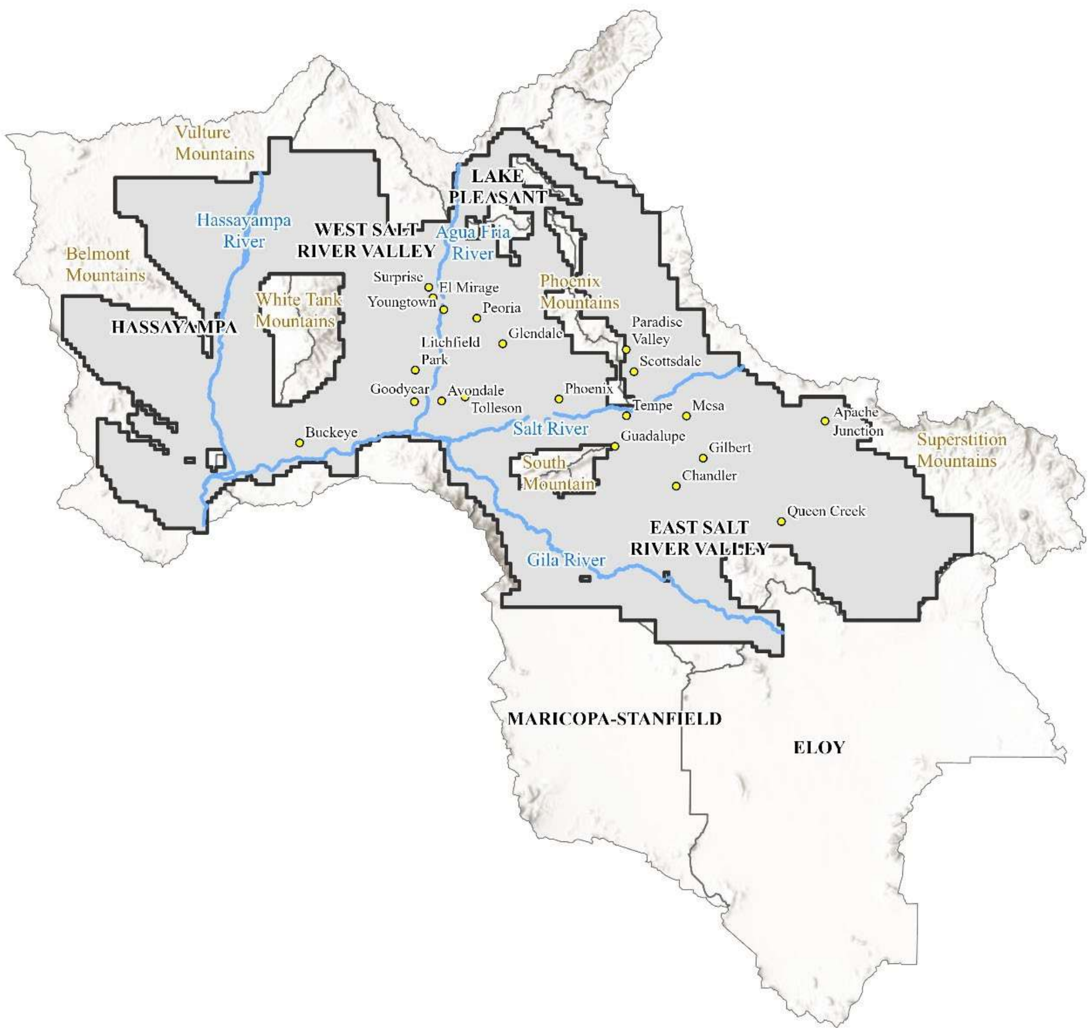
ARIZONA DEPARTMENT OF WATER RESOURCES

Groundwater Flow Model of the Phoenix Active Management Area



Groundwater Modeling Section
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Modeling Report No. 28

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Groundwater Flow Model of the Phoenix Active Management Area

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List of Acronyms

%	percent
AAWS	Assured and Adequate Water Supply
ADWR	Arizona Department of Water Resources
AF	Acre-Feet
AFY	Acre-Feet per Year
AMA	Active Management Area
AMWUA	Arizona Municipal Water Users Association
AMSL	above mean sea level
BIC	Buckeye Irrigation Canal
BWCDD	Buckeye Water Conservation and Drainage District
CAP	Central Arizona Project
cfs	cubic feet per second
DIS	Discretization (package)
ESRV	East Salt River Valley
ET	Evapotranspiration
ft	feet
GAGE	Stream Gaging Station (package)
GHB	General Head Boundary (package)
GRIR	Gila River Indian Reservation
GWSI	Groundwater Site Inventory
HOB	Head Observation (package)
HSU	Hydrostratigraphic Unit
IBW	Indian Bend Wash
ID	Irrigation District
Kh	Horizontal hydraulic conductivity
Kv	Vertical hydraulic conductivity
LAU	Lower Alluvial Unit
MAU	Middle Alluvial Unit
MNW2	Multi-Node Well (package)
NWT	Newton-Raphson (solver)
RCH	Recharge (package)
RGR	Registry of Groundwater Rights
RMSE	Root Mean Square Error
RWCD	Roosevelt Water Conservation District
SCIP	San Carlos Irrigation Project
SFR2	Streamflow Routing (package)
SRP	Salt River Project
SRPMIC	Salt River Pima Maricopa Indian Community

SRV	Salt River Valley
SRVWUA	Salt River Valley Water Users Association
sq. mi.	square miles
Ss	Specific storage
SVPA	Superstition Vistas Planning Area
Sy	Specific yield
UAU	Upper Alluvial Unit
UPW	Upstream Weighting Groundwater Flow (package)
USF	Underground Storage Facility
USGS	United States Geological Survey
WEL	Well (package)
WSRV	West Salt River Valley
WWTP	Wastewater Treatment Plant

Executive Summary

The Arizona Department of Water Resources (ADWR) has developed and calibrated a groundwater flow model of the Phoenix Active Management Area (AMA). The model area combines the Lower Hassayampa, West Salt River Valley (WSRV), and East Salt River Valley (ESRV) sub-basins; and includes portions of the Maricopa-Stanfield, Lake Pleasant, and Eloy sub-basins. The Phoenix AMA model replaces the existing Salt River Valley (SRV) and Lower Hassayampa sub-basin groundwater models.

The model is calibrated to the time period of pre-1900 through 2021. Data used in the calibration include 40,577 water level measurements collected from 4,562 wells, 325 aquifer test results, vertical head difference observations from 56 well pairs, observations of stream gains prior to widespread groundwater pumping, and gaged streamflow rates on the Salt and Gila Rivers. The calibration results indicate that the model reasonably reproduces the study area's historical water level and streamflow conditions. Residuals are calculated as observed minus simulated values. The mean, absolute mean, and the root mean square error (RMSE) for the head residuals are 1.2 feet, 37.2 feet, and 49.7 feet, respectively. The normalized RMSE is 3.6%. These calibration statistics indicate that the regional model is well-calibrated. Furthermore, the model covers 122 years, during which the system undergoes a wide range of hydrologic conditions, making the model suitable to handle future anticipated conditions that fall within the variability that the long history has covered.

The simulated water budget includes natural inflows to the study area consisting of mountain-front recharge from the surrounding mountains; streambed leakage from the Salt, Gila, Santa Cruz, Agua Fria, and Hassayampa Rivers; and ephemeral flood recharge from the numerous washes. Natural outflows occur as riparian vegetation evapotranspiration and stream baseflow. Groundwater enters the model as underflow from adjacent groundwater basins and sub-basins, including Eloy (near the Town of Florence and on the Gila River Indian Reservation [GRIR] near Sacaton), Maricopa-Stanfield (near the City of Maricopa and the Ak-Chin Indian Reservation), Lake Pleasant, and Upper Hassayampa. Groundwater exits the model as underflow to the Gila Bend sub-basin at the Gillespie Dam. The Maricopa-Stanfield boundary is modeled with underflow entering the Phoenix AMA until the early 1950s. After

this point, the boundary becomes an outflow boundary due to gradient reversal resulting from groundwater pumping in the Pinal AMA.

The major anthropogenic influences on the water budget are well pumping and recharge from human activity, largely related to agriculture (return flow and canal seepage). Between 1900 and 2021, an estimated 115.7 million acre-feet (AF) of water was pumped out of the study area, while another 111.9 million AF of water recharged the aquifer due to precipitation and recharge from human activity. Some of the water in the model domain is from surface water sources such as imported Central Arizona Project (CAP) water, the Salt River Project (SRP), and the Gila River. Intentional (artificial) recharge occurs later in the simulation period via Underground Storage Facilities (USFs), representing a progressively more significant portion of the water budget in later years. Recharge at the USFs within the model domain begins in 1989 and continues through 2021; overall, USFs have recharged approximately 5.02 million AF of water to the aquifer.

The calibrated model indicates an aquifer storage loss of approximately 20.6 million AF over the historical period. Much of this loss occurred in the middle of the 20th century when agriculture was widespread in the AMA and pumping volumes approached 2 million AF per year. During the thirty years between 1950 and 1980, the average annual deficit to the aquifer was 540,000 AF (i.e., more water was being pumped out than was being recharged). This trend has changed in recent years. Between 2000 and 2021, the average annual deficit to the aquifer was only 30,000 AF, largely due to lower pumping rates due to urbanization and conservation efforts, as well as enhanced recharge of CAP and other water sources at permitted facilities.

1.0 Introduction

The Arizona Department of Water Resources (ADWR) has developed a numerical groundwater flow model encompassing the Phoenix Active Management Area (AMA). The purposes of this document are to record the data that went into the Phoenix AMA groundwater model, describe the calibration process, present the calibrated model results, discuss model limitations, and present suggestions for future work. This model updates and expands upon its predecessor, the Salt River Valley (SRV) model (Freihoefer et al., 2009), with a steady-state simulation of pre-development conditions (pre-1900), a lengthened transient period (1900-2021), and an expanded active domain that includes the Lower Hassayampa sub-basin. The Phoenix AMA model is a regional-scale model suitable for use with agency-related applications and simulation of regional potential future scenarios.

The purpose of replacing the SRV model with the Phoenix AMA model is to continue to update and improve the primary tool used to simulate and regulate groundwater conditions in the Phoenix AMA. Specifically:

- Incorporate the Lower Hassayampa sub-basin into the numerical model;
- Incorporate a steady-state stress period representing pre-development conditions at the start of the simulation;
- Take advantage of more than a decade of data collected since the SRV model was last calibrated;
- Use the MODFLOW multi-node well (MNW2) package to allow for wells penetrating multiple layers of the model and proportional decreases of pumping if layers go dry;
- Incorporate multiple types of calibration targets to improve the estimation of aquifer parameters; and
- Provide a repository for hydrologic information in the Phoenix AMA.

The Phoenix AMA model replaces the SRV and Lower Hassayampa sub-basin models for ADWR's management of water resources in the Phoenix AMA. The Phoenix AMA model may be used for regulatory purposes, including Assured and Adequate Water Supply (AAWS) permitting, stakeholder use, and evaluating the AMA goal of safe yield.

2.0 Study Area

The Phoenix AMA groundwater basin is 5,646 square miles (sq. mi.) in size and is located in central Arizona within the Basin and Range physiographic province, which features thick sequences of sediments in basins surrounded by low-elevation bedrock mountain ranges. The Phoenix AMA model encompasses the Lower Hassayampa, West Salt River Valley (WSRV), and East Salt River Valley (ESRV) sub-basins and parts of the Lake Pleasant, Eloy, and Maricopa-Stanfield sub-basins (**Figures 2-1** and **2-2**). The groundwater sub-basins are surrounded by mountain ranges, including the McDowell, Usery, Goldfield, Superstition, San Tan, Sierra Estrella, White Tank, Belmont, Vulture, Wickenburg, and Hieroglyphic Mountains. The southern portion of the model overlaps with the Pinal AMA groundwater model (Liu et al., 2014). The active model domain encompasses 2,969 sq. mi. The model time begins with a steady-state stress period representing pre-development conditions (pre-1900) and follows with 104 transient stress periods from 1900 to 2021.

The modeled area is in the Sonoran Desert, where surface water is limited and generally ephemeral in nature. The climate is semi-arid, with hot summers and mild winters. Precipitation is minimal and ranges from seven to eight inches per year at the basin floor to close to 20 inches per year in the Hieroglyphic Mountains of the Lower Hassayampa sub-basin. Surface water flows in response to high-intensity precipitation events are a significant source of recharge to the aquifer. Recharge from the surrounding low-elevation[1] mountain ranges is another, albeit more minor, water budget component. Recharge from areally distributed precipitation in the valley is minimal to non-existent and is not explicitly modeled. Evaporation far exceeds annual precipitation. Evapotranspiration from riparian plants is a major component of the water budget in the pre-development simulation but becomes less significant in later years as the water table declines.

Land subsidence due to groundwater pumping has been observed in the Phoenix AMA. Areas with notable subsidence include the WSRV sub-basin near the Luke Air Force Base, the Lower Hassayampa sub-basin near Buckeye and Arlington, and the ESRV sub-basin in

[1] Less than 4,000 feet above mean sea level (ft AMSL).

Apache Junction, Mesa, Chandler, and in North Scottsdale near the Loop 101 and Scottsdale Road. ADWR monitors subsidence in the entire AMA and has measured up to 5.9 inches in these areas since 2010 (ADWR, 2019). Subsidence impacts the aquifer by reducing the capacity of the aquifer to store water, compressing the aquifer material, and lowering the land surface elevation.

ADWR has implemented automated groundwater monitoring systems around the Phoenix AMA to track groundwater levels and monitor trends. In the ESRV, some of these monitoring stations show that groundwater levels have started to recover from historical pumping, slowing subsidence in the area. For example, between 2013 and 2014, ADWR measured subsidence of 0.75 inches in the ESRV, but between 2014 and 2016 measured an uplift of 0.67 inches (ADWR, 2017).

Groundwater pumping in the 20th century significantly impacted the aquifer and the hydrology of the Phoenix AMA. Prior to the middle of the century, stretches of the Salt and Gila Rivers were perennial (flowed year-round). Between 1940 and 1960, pumping increased significantly. In 1940, pumping was estimated at 250,000 acre-feet (AF) per year; by 1960, it was estimated at 2.3 million AF per year, a nearly 10-times increase. Following the Groundwater Management Act in 1980 and the initiation of the Colorado River water deliveries from the Central Arizona Project (CAP), groundwater pumping started to decline. By the 2010s, groundwater pumping had declined to approximately 850,000 AF per year (ADWR, 2022). The agricultural sector had the highest demand for water in the Phoenix AMA until approximately 2000, when the municipal sector demand exceeded agricultural demand for the first time.

3.0 Hydrogeology

3.1 Model Layer Structure

The Phoenix AMA model encompasses the alluvial deposits of the Salt River Valley, extending from the Belmont Mountains in the west to the Superstition Mountains in the east. The total active modeled area is 2,969 sq. mi.

The three model layers represent the Upper Alluvial Unit (UAU), Middle Alluvial Unit (MAU), and Lower Alluvial Unit (LAU). Contact elevations are carried over from the SRV model or the Brown and Caldwell 2006 model of the Lower Hassayampa sub-basin, with modifications described in Dubas (2010) and below.

The model unit layers have been described in previous reports for the SRV model (Corkhill et al., 1993; Freihoefer et al., 2009), but generally, the UAU is defined by gravel, sand, and silt, the MAU by clay, silt, mudstone, and gypsiferous mudstone, and the LAU by conglomerate and gravel near basin margins and mudstone, gypsiferous and anhydritic mudstone, and anhydrite in the basin centers.

In areas where the total model thickness was less than 1/10th of the cell width (i.e., 264 ft), the bottom of the LAU was extended so that the total thickness was at least 264 ft. This was done to improve model convergence. In areas where the MAU is absent, a standard thickness of 49 ft was assigned to the MAU cells, and the LAU's top was lowered by 49 ft. This provided a means to track the areas without the MAU to ensure the assigned aquifer properties were appropriate. This situation generally occurred in the Lower Hassayampa sub-basin.

Contact elevations in the Superstition Vistas Planning Area (SVPA) were derived from Gootee et al. (2017). Of note in this area is the presence of the Higley and Elephant Butte faults. The Higley Fault is a low-angle fault that contours around the northern edge of the Santan Mountains. The Elephant Butte Fault is a major normal fault that bounds the northeastern, eastern, and possibly southeastern boundary of the SVPA. The faults have created ridge-like protrusions of bedrock beneath the LAU. For the Phoenix AMA groundwater model, the mapped contact elevations of these protrusions were smoothed into the surrounding bedrock where necessary to prevent very thin model cells in Layer 3.

Lastly, ADWR-approved modifications to cell bottom elevations in the SRV model made during the years the model was used to support applications for Certificates, Analyses, and Designations of Assured Water Supply were carried over into the Phoenix AMA model geometry. These changes include:

- Deepening the bottom of the LAU in seven model cells within the EPCOR-PV service area,
- Deepening the bottom of the LAU in model cells within the Clearwater Utility area south of Buckeye,
- Redefined depth to bedrock in 120 model cells in the area near Apache Junction, and
- Deepening the bottom of the LAU in five model cells near the intersection of State Route 79 and U.S. Route 60.

Figures 3-1 through **3-6** identify the areas where the model geometry was modified from the SRV and Hassayampa models.

3.2 Groundwater Flow System

Groundwater flows are more or less unconfined within the three hydrostratigraphic units, although semi-confined and confined conditions may exist locally in the lower units. The permeability of the aquifer material can vary considerably depending on the location and depth within the basin. Conceptual understanding of aquifer parameters is as follows (abstracted from Anderson et al., 1992):

- Generally, the lower basin-fill unit (corresponding to the LAU and parts of MAU) is more highly consolidated, deformed, and finer-grained than the upper basin-fill unit (generally corresponding to the UAU).

- Basin-fill sediments have a varied and distinct facies distribution and consist mainly of weakly to moderately consolidated gravel, sand, silt, and clay that occur as distinct layers or poorly sorted mixtures.

- The deposits generally consist of poorly sorted gravel, sand, and some silt at the basin margins that grade, often abruptly, to sand, silt, and clay toward the basin centers.

- The percentage of fine-grained material (less than 0.0625 mm in diameter) generally is about 10 to 50 percent near the basin margins and can be up to 60 to 90 percent at the basin centers.

Vertical gradients between the units are minimal, but localized head differences of up to 100 ft have been recorded between the MAU and the LAU (Rascona, 2003). Particularly in the WSRV, lenses of silt and clay are present near Goodyear, Luke Air Force Base, and Glendale, and these materials form confining beds that slow the vertical movement of groundwater (Stulik and Twenter, 1964; Brown and Pool, 1989; Edmonds and Gellenbeck, 2002). In the pre-development era, localized confining conditions were present at depths greater than 100 ft below the ground surface, based on multiple reports of water rising in well casings (Lee, 1904).

Aquifer parameters in the three units have been documented in technical reports and field tests. The stream alluvium generally has the highest hydraulic conductivities and specific yields at 30 to 1,000 ft per day and 15 to 25 percent, respectively. The UAU, MAU, and LAU parameters vary but generally range from hydraulic conductivities of 1 to 100 ft per day with specific yields between 3 and 25 percent.

3.2.1 Steady-State Groundwater Flow System (pre-1900)

Human habitation and irrigated agriculture have been part of the history of the modeled area for hundreds of years. The Hohokam Native Americans inhabited the Salt River Valley from 300 A.D., possibly earlier, until approximately 1450 A.D. The Hohokam constructed over 500 miles of irrigation canals to divert water from the Salt and Gila Rivers, supplying water to 110,000 acres of crops around present-day Mesa, Tempe, and Phoenix (Arizona Museum of Natural History, 2020).

When non-Indian settlers arrived in the Salt River Valley in the 1860s, they rehabilitated what remained of the ancient canal system and expanded upon it to create the current network of irrigation canals. Although the Hohokam had disappeared hundreds of years before the arrival of the Mexican and American settlers, in the 1860s, the Pima Indians were living and farming an estimated 15,800 acres along the Gila River (Olberg, 1919; Zarbin, 1997). By the early 1900s, an estimated 200,000 acres of land were under cultivation, with an estimated 60,000 acres receiving irrigation water (Davis, 1897; Zarbin, 1997).

At the time of the earliest measurements (approximately 1897 to 1905), the hydrologic system had already been altered by over 1,000 years of human activity. However, as noted in past reports for the SRV model, the system was considered to be in equilibrium because inflows generally balanced outflows (Corkhill et al., 1993). The direct impact of the irrigation activity on the hydrologic system was the re-distribution of surface water recharge from streambeds and floodplains to more distant cultivated lands served by canals. A conceptual water budget of the steady-state period (pre-1900) is presented in **Table 3-1**.

Inflows to the study area during the steady-state period include (**Figure 3-7**):

- Precipitation recharge along the mountain fronts surrounding the basin,
- Recharge from perennial and ephemeral streams, and
- Groundwater underflow from the Upper Hassayampa, Lake Pleasant, Eloy, and Maricopa-Stanfield sub-basins.

Outflows from the study area during the steady-state period include (**Figure 3-7**):

- Evapotranspiration by riparian vegetation,
- Groundwater underflow to the Gila Bend sub-basin at the Gillespie Dam, and
- Discharge to the Salt and Gila Rivers as baseflow.

3.2.2 Transient Groundwater Flow System (1900-2021)

The hydrogeology in the Phoenix AMA in the years after extensive groundwater development differs from the pre-development system. Groundwater pumping has created an imbalance in the system inflows and outflows, aquifer discharge to streams has largely ceased, and the groundwater flow direction is locally variable and toward cones of depression.

The post-development water budget for the Phoenix AMA has more significant outflows from the aquifer (up to 2 million acre-feet per year [AFY]) than the pre-development period and subsequently increased inflows from incidental recharge (up to 1 million AFY). The net change removes water from the system, which is reflected in generally declining water levels and observed subsidence. Conceptual estimates of post-development water budget components vary substantially between sources. An estimated conceptual transient water budget is shown in **Table 3-2**. **Table 3-3** is an assignment of wet, dry, average, or flood conditions for each year and is relevant to how specific model inputs are derived.

Inflows to the study area in the transient period include (**Figure 3-8**):

- Precipitation recharge along the mountain fronts surrounding the basin,
- Recharge from perennial and ephemeral streams, including Indian Bend Wash (IBW),
- Groundwater underflow from the Upper Hassayampa, Lake Pleasant, Eloy, and Maricopa-Stanfield sub-basins, and
- Recharge from anthropogenic sources.

Outflows from the study area in the transient period include the following (**Figure 3-9**):

- Evapotranspiration by riparian vegetation,
- Groundwater underflow to the Gila Bend sub-basin at the Gillespie Dam,
- Discharge to the Salt and Gila Rivers as baseflow, and
- Groundwater pumping.

4.0 Numerical Model Development

4.1 Previous Models

A number of regional-scale groundwater flow models have been developed that cover parts or all of the SRV (Anderson, 1968; Long et al., 1982; Thomsen and Eychaner, 1991; Thomsen and Porcello, 1991; Corell and Corkhill, 1994; Freihoefer et al., 2009) and at least two models covering the Lower Hassayampa sub-basin (Brown and Caldwell, 2006; ADWR, 2023).

4.1.1 SRV Model

The first computer model of the SRV was an electrical analog model by Anderson (1968), which had a historical time period of 1923 to 1964. This model was developed to predict future groundwater levels (1964-1984) under conditions of withdrawals exceeding replenishment. The Salt River Valley Cooperative Study Modeling effort (Long et al., 1982) developed a groundwater model for use by ADWR, SRP, and the Arizona Municipal Water Users Association (AMWUA) in groundwater management and planning programs. This effort consisted of a groundwater database from 1964 to 1977 and a numerical model calibrated from 1972 to 1977.

Two numerical models were then developed to study the predevelopment hydrology of the Gila River Indian Reservation and the Salt River Indian Reservation (Thomsen and Eychaner, 1991; Thomsen and Porcello, 1991). These studies were used to provide information for the adjudication of water rights.

The first ADWR MODFLOW model was released in 1994 (Corell and Corkhill, 1994). Since then, the model has been updated, most recently in 2009 (Freihoefer et al., 2009). The SRV model active domain covers 2,354 sq. mi. with grid cells sized 0.5 mile by 0.5 mile (160 acres). The model simulates transient conditions from 1983 to 2006. The model was divided into three layers and includes the East and West SRV sub-basins and portions of the Lake Pleasant, Lower Hassayampa, Eloy, and Maricopa-Stanfield sub-basins.

4.1.2 Lower Hassayampa Model

In 2006, Brown and Caldwell developed a three-layer MODFLOW-2000 groundwater flow model for the Lower Hassayampa sub-basin. The active domain of the model includes the Lower Hassayampa sub-basin and some adjacent areas of the WSRV sub-basin to the east. The model has a total active area of approximately 886 sq. mi.

The Brown and Caldwell model was calibrated to historical aquifer conditions from 1930 through 2003. In 2023 ADWR updated and re-calibrated the Brown and Caldwell model to 2016.

4.1.3 Updates from Previous Models

Updates to the Phoenix AMA model from the SRV model include:

- A steady-state stress period that provides initial heads for the transient simulation,
- A longer transient simulation,
- An expanded model domain that now includes the Lower Hassayampa sub-basin, eliminating the need for artificial boundaries between the WSRV and Lower Hassayampa sub-basins,
- Revised geology as described in Section 3.1,

- Re-calibrated aquifer parameters based on sediment texture data,
- Groundwater well pumping simulated using the MNW2 package, and
- Groundwater modeling code updated to MODFLOW-NWT, designed to solve non-linear unconfined groundwater flow problems.

4.2 Components of the Numerical Model

This section summarizes the packages used to develop the numerical model. The model grid in the active domain is presented in **Figure 4-1,** and cross-sections of the model are in **Figures 4-2** through **4-4**.

4.2.1 MODFLOW Code

The Phoenix AMA model was developed with MODFLOW-NWT (Niswonger et al., 2011) version 1.3.0 with the upstream weighting groundwater flow (UPW) package and the Newton-Raphson (NWT) solver (Ibaraki, 2005) to improve the solution of unconfined groundwater-flow problems.

4.2.2 Discretization (DIS)

The discretization (DIS) package defines the spatial and temporal resolution of the model. The finite-difference grid used to represent the model domain consists of orthogonal cells oriented on a north/south axis with no rotation. The model grid comprises 3 layers, 125 rows, and 222 columns, with a uniform horizontal discretization of 0.5 mile by 0.5 mile. Individual model cell thickness varies in accordance with local hydrogeologic stratification at a 0.5-mile scale. Although portions of the alluvial basin exceed a thickness of 10,000 ft, the Phoenix AMA model thickness is truncated at about 3,000 ft. This is consistent with the approach taken in the SRV model and was done because few wells exist at this depth.

The simulation timeframe (1900-2021) is divided into stress periods in the DIS package (**Table 4-1**). Each stress period is assigned a set of representative boundary conditions for that period (inflow or outflow components) representing change in hydrologic conditions over time. The model grid and aquifer properties are held constant throughout the simulation period.

4.2.3 Underflow from Adjacent Basins and Mountain Fronts (WEL)

The WEL package (Harbaugh et al., 2000) simulates groundwater underflow to and from adjacent basins and mountain-front recharge (**Figure 4-5**). The basin boundaries where this underflow occurs are Florence, GRIR (aka Santan-Sacaton), Harquahala, Hassayampa, Lake Pleasant, Maricopa-Stanfield, and Santa Cruz. The mountain front inflow boundaries are along the Belmont, Vulture, White Tank, Hieroglyphic, McDowell, Usery, Goldfield, Superstition, and Sierra Estrella Mountains.

The Maricopa-Stanfield underflow boundary is modeled with underflow entering the model until 1951. After 1951 this boundary became an outflow boundary due to the gradient reversal induced by groundwater pumping in the Pinal AMA. Underflow volumes for the Florence, GRIR, Santa Cruz, and Maricopa-Stanfield boundaries were derived from the Pinal model (Liu et al., 2014). Lake Pleasant underflow was carried over from the SRV model, and the Hassayampa boundary underflow was obtained from the Lower Hassayampa model. Inflows along the mountain fronts were initially derived from the SRV and Lower Hassayampa models (Freihoefer et al., 2009; Brown and Caldwell, 2006) and adjusted during calibration.

4.2.4 Recharge (RCH)

The following components of the water budget are simulated using the MODFLOW-NWT recharge (RCH) package: agricultural recharge, canal seepage, ephemeral wash recharge, flood recharge, artificial lakes, urban turf recharge, and artificial recharge via underground storage facilities (USFs).

<u>Agricultural Recharge</u>

Agricultural recharge (**Figure 4-6**) is water applied to the fields in excess of what evaporates or the crop consumes that eventually returns to the aquifer. This is the most significant component of the recharge package for most of the transient time period (in 2006, USF recharge overtakes estimated agricultural recharge as the dominant recharge component). Agricultural recharge is estimated in the following way:

- Historical aerial photography and maps were used to identify and digitize irrigated land at different points in time. The years with available maps or aerial photos are 1937, 1947, 1954, 1963, 1973, 1990, 1995, 2000, 2009, 2010, 2012, 2014, and 2016 (later year aerial photography is available annually, so only every other year was referenced).

- After reviewing historical cropping patterns and consumptive uses of crops in the southwest United States, an average value of 3.7 AF per acre per year was assumed for crop needs in the Phoenix AMA. Of this, 25% was assumed to infiltrate as recharge.

- The recharge rate was prorated based on the observed portion of irrigated land within a given model cell.

- As land urbanizes within the model domain, agricultural recharge is removed from the footprint of the urbanization.

- The initial values derived using the methodology outlined above were adjusted during calibration. Agricultural areas were delineated by irrigation district (ID) (**Table 4-2**), and the districts were calibrated as individual entities.

Recharge from Canal Seepage

Canal seepage (**Figure 4-7**) is based on three types of canals in the study area: the CAP canal, San Carlos Irrigation Project (SCIP) canals, and non-SCIP canals. Note that the Buckeye Irrigation Canal (BIC) is represented in the model with the SFR2 package. Canal seepage is estimated in the following way:

- The CAP publishes estimates of canal seepage on its website (https://www.cap-az.com/about/faq/). Seepage from the CAP canal was assumed to be equal for all cells in the model and was prorated based on the length of the CAP canal within the active domain. The volume of CAP seepage was not adjusted during calibration and is equal to 4,961 AFY starting in 1982.

- SCIP canals consist of the Casa Blanca, Northside, Pima, and Southside canals. Laterals are not explicitly modeled, as losses here are assumed to be part of the agricultural recharge value. Seepage rates from the Pinal model (Liu et al., 2014) were averaged and used as an initial constant rate for the 1900-2010 period. From 2011 onward, the rate was incrementally decreased to reflect canal improvement activities. The initial rate was adjusted during calibration.

- Non-SCIP canals consist of the Arlington, Arizona, Beardsley, Consolidated, Crosscut, Eastern, Grand, Hayden Branch, Highline, Kyrene, Roosevelt Irrigation District, Roosevelt Water Conservation District, St Johns, San Francisco, South, Tempe, and Western canals. Initial seepage rates were developed based on an assumed base seepage rate that depended on the canal footprint within the model. The initial rates were reduced as the canal was lined (SRVWUA, 1982) and adjusted during calibration.

Ephemeral Recharge

Ephemeral recharge (**Figure 4-8**) occurs in the following channels: Queen Creek, Cave Creek, Skunk Creek, New River, Indian Bend Wash, and Centennial Wash. Ephemeral recharge was estimated in the following way:

- Surface water gage measurements, if available, were tabulated for the washes. For washes without gage measurements, the ratio of annual virgin flow in the Salt and Gila River watersheds by Gookin (2009) was used to estimate surface water flow.

- The periods of record for the gages do not cover the entire model period, so the record was developed by relating the type of year as determined from the conceptual water budget (**Table 3-3**) to the corresponding value in the data series (flood year = maximum value, wet = average value, average = median value, and dry = 1st quartile).

- A percentage of the surface flow was assumed to infiltrate; this varied from 100% for flows less than 20,000 AFY to approximately 10% for flows greater than 1.5 million AFY.

Ephemeral recharge for a given wash is applied evenly to all model cells representing that wash, and the initial values were adjusted during calibration.

Flood Recharge

Flood flows (**Figure 4-8**) are supplemental slugs of recharge that are applied to the Salt, Gila, and Santa Cruz Rivers in historical flood years. The historical flood years are 1941 (Smith and Heckler, 1955), 1951, 1964, 1965 (Werho, 1967), 1970, 1972, 1978, 1979, 1980 (Corkhill et al., 1993), 1983 (Konieczki and Anderson, 1990), 1992, 1993, and 2014 (Holstege, 2015). Flood flows are estimated in the following way:

- Flood recharge in the Salt River was estimated by assuming a percentage of recorded spills over Granite Reef Dam infiltrate the aquifer (as with ephemeral recharge, the percentage varies from 100% for flows less than 20,000 AFY to approximately 10% for flows greater than 1.5 million AFY).

- For the Gila and Santa Cruz Rivers, calibrated recharge values from the Pinal AMA model were used. To assign the flood flow recharge rates for the years listed above, the average recharge volume from non-zero years for the respective stream was calculated and assigned to the length of the stream channel.

Flood recharge is applied evenly to all model cells representing a given stream, and the initial values were adjusted during calibration.

Lake and Urban Turf Recharge

Artificial lake and urban turf recharges where municipal development is located within the active model domain **(Figure 4-9)**. These recharge components are estimated in the following way:

- Artificial lakes were identified using aerial photography. A lake becomes active in the model from the year it first appears in imagery. Some lakes were observed as early as 1985. Acreages were measured in ArcGIS. The initial seepage rate was estimated for all lakes as 5 ft per year and was adjusted during calibration. The adjusted rate remained constant over time.

- Urban turf was identified using aerial photography. The model has approximately 250,000 acres of developed turf, and the initial seepage rate was assumed to be 0.2 ft per year. This initial rate was adjusted during calibration, and the adjusted rate remained constant over time.

Artificial Recharge

The artificial recharge component represents water recharged via Underground Storage Facilities (USF) (**Figure 4-10**). All USF recharge, including recharge via injection well, is represented with the recharge (RCH) package. Recharge began in 1989 and continues through the end of the historical simulation. This component was developed in the following way:

- Annual recharged volumes for each facility were obtained from ADWR databases and records relating to the Recharge and Recovery Program.

- The locations of the USFs in the model are based on aerial photos and ADWR records. For facilities represented by more than one model cell, the annual recharge volume was divided by the number of cells so that all cells representing a single facility have the same rate in a given year.

- This recharge component was not adjusted during calibration.

4.2.4 Streamflow and Streambed Leakage (SFR2)

The SFR2 package (Niswonger and Prudic, 2005) is used to simulate streamflow and streambed leakage in the Salt, Gila, Santa Cruz, Agua Fria, and Hassayampa Rivers, leakage from the BIC, and effluent discharges from wastewater treatment plants (WWTPs). **Figure 4-11** shows the location of SFR2 cells in the model. The inflows at the top of the Salt, Gila, Santa Cruz, Agua Fria, and Hassayampa Rivers are derived as follows:

- *Salt River:* The Salt River Project (SRP) provided a monthly record of spills over the Granite Reef Dam from 1913 to 2021. Prior to 1913, ADWR estimated the flow at Granite Reef Dam using the natural flows calculated by Gookin (2009). The pre-development estimate was sourced from Thomsen and Porcello (1991).

- *Gila River:* San Carlos Irrigation Project (SCIP) reports from 1930 to 2021 provide annual volumes of water spilled and sluiced over the Ashurst-Hayden Diversion Dam (i.e., water in the Gila River channel). Prior to 1930, ADWR estimated the flow at the Gila River, where it enters the model using natural flows calculated by Gookin (2009). The Ashurst-Hayden dam is upstream from the Phoenix AMA model boundary, so the reported and estimated flows were prorated by a factor (0.61) to account for seepage in the channel. The factor is derived by dividing the total miles of Gila River within the active model domain by the total miles of Gila River from the Laveen gage to the Ashurst-Hayden dam. For all flows, if the volume recorded (or estimated) at the Ashurst-Hayden dam is less than 18,900 AF, the flow at the model boundary is zero.

- *Santa Cruz River*: there is zero inflow in the Santa Cruz at the model boundary. This river is represented using SFR2 cells to allow for gains via high groundwater in the area of the Santa Cruz/Gila River confluence by Gila Crossing.

- *Agua Fria River:* this river was free-flowing until the Waddell Dam was completed in 1927. Spill frequencies and quantities between 1927 and 1989 were documented in the application by the Central Arizona Water Conservation District (CAWCD) to appropriate waters of the Agua Fria as part of the New Waddell Dam construction (ADWR, 1993). In 1992 the New Waddell Dam was completed, and most years after that had zero flow in the Agua Fria. ADWR assumed spills in 1993 and 2005.

- *Hassayampa River:* United States Geological Survey (USGS) gage 09516500, Hassayampa River near Morristown, AZ, has a period of record from 1938 to 2021 and was used to estimate flow in the Hassayampa River. Prior to 1938, ADWR estimated the flow in the Hassayampa River, where it enters the model by assuming a ratio based on the natural flows calculated by Gookin (2009).

The BIC diverts directly from the Gila River at the BIC headgate. Monthly diversion amounts are derived from gage data (USGS Gage 09514000) and Buckeye Water Conservation and Drainage District (BWCDD) records. The BIC is the only canal modeled using the SFR2 package because its headgate is the only one within the model domain.

Wastewater treatment plant effluent discharges are modeled as inflows to the stream. The two largest facilities in the Phoenix AMA, the 23rd Avenue and 91st Avenue WWTPs, are included in the model. Treated effluent from the 23rd Avenue facility discharges to the Salt River, the Roosevelt Irrigation District canal system, and reclaimed water basins to be recycled. The 91st Avenue facility delivers treated effluent to several customers and discharges the remainder into the Tres Rios wetland on the Gila River downstream of its confluence with the Salt River. Effluent discharges were calculated as follows:

- The City of Phoenix provided effluent reports for both WWTPs from 1996 through 2021. Deliveries to the Palo Verde Generating Station are, on average, 60,000 AF per year. Deliveries to Roosevelt Irrigation District average 31,000 AF per year and approximately 20,000 AF per year is delivered to the BWCDD via the Salt and Gila Rivers. The remainder is the assigned effluent discharge to the stream.

- Discharges from each plant before 1996 are estimated based on a ratio calculated using the known discharge volumes and population data. The 91st Ave WWTP ratio is 0.111 acre-ft per year per capita, and the 23rd Ave WWTP ratio is 0.038 acre-ft per year per capita.

- Discharges began in 1932 and 1958 from the 23rd Ave and 91st Ave WWTPs, respectively.

Stream depth is calculated in the model using Manning's equation for all 18 stream segments. Stream channel geometry is based on aerial photographs and other records and is constant throughout the simulation. Stream channel conductance, which contributes to how readily water moves across the streambed/aquifer boundary, varies by reach and does not change over time. Manning's roughness coefficient (n) for the stream channels is 0.04, a typical value for cobble-bed channels (Phillips and Tadayon, 2007). The BIC is assigned n = 0.02 (firm earth).

Most streams simulated with the SFR2 package are losing streams (i.e., net inflow to the aquifer). Some reaches are gaining; these are generally in the following locations: in the Salt River near Hayden Butte in Tempe, in the Gila River in the western third of the GRIR, and at the confluence of the Salt and Gila Rivers. Losses from the streams overshadow the gains to the stream, so this water budget component generally shows up as net recharge to the aquifer.

4.2.5 General Head (GHB)

The GHB package (Harbaugh et al., 2000) simulates groundwater outflow to the Gila Bend sub-basin at the Gillespie Dam. Head observations from ADWR Groundwater Site Inventory (GWSI) Well 331143112450801 were used to assign the boundary head values. This is an irrigation well that was drilled in 1940; the first measurement was in December 1945. The steady-state head value at this location is 699 ft (Freethey and Anderson, 1986), so head values before 1945 were linearly interpolated back to the pre-development value. The GHB cells are assigned to all three layers (**Figure 4-12**).

4.2.6 Evapotranspiration (ET)

The ET package (Harbaugh et al., 2000) simulates evapotranspiration. This occurs in locations surrounding the Salt, Gila, and Santa Cruz waterways. The delineation of ET cells (**Figure 4-12**) was carried over from the SRV and Lower Hassayampa models. The extinction depth is 30 ft where ET is active, and the maximum ET rates are either 0.005 ft/day (Salt River, Santa Cruz River, and Gila River upstream of confluence) or 0.008 ft/day (Gila River downstream of confluence) (Nadeau and Megdal, 2012).

4.2.7 Simulated Pumping (MNW2)

Groundwater pumping is the dominant outflow component from the regional water budget and is simulated with the MNW2 package (Konikow et al., 2009). **Figures 4-13** through **4-17** illustrate the locations of pumping wells in the model at the end of 1900, 1941, 1960, 1997, and 2017.

The SRV model simulated pumpage back to 1983 and was based on data from the ADWR Registry of Grandfathered Rights (RGR). Transient pumpage in the Phoenix AMA model prior to 1983 was developed using the following sources, which provided the basis for the simulated pumping in the model:

- 1900 to 1911 is based on Lee (1904, 1905)
- 1912 to 1932 is based on Anning and Duet (1994)

- 1933 to 1951 is based on Halpenny (1952)
- 1923 to 1964 is based on Anderson (1968)
- 1957 to 1978 is based on Long et al. (1982)
- 1979 to 1982 is based on Anning and Duet (1994)
- 1983 is based on Freifhoefer et al. (2009)
- 1984 to 2021 is from the ADWR RGR database

In instances where sources overlapped years, both sources were reviewed and, in most cases, the reported pumping values were consistent. The Long et al. (1982) report was prioritized over others where overlap occurred because of the extensive outreach to irrigation districts, municipalities, and private water companies to obtain comprehensive pumpage data.

Well-construction data were derived in two ways. For wells that were only pumped before 1984 or for post-1984 non-exempt wells without construction information in the RGR database, ADWR reviewed construction logs to determine the location and screened intervals. For wells in the RGR database, construction data was exported from RGR and formatted for the MNW2 package. Slight modifications to screened intervals were made when the screen top or bottom was very close to a layer top or bottom elevation. This was done to improve model stability.

There is no requirement for groundwater pumpage on Indian lands to be reported to the state. Annual pumping records for wells owned by SCIP are available; pumping for other large-capacity irrigation wells on the Salt River Pima Maricopa Indian Community (SRPMIC) and GRIR was estimated based on a water budget approach. Estimates derived from past models were used where available.

5.0 Calibration Methodology

ADWR's calibration effort aimed to better understand the regional groundwater flow system in the Phoenix AMA. This was generally accomplished by exploring the conceptual model through multiple numerical alternative conceptual models, identifying central tendencies of the water budget components, and then using inverse calibration to adjust parameters to minimize the residual between measured and modeled targets. The Phoenix AMA model was calibrated by adjusting model input parameters within a reasonable range, constraining water budgets, and utilizing the calibration process as a diagnostic tool to identify any local- or regional-scale bias in the model. This methodology honors the hydrogeologic conceptual model, estimated aquifer parameters, and water budgets and avoids overfitting. As a result, the model is suitable for predictive analysis. ADWR worked with S.S. Papadopulos and Associates (SSP&A) to complete the calibration process. Calibration was facilitated by the inverse modeling software for parameter estimation PEST (Watermark Numerical Computing, 2020). This section documents the calibration procedure, adjustable parameters, and observation data.

5.1 Calibration Procedure

The model calibration procedure involved an iterative process. First, water budget estimates available from independent sources (see Section 3.2) were utilized to ascertain that the model generates reasonable water budgets. These water budget estimates were used as "soft" or "qualitative" targets not included within the PEST framework. Second, calibration was performed using PEST to estimate aquifer parameters and boundary conditions to match model-generated values to measured ("hard" or "quantitative") targets. These targets included aquifer test results, observed groundwater levels, streamflow measurements, and estimated surface water/groundwater interactions. Aquifer test results provide hydraulic conductivity values that become model inputs and can be calibrated without a model simulation, while other targets, such as groundwater heads and flow measurements, are based on model outputs. The iterative procedure between PEST-generated results (quantitative targets) and water budget evaluation (qualitative targets) follows the Pareto principle of balancing the model's goodness-of-fit and estimating plausible parameter values and reasonable water budgets generated by the calibrated model. PEST simulations included the adjustable parameters and observation targets listed below.

Adjustable parameters were:

- Aquifer parameters, including:

- Representative hydraulic conductivity, specific yield, and specific storage for coarse-grained material (gravel and sand) and fine-grained material (clay)
    - Percent coarse-grained material (such as sand fraction) as related to control points in the model (coupling this with representative values from above produces hydraulic conductivity, specific yield, and specific storage values for different aquifer materials)
    - Anisotropy (the ratio between horizontal and vertical hydraulic conductivity)
    - Hydraulic conductivity decrease with depth
- Mountain-front inflow (recharge)
- Recharge components described in Section 4.2.4
- Hydraulic conductivity of streambed and conductance of general head boundary cells

Observation group types were:

- Hydraulic conductivity from aquifer test data
- Groundwater level measurements (head targets)
- Vertical head differences
- Streamflow targets
- Groundwater/surface water interaction flux targets (also referred to as baseflow)
- Regularization targets

5.2 Adjustable Parameters

This section describes the model parameters that were adjusted during calibration.

5.2.1 Aquifer Parameters

The parameterization of aquifer properties, particularly horizontal hydraulic conductivity (K_h), was a primary focus of model calibration. ADWR endeavored to use a parameterization that was as simple as possible while allowing for enough complexity to represent the thousands of observations throughout the Phoenix AMA accurately. The approach for the Phoenix AMA model was to use a program developed by SSP&A called Texture2Par (Scantlebury et al., 2023, *under review*). This program uses texture data from known and unknown (control) well logs and interpolates that data to each model cell. The interpolation is performed separately for each model layer.

Grain-size (texture) data from lithologic logs contained in ADWR databases Wells 35 and Wells 55 were tabulated as percent coarse, expressed as a fraction. The vertical interval on the lithologic log was compared to the vertical discretization in the model to assign a layer for a given entry in the log. The percent coarse fractions per entry recorded within a model layer were averaged to obtain a single value per layer per well. One hundred and seventy-nine wells had usable lithologic logs in the Phoenix AMA. **Figures 5-1, 5-2**, and **5-3** show the locations of the 179 wells and the percent coarse at each well in Layers 1, 2, and 3, respectively. Not all wells penetrated all three layers.

Control points were added in locations where the model lacked information from actual logs. The location of the control points is shown in **Figure 5-4**. Because control point well logs represent unknown texture data, these were first incorporated into PEST to estimate percent coarse values for the three layers to match aquifer test data. Once aquifer test data were calibrated, the control point well logs were locked (not calibrated further).

Each cell in the model was assigned a value of percent coarse using the lithologic logs and the control points. This was achieved through kriging, a spatial interpolation method built within Texture2Par. The resultant distribution of coarse/fine grained materials created the basis for the K_h calculation, which applies the power law equation:

$$X_B = \left[P_C X_C^p + (1 - P_C) X_F^p\right]^{1/p} \qquad (Eqn.\ 5\text{-}1)$$

Where:

X_B = the parameter being estimated at a given point

P_C = percent coarse at that point, based on kriging

X_C^p= the value of the parameter for 100% coarse-grained material raised to a power

X_F^p= the value of the parameter for 100% fine-grained material raised to a power

p = averaging exponent

Pilot points were assigned at locations in the model to provide sediment-level parameter values that appear in the power law equation (**Figure 5-5**). Different sediment-level parameters for different pilot points represent spatial variability. Pilot points were grouped with specific model cells to define regional subareas that exhibit similar ranges of sediment parameter values. This step defined two unique hydrostratigraphic units (HSUs): one HSU for the floodplain surrounding the streams in Layer 1 and the other HSU for all other areas in the model. This was done for consistency with the conceptual model to recognize the distinct sediment unit surrounding the streams in Layer 1. Texture2Par only interpolated texture data from wells within the HSU to the cell within the unit. Pilot points were grouped by the HSU zones specifically to differentiate the high conductivity formation on the surface. The HSU/pilot point zones were created by GIS processing and intersecting surficial geology maps with the model grid.

The second calculation within Texture2Par involves depth dependency of hydraulic conductivity. Conceptually, hydraulic conductivity decreases with depth due to consolidation and increased geostatic loading (Faunt, 2009). To account for this, Texture2Par includes an exponential depth-decay function:

$$K_{hc} = K_{min} + (K_{max} - K_{min})\exp(-kd) \quad (\textit{Eqn. 5-2})$$

Where:
K_{hc} = the coarse-grained hydraulic conductivity being estimated at a given point

K_{min} = minimum value of K_h at a given point

K_{max} = maximum value of K_h at a given point

kd = decay variable

Texture2Par, although a stand-alone utility, can be seamlessly integrated within the PEST framework. Texture2Par interacts with PEST via the parameter groups KCMin, DeltaKC, KFMin, DeltaKF, SsC, SsF, SyC, SyF, AnisoC, AnisoF, PC, decay, and power. KCMin and KFMin are the pilot point values of K_{min} for coarse-grained and fine-grained materials, respectively. DeltaKC and DeltaKF represent K_{max} (by adding KCMin and KFMin, respectively) for coarse-grained and fine-grained materials. SsC and SsF are the specific storage values for coarse-grained and fine-grained materials, respectively. SyC and SyF are the specific yield values for coarse-grained and fine-grained materials, respectively. AnisoC and AnisoF are the anisotropy ratios for coarse-grained and fine-grained materials, respectively. PC is the percent coarse-grained material averaged for well logs and assigned to the control points.

The decay parameter is the decay variable in Equation 5-2. The power parameter is the averaging exponent in Equation 5-1.

The advantages of using Texture2Par rather than more traditional zone or pilot point methodologies are that the number of calibration parameters was kept relatively low, and parameter values are based on sediment properties in lithologic logs. Cell-by-cell values scaled up and down according to the minimum and maximum values of the pilot points, which provided a large-scale control on the parameterization of the aquifer. Sediment data created heterogeneity in the model. The approach used with Texture2Par lends itself to model improvement as more lithologic data become available in the future, particularly in the areas where control logs are currently used.

In addition to field observations such as groundwater heads, control on aquifer parameters was achieved using aquifer test data as observation targets, discussed in more detail in Section 5.3.

5.2.2 Recharge

The recharge package (RCH) consists of different components of recharge, the development of which was described in Section 4.2.4. The initial values were adjusted during calibration by using a multiplier with an upper and lower limit. Each recharge component has a unique multiplier. The multiplier applies to all transient stress periods. This means that if the multiplier for a recharge component is 0.5, then the initial recharge for that component in stress periods 2 through 105 will be multiplied by 0.5 in a pre-processing step before becoming part of the MODFLOW calculation. All recharge components are part of the RCH parameter group. **Table 5-1** relates the RCH group parameter name to the identification code used in the PEST control file.

The agricultural and the non-SCIP canal recharge components of the recharge package were divided into smaller categories based on spatial attributes. Agricultural recharge was divided into 11 sub-groups based on irrigation district or location within the GRIR or SRPMIC. Each of these sub-groups had a unique multiplier. Non-SCIP canal recharge was similarly divided into smaller categories based on individual canals.

Recharge in the steady state stress period; supplemental agricultural recharge in transient stress periods 2 through 4; and recharge associated with ephemerals, floods, Indian Bend Wash, artificial lakes, and urban turf all received a single multiplier per group. Steady-state recharge includes agriculture, mountain-front, ephemerals, and floods. Supplemental agricultural recharge is located in the SRP irrigation district and includes land that would have been irrigated between 1900 and 1920. This was included separately from the larger agricultural recharge component to allow the two time periods to have unique multipliers.

The CAP and USF recharge components were not adjusted during calibration. The multiplier for these components was fixed at 1.0. Mountain-front recharge was initially included in the recharge package but later moved to the WEL package; although present in the PEST control file, this recharge component is null.

5.2.3 Mountain-Front Inflow

Mountain-front inflow, simulated using the WEL package, consists of inflow to the Phoenix AMA from the surrounding mountains. This was divided into 17 zones and applied in all three model layers. **Table 5-2** relates the zone description to the PEST ID. Mountain-front inflow is a relatively small and uncertain component of the water budget. For this reason, the range between the lower and upper limits on the multiplier was large. This parameter is in the MTN parameter group.

5.2.4 Hydraulic Conductivity of Streambed and Conductance of General Head Boundary

The SFR package divided the streams into 18 segments, each with an adjustable streambed hydraulic conductivity. For the GHB package, conductance is a function of the hydraulic conductivity and the distance between the cell and the reference head. The GHB conductance is a single value.

5.3 Observation Groups

This section describes the observation groups used during calibration.

5.3.1 Aquifer Test Targets

Aquifer tests provide valuable information regarding the hydrogeologic conceptual model of the Phoenix AMA. The hydraulic conductivity estimates derived from the aquifer tests provide a set of observations that can be utilized externally to model simulations. These "observations" provide data to calibrate the sediment-level parameters, particularly the horizontal hydraulic conductivity, to obtain the bulk hydraulic conductivity of the aquifer. Aquifer test targets were independently calibrated from other PEST targets, such as groundwater heads and streamflow measurements. This approach enables the use of multiple lines of evidence for comprehensive model calibration.

There are 244 non-zero-weighted K_h targets (targets included in model calibration) in the model. These are derived from aquifer tests within the Phoenix AMA and are in the "aqk" target group. The values are log-transformed to avoid overemphasizing the higher values.

The aquifer test data came from several sources, including Brown and Caldwell (2006), data provided by SRP, and data tabulated by ADWR from well records. **Figure 5-6** shows the location of the aquifer tests, and **Table 5-3** contains the aquifer test data.

5.3.2 Groundwater Level Measurements (Head Targets)

The Phoenix AMA groundwater model has 40,577 non-zero-weighted hydraulic head targets from 4,562 well locations. One hundred and forty-one of these observations relate to the steady-state period, and the remainder are in the transient period. Transient head observations were given zero weight if the well data were reviewed and determined to be of sufficiently poor quality to eliminate from the calibration dataset. For example, the recorded well head elevation had an uncertainty greater than 100 feet, or nearby pumping could not be eliminated. One hundred and fifty-one head measurements from 48 wells were zero-weighted, representing less than 0.4% of the target group.

Steady-state head targets were derived from either Corkhill et al. (1993) or Freethey and Anderson (1986). **Appendix A** contains a memo describing the process of developing these targets. Transient head targets were obtained from the ADWR GWSI database. The targets were assigned a descriptor of either "I" for Index Well, "A" for Automated Site, or "G" for Other. Transient water levels are available from 1907 to 2021. The measurements were filtered to include unremarked and unique measurements within the model domain. Head targets are included in the Head Observation (HOB) package (Hill et al., 2000). **Appendix B** contains an electronic table relating the HOB target name to the ADWR well registry number, measurement dates, and groundwater head observations.

5.3.3 Vertical Head Differences

Groundwater level measurements, in addition to the head values, provide information regarding any vertical head differences potentially caused by impermeable material. These derived observations aid in the calibration process by parameterizing anisotropy. There are 505 non-zero-weighted vertical head difference targets from 56 well pairs. **Table 5-4** presents the well pairs and observations used in the calibration. The well pairs were chosen by searching the GWSI database for the following criteria:

- Overlapping period of record for water level measurements
- Screen intervals in different model layers
- Location within one mile of the other well in the pair

The vertical head difference was calculated by subtracting the water level measurements from the two wells at overlapping times. The zero-weighted measurements are measurements that were reviewed and determined to be impacted by duplicate measurements or anomalous data.

5.3.4 Streamflow Targets

Streamflow targets do not measure groundwater conditions directly but play an important role in evaluating the overall water budget in a groundwater model. These measurements help constrain the flow through the system. Streamflow targets are implemented in the model using the Stream Gaging Station (GAGE) package (Niswonger and Prudic, 2005). There are three gage groups that consist of one or more individual gages: annualgr1 is a combined-gage target consisting of three gages centered around the Gila/Salt River confluence; annualgr4 is an individual gage target on the Gila River at Gillespie Dam; and annualgr5 is an individual gage target at the Buckeye Irrigation Canal headgate. Data for the streamflow targets were obtained from the following sources:

1. Historical measurements of the Gila and Salt Rivers (Buckeye Irrigation District, 1941)

2. USGS gage flow in the Gila River downstream of the Gillespie Dam (USGS 09519500 and USGS 09519501) plus the diversions into the Enterprise Canal (USGS 09519000) and the Gila Bend Canal (USGS 09518500)
3. Recorded diversions at the BIC headgate (Buckeye Irrigation District, 1941; Halpenny and Greene, 1975; USGS 09514000; USGS 09514100)

Annualgr4 is intentionally missing a target for 2005 because flow measurements at the two canals are missing for the water year 2005, which encompasses most of the calendar year 2005. The target for 2004 may be slightly underestimated because the calendar year 2004 is subsequently missing data for three months. Streamflow target locations are shown in **Figure 5-7,** and the observation values are presented in **Table 5-5**.

5.3.5 Groundwater/Surface Water Interaction Flux Targets

Groundwater/surface water flux targets, also called baseflow targets, are implemented in the model as part of the PEST calibration process. There are four steady-state and 15 transient baseflow targets; these are found in the PEST target groups "underflow" and "underflowtr", respectively. The steady-state targets were developed based on historically observed gains to the Salt and Gila Rivers recorded in Lee (1904; 1905), Buckeye Irrigation District (1941), and Harding (1942). Transient underflow targets are based on observations of seepage gain along the Gila River during months free from flood flows from 1937 through 1941, recorded in Buckeye Irrigation District (1941). **Figure 5-8** shows the locations of the underflow target cells in the model. **Table 5-6** contains the baseflow target descriptions.

5.3.6 Regularization Targets

Regularization targets were used to penalize PEST for allowing the values of parameters within neighboring sets of pilot point groups to deviate from each other. There are two regularization targets: regul_rch, which applies to the seepage along the non-SCIP canals, and ppvar, which applies to the texture pilot points in Texture2Par. Both of these target groups serve to keep the calibrated values of the aforementioned parameters as close to the initial values as possible.

6.0 Calibration Results

This section describes the results of the Phoenix AMA model calibration. **Table 6-1** provides a summary of the PEST residual results. The table provides relative contributions of different observation groups on the overall objective function, however, these contributions changed during the calibration process and the numbers provided in **Table 6-1** only represent the last calibration run. Calibrated recharge rates for components discussed below are contained in the geodatabase accompanying the report and model files.

6.1 Adjustable Parameters

The calibrated values of the adjustable parameters are presented in this section.

6.1.1 Aquifer Parameters

The calibrated aquifer parameters are the sediment-level properties translated to bulk aquifer parameters used by the model. The aquifer parameters include horizontal hydraulic conductivity (K_h), vertical hydraulic conductivity (K_v), specific yield (S_y), and specific storage (S_s). Calibrated K_h is presented in **Figures 6-1** through **6-3**; vertical anisotropy (K_h/ K_v) is shown in **Figures 6-4** through **6-6**; S_y is shown in **Figures 6-7** through **6-9**, and S_s is shown in **Figures 6-10** and **6-11**.

The sediment-level parameter values for the pilot points in the model are presented in **Table 6-2**. As described in Section 5.2.3, the aquifer parameters were calibrated with a program called Texture2Par that uses a power law equation to calculate spatially distributed bulk aquifer properties from sediment-level parameter values at pilot points.

6.1.2 Recharge

Recharge in the model was calibrated using a multiplier that adjusted the initial values of 39 parameters within a predetermined range. **Table 6-3** presents the calibrated multipliers on the recharge components. CAP and USF recharge was not adjusted during calibration, so the multiplier is fixed at 1. Mountain-front recharge (mftrch) was moved to the WEL package during the calibration process, and canal seepage for non-SCIP canals (nonsciprch) was subdivided by canal system, so those two parameters are inactive. The Gila Drain North and

South canals were removed from the calibration and are inactive. The remaining recharge components in **Table 6-3** were adjusted during calibration.

The multipliers for 17 recharge components were reduced to the lower allowable bound. These components are: recharge in the steady-state period; supplemental agricultural recharge between 1900 and 1920; recharge from ephemeral streams; seepage from SCIP canals; seepage from the RID (nonscip_02), Arizona Canal East (nonscip_05), South (nonscip_06), Crosscut (nonscip_07), Western (nonscip_08), Highline (nonscip_09), RWCD (nonscip_10), Consolidated (nonscip_11), Eastern (nonscip_13), Tempe (nonscip_14), San Fran North Branch (nonscip_17), and Kyrene (nonscip_20) canals; and the Tonopah irrigation district (model zone f). This indicates that the initial estimate of recharge for these components may be too high. It could also be a reflection of excess water along those model cells, and the PEST adjustment found these components to be most effective at reducing the overestimation.

The multipliers for five recharge components were increased to the highest allowable bound. These components are: flood, artificial lakes, urban turf, the Buckeye irrigation district (model zone g), and the GRIR irrigation area (model zone j). This indicates that the initial estimate of recharge for these components may have been underestimated. Notably, the model results suggest that flood events contribute more recharge to the aquifer than previously thought.

The multipliers for the remaining 17 recharge components were within the lower and upper bounds. These components are: IBW recharge; seepage from the Beardsley (nonscip_01), Arizona Canal West (nonscip_03), Grand (nonscip_04), San Fran South Branch (nonscip_12), San Fran Main Branch (nonscip_15), St Johns (nonscip_16), Hayden Branch (nonscip_18), and Arlington (nonscip_19) canals; and recharge in Queen Creek and other IDs (model zone b), RWCD (model zone c), Salt River Valley Water Users Association and other IDs (model zone d), Arlington ID (model zone e), RID (model zone h), Maricopa Water District and other IDs (model zone i), SRPMIC (model zone k), and all other irrigated model cells (model zone a).

A summary water budget (in AFY) for the calibrated recharge components is presented in **Table 6-4**. Rounding to the nearest thousand, the total recharge in the model ranges between 452,000 AFY and 2,196,000 AFY. Years with floods and between 1940 and 1970, when agriculture in the Phoenix AMA was most widespread, tend to be the years with the highest recharge volume to the aquifer. Agricultural recharge is a dominant recharge component in the historical period, peaking at 867,000 AF in 1954 and then declining through 2021 due to decreased agricultural footprint and improved irrigation efficiency. Starting in the 1980s, artificial lakes, urban turf, and USFs become a progressively larger part of the total recharge, contributing as much as 470,000 AFY in later years. Flood recharge adds 1,166,000 AF to the aquifer in years when floods occur. Canal recharge (CAP, non-SCIP, and SCIP) contributes as much as 186,000 AFY in the early years before the majority of the canals were lined and averages 75,000 AFY in later years after widespread lining. Ephemeral waterways are a relatively small component of the water budget, contributing between 900 AFY and 24,000 AFY, depending on if the year is dry, average, or wet. Since 1989 when USFs began operating in the Phoenix AMA, 5,022,000 AF of water has been recharged to the aquifer via permitted facilities.

6.1.3 Mountain-Front Inflow

Inflow to the model from the mountain-front boundaries was calibrated as a volumetric rate in the WEL package. The mountain-front areas were divided into 17 zones with three layers per zone. **Table 6-5** presents the calibrated rates by zone and by layer. **Table 6-6** summarizes the inflow volume by zone and by layer. In total, mountain-front inflow contributes 64,490 AFY to the Phoenix AMA model.

The mountain-front regions with the highest inflows are the Vulture Mountains in the Lower Hassayampa sub-basin, which accounts for 22,985 AFY, and the Queen Creek inflow zone in the Superstition Mountains, which accounts for 21,678 AFY. In the case of the Vulture Mountains, most of the inflow occurs in Layers 2 and 3 because Layer 1 tends to be dewatered in the Hassayampa Plains area of the model due to the greater depth of groundwater. Almost all of the inflow in the Queen Creek zone occurs in Layer 3 for the same reason.

The mountain-front regions with the smallest inflows are the Hieroglyphic and Belmont Mountains in the Lower Hassayampa sub-basin, the New River / Anthem zone in the WSRV, and the Usery Mountains in the ESRV. In these cases, the model calibration may be limiting recharge in the mountain-front zones because there is already sufficient recharge in another component. For example, the Usery Mountain zone is in the same location as the Salt River, so the Salt River inflows may suffice for natural recharge in that area.

6.1.4 Hydraulic Conductivity of Streambed and Conductance of General Head Boundary

The 18 SFR segments had initial hydraulic conductivity values based on whether the segment was a higher-velocity upstream reach (higher initial conductivity) or a lower-velocity downstream reach (lower initial conductivity). The ratio of those initial conductivity values was maintained during calibration, but the absolute value was adjusted. The GHB conductance was adjusted as a single value.

6.2 Observation Groups

The simulated values from the calibrated model are compared to the target observations in this section.

6.2.1 Aquifer Test Targets

The calibrated horizontal hydraulic conductivity compared to the aquifer test conductivity is shown in **Figure 6-12**. The X-Y scatter plot of conductivities indicates that the calibrated parameters are a good match to the observed values that range more than two orders of magnitude. The plot of observed versus simulated percentile indicates that the simulated values fall in the same range as the observed values and that the hydraulic conductivities line up in the same percentiles as the observed values. The good match between simulated and observed hydraulic conductivities provides a constraint to other adjustable parameters in the model, specifically recharge, leading to meaningful water budgets. Unreasonably high or low hydraulic conductivities would allow for over- or under-estimates of recharge since the simulated aquifer would either be able to let too much or not enough water flow through the groundwater system. The confidence level in the inherently uncertain recharge rates is higher because the simulated hydraulic conductivities closely match the observed data. Unreasonable storage values can also compensate for water budget errors, but this usually manifests as elevated storage parameters accommodating excess water in the model. To guard against this, storage parameters were monitored during calibration and maintained within plausible ranges.

6.2.2 Groundwater Level Measurements (Head Targets)

The head calibration for the Phoenix AMA groundwater flow model is shown in **Figure 6-13**, which presents three graphs illustrating different qualities of the calibration. The graph of simulated versus observed heads demonstrates that the model is well-calibrated to the measured head with a coefficient of determination (R^2) value of 0.90, an absolute residual mean of 37.2 ft, and a normalized root mean square error of 3.6%. The distribution plot of head residuals shows that the average residual is close to zero (1.2 ft) and that 75% of all the simulated head values fall within plus or minus 50 ft of observed values. Finally, the plot of residuals versus time indicates that the residuals are randomly distributed around the zero line with no major temporal trends. Head residual is calculated as the observed head minus the simulated head. **Appendix C** provides a full table of measured and modeled heads. **Appendix D** contains scatterplots of heads by time period and by layer.

The difference between measured and modeled heads, or head residuals, at observation wells is often used to assess how a model reproduces the natural water level configuration in a groundwater flow system. For this updated model, the average head residuals (pre-1900 through 2021) at observation wells were used to evaluate how the model simulates the average conditions across the study area. The distributions of head residuals for Layers 1, 2, and 3 are presented in **Figures 6-14, 6-15,** and **6-16**, respectively. Generally, the positive and negative residuals for Layers 1, 2, and 3 are evenly distributed. The highest residuals are observed in Layers 1 and 2 east of the Palo Verde Hills. This portion of the model overlaps with outcropping volcanic bedrock, which is known to be locally fractured/faulted (Corell and Corkhill, 1994) and could influence local water levels. The highest residuals in Layer 3 are underestimated water levels typically found along the edge of the model domain. This suggests that boundary effects may influence the model calibration or that the geology at that location is more complex than the regional model can represent.

Simulated water table contours for stress periods 2 (1900), 25 (1941), and 44 (1960) are presented in **Figures 6-17** through **6-19**. Stress periods 2 and 44 represent dry years while stress period 25 represents a wet year. Simulated water table contours for stress periods 81 (1997) and 101 (2017) are presented in **Figures 6-20** through **6-25**. Stress periods 81 and 101 are generally representative of average years. The years 1997 and 2017 are also "sweep" years, which are years that ADWR measures the water level in as many wells as possible in a short time frame (typically one to two months), so these years provide more comprehensive water level data sets. For this reason, simulated water levels in stress periods 81 and 101 are plotted with observed water level elevations for each layer as a comparison.

The simulated water level contours indicate the following:

- Groundwater flow direction in the Lower Hassayampa sub-basin is generally north to south for the entirety of the simulation period, with localized exceptions due to pumping and artificial recharge in later years. In particular, recharge at the Tonopah Desert USF is apparent.
- Groundwater flow direction in the WSRV is generally northeast to southwest in earlier years, while in later years, flow occurs towards local cones of depression. In the southern part of the WSRV, groundwater direction shifts from flowing towards the Lower Hassayampa sub-basin along the path of the Gila River to flowing northwest, towards the cone of depression caused by groundwater pumping east of the White Tank Mountains.
- Groundwater flow direction in the ESRV is generally east to west (around the East Valley and GRIR) or north to south (around Cave Creek and Scottsdale) in all stress periods, but localized exceptions are present in later stress periods due to pumping and recharge. In particular, recharge at the Superstition Mountain Recharge Project and the City of Phoenix injection wells is apparent in the model in the last years of the simulation.
- The Gila River gains from groundwater in the area of the model between South Mountain and the Sierra Estrella Mountains down through Buckeye, as represented by inverse V-shaped contours along the river.

Hydrographs from 1,708 of the 4,562 wells are available electronically in **Appendix E1**. Based on a review of the hydrographs in **Appendix E1**, specific trends are apparent and discussed further (see **Appendix E2**, Hydrograph Subset).

Model Simulates Steep Water Level Changes

Steep changes in groundwater levels over a short period indicate nearby stress on the aquifer, such as a high-volume pumping well or a newly-constructed USF. Storage parameters are important to simulate changes in water levels accurately. Three examples where the model is correctly simulating the steep change observed in real life include:

- *G_1269 (no 55 number; GWSI Site ID 332148111534301)*: Located near South Mountain in Layer 1. The observed water level in this well started at 1169 ft above mean sea level (AMSL) in the early 1940s and declined by more than 40 ft by 1949. The simulated water level starts at 1143 ft AMSL in the early 1940s and reflects over 30 ft of decline by 1949, indicating that the specific yield in the model at this location is appropriate and the model captures local pumping stresses.

- *G_1071 (55-617155; GWSI Site ID 332031111470301)*: Located in the south-central portion of the ESRV in Layer 2. The observed water level in this well increased almost 100 ft from 979 ft AMSL to 1073 ft AMSL between 1979 and the late 2000s. The simulated water level matches this increase over the same period, again indicating that the storage parameters in the model at this location are appropriate and the model captures local stresses.

- *G_0140 (55-615301; GWSI Site ID 330757111295501)*: Located on the east side of San Tan Mountain in Layer 3. The observed water level in this well started at 1371 ft AMSL in 1940 and declined by more than 40 ft to 1317 ft AMSL in 1952. The simulated water level starts at 1360 ft AMSL and declines to 1308 ft AMSL, indicating that the specific storage and boundary conditions at this location are appropriate.

Artificial recharge in the Phoenix AMA has produced steep localized increases in water levels. Two examples of hydrographs near artificial recharge facilities are as follows:

- *I_4396 (55-635284; GWSI Site ID 334358112161501)*: Located in the northern part of the WSRV next to the Agua Fria USF in Layer 3. The period of record started in the early 1980s and observed water levels fluctuated between 1175 ft AMSL and 1195 ft AMSL throughout the early 2000s. At this point, the USF becomes active, and the observed water level increased by more than 50 ft to 1229 ft AMSL. The simulated water level misses the fluctuation in the early years but correctly simulates the increase due to artificial recharge.

- *I_3458 (55-501700; GWSI Site ID 333252113013801)*: Located at the western edge of the Lower Hassayampa sub-basin next to the Tonopah Desert USF in Layer 3. Water levels at this well declined roughly 30 ft between the early 1980s and mid-2000s. When recharge started at the USF, water levels increased by more than 100 ft in less than 10 years. Simulated water levels match the decline and subsequent increase.

Model Misses Water Level Change

In some cases, the model misses local stresses and, as a result, simulates a relatively flat water table when there are observed changes. Two examples of this are as follows:

- *A_3449 (55-626816; GWSI Site ID 333248111535801)*: Located near McCormick Ranch and the Indian Bend Wash in Layer 3. The observed water level rose 245 ft from about 870 ft AMSL in the mid-1980s to over 1100 ft AMSL by the late 2010s. The modeled water level rises 44 ft in that same time period. This could be attributed to localized recharge that has not been adequately captured in the regional model or a misrepresentation of anisotropy at a local scale.

- *I_3994 (55-626829; GWSI Site ID 333755111542601)*: Located in Scottsdale near the Water Campus USF in Layer 3. The observed water level has increased over 60 ft in the 20 years since the USF started operating. The model misses the magnitude and shows a modest increase of 5 ft over 20 years. This could indicate the need for local refinement of aquifer properties or boundary conditions.

Model Matches Trends but not Elevation

There are wells in the model where simulated heads follow the observed trend, but the water level is higher or lower than the observed value. Two examples of this are as follows:

- *G_3392 (55-524268; GWSI Site ID 333217112445201)*: Located near the pinch point in the middle of the Lower Hassayampa sub-basin in Layer 3. The observed water level has been relatively flat, around 1050 ft AMSL for about 30 years. The simulated water level matches the trend but overestimates the water level by about 40 ft.
- *I_0028 (no 55 number; GWSI Site ID 330515111245601)*: Located at the boundary between the Phoenix and Pinal AMAs in the Eloy sub-basin in Layer 3. The water level was relatively flat between 1978 and 1986, increased by over 40 ft between 1986 and the late 1990s, and decreased by 30 ft between the late 1990s and 2021. The simulated value misses the early trend and decreases through the mid-1990s. It then increases in the same manner as the observed water level until the late 1990s, but instead of decreasing through 2021, the simulated water level stabilizes/continues to increase.

When a modeled well matches the trend but misses the mark on water level, it suggests that conditions in the model prior to the measurement are inaccurately simulated, producing an inaccurate starting point for the target comparison.

Model Matches Complex Hydrographs

Complex hydrographs have many measurements and notable water level fluctuation over time. For a transient model to match both the water level elevation and the fluctuation means that aquifer parameters and boundary conditions (recharge rates and pumping) need to be well-estimated. Several examples of this are as follows:

- *I_0532 (55-805914; GWSI Site ID 331518112454801)*: Located in Layer 3 in the Lower Hassayampa basin near the Gila River. The observed period of record starts in the mid-1950s and goes through 2021. Water levels fluctuated over 40 ft, declining through 1970, then increasing through the mid-1980s, declining slightly through the 2000s, and declining more rapidly after 2010. The model generally simulates those trends within 10 to 20 ft of the recorded measurements.

- *I_3418 (55-629184; GWSI Site ID 333237112530501)*: Located near the Tonopah Desert USF on the south side of the Belmont Mountains in Layer 3. Observations began in the early 1960s showing that the water level declined by over 120 ft through the late 1980s. Water levels stabilized in the 1990s, presumably in response to CAP imports, and then increased sharply in 2006 when artificial recharge began. The model misses the magnitude of the early decline but generally simulates these trends, particularly the recovery due to artificial recharge.

- *A_1029 (55-617083; GWSI Site ID 332008111495801)*: Located in Gilbert in the ESRV in Layer 2. Observations begin in the 1950s and continue through 2021. Over that period of time, water levels have declined over 100 ft and subsequently recovered over 100 ft, returning to the initial water level. The model matches both decline and recovery within a few feet of the observations.

- *A_1160 (55-614938; GWSI Site ID 332102112291201)*: Located in Liberty south of the Gila River in Layer 2. Observations began in the mid-1950s and show relatively stable water level elevations throughout 2021, likely due to the well's proximity to the Gila River. The model matches the stable trend until the mid-2000s, at which point simulated water levels decline erroneously.

- *A_2505 (55-607670; GWSI Site ID 332711111482601)*: Located in Mesa south of the Salt River in Layer 1. Observations began in the 1970s and show rising water levels through the early 2000s, at which point water levels stabilized. The model generally matches this trend.

Model Grid is Too Large to Allow for Local Variability

There are places in the model where hydrographs located in the same or adjacent model cell have water level elevations differing on the order of 100 ft. Two examples of this are as follows:

- Model cell row 96, column 160 in the ESRV contains three GWSI wells measured in the 2002-2003 winter sweep. Reported water level elevations ranged from 1086 ft

AMSL to 1221 ft AMSL, a difference of 135 ft within a single model cell. At that time, the modeled water level in that cell is 1112 ft AMSL.

- Model cell row 78, column 27 in the Lower Hassayampa sub-basin contains a GWSI well (G_1223, no 55 number; GWSI Site ID 332132112564001) with a measured water level elevation of 695 ft AMSL in October 1997. In the adjacent model cell (row 78, column 26), GWSI well G_1238 (no 55 number; GWSI Site ID 332137112565201) had a measured water level elevation of 925.9 ft AMSL in December 1997. The model fails to simulate this difference of 230.9 ft (the modeled water level in both cells is 760 ft AMSL).

The above two examples highlight the difficulty of addressing some of the highest head residuals in the model and are common limitations of regional scale models.

6.2.3 Vertical Head Differences

The simulated versus observed vertical head differences are plotted in **Figure 6-26**. Observed vertical head differences range from -21.28 ft to 88.13 ft (the sign is arbitrary and depends on which measurement is subtracted from the other); simulated vertical head differences range from -34.41 ft to 93.06 ft. This indicates that the model simulates a larger range of vertical differences than observed, which is promising given the model cell size. The model tends to underestimate the largest vertical head differences while matching the smallest reasonably well. The model included these targets to provide more information about hydraulic conductivity and vertical anisotropy values.

6.2.4 Streamflow Targets

The cumulative simulated streamflows versus observed streamflows at the five gage locations are shown in **Figure 6-27**.

The model generally overestimates streamflows at Gages 1 through 3 in the 1930 to 1940 period. This could be due to uncertainty in historical diversion records, an overestimate of historical stream inflows, or an overestimate of recharge near the stream cells resulting in excess simulated baseflow. Further downstream and later in time, the simulated flows at Gage 4 are slightly underestimated.

Gage 5 is the diversion point for the BIC. The simulated diversions match the measured diversions until the mid-1980s, at which point the simulated diversions are underestimated. This could be due to a change in diversion practices; for example, as the baseflow along the Gila River declined, and direct surface water diversion became less practical, many irrigation districts began to supplement canal supply with pumps.

6.2.5 Groundwater/Surface Water Interaction Flux Targets

The cumulative simulated baseflows versus observed baseflows at the target locations are shown in **Figure 6-28**.

There are four steady-state baseflow targets, two of which are also used in the transient period, and three transient baseflow targets. From upstream to downstream, the targets are: steady-state target streaml6, which represents a portion of the Salt River just upstream of the City of Tempe (no equivalent transient target); steady-state target streaml8, which represents a portion of the Gila River in the GRIR upstream of the confluence with the Salt River (no equivalent transient target); and steady-state targets streaml3 and streaml2, which cover the Gila River from the confluence with the Salt River to the Gillespie Dam (equivalent to transient targets streaml2, streaml3, and streaml4).

The estimated steady-state baseflow on the Salt River upstream of the City of Tempe is 35 cubic feet per second (cfs). The model simulates 6 cfs at this location, which is on the low side but considered a reasonable match, given the model cell size and the uncertainty with the original early 1900s measurement (Lee, 1904). Along the Gila River upstream of the confluence, the estimated steady-state baseflow is 50 cfs. The model simulates 89 cfs at this location, which is an overestimate but considered reasonable. This measurement was also collected in the early 1900s (Lee, 1905). Most importantly, both locations show gains to the streams, meaning the heads and gradients are generally correct.

The stretch of Gila River between the confluence and the Gillespie Dam has baseflow observations from the late 1930s/early 1940s as both steady-state and transient targets. From the confluence to the BIC headgate, there is an estimated (measured) 5.6 cfs of gains to the Gila River, and the model simulates 3 cfs of gains in the steady-state period. This is a good match. In the transient period, the same reach simulates an average of 23 cfs, which is an overestimate. This excess simulated baseflow could explain why the modeled streamflow at the gage target in this location is also too high. From the BIC headgate to the Arlington headgate, there was an estimated (measured) 51 cfs of baseflow, and the model simulates an average of 64 cfs in this reach. This is an overestimate but reasonable given the model cell size and uncertainty surrounding the measurements. Notably, in 1941 the simulated baseflow jumps up to 146 cfs, whereas the average of the other years (1937 to 1940) is 44 cfs. Because 1941 is one of the years designated as a flood year, the model could be overestimating the amount of water recharged due to flooding and therefore incorrectly producing excess baseflow, or the baseflow target could be artificially low (recall from Section 5.3.4 that the Buckeye Irrigation District measured baseflow in months free from flood flow).

From the Arlington headgate to the Gillespie Dam, there was an estimated (measured) 51 cfs of baseflow (identical to the previous reach), and the model simulates an average of 63 cfs in this reach (48 cfs if the flood year of 1941 is removed from the calculation). This good match is particularly significant because this reach of the Gila River is near the model outflow point at Gillespie Dam. Having a control of the surface flow leaving the model domain at this location adds confidence to the estimate of underflow leaving via the GHB cells.

6.2.6 Regularization Targets

The regularization targets regul_rch and ppvar contributed 0% and 6.0% to the sum of squared errors in the model (**Table 6-1**), indicating that these had negligible impact on the calibration. These are valuable targets to ensure that like parameters do not deviate from each other without justification. For this reason, the regularization targets were retained in the model during calibration.

6.3 Simulated Water Budget

Evaluation of the simulated water budget is a qualitative way to check that the updated model simulates the regional groundwater flows in a manner consistent with the conceptual understanding of the regional geology, hydrogeology, surface water hydrology, and regional climate.

The term "aquifer storage" can be ambiguous or unclear in the context of the MODFLOW water budget. MODFLOW is aquifer-centric, and because of this, flows to the aquifer will be positive values, and flows out of the aquifer will be negative. The model treats storage as a component separate from the active aquifer. Therefore, when inflow is greater than outflow, the system transfers water to and increases the storage (i.e., water levels rise); this is represented in MODFLOW with negative values. When inflow is less than outflow, the system obtains water from and decreases the storage (i.e., water levels fall); this is represented in MODFLOW with positive values. For purposes of communicating results, ADWR has multiplied the net storage values by negative one (-1) so that a negative storage change intuitively means water leaving the aquifer (i.e., water levels fall), and a positive storage change means water entering the aquifer (i.e., water levels rise). Water budget results have been rounded to the nearest 1,000 AF for ease of discussion.

6.3.1 Boundary Underflow from Adjacent Basins and Mountain-Fronts

Inflows due to adjacent basin underflow and mountain-front recharge are shown in **Figure 6-29**. This component of the water budget is relatively stable. The time series indicates that there has been a slight decrease in inflows between the 1900-1950 period and the post-1950 period. This is likely due to the gradient reversal at the Maricopa-Stanfield boundary caused by groundwater pumping in the Pinal AMA. The average annual inflow is 63,000 AF, with a high of 92,000 AFY occurring in the early part of the transient period and a low of 24,000 AFY in the early 1980s, likely due to elevated groundwater levels in the Phoenix AMA following flood events.

6.3.2 Recharge

Inflows due to recharge are shown in **Figure 6-30**. The shape of the percentile graph reflects the peaky nature of recharge in the Phoenix AMA – most years are dry or "average," while the wet years are infrequent and significantly wetter than the majority of years. The average annual recharge is 917,000 AF. Very wet years (top 10^{th} percentile), when they do occur, provide an average of 2.1 million AF to the aquifer. Arid years (bottom 10^{th} percentile) provide an average of 578,000 AF of recharge. Cumulative recharge in the historical period has added 111.9 million AF to the aquifer.

6.3.3 Streambed Leakage

Net streambed leakage provides an inflow to the aquifer, as shown in **Figure 6-31**. The percentile graph shows that most stream flux is small (plus or minus 100,000 AFY), and the highest gains and losses occur less than 10 percent of the time. The timeseries plot shows that, overall, streams in the Phoenix AMA were gaining (connected to the aquifer and receiving baseflow from groundwater) until the late 1950s, when the net stream flux reversed to overall losing streams. These results are consistent with the conceptual model. In recent years (2000 to 2021), stream leakage has contributed an average of 49,000 AFY to the aquifer.

6.3.4 General Head Boundary

Outflows from the Lower Hassayampa sub-basin to the Gila Bend basin, modeled using GHB cells, are shown in **Figure 6-32**. The average annual outflow in the calibration period is 15,000 AF. The highest outflows occurred in the earlier part of the century, peaking around 1965 and declining through 2000. This could reflect a relatively "full" aquifer and substantial return flow from agriculture, creating conditions where the hydraulic gradient to the downstream basin was high. The decrease in underflow between 1970 and 2000 could reflect relatively more water leaving the model via the streams, since this was a period of relatively higher precipitation and streamflows. It could also reflect a flattening of the hydraulic gradient between basins due to groundwater pumping in each. The highest modeled outflow was 28,000 AF in 1965 and the lowest was 3,000 AF in 2006.

6.3.5 Evapotranspiration

Outflows due to evapotranspiration are shown in **Figure 6-33**. The average annual ET demand in the calibration period is 137,000 AF. ET demand was highest in the first half of the transient simulation when groundwater levels were higher throughout the Phoenix AMA. There is a notable decrease in ET between 1950 and 1960, likely due to the increased pumping in that decade. Periodic increases in ET are seen during flood years. The highest outflow due to ET is 219,000 AF in 1941 (an early flood year), and the lowest ET outflow is 52,000 AF in 2021.

6.3.6 Simulated Pumping

Outflows due to simulated pumping are shown in **Figure 6-34**. The annual average pumping in the historical period was 949,000 AF. Pumping peaked in the 1950s at around 2.2 million AF per year and then declined slowly through the 1980s when the average annual demand settled around 898,000 AF in recent years (2000 to 2021). Cumulative pumping in the historical period is estimated to have removed 115.7 million AF from the aquifer.

6.3.7 Storage Change

Storage change is shown in **Figure 6-34**. The timeseries indicates that net storage change was close to zero from 1900 to 1920, which is reasonable given that this was prior to large-scale groundwater pumping or surface water importation. Net storage change between the 1920s and 1960s is largely negative (removing water from the aquifer/declining water levels), as these years experienced some of the highest pumping demands on the aquifer without the benefit of imported surface water supplies. Starting around 1970, a combination of wet years throughout the 1980s and the start of CAP water deliveries in the early 1990s resulted in positive net storage change for most of the 30-year period. This is reflected in rising water levels throughout the Phoenix AMA. The drought that began in 2000 is evident through net storage, as each year's storage change fluctuates around zero.

Modeled change in storage over the entire simulated period shows a total aquifer storage loss of approximately 20.55 million AF. As a result, groundwater levels in the AMA declined an average of 92 feet between 1899 and 2021.

Overall, the simulated water budget shows the following characteristics:

- Recharge dominates the inflow; the recharge spikes are due to impulsive flooding events.
- Groundwater pumping dominates the outflow and has experienced a decline since 1980.
- The Gila River was primarily a gaining stream before 1950 and became a losing stream afterward.
- Evapotranspiration was relatively stable before 1950 but has been slowly decreasing due to the decline in groundwater levels.

- Groundwater storage experienced a significant decline between 1940 and 1980 and has stabilized since then.
- Sporadic flooding along the rivers contributes large volumes of water to the aquifer in the years these flood events occur.

Appendix F contains an electronic tabulation of the simulated water budget.

7.0 Sensitivity Analysis

After calibrating the model, a sensitivity analysis was performed to analyze how model results change given a change to calibrated input parameters. The value of this exercise is to help understand uncertainty in the model outputs resulting from uncertainty in the input parameters. The following input parameters were investigated for their sensitivity:

- Maximum evapotranspiration rate in the ET package,
- Conductance of the GHB package,
- Pumping rates in the MNW2 package,
- Recharge rates in the RCH package,
- Streambed hydraulic conductivity in the SFR2 package,
- Hydraulic properties (horizontal and vertical conductivity, specific storage, and specific yield) in the UPW package, and
- Mountain front inflow and boundary underflow in the well (WEL) package.

7.1 Sensitivity Analysis Methodology

The sensitivity analysis was performed by systematically changing one parameter at a time, running the model, and tabulating the results. When testing the evapotranspiration rate, pumping, recharge rates, mountain front inflow and boundary underflow, and the specific yield, the parameters were independently adjusted by factors of 0.5 and 1.5. This represents a 50% decrease and increase, respectively, from the calibrated value. When testing the conductance of the general head boundary and streambed cells, horizontal and vertical hydraulic conductivities, and specific storage, the parameters were independently adjusted by factors of 0.1 and 10. This represents an order of magnitude decrease and increase, respectively, from the calibrated value. The different testing factors were selected to represent realistic values for the specified parameters. For instance, an increase or decrease of streambed conductivity by 50% would not be a significant enough change to elicit a response from the model.

Three target groups were evaluated for sensitivity: heads, streamflows (surface), and baseflows (flux). Residuals are calculated as observation minus simulated value. After each model run, a comparison was made of the average (mean) residuals from the sensitivity run with the average residuals from the calibrated model using the following equations:

1) Head:

$$RMHRC = (MHR_{sen} - MHR_{cal}) / MHR_{cal}$$

Where:

$RMHRC$ = relative mean head residual change

$(MHR_{sen} - MHR_{cal})$ = water level mean residual difference

MHR_{sen} = mean head residual from sensitivity simulation

MHR_{cal} = mean head residual from calibrated model

2) Streamflow:

$$RMSFRC = (MSFR_{sen} - MSFR_{cal}) / MSFR_{cal}$$

Where:

$RMSFRC$ = relative mean streamflow residual change

$(MSFR_{sen} - MSFR_{cal})$ = streamflow mean residual difference

$MSFR_{sen}$ = mean streamflow residual from sensitivity simulation

$MSFR_{cal}$ = mean streamflow residual from calibrated model

3) Baseflow:

$$RMBFRC = (MBFR_{sen} - MBFR_{cal}) / MBFR_{cal}$$

Where:

$RMBFRC$ = relative mean baseflow residual change

$(MBFR_{sen} - MBFR_{cal})$ = baseflow mean residual difference

$MBFR_{sen}$ = mean baseflow residual from sensitivity simulation

$MBFR_{cal}$ = mean baseflow residual from calibrated model

Comparing the relative change in residuals is a way to normalize the results to facilitate comparison across different units of measurement.

7.2 Sensitivity Analysis Results

The sensitivity analysis indicates that hydraulic heads, streamflows, and baseflows are most sensitive to groundwater pumping and recharge. This is a logical result because these are two of the most significant water budget components, and both are widespread within the model. The magnitude, timing, and location of groundwater pumping are relatively well-understood, as wells are registered, and pumping is reported within the Phoenix AMA. Although the model is sensitive to groundwater pumping, there is high confidence in the pumping volumes within the Phoenix AMA groundwater model. Recharge is lesser-known as it consists of inputs that cannot be measured directly, for example, recharge resulting from urban turf and artificial lakes. For this reason, focusing future efforts on improving the confidence of recharge estimates would result in higher confidence that the calibrated model accurately represents the groundwater system.

Figure 7-1 shows the sensitivity of hydraulic heads to changes in the ET, MNW2, RCH, WEL, and the specific yield parameters. Of these parameters, the hydraulic heads are most sensitive to changes in groundwater pumping and groundwater recharge. Specific yield is the second most sensitive parameter with respect to hydraulic heads. The rate of mountain-front recharge has a moderate impact on the simulated head. The hydraulic heads are least sensitive to the maximum evapotranspiration rate along the riparian zone and boundary flow.

Figure 7-2 shows the sensitivity of hydraulic heads to changes in the GHB, SFR2, horizontal and vertical hydraulic conductivities, and specific storage parameters. Of these parameters, the hydraulic heads are most sensitive to aquifer horizontal hydraulic conductivity changes. The hydraulic conductivity of the streambeds had a moderate impact on hydraulic heads. The hydraulic heads are least sensitive to the conductance of the general head boundary, vertical hydraulic conductivity, and specific storage of the aquifer.

Figure 7-3 shows the sensitivity of streamflow to changes in the ET, MNW2, RCH, WEL, and the specific yield parameters. Of these parameters, modeled streamflow is most sensitive to changes in groundwater pumping and groundwater recharge. Maximum evapotranspiration rate and specific yield are the second most sensitive parameters with respect to streamflow. Streamflow is least sensitive to the mountain-front recharge and the underflow between the modeled area and adjacent sub-basins.

Figure 7-4 shows the sensitivity of streamflow to changes in the GHB, SFR2, horizontal and vertical hydraulic conductivities, and specific storage parameters. Of these parameters, aquifer horizontal and streambed conductivities are the most sensitive. Streambed hydraulic conductivity is more sensitive when given a higher magnitude in comparison to when it is tested at a lower magnitude. The aquifer vertical hydraulic conductivity, specific storage, and the conductance of the general head boundary are the least sensitive with respect to streamflow.

Figure 7-5 shows the sensitivity of stream baseflow to changes in the ET, MNW2, RCH, WEL, and the specific yield parameters. Of these parameters, the stream baseflow is most sensitive to the changes in recharge. Maximum evapotranspiration rate and groundwater pumping moderately impact groundwater interactions with surface water. Stream baseflow is least sensitive to the mountain-front recharge, boundary underflow, and specific yield.

Figure 7-6 shows the sensitivity of stream baseflow to changes in the GHB, SFR2, horizontal and vertical hydraulic conductivities, and specific storage parameters. Of these parameters, aquifer horizontal hydraulic conductivity has the greatest impact on the simulated stream baseflow. The hydraulic conductivity of the streambed has a moderate impact on the sensitivity with respect to groundwater interactions with surface water. The conductance of the general head boundary, the vertical hydraulic conductivity, and specific storage have minimal impact on the baseflow sensitivity.

A table with the calculated average target residual per sensitivity run is provided in **Appendix G**.

8.0 Model Limitations

Numerical groundwater flow models are powerful tools for predicting the behavior of groundwater systems. However, like all models, they have certain limitations that need to be considered when using them to make predictions or decisions. These limitations are usually associated with the purpose of the model, the current understanding of the simulated system, the quantity and quality of data, and the assumptions made during model development.

Numerical groundwater flow models have simplifying assumptions. Groundwater models are based on mathematical equations that simplify the complex behavior of groundwater flow in the real world. These equations are based on assumptions about the nature of the aquifer, such as its homogeneity, isotropy, and hydraulic properties. While these assumptions are necessary to make the models computationally tractable, they can introduce errors in the predictions.

Limited grain-size distribution information is available in areas with limited lithologic/well logs, leading to the use of control logs to support the parameter interpolation in Texture2Par. Lithology information would be beneficial to improve aquifer characterization in these areas. Additionally, interpolation of sediment values between available well logs may not fully represent the extent of heterogeneity in the aquifer.

Recharge is assumed to reach the water table instantaneously, when in reality, there is a travel time for that water through the unsaturated (vadose) zone. Incorporating vadose zone processes in future modeling may improve some simulated trends, although the current quantification of the water budget will still be valid.

Groundwater models are typically developed at a specific spatial and temporal scale, which can limit their applicability to other scales. For example, a model developed at a regional scale may not be appropriate for predicting the behavior of highly-localized conditions. Also, a model developed at a coarse time scale may not represent short-duration hydrologic events.

For the Phoenix AMA model, the cells were defined as 160 acres squares, and the real-life aquifer properties were averaged over the thickness of the model layer, which can be 1,000s of feet in some locations. Short-term changes to the hydrology, such as floods or short-term pumping, get averaged over annual stress periods, damping the impacts. The Phoenix AMA model is best suited for regional analyses over large time scales; the scales at which the model has been developed.

Groundwater models are also limited by data availability. The accuracy of groundwater models depends on the quality and quantity of data available to calibrate and validate the model. Unfortunately, groundwater data is often sparse and uncertain, particularly in regions with limited monitoring infrastructure or complex geological settings. This can make it challenging to develop accurate models that reflect real-world conditions.

For the Phoenix AMA, there are areas with abundant data and areas with no data. The modeling challenge was integrating the entire domain in a way that respected the available data and conceptual model. Besides groundwater head data, the Phoenix AMA has historical observations of baseflow, stream gauge records, and aquifer test data to inform aquifer properties. These quantitative targets are important for constraining estimated parameters. Conceptual estimates of the water budget, which exist for various locations within the Phoenix AMA over the 122-year historical period, are another tool used to check that the parameters estimated during calibration are reasonable.

Land subsidence has been omitted in the model, while subsidence has occurred in multiple locations within the Phoenix AMA. Land subsidence occurs when there is excessive extraction of groundwater, lowering the water table. As a result, the void space previously occupied by groundwater is now filled with air or the compacted sediment above it, causing the layers of sediment to compress and the land surface to sink or subside. The compaction of the sediment is irreversible, resulting in a reduction of the aquifer storage capacity. Subsidence compacts the aquifer material, forcing groundwater out of the formation and reducing storage capacity. Water levels in the model where subsidence has occurred, such as the Luke Air Force Base subsidence feature, would ideally be systematically underestimated to account for the lack of integrated subsidence in the model. This is not necessarily the case, so those areas of the model may inadvertently overestimate the amount of water in storage.

Groundwater models inherently contain uncertainty. Groundwater models require input parameters that describe the aquifer's properties and the groundwater system's behavior. These parameters can be uncertain due to limited data availability, measurement error, or natural variability in the aquifer properties. Groundwater systems are inherently variable due to natural factors such as geologic heterogeneity, climate variability, and hydrologic cycles. Natural variability can introduce uncertainty in model predictions, particularly for long-term forecasting or for systems that are sensitive to climate change.

The Phoenix AMA groundwater flow model's primary objective is to simulate the groundwater system's behavior in response to various boundary conditions and management scenarios. The Phoenix AMA model provides decision-makers with a scientific basis for evaluating and selecting management strategies, making informed decisions, and communicating the potential outcomes of different management scenarios to stakeholders.

9.0 Summary

ADWR has developed and calibrated a groundwater flow model of the Phoenix AMA. The model area combines the Lower Hassayampa, WSRV, and ESRV sub-basins; and includes portions of the Maricopa-Stanfield, Lake Pleasant, and Eloy sub-basins. The Phoenix AMA model replaces the existing SRV and Lower Hassayampa sub-basin groundwater models.

The model is calibrated to the time period of pre-1900 through 2021. Data used in the calibration include water level measurements, aquifer test results, vertical head difference observations, observations of stream gains prior to widespread groundwater pumping, and gaged streamflow rates on the Salt and Gila Rivers. The calibration results indicate that the model is well-calibrated and reasonably reproduces the study area's historical conditions. The calibration approach uses multiple lines of evidence to simulate meaningful water budgets, aquifer parameters, groundwater heads, streamflows, and other boundary conditions. Avoiding overfitting of parameters during calibration helped achieve a reasonable model that can be used to inform groundwater management decisions.

A number of model limitations have been noted. Some of these limitations are inherent in a regional scale model while others can be improved as additional data become available. However, model calibration and sensitivity analyses indicate that the current model can be used to show the physical availability of groundwater as required by the Assured Water Supply program.

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TABLES

Table 3-1 Pre-Development Groundwater Budget for Phoenix AMA Study Area (Nearest 1,000 Acre-Feet)

Water Budget Component	Estimate or Estimate Range (AFY)	Source
INFLOWS		
Perennial Stream Channel Recharge – SRV Domain	81,000	Corkhill et al. (1993)
Perennial Stream Channel Recharge – Outside SRV Domain	56,000	Buckeye Waterlogged Area Review and Recommendation, ADWR (2019)
Pre-1900 Incidental Recharge - SRV Domain	60,000 to 150,000	Davis (1897)
Pre-1930 Incidental Recharge - Outside SRV Domain	60,000	Buckeye Waterlogged Area Review and Recommendation, ADWR (2019)
Ephemeral Stream Recharge	108,000 to 163,000	Corkhill et al. (1993)
		Brown and Caldwell (2006)
		Smith and Heckler (1955)
		USGS Gage Data
		Buckeye Waterlogged Area Review and Recommendation, ADWR (2019)
Mountain Front Recharge	11,000	Corkhill et al. (1993)
		Brown and Caldwell (2006)
Underflow into Phoenix AMA Model Domain	33,000	Liu et al. (2014)
		Freihoefer et al. (2009)
		Corkhill et al. (1993)
		Brown and Caldwell (2006)
Total Inflow	**409,000 to 554,000**	
OUTFLOWS		
Perennial Stream Channel Discharge - SRV Domain	61,000	Corkhill et al. (1993)
Perennial Stream Channel Discharge - Outside SRV Domain	135,000	Buckeye Waterlogged Area Review and Recommendation, ADWR (2019)
Evapotranspiration	220,000	Thomsen and Eychaner (1991)
Underflow out of Phoenix AMA Model Domain	2,000 to 26,000	Freethey and Anderson (1986)
		Buckeye Waterlogged Area Review and Recommendation, ADWR (2019)
Total Outflow	**418,000 to 442,000**	

Abbreviations:
ADWR = Arizona Department of Water Resources
AFY = Acre-feet per year
AMA = Active Management Area
SRV = Salt River Valley (groundwater model)
USGS = United States Geological Survey

Table 3-2 Post-Development Groundwater Budget for Phoenix AMA Study Area (Rounded to Nearest 1,000 Acre-Feet)

Water Budget Component	1900 to 1950	1951-1980	1981-2000	2001-2017
INFLOWS				
Perennial Stream Channel Recharge – SRV Domain[1]	81,000	81,000	81,000	81,000
Perennial Stream Channel Recharge – Outside SRV Domain[2], [3]	56,000	56,000	17,000	22,000
Ephemeral Stream Recharge[4]	108,000 to 163,000	108,000 to 163,000	108,000 to 163,000	108,000 to 163,000
Mountain Front Recharge[4]	11,000	11,000	11,000	11,000
Underflow into Phoenix AMA Model Domain[4], [5]	33,000	17,000	17,000	17,000
Incidental Recharge[5], [6], [7]	360,000 to 480,000	940,000	688,000	636,000
Artificial Recharge at Permitted Facilities[8]	0	0	50,000	210,000
OUTFLOWS	**1900 to 1950**	**1951-1980**	**1981-2000**	**2001-2017**
Perennial Stream Channel Discharge - SRV Domain[1]	61,000	61,000	0	0
Perennial Stream Channel Discharge - Outside SRV Domain[2]	135,000	33,000	33,000	33,000
Groundwater Pumping[10], [11]	<20,000 to 1,850,000	1,000,000 to 2,300,000	680,000 to 1,600,000	660,000 to 1,100,000
Evapotranspiration[4], [9], [5], [7]	220,000	90,000	48,000	25,000
Underflow out of Phoenix AMA Model Domain[4]	2,000 to 26,000	2,000 to 26,000	2,000 to 26,000	2,000 to 26,000

References:

(1) Corkhill et al. (1993)
(2) Buckeye Waterlogged Area Review and Recommendation, ADWR (2019)
(3) USGS Gages 9517000 and 9516500
(4) Reference listed in Table 3-1
(5) Corell and Corkhill (1994)
(6) Halpenny (1952)
(7) Freihoefer et al. (2009)
(8) ADWR Recharge Database
(9) Halpenny and Greene (1975)
(10) Anning and Duet (1994)
(11) ADWR Active Management Area Reports

Abbreviations:

ADWR = Arizona Department of Water Resources
AMA = Active Management Area
SRV = Salt River Valley
USGS = United States Geological Survey

Table 3-3 Dry, Average, Wet, and Flood Conditions by Year in the Phoenix AMA

Stress Period	Corresponding Year(s)	Type of Year	Reference
2	1900-1910	Dry	Gookin (2009); Buckeye Irrigation District (1941)
3, 4	1911-1915, 1916-1920	Wet	Buckeye Irrigation District (1941)
5 to 15	1921 to 1931	Average	No reference found - assume average
16 to 20	1932 to 1936	Dry	Paulson et al. (1991)
21 to 24	1937 to 1940	Average	No reference found - assume average
25	1941	Flood	Thomas (1962); Halpenny (1952); Smith and Heckler (1955)
26 to 33	1942 to 1949	Dry	Paulson et al. (1991)
34	1950	Wet	Werho (1967); Thomas (1962)
35	1951	Flood	Werho (1967); Thomas (1962)
36	1952	Wet	Werho (1967); Thomas (1962)
37 to 43	1953 to 1959	Dry	Gookin (2009)
44 to 47	1960 to 1963	Dry	Paulson et al. (1991)
48 to 49	1964 to 1965	Flood	Werho (1967); Aldridge (1970)
50	1966	Wet	Aldridge (1970)
51 to 52	1967 to 1968	Average	Paulson et al. (1991)
53	1969	Wet	Paulson et al. (1991)
54	1970	Flood	Corkhill et al. (1993); NOAA (1971)
55	1971	Wet	Paulson et al. (1991)
56	1972	Flood	Corkhill et al. (1993); Paulson et al. (1991)
57 to 61	1973 to 1977	Dry	Paulson et al. (1991)
62 to 64	1978 to 1980	Flood	Aldridge and Hales (1984); Paulson et al. (1991)
65 to 66	1981 to 1982	Wet	Gookin (2009)
67	1983	Flood	Konieczki and Anderson (1990); Paulson et al. (1991)
68 to 73	1984 to 1989	Wet	Gookin (2009)
74	1990	Average	No reference found - assume average
75	1991	Wet	Freihoefer et al. (2009)
76 to 77	1992 to 1993	Flood	Holstege (2015)
78 to 79	1994 to 1995	Wet	Freihoefer et al. (2009)
80 to 82	1996 to 1998	Average	No reference found - assume average
83 to 88	1999 to 2004	Dry	Phillips and Thomas (2005)
89	2005	Wet	Phillips and Thomas (2005)
90 to 97	2006 to 2013	Average	No reference found - assume average
98	2014	Flood	Holstege (2015)
99 to 105	2015 to 2021	Average	No reference found - assume average

Abbreviations:
NOAA = National Oceanic and Atmospheric Administration

Table 4-1 Temporal Discretization of the Calibrated Model

Stress Period	Year(s)	Length in Days	Stress Period Type
1	pre-1900	1e-6 (length of steady state does not impact model simulation)	Steady State
2	1900-1910	4,018	Transient
3	1911-1915	1,826	Transient
4	1916-1920	1,827	Transient
5	1921	365	Transient
6	1922	365	Transient
7	1923	365	Transient
8	1924	366	Transient
9	1925	365	Transient
10	1926	365	Transient
11	1927	365	Transient
12	1928	366	Transient
13	1929	365	Transient
14	1930	365	Transient
15	1931	365	Transient
16	1932	366	Transient
17	1933	365	Transient
18	1934	365	Transient
19	1935	365	Transient
20	1936	366	Transient
21	1937	365	Transient
22	1938	365	Transient
23	1939	365	Transient
24	1940	366	Transient
25	1941	365	Transient
26	1942	365	Transient
27	1943	365	Transient
28	1944	366	Transient
29	1945	365	Transient
30	1946	365	Transient
31	1947	365	Transient
32	1948	366	Transient
33	1949	365	Transient
34	1950	365	Transient
35	1951	365	Transient
36	1952	366	Transient
37	1953	365	Transient
38	1954	365	Transient
39	1955	365	Transient
40	1956	366	Transient
41	1957	365	Transient
42	1958	365	Transient
43	1959	365	Transient
44	1960	366	Transient

Table 4-1 Temporal Discretization of the Calibrated Model

Stress Period	Year(s)	Length in Days	Stress Period Type
45	1961	365	Transient
46	1962	365	Transient
47	1963	365	Transient
48	1964	366	Transient
49	1965	365	Transient
50	1966	365	Transient
51	1967	365	Transient
52	1968	366	Transient
53	1969	365	Transient
54	1970	365	Transient
55	1971	365	Transient
56	1972	366	Transient
57	1973	365	Transient
58	1974	365	Transient
59	1975	365	Transient
60	1976	366	Transient
61	1977	365	Transient
62	1978	365	Transient
63	1979	365	Transient
64	1980	366	Transient
65	1981	365	Transient
66	1982	365	Transient
67	1983	365	Transient
68	1984	366	Transient
69	1985	365	Transient
70	1986	365	Transient
71	1987	365	Transient
72	1988	366	Transient
73	1989	365	Transient
74	1990	365	Transient
75	1991	365	Transient
76	1992	366	Transient
77	1993	365	Transient
78	1994	365	Transient
79	1995	365	Transient
80	1996	366	Transient
81	1997	365	Transient
82	1998	365	Transient
83	1999	365	Transient
84	2000	366	Transient
85	2001	365	Transient
86	2002	365	Transient
87	2003	365	Transient
88	2004	366	Transient
89	2005	365	Transient

Table 4-1 Temporal Discretization of the Calibrated Model

Stress Period	Year(s)	Length in Days	Stress Period Type
90	2006	365	Transient
91	2007	365	Transient
92	2008	366	Transient
93	2009	365	Transient
94	2010	365	Transient
95	2011	365	Transient
96	2012	366	Transient
97	2013	365	Transient
98	2014	365	Transient
99	2015	365	Transient
100	2016	366	Transient
101	2017	365	Transient
102	2018	365	Transient
103	2019	365	Transient
104	2020	366	Transient
105	2021	365	Transient

Table 4-2 Irrigation District Zones in Model

Irrigation District Name	Zone in Model
Chandler Heights Citrus Irrigation District	b
Country Farms Irrigation and Management Co.	b
New Magma Irrigation and Drainage District	b
Queen Creek Irrigation District	b
Queen Creek Irrigation Water Delivery District	b
Queen Creek Suburban Ranches	b
Ranchos Jardines Irrigation Delivery District	b
San Tan Irrigation District	b
Suburban Irrigation District	b
Sun Valley Farms Coop III (Inactive 2001)	b
Sun Valley Farms Unit II	b
Sun Valley Farms Unit IV	b
Sun Valley Farms Unit VII	b
Citrus Heights Ranch	c
Roosevelt Water Conservation District	c
Arcadia Water Company	d
New State Irrigation & Drainage District	d
Peninsula Ditch and Irrigation District	d
Saint Johns Irrigation District	d
Salt River Valley Water Users Association	d
Arlington	e
Tonopah	f
Buckeye Irrigation District	g
Roosevelt Irrigation District	h
100 Coop	i
200 Coop	i
Adaman Irrigation Water Delivery District #36	i
Citrus Glen Owners Association Inc.	i
Clearwater Farms Unit I	i
Clearwater Farms Unit II	i
Maricopa Water District	i
Olive Avenue Homeowners Association	i
Agriculture within GRIR	j
Agriculture within SRPMIC	k
All other areas not included in the above zones	a

Abbreviations:
GRIR = Gila River Indian Reservation
SRPMIC = Salt River Pima Maricopa Indian Community

Table 5-1 Recharge Group Parameter Name and ID in PEST Control File

Recharge Group Parameter Name	PEST ID
Steady-state recharge	rchss
Supplemental agricultural recharge	agsuplrch
CAP canal seepage	caprch
Ephemeral recharge	epherch
Flood recharge	floodrch
IBW recharge	ibwrch
Artificial lake recharge	lakerch
Mountain-front recharge	mftrch*
Non-SCIP canal seepage	nonsciprch*
SCIP canal seepage	sciprch
Urban turf recharge	urbturfrch
USF recharge	usfrch
Beardsley	nonscip_01
RID	nonscip_02
AZ-West	nonscip_03
Grand	nonscip_04
AZ	nonscip_05
South	nonscip_06
Crosscut	nonscip_07
Western	nonscip_08
Highline	nonscip_09
RWCD	nonscip_10
Consolidated	nonscip_11
San Fran South Branch	nonscip_12
Eastern	nonscip_13
Tempe	nonscip_14
San Fran Canal	nonscip_15
St Johns	nonscip_16
San Fran North Branch	nonscip_17
Hayden Branch	nonscip_18
Arlington	nonscip_19
Kyrene	nonscip_20
Gila Drain North	nonscip_21*
Gila Drain South	nonscip_22*
Irrigation district zone a	a_001 through a_105
Irrigation district zone b	b_001 through b_105
Irrigation district zone c	c_001 through c_105
Irrigation district zone d	d_001 through d_105
Irrigation district zone e	e_001 through e_105
Irrigation district zone f	f_001 through f_105
Irrigation district zone g	g_001 through g_105

Table 5-1 Recharge Group Parameter Name and ID in PEST Control File

Recharge Group Parameter Name	PEST ID
Irrigation district zone h	h_001 through h_105
Irrigation district zone i	i_001 through i_105
Irrigation district zone j	j_001 through j_105
Irrigation district zone k	k_001 through k_105

Abbreviations:
AZ = Arizona Canal
AZ-West = Arizona Canal west of the Phoenix Mountains
CAP = Central Arizona Project
IBW = Indian Bend Wash
RID = Roosevelt Irrigation District
RWCD = Roosevelt Water Conservation District
SCIP = San Carlos Irrigation Project
USF = Underground Storage Facility

Note:
* indicates the parameter is inactive or null.

Table 5-2 MTN Group Parameter Name and ID in PEST Control File

MTN Group Parameter Name	PEST ID
North Belmont Mountains (Steady-state, Layer 1)	mtn_00_1s
North Belmont Mountains (Steady-state, Layer 2)	mtn_00_2s
North Belmont Mountains (Steady-state, Layer 3)	mtn_00_3s
Vulture Mountains east of Hassayampa River (Steady-state, Layer 1)	mtn_01_1s
Vulture Mountains east of Hassayampa River (Steady-state, Layer 2)	mtn_01_2s
Vulture Mountains east of Hassayampa River (Steady-state, Layer 3)	mtn_01_3s
Vulture Mountains at Hassayampa River (Steady-state, Layer 1)	mtn_02_1s
Vulture Mountains at Hassayampa River (Steady-state, Layer 2)	mtn_02_2s
Vulture Mountains at Hassayampa River (Steady-state, Layer 3)	mtn_02_3s
Vulture Mountains west of Hassayampa River (Steady-state, Layer 1)	mtn_03_1s
Vulture Mountains west of Hassayampa River (Steady-state, Layer 2)	mtn_03_2s
Vulture Mountains west of Hassayampa River (Steady-state, Layer 3)	mtn_03_3s
North Belmont Mountains (Layer 1)	mtn_00_1
North Belmont Mountains (Layer 2)	mtn_00_2
North Belmont Mountains (Layer 3)	mtn_00_3
Vulture Mountains east of Hassayampa River (Layer 1)	mtn_01_1
Vulture Mountains east of Hassayampa River (Layer 2)	mtn_01_2
Vulture Mountains east of Hassayampa River (Layer 3)	mtn_01_3
Vulture Mountains at Hassayampa River (Layer 1)	mtn_02_1
Vulture Mountains at Hassayampa River (Layer 2)	mtn_02_2
Vulture Mountains at Hassayampa River (Layer 3)	mtn_02_3
Vulture Mountains west of Hassayampa River (Layer 1)	mtn_03_1
Vulture Mountains west of Hassayampa River (Layer 2)	mtn_03_2
Vulture Mountains west of Hassayampa River (Layer 3)	mtn_03_3
Hieroglyphic Mountains (Layer 1)	mtn_04_1
Hieroglyphic Mountains (Layer 2)	mtn_04_2
Hieroglyphic Mountains (Layer 3)	mtn_04_3
Hieroglyphic / Bradshaw Mountains (Layer 1)	mtn_05_1
Hieroglyphic / Bradshaw Mountains (Layer 2)	mtn_05_2
Hieroglyphic / Bradshaw Mountains (Layer 3)	mtn_05_3
Cave Creek / McDowell Mountains (Layer 1)	mtn_06_1
Cave Creek / McDowell Mountains (Layer 2)	mtn_06_2
Cave Creek / McDowell Mountains (Layer 3)	mtn_06_3
Carefree (Layer 1)	mtn_07_1
Carefree (Layer 2)	mtn_07_2
Carefree (Layer 3)	mtn_07_3
New River / Anthem east of I-17 (Layer 1)	mtn_08_1
New River / Anthem east of I-17 (Layer 2)	mtn_08_2
New River / Anthem east of I-17 (Layer 3)	mtn_08_3
Anthem (Layer 1)	mtn_09_1
Anthem (Layer 2)	mtn_09_2
Anthem (Layer 3)	mtn_09_3
Superstition Mountains (Layer 1)	mtn_10_1
Superstition Mountains (Layer 2)	mtn_10_2
Superstition Mountains (Layer 3)	mtn_10_3

Table 5-2 MTN Group Parameter Name and ID in PEST Control File

MTN Group Parameter Name	PEST ID
Fountain Hills (Layer 1)	mtn_11_1
Fountain Hills (Layer 2)	mtn_11_2
Fountain Hills (Layer 3)	mtn_11_3
Usery Mountains (Layer 1)	mtn_12_1
Usery Mountains (Layer 2)	mtn_12_2
Usery Mountains (Layer 3)	mtn_12_3
Goldfield Mountains (Layer 1)	mtn_13_1
Goldfield Mountains (Layer 2)	mtn_13_2
Goldfield Mountains (Layer 3)	mtn_13_3
Gold Canyon (Layer 1)	mtn_14_1
Gold Canyon (Layer 2)	mtn_14_2
Gold Canyon (Layer 3)	mtn_14_3
Queen Creek (Layer 1)	mtn_15_1
Queen Creek (Layer 2)	mtn_15_2
Queen Creek (Layer 3)	mtn_15_3
White Tank Mountains (Layer 1)	mtn_16_1
White Tank Mountains (Layer 2)	mtn_16_2
White Tank Mountains (Layer 3)	mtn_16_3
Sierra Estrella Mountains (Layer 1)	mtn_17_1
Sierra Estrella Mountains (Layer 2)	mtn_17_2
Sierra Estrella Mountains (Layer 3)	mtn_17_3

Note:
Lateral groundwater inflow in the vicinity of Vulture Mountains was independently calibrated for the steady-state period to obtain reasonable initial heads in the area.

Table 5-3 Aquifer Test Data

PEST ID	Well Registration Number (55-)	Model Layer	Kh (ft/day)	Log-transformed Kh	Included in Calibration
Aqk001	594056	3	1.70	0.23	Yes
Aqk002	594056	N/A	2.11	0.33	No
Aqk003	617178	N/A	0.16	-0.80	No
Aqk004	564428	N/A	29.45	1.47	No
Aqk005	532477	3	11.87	1.07	Yes
Aqk006	516567	N/A	15.13	1.18	No
Aqk007	214510	3	6.31	0.80	Yes
Aqk008	209991	3	6.38	0.80	Yes
Aqk009	209990	3	6.39	0.81	Yes
Aqk010	577733	N/A	33.12	1.52	No
Aqk011	516564	3	43.31	1.64	Yes
Aqk012	516563	3	4.81	0.68	Yes
Aqk013	593634	3	7.21	0.86	Yes
Aqk014	593635	3	4.83	0.68	Yes
Aqk015	205600	3	0.29	-0.53	Yes
Aqk016	611447	3	19.12	1.28	Yes
Aqk017	595224	3	13.58	1.13	Yes
Aqk018	206656	3	7.95	0.90	Yes
Aqk019	516565	3	15.24	1.18	Yes
Aqk020	587818	N/A	0.77	-0.11	No
Aqk021	207985	N/A	22.73	1.36	No
Aqk022	617024	N/A	357.44	2.55	No
Aqk023	214664	N/A	122.92	2.09	No
Aqk024	517028	3	123.52	2.09	Yes
Aqk025	517030	N/A	205.87	2.31	No
Aqk026	630071	2	8.44	0.93	Yes
Aqk027	516562	3	25.40	1.40	Yes
Aqk028	210423	N/A	1.19	0.07	No
Aqk029	210425	3	68.97	1.84	Yes
Aqk030	630072	2	11.89	1.08	Yes
Aqk031	215990	2	5.05	0.70	Yes
Aqk032	607684	1	18.06	1.26	Yes
Aqk033	593411	3	4.80	0.68	Yes
Aqk034	593411	N/A	4.89	0.69	No
Aqk035	208421	3	3.13	0.50	Yes
Aqk036	214257	3	1.50	0.18	Yes
Aqk037	599201	3	6.03	0.78	Yes
Aqk038	216450	2	3.50	0.54	Yes
Aqk039	590334	2	2.18	0.34	Yes
Aqk040	203264	2	3.65	0.56	Yes
Aqk041	607743	2	8.64	0.94	Yes
Aqk042	212491	N/A	1.24	0.09	No
Aqk043	219594	2	4.79	0.68	Yes
Aqk044	608414	N/A	9.66	0.98	No
Aqk045	617092	2	3.76	0.58	Yes

Table 5-3 Aquifer Test Data

PEST ID	Well Registration Number (55-)	Model Layer	Kh (ft/day)	Log-transformed Kh	Included in Calibration
Aqk046	218298	2	12.07	1.08	Yes
Aqk047	608373	2	5.40	0.73	Yes
Aqk048	517025	3	72.86	1.86	Yes
Aqk049	517029	N/A	43.18	1.64	No
Aqk050	612054	N/A	4.82	0.68	No
Aqk051	212424	N/A	4.50	0.65	No
Aqk052	607687	2	1.86	0.27	Yes
Aqk053	212434	2	9.66	0.98	Yes
Aqk054	565555	2	1.28	0.11	Yes
Aqk055	608406	2	4.51	0.65	Yes
Aqk056	608400	2	13.82	1.14	Yes
Aqk057	608402	2	13.79	1.14	Yes
Aqk058	607734	3	97.86	1.99	Yes
Aqk059	608403	2	2.49	0.40	Yes
Aqk060	608405	1	5.73	0.76	Yes
Aqk061	525592	N/A	42.84	1.63	No
Aqk062	601889	N/A	12.07	1.08	No
Aqk063	608545	2	3.07	0.49	Yes
Aqk064	607737	2	13.27	1.12	Yes
Aqk065	618619	1	16.27	1.21	Yes
Aqk066	607740	2	3.02	0.48	Yes
Aqk067	607719	2	12.44	1.09	Yes
Aqk068	607682	2	9.09	0.96	Yes
Aqk069	524269	3	11.34	1.05	Yes
Aqk070	524268	3	54.99	1.74	Yes
Aqk071	211427	3	2.04	0.31	Yes
Aqk072	524271	2	13.60	1.13	Yes
Aqk073	211429	3	1.35	0.13	Yes
Aqk074	524267	N/A	30.99	1.49	No
Aqk075	608419	2	4.70	0.67	Yes
Aqk076	608426	3	37.51	1.57	Yes
Aqk077	202099	N/A	88.76	1.95	No
Aqk078	617844	N/A	8.33	0.92	No
Aqk079	525594	N/A	3.30	0.52	No
Aqk080	617315	2	23.86	1.38	Yes
Aqk081	524270	3	15.77	1.20	Yes
Aqk082	608411	2	17.81	1.25	Yes
Aqk083	608360	2	16.02	1.20	Yes
Aqk084	608390	2	8.17	0.91	Yes
Aqk085	203885	N/A	31.05	1.49	No
Aqk086	608409	N/A	16.04	1.21	No
Aqk087	214647	2	4.06	0.61	Yes
Aqk088	607710	2	5.74	0.76	Yes
Aqk089	207793	3	1.94	0.29	Yes
Aqk090	207796	3	8.69	0.94	Yes

Table 5-3 Aquifer Test Data

PEST ID	Well Registration Number (55-)	Model Layer	Kh (ft/day)	Log-transformed Kh	Included in Calibration
Aqk091	608361	2	16.48	1.22	Yes
Aqk092	617098	2	13.47	1.13	Yes
Aqk093	617099	N/A	4.38	0.64	No
Aqk094	608382	2	14.44	1.16	Yes
Aqk095	608424	3	86.68	1.94	Yes
Aqk096	617843	2	26.87	1.43	Yes
Aqk097	214539	2	9.70	0.99	Yes
Aqk098	608356	2	14.25	1.15	Yes
Aqk099	608359	1	32.00	1.51	Yes
Aqk100	608394	2	14.18	1.15	Yes
Aqk101	608408	2	14.07	1.15	Yes
Aqk102	608376	N/A	4.13	0.62	No
Aqk103	209184	2	13.86	1.14	Yes
Aqk104	608391	2	14.16	1.15	Yes
Aqk105	608372	2	10.71	1.03	Yes
Aqk106	214512	2	1.83	0.26	Yes
Aqk107	524272	2	6.32	0.80	Yes
Aqk108	617317	3	11.01	1.04	Yes
Aqk109	617443	3	11.33	1.05	Yes
Aqk110	598826	3	1.97	0.29	Yes
Aqk111	598826	N/A	3.05	0.48	No
Aqk112	608437	1	25.37	1.40	Yes
Aqk113	617100	2	18.21	1.26	Yes
Aqk114	608393	2	13.85	1.14	Yes
Aqk115	608392	2	21.47	1.33	Yes
Aqk116	608385	2	10.91	1.04	Yes
Aqk117	608358	1	32.66	1.51	Yes
Aqk118	608387	2	14.22	1.15	Yes
Aqk119	607675	2	18.94	1.28	Yes
Aqk120	608374	2	18.97	1.28	Yes
Aqk121	608381	2	28.94	1.46	Yes
Aqk122	617850	2	16.98	1.23	Yes
Aqk123	608431	N/A	188.16	2.27	No
Aqk124	608433	1	83.13	1.92	Yes
Aqk125	607748	1	22.53	1.35	Yes
Aqk126	617097	2	49.66	1.70	Yes
Aqk127	617442	3	14.21	1.15	Yes
Aqk128	607727	1	57.03	1.76	Yes
Aqk129	201730	2	13.57	1.13	Yes
Aqk130	608407	2	18.78	1.27	Yes
Aqk131	608389	2	29.29	1.47	Yes
Aqk132	608377	2	16.92	1.23	Yes
Aqk133	607731	3	27.27	1.44	Yes
Aqk134	202398	N/A	148.92	2.17	No
Aqk135	607739	N/A	111.89	2.05	No

Table 5-3 Aquifer Test Data

PEST ID	Well Registration Number (55-)	Model Layer	Kh (ft/day)	Log-transformed Kh	Included in Calibration
Aqk136	607730	2	65.95	1.82	Yes
Aqk137	617109	2	98.41	1.99	Yes
Aqk138	617447	3	12.54	1.10	Yes
Aqk139	525993	N/A	1.41	0.15	No
Aqk140	578744	N/A	14.40	1.16	No
Aqk141	212862	2	46.12	1.66	Yes
Aqk142	221288	2	65.85	1.82	Yes
Aqk143	585036	2	83.77	1.92	Yes
Aqk144	607700	N/A	90.54	1.96	No
Aqk145	619314	1	99.02	2.00	Yes
Aqk146	608384	N/A	39.97	1.60	No
Aqk147	607736	2	23.90	1.38	Yes
Aqk148	205584	2	79.86	1.90	Yes
Aqk149	512354	2	43.64	1.64	Yes
Aqk150	594975	2	43.64	1.64	Yes
Aqk151	594975	N/A	60.27	1.78	No
Aqk152	617871	2	69.23	1.84	Yes
Aqk153	617871	N/A	71.39	1.85	No
Aqk154	607735	N/A	44.48	1.65	No
Aqk155	608380	1	67.61	1.83	Yes
Aqk156	578322	2	74.51	1.87	Yes
Aqk157	607708	1	64.37	1.81	Yes
Aqk158	607738	1	31.67	1.50	Yes
Aqk159	536774	1	36.90	1.57	Yes
Aqk160	536774	N/A	80.04	1.90	No
Aqk161	803651	N/A	0.16	-0.78	No
Aqk162	607711	2	35.94	1.56	Yes
Aqk163	209392	N/A	16.67	1.22	No
Aqk164	212105	3	7.00	0.85	Yes
Aqk165	210705	1	15.44	1.19	Yes
Aqk166	608428	2	17.83	1.25	Yes
Aqk167	607728	2	22.94	1.36	Yes
Aqk168	608363	2	41.78	1.62	Yes
Aqk169	608365	2	27.87	1.45	Yes
Aqk170	607671	1	64.71	1.81	Yes
Aqk171	607678	1	152.19	2.18	Yes
Aqk172	201426	3	11.46	1.06	Yes
Aqk173	219124	2	39.71	1.60	Yes
Aqk174	607718	1	43.29	1.64	Yes
Aqk175	617112	2	16.23	1.21	Yes
Aqk176	607701	2	75.91	1.88	Yes
Aqk177	607680	N/A	224.21	2.35	No
Aqk178	607704	2	53.26	1.73	Yes
Aqk179	607670	1	105.42	2.02	Yes
Aqk180	617865	2	51.95	1.72	Yes

Table 5-3 Aquifer Test Data

PEST ID	Well Registration Number (55-)	Model Layer	Kh (ft/day)	Log-transformed Kh	Included in Calibration
Aqk181	598655	3	4.68	0.67	Yes
Aqk182	598655	N/A	10.07	1.00	No
Aqk183	608436	2	60.06	1.78	Yes
Aqk184	608362	2	10.70	1.03	Yes
Aqk185	607750	2	58.99	1.77	Yes
Aqk186	221867	2	73.60	1.87	Yes
Aqk187	607677	1	101.14	2.00	Yes
Aqk188	607709	1	153.22	2.19	Yes
Aqk189	213838	2	30.40	1.48	Yes
Aqk190	213839	2	40.88	1.61	Yes
Aqk191	218281	N/A	28.37	1.45	No
Aqk192	617842	N/A	57.41	1.76	No
Aqk193	617121	2	42.61	1.63	Yes
Aqk194	617101	1	107.23	2.03	Yes
Aqk195	542432	1	96.66	1.99	Yes
Aqk196	206639	3	69.05	1.84	Yes
Aqk197	217538	2	32.29	1.51	Yes
Aqk198	608386	2	40.98	1.61	Yes
Aqk199	617114	2	43.16	1.64	Yes
Aqk200	617120	1	196.79	2.29	Yes
Aqk201	617870	N/A	99.50	2.00	No
Aqk202	206374	3	0.92	-0.04	Yes
Aqk203	212487	2	12.67	1.10	Yes
Aqk204	214666	3	139.13	2.14	Yes
Aqk205	523773	1	891.19	2.95	No
Aqk206	608364	2	73.68	1.87	Yes
Aqk207	607744	2	18.85	1.28	Yes
Aqk208	617841	2	39.01	1.59	Yes
Aqk209	607747	2	81.12	1.91	Yes
Aqk210	208417	3	7.73	0.89	Yes
Aqk211	202889	3	19.11	1.28	Yes
Aqk212	608427	2	49.22	1.69	Yes
Aqk213	542846	3	27.63	1.44	Yes
Aqk214	617837	N/A	16.97	1.23	No
Aqk215	617831	N/A	106.91	2.03	No
Aqk216	626567	2	538.07	2.73	No
Aqk217	608395	3	33.32	1.52	Yes
Aqk218	607688	3	26.48	1.42	Yes
Aqk219	607741	2	12.64	1.10	Yes
Aqk220	221535	1	148.60	2.17	Yes
Aqk221	202887	3	0.91	-0.04	Yes
Aqk222	202887	N/A	1.17	0.07	No
Aqk223	214672	3	140.00	2.15	Yes
Aqk224	586184	2	103.43	2.01	Yes
Aqk225	578323	2	63.10	1.80	Yes

Table 5-3 Aquifer Test Data

PEST ID	Well Registration Number (55-)	Model Layer	Kh (ft/day)	Log-transformed Kh	Included in Calibration
Aqk226	626563	N/A	516.19	2.71	No
Aqk227	617122	2	27.75	1.44	Yes
Aqk228	607679	2	29.80	1.47	Yes
Aqk229	617845	2	15.57	1.19	Yes
Aqk230	607699	N/A	30.58	1.49	No
Aqk231	572660	3	76.59	1.88	Yes
Aqk232	565551	3	3.20	0.51	Yes
Aqk233	211791	N/A	26.67	1.43	No
Aqk234	211795	3	9.19	0.96	Yes
Aqk235	623537	2	0.71	-0.15	Yes
Aqk236	626564	3	103.84	2.02	Yes
Aqk237	219155	2	43.79	1.64	Yes
Aqk238	617864	1	29.53	1.47	Yes
Aqk239	617852	2	41.33	1.62	Yes
Aqk240	607706	2	24.67	1.39	Yes
Aqk241	617840	2	10.11	1.00	Yes
Aqk242	607676	N/A	215.40	2.33	No
Aqk243	617087	N/A	14.78	1.17	No
Aqk244	593637	2	34.09	1.53	Yes
Aqk245	585039	2	19.54	1.29	Yes
Aqk246	616589	N/A	2.42	0.38	No
Aqk247	211612	3	22.04	1.34	Yes
Aqk248	595236	2	8.51	0.93	Yes
Aqk249	617118	N/A	239.17	2.38	No
Aqk250	610924	3	32.66	1.51	Yes
Aqk251	617096	N/A	6.79	0.83	No
Aqk252	213196	2	13.16	1.12	Yes
Aqk253	617094	N/A	29.10	1.46	No
Aqk254	212509	2	23.01	1.36	Yes
Aqk255	547844	2	11.43	1.06	Yes
Aqk256	617113	N/A	28.65	1.46	No
Aqk257	208093	2	13.13	1.12	Yes
Aqk258	208409	N/A	18.82	1.27	No
Aqk259	617853	2	79.83	1.90	Yes
Aqk260	542431	2	6.40	0.81	Yes
Aqk261	617106	N/A	15.96	1.20	No
Aqk262	594062	2	5.05	0.70	Yes
Aqk263	617116	2	39.00	1.59	Yes
Aqk264	629645	N/A	74.28	1.87	No
Aqk265	587025	3	36.52	1.56	Yes
Aqk266	587025	N/A	26.25	1.42	No
Aqk267	617826	3	26.23	1.42	Yes
Aqk268	617854	2	54.66	1.74	Yes
Aqk269	595235	2	27.73	1.44	Yes
Aqk270	617860	2	44.17	1.65	Yes

Table 5-3 Aquifer Test Data

PEST ID	Well Registration Number (55-)	Model Layer	Kh (ft/day)	Log-transformed Kh	Included in Calibration
Aqk271	608417	2	52.92	1.72	Yes
Aqk272	617861	2	57.25	1.76	Yes
Aqk273	607707	2	29.50	1.47	Yes
Aqk274	617855	2	27.23	1.44	Yes
Aqk275	617859	2	29.71	1.47	Yes
Aqk276	617835	2	15.59	1.19	Yes
Aqk277	617105	2	13.19	1.12	Yes
Aqk278	205591	2	11.14	1.05	Yes
Aqk279	587026	3	20.96	1.32	Yes
Aqk280	587026	N/A	25.93	1.41	No
Aqk281	585910	3	27.89	1.45	Yes
Aqk282	623227	3	18.00	1.26	Yes
Aqk283	628646	3	8.26	0.92	Yes
Aqk284	587021	3	29.49	1.47	Yes
Aqk285	587021	N/A	15.34	1.19	No
Aqk286	808149	N/A	64.10	1.81	No
Aqk287	602601	3	13.25	1.12	Yes
Aqk288	618943	1	39.23	1.59	Yes
Aqk289	565549	2	9.38	0.97	Yes
Aqk290	587022	N/A	4.47	0.65	No
Aqk291	587022	N/A	6.63	0.82	No
Aqk292	587023	3	7.94	0.90	Yes
Aqk293	587023	N/A	8.66	0.94	No
Aqk294	602602	3	14.29	1.15	Yes
Aqk295	602602	N/A	14.52	1.16	No
Aqk296	611625	2	135.72	2.13	Yes
Aqk297	617862	2	33.61	1.53	Yes
Aqk298	617090	2	8.54	0.93	Yes
Aqk299	583449	2	5.65	0.75	Yes
Aqk300	209177	2	21.50	1.33	Yes
Aqk301	595211	2	42.03	1.62	Yes
Aqk302	617863	2	40.44	1.61	Yes
Aqk303	617110	2	9.15	0.96	Yes
Aqk304	584725	3	41.44	1.62	Yes
Aqk305	557110	3	62.06	1.79	Yes
Aqk306	617832	N/A	876.35	2.94	No
Aqk307	617119	2	5.76	0.76	Yes
Aqk308	216255	1	78.26	1.89	Yes
Aqk309	207449	2	1.56	0.19	Yes
Aqk310	207055	1	116.67	2.07	Yes
Aqk311	207056	1	141.67	2.15	Yes
Aqk312	216246	1	68.00	1.83	Yes
Aqk313	580089	N/A	220.00	2.34	No
Aqk314	585918	1	180.00	2.26	Yes
Aqk315	585920	N/A	237.50	2.38	No

Table 5-3 Aquifer Test Data

PEST ID	Well Registration Number (55-)	Model Layer	Kh (ft/day)	Log-transformed Kh	Included in Calibration
Aqk316	617091	2	12.54	1.10	Yes
Aqk317	218204	N/A	697.40	2.84	No
Aqk318	218205	N/A	353.73	2.55	No
Aqk319	211431	N/A	6.55	0.82	No
Aqk320	211808	N/A	638.45	2.81	No
Aqk321	627092	2	16.57	1.22	Yes
Aqk322	214675	N/A	30.76	1.49	No
Aqk323	609350	N/A	29.66	1.47	No
Aqk324	627105	3	76.74	1.89	Yes
Aqk325	571198	3	0.31	-0.51	Yes

Abbreviations:
ft/day = feet per day
Kh = horizontal hydraulic conductivity
N/A = not applicable

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
1	G_2380	G_2349	20794	20767	990.85	938	DG_2380_20794	52.85	Yes
1	G_2380	G_2349	21534	21534	980.87	931.89	DG_2380_21534	48.98	Yes
1	G_2380	G_2349	21976	21976	979.73	927.27	DG_2380_21976	52.46	Yes
1	G_2380	G_2349	22718	22719	993.7	912.48	DG_2380_22718	81.22	Yes
1	G_2380	G_2349	23069	23069	985.93	901.14	DG_2380_23069	84.79	Yes
1	G_2380	G_2349	25581	25581	988.7	887.6	DG_2380_25581	101.1	Yes
1	G_2380	G_2349	29615	29615	954.5	844.7	DG_2380_29615	109.8	Yes
2	G_3105	G_3104	33562	33562	939.5	846.3	DG_3105_33562	93.2	Yes
2	G_3105	G_3104	35731	35731	956	900	DG_3105_35731	56	Yes
2	G_3105	G_3104	37595	37595	954.2	900.8	DG_3105_37595	53.4	Yes
2	G_3105	G_3104	38063	38063	955.1	901.5	DG_3105_38063	53.6	Yes
2	G_3105	G_3104	43083	43083	965.4	958.8	DG_3105_43083	6.6	Yes
3	G_2511	G_2548	26289	26289	963.75	965.8	DG_2511_26289	-2.05	Yes
3	G_2511	G_2548	29615	29615	959.6	962.6	DG_2511_29615	-3	Yes
3	G_2511	G_2548	29978	29978	960.21	962.4	DG_2511_29978	-2.19	Yes
3	G_2511	G_2548	35752	35752	959	961	DG_2511_35752	-2	Yes
3	G_2511	G_2548	37658	37658	958.31	960.5	DG_2511_37658	-2.19	Yes
3	G_2511	G_2548	38055	38069	957.8	960.4	DG_2511_38055	-2.6	Yes
4	G_2507	G_2441	38055	38055	963.9	957.59	DG_2507_38055	6.31	Yes
5	G_0625	G_0644	31421	31421	733.48	742.93	DG_0625_31421	-9.45	Yes
5	G_0625	G_0644	31747	31747	728.69	735.9	DG_0625_31747	-7.21	Yes
5	G_0625	G_0644	33554	33554	737.8	748.8	DG_0625_33554	-11	Yes
5	G_0625	G_0644	35767	35726	736	748	DG_0625_35767	-12	Yes
6	G_2232	G_2160	25274	25275	947.55	936	DG_2232_25274	11.55	Yes
6	G_2232	G_2160	25584	25584	953.9	941.9	DG_2232_25584	12	Yes
6	G_2232	G_2160	27409	27410	950	937.35	DG_2232_27409	12.65	Yes
6	G_2232	G_2160	33575	33577	952.8	945.5	DG_2232_33575	7.3	Yes
6	G_2232	G_2160	38062	38056	954	945.8	DG_2232_38062	8.2	Yes
7	G_0924	G_0918	29619	29619	793.5	788.6	DG_0924_29619	4.9	Yes
7	G_0924	G_0918	29970	29970	793.4	789.21	DG_0924_29970	4.19	Yes
7	G_0924	G_0918	33548	33548	787.8	780.1	DG_0924_33548	7.7	Yes
7	G_0924	G_0918	34075	34075	789.7	781.5	DG_0924_34075	8.2	Yes
7	G_0924	G_0918	38056	38056	784.8	778.4	DG_0924_38056	6.4	Yes
7	G_0924	G_0918	43097	43097	790.3	785	DG_0924_43097	5.3	Yes
8	G_1063	I_1109	23033	23033	803.6	813.5	DG_1063_23033	-9.9	Yes
8	G_1063	I_1109	37631	37578	810.81	820.3	DG_1063_37631	-9.49	Yes
8	G_1063	I_1109	38056	38056	810.8	820.8	DG_1063_38056	-10	Yes
8	G_1063	I_1109	39784	39784	816.4	825.6	DG_1063_39784	-9.2	Yes
9	G_1584	G_1500	30286	30286	854.9	849.3	DG_1584_30286	5.6	Yes
9	G_1584	G_1500	31026	31026	853.3	829.6	DG_1584_31026	23.7	Yes
9	G_1584	G_1500	31425	31425	854.1	848.1	DG_1584_31425	6	Yes
9	G_1584	G_1500	33568	33568	846.5	840.7	DG_1584_33568	5.8	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
9	G_1584	G_1500	35739	35739	852	846	DG_1584_35739	6	Yes
9	G_1584	G_1500	37592	37593	854.2	847.6	DG_1584_37592	6.6	Yes
9	G_1584	G_1500	39797	39797	857.6	851.3	DG_1584_39797	6.3	Yes
9	G_1584	G_1500	43075	43075	850.4	845.9	DG_1584_43075	4.5	Yes
10	G_1370	I_1371	30291	30291	842.6	840.5	DG_1370_30291	2.1	Yes
10	G_1370	I_1371	31033	31033	836.1	834.4	DG_1370_31033	1.7	Yes
10	G_1370	I_1371	31419	31419	841.9	839.7	DG_1370_31419	2.2	Yes
10	G_1370	I_1371	33561	33561	838.4	836.2	DG_1370_33561	2.2	Yes
10	G_1370	I_1371	37578	37578	842.3	840.6	DG_1370_37578	1.7	Yes
10	G_1370	I_1371	39784	39784	841.1	839	DG_1370_39784	2.1	Yes
10	G_1370	I_1371	41226	41226	840.1	837.9	DG_1370_41226	2.2	Yes
11	G_1978	G_2111	30288	30288	858.8	849.6	DG_1978_30288	9.2	Yes
11	G_1978	G_2111	31030	31034	868.9	856.7	DG_1978_31030	12.2	Yes
11	G_1978	G_2111	31425	31421	863.5	853.2	DG_1978_31425	10.3	Yes
11	G_1978	G_2111	32899	32853	862.8	854.9	DG_1978_32899	7.9	Yes
11	G_1978	G_2111	35740	35740	864	857	DG_1978_35740	7	Yes
11	G_1978	G_2111	37585	37586	859.41	850.2	DG_1978_37585	9.21	Yes
11	G_1978	G_2111	39794	39794	860.1	852.1	DG_1978_39794	8	Yes
11	G_1978	G_2111	43076	43076	851.1	844.2	DG_1978_43076	6.9	Yes
11	G_2111	G_2079	30288	30237	849.6	839.6	DG_2111_30288	10	Yes
11	G_2111	G_2079	31034	31030	856.7	877.2	DG_2111_31034	-20.5	Yes
11	G_2111	G_2079	31421	31425	853.2	876.1	DG_2111_31421	-22.9	Yes
11	G_2111	G_2079	33575	33574	851.4	856	DG_2111_33575	-4.6	Yes
11	G_2111	G_2079	35740	35740	857	864.5	DG_2111_35740	-7.5	Yes
11	G_2111	G_2079	37586	37585	850.2	851.61	DG_2111_37586	-1.41	Yes
11	G_2111	G_2079	39794	39794	852.1	860.2	DG_2111_39794	-8.1	Yes
11	G_2111	G_2079	43076	43076	844.2	851.2	DG_2111_43076	-7	Yes
12	G_2427	G_2426	30288	30288	843.9	830.1	DG_2427_30288	13.8	Yes
12	G_2427	G_2426	31028	31028	855	844.4	DG_2427_31028	10.6	Yes
12	G_2427	G_2426	31422	31422	886.9	839.7	DG_2427_31422	47.2	Yes
12	G_2427	G_2426	33568	33568	856.1	847.3	DG_2427_33568	8.8	Yes
13	G_2315	G_2357	26304	26304	803	804.9	DG_2315_26304	-1.9	Yes
13	G_2315	G_2357	32853	32853	857.9	845.6	DG_2315_32853	12.3	Yes
13	G_2315	G_2357	33574	33574	855.6	848	DG_2315_33574	7.6	Yes
13	G_2315	G_2357	35740	35740	865.5	856.6	DG_2315_35740	8.9	Yes
13	G_2315	G_2357	37586	37586	857.31	850.4	DG_2315_37586	6.91	Yes
13	G_2315	G_2357	39794	39793	861.5	854.2	DG_2315_39794	7.3	Yes
14	I_1985	G_2049	23008	23008	835.41	837.2	DI_1985_23008	-1.79	Yes
14	I_1985	G_2049	33555	33568	872.31	877.5	DI_1985_33555	-5.19	No
14	I_1985	G_2049	33568	33568	877.01	877.5	DI_1985_33568	-0.49	Yes
14	I_1985	G_2049	35730	35760	876.21	882.2	DI_1985_35730	-5.99	Yes
14	I_1985	G_2049	37596	37595	875.51	872.91	DI_1985_37596	2.6	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
15	G_3095	G_3114	22341	22280	791.3	793.46	DG_3095_22341	-2.16	Yes
15	G_3095	G_3114	35747	35732	769	788	DG_3095_35747	-19	Yes
15	G_3095	G_3114	37579	37579	802.4	819.31	DG_3095_37579	-16.91	Yes
16	G_3490	G_3466	33547	33547	709.8	736.4	DG_3490_33547	-26.6	No
16	G_3490	G_3466	35723	35723	722.7	718	DG_3490_35723	4.7	Yes
16	G_3490	G_3466	37585	37585	740.71	728.3	DG_3490_37585	12.41	Yes
17	G_1729	I_1667	35751	35737	899	893.44	DG_1729_35751	5.56	Yes
17	G_1729	I_1667	37616	37582	895	891.95	DG_1729_37616	3.05	Yes
18	G_2750	G_2704	26305	26305	855.7	859	DG_2750_26305	-3.3	Yes
19	G_3822	I_3816	22999	22999	822.9	821.3	DG_3822_22999	1.6	Yes
19	G_3822	I_3816	33548	33548	752	737.4	DG_3822_33548	14.6	Yes
19	G_3822	I_3816	34296	34296	775.9	777.4	DG_3822_34296	-1.5	Yes
19	G_3822	I_3816	34690	34690	753.6	756.6	DG_3822_34690	-3	Yes
19	G_3822	I_3816	35052	35024	722.1	751.2	DG_3822_35052	-29.1	Yes
19	G_3822	I_3816	36130	36129	718.1	723.5	DG_3822_36130	-5.4	Yes
19	G_3822	I_3816	36594	36594	737.1	740.8	DG_3822_36594	-3.7	Yes
19	G_3822	I_3816	37602	37596	829.9	763.3	DG_3822_37602	66.6	Yes
19	G_3822	I_3816	37998	37985	834.6	764.7	DG_3822_37998	69.9	Yes
19	G_3822	I_3816	38341	38341	834.4	785.8	DG_3822_38341	48.6	Yes
20	G_2042	G_2059	35747	35782	904	907.7	DG_2042_35747	-3.7	Yes
22	G_3154	G_3163	22280	22280	863.22	859.42	DG_3154_22280	3.8	No
22	G_3154	G_3163	35734	35752	886.3	875	DG_3154_35734	11.3	No
23	G_3919	G_3942	35767	35765	793	786	DG_3919_35767	7	Yes
23	G_3919	G_3942	39860	39805	773.8	780.9	DG_3919_39860	-7.1	Yes
24	G_2717	G_2671	26316	26316	872	876	DG_2717_26316	-4	Yes
24	G_2717	G_2671	32853	32853	921.5	915.8	DG_2717_32853	5.7	Yes
24	G_2717	G_2671	35747	35747	917.1	919	DG_2717_35747	-1.9	Yes
24	G_2717	G_2671	37578	37578	881.7	881.4	DG_2717_37578	0.3	Yes
24	G_2717	G_2671	39792	39792	894.4	893.7	DG_2717_39792	0.7	Yes
25	I_3235	G_3191	26665	26665	902	798	DI_3235_26665	104	No
25	I_3235	G_3191	26755	26755	909.2	906	DI_3235_26755	3.2	Yes
25	I_3235	G_3191	28522	28522	893	896	DI_3235_28522	-3	Yes
25	I_3235	G_3191	28856	28856	907	907	DI_3235_28856	0	Yes
25	I_3235	G_3191	28956	28956	909	909	DI_3235_28956	0	Yes
25	I_3235	G_3191	28991	28991	911	910	DI_3235_28991	1	Yes
25	I_3235	G_3191	29209	29209	912	918	DI_3235_29209	-6	Yes
25	I_3235	G_3191	29353	29353	920	925	DI_3235_29353	-5	Yes
25	I_3235	G_3191	29587	29587	933	936	DI_3235_29587	-3	Yes
25	I_3235	G_3191	33547	33547	937.8	932.6	DI_3235_33547	5.2	Yes
25	I_3235	G_3191	35748	35748	942	943	DI_3235_35748	-1	Yes
25	I_3235	G_3191	37585	37585	895.31	894.2	DI_3235_37585	1.11	Yes
25	I_3235	G_3191	39784	39848	909.1	898.1	DI_3235_39784	11	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
26	G_3442	G_3468	33562	33562	926.3	932.2	DG_3442_33562	-5.9	Yes
27	G_2466	G_2468	32854	32854	963.3	961.49	DG_2466_32854	1.81	Yes
27	G_2466	G_2468	33554	33554	957.9	956.19	DG_2466_33554	1.71	Yes
27	G_2466	G_2468	35745	35751	951.9	945.29	DG_2466_35745	6.61	Yes
27	G_2466	G_2468	37581	37581	931.91	929	DG_2466_37581	2.91	Yes
27	G_2466	G_2468	39791	39791	931.3	929.89	DG_2466_39791	1.41	Yes
27	G_2466	G_2468	43081	43081	907.6	906.29	DG_2466_43081	1.31	Yes
28	G_2121	G_2143	33553	33553	960.99	964.63	DG_2121_33553	-3.64	Yes
28	G_2121	G_2143	35746	35746	951.59	956.13	DG_2121_35746	-4.54	Yes
28	G_2121	G_2143	37582	37582	937.39	942.33	DG_2121_37582	-4.94	Yes
28	G_2121	G_2143	39791	39791	937.49	939.23	DG_2121_39791	-1.74	Yes
29	G_1661	I_1588	33557	33555	979.5	977.9	DG_1661_33557	1.6	Yes
29	G_1661	I_1588	35737	35752	975	976.6	DG_1661_35737	-1.6	Yes
30	I_3164	G_3167	35747	35738	1005.22	998	DI_3164_35747	7.22	Yes
30	I_3164	G_3167	37593	37592	988.43	974.61	DI_3164_37593	13.82	Yes
30	I_3164	G_3167	39784	39839	994.32	982.1	DI_3164_39784	12.22	Yes
30	I_3164	G_3167	41291	41309	993.22	984.4	DI_3164_41291	8.82	Yes
31	G_2023	G_2006	30292	30292	985	986.12	DG_2023_30292	-1.12	Yes
31	G_2023	G_2006	31019	31019	994.3	995.12	DG_2023_31019	-0.82	Yes
31	G_2023	G_2006	33562	33562	984.7	984.62	DG_2023_33562	0.08	Yes
31	G_2023	G_2006	35746	35746	981.2	981.42	DG_2023_35746	-0.22	Yes
31	G_2023	G_2006	39791	39791	966.6	967.62	DG_2023_39791	-1.02	Yes
32	G_1385	I_1485	33553	33553	1018	1023.44	DG_1385_33553	-5.44	Yes
32	G_1385	I_1485	37592	37592	1016.9	998.75	DG_1385_37592	18.15	Yes
33	G_3197	G_3259	33554	33547	1037.19	1029.9	DG_3197_33554	7.29	Yes
33	G_3197	G_3259	35744	35732	1074.19	1056	DG_3197_35744	18.19	Yes
34	G_2100	G_2099	23684	23684	1034.8	1037.87	DG_2100_23684	-3.07	Yes
34	G_2100	G_2099	23698	23698	1034.45	1037.68	DG_2100_23698	-3.23	Yes
34	G_2100	G_2099	23706	23706	1034.14	1037.57	DG_2100_23706	-3.43	Yes
34	G_2100	G_2099	23719	23719	1033.51	1037.01	DG_2100_23719	-3.5	Yes
34	G_2100	G_2099	23729	23729	1033.18	1036.67	DG_2100_23729	-3.49	Yes
34	G_2100	G_2099	23753	23753	1032.85	1036.1	DG_2100_23753	-3.25	Yes
34	G_2100	G_2099	23772	23772	1032.82	1035.8	DG_2100_23772	-2.98	Yes
34	G_2100	G_2099	23803	23803	1033.12	1035.78	DG_2100_23803	-2.66	Yes
34	G_2100	G_2099	23820	23820	1032.95	1035.58	DG_2100_23820	-2.63	Yes
34	G_2100	G_2099	23852	23855	1032.8	1035.67	DG_2100_23852	-2.87	No
34	G_2100	G_2099	23855	23855	1032.55	1035.67	DG_2100_23855	-3.12	Yes
34	G_2100	G_2099	23858	23858	1033.71	1035.83	DG_2100_23858	-2.12	Yes
34	G_2100	G_2099	23865	23865	1036.44	1036.71	DG_2100_23865	-0.27	Yes
34	G_2100	G_2099	23876	23876	1037.12	1038.3	DG_2100_23876	-1.18	Yes
34	G_2100	G_2099	23923	23923	1035.8	1038.1	DG_2100_23923	-2.3	Yes
34	G_2100	G_2099	23953	23953	1037.3	1039.2	DG_2100_23953	-1.9	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
34	G_2100	G_2099	23985	23985	1036.78	1039.52	DG_2100_23985	-2.74	Yes
34	G_2100	G_2099	24012	24012	1037.9	1038.1	DG_2100_24012	-0.2	Yes
34	G_2100	G_2099	24042	24042	1038	1040.5	DG_2100_24042	-2.5	Yes
34	G_2100	G_2099	24076	24076	1038.12	1041.14	DG_2100_24076	-3.02	Yes
34	G_2100	G_2099	24105	24105	1040.8	1041.46	DG_2100_24105	-0.66	Yes
34	G_2100	G_2099	24118	24118	1052.2	1052.7	DG_2100_24118	-0.5	Yes
34	G_2100	G_2099	24125	24125	1071.03	1059.66	DG_2100_24125	11.37	Yes
34	G_2100	G_2099	24142	24147	1069.26	1066.83	DG_2100_24142	2.43	Yes
34	G_2100	G_2099	24149	24149	1067.74	1067.66	DG_2100_24149	0.08	Yes
34	G_2100	G_2099	24163	24163	1068.72	1068.84	DG_2100_24163	-0.12	Yes
34	G_2100	G_2099	24173	24173	1071.82	1070.76	DG_2100_24173	1.06	Yes
34	G_2100	G_2099	24195	24195	1067.7	1071.42	DG_2100_24195	-3.72	Yes
34	G_2100	G_2099	24222	24222	1063.6	1068.46	DG_2100_24222	-4.86	Yes
34	G_2100	G_2099	24252	24251	1061.76	1066.85	DG_2100_24252	-5.09	Yes
34	G_2100	G_2099	24285	24285	1060.36	1064.51	DG_2100_24285	-4.15	Yes
34	G_2100	G_2099	24287	24285	1060.3	1064.51	DG_2100_24287	-4.21	No
34	G_2100	G_2099	24315	24315	1060.08	1064	DG_2100_24315	-3.92	Yes
34	G_2100	G_2099	24345	24345	1061.45	1064.5	DG_2100_24345	-3.05	Yes
34	G_2100	G_2099	24378	24378	1062.12	1065.15	DG_2100_24378	-3.03	Yes
34	G_2100	G_2099	24406	24406	1058.99	1063.43	DG_2100_24406	-4.44	Yes
34	G_2100	G_2099	24442	24442	1056.62	1061.2	DG_2100_24442	-4.58	Yes
34	G_2100	G_2099	24468	24468	1055.25	1059.64	DG_2100_24468	-4.39	Yes
34	G_2100	G_2099	24496	24496	1054.23	1058.3	DG_2100_24496	-4.07	Yes
34	G_2100	G_2099	24530	24530	1052.87	1055.86	DG_2100_24530	-2.99	Yes
34	G_2100	G_2099	24560	24560	1052.34	1055.84	DG_2100_24560	-3.5	Yes
34	G_2100	G_2099	24589	24589	1051.58	1054.9	DG_2100_24589	-3.32	Yes
34	G_2100	G_2099	24617	24617	1050.77	1054.02	DG_2100_24617	-3.25	Yes
34	G_2100	G_2099	24651	24651	1049.74	1052.84	DG_2100_24651	-3.1	Yes
34	G_2100	G_2099	24680	24680	1049.15	1052.13	DG_2100_24680	-2.98	Yes
34	G_2100	G_2099	24714	24714	1048.84	1052.91	DG_2100_24714	-4.07	Yes
34	G_2100	G_2099	24742	24742	1048.01	1051.04	DG_2100_24742	-3.03	Yes
34	G_2100	G_2099	24770	24769	1047.38	1050.35	DG_2100_24770	-2.97	Yes
34	G_2100	G_2099	24806	24806	1046.43	1049.58	DG_2100_24806	-3.15	Yes
34	G_2100	G_2099	24833	24833	1051.02	1049.54	DG_2100_24833	1.48	Yes
34	G_2100	G_2099	24867	24867	1050.8	1053.17	DG_2100_24867	-2.37	Yes
34	G_2100	G_2099	24883	24883	1049.47	1052.72	DG_2100_24883	-3.25	Yes
34	G_2100	G_2099	24884	24883	1049.43	1052.72	DG_2100_24884	-3.29	No
34	G_2100	G_2099	24887	24887	1050.98	1053.77	DG_2100_24887	-2.79	Yes
34	G_2100	G_2099	24894	24894	1054.2	1054.05	DG_2100_24894	0.15	Yes
34	G_2100	G_2099	24898	24898	1056.86	1055.33	DG_2100_24898	1.53	Yes
34	G_2100	G_2099	24902	24902	1058.76	1056.35	DG_2100_24902	2.41	Yes
34	G_2100	G_2099	24908	24908	1059.86	1058	DG_2100_24908	1.86	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
34	G_2100	G_2099	24912	24912	1061.34	1062.1	DG_2100_24912	-0.76	Yes
34	G_2100	G_2099	24916	24916	1062.89	1060.49	DG_2100_24916	2.4	Yes
34	G_2100	G_2099	24919	24919	1062.66	1061.06	DG_2100_24919	1.6	Yes
34	G_2100	G_2099	24923	24923	1063.81	1062.1	DG_2100_24923	1.71	Yes
34	G_2100	G_2099	24926	24926	1063.52	1062.6	DG_2100_24926	0.92	Yes
34	G_2100	G_2099	24930	24930	1063.08	1063.17	DG_2100_24930	-0.09	Yes
34	G_2100	G_2099	24933	24933	1062.6	1063.4	DG_2100_24933	-0.8	Yes
34	G_2100	G_2099	24940	24940	1061.92	1060.55	DG_2100_24940	1.37	Yes
34	G_2100	G_2099	24947	24947	1062.84	1064.01	DG_2100_24947	-1.17	Yes
34	G_2100	G_2099	24954	24954	1062.85	1065.26	DG_2100_24954	-2.41	Yes
34	G_2100	G_2099	24961	24961	1066.4	1066.49	DG_2100_24961	-0.09	Yes
34	G_2100	G_2099	24987	24987	1065.52	1067.55	DG_2100_24987	-2.03	Yes
34	G_2100	G_2099	25020	25020	1064.1	1066.81	DG_2100_25020	-2.71	Yes
34	G_2100	G_2099	25049	25049	1063.2	1066.52	DG_2100_25049	-3.32	Yes
34	G_2100	G_2099	25055	25055	1063.38	1066.45	DG_2100_25055	-3.07	Yes
34	G_2100	G_2099	25079	25076	1063.25	1066.8	DG_2100_25079	-3.55	Yes
34	G_2100	G_2099	25106	25106	1062.15	1065.66	DG_2100_25106	-3.51	Yes
34	G_2100	G_2099	25133	25133	1061.35	1064.75	DG_2100_25133	-3.4	Yes
34	G_2100	G_2099	25168	25168	1059.8	1063.46	DG_2100_25168	-3.66	Yes
34	G_2100	G_2099	25196	25196	1058.64	1062.14	DG_2100_25196	-3.5	Yes
34	G_2100	G_2099	25233	25233	1057.92	1061.2	DG_2100_25233	-3.28	Yes
34	G_2100	G_2099	25261	25261	1056.62	1060.07	DG_2100_25261	-3.45	Yes
34	G_2100	G_2099	25287	25287	1056.41	1059.2	DG_2100_25287	-2.79	Yes
34	G_2100	G_2099	25290	25290	1056.25	1059.16	DG_2100_25290	-2.91	Yes
34	G_2100	G_2099	25323	25323	1056.35	1058.96	DG_2100_25323	-2.61	Yes
34	G_2100	G_2099	25357	25357	1055.9	1058.61	DG_2100_25357	-2.71	Yes
34	G_2100	G_2099	25378	25378	1056.17	1058.56	DG_2100_25378	-2.39	Yes
34	G_2100	G_2099	25414	25414	1056.17	1058.5	DG_2100_25414	-2.33	Yes
34	G_2100	G_2099	25441	25441	1056.96	1058.4	DG_2100_25441	-1.44	Yes
34	G_2100	G_2099	25475	25475	1056.96	1059.06	DG_2100_25475	-2.1	Yes
34	G_2100	G_2099	25479	25479	1056.8	1059.12	DG_2100_25479	-2.32	Yes
34	G_2100	G_2099	25503	25503	1056.5	1058.25	DG_2100_25503	-1.75	Yes
34	G_2100	G_2099	25506	25506	1056.04	1058.2	DG_2100_25506	-2.16	Yes
34	G_2100	G_2099	25531	25531	1055.34	1057.7	DG_2100_25531	-2.36	Yes
34	G_2100	G_2099	25567	25567	1053.99	1055.93	DG_2100_25567	-1.94	Yes
34	G_2100	G_2099	25595	25595	1053.24	1056.33	DG_2100_25595	-3.09	Yes
34	G_2100	G_2099	25626	25626	1052.87	1055.31	DG_2100_25626	-2.44	Yes
34	G_2100	G_2099	25688	25688	1052.55	1054.77	DG_2100_25688	-2.22	Yes
34	G_2100	G_2099	25716	25716	1052.8	1055.09	DG_2100_25716	-2.29	Yes
34	G_2100	G_2099	25743	25743	1052.9	1055	DG_2100_25743	-2.1	Yes
34	G_2100	G_2099	25779	25779	1052.23	1054.84	DG_2100_25779	-2.61	Yes
34	G_2100	G_2099	25808	25808	1051.5	1053.05	DG_2100_25808	-1.55	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
34	G_2100	G_2099	25841	25841	1058.48	1058.23	DG_2100_25841	0.25	Yes
34	G_2100	G_2099	25869	25869	1056.54	1058.65	DG_2100_25869	-2.11	Yes
34	G_2100	G_2099	25895	25895	1054.98	1057.99	DG_2100_25895	-3.01	Yes
34	G_2100	G_2099	25925	25925	1053.63	1056.73	DG_2100_25925	-3.1	Yes
34	G_2100	G_2099	25959	25959	1052.57	1055.64	DG_2100_25959	-3.07	Yes
34	G_2100	G_2099	25990	25990	1051.71	1054.7	DG_2100_25990	-2.99	Yes
34	G_2100	G_2099	26024	26034	1050.68	1053.7	DG_2100_26024	-3.02	Yes
34	G_2100	G_2099	26050	26050	1050.13	1052.98	DG_2100_26050	-2.85	Yes
34	G_2100	G_2099	26077	26077	1049.35	1052.1	DG_2100_26077	-2.75	Yes
35	I_2906	G_2987	26755	26755	1213.8	1237	DI_2906_26755	-23.2	Yes
35	I_2906	G_2987	28522	28522	1208.8	1187	DI_2906_28522	21.8	No
35	I_2906	G_2987	28856	28856	1211.8	1228	DI_2906_28856	-16.2	Yes
35	I_2906	G_2987	28956	28956	1212.8	1235	DI_2906_28956	-22.2	Yes
35	I_2906	G_2987	29209	29209	1210.8	1235	DI_2906_29209	-24.2	Yes
35	I_2906	G_2987	29353	29353	1212.8	1235	DI_2906_29353	-22.2	Yes
35	I_2906	G_2987	29587	29587	1212.8	1235	DI_2906_29587	-22.2	Yes
35	I_2906	G_2987	30285	30317	1212.3	1227	DI_2906_30285	-14.7	Yes
35	I_2906	G_2987	33554	33555	1194.1	1223.7	DI_2906_33554	-29.6	Yes
35	I_2906	G_2987	35751	35773	1209.2	1226.2	DI_2906_35751	-17	Yes
36	G_0845	G_0843	23309	23309	1069	1056.5	DG_0845_23309	12.5	Yes
36	G_0845	G_0843	30231	30231	1066.6	1051	DG_0845_30231	15.6	Yes
36	G_0845	G_0843	30291	30291	1067	1057	DG_0845_30291	10	Yes
36	G_0845	G_0843	31015	31015	1067.6	1059.4	DG_0845_31015	8.2	Yes
37	G_1193	G_1209	33546	33549	1069.6	1054.4	DG_1193_33546	15.2	Yes
37	G_1193	G_1209	35746	35766	1087	1073	DG_1193_35746	14	Yes
38	G_2483	G_2455	30284	30329	1076.9	994.7	DG_2483_30284	82.2	Yes
38	G_2483	G_2455	35724	35723	1108	1060.9	DG_2483_35724	47.1	Yes
38	G_2483	G_2455	37578	37579	1104	1038.31	DG_2483_37578	65.69	Yes
39	G_3503	G_3516	30595	30595	939.8	914.2	DG_3503_30595	25.6	Yes
39	G_3503	G_3516	33563	33563	1018.3	933.2	DG_3503_33563	85.1	Yes
39	G_3503	G_3516	35772	35772	1099	970	DG_3503_35772	129	Yes
39	G_3503	G_3516	37634	37634	1121.81	992.21	DG_3503_37634	129.6	Yes
39	G_3503	G_3516	39868	39868	1088.9	1052.5	DG_3503_39868	36.4	Yes
39	G_3503	G_3516	43076	43076	1161.8	1055.9	DG_3503_43076	105.9	Yes
40	G_3716	A_3671	33556	33547	1039.2	975.87	DG_3716_33556	63.33	Yes
40	G_3716	A_3671	35774	35782	1090	983.87	DG_3716_35774	106.13	Yes
40	G_3716	A_3671	37586	37638	1090.61	993.78	DG_3716_37586	96.83	Yes
40	G_3716	A_3671	43077	43083	1114.5	1042.84	DG_3716_43077	71.66	Yes
41	G_3731	G_3726	26668	26668	1120.9	1112.1	DG_3731_26668	8.8	Yes
41	G_3731	G_3726	27050	27050	1101	1088.9	DG_3731_27050	12.1	Yes
41	G_3731	G_3726	27415	27415	1100.6	1096.9	DG_3731_27415	3.7	Yes
41	G_3731	G_3726	27754	27754	1071.4	1102.4	DG_3731_27754	-31	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
41	G_3731	G_3726	28516	28516	1081.4	1090.8	DG_3731_28516	-9.4	Yes
41	G_3731	G_3726	29286	29286	1092.5	1095.4	DG_3731_29286	-2.9	Yes
41	G_3731	G_3726	29628	29629	1096.7	1091.7	DG_3731_29628	5	Yes
41	G_3731	G_3726	29966	29966	1096.1	1089	DG_3731_29966	7.1	Yes
41	G_3731	G_3726	30287	30328	1092.5	1087.1	DG_3731_30287	5.4	Yes
41	G_3731	G_3726	30664	30664	1100	1089	DG_3731_30664	11	Yes
41	G_3731	G_3726	31013	31013	1095	1087.1	DG_3731_31013	7.9	Yes
41	G_3731	G_3726	33556	33547	1084.3	1077	DG_3731_33556	7.3	Yes
41	G_3731	G_3726	35774	35782	1090	1082	DG_3731_35774	8	Yes
42	G_3747	G_3746	24342	24341	1122	1081.4	DG_3747_24342	40.6	Yes
42	G_3747	G_3746	31490	31490	1084.7	1046.7	DG_3747_31490	38	Yes
42	G_3747	G_3746	33575	33575	1079.4	1044.1	DG_3747_33575	35.3	Yes
42	G_3747	G_3746	35780	35780	1085	1058	DG_3747_35780	27	Yes
42	G_3747	G_3746	37638	37638	1107.4	1094.21	DG_3747_37638	13.19	Yes
43	G_0700	G_0696	26290	26290	1064.3	1060.5	DG_0700_26290	3.8	Yes
43	G_0700	G_0696	26371	26290	1061.6	1060.5	DG_0700_26371	1.1	No
43	G_0700	G_0696	26725	26663	1063.1	1060	DG_0700_26725	3.1	Yes
43	G_0700	G_0696	30300	30293	1092.5	1059.9	DG_0700_30300	32.6	Yes
43	G_0700	G_0696	33547	33547	1105	1085.4	DG_0700_33547	19.6	Yes
44	G_2014	G_2035	26755	26755	985.5	974.4	DG_2014_26755	11.1	Yes
44	G_2014	G_2035	28522	28522	960	954	DG_2014_28522	6	Yes
44	G_2014	G_2035	28856	28856	975	966	DG_2014_28856	9	Yes
44	G_2014	G_2035	28956	28956	992	988	DG_2014_28956	4	Yes
44	G_2014	G_2035	28991	28991	995	994	DG_2014_28991	1	Yes
44	G_2014	G_2035	29209	29209	1010	1024	DG_2014_29209	-14	Yes
44	G_2014	G_2035	29353	29353	1016	1011	DG_2014_29353	5	Yes
44	G_2014	G_2035	29587	29587	1031	1025	DG_2014_29587	6	Yes
44	G_2014	G_2035	30284	30284	1000.5	984	DG_2014_30284	16.5	Yes
44	G_2014	G_2035	31014	31023	1032.6	1026.5	DG_2014_31014	6.1	Yes
44	G_2014	G_2035	33555	33555	1034.2	1022.2	DG_2014_33555	12	Yes
44	G_2014	G_2035	35753	35753	1082.9	1079.7	DG_2014_35753	3.2	Yes
44	G_2014	G_2035	37603	37603	1072.31	1062.2	DG_2014_37603	10.11	Yes
44	G_2014	G_2035	39791	39791	1114.3	1103.9	DG_2014_39791	10.4	Yes
45	G_0708	G_0678	26665	26665	1055.9	1039	DG_0708_26665	16.9	Yes
45	G_0708	G_0678	28522	28522	1047	1026	DG_0708_28522	21	Yes
45	G_0708	G_0678	28856	28856	1044	1028	DG_0708_28856	16	Yes
45	G_0708	G_0678	28956	28956	1052	1016	DG_0708_28956	36	Yes
45	G_0708	G_0678	28991	28991	1048	1001	DG_0708_28991	47	Yes
45	G_0708	G_0678	29209	29209	1051	1031	DG_0708_29209	20	Yes
45	G_0708	G_0678	29353	29353	1056	1015	DG_0708_29353	41	Yes
45	G_0708	G_0678	29587	29587	1062	1041	DG_0708_29587	21	Yes
45	G_0708	G_0678	33549	33549	1080.2	1050.2	DG_0708_33549	30	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
45	G_0708	G_0678	35759	35759	1101.6	1079	DG_0708_35759	22.6	Yes
46	A_2505	G_2493	26665	26665	948.78	951	DA_2505_26665	-2.22	Yes
46	A_2505	G_2493	26755	26755	959.88	961	DA_2505_26755	-1.12	Yes
46	A_2505	G_2493	28856	28856	948.78	954	DA_2505_28856	-5.22	Yes
46	A_2505	G_2493	28956	28956	965.78	963	DA_2505_28956	2.78	Yes
46	A_2505	G_2493	28991	28991	964.78	969	DA_2505_28991	-4.22	Yes
46	A_2505	G_2493	29209	29209	986.78	990	DA_2505_29209	-3.22	Yes
46	A_2505	G_2493	29353	29353	994.78	1002	DA_2505_29353	-7.22	Yes
46	A_2505	G_2493	29587	29587	1003.78	1017	DA_2505_29587	-13.22	Yes
46	A_2505	G_2493	33555	33555	1012.58	1021	DA_2505_33555	-8.42	Yes
46	A_2505	G_2493	35774	35774	1093.08	1098.3	DA_2505_35774	-5.22	Yes
46	A_2505	G_2493	39762	39792	1131.98	1121.1	DA_2505_39762	10.88	No
46	A_2505	G_2493	39780	39792	1127.02	1121.1	DA_2505_39780	5.92	Yes
47	G_0914	I_0923	33548	33546	1080.5	1068.98	DG_0914_33548	11.52	Yes
47	G_0914	I_0923	35766	35755	1100.9	1103.68	DG_0914_35766	-2.78	Yes
47	G_0914	I_0923	37582	37592	1093.31	1094.28	DG_0914_37582	-0.97	Yes
48	G_0080	G_0081	37658	37658	1200.7	1176.4	DG_0080_37658	24.3	Yes
48	G_0080	G_0081	39455	39455	1198.5	1169.3	DG_0080_39455	29.2	Yes
49	G_2020	G_2043	31005	31005	904.1	911.3	DG_2020_31005	-7.2	Yes
49	G_2020	G_2043	37623	37623	1031.4	1038.61	DG_2020_37623	-7.21	Yes
49	G_2020	G_2043	39806	39806	1084	1090.6	DG_2020_39806	-6.6	Yes
50	G_1650	G_1680	30288	30315	887.7	875.9	DG_1650_30288	11.8	Yes
50	G_1650	G_1680	33554	33553	940.8	933.1	DG_1650_33554	7.7	Yes
50	G_1650	G_1680	35787	35765	1019	1007.5	DG_1650_35787	11.5	Yes
51	G_1649	G_1580	33548	33548	931.8	934.8	DG_1649_33548	-3	Yes
51	G_1649	G_1580	37623	37623	1032.11	1032.11	DG_1649_37623	0	Yes
51	G_1649	G_1580	39806	39806	1076.1	1074.5	DG_1649_39806	1.6	Yes
52	I_0857	I_0856	26238	26238	1197.4	1197.6	DI_0857_26238	-0.2	Yes
52	I_0857	I_0856	26269	26269	1199.2	1198.6	DI_0857_26269	0.6	Yes
52	I_0857	I_0856	26322	26322	1200	1198.8	DI_0857_26322	1.2	Yes
52	I_0857	I_0856	26361	26361	1198.1	1198.4	DI_0857_26361	-0.3	Yes
52	I_0857	I_0856	26385	26385	1196.4	1197.6	DI_0857_26385	-1.2	Yes
52	I_0857	I_0856	26569	26569	1190.6	1197	DI_0857_26569	-6.4	Yes
52	I_0857	I_0856	29250	29250	1177.2	1155.8	DI_0857_29250	21.4	Yes
52	I_0857	I_0856	32490	32490	1161.8	1122.2	DI_0857_32490	39.6	Yes
52	I_0857	I_0856	32841	32841	1158.7	1118.6	DI_0857_32841	40.1	Yes
52	I_0857	I_0856	33218	33218	1159.1	1117.1	DI_0857_33218	42	Yes
52	I_0857	I_0856	33550	33550	1155.7	1114.5	DI_0857_33550	41.2	Yes
52	I_0857	I_0856	33924	33924	1161.4	1116.2	DI_0857_33924	45.2	Yes
52	I_0857	I_0856	34297	34297	1164.1	1116.9	DI_0857_34297	47.2	Yes
52	I_0857	I_0856	34660	34660	1163.9	1115.4	DI_0857_34660	48.5	Yes
52	I_0857	I_0856	35024	35024	1163.2	1114.2	DI_0857_35024	49	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
52	I_0857	I_0856	35409	35409	1164.8	1115.5	DI_0857_35409	49.3	Yes
52	I_0857	I_0856	35766	35766	1165.4	1115.9	DI_0857_35766	49.5	Yes
52	I_0857	I_0856	36130	36130	1163.2	1126.2	DI_0857_36130	37	Yes
52	I_0857	I_0856	36473	36473	1164.2	1125.1	DI_0857_36473	39.1	Yes
52	I_0857	I_0856	36843	36843	1164	1139.5	DI_0857_36843	24.5	Yes
52	I_0857	I_0856	37193	37193	1164	1139.8	DI_0857_37193	24.2	Yes
52	I_0857	I_0856	37984	37984	1166.1	1150	DI_0857_37984	16.1	Yes
52	I_0857	I_0856	38393	38393	1168.1	1152.5	DI_0857_38393	15.6	Yes
52	I_0857	I_0856	38722	38722	1169.6	1155.1	DI_0857_38722	14.5	Yes
52	I_0857	I_0856	39087	39087	1169.4	1158.1	DI_0857_39087	11.3	Yes
52	I_0857	I_0856	39449	39449	1171	1163.8	DI_0857_39449	7.2	Yes
52	I_0857	I_0856	39793	39793	1170.4	1162.9	DI_0857_39793	7.5	Yes
52	I_0857	I_0856	40156	40156	1172.9	1170.8	DI_0857_40156	2.1	Yes
52	I_0857	I_0856	40520	40520	1177	1176.7	DI_0857_40520	0.3	Yes
52	I_0857	I_0856	40882	40882	1180.6	1181.4	DI_0857_40882	-0.8	Yes
52	I_0857	I_0856	41240	41240	1182.7	1183.9	DI_0857_41240	-1.2	Yes
52	I_0857	I_0856	41590	41590	1185.2	1186.4	DI_0857_41590	-1.2	Yes
52	I_0857	I_0856	41960	41960	1187.7	1188.7	DI_0857_41960	-1	Yes
52	I_0857	I_0856	42345	42345	1191.4	1192.8	DI_0857_42345	-1.4	Yes
52	I_0857	I_0856	42702	42702	1192.1	1194.6	DI_0857_42702	-2.5	Yes
52	I_0857	I_0856	43084	43084	1182.1	1182	DI_0857_43084	0.1	Yes
53	I_0985	I_0984	28903	28903	1256.3	1168.2	DI_0985_28903	88.1	Yes
53	I_0985	I_0984	31411	31411	1244.1	1137.6	DI_0985_31411	106.5	Yes
53	I_0985	I_0984	31566	31566	1246.6	1138.5	DI_0985_31566	108.1	Yes
53	I_0985	I_0984	31751	31751	1249.8	1140.7	DI_0985_31751	109.1	Yes
53	I_0985	I_0984	31936	31936	1246.4	1135.5	DI_0985_31936	110.9	Yes
53	I_0985	I_0984	32134	32134	1244.8	1133.9	DI_0985_32134	110.9	Yes
53	I_0985	I_0984	32303	32303	1246.4	1132.1	DI_0985_32303	114.3	Yes
53	I_0985	I_0984	32485	32485	1243.1	1128.8	DI_0985_32485	114.3	Yes
53	I_0985	I_0984	32841	32841	1241.2	1131.6	DI_0985_32841	109.6	Yes
53	I_0985	I_0984	33221	33221	1240.6	1124.5	DI_0985_33221	116.1	Yes
53	I_0985	I_0984	33554	33554	1239.7	1122.1	DI_0985_33554	117.6	Yes
53	I_0985	I_0984	33924	33924	1239.2	1122.9	DI_0985_33924	116.3	Yes
53	I_0985	I_0984	34333	34333	1240.8	1120.2	DI_0985_34333	120.6	Yes
53	I_0985	I_0984	34653	34653	1241	1121.5	DI_0985_34653	119.5	Yes
53	I_0985	I_0984	35002	35002	1240.8	1121.2	DI_0985_35002	119.6	Yes
53	I_0985	I_0984	35375	35375	1236.9	1120.4	DI_0985_35375	116.5	Yes
53	I_0985	I_0984	35779	35779	1237.5	1120.3	DI_0985_35779	117.2	Yes
53	I_0985	I_0984	36117	36117	1236.7	1120.1	DI_0985_36117	116.6	Yes
53	I_0985	I_0984	36474	36474	1235.9	1118.1	DI_0985_36474	117.8	Yes
53	I_0985	I_0984	36837	36837	1234.1	1117.6	DI_0985_36837	116.5	Yes
53	I_0985	I_0984	37200	37200	1233	1122.1	DI_0985_37200	110.9	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
53	I_0985	I_0984	41226	41226	1229.9	1229.7	DI_0985_41226	0.2	Yes
53	I_0985	I_0984	41627	41627	1229.7	1229.5	DI_0985_41627	0.2	Yes
53	I_0985	I_0984	41960	41960	1229.1	1228.7	DI_0985_41960	0.4	Yes
53	I_0985	I_0984	42324	42324	1228.5	1227.6	DI_0985_42324	0.9	Yes
53	I_0985	I_0984	42683	42683	1228.8	1228.6	DI_0985_42683	0.2	Yes
53	I_0985	I_0984	43038	43038	1228.8	1228.2	DI_0985_43038	0.6	Yes
54	I_0705	I_0703	28940	28940	1166.64	1155.14	DI_0705_28940	11.5	Yes
54	I_0705	I_0703	28976	28976	1162.74	1155.34	DI_0705_28976	7.4	Yes
54	I_0705	I_0703	29014	29014	1158.64	1154.94	DI_0705_29014	3.7	Yes
54	I_0705	I_0703	29046	29046	1160.04	1157.04	DI_0705_29046	3	Yes
54	I_0705	I_0703	29075	29075	1156.34	1156.04	DI_0705_29075	0.3	Yes
54	I_0705	I_0703	29112	29112	1153.64	1156.54	DI_0705_29112	-2.9	Yes
54	I_0705	I_0703	29152	29152	1155.14	1155.74	DI_0705_29152	-0.6	Yes
54	I_0705	I_0703	29175	29175	1159.04	1154.94	DI_0705_29175	4.1	Yes
54	I_0705	I_0703	29252	29252	1170.34	1156.74	DI_0705_29252	13.6	Yes
54	I_0705	I_0703	29292	29292	1171.04	1157.14	DI_0705_29292	13.9	Yes
54	I_0705	I_0703	29329	29329	1170.64	1158.14	DI_0705_29329	12.5	Yes
54	I_0705	I_0703	29396	29396	1166.34	1155.54	DI_0705_29396	10.8	Yes
54	I_0705	I_0703	29427	29427	1161.54	1155.34	DI_0705_29427	6.2	Yes
54	I_0705	I_0703	29455	29455	1157.44	1155.14	DI_0705_29455	2.3	Yes
54	I_0705	I_0703	29486	29486	1158.94	1153.54	DI_0705_29486	5.4	Yes
54	I_0705	I_0703	29518	29518	1158.24	1154.04	DI_0705_29518	4.2	Yes
54	I_0705	I_0703	29545	29545	1157.64	1153.84	DI_0705_29545	3.8	Yes
54	I_0705	I_0703	29577	29577	1157.54	1153.44	DI_0705_29577	4.1	Yes
54	I_0705	I_0703	29610	29610	1158.24	1153.64	DI_0705_29610	4.6	Yes
54	I_0705	I_0703	29642	29642	1157.64	1152.84	DI_0705_29642	4.8	Yes
54	I_0705	I_0703	29670	29670	1159.84	1153.74	DI_0705_29670	6.1	Yes
54	I_0705	I_0703	29703	29703	1159.04	1153.14	DI_0705_29703	5.9	Yes
54	I_0705	I_0703	29732	29732	1157.84	1152.54	DI_0705_29732	5.3	Yes
54	I_0705	I_0703	29761	29761	1157.34	1152.54	DI_0705_29761	4.8	Yes
54	I_0705	I_0703	29948	29979	1160.14	1149.84	DI_0705_29948	10.3	Yes
54	I_0705	I_0703	29979	29979	1163.44	1149.84	DI_0705_29979	13.6	No
54	I_0705	I_0703	30648	30648	1159.64	1145.74	DI_0705_30648	13.9	Yes
54	I_0705	I_0703	30708	30708	1164.24	1145.84	DI_0705_30708	18.4	Yes
54	I_0705	I_0703	30858	30858	1163.14	1144.64	DI_0705_30858	18.5	Yes
54	I_0705	I_0703	31012	31012	1162.04	1143.44	DI_0705_31012	18.6	Yes
54	I_0705	I_0703	31098	31098	1166.54	1146.14	DI_0705_31098	20.4	Yes
54	I_0705	I_0703	31188	31188	1164.14	1144.94	DI_0705_31188	19.2	Yes
54	I_0705	I_0703	31278	31278	1160.74	1140.64	DI_0705_31278	20.1	Yes
54	I_0705	I_0703	31372	31372	1162.14	1140.14	DI_0705_31372	22	Yes
54	I_0705	I_0703	31566	31566	1154.24	1140.74	DI_0705_31566	13.5	Yes
54	I_0705	I_0703	31760	31750	1153.44	1135.84	DI_0705_31760	17.6	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
54	I_0705	I_0703	34129	34129	1155.54	1127.84	DI_0705_34129	27.7	Yes
54	I_0705	I_0703	34653	34653	1155.14	1131.94	DI_0705_34653	23.2	Yes
54	I_0705	I_0703	35002	35002	1155.64	1134.34	DI_0705_35002	21.3	Yes
54	I_0705	I_0703	35375	35375	1152.84	1135.04	DI_0705_35375	17.8	Yes
54	I_0705	I_0703	35779	35779	1156.74	1137.04	DI_0705_35779	19.7	Yes
54	I_0705	I_0703	36117	36117	1158.74	1138.64	DI_0705_36117	20.1	Yes
54	I_0705	I_0703	36474	36474	1160.54	1140.24	DI_0705_36474	20.3	Yes
54	I_0705	I_0703	36888	36888	1163.14	1142.44	DI_0705_36888	20.7	Yes
54	I_0705	I_0703	37974	37974	1163.24	1144.44	DI_0705_37974	18.8	Yes
54	I_0705	I_0703	38335	38335	1166.64	1147.64	DI_0705_38335	19	Yes
54	I_0705	I_0703	38714	38714	1169.84	1147.54	DI_0705_38714	22.3	Yes
54	I_0705	I_0703	39078	39078	1167.54	1148.54	DI_0705_39078	19	Yes
54	I_0705	I_0703	39798	39798	1169.14	1152.34	DI_0705_39798	16.8	Yes
54	I_0705	I_0703	40135	40135	1171.14	1153.74	DI_0705_40135	17.4	Yes
54	I_0705	I_0703	40519	40519	1171.04	1156.84	DI_0705_40519	14.2	Yes
54	I_0705	I_0703	40941	40941	1174.14	1158.54	DI_0705_40941	15.6	Yes
54	I_0705	I_0703	41226	41226	1174.64	1158.74	DI_0705_41226	15.9	Yes
54	I_0705	I_0703	41627	41627	1174.54	1158.44	DI_0705_41627	16.1	Yes
54	I_0705	I_0703	41961	41961	1178.54	1161.14	DI_0705_41961	17.4	Yes
54	I_0705	I_0703	42324	42324	1178.64	1158.14	DI_0705_42324	20.5	Yes
54	I_0705	I_0703	42683	42683	1178.94	1163.24	DI_0705_42683	15.7	Yes
54	I_0705	I_0703	43038	43038	1182.64	1164.04	DI_0705_43038	18.6	Yes
55	I_0362	I_0361	28906	28906	1086	1104.7	DI_0362_28906	-18.7	Yes
55	I_0362	I_0361	28907	28906	1086	1104.7	DI_0362_28907	-18.7	No
55	I_0362	I_0361	28940	28940	1032	1082.5	DI_0362_28940	-50.5	Yes
55	I_0362	I_0361	28976	28976	1053.3	1084	DI_0362_28976	-30.7	Yes
55	I_0362	I_0361	29014	29014	1059.7	1088	DI_0362_29014	-28.3	Yes
55	I_0362	I_0361	29046	29046	1015.9	1071.4	DI_0362_29046	-55.5	Yes
55	I_0362	I_0361	29076	29076	1006.1	1064.5	DI_0362_29076	-58.4	Yes
55	I_0362	I_0361	29112	29076	1018.6	1064.5	DI_0362_29112	-45.9	No
55	I_0362	I_0361	29151	29152	1072.4	1092.5	DI_0362_29151	-20.1	Yes
55	I_0362	I_0361	29175	29175	1078.7	1096.1	DI_0362_29175	-17.4	Yes
55	I_0362	I_0361	29259	29259	1087.2	1104.6	DI_0362_29259	-17.4	Yes
55	I_0362	I_0361	29292	29292	1062.5	1093.3	DI_0362_29292	-30.8	Yes
55	I_0362	I_0361	29329	29329	1045.9	1077.9	DI_0362_29329	-32	Yes
55	I_0362	I_0361	29363	29363	1037.2	1082.5	DI_0362_29363	-45.3	Yes
55	I_0362	I_0361	29396	29396	1013	1069.4	DI_0362_29396	-56.4	Yes
55	I_0362	I_0361	29426	29396	1001.7	1069.4	DI_0362_29426	-67.7	No
55	I_0362	I_0361	29455	29396	995.3	1069.4	DI_0362_29455	-74.1	No
55	I_0362	I_0361	29486	29517	999.6	1084.1	DI_0362_29486	-84.5	No
55	I_0362	I_0361	29517	29517	1061.3	1084.1	DI_0362_29517	-22.8	Yes
55	I_0362	I_0361	29545	29545	1071.1	1091.3	DI_0362_29545	-20.2	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
55	I_0362	I_0361	29577	29577	1057.3	1090.5	DI_0362_29577	-33.2	Yes
55	I_0362	I_0361	29609	29609	1067.1	1094.6	DI_0362_29609	-27.5	Yes
55	I_0362	I_0361	29642	29642	1052.7	1084.8	DI_0362_29642	-32.1	Yes
55	I_0362	I_0361	29670	29670	1008.9	1070.7	DI_0362_29670	-61.8	Yes
55	I_0362	I_0361	29700	29727	997	1074.2	DI_0362_29700	-77.2	No
55	I_0362	I_0361	29727	29727	978	1074.2	DI_0362_29727	-96.2	Yes
55	I_0362	I_0361	29761	29727	997.7	1074.2	DI_0362_29761	-76.5	No
55	I_0362	I_0361	29790	29727	979.8	1074.2	DI_0362_29790	-94.4	No
55	I_0362	I_0361	29817	29882	985	1076.4	DI_0362_29817	-91.4	No
55	I_0362	I_0361	29850	29882	1044.8	1076.4	DI_0362_29850	-31.6	No
55	I_0362	I_0361	29882	29882	1050.3	1076.4	DI_0362_29882	-26.1	Yes
55	I_0362	I_0361	29910	29882	1061.7	1076.4	DI_0362_29910	-14.7	No
55	I_0362	I_0361	29943	29943	1060.4	1086.9	DI_0362_29943	-26.5	Yes
55	I_0362	I_0361	29979	29979	1066.3	1089.6	DI_0362_29979	-23.3	Yes
55	I_0362	I_0361	30217	30217	1033.9	1061.6	DI_0362_30217	-27.7	Yes
55	I_0362	I_0361	30246	30246	1056.9	1076.7	DI_0362_30246	-19.8	Yes
55	I_0362	I_0361	30343	30343	1066.7	1087.5	DI_0362_30343	-20.8	Yes
55	I_0362	I_0361	30551	30551	1058.1	1068.5	DI_0362_30551	-10.4	Yes
55	I_0362	I_0361	30649	30649	1076.1	1089.4	DI_0362_30649	-13.3	Yes
55	I_0362	I_0361	30706	30706	1077.3	1090.7	DI_0362_30706	-13.4	Yes
55	I_0362	I_0361	30735	30735	1075.5	1089.6	DI_0362_30735	-14.1	Yes
55	I_0362	I_0361	30859	30859	1075	1088.3	DI_0362_30859	-13.3	Yes
55	I_0362	I_0361	31012	31012	1073.8	1080.8	DI_0362_31012	-7	Yes
55	I_0362	I_0361	31098	31098	1075.8	1090.2	DI_0362_31098	-14.4	Yes
55	I_0362	I_0361	31188	31188	1075.5	1089.1	DI_0362_31188	-13.6	Yes
55	I_0362	I_0361	31279	31279	1012.4	1038.8	DI_0362_31279	-26.4	Yes
55	I_0362	I_0361	31372	31372	1018.8	1041.4	DI_0362_31372	-22.6	Yes
55	I_0362	I_0361	31469	31470	1070.6	1086.2	DI_0362_31469	-15.6	Yes
55	I_0362	I_0361	31552	31552	1024.1	1063.4	DI_0362_31552	-39.3	Yes
55	I_0362	I_0361	31582	31582	1018	1062.3	DI_0362_31582	-44.3	Yes
55	I_0362	I_0361	31615	31615	1020.1	1056.8	DI_0362_31615	-36.7	Yes
55	I_0362	I_0361	31642	31642	1009.8	1053.1	DI_0362_31642	-43.3	Yes
55	I_0362	I_0361	31691	31691	1052.9	1064.1	DI_0362_31691	-11.2	Yes
55	I_0362	I_0361	31700	31700	1056.8	1068.6	DI_0362_31700	-11.8	Yes
55	I_0362	I_0361	31734	31734	1064.4	1077.4	DI_0362_31734	-13	Yes
55	I_0362	I_0361	31762	31762	1073.8	1082	DI_0362_31762	-8.2	Yes
55	I_0362	I_0361	31797	31797	1071.5	1085.5	DI_0362_31797	-14	Yes
55	I_0362	I_0361	31826	31826	1073.2	1088.4	DI_0362_31826	-15.2	Yes
55	I_0362	I_0361	31853	31853	1056.6	1087.1	DI_0362_31853	-30.5	Yes
55	I_0362	I_0361	31892	31890	1056.3	1080.5	DI_0362_31892	-24.2	Yes
55	I_0362	I_0361	31915	31915	1058.5	1076.3	DI_0362_31915	-17.8	Yes
55	I_0362	I_0361	31951	31951	1057.6	1075.2	DI_0362_31951	-17.6	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
55	I_0362	I_0361	31979	31979	1057.4	1076.9	DI_0362_31979	-19.5	Yes
55	I_0362	I_0361	32014	32014	1057	1053.9	DI_0362_32014	3.1	Yes
55	I_0362	I_0361	32045	32049	1058	1055.1	DI_0362_32045	2.9	Yes
55	I_0362	I_0361	32076	32076	1057.9	1072.6	DI_0362_32076	-14.7	Yes
55	I_0362	I_0361	32105	32105	1064.7	1081	DI_0362_32105	-16.3	Yes
55	I_0362	I_0361	32139	32139	1069.6	1086.1	DI_0362_32139	-16.5	Yes
55	I_0362	I_0361	32171	32171	1073.7	1090.8	DI_0362_32171	-17.1	Yes
55	I_0362	I_0361	34129	34129	1091	1104.8	DI_0362_34129	-13.8	Yes
55	I_0362	I_0361	34540	34540	1105.3	1113.3	DI_0362_34540	-8	Yes
55	I_0362	I_0361	34653	34653	1110.4	1117.7	DI_0362_34653	-7.3	Yes
55	I_0362	I_0361	35002	35002	1105.7	1126.1	DI_0362_35002	-20.4	Yes
55	I_0362	I_0361	35375	35375	1119.1	1129.6	DI_0362_35375	-10.5	Yes
55	I_0362	I_0361	35779	35779	1129.1	1139.3	DI_0362_35779	-10.2	Yes
55	I_0362	I_0361	36117	36117	1136.7	1145.6	DI_0362_36117	-8.9	Yes
55	I_0362	I_0361	36474	36474	1143	1150.8	DI_0362_36474	-7.8	Yes
55	I_0362	I_0361	36837	36837	1148	1151.1	DI_0362_36837	-3.1	Yes
55	I_0362	I_0361	37214	37214	1148.7	1168.75	DI_0362_37214	-20.05	Yes
55	I_0362	I_0361	37557	37557	1157.25	1164.5	DI_0362_37557	-7.25	Yes
55	I_0362	I_0361	37974	37974	1166	1169.4	DI_0362_37974	-3.4	Yes
55	I_0362	I_0361	38334	38334	1171.3	1173.8	DI_0362_38334	-2.5	Yes
55	I_0362	I_0361	38706	38706	1172.2	1176.7	DI_0362_38706	-4.5	Yes
55	I_0362	I_0361	39798	39798	1177.6	1179.8	DI_0362_39798	-2.2	Yes
55	I_0362	I_0361	40128	40135	1176.4	1181.4	DI_0362_40128	-5	Yes
55	I_0362	I_0361	40528	40528	1185.6	1188.1	DI_0362_40528	-2.5	Yes
55	I_0362	I_0361	40934	40934	1172.9	1190.2	DI_0362_40934	-17.3	Yes
55	I_0362	I_0361	41228	41228	1187.1	1186.4	DI_0362_41228	0.7	Yes
55	I_0362	I_0361	41627	41627	1189.9	1188.9	DI_0362_41627	1	Yes
55	I_0362	I_0361	41961	41961	1191.4	1192	DI_0362_41961	-0.6	Yes
55	I_0362	I_0361	42326	42326	1190.6	1191.1	DI_0362_42326	-0.5	Yes
55	I_0362	I_0361	42746	42746	1201	1197.1	DI_0362_42746	3.9	Yes
56	I_0230	I_0229	28906	28906	1147.9	1152.6	DI_0230_28906	-4.7	Yes
56	I_0230	I_0229	31400	31400	1130.2	1134.7	DI_0230_31400	-4.5	Yes
56	I_0230	I_0229	31568	31568	1127.7	1129.8	DI_0230_31568	-2.1	Yes
56	I_0230	I_0229	31937	31937	1129	1133.7	DI_0230_31937	-4.7	Yes
56	I_0230	I_0229	32139	32139	1129.2	1134.8	DI_0230_32139	-5.6	Yes
56	I_0230	I_0229	32303	32303	1119.9	1130	DI_0230_32303	-10.1	Yes
56	I_0230	I_0229	32484	32484	1127.4	1131.5	DI_0230_32484	-4.1	Yes
56	I_0230	I_0229	32843	32843	1127.5	1131.5	DI_0230_32843	-4	Yes
56	I_0230	I_0229	33221	33221	1127.5	1131.9	DI_0230_33221	-4.4	Yes
56	I_0230	I_0229	33556	33556	1127.9	1132.4	DI_0230_33556	-4.5	Yes
56	I_0230	I_0229	33926	33926	1130.7	1136.4	DI_0230_33926	-5.7	Yes
56	I_0230	I_0229	34303	34303	1136	1140.4	DI_0230_34303	-4.4	Yes

Table 5-4 Vertical Head Difference Pairs

Pair No.	Well1	Well2	Time1	Time2	OBS1	OBS2	OBSNAM	OBSVAL	Included in Calibration
56	I_0230	I_0229	34661	34660	1140.5	1147.1	DI_0230_34661	-6.6	Yes
56	I_0230	I_0229	35024	35024	1145.8	1152.1	DI_0230_35024	-6.3	Yes
56	I_0230	I_0229	35726	35726	1157.3	1163.8	DI_0230_35726	-6.5	Yes
56	I_0230	I_0229	36132	36132	1163	1168.6	DI_0230_36132	-5.6	Yes
56	I_0230	I_0229	36474	36474	1166.2	1168.7	DI_0230_36474	-2.5	Yes
56	I_0230	I_0229	36843	36843	1173.4	1177.2	DI_0230_36843	-3.8	Yes
56	I_0230	I_0229	37194	37194	1178.4	1181.7	DI_0230_37194	-3.3	Yes
56	I_0230	I_0229	37634	37634	1184.9	1187.9	DI_0230_37634	-3	Yes
56	I_0230	I_0229	38364	38364	1192.3	1194.5	DI_0230_38364	-2.2	Yes
56	I_0230	I_0229	38723	38723	1196.6	1198.6	DI_0230_38723	-2	Yes
56	I_0230	I_0229	39086	39086	1197.4	1198.8	DI_0230_39086	-1.4	Yes
56	I_0230	I_0229	39449	39449	1199.3	1200.6	DI_0230_39449	-1.3	Yes
56	I_0230	I_0229	39798	39798	1200.4	1201.3	DI_0230_39798	-0.9	Yes
56	I_0230	I_0229	40158	40158	1202.7	1203.6	DI_0230_40158	-0.9	Yes
56	I_0230	I_0229	40519	40519	1206.4	1207.1	DI_0230_40519	-0.7	Yes
56	I_0230	I_0229	40885	40885	1208.3	1209.3	DI_0230_40885	-1	Yes
56	I_0230	I_0229	41242	41242	1209.4	1210.5	DI_0230_41242	-1.1	Yes
56	I_0230	I_0229	41593	41593	1210.5	1211.8	DI_0230_41593	-1.3	Yes
56	I_0230	I_0229	41962	41962	1212.3	1213.6	DI_0230_41962	-1.3	Yes
56	I_0230	I_0229	42348	42348	1213	1214.3	DI_0230_42348	-1.3	Yes
56	I_0230	I_0229	42704	42704	1213.5	1214.6	DI_0230_42704	-1.1	Yes

Notes:
Time is in model days (cumulative from 1/1/1900).
Observations are in feet above mean sea level.
OBSVAL calculated as OBS1 minus OBS2.

Table 5-5 Streamflow Target Descriptions

PEST ID	Group	Observation (CFD)	Observation (AFY)	Row	Column	Description
gage1_30	annualgr1	5.18E+06	43,468	77	101	Gila River before confluence - 1930
gage1_31	annualgr1	4.32E+06	36,223	77	101	Gila River before confluence - 1931
gage1_32	annualgr1	5.18E+06	43,468	77	101	Gila River before confluence - 1932
gage1_33	annualgr1	4.32E+06	36,223	77	101	Gila River before confluence - 1933
gage1_34	annualgr1	3.46E+06	28,979	77	101	Gila River before confluence - 1934
gage1_35	annualgr1	3.89E+06	32,601	77	101	Gila River before confluence - 1935
gage1_36	annualgr1	4.15E+06	34,774	77	101	Gila River before confluence - 1936
gage1_37	annualgr1	4.32E+06	36,223	77	101	Gila River before confluence - 1937
gage1_38	annualgr1	3.46E+06	28,979	77	101	Gila River before confluence - 1938
gage1_39	annualgr1	3.46E+06	28,979	77	101	Gila River before confluence - 1939
gage1_40	annualgr1	3.46E+06	28,979	77	101	Gila River before confluence - 1940
gage2_30	annualgr1	7.78E+06	65,202	76	102	Salt River before confluence - 1930
gage2_31	annualgr1	6.91E+06	57,957	76	102	Salt River before confluence - 1931
gage2_32	annualgr1	6.05E+06	50,712	76	102	Salt River before confluence - 1932
gage2_33	annualgr1	5.62E+06	47,090	76	102	Salt River before confluence - 1933
gage2_34	annualgr1	5.18E+06	43,468	76	102	Salt River before confluence - 1934
gage2_35	annualgr1	5.18E+06	43,468	76	102	Salt River before confluence - 1935
gage2_36	annualgr1	6.05E+06	50,712	76	102	Salt River before confluence - 1936
gage2_37	annualgr1	6.05E+06	50,712	76	102	Salt River before confluence - 1937
gage2_38	annualgr1	6.91E+06	57,957	76	102	Salt River before confluence - 1938
gage2_39	annualgr1	5.62E+06	47,090	76	102	Salt River before confluence - 1939
gage2_40	annualgr1	4.32E+06	36,223	76	102	Salt River before confluence - 1940
gage3_30	annualgr1	1.47E+07	123,259	75	95	Gila River above Agua Fria - 1930
gage3_31	annualgr1	1.38E+07	115,713	75	95	Gila River above Agua Fria - 1931
gage3_32	annualgr1	1.43E+07	119,905	75	95	Gila River above Agua Fria - 1932
gage3_33	annualgr1	1.21E+07	101,458	75	95	Gila River above Agua Fria - 1933
gage3_34	annualgr1	1.08E+07	90,558	75	95	Gila River above Agua Fria - 1934
gage3_35	annualgr1	9.94E+06	83,313	75	95	Gila River above Agua Fria - 1935
gage3_36	annualgr1	1.04E+07	87,204	75	95	Gila River above Agua Fria - 1936
gage3_37	annualgr1	1.12E+07	93,912	75	95	Gila River above Agua Fria - 1937
gage3_38	annualgr1	1.17E+07	98,104	75	95	Gila River above Agua Fria - 1938
gage3_39	annualgr1	9.50E+06	79,691	75	95	Gila River above Agua Fria - 1939
gage3_40	annualgr1	8.81E+06	73,895	75	95	Gila River above Agua Fria - 1940
gage4_94	annualgr4	1.90E+07	159,315	96	47	Gila River at Gillespie Dam - 1994
gage4_95	annualgr4	1.26E+08	1,056,508	96	47	Gila River at Gillespie Dam - 1995
gage4_96	annualgr4	1.18E+07	98,943	96	47	Gila River at Gillespie Dam - 1996
gage4_97	annualgr4	1.15E+07	96,427	96	47	Gila River at Gillespie Dam - 1997
gage4_98	annualgr4	1.52E+07	127,452	96	47	Gila River at Gillespie Dam - 1998
gage4_99	annualgr4	1.27E+07	106,489	96	47	Gila River at Gillespie Dam - 1999
gage4_00	annualgr4	1.58E+07	132,483	96	47	Gila River at Gillespie Dam - 2000
gage4_01	annualgr4	1.27E+07	106,489	96	47	Gila River at Gillespie Dam - 2001
gage4_02	annualgr4	9.49E+06	79,550	96	47	Gila River at Gillespie Dam - 2002
gage4_03	annualgr4	9.24E+06	77,460	96	47	Gila River at Gillespie Dam - 2003
gage4_04	annualgr4	8.90E+06	74,629	96	47	Gila River at Gillespie Dam - 2004
gage4_06	annualgr4	9.93E+06	83,302	96	47	Gila River at Gillespie Dam - 2006
gage4_07	annualgr4	9.26E+06	77,647	96	47	Gila River at Gillespie Dam - 2007

Table 5-5 Streamflow Target Descriptions

PEST ID	Group	Observation (CFD)	Observation (AFY)	Row	Column	Description
gage4_08	annualgr4	1.94E+07	162,669	96	47	Gila River at Gillespie Dam - 2008
gage4_09	annualgr4	1.15E+07	96,427	96	47	Gila River at Gillespie Dam - 2009
gage4_10	annualgr4	6.85E+07	574,372	96	47	Gila River at Gillespie Dam - 2010
gage4_11	annualgr4	8.40E+06	70,425	96	47	Gila River at Gillespie Dam - 2011
gage4_12	annualgr4	7.57E+06	63,510	96	47	Gila River at Gillespie Dam - 2012
gage4_13	annualgr4	7.41E+06	62,106	96	47	Gila River at Gillespie Dam - 2013
gage4_14	annualgr4	8.39E+06	70,313	96	47	Gila River at Gillespie Dam - 2014
gage4_15	annualgr4	6.99E+06	58,639	96	47	Gila River at Gillespie Dam - 2015
gage4_16	annualgr4	7.43E+06	62,279	96	47	Gila River at Gillespie Dam - 2016
gage4_17	annualgr4	9.34E+06	78,299	96	47	Gila River at Gillespie Dam - 2017
gage4_18	annualgr4	1.32E+06	11,083	96	47	Gila River at Gillespie Dam - 2018
gage4_19	annualgr4	3.52E+06	29,474	96	47	Gila River at Gillespie Dam - 2019
gage4_20	annualgr4	1.19E+06	10,004	96	47	Gila River at Gillespie Dam - 2020
gage4_21	annualgr4	1.15E+06	9,674	96	47	Gila River at Gillespie Dam - 2021
gage5_22	annualgr5	1.50E+07	125,775	75	94	BIC headgate diversion - 1922
gage5_23	annualgr5	1.93E+07	161,830	75	94	BIC headgate diversion - 1923
gage5_24	annualgr5	1.83E+07	153,445	75	94	BIC headgate diversion - 1924
gage5_25	annualgr5	1.98E+07	166,023	75	94	BIC headgate diversion - 1925
gage5_26	annualgr5	1.91E+07	160,153	75	94	BIC headgate diversion - 1926
gage5_27	annualgr5	1.95E+07	163,507	75	94	BIC headgate diversion - 1927
gage5_28	annualgr5	1.70E+07	142,545	75	94	BIC headgate diversion - 1928
gage5_29	annualgr5	1.61E+07	134,998	75	94	BIC headgate diversion - 1929
gage5_30	annualgr5	1.51E+07	126,613	75	94	BIC headgate diversion - 1930
gage5_31	annualgr5	1.39E+07	116,551	75	94	BIC headgate diversion - 1931
gage5_32	annualgr5	1.44E+07	120,744	75	94	BIC headgate diversion - 1932
gage5_33	annualgr5	1.21E+07	101,458	75	94	BIC headgate diversion - 1933
gage5_34	annualgr5	1.02E+07	85,527	75	94	BIC headgate diversion - 1934
gage5_35	annualgr5	1.22E+07	102,297	75	94	BIC headgate diversion - 1935
gage5_36	annualgr5	1.12E+07	93,912	75	94	BIC headgate diversion - 1936
gage5_37	annualgr5	1.30E+07	109,005	75	94	BIC headgate diversion - 1937
gage5_38	annualgr5	1.10E+07	92,235	75	94	BIC headgate diversion - 1938
gage5_39	annualgr5	1.03E+07	86,365	75	94	BIC headgate diversion - 1939
gage5_40	annualgr5	9.14E+06	76,680	75	94	BIC headgate diversion - 1940
gage5_41	annualgr5	1.43E+07	119,905	75	94	BIC headgate diversion - 1941
gage5_42	annualgr5	1.02E+07	85,527	75	94	BIC headgate diversion - 1942
gage5_43	annualgr5	9.49E+06	79,589	75	94	BIC headgate diversion - 1943
gage5_44	annualgr5	9.70E+06	81,321	75	94	BIC headgate diversion - 1944
gage5_45	annualgr5	9.65E+06	80,902	75	94	BIC headgate diversion - 1945
gage5_46	annualgr5	9.83E+06	82,424	75	94	BIC headgate diversion - 1946
gage5_47	annualgr5	7.42E+06	62,217	75	94	BIC headgate diversion - 1947
gage5_48	annualgr5	4.96E+06	41,569	75	94	BIC headgate diversion - 1948
gage5_49	annualgr5	4.96E+06	41,591	75	94	BIC headgate diversion - 1949
gage5_50	annualgr5	3.94E+06	33,026	75	94	BIC headgate diversion - 1950
gage5_51	annualgr5	4.18E+06	35,058	75	94	BIC headgate diversion - 1951
gage5_52	annualgr5	5.61E+06	47,022	75	94	BIC headgate diversion - 1952
gage5_53	annualgr5	3.90E+06	32,731	75	94	BIC headgate diversion - 1953

Table 5-5 Streamflow Target Descriptions

PEST ID	Group	Observation (CFD)	Observation (AFY)	Row	Column	Description
gage5_54	annualgr5	3.99E+06	33,470	75	94	BIC headgate diversion - 1954
gage5_55	annualgr5	4.09E+06	34,267	75	94	BIC headgate diversion - 1955
gage5_56	annualgr5	1.91E+06	16,011	75	94	BIC headgate diversion - 1956
gage5_57	annualgr5	1.18E+06	9,853	75	94	BIC headgate diversion - 1957
gage5_58	annualgr5	2.46E+06	20,647	75	94	BIC headgate diversion - 1958
gage5_59	annualgr5	1.70E+06	14,272	75	94	BIC headgate diversion - 1959
gage5_60	annualgr5	2.16E+06	18,112	75	94	BIC headgate diversion - 1960
gage5_61	annualgr5	1.71E+06	14,344	75	94	BIC headgate diversion - 1961
gage5_62	annualgr5	1.95E+06	16,373	75	94	BIC headgate diversion - 1962
gage5_63	annualgr5	2.23E+06	18,691	75	94	BIC headgate diversion - 1963
gage5_64	annualgr5	3.37E+06	28,254	75	94	BIC headgate diversion - 1964
gage5_65	annualgr5	3.07E+06	25,718	75	94	BIC headgate diversion - 1965
gage5_66	annualgr5	5.07E+06	42,526	75	94	BIC headgate diversion - 1966
gage5_67	annualgr5	5.50E+06	46,076	75	94	BIC headgate diversion - 1967
gage5_68	annualgr5	7.31E+06	61,290	75	94	BIC headgate diversion - 1968
gage5_69	annualgr5	7.09E+06	59,478	75	94	BIC headgate diversion - 1969
gage5_70	annualgr5	6.23E+06	52,234	75	94	BIC headgate diversion - 1970
gage5_71	annualgr5	7.74E+06	64,912	75	94	BIC headgate diversion - 1971
gage5_72	annualgr5	7.02E+06	58,878	75	94	BIC headgate diversion - 1972
gage5_73	annualgr5	8.34E+06	69,957	75	94	BIC headgate diversion - 1973
gage5_74	annualgr5	8.22E+06	68,915	75	94	BIC headgate diversion - 1974
gage5_75	annualgr5	7.17E+06	60,099	75	94	BIC headgate diversion - 1975
gage5_76	annualgr5	8.88E+06	74,483	75	94	BIC headgate diversion - 1976
gage5_77	annualgr5	1.04E+07	87,204	75	94	BIC headgate diversion - 1977
gage5_78	annualgr5	7.88E+06	66,103	75	94	BIC headgate diversion - 1978
gage5_79	annualgr5	9.12E+06	76,439	75	94	BIC headgate diversion - 1979
gage5_80	annualgr5	1.16E+07	97,266	75	94	BIC headgate diversion - 1980
gage5_81	annualgr5	1.61E+07	134,998	75	94	BIC headgate diversion - 1981
gage5_82	annualgr5	1.61E+07	134,998	75	94	BIC headgate diversion - 1982
gage5_83	annualgr5	1.12E+07	93,912	75	94	BIC headgate diversion - 1983
gage5_84	annualgr5	1.64E+07	137,514	75	94	BIC headgate diversion - 1984
gage5_85	annualgr5	1.37E+07	114,874	75	94	BIC headgate diversion - 1985
gage5_86	annualgr5	1.89E+07	158,476	75	94	BIC headgate diversion - 1986
gage5_87	annualgr5	1.87E+07	156,799	75	94	BIC headgate diversion - 1987
gage5_88	annualgr5	1.77E+07	148,414	75	94	BIC headgate diversion - 1988
gage5_89	annualgr5	1.72E+07	144,222	75	94	BIC headgate diversion - 1989
gage5_90	annualgr5	1.60E+07	134,160	75	94	BIC headgate diversion - 1990
gage5_91	annualgr5	1.56E+07	130,806	75	94	BIC headgate diversion - 1991
gage5_92	annualgr5	1.17E+07	98,104	75	94	BIC headgate diversion - 1992
gage5_93	annualgr5	9.56E+06	80,126	75	94	BIC headgate diversion - 1993
gage5_94	annualgr5	9.07E+06	76,069	75	94	BIC headgate diversion - 1994
gage5_95	annualgr5	8.99E+06	75,344	75	94	BIC headgate diversion - 1995
gage5_96	annualgr5	8.73E+06	73,171	75	94	BIC headgate diversion - 1996
gage5_97	annualgr5	1.57E+07	131,644	75	94	BIC headgate diversion - 1997
gage5_98	annualgr5	1.69E+07	141,706	75	94	BIC headgate diversion - 1998
gage5_99	annualgr5	1.57E+07	131,644	75	94	BIC headgate diversion - 1999

Table 5-5 Streamflow Target Descriptions

PEST ID	Group	Observation (CFD)	Observation (AFY)	Row	Column	Description
gage5_00	annualgr5	1.64E+07	137,514	75	94	BIC headgate diversion - 2000
gage5_01	annualgr5	1.22E+07	102,297	75	94	BIC headgate diversion - 2001
gage5_02	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2002
gage5_03	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2003
gage5_04	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2004
gage5_05	annualgr5	1.66E+07	139,191	75	94	BIC headgate diversion - 2005
gage5_06	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2006
gage5_07	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2007
gage5_08	annualgr5	1.19E+07	99,781	75	94	BIC headgate diversion - 2008
gage5_09	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2009
gage5_10	annualgr5	1.48E+07	124,098	75	94	BIC headgate diversion - 2010
gage5_11	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2011
gage5_12	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2012
gage5_13	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2013
gage5_14	annualgr5	1.22E+07	102,297	75	94	BIC headgate diversion - 2014
gage5_15	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2015
gage5_16	annualgr5	1.23E+07	103,135	75	94	BIC headgate diversion - 2016
gage5_17	annualgr5	1.21E+07	101,458	75	94	BIC headgate diversion - 2017

Abbreviations:
AFY = acre-feet per year
BIC = Buckeye Irrigation Canal
CFD = cubic feet per day

Table 5-6 Baseflow Target Descriptions

PEST ID	Group	Observation (CFD)	Observation (AFY)	Description
streaml2	underflow	-8.78E+06	-73,654	Gila River from BIC Headgate to Gillespie Dam
streaml3	underflow	-4.83E+05	-4,050	Confluence to BIC Headgate
streaml6	underflow	-3.02E+06	-25,356	Salt River upstream of Tempe
streaml8	underflow	-4.32E+06	-36,223	Gila River in the Western 1/3rd of the GRIR
streaml21	underflowtr	-4.83E+05	-4,053	Confluence to BIC Headgate - 1937
streaml31	underflowtr	-4.39E+06	-36,825	BIC Headgate to Arlington Headgate - 1937
streaml41	underflowtr	-4.40E+06	-36,875	Arlington Headgate to Gillespie Dam - 1937
streaml22	underflowtr	-4.83E+05	-4,053	Confluence to BIC Headgate - 1938
streaml32	underflowtr	-4.39E+06	-36,825	BIC Headgate to Arlington Headgate - 1938
streaml42	underflowtr	-4.40E+06	-36,875	Arlington Headgate to Gillespie Dam - 1938
streaml23	underflowtr	-4.83E+05	-4,053	Confluence to BIC Headgate - 1939
streaml33	underflowtr	-4.39E+06	-36,825	BIC Headgate to Arlington Headgate - 1939
streaml43	underflowtr	-4.40E+06	-36,875	Arlington Headgate to Gillespie Dam - 1939
streaml24	underflowtr	-4.82E+05	-4,042	Confluence to BIC Headgate - 1940
streaml34	underflowtr	-4.38E+06	-36,725	BIC Headgate to Arlington Headgate - 1940
streaml44	underflowtr	-4.39E+06	-36,774	Arlington Headgate to Gillespie Dam - 1940
streaml25	underflowtr	-4.83E+05	-4,053	Confluence to BIC Headgate - 1941
streaml35	underflowtr	-4.39E+06	-36,825	BIC Headgate to Arlington Headgate - 1941
streaml45	underflowtr	-4.40E+06	-36,875	Arlington Headgate to Gillespie Dam - 1941

Abbreviations:
BIC = Buckeye Irrigation Canal
CFD = cubic feet per day
GRIR = Gila River Indian Reservation

Table 6-1 Summary of PEST Calibration

Observation Group	Number of residuals with non-zero weight	Mean value of non-zero weighted residuals	Maximum weighted residual	Minimum weighted residual	Standard variance of weighted residuals	Standard error of weighted residuals	Sum of squared weighted residuals (phi)	Percent contribution to phi
All	41,573	0.198	123	-201	33.8	5.81	1.40E+06	100.00%
ss_hob	141	-1.45	37.6	-31.0	186	13.6	26,180	1.87%
tr_hsym	5,020	-0.367	13.6	-11.3	9.97	3.16	50,071	3.58%
tr_west	17,744	0.292	16.8	-19.8	11.7	3.42	2.08E+05	14.86%
tr_east	17,672	0.013	21.9	-20.9	17.2	4.15	3.04E+05	21.74%
hdt	505	11.1	123	-50.6	948	30.8	4.79E+05	34.24%
annualgr1	33.0	-32.4	25.3	-201	5,768	75.9	1.90E+05	13.62%
annualgr4	27.0	1.03	86.3	-44.5	869	29.5	23,448	1.68%
annualgr5	96.0	7.69	65.7	-0.301	274	16.5	26,267	1.88%
underflow	4.00	-8.32	17.0	-36.7	448	21.2	1,790	0.13%
underflowtr	15.0	6.16	40.9	-12.2	243	15.6	3,642	0.26%
aqk	244	-0.095	8.13	-7.42	7.89	2.81	1,925	0.14%
regul_rch	22.0	4.1E-06	7.8E-06	-5.5E-06	4.3E-11	6.6E-06	9.5E-10	0.00%
ppvar	50.0	-8.87	95.9	-130	1680	41.0	83,978	6.01%

Notes:
Reference file = phx.rec

Table 6-2 Calibrated Sediment-Level Parameter Values

Group:	1	2	3	4	5	6	11
KCmin (fpd)	43.42	13.78	35.10	62.48	64.03	19.38	1.10
KCmax (fpd)	179.64	79.57	159.86	199.41	201.51	110.49	531.10
KFmin (fpd)	1.01	0.75	0.90	0.35	0.96	0.57	0.12
KFmax (fpd)	1.01	0.75	0.90	0.35	0.96	0.57	38.62
SsC (1/ft)	1.9E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07	3.6E-07
SsF (1/ft)	4.5E-07	4.6E-07	4.6E-07	4.6E-07	4.6E-07	4.6E-07	4.6E-07
SyC	0.12	0.19	0.18	0.20	0.16	0.11	0.30
SyF	0.04	0.07	0.06	0.07	0.05	0.04	0.10
AnisoC (Kh/Kv)	5.03	5.01	5.00	5.01	5.00	5.00	5.55
AnisoF (Kh/Kv)	84.39	57.32	57.03	137.91	25.10	20.41	9.14

Abbreviations:

AnisoC = coarse-grain anisotropy
AnisoF = fine-grain anisotropy
fpd = feet per day
KCmin = minimum hydraulic conductivity coarse-grained material
KCmax = maximum hydraulic conductivity coarse-grained material
KFmin = minimum hydraulic conductivity fine-grained material
KFmax = maximum hydraulic conductivity fine-grained material
Kh = horizontal hydraulic conductivity
Kv = vertical hydraulic conductivity
SsC = specific storage coarse-grained material
SsF = specific storage fine-grained material
SyC = specific yield coarse-grained material
SyF = specific yield fine-grained material

Table 6-3 Calibrated Recharge Multipliers

PEST ID	Transformation	Change Limit	Calibrated Value	Lower Bound	Upper Bound
rchss	log	factor	0.9	0.9	5
agsuplrch	log	factor	0.625	0.625	2
caprch	fixed	na	1	na	na
epherch	log	factor	0.300	0.3	5
floodrch	log	factor	10	0.1	10
ibwrch	log	factor	1.578253	0.5	2
lakerch	log	factor	1.8	0.4	1.8
mftrch	fixed	na	1	na	na
nonsciprch	fixed	na	1	na	na
sciprch	log	factor	0.5	0.5	2
urbturfrch	log	factor	2.5	2.00E-02	2.5
usfrch	fixed	na	1	na	na
nonscip_01	log	factor	2.779	0.167	3.6
nonscip_02	log	factor	0.167	0.167	3.6
nonscip_03	log	factor	2.498	0.167	3.6
nonscip_04	log	factor	1.434	0.167	3.6
nonscip_05	log	factor	0.167	0.167	3.6
nonscip_06	log	factor	0.167	0.167	3.6
nonscip_07	log	factor	0.167	0.167	3.6
nonscip_08	log	factor	0.167	0.167	3.6
nonscip_09	log	factor	0.167	0.167	3.6
nonscip_10	log	factor	0.167	0.167	3.6
nonscip_11	log	factor	0.167	0.167	3.6
nonscip_12	log	factor	0.310	0.167	3.6
nonscip_13	log	factor	0.167	0.167	3.6
nonscip_14	log	factor	0.167	0.167	3.6
nonscip_15	log	factor	0.248	0.167	3.6
nonscip_16	log	factor	0.192	0.167	3.6
nonscip_17	log	factor	0.167	0.167	3.6
nonscip_18	log	factor	0.629	0.167	3.6
nonscip_19	log	factor	3.526	0.167	3.6
nonscip_20	log	factor	0.167	0.167	3.6
nonscip_21	log	factor	2.788	0.167	3.6
nonscip_22	log	factor	2.788	0.167	3.6
a_001	log	factor	2.310	0.1	3
b_001	log	factor	0.359	0.1	3
c_001	log	factor	1.680	0.1	3
d_001	log	factor	2.406	0.1	3
e_001	log	factor	0.316	0.1	3
f_001	log	factor	0.1	0.1	3
g_001	log	factor	3	0.1	3
h_001	log	factor	2.774	0.1	3
i_001	log	factor	0.657	0.1	3
j_001	log	factor	3	0.1	3

Table 6-3 Calibrated Recharge Multipliers

PEST ID	Transformation	Change Limit	Calibrated Value	Lower Bound	Upper Bound
k_001	log	factor	0.201	0.1	3

Notes:
Irrigation zones x_002 through x_105 are tied to x_001 with a 1:1 ratio and not shown here.
Reference file = phx.pst

Table 6-4 Calibrated Recharge by Component (Acre-Feet per Year)

Stress Period	01_Ag	02_AgSupp	03_CAP	04_Ephem	05_Flood	06_IBW	07_Lakes	09_NonSCIP	10_SCIP	11_UrbanTurf	12_USF	Total
1	na	na	na	na	na	na	na	na	na	na	na	197,713
2	221,536	59,978	0	899	0	3,600	0	153,447	10,859	1,282	0	451,602
3	328,104	59,978	0	4,349	0	3,600	0	159,037	10,857	1,281	0	567,206
4	394,949	59,978	0	4,351	0	3,601	0	161,177	10,863	1,282	0	636,202
5	374,527	0	0	1,716	0	3,598	0	162,790	10,851	1,281	0	554,762
6	387,847	0	0	1,716	0	3,598	0	162,790	10,851	1,281	0	568,082
7	401,159	0	0	1,716	0	3,598	0	161,213	10,851	5,481	0	584,019
8	402,258	0	0	1,721	0	3,607	0	161,655	10,881	5,496	0	585,619
9	401,159	0	0	1,716	0	3,598	0	159,766	10,851	5,481	0	582,572
10	401,159	0	0	1,716	0	3,598	0	159,766	10,851	5,481	0	582,572
11	421,018	0	0	1,716	0	3,598	0	174,742	10,851	5,481	0	617,406
12	442,112	0	0	1,721	0	3,607	0	175,220	10,881	5,496	0	639,038
13	460,777	0	0	1,716	0	3,598	0	174,742	10,851	5,481	0	657,165
14	480,634	0	0	1,716	0	3,598	0	174,742	10,851	5,481	0	677,022
15	500,508	0	0	1,716	0	3,598	0	174,742	10,851	5,481	0	696,896
16	521,811	0	0	901	0	3,607	0	175,220	10,881	5,496	0	717,917
17	540,255	0	0	899	0	3,598	0	174,742	10,851	5,481	0	735,825
18	560,126	0	0	899	0	3,598	0	174,742	10,851	5,481	0	755,696
19	573,986	0	0	899	0	3,598	0	174,742	10,851	5,481	0	769,557
20	589,498	0	0	901	0	3,607	0	175,220	10,881	5,496	0	785,605
21	601,773	0	0	1,716	0	3,598	0	174,742	10,851	5,481	0	798,162
22	615,663	0	0	1,716	0	3,598	0	172,215	10,851	5,481	0	809,524
23	629,540	0	0	1,716	0	3,598	0	172,215	10,851	7,018	0	824,939
24	645,193	0	0	1,721	0	3,607	0	172,687	10,881	7,037	0	841,126
25	657,316	0	0	24,301	1,164,922	3,598	0	172,215	10,851	7,018	0	2,040,221
26	671,211	0	0	899	0	3,598	0	172,215	10,851	7,018	0	865,792
27	685,097	0	0	899	0	3,598	0	168,172	10,851	11,916	0	880,533
28	700,898	0	0	901	0	3,607	0	168,633	10,881	11,949	0	896,870
29	712,854	0	0	899	0	3,598	0	168,172	10,851	11,916	0	908,290
30	726,746	0	0	899	0	3,598	0	168,172	10,851	11,916	0	922,182
31	740,644	0	0	899	0	3,598	0	168,172	10,851	11,916	0	936,080

Table 6-4 Calibrated Recharge by Component (Acre-Feet per Year)

Stress Period	01_Ag	02_AgSupp	03_CAP	04_Ephem	05_Flood	06_IBW	07_Lakes	09_NonSCIP	10_SCIP	11_UrbanTurf	12_USF	Total
32	760,718	0	0	901	0	3,607	0	168,633	10,881	11,949	0	956,689
33	776,668	0	0	899	0	3,598	0	168,172	10,851	11,916	0	972,105
34	794,694	0	0	4,347	0	3,598	0	168,172	10,851	11,916	0	993,578
35	812,708	0	0	24,301	1,164,922	3,598	0	168,172	10,851	11,916	0	2,196,468
36	832,995	0	0	4,358	0	3,607	0	168,633	10,881	11,949	0	1,032,424
37	848,743	0	0	899	0	3,598	0	150,359	10,851	14,413	0	1,028,862
38	866,745	0	0	899	0	3,598	0	150,359	10,851	14,413	0	1,046,864
39	857,545	0	0	899	0	3,598	0	150,359	10,851	14,413	0	1,037,663
40	850,690	0	0	901	0	3,607	0	150,771	10,881	14,452	0	1,031,302
41	839,171	0	0	899	0	3,598	0	150,359	10,851	14,413	0	1,019,290
42	829,980	0	0	899	0	3,598	0	134,085	10,851	22,123	0	1,001,535
43	820,783	0	0	899	0	3,598	0	134,085	10,851	22,123	0	992,338
44	813,814	0	0	901	0	3,607	0	134,452	10,881	22,184	0	985,840
45	802,386	0	0	899	0	3,598	0	134,085	10,851	22,123	0	973,942
46	793,189	0	0	899	0	3,598	0	134,085	10,851	22,123	0	964,744
47	783,991	0	0	899	0	3,598	0	134,085	10,851	22,123	0	955,546
48	787,031	0	0	24,367	1,168,114	3,607	0	134,452	10,881	22,184	0	2,150,637
49	785,795	0	0	24,301	1,164,922	3,598	0	133,200	10,851	33,164	0	2,155,831
50	786,692	0	0	4,347	0	3,598	0	133,200	10,851	33,164	0	971,851
51	787,589	0	0	1,716	0	3,598	0	133,200	10,851	33,164	0	970,118
52	790,650	0	0	1,721	0	3,607	0	133,565	10,881	33,255	0	973,679
53	789,392	0	0	4,347	0	3,598	0	133,200	10,851	33,164	0	974,551
54	790,288	0	0	24,301	1,164,922	3,598	0	124,724	10,851	52,905	0	2,171,588
55	791,183	0	0	4,347	0	3,598	0	124,724	10,851	52,905	0	987,607
56	794,232	0	0	24,367	1,168,114	3,607	0	125,066	10,881	53,050	0	2,179,317
57	792,977	0	0	899	0	3,598	0	124,724	10,851	52,905	0	985,953
58	781,649	0	0	899	0	3,598	0	124,724	10,851	52,905	0	974,625
59	770,473	0	0	899	0	3,598	0	112,701	10,851	69,368	0	967,889
60	761,322	0	0	901	0	3,607	0	113,009	10,881	69,558	0	959,279
61	748,027	0	0	899	0	3,598	0	112,701	10,851	69,368	0	945,443
62	736,807	0	0	24,301	1,164,922	3,598	0	112,701	10,851	69,368	0	2,122,547

Table 6-4 Calibrated Recharge by Component (Acre-Feet per Year)

Stress Period	01_Ag	02_AgSupp	03_CAP	04_Ephem	05_Flood	06_IBW	07_Lakes	09_NonSCIP	10_SCIP	11_UrbanTurf	12_USF	Total
63	725,589	0	0	24,301	1,164,922	3,598	0	112,701	10,851	69,368	0	2,111,329
64	716,332	0	0	24,367	1,168,114	3,607	0	107,931	10,881	82,841	0	2,114,074
65	703,158	0	0	4,347	0	3,598	0	107,636	10,851	82,615	0	912,204
66	691,930	0	4,958	4,347	0	3,598	0	107,636	10,851	82,615	0	905,934
67	680,711	0	4,958	24,301	1,164,922	3,598	0	67,519	10,851	133,617	0	2,090,478
68	671,330	0	4,972	4,358	0	3,607	0	67,704	10,881	133,983	0	896,836
69	658,274	0	4,958	4,347	0	3,598	24,259	67,519	10,851	133,617	0	907,423
70	647,056	0	4,958	4,347	0	3,598	24,259	67,519	10,851	133,617	0	896,205
71	635,829	0	4,958	4,347	0	3,598	24,259	67,519	10,851	133,617	0	884,977
72	626,323	0	4,972	4,358	0	3,607	24,325	67,704	10,881	133,983	0	876,154
73	613,393	0	4,958	4,347	0	3,598	24,259	67,519	10,851	133,617	738	863,280
74	592,174	0	4,958	1,716	0	3,598	24,259	67,519	10,851	133,617	1,861	840,553
75	584,264	0	4,958	4,347	0	3,598	24,259	67,519	10,851	133,617	5,412	838,825
76	577,934	0	4,972	24,367	1,168,114	3,607	25,587	67,704	10,881	133,983	5,135	2,022,285
77	568,441	0	4,958	24,301	1,164,922	3,598	25,517	67,519	10,851	133,617	5,647	2,009,371
78	560,528	0	4,958	4,347	0	3,598	25,517	67,519	10,851	133,617	49,463	860,398
79	552,618	0	4,958	4,347	0	3,598	25,607	67,519	10,851	133,617	75,108	878,224
80	543,499	0	4,972	1,721	0	3,607	25,677	67,704	10,881	133,983	66,725	858,770
81	531,454	0	4,958	1,716	0	3,598	28,205	67,519	10,851	133,617	54,033	835,951
82	520,862	0	4,958	1,716	0	3,598	28,205	67,519	10,851	133,617	82,721	854,047
83	510,277	0	4,958	899	0	3,598	28,205	67,519	10,851	133,617	105,975	865,899
84	501,137	0	4,972	901	0	3,607	28,282	67,704	10,881	133,983	131,939	883,406
85	483,616	0	4,958	899	0	3,598	28,205	67,519	10,851	133,617	128,720	861,983
86	467,494	0	4,958	899	0	3,598	29,545	67,519	10,851	133,617	166,378	884,859
87	451,373	0	4,958	899	0	3,598	30,795	67,519	10,851	133,617	154,923	858,533
88	436,459	0	4,972	901	0	3,607	31,078	67,704	10,881	133,983	198,642	888,227
89	419,151	0	4,958	4,347	0	3,598	31,056	67,519	10,851	133,617	138,670	813,766
90	403,023	0	4,958	1,716	0	3,598	31,362	67,519	10,851	133,617	267,476	924,121
91	386,898	0	4,958	1,716	0	3,598	31,901	67,519	10,851	133,617	318,016	959,074
92	371,719	0	4,972	1,721	0	3,607	32,349	67,704	10,881	133,983	227,716	854,653
93	354,699	0	4,958	1,716	0	3,598	32,288	67,519	10,851	133,617	307,337	916,584

Table 6-4 Calibrated Recharge by Component (Acre-Feet per Year)

Stress Period	01_Ag	02_AgSupp	03_CAP	04_Ephem	05_Flood	06_IBW	07_Lakes	09_NonSCIP	10_SCIP	11_UrbanTurf	12_USF	Total
94	303,100	0	4,958	1,716	0	3,598	32,288	67,519	10,851	133,617	304,081	861,728
95	302,135	0	4,958	1,716	0	3,598	32,558	67,519	10,851	133,617	241,646	798,598
96	301,990	0	4,972	1,721	0	3,607	32,647	67,704	9,532	133,983	195,636	751,792
97	296,062	0	4,958	1,716	0	3,598	32,558	67,519	8,167	133,617	167,273	715,468
98	290,926	0	4,958	24,301	1,164,922	3,598	32,558	67,519	6,829	133,617	185,907	1,915,134
99	286,921	0	4,958	1,716	0	3,598	32,558	67,519	5,501	133,617	191,843	728,231
100	283,716	0	4,972	1,721	0	3,607	32,647	67,704	4,163	133,983	192,466	724,979
101	282,941	0	4,958	1,716	0	3,598	32,558	67,519	2,815	133,617	175,190	704,912
102	279,333	0	4,958	899	0	3,598	32,558	67,519	2,815	133,618	206,472	731,770
103	278,027	0	4,958	1,716	0	3,598	32,558	67,519	2,815	133,618	202,173	726,981
104	278,375	0	4,972	1,721	0	3,607	32,647	67,704	2,823	133,984	252,727	778,560
105	277,558	0	4,958	899	0	3,598	32,558	67,519	2,815	133,618	214,195	737,717
Non-Zero Average	588,634	59,978	4,961	4,725	1,165,904	3,600	29,188	119,364	10,279	64,510	152,189	999,162
Average (Including Zero)	588,634	1,730	1,908	4,725	145,738	3,600	10,384	119,364	10,279	64,510	48,291	999,162
Minimum	221,536	0	0	899	0	3,598	0	67,519	2,815	1,281	0	451,602
Maximum	866,745	59,978	4,972	24,367	1,168,114	3,607	32,647	175,220	10,881	133,984	318,016	2,196,468

Abbreviations:

Ag = agricultural incidental recharge
AgSupp = ag incidental recharge from 1900-1920 in Salt River Valley Water Users Association irrigation district
CAP = Central Arizona Project (canal seepage)
Ephem = ephemeral
Flood = flood recharge
IBW = Indian Bend Wash
Lakes = artificial urban lakes
NonSCIP = canals not belonging the San Carlos Irrigation Project
SCIP = canals belonging to the San Carlos Irrigation Project
USF = Underground Storage Facility

Table 6-5 Calibrated Mountain-Front Inflow (WEL) Rates

PEST ID	Model Cells per Group	Calibrated Rate (CFD)
mtn_00_1s	36	4.62
mtn_00_2s	36	0.591
mtn_00_3s	36	1.47
mtn_01_1s	6	0.544
mtn_01_2s	6	175815
mtn_01_3s	6	1201
mtn_02_1s	5	465
mtn_02_2s	5	413
mtn_02_3s	5	147
mtn_03_1s	31	0.517
mtn_03_2s	31	159
mtn_03_3s	31	2625
mtn_00_1	36	0.713
mtn_00_2	36	0.886
mtn_00_3	36	2.16
mtn_01_1	6	1.41
mtn_01_2	6	164104
mtn_01_3	6	350
mtn_02_1	5	116388
mtn_02_2	5	78377
mtn_02_3	5	74754
mtn_03_1	31	0.409
mtn_03_2	31	6581
mtn_03_3	31	6540
mtn_04_1	38	0.198
mtn_04_2	38	0.242
mtn_04_3	38	0.216
mtn_05_1	19	78.2
mtn_05_2	19	137
mtn_05_3	19	119
mtn_06_1	10	59197
mtn_06_2	10	32.0
mtn_06_3	10	21.0
mtn_07_1	11	18123
mtn_07_2	11	207
mtn_07_3	11	0.546
mtn_08_1	5	0.341
mtn_08_2	5	0.449
mtn_08_3	5	0.216
mtn_09_1	6	0.118
mtn_09_2	6	0.184
mtn_09_3	6	21673
mtn_10_1	53	1.17
mtn_10_2	53	8559

Table 6-5 Calibrated Mountain-Front Inflow (WEL) Rates

PEST ID	Model Cells per Group	Calibrated Rate (CFD)
mtn_10_3	53	154
mtn_11_1	21	0.267
mtn_11_2	21	96.9
mtn_11_3	21	46.4
mtn_12_1	12	0.283
mtn_12_2	12	0.603
mtn_12_3	12	0.194
mtn_13_1	11	0.225
mtn_13_2	11	9730
mtn_13_3	11	73167
mtn_14_1	6	287
mtn_14_2	6	77.8
mtn_14_3	6	382
mtn_15_1	7	0.023
mtn_15_2	7	3840
mtn_15_3	7	365487
mtn_16_1	85	67.2
mtn_16_2	85	92.9
mtn_16_3	85	95.5
mtn_17_1	63	131
mtn_17_2	63	324
mtn_17_3	63	38.5

Abbreviations:
CFD = cubic feet per day

Table 6-6 Calibated Mountain-Front Inflow Volume (AFY)

PEST ID	MTN Group Parameter Name	Inflow Layer 1	Inflow Layer 2	Inflow Layer 3	Sum
MTN_00	North Belmont Mountains	0.2	0.3	0.7	**1.1**
MTN_01	Vulture Mountains east of Hassayampa River	0.1	8,256	18	**8,274**
MTN_02	Vulture Mountains at Hassayampa River	4,880	3,286	3,134	**11,300**
MTN_03	Vulture Mountains west of Hassayampa River	0.1	1,711	1,700	**3,411**
MTN_04	Hieroglyphic Mountains	0.1	0.1	0.1	**0.2**
MTN_05	Hieroglyphic / Bradshaw Mountains	12	22	19	**53**
MTN_06	Cave Creek / McDowell Mountains	4,964	2.7	1.8	**4,968**
MTN_07	Carefree	1,672	19	0.1	**1,691**
MTN_08	New River / Anthem east of I-17	0.0	0.0	0.0	**0.0**
MTN_09	Anthem	0.0	0.0	1,090	**1,090**
MTN_10	Superstition Mountains	0.5	3,804	68	**3,873**
MTN_11	Fountain Hills	0.0	17.1	8.2	**25**
MTN_12	Usery Mountains	0.0	0.1	0.0	**0.1**
MTN_13	Goldfield Mountains	0.0	897	6,749	**7,646**
MTN_14	Gold Canyon	14	3.9	19	**38**
MTN_15	Queen Creek	0.0	225	21,452	**21,678**
MTN_16	White Tank Mountains	48	66	68	**182**
MTN_17	Sierra Estrella Mountains	69	171	20	**261**
	Total:	**11,660**	**18,481**	**34,348**	**64,490**

Abbreviations:
AFY = Acre-feet per year

FIGURES

available online at:

https://infoshare.azwater.gov/docushare/dsweb/View/Collection-21999

APPENDIX

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