274 AFY. The volume listed in the D&O for SPA1 is 9,774 AFY. The difference between the D&O and DAWS model (500 AFY) is assumed to be simulated pumping of recharged effluent. The difference between the ADWR model and the DAWS model

(~3,200 AFY) is unclear but likely based on Registry of Grandfathered Rights (RGR) reported pumping being used in the ADWR model vs. planned pumping plus some other non-DAWS pumping being used in the DAWS model. ADWR made the following adjustments to the City of Surprise SPA1 so that the revised projection is consistent with the approved DAWS model:

- All Designation wells receive the pumping rate listed in the DAWS model.
- All LTSC wells receive the pumping rate listed in the DAWS model plus the pumping rate in the ADWR model. This is because the ADWR model assumes the removal of historical LTSCs at 1/100th per total volume per year, whereas the DAWS model assumes that the wells labeled “LTSC” and owned by the City of Surprise will also pump groundwater.

Note that the volume of historical LTSC pumping in SPA1 in the ADWR model is small (around 450 AFY).

- SPA2 – the 2023 projection model contained the same number of City of Surprise-owned wells as the DAWS model, but the pumping and sector assignment differed. The ADWR model had about one-tenth of the pumping in SPA2 that the DAWS model has (around 850 AFY vs. 8,150 AFY). The ADWR model wells inside SPA2 were classified as either “Municipal” or “Industrial”; not “Designation”. On the assumption that none of the DAWS pumping for SPA2 was included in the ADWR 2023 model (because the wells would have been assigned to the “Designation” sector if it had been), the approach to revising pumping in SPA2 is to create new wells based on the locations in the DAWS model and add the DAWS pumping on top of existing pumping.

- SPA3 – none of the DAWS pumping was reflected in the ADWR 2023 model, so the wells and the pumping rates shown in the DAWS model were added to the revised projection.
- SPA4 – none of the DAWS pumping was reflected in the ADWR 2023 model, so the wells and the pumping rates shown in the DAWS model were added to the revised projection.
- **phx_ama_proj.sfr**: The surface water inputs were averaged differently based on the discharge point being considered. The Gila, Salt, and Hassayampa Rivers releases/flow rates and the Buckeye Irrigation Canal diversions were assumed to be the average of the entire historical period and were updated to include 2022 data. The Agua Fria River in the model domain flows in response to releases from New Waddell Dam. Releases in the projection period are assumed to be the average of releases after the dam expansion in 1991. The 23rd Avenue Wastewater Treatment Plant (WWTP) has zero releases, and the 91st Avenue WWTP releases are assumed to be the average of the last 5 years of the calibrated period due to reductions in discharge to the Salt River compared to earlier years. **Table 3-4** summarizes the discharge, release, or diversion rates used in the projection period.

3.3 Updated Projection Aquifer Conditions

The updated projection simulation indicates that, at the end of the 100-year projection period (2023 to 2122), the following conditions are present in the AMA (see **Table 3-5**):

- As with the original projection (ADWR, 2023b), the areas southwest of the Superstition Mountains, south of Carefree, and south of the Vulture Mountains may have a water level depth exceeding 1,000 feet bls. Several areas close to mountain ranges where the aquifer is relatively thin, such as south and northwest of the White Tank Mountains, south of the Belmont Mountains, south of the Hieroglyphic Mountains, around the Palo Verde Hills, north of the Gila Bend Mountains, around the Phoenix Mountains, and east of the San Tan Mountains may experience water level decline below the top of bedrock.

- Groundwater pumping (including dewatering/drainage) has fluctuated around 900,000 acre-feet per year from the early 1980s to 2022 but has increased to an assigned value of 1,363,547 AFY for the projection period. This reflects the “issued but unbuilt” determinations within the AMA.
- The groundwater level is expected to drop noticeably across the Phoenix AMA, with an average decline of about 210 feet from the end of 2022 to the end of 2122. In contrast, the average simulated decline in the 2023 projection was about 185 feet from the end of 2021 to the end of 2121. The difference can be attributed to less unmet demand and more water being pumped from the aquifer. To further this point, the revised simulated aquifer storage loss is projected to be 43,857,914 acre-feet (an increase of approximately 5.2 MAF from the 2023 projection).
- As with the 2023 projection, the alluvial aquifer is expected to receive less groundwater recharge during the projection period than the historical period, mainly due to decreasing agricultural and artificial recharge.
- Continuous water level decline during the projection period will reduce evapotranspiration along the Gila River riparian zone and the Salt River riparian zone from about 45,500 acre-feet per year in 2023 to less than 3,000 acre-feet per year in 2121. The decline in groundwater level is expected to change the Gila River from an overall gaining reach (groundwater discharge to rivers) in the historical period to an overall losing reach (river leakage to groundwater) in the projection period. Underflow from the Lower Hassayampa Subbasin to the Gila Bend Basin is expected to decrease noticeably from the historical period to the projection period, from over 12,000 AFY to less than 1,000 AFY, assuming groundwater levels in the adjacent Gila Bend Basin remain static during the projection period. These results are very similar to the 2023 projection results.
- In the historical period, the estimated overdraft (aquifer storage loss) from the alluvial aquifer averages 174,545 acre-feet per year. In the projection period, the overdraft averages 438,579 acre-feet per year. The greater annual storage loss in the

projection period is due to increased pumping demand, decreased agricultural recharge, and reduced artificial recharge.

4.0 100-Year AWS Projection Model Results

This section discusses the results of the projection model simulation in the context of the physical availability requirements for AWS applications. Under the AWS program, the physical availability of groundwater in the Phoenix AMA must be demonstrated using a groundwater model. As described in Section 1.0, in the Phoenix AMA, an applicant must demonstrate that the water level decline after 100 years of groundwater withdrawals to satisfy the demands of existing uses, issued AWS determinations, and the applicant's demand will not exceed 1,000 feet bls or bedrock, whichever is shallower. Unmet groundwater demands associated with LTSCs and AWS determinations over the 100-year projection period are not acceptable.

As with the 2023 projection, there are both depth-to-water exceedances and unmet demand in protected sectors in this updated projection.

4.1 Depth to Water Level

Depth to water is calculated by taking the difference between the land surface elevation and the simulated water level elevation at the end of 100 years (2122). Because the model has three layers, and each layer can return a different water level depending on the amount of pumping and vertical anisotropy at that particular location, ADWR conservatively chose the minimum water level at a location to calculate the depth-to-water.

When ADWR evaluates if the simulated water depth exceeds the AWS physical availability requirement by the end of the 100-year projection, all of the following conditions must be met:

- The initial water depth at a model cell at the beginning of 2023 must be above the AWS physical availability requirement. Model cells with AWS violations at the beginning of 2023 are excluded when evaluating AWS violations at the end of 2122. None of the cells that fall into this category are associated with AWS wells.

- The water depth at the same model cell by the end of 2122 must be lower than the AWS physical availability requirement.
- There must be simulated demand in the model cell belonging to an AWS sector well.

The simulated water depth in the Phoenix AMA by the end of 2122 results in a violation of the AWS physical availability requirement in the following areas:

- Southwest of the Superstition Mountains (simulated water level is deeper than 1,000 feet below the ground surface and AWS wells in cells).
- East of the San Tan Mountains (simulated water level below the top of bedrock and AWS wells in cells).
- North of Sun City West (simulated water level below the top of bedrock and AWS wells in cells).

The geodatabase accompanying this model update contains simulated depths to water and starting and ending heads, drawdown, and saturated thickness for every cell in the model. In general, the results of this updated projection were similar to the results of the previous version. There are additional areas where the simulated depth to water after 100 years exceeds 1,000 ft, but those cells have no AWS demands.

From 2023 to 2122, the saturated thickness of the alluvial aquifer above bedrock is expected to decrease across the whole study area, with an average simulated water level decline across the study area of 210 feet between 2023 and 2122. As a result of the declining water table, some pumping wells go dry and fail to pump the total assigned volume.

4.2 Unmet Demand

Unmet demand is calculated by taking the difference between the assigned and simulated demands. Assigned demand is a model input. Simulated demand is a model output and can be less than the assigned demand if the aquifer cannot support the assigned pumping volumes throughout the projection period. The simulated pumping by sector is shown in **Table 4-1**. The average annual and cumulative unmet demand for 10 sectors (excluding

drainage demand) is shown in **Table 4-2**. The total, cumulative unmet demand in the Phoenix AMA at the end of 100 years is 3,604,476 AF. Within the AWS and LTSC sectors, the total cumulative unmet demand is 704,365 AF.

In the 2023 projection (ADWR, 2023b), several existing municipal wells not associated with designated providers were simulated as experiencing unmet demand with a cumulative unmet demand of 6,732 acre-feet from 2022 to 2121. This has gone to zero in the updated projection, and the reason for this is that the reported pumping rate in 2022 is considerably lower than the previous rate.

5.0 Summary and Limitations

ADWR has updated the Phoenix AMA groundwater flow model and the 100-year AWS projection to incorporate the most recent available data, reasonable well movement requests by applicants or well owners, feedback from AWS applicants and members of the public, and areas of improvement from internal review over the last year since the initial release of the model and projection in June 2023. The amended model reflects ADWR's policy of accepting reasonable well movements by the applicant and/or the well owner. The results from the updated groundwater model and the 100-year projection are similar to those from the previous versions. Exceedances of the 1,000 foot depth to water limit still exist. While unmet demand has been reduced due to well movements, unmet demand still exists in the protected sectors. As a result of well movement by applicants to the AWS program, unmet demand has shifted from wells in the Analysis and Certificate sectors to other sectors, such as the Designations of AWS, agricultural use, and industrial use. Although unmet demand has been reduced, these well movements allow for additional groundwater to be withdrawn from the aquifer, further mining the resource.

Tables 5-1 and **5-2**, which summarize the assigned, simulated, and unmet demands for the 100-year projection and the cumulative and average water budgets for the historical and projection periods, respectively, are formatted to allow direct comparison with the tables provided in the June 2023 Technical Memorandum (ADWR, 2023b).

Compared to the previous model, the updated groundwater model has a lower annual average recharge rate (lower by 9,600 AFY) due to the rate revision in the urban turf and agricultural recharge categories. All other inflows are approximately equal (within +/- 100 AFY) to the previous version. The average annual outflows of pumping, stream leakage, and evapotranspiration exhibited minor differences due to updated pumping from 2022 and overall slightly lower simulated heads. On average, the updated model has about 1,100 AFY less ET than the previous version. There is also slightly less simulated flux to the streams (1,500 AFY less). These results are consistent with slightly lower average heads across the southern part of the model domain, where these boundaries exist.

The updated model shows that storage change in the aquifer continues to be negative as of the end of 2022, meaning the aquifer is in an overdraft condition. The last time the aquifer experienced an annual gain was in 2014 when a September monsoon resulted in widespread flooding (and subsequent natural groundwater recharge) in the Phoenix metropolitan area. The average annual overdraft has been approximately 175,200 AFY throughout the historical period (**Table 5-2**). The model-simulated overdraft in 2022 was higher than the historical average, at 217,000 AF (**Table 2-5**). The AMA section of ADWR also tracks annual overdrafts, although their calculations currently end in 2019. In general, the AMA overdraft estimate is higher than the modeled overdraft estimate⁴, but both sources agree on the existence of groundwater overdraft in the Phoenix AMA.

Most changes between the updated and previous projection runs occur in the AWS sector. The total number of wells in the Analysis and Certificate sectors was reduced by 50 and 35 when compared to the June 2023 model, respectively (**Table 5-1**). These are primarily hypothetical (unbuilt) locations, and well movements/demand redistributions are allowable under ADWR Substantive Policy Statement AWS 8. The number of wells in the Designation sector increased by 24 to reflect the revised City of Surprise DAWS. The number of wells in all other sectors remained the same; likewise, changes to assigned total annual demand changed in the AWS sectors and nowhere else. Annual pumping in the Analysis and Designation sectors increased by 42.15 AFY and 11,228 AFY, respectively. Due to the

⁴ The AMA overdraft dashboard is available online at <https://www.azwater.gov/ama/ama-data>

hypothetical well grouping proposed by applicants to the AWS program, pumping in the Certificate sector appears to have decreased while pumping in the Analysis sector appears to have increased, but this is simply a grouping issue that ADWR plans to correct and does not change the results of the projection nor does it impact the assigned and simulated pumping volumes in the AWS sector. These changes reflect the redistributions and updates described in Section 3.

The 100-year AWS projection continues to show unmet demand and depth-to-water exceedances in the Phoenix AMA. The primary change between this year's updated projection and the June 2023 projection is in the Analysis sector. After relocating a number of hypothetical wells per the request of landowner applicants to the AWS program, the 100-year volume of unmet demand in the Analysis sector decreased from 1,292,209 AF to 141,161 AF and from 679,649 AF to 386,480 AF in the Certificate sector. Unmet demand in the Designation sector increased from 108,528 AF to 165,735 AF. In the Agricultural and Industrial sectors, which are not protected under the AWS program, unmet demand increased from 2,727,020 AF to 2,842,607 AF and from 25,265 AF to 42,524 AF, respectively. Finally, the 100-year projected cumulative loss in storage increased from 38,671,748 AF to 43,857,914 AF. This result is the expected outcome of more wells being able to pump longer in the projection period.

The model and projection simulation are regional-scale tools appropriate for water budget analyses and evaluations of physical availability for the AWS program. Small-scale (cell level) inaccuracies may be present, and ADWR encourages the public to continue to review the model and contact ADWR with suggestions for improvement. As with any groundwater modeling projection, if the future hydrologic conditions differ from the assumptions made in the projection simulation, the groundwater levels and flows may significantly differ from those presented herein.

6.0 References

- ADWR, 2023a. Groundwater Flow Model of the Phoenix AMA, Arizona. Modeling Report No. 28.
- ADWR, 2023b. Technical Memorandum, Phoenix AMA 100-Year Assured Water Supply Projection.
- CAGRD, 2015. Plan of Operation. <https://cagr.com/operations/plan-of-operation-and-mid-plan-reviews/>
- Gootee, B.F., Cook, J.P., Young, J.A., and Pearthree, P.A., 2017. Subsurface hydrogeologic investigation of the Superstition Vistas Planning Area, Maricopa and Pinal Counties, Arizona. Arizona Geological Survey Special Paper 11, 70 p., 2 Map Plates – 1:60,000 scale, 10 appendices, GIS data.
- Hipke, W. 2010. 100-Year Predictive Scenarios Used for the Determination of Physical Availability in the Phoenix Active Management Area. Modeling Report No. 22.
- PRISM, 2024. PRISM Climate Group, Oregon State University, <https://prism.oregonstate.edu>. Data created 20220716, 20220820, 20220920, 20221026, 20221120, 20221218, 20230117, 20230215, 20230315, 20230415, 20230515, 20230615, accessed June 19, 2024.