Groundwater Resources Impact Assessment

Pine Valley Water Supply Project

Iron and Beaver Counties, Utah

Prepared for:

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Appendices

Appendix A– Development of the GBCAAS-PV Groundwater Flow Model

Appendix B– Aquifer Test Analyses

Appendix C– Points of Diversion from Utah Water Rights Database

LIST OF ABBREVIATIONS

%	percent
ACOE	U.S. Army Corps of Engineers
AFY	acre-feet per year
amsl	above mean sea level
ANWS	Adaptive Northern Well Sites
APE	Area of Potential Effects
bgs	below ground surface
BLM	Bureau of Land Management
°C	Degrees Celsius
CEQ	Council on Environmental Quality
cfs	cubic feet per second
CICWCD	Central Iron County Water Conservancy District
cm/yr	centimeters per year
COOP	Cooperative Observer Program
CPM	Crystal Peak Minerals
DNR	Department of Natural Resources
DPS	Department of Public Safety
DWR	Division of Water Resources
DWRi	Division of Water Rights
EC	Eddy Covariance
EIS	Environmental Impact Statement
EM	Electromagnetic
EPA	Environmental Protection Agency
ET	Evapotranspiration
ETa	Actual Evapotranspiration
ETg	Groundwater Discharge by Evapotranspiration
EVI	Enhanced Vegetation Index

EVT	Evapotranspiration Package
°F	Degrees Fahrenheit
ft	feet
ft^2/d	square feet per day
ft^3/s	cubic feet per second
GBCAAS	Great Basin Carbonate and Alluvial Aquifer System
GBCAAS-PV	Great Basin Carbonate and Alluvial Aquifer System-Pine Valley
GBGP	Great Basin Geomorphic Province
GDA	Groundwater Discharge Area
GDE	Groundwater Dependent Ecosystem
GDP	Gridded Data Products
gpm	gallon per minute
gpm/ft	gallon per minute per foot
GMP	Groundwater Management Plan
GRIA	Groundwater Resources Impact Assessment
HA	Hydrographic Area
HGU	Hydrogeologic Unit
IBF	Interbasin Flow
in	inches
InSAR	Interferometric Synthetic Aperture Radar
IPCC	Intergovernmental Panel on Climate Change
K	hydraulic conductivity
km	kilometers
LAI	Leaf Area Index
m	meters
MCL	Maximum Contaminant Level
mg/L	milligrams per liter
MSAVI	Modified Soil Adjusted Vegetation Index
NA	Not Available

NDVI	Normalized Difference Vegetation Index
NEPA	National Environmental Policy Act
NGTs	Noble Gas and Water-Table Temperatures
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NR	Not Reported
NWIS	National Water Information System
PRISM	Parameter-elevation Relationships on Independent Slopes Model
PVWS	Pine Valley Water Supply
RAWS	Remote Automatic Weather Stations
SITLA	Utah School and Institutional Trust Lands Administration
SNWA	Southern Nevada Water Authority
TDS	Total Dissolved Solids
UGS	Utah Geological Survey
USDM	U.S. Drought Monitor
USGS	U.S. Geological Survey

1 INTRODUCTION

Central Iron County Water Conservancy District (CICWCD) proposes to develop the Pine Valley Water Supply (PVWS) Project to extract groundwater from a wellfield in Pine Valley in Beaver County in southwest Utah for beneficial use in its service territory in Cedar Valley, approximately 40 miles to the southeast (the PVWS Project) (Figure 1-1). Formation Environmental, Inc. (Formation) has prepared this Groundwater Resources Impact Assessment (GRIA) report as a subcontractor to Transcon Environmental, Inc. (Transcon) on behalf of the Bureau of Land Management (BLM) to assess the potential groundwater resources-related impacts associated with the PVWS Project. The information provided in this GRIA will support development of an Environmental Impact Statement (EIS) under the National Environmental Policy Act (NEPA) for the PVWS Project. Alternatives evaluated in the EIS include a southern wellfield alternative and pipeline (the Proposed Action), and a northern wellfield alternative and pipeline (the Adaptive Northern Well Sites Alternative or ANWS Alternative). These alternatives are further described in Chapter 2.

1.1 PROJECT TECHNICAL REVIEW COMMITTEE

The studies described herein and preparation of this GRIA report were performed through a collaborative process that was implemented by Transcon and included participants representing the BLM and a diverse group of agencies, technical experts and stakeholders. The Groundwater Technical Team included biologists, hydrologists and NEPA experts with BLM, hydrogeologists from the United States Geological Survey (USGS) with extensive experience in the area, CICWCD, CICWCD's District Engineer (Ensign Engineering (Ensign)), Barnett Intermountain, Transcon, AquaGeo, and Formation. Representatives from the Utah State Engineer's office were also invited to participate. A series of 24 web-based meetings were held from May 2019 through November 2020. These Groundwater Technical Team meetings provided a forum for discussion of information regarding characterization of the affected environment, the development of a groundwater flow model and project and cumulative impact assessment.

1.2 BACKGROUND

CICWCD supplies water for municipal and other water uses within its district boundaries in Cedar Valley in Iron County, Utah. CICWCD is reliant almost entirely on locally pumped groundwater for its water supplies. Cumulative groundwater extraction in Cedar Valley has led to aquifer storage depletion and an overdraft deficit currently estimated at 7,000 acre-feet per year (AFY). Urban water demand in Cedar Valley is projected to continue to grow, and CICWCD has explored a number of options to address the gap between water supply and demand in its service area. The decision to develop groundwater supplies in Pine Valley was made after implementation of water conservation measures, development of several recharge projects, and exploration of other options for sourcing additional water. CICWCD verified the necessary supplemental water supply volume needed to address the current deficit and determined construction of the PVWS project is the most viable option for doing so. CICWCD obtained water rights in Pine Valley, located in adjoining western Beaver County, Utah, and has applied for a right-of-way grant from BLM to develop wells on BLM land within Pine Valley under these water rights and to convey the water into the existing CICWCD water distribution system via a pipeline on BLM land (Figure 1-1).

The proposed PVWS Project will be located in southwestern Utah, in the southeast portion of the Basin and Range physiographic province (Fenneman and Johnson 1946), which covers about 200,000 square miles of the western United States that extends eastward from southeastern Oregon and eastern California and includes most of Nevada and portions of northern Arizona, southern Idaho, and western Utah. It consists of a system of fault-bounded, north-northeast trending alluvial basins that are hydrologically separated by uplifted bedrock mountain ranges. The region is relatively arid, and surface drainage in many of the basins is internal. Within the Basin and Range physiographic province, the Great Basin Carbonate and Alluvial Aquifer System (GBCAAS) covers an area of approximately 110,000 square miles where the alluvial basins are underlain and separated by carbonate bedrock systems that act as regional aquifers. These regional carbonate aquifers allow groundwater to flow between the individual basins in the GBCAAS and allow groundwater effects to be regionally transmitted over wide areas.

The basins of the Basin and Range physiographic province and the alluvial valley fill they contain were designated as individual Hydrographic Areas (HAs) by the U.S. Geological Survey (USGS) and Nevada Division of Water Resources (Nevada DWR) in the late 1960s for scientific, water resources planning and administrative management purposes (Rush 1968; Cardinalli *et al*. 1968).[1] The PVWS Project is located in the Pine Valley HA in the southeastern portion of the GBCAAS (Buto 2009). This GRIA therefore includes evaluation of hydrogeologic effects across a broad area encompassing several adjacent HAs, including Snake Valley (which includes Hamlin Valley), Tule Valley, Sevier Desert, Wah Wah Valley, Milford Area and Beryl-Enterprise Area HAs.

1.3 PRIOR WORK

A number of studies have been performed to characterize the GBCAAS. The prior studies most relevant to understanding conditions in the southeastern portion of the GBCAAS and evaluating the potential effects of the PVWS Project are introduced and briefly summarized below.

1.3.1 STEPHENS 1974 AND 1976

The first comprehensive study of groundwater resources in the Pine Valley HA was conducted by Stephens (1976). The study was conducted as a joint project between USGS and Utah Department of Natural Resources (Utah DNR) to characterize groundwater conditions and supply availability and inform regulation of water rights. A related study was completed by Stephens for the Wah Wah Valley HA in 1974 (Stephens 1974). The studies included evaluation of the geologic and hydrogeologic setting and characteristics of the HAs; groundwater occurrence, flow and quality; surface water, springs, phreatophytes and their interconnection with groundwater; the existing state of groundwater development and use, and the groundwater budgets of the HAs, including recharge and discharge estimates. The estimated recharge component of the groundwater budget for Pine Valley HA was 21,000 AFY, 3,000 AFY of which was accounted as recharge to the Wah Wah Valley HA due to local hydrostratigraphic conditions. This number was used to inform the regulation of water rights in the basin

[1] The HA naming and numbering system used by Utah DNR differs slightly from the designations used by USGS and Nevada DNR, and some HAs are further subdivided; however, the essential boundaries are the same.

and remains the technical basis for the understanding of the water volume available for appropriation determined by the Utah DNR Division of Water Rights (DWRi).

1.3.2 USGS REGIONAL GBCAAS STUDIES

To help address the potential implications of groundwater supply development in the GBCAAS, the USGS performed studies to characterize groundwater supplies and provide information that would aid in understanding the future implications of expanding groundwater demand in this geological system in California, Nevada, Utah and Arizona. The USGS published several studies characterizing the GBCAAS aquifer system, including a characterization of the aquifer systems in the Great Basin region of Nevada, Utah, and adjacent states (Harrill and Prudic 1998) and a characterization of the GBCAAS (Heilweil and Brooks 2011). In 2014, the USGS developed a regional steady state numerical groundwater flow model of the GBCAAS, referred to as GBCAAS v. 1.0 (Brooks *et al*. 2014). In this model, the recharge component of the groundwater budget for the Pine Valley HA was 24,000 AFY.

1.3.3 USGS PINE AND WAH WAH VALLEY STUDIES

In order to provide additional scientific context for the potential development of groundwater supplies in the southeastern portion of the GBCAAS in Utah, USGS performed additional hydrogeologic studies and updated GBCAAS v. 1.0 to provide perspective on the potential effects of groundwater supply development in the Pine Valley, Wah Wah Valley and Parowan Valley HAs. The subregionally-updated version of the steady state GBCAAS model was referred to as GBCAAS v. 3.0.

To update the GBCAAS model Gardner *et al.* (2020) conducted a hydrogeologic and geochemical investigation of the Pine and Wah Wah Valley HAs to further characterize aquifer conditions, groundwater occurrence and flow, groundwater recharge and discharge volume estimates, and the source and age of aquifer water and spring discharge. The investigation included pump testing of several wells to better characterize aquifer conditions; sampling and geochemical analysis of groundwater samples from wells to assess the nature, age and source of the water; sampling and geochemical analysis of water from springs to determine whether they are connected to the regional aquifer system or discharge water from perched aquifers; and an evaluation of evapotranspiration in groundwater discharge areas in the Tule Valley and Sevier Desert HAs and further constrain groundwater budget estimates.

Using the data developed by Gardner, Brooks (2017) updated and recalibrated GBCAAS v. 1.0 in the area surrounding Pine and Wah Wah Valleys. GBCAAS v. 3.0 incorporated changes to the groundwater budget and recalibrated basin fill hydraulic conductivities based on the assumed water budget changes. Notably, the groundwater recharge component of the groundwater budget for the Pine Valley HA was decreased to 11,000 AFY; however, hydraulic conductivities of the alluvial aquifer had to be decreased below measured levels in order to meet calibration targets. The updated model was used to evaluate the aquifer response to long-term pumping stresses in the Pine Valley and Wah Wah Valley HAs. The study included a theoretical analysis of drawdown impacts that would result if groundwater pumping were continued for 62 years, 1,000 years, and 5,000 years. While simulations of 1,000 and 5,000 years can provide valuable scientific context to understand the nature of the aquifer system, they are too speculative and hypothetical to be considered for use in assessing the actual effects of a project.

1.4 PURPOSE OF THE GRIA

This GRIA report has been prepared to update prior hydrogeologic studies in the area surrounding the Pine Valley HA, and to support evaluation of potential impacts of implementing the PVWS Project that could result from groundwater withdrawal in Pine Valley. The GRIA is intended to fulfill the requirements of NEPA to describe the environmental resources that could potentially be affected and evaluate the environmental consequences of implementing the PVWS Project, with a specific focus on effects related to groundwater extraction. To support this objective, this report includes a description of groundwater extraction under the PVWS Project alternatives, a characterization of the hydrogeologic setting and groundwater-related resources that could be affected by the project, an assessment of project effects using a groundwater flow model, and an evaluation of potential impacts to groundwater resources and resources dependent on groundwater. Recommended monitoring and mitigation measures being considered for incorporation into the proposed project are also described.

1.4.1 REPORT OBJECTIVES

The specific objectives of the GRIA report are to:

(1) Describe the groundwater extraction-related components of the PVWS Project that could result in environmental effects, including applicant-provided adaptive management strategies that are intended to avoid or minimize potentially adverse impacts;
(2) Refine the understanding of aquifer conditions in the area surrounding the Pine Valley HA adequately to describe the affected environment and support analysis of the PVWS Project's hydrogeologic effects;
(3) Develop a refined groundwater flow model (the GBCAAS-PV model) in the area surrounding the Pine Valley HA that is adequate to simulate the potential future effects of groundwater extraction by the PVWS Project, using GBCAAS v. 3.0 as a starting point;
(4) Use the updated GBCAAS-PV model to simulate future groundwater extraction during the project implementation period and evaluate the potential project and cumulative effects of the PVWS Project alternatives;
(5) Based on the predicted effects, evaluate the potential environmental impacts related to groundwater extraction that could result from implementing the PVWS Project;
(6) Characterize potential uncertainties inherent in the predicted environmental consequences of the PVWS Project; and
(7) Provide recommendations for monitoring and mitigation measures to avoid, minimize or mitigate potential significant adverse impacts associated with the PVWS Project, and to address potential risks and uncertainties.

1.4.2 MANAGEMENT OF UNCERTAINTIES AND RISKS

Groundwater systems are complex, and models used to predict their response to pumping entail inherent uncertainties that must be understood and appropriately managed. In Pine and Wah Wah Valleys and the surrounding basins, groundwater resources have been very sparsely developed. As a result, significant data gaps exist in the hydrogeologic characterization of the area. Some of these cannot be ascertained until significant pumping stresses are applied, such as during implementation of the PVWS Project. The *Hydrogeologic and Geochemical Characterization of Groundwater Resources in Pine and Wah Wah*

Valleys, Iron, Beaver, and Millard Counties, Utah report prepared by the USGS (Gardner *et al*. 2020) represents the most recent update in the hydrogeologic understanding of the area. The purpose of this work was to gather additional data and refine the conceptual hydrogeologic model and water budget for the area and use the information to update the GBCAAS model. However, because the scope of the study was limited, there are still significant uncertainties in the amount and distribution of groundwater recharge and discharge, as well as the aquifer properties and the hydrogeologic conceptual model. These uncertainties must be sufficiently addressed in the GRIA to meet the objectives discussed above in Section 1.3.1. This can occur through a combination of (1) additional data evaluation and model refinement; (2) analyzing uncertainties and their implications; (3) implementing an adaptive management strategy that avoids or minimizes the potential for adverse impacts; and/or (4) implementing a project monitoring and mitigation program. This GRIA adopts a combination of all these approaches.

Specific data gaps and uncertainties remaining after the Gardner study include the following:

- Whether aquifers in the mountains surrounding Pine and Wah Wah Valleys are perched or semi-perched (i.e., whether they contribute recharge to the underlying regional aquifer system);
- The nature of the aquifer system in the vicinity of Sevier Lake, including whether any regional groundwater discharge occurs at the lake and whether phreatophytes receive groundwater discharge from local perched aquifers (i.e., the degree to which groundwater-dependent vegetation in this area derives groundwater from the regional aquifer system vs. local shallow aquifers);
- Aquifer parameters for the alluvial and carbonate aquifer systems, which are relatively sparsely characterized;
- Water budgets for the Pine Valley and Wah Wah Valley HAs, especially including precipitation and evapotranspiration (ET), which are important to understand in closed basins and were not evaluated by Gardner *et al*. (2020);
- Conclusions regarding alluvial aquifer groundwater age or recharge characteristics based on samples collected from wells with long screen intervals, which tend to mask vertical variations along shallow versus deeper flow paths;
- The contribution of a local perched or semi-perched aquifer to discharge from Wah Wah Springs, the spring most likely to be affected by pumping associated with the PVWS Project;
- Conclusive determination whether the springs in the mountains surrounding Pine and Wah Wah Valleys have a hydraulic connection to the regional carbonate and alluvial aquifer system;
- Historical groundwater levels in southern Pine Valley show a relatively steep gradient across an area where the southern edge of a volcanic caldera complex has been mapped based on gravity data, suggesting the potential presence of a flow impeding barrier; however, the existence of the

barrier cannot be verified based on the available data and is best verified by long-term aquifer stress, such as will be produced by implementation of the PVWS Project.

These data gaps and uncertainties and their implications are discussed in the subsequent chapters of this GRIA.

1.4.3 SCOPING CONSIDERATIONS

Development of the scope and approach to assessment of potential impacts related to groundwater extraction by the PVWS Project was informed by issues identified by BLM staff and consultation with stakeholders and responsible agencies during the EIS scoping process. As documented in the EIS, these included the following questions:

- How would the Proposed Action affect springs, seeps, streams, wetlands, and other surface waters?
- How would the Proposed Action affect groundwater wells within the analysis area?
- How would the Proposed Action affect senior water rights holders?
- How would the Proposed Action affect groundwater aquifer balance?
- How would the Proposed Action affect phreatophytes and other groundwater-dependent vegetation?
- How would the Proposed Action affect intra-basin transfer of water across the Utah-Nevada state line?
- Would the Proposed Action impact groundwater resources in Lincoln County, Nevada; White Pine County, Nevada; and Millard County, Utah?
- How would the Proposed Action affect the long-term water supply in Beaver County, Utah?
- How would the Proposed Action affect groundwater resources in Tule Valley, Fish Springs National Wildlife Refuge, and Sevier Lake?
- How would the Proposed Action affect downgradient groundwater basins and the Greater Salt Lake Desert regional groundwater flow system?
- How would the Proposed Action draw down or otherwise affect groundwater resources in and around Pine Valley over a long period, such as the next 200 years?
- How would the Proposed Action affect federally reserved water rights?
- How could the Proposed Action include the data and analysis of previous U.S. Geological Survey (USGS) studies, reports, and models, including the Great Basin Carbonate-Alluvial Aquifer System regional model?

- How would the Proposed Action affect water quality in neighboring basins within the analysis areas: Snake Valley basin, Tule Valley basin, Sevier Desert basin, Wah Wah Valley basin, Milford Area basin, and Beryl-Enterprise area basin?
- How would the Proposed Action impact the proposed draft GMP for the Cedar Valley basin?
- How would the Proposed Action interact with other water management plans for Pine Valley and the surrounding basins, including the Beryl-Enterprise GMP?
- How would the potential for land subsidence due to extraction of groundwater by the Proposed Action be addressed?
- How would impacts to surface water and groundwater be monitored and mitigated and the Proposed Action adaptively managed to prevent or reduce impacts to water-dependent resources?
- How would impacts to springs due to the Proposed Action be addressed?
- How would impacts to other water rights holders due to the Proposed Action be addressed?
- How would the Proposed Action affect groundwater quality?

During the EIS scoping process, the BLM, in consultation with Formation and the USGS, decided to move forward with a planning horizon of 50 years of project groundwater pumping followed by 200 years of aquifer recovery. Other timeframes considered included scenarios of up to 200 years of groundwater pumping followed by 200 years of recovery. A 200-year scenario was deemed to rely upon assumptions and information that are unavailable or highly uncertain and therefore not essential to a reasoned choice among alternatives. As discussed in Section 2, PVWS Project is subject to adaptive management, the DWRi water right order for the Project, and the Utah State Code. These would curtail pumping if the safe yield of the basin is exceeded, or prior water rights are impaired. Consequently, the assumption that pumping will automatically continue on the same pumping schedule and in the same geographic distribution was determined to be speculative.

The Council on Environmental Quality (CEQ) regulations require the BLM to obtain information if it is "relevant to reasonably foreseeable significant adverse impacts," if it is "essential to a reasoned choice among alternatives," and if "the overall cost of obtaining it is not exorbitant" (40 CFR 1502.22). BLM NEPA Handbook (H-1790-1), Section 6.7.2. states that the following information should be provided in a NEPA document when this is the case:

- A statement that such information is incomplete or unavailable;
- A statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment;

- A summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment; and

- The agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community. For the purposes of this section, "reasonably foreseeable" includes impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason [40 CFR 1502.22(b)].

A scoping-level analysis was completed for a 200-year pumping scenario to provide perspective on the kinds of impacts that could occur if pumping were to continue at the same rates by the PVWS Project and in the surrounding hydrologic areas. More information about the 200-year pumping scenario, which was updated using the GBCAAS-PV model developed for this GRIA, is contained in the *Technical Memorandum – Supplemental Analysis of Drawdown, Spring Flow Depletion and Wellfield Effects Assuming a Theoretical 200-Year Project Pumping Duration, Pine Valley Water Supply Project, Iron, Beaver and Millard Counties, Utah* (Formation, 2021; hereinafter the Supplemental 200-Year Analysis). Because modeling a 200-year pumping scenario relies upon assumptions and information that are unavailable or highly uncertain, it is not essential to a reasoned choice among alternatives. Information associated with the following variables that would affect Project pumping rates are highly uncertain beyond a 50-year timeframe:

- The ability of project wells to sustain the simulated pumping rates as groundwater levels in Pine Valley continue to drop;

- Future changes in pumping by CICWCD in response to changes in water demand, adaptive management, and State requirements;

- Future changes and distribution of urban, agricultural and range land use patterns and associated water demands;

- The location, amount, and timing of groundwater demand, including changes created by groundwater and surface water projects in other basins and changes created by water use technology;

- The volume, timing, and distribution of groundwater recharge, as influenced by land use, drought, and climate change; and

- Groundwater management responses implemented by water users and governments in response to changed groundwater supply and environmental conditions, including changes to Utah water law and regulations.

The Supplemental 200-Year Analysis indicates that pumping effects would develop substantially during the first few decades of project pumping, which would allow time for adaptive management to address or avoid future impacts. As described in Sections 2 and 6, the project proponent has committed to installation of monitoring locations in Pine Valley that allow early and ongoing assessment of whether the

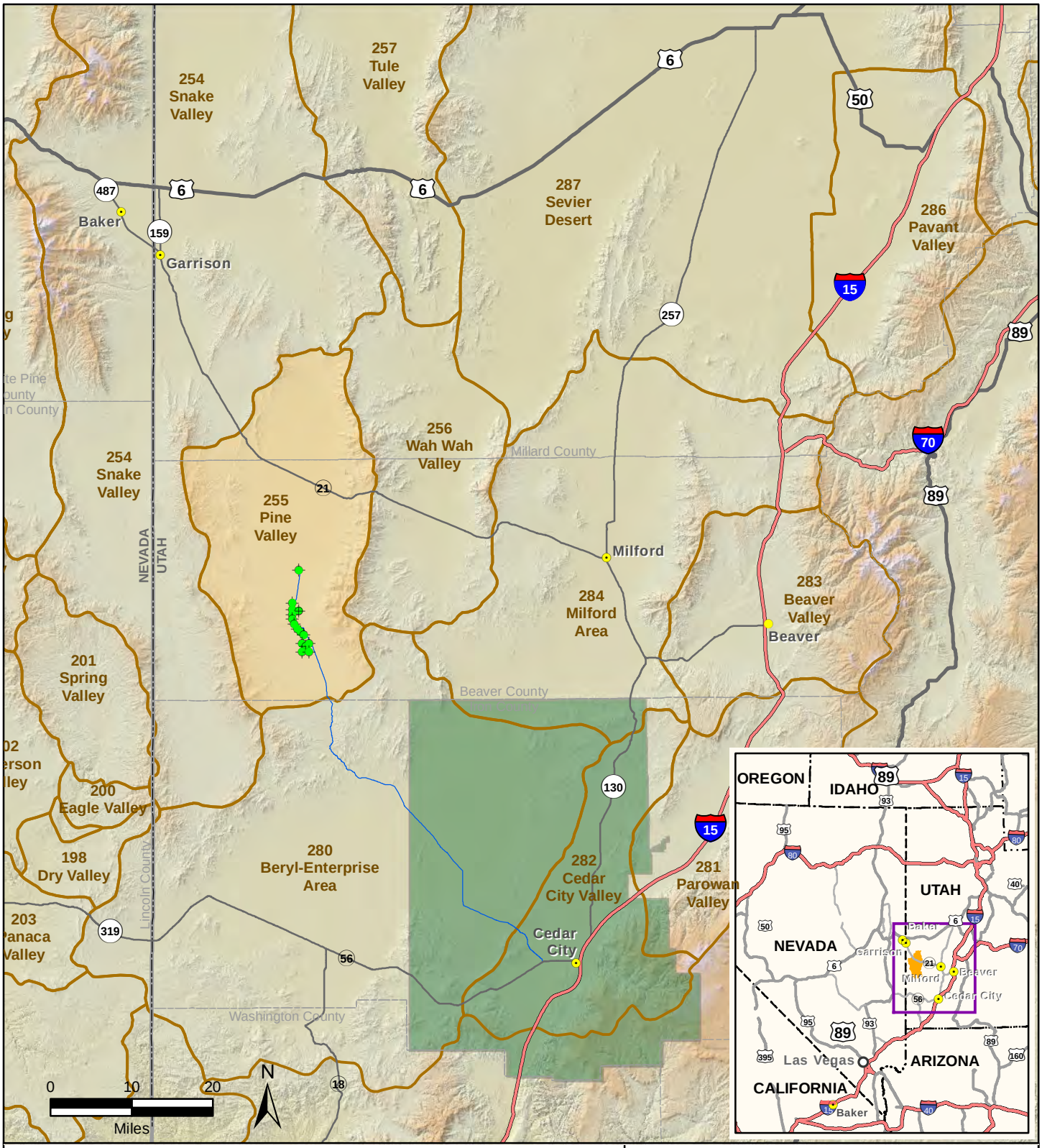
basin is behaving as predicted and allow early warning of potential impacts that exceed those predicted by the model, allowing adaptive management to be implemented to minimize or avoid these impacts. If the monitoring results show a potential for unacceptable impacts, the adaptive management program included in the proposed action would be triggered. If, in 50 years at the time when project reauthorization is being considered, groundwater modeling utilizing updated assumptions and information indicates that continued pumping would have unacceptable impacts to the Pine Valley aquifer system or to other aquifers within the Great Salt Lake Flow System, the authorized project pumping schedule would be adjusted to prevent these impacts.

1.5 REPORT ORGANIZATION

This GRIA report includes the following chapters:

- Chapter 1, *Introduction,* which describes the background, purpose, and objectives of the study.
- Chapter 2, *Project Description*, which provides a brief overview of the PVWS Project, describes the project features related to groundwater extraction, discusses adaptive management strategies that will be implemented to avoid or minimize the potential for adverse effects resulting from groundwater extraction, identifies the project alternatives, and summarizes the applicable regulations and existing water rights.
- Chapter 3, *Affected Environment*, which defines the Study Area and provides an overview of its physical setting and surface water hydrology, with a focused discussion of hydrogeology and groundwater resources, and a description of the surface water and biological resources that could be affected by groundwater withdrawal.
- Chapter 4, E*ffects Analysis,* which presents the methods and results of an evaluation of the proposed groundwater extraction associated with the PVWS Project on groundwater resources, including cumulative effects.
- Chapter 5, *Environmental Consequences,* which presents a reasoned analysis of the potential impacts resulting from groundwater extraction associated with the PVWS Project on the environment, including cumulative impacts.
- Chapter 6, *Monitoring and Mitigation Measures,* which describes recommended monitoring and mitigation measures being considered for incorporation into the PVWS Project.
- Chapter 7, *References,* which includes a list of documents cited in this report.

Appendix A includes a summary of the methods and results used to develop and calibrate the GBCAAS-PV model, and presents the results of the predictive runs used to inform the GRIA.



Legend

- PVWS Project Well
- Hydrographic Area
- CICWCD Service Boundary
- Project Pipeline Alignment
- Interstate
- US Route
- State Route

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 1-1

LOCATION OF PINE VALLEY WATER SUPPLY PROJECT

DATE: DEC 29, 2020

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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2 PROJECT DESCRIPTION

2.1 PROJECT OVERVIEW

CICWCD proposes to install and operate a wellfield with production and monitoring wells in the Pine Valley HA to extract up to 15,000 AFY of groundwater to be conveyed to Cedar Valley, approximately 40 miles to the southeast, for beneficial use to serve CICWCD's customers. The PVWS Project includes construction, operation and maintenance of well and pumping facilities, a solar power generation plant, power distribution lines, water transmission pipelines, water storage tanks, access roads, and related appurtenances. The wellfield and pumping facilities will be powered by an approximately 200-acre solar photovoltaic power plant to be constructed on land acquired by CICWCD. Most of the remaining project facilities in Pine Valley will be constructed on BLM-managed land. Groundwater will be pumped from the wells, collected in a network of lateral pipelines connected to the Pine Valley main pipeline, and pumped to storage tanks at the high point of the alignment at the southern end of Pine Valley. From there the water will be released to a water transmission pipeline and will flow to Cedar Valley.

Under the Proposed Action, a wellfield with production and monitoring wells is proposed to be constructed in the southern portion of Pine Valley. Under the ANWS Alternative, all but the first six of the production wells would be shifted farther to the north in Pine Valley to decrease aquifer stress in the southern portion of Pine Valley. The Pine Valley main pipeline, lateral pipelines, power distribution lines, and access roads and other appurtenances would also be extended to service these wells. The water supply wells are anticipated to be completed to depths ranging from approximately 500 to 2,000 feet below ground surface (bgs) to extract water from the alluvial aquifer beneath the valley. At this time, it is anticipated that approximately 15 production wells and seven new wellfield monitoring wells will be constructed. The production wells are anticipated to be constructed with 16-inch diameter steel casings and screens, and equipped with electrical line shaft turbine pumps.

The proposed well layout for the Proposed Action is shown on Figure 2-1 and the proposed layout for the ANWS Alternative is shown on Figure 2-2. The locations of the wells will be determined in accordance with the Wellfield Adaptive Management Program described in Section 2.3, and the ANWS Alternative assumes that all except the first six production wells are shifted northward. The actual number of wells and completion details may vary based on the conditions encountered and the well yields achieved at each location but will be substantially like the wellfield layouts shown in the figures and will result in similar impacts. The PVWS Project will include rights of way for potential well construction at a number of alternative sites to allow flexibility in the selection of well locations and facilitate implementation of the adaptive management program.

Each well is assumed to pump groundwater at an annualized average rate of approximately 1,000 AFY, or just over 620 gallons per minute (gpm); however, the actual distribution of pumping may depend on individual well yields. The wells will likely vary in capacity, and instantaneous pumping rates will likely average between 600 and 1,000 gpm per well, with rates for individual wells possibly as high as about 2,000 gpm, depending on the strata encountered by the wells. Pumping is expected to vary seasonally

and to be greatest during summer peak demand and power production periods. In addition, pumping may be shifted or timed in accordance with a Wellfield Operational Plan developed in accordance with the Wellfield Adaptive Management Program described in Section 2.3.

2.2 APPLICABLE WATER RIGHTS AND REGULATIONS

The PVWS Project involves the exercise of a water right granted to CICWCD for the appropriation of 15,000 AFY of groundwater from beneath Pine Valley. The wells lie within Water Right Area 14 designated by Utah DWRi (equivalent to the Pine Valley HA). Utah DWRi's Groundwater Management Policy for Area 14 states that it believes there are unappropriated water rights available in the underground aquifer system of the Area (DWRi 2014a). On October 17, 2006, CICWCD filed Application to Appropriate Water Number 14-118 (A76676), to appropriate 15,000 AFY of groundwater from the aquifer underlying Pine Valley. After a lengthy hearing process, the application was approved by Utah DWRi in an Order dated May 13, 2014 (DWRi 2014b) and subsequently challenged in court. On February 27, 2019, the court issued a Stipulated Judgment approving the water right for permanent appropriation of 15,000 AFY of groundwater from Pine Valley for 100 percent (%) consumptive use (Fifth Judicial District Court, State of Utah 2019a), and the parties to the lawsuit entered into a Settlement Agreement (Fifth Judicial District Court, State of Utah 2019b).

Utah DWRi's 2014 Order required (among other things) that a permanent record of the diversions from each well be maintained, and that CICWCD "*shall develop a monitoring program to ensure that no prior rights are being impaired and that the aquifer system is not exceeding safe yield.*" The 2019 Settlement Agreement further stated the following:

> *The Parties acknowledge they have a difference of opinion regarding the amount of water available for development in … Pine Valley - namely, the safe yield of the aquifers… . By way of this Agreement the State Engineer will allow the non-State Engineer Parties to proceed with plans to develop the amount of water stated herein with the understanding that the non-State Engineer Parties assume all risk and full responsibility for the possibility that the safe annual yield of the … the Pine Valley aquifer is less than the amounts referenced … and that approvals provided under this Agreement may be for more water than future facts demonstrate is actually available for long-term beneficial use. They further understand and acknowledge that under Utah Code Section 73-5-15, the State Engineer may regulate groundwater withdrawals within a specific groundwater basin by adopting a groundwater management plan… .*

Groundwater resources in the Pine Valley HA have been very sparsely developed. The State Engineer has adopted a recharge estimate of 21,000 AFY for the basin based on the characterization by Stephens (Stephens 1976), and indicated it has reason to believe that groundwater in the basin is available for appropriation (DWRi 2014a). However, as noted in the 2019 Settlement Agreement and discussed in Section 1.3.2, uncertainty remains regarding the amount of recharge in the Pine Valley HA. The precise safe yield of the basin is therefore unknown and, for the purposes of compliance with the Utah Code, can only be reliably established based on long-term groundwater level measurement in response to pumping.

To address this uncertainty and comply with the requirements of the Utah DWRi's 2014 Order, CICWCD must implement a groundwater level monitoring program to verify the basin's safe yield is not being exceeded. The Utah Code defines safe yield as "*the amount of groundwater that can be withdrawn from a groundwater basin over a period of time without exceeding the long-term recharge of the basin or unreasonably affecting the basin's physical and chemical integrity"* (Utah Code §73-5-15(1)(b)). If Utah DWRi determines that the basin's safe yield is being exceeded, or more than 1/3 of the water rights holders in the basin request it, a Groundwater Management Plan (GMP) must be adopted that limits groundwater extractions to the safe yield (Utah Code §73-5-15(2)).

If groundwater pumping is otherwise required to be limited or curtailed pursuant to the monitoring and mitigation program adopted for the PVWS Project to avoid potential adverse impacts under NEPA (see Appendix F of EIS), such actions would need to be coordinated with the DWRi through a GMP, since it is the agency with authority to limit water rights granted by the state.

2.3 WELLFIELD ADAPTIVE MANAGEMENT PROGRAM

In order to address the monitoring requirements in the Utah DWRi's Water Rights Order (DWRi 2014b), manage uncertainty in the aquifer response to pumping and avoid or minimize potential adverse effects related to groundwater extraction for the PVWS Project, the following adaptive management program has been incorporated as part of the project.

2.3.1 WELLFIELD CONSTRUCTION ADAPTIVE MANAGEMENT

As discussed in Chapter 3, the southern portion of the Pine Valley HA is underlain by volcanic bedrock. Gravity data and geologic mapping suggests the presence of several caldera complexes in the volcanic basement rocks beneath the valley alluvial fill. Historical groundwater levels recorded in wells in this area show a relatively sharp decline across the southern edge of this caldera complex, suggesting the possible presence of a flow-impeding structure in this area. The presence of such a structure, and its effect if present, cannot be assessed based on the existing data, and is best verified by monitoring during significant aquifer stresses, such as will be imposed by the proposed pumping for the PVWS Project. However, the effect of a flow impedance or barrier north of all or part the proposed wellfield would be to increase drawdown to the south above that predicted by the GBCAAS-PV model, increasing impacts to the Beryl-Enterprise Area HA.

In order to avoid or minimize drawdown impacts to the south beyond those predicted by the GBCAAS-PV model, the following adaptive management program will be implemented.

- Initially, the six startup production wells shown on Figure 2-3 will be constructed and pumped for a period of approximately three to 12 months. Four wellfield monitoring wells (one existing well and three new wells) will be used to monitor the drawdown response in the aquifer during the initial wellfield operation. The locations of these wells and predicted drawdown responses for the first year of pumping are shown in Figure 2-4. Additional information regarding the construction and monitoring of these wells is discussed in Chapter 6.

- The drawdown response at the wellfield monitoring wells was simulated using the GBCAAS-PV model as summarized in the graphs shown in Figure 2-4. The actual and predicted drawdowns will be compared and the model will be updated as appropriate.

    - If the actual drawdown effects are similar to or less than those shown in Figure 2-4, the remainder of the wellfield will be constructed as specified in the Proposed Action (Figure 2-1).
    - If the actual drawdown effects are greater than those shown in Figure 2-4, the updated GBCAAS-PV model will be used to determine how many of the remaining wells must be shifted to the northern alternative locations so that impacts to the Beryl-Enterprise Area remain similar to those predicted in this GRIA. If all of the remaining wells are shifted northwards, the result will be a wellfield configuration as shown in Figure 2-2 for the ANWS Alternative.

2.3.2 WELLFIELD OPERATION ADAPTIVE MANAGEMENT PROGRAM

Because groundwater development and aquifer stress is currently very limited in the Pine Valley HA, predicting the aquifer response to PVWS Project pumping entails inherent uncertainties. Much valuable information will be obtained by monitoring the groundwater level response to operation of the project wells. In order to adapt project pumping appropriately to the actual aquifer response and avoid or minimize potential adverse effects, the following adaptive management strategy will be implemented during project operation:

- Nearfield and farfield monitoring wells will be installed to the north, south, east, and west of the PVWS Project wellfield. The proposed locations of the monitoring wells are shown in Figure 2-5 and Figure 2-6 relative to the predicted extent and timing of drawdown effects for the Proposed Action and the ANWS Alternative. Nearfield monitoring well locations were selected to generally coincide with areas predicted to experience at least approximately 5 feet of drawdown within 10 years of PVWS Project operation. Farfield monitoring well locations were selected to coincide with areas predicted to experience about 10 feet of drawdown within 20 years of operation. These location criteria were selected to generate monitoring data that would allow course corrections, if necessary, during the early years of project operation. The proposed locations include four new wells. In addition, six existing wells will be used, if possible. Additional information regarding the proposed wells and the monitoring program is provided in Chapter 6. The actual monitoring well locations may differ from those shown, but will generally be within approximately 2,500 feet.

- Drawdown at the nearfield and farfield monitoring wells will be simulated using GBCAAS-PV once the final wellfield configuration is determined and final monitoring well locations have been selected.

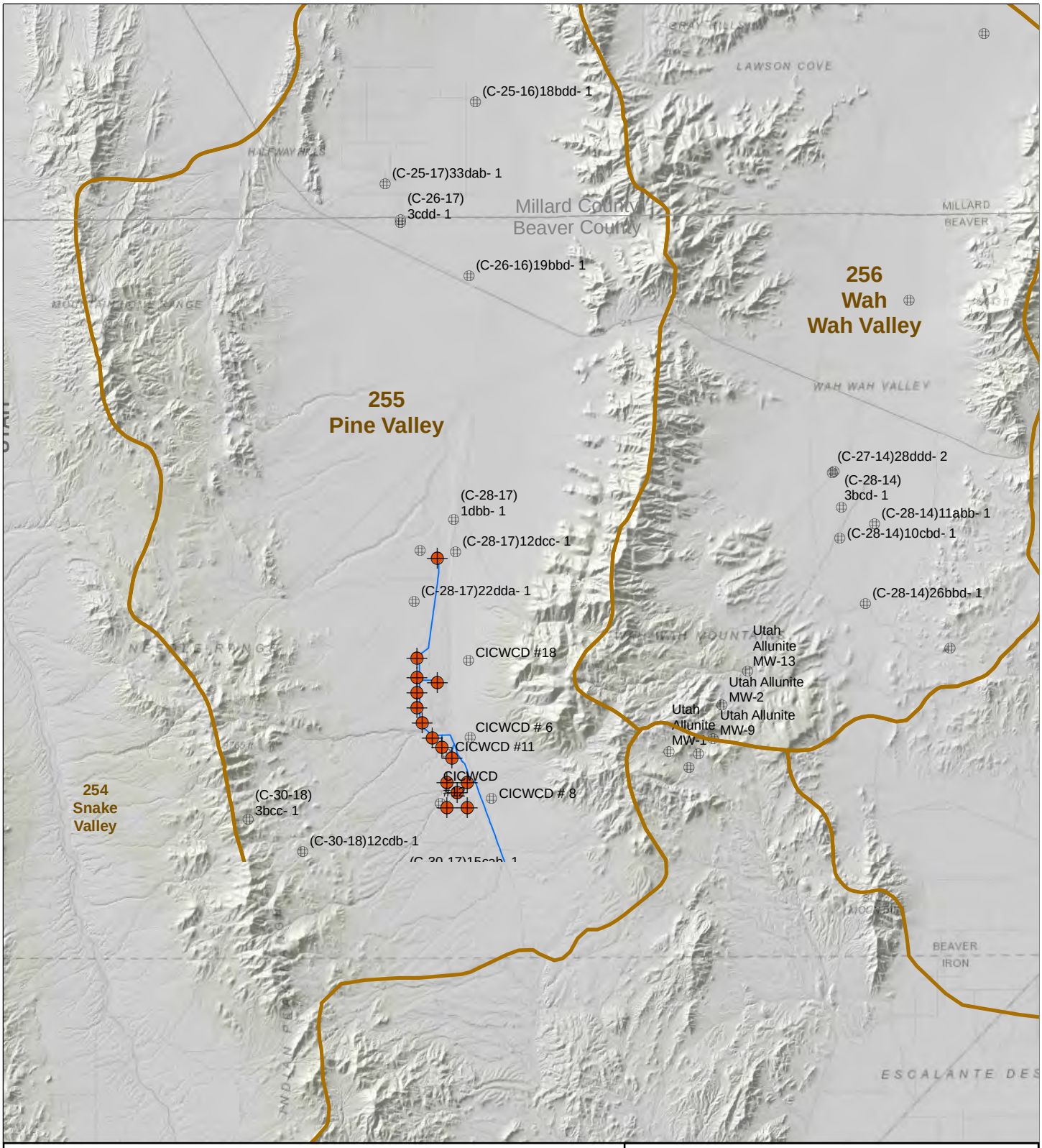
- The actual and predicted drawdowns at the nearfield and farfield monitoring wells will be compared annually, and the model will be updated as appropriate.

    - If the actual drawdown effects are similar to or less than predicted drawdowns, wellfield operation will continue unchanged.
    - If the actual drawdown effects are greater than those predicted, the updated GBCAAS-PV model will be used to develop a Modified Wellfield Operation Plan that will shift the

timing, location and/or quantity of pumping, as appropriate, to avoid or minimize potential adverse impacts.

2.4 ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

The ANWS Alternative represents the endpoint of the Wellfield Construction Adaptive Management Program described in Section 2.3.1 if all but the initial six wells are shifted to their northern alternative locations. The wellfield configuration for this alternative is shown in Figure 2-2 and the proposed nearfield and farfield monitoring locations are shown in Figure 2-6. While this wellfield configuration is a possible result of implementing the Proposed Action if the Wellfield Construction Adaptive Management Program is fully implemented, it is evaluated as a separate alternative under NEPA in this GRIA for comparison.



Legend

- PVWS Project Well
- Existing Well Locations
- Hydrographic Area
- Project Pipeline Alignment

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Miles

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 2-1

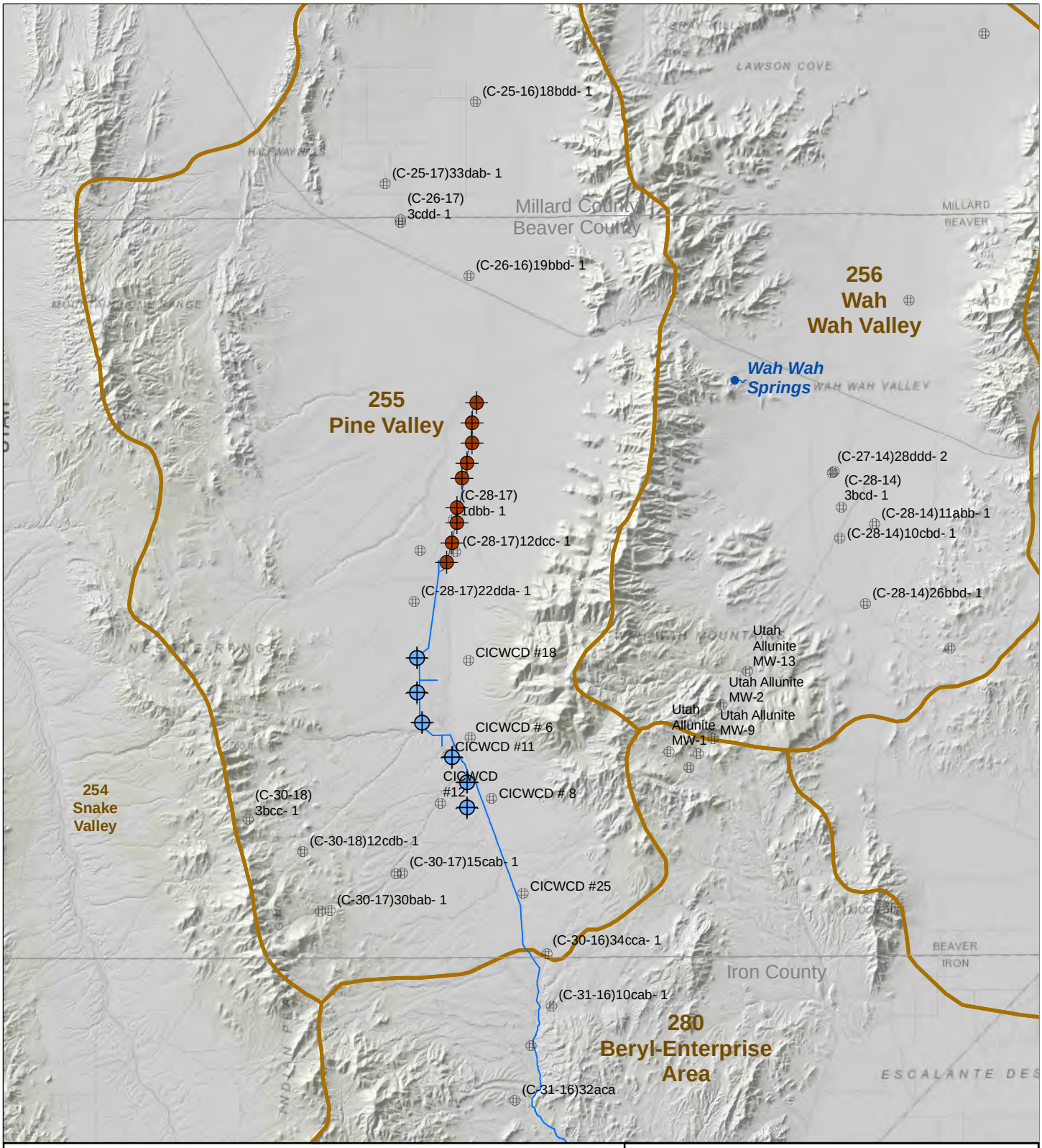
WELLFIELD LAYOUT FOR PROPOSED ACTION

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BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- ANWS Alternative Well
- Startup pumping well
- Existing Well Locations
- Hydrographic Area
- Project Pipeline Alignment

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0 4 8

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PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 2-2

WELLFIELD LAYOUT FOR ANWS ALTERNATIVE

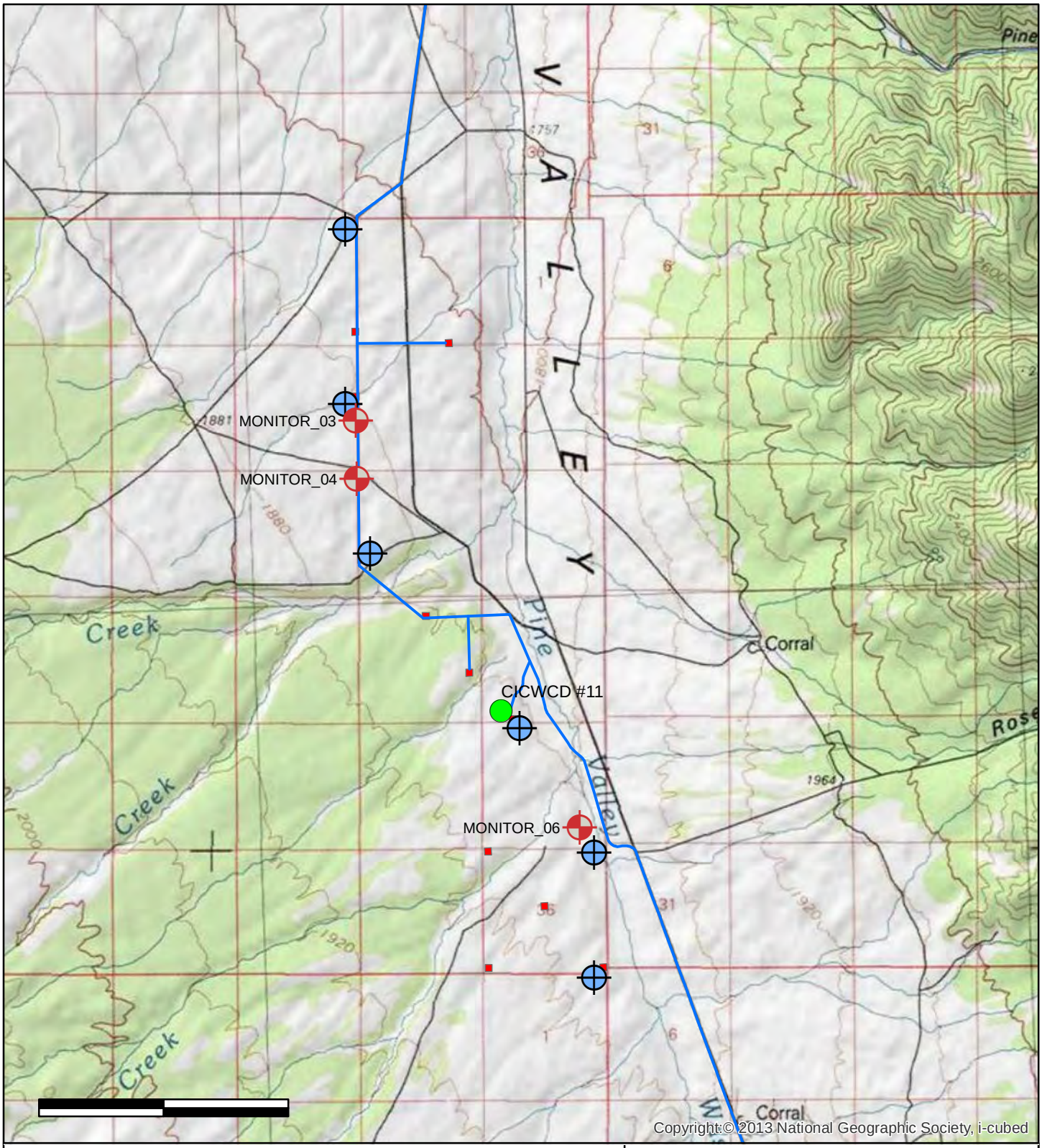
DATE: DEC 29, 2020

BY: CRL

FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- Proposed startup monitoring well
- CICWCD startup monitoring well (existing)
- Startup pumping well
- Project Pipelne Alignment
- CICWCD well parcel

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

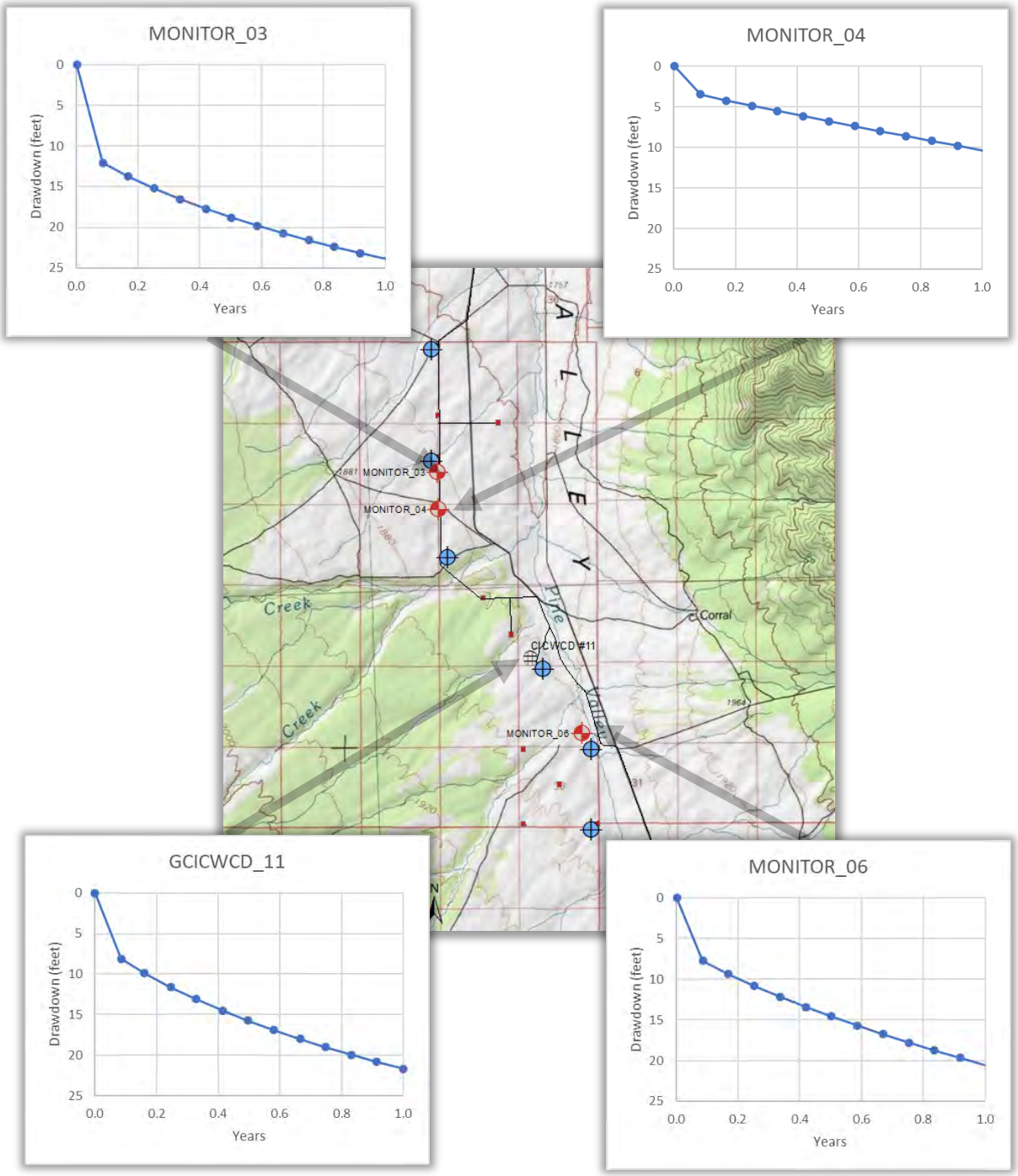
FIGURE 2-3

STARTUP PRODUCTION WELLS

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BY: CRL	FOR: PHT	

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Legend

- Proposed startup monitoring well
- CICWCD startup monitoring well (existing)
- Startup pumping well
- Hydrographic Area
- Project Alignment
- CICWCD well parcel

PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 2-4

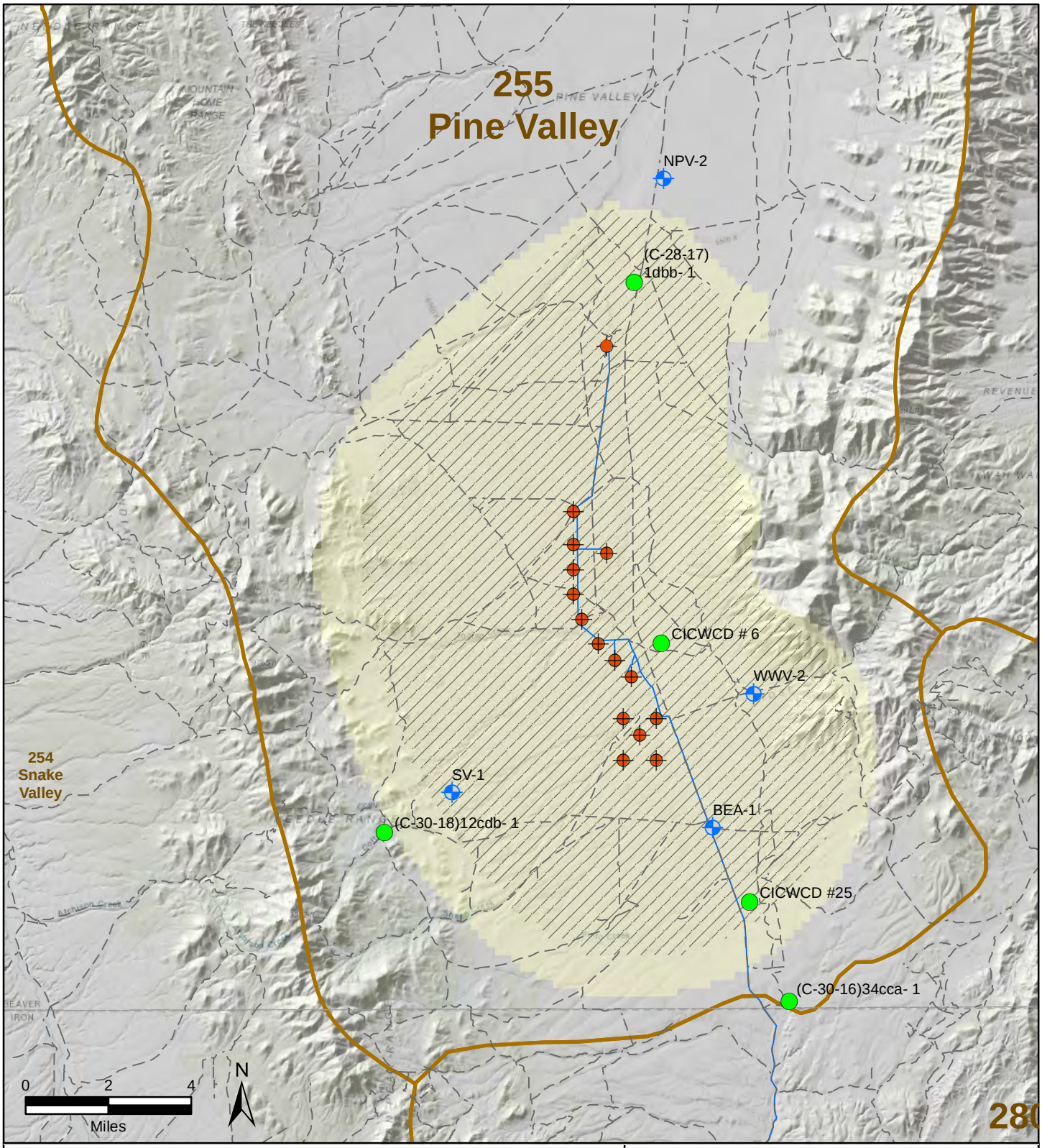
SIMULATED DRAWDOWN AT PROPOSED WELLFIELD MONITORING WELLS

DATE: SEPTEMBER 2020

BY: PHT | FOR: MT

FORMATION ENVIRONMENTAL

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Legend

- PVWS Project Well
- Monitoring Well (new)
- Monitoring Well (existing)
- Hydrographic Area
- Predicted Drawdown >5 ft after 10 years pumping
- Predicted Drawdown >10 ft after 20 years pumping
- Local Access Road

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 2-5

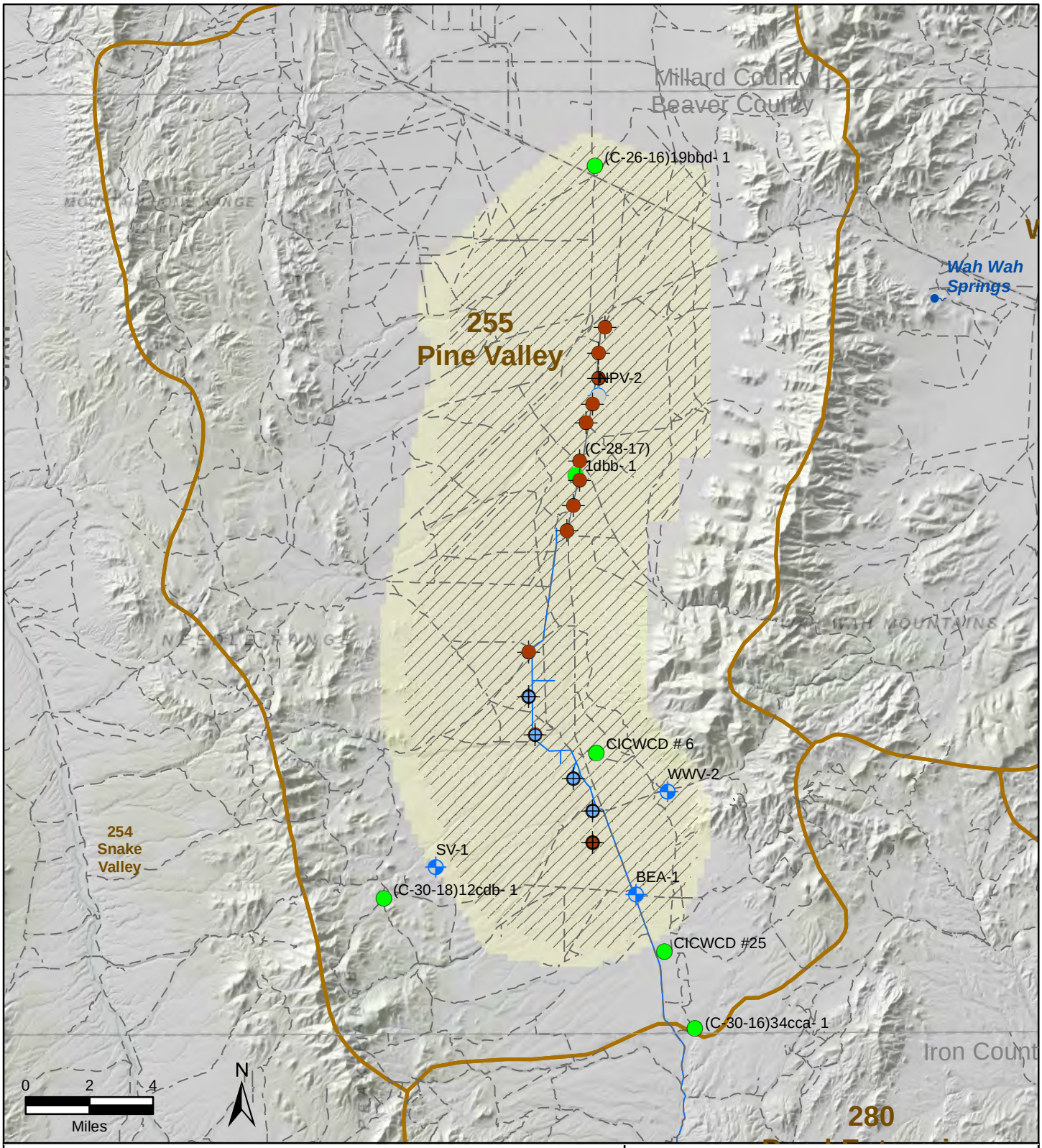
NEARFIELD AND FARFIELD MONITORING WELL LOCATIONS FOR PROPOSED ACTION

DATE: MAY 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- Startup pumping well
- ANWS Alternative Well
- Monitoring Well (existing)
- Monitoring Well (new)
- Hydrographic Area
- Drawdown >5 ft after 10 years pumping
- Drawdown >10 ft after 20 years pumping
- Local Access Road

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 2-6

NEARFIELD AND FARFIELD MONITORING WELL LOCATIONS FOR ANWS ALTERNATIVE

DATE: MAY 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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3 AFFECTED ENVIRONMENT

3.1 STUDY AREA

The Study Area for this GRIA is shown in Figure 3-1 and was established based on the extent of reasonably anticipated PVWS Project hydrogeologic and groundwater budget effects. It is expected that groundwater extraction in the Pine Valley HA may affect the groundwater budgets for the Snake Valley (including Hamlin Valley), Tule Valley, Sevier Desert (in the area around Sevier Lake), Wah Wah Valley, Beryl-Enterprise Area, and Milford Area HAs. Although the observable effects induced by the PVWS Project are not expected to extend through the entirety of these HAs, they have been included in their entirety to bracket the area of potential interest to this study, and the study area has been delineated to include these areas (the Study Area). The area predicted to experience drawdown induced by pumping for the PVWS Project falls within this area (see Appendix A). This is considered the Area of Project Effects (APE) and is delineated based on the maximum predicted 1-foot drawdown contour resulting from simulation of the project. Drawdown less than this amount generally would not be distinguishable from natural seasonal and inter-annual fluctuations, and would not be expected to result in adverse impacts to groundwater-related resources. Hydrogeologic conditions in this area were evaluated in greater detail, and the GBCAAS-PV model was developed and refined as a child model to the regional GBCAAS v. 3.0 model to focus more closely on this area, while still being able to evaluate effects in other portions of the HAs surrounding Pine Valley using the parent model. The boundaries of the GBCAAS-PV chile model were selected to fall along or close to natural hydrogeologic boundaries and limit the potential effects of model boundary selection on simulations in the area of interest. Of the simulated areas, the most pronounced effects induced by the PVWS Project would occur in the Pine Valley HA, and to a lesser extent in the Wah Wah Valley HA, and would extend into the surrounding portions of the Study Area and attenuate with distance.

3.2 SITE LOCATION AND LAND USE

Pine Valley is a relatively undeveloped rural valley located approximately 50 miles northwest of Cedar City in southwest Utah, and 50 miles southeast of Baker, Nevada (Figure 1-1). Great Basin National Park is located approximately 55 miles northwest of Pine Valley, west of Baker along Highway 50. Pine Valley is a hydrologic and structural basin typical of the Great Basin Geomorphic Province (GBGP) that trends north-northeast and encompasses about 730 square miles in Iron, Beaver and Millard Counties, Utah. It is located east of Snake Valley in eastern Nevada, north of the Beryl-Enterprise area, and south of Tule Valley and the Sevier Desert. Wah Wah Valley lies immediately to the east of Pine Valley and encompasses about 600 square miles. Access to the Pine Valley area from the north is via State Route 21 which passes though the northern portion of the valley, or from the south via a series of unimproved dirt roads (Figure 1-1).

The Pine Valley and Wah Wah Valley HAs are sparsely inhabited. There are no permanent residences or commercial establishments in the Pine Valley HA. The U.S. Forest Service (Forest Service) Desert Experimental Range is located at the northwestern end of the valley north of State Route 21 and is occasionally occupied. Several cabins in the surrounding mountains are also reported to be occasionally

occupied. In the Wah Wah Valley HA, there is one ranch with irrigated land, Wah Wah Ranch, about ½ mile north of State Route 21 near the center of the valley. The abandoned town of Newhouse is located about 30 miles west of Milford in Wah Wah Valley and was a mining town associated with the Cactus Mine and Mill, which operated from about 1870 to 1914. The primary land use in Pine Valley is open range land used for livestock grazing and recreational activities on federally owned lands. A pole line runs along State Route 21 and power has been provided to Wah Wah Ranch since 1988 from a hydroelectric turbine placed in a water pipeline that runs from Wah Wah Springs in the Wah Wah Mountains to the ranch.

Land ownership in the Pine Valley area is a combination of private, state, and federal land (Figure 3-2). Approximately 42,000 acres is private land, about 11,000 acres is state trust land managed by the Utah School and Institutional Trust Lands Administration (SITLA) and includes the Indian Peak Wildlife Management Area, and 420,000 acres is federally owned land, most of which is managed by BLM (370,000 acres). The remainder is Forest Service land (50,000 acres) of the Desert Experimental Range. As previously mentioned, CICWCD acquired approximately 200 acres of private land in the southern portion of Pine Valley for construction of the PVWS Project solar field. Land ownership in the Wah Wah Valley area is also a combination of private and federal land (Figure 3-2). Approximately 63,000 acres is private land and about 324,000 acres is federal land managed by BLM. The private land includes Wah Wah Ranch, which has been privately owned since 1896.

The location of the PVWS Project and predicted APE and Study Area is shown on Figure 3-1 relative to potentially sensitive resources and protected lands. These include regional spring resources, wetlands, other surface water resources, managed habitat areas, National and State Parks, wilderness areas and wilderness study areas.

3.3 PHYSIOGRAPHY

The Pine Valley and Wah Wah Valley HAs are in the Great Basin region of the Basin and Range physiographic province (Fenneman and Johnson 1946), which covers an area of about 200,000 square miles of the western United States. The Great Basin region is in the northern part of the Basin and Range, primarily in Nevada and Utah. The region is characterized by generally parallel, north- to northeast-trending mountain ranges separated by broad alluvial desert valleys (Harrill and Prudic 1998). Typically, an intermediate slope separates the valley floor from the bordering mountain ranges. This slope is formed either by coalescing alluvial fans (bajadas) or by sedimentary materials thinly mantling eroded bedrock surfaces (pediments). Gradients of these slopes generally range from a few tens of feet to several hundreds of feet per mile.

Pine Valley is an elongate, topographically closed basin bounded by the Wah Wah Mountains to the east, and the Needle Mountains, comprised of the Mountain Home Range and Indian Peak Range, to the west (Figure 3-3). The valley extends about 40 miles from north to south and is about 20 miles wide. There is a dry playa near the northern end of the valley referred to as the Pine Valley Hardpan on USGS topographic maps. Ground surface elevation of the valley ranges from a low of about 5,075 feet above mean sea level (amsl) at the playa to 6,000 feet amsl along the mountain fronts. Elevations of the mountains surrounding Pine Valley range from about 6,500 to 7,500 feet amsl at mountain passes to over 9,000 feet at the highest

peaks. Peak elevations are 9,480 feet amsl at Needle Benchmark in the Mountain Home Range, 9,790 feet amsl at Indian Peak and 9,393 feet amsl in the southern Wah Wah Mountains. The northern end of the valley is separated from the Ferguson Desert by a broad low divide connecting the northern end of the Wah Wah Mountains with isolated bedrock ranges at Middle Mountain, Tunnel Spring Mountains, and the Needle Mountains. The elevation of the northern drainage divide is about 5,800 feet amsl. The southern end of the valley is separated from Escalante Valley by a low volcanic and alluvial divide between the Wah Wah Mountains and the Indian Peak Range. The elevation of the drainage divide at the southern end of the valley is about 6,200 feet amsl.

Wah Wah Valley is also a closed basin with a dry playa near the northern end referred to as the Wah Wah Valley Hardpan on USGS topographic maps. The valley is bounded by the Wah Wah Mountains to the west, the Confusion Range and House Range to the north, and the San Francisco Mountains to the east (Figure 3-3). State Route 21 bisects the Wah Wah Mountains, crossing over Wah Wah Summit at about 6,500 feet amsl. The valley ranges in elevation from about 4,600 feet amsl at the playa to approximately 6,000 feet at the mountain fronts. Elevations in the San Francisco Mountains reach 9,660 feet amsl at Frisco Peak. A broad low divide between the House Range and the San Francisco Mountains separates the northeastern end of Wah Wah Valley from the Sevier Desert. The elevation of the divide is about 4,625 feet amsl.

3.4 CLIMATE

The climate of Pine and Wah Wah Valleys is arid and characterized by low to moderate precipitation and orographic effects with precipitation closely tied to elevation. There are large daily temperature changes, moderately cold winters, and warm dry summers (Gardner *et al*. 2020). The mountains typically receive several feet of snow in the winter, but the data reportedly indicate that the proportion of precipitation falling as warm weather rain in the mountains surrounding Pine and Wah Wah Valleys is greater than in mountain ranges further to the west, which receive most of their precipitation in the form of winter snowfall. Several meteorological stations maintained under the Remote Automated Weather Stations (RAWS) network are located in the area, as are numerous precipitation gauges maintained by the local BLM field offices. The Desert Experimental Range station (National Oceanic and Atmospheric Administration (NOAA) Cooperative Observer Network (COOP) station 422116) is in Pine Valley at an elevation of 5,246 feet and has a historical period of record from January 1950 to September 1984. The Wah Wah Ranch station (NOAA COOP station 429152) is in Wah Wah Valley at an elevation of 4,885 feet and has a historical period of record from August 1955 to June 2008. The locations of these stations are shown on Figure 3-17.

The average monthly precipitation in Pine Valley during the period of record ranges from about 0.3 inches during the winter months from November through February, to about 0.9 inches during July and August (Table 3-1). Average total annual snowfall is about 10 inches. The average annual air temperature in Pine Valley was 49 degrees Fahrenheit (°F) for the 34-year period of record, with an average minimum

temperature of 12°F in January and an average maximum temperature of 92°F in July.[2] Daily temperature swings of 50°F are common during the summer.

The average monthly precipitation in Wah Wah Valley during the period of record was similar in magnitude and trend to the precipitation in Pine Valley and ranges from about 0.3 inches during the winter months to about 1 inch during August (Table 3-2). Average total annual snowfall is lower than in Pine Valley and is about 5 inches. The average annual air temperature in Wah Wah Valley was 51°F for the 53-year period of record, with an average minimum temperature of 14°F in January and an average maximum temperature of 95°F in July.[3]

As shown on the U.S. Drought Monitor (USDM) map, both Pine Valley and Wah Wah Valley are reported to currently be experiencing severe drought conditions (as of August 2020), with crop or pasture loss likely, water shortages common, and water restrictions imposed, as applicable.[4] To the north, the Sevier Desert is reported to currently be experiencing extreme drought conditions, with major crop and pasture losses and widespread water shortages or restrictions.

TABLE 3-1. TEMPERATURE AND PRECIPITATION SUMMARY FOR PINE VALLEY

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave Max Temp (°F)	41.1	47.6	53.7	62.5	72.9	84.4	92.2	89.3	80.8	68.0	52.7	42.8	65.7
Ave Min Temp (°F)	12.1	18.3	23.5	30.2	38.7	47.0	55.1	53.4	43.8	32.4	21.4	13.3	32.4
Ave Temp (°F)	26.6	33.0	38.6	46.4	55.8	65.7	73.7	71.4	62.3	50.2	37.1	28.1	49.1
Total Precip (in)	0.3	0.28	0.54	0.58	0.62	0.39	0.81	0.91	0.62	0.52	0.35	0.29	6.22
Total Snowfall (in)	2.1	0.8	2.5	0.7	0.4	0	0	0	0	0	0	1	10.2

Notes: in-= inches, °F = degrees Fahrenheit

TABLE 3-2. TEMPERATURE AND PRECIPITATION SUMMARY FOR WAH WAH VALLEY

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave Max Temp (°F)	42.6	49.5	58.0	65.9	76.4	87.1	94.7	92.0	83.3	70.6	55.0	43.9	68.2
Ave Min Temp (°F)	14.2	20.8	26.3	32.3	40.8	49.6	58.0	56.2	45.8	33.9	23.2	14.6	34.6
Ave Temp (°F)	28.4	35.2	42.2	49.1	58.6	68.4	76.4	74.1	64.6	52.3	39.1	29.3	51.4
Total Precip (in)	0.32	0.39	0.58	0.65	0.66	0.42	0.59	0.97	0.73	0.72	0.49	0.27	6.77
Total Snowfall (in)	0.5	1.4	1.0	0.3	0	0	0	0	0.1	0	0.7	1.1	5.2

[2]Western Regional Climate Center climate summary accessed April 2020 at https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ut2116
[3]Western Regional Climate Center climate summary accessed April 2020 at https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ut9152
[4]National Integrated Drought Information System accessed April 2020 at https://www.drought.gov/drought/states/utah

The potential effects of climate change in the Study Area during the analysis forecast period should be understood to evaluate the potential effects of the PVWS Project (Utah DPS 2019). Warmer temperatures may cause more rainfall because warmer air holds more water vapor than colder air. Climate change may result in increased average temperatures and corresponding increases in precipitation, but this may be offset by increased evapotranspiration. In addition, there may be more rainfall and less mountain snow. Finally, changing weather patterns may cause longer periods without storms or changes in storm intensity. Because Utah's climate is very dry, the area is susceptible to strong thunderstorms that cause flash floods, and these storms may become more common and more intense as a result of climate change.

Based on historical data, average temperatures in St. George, in southwestern Utah have been steadily warming since 1895 and have increased by approximately 3°F during the period of record (DPS 2019). The temperature record for Cedar City indicates more variable average temperatures, but also with an overall increasing trend of about 0.5°F since 1950. No long-term trends in precipitation were observed at either location during the periods of record. The long-term average annual precipitation is approximately 11 inches for Cedar City and 8 inches for St. George. Significant periods of drought occurred in the 1930s in St. George and in the 1950s and early 2000s in both locations.

Temperatures in St George Utah are projected to warm by 2.5 to 5.5°F over the next 50 years (DPS 2019) under a moderate emission scenario (Representative Concentration Pathway (RCP) 4.5) and a high emissions scenario (RCP 8.5), respectively, developed by the Intergovernmental Panel on Climate Change (IPCC). Long-range climate models do not provide clear projections of how precipitation will change in southwestern Utah, and do not predict an increase in precipitation. However, increased temperatures would be expected to raise potential evapotranspiration (ET), and may decrease the amount of precipitation that falls as snow, with both effects depending upon the timing of storm events. Gardner *et al*. (2020) collected geochemical data from wells within the Pine and Wah Wah Valley HAs that indicates snowfall is a less important source of groundwater recharge than higher temperature storms in the Study Area (Section 3.8.6), so the effect of climate change on groundwater recharge in these basins is not clear. It is likely that increased potential ET will result in some decrease in the amount of groundwater available for mountain recharge, but the magnitude of this effect is uncertain. However, it is possible that groundwater discharge rates by ET in basins located further to the north may increase. The distance between the mountain recharge areas in Pine Valley and discharge area to the north suggests that the groundwater flow system would take a long time to equilibrate to these trends.

3.5 VEGETATION

Because of the aridity of the area, native vegetation in Pine and Wah Wah Valleys consists primarily of salt-desert shrubs that are typical of the Great Basin region (Stephens 1976). Vegetation is absent on the playas. A mixture of shadscale (*Atriplex* sp.) and bunchgrasses predominate on the gravelly soils that surround the playas and cover most of the valley floor. The vegetative cover is sparse, and generally covers less than 10 percent of the ground surface.

On the alluvial slopes adjacent to the valley floor, sagebrush *(Artemesia* sp.) is the dominant vegetation below an altitude of about 6,000 feet (Stephens 1976). Above that altitude juniper *(Juniperus* sp.) and

pinyon *(Pinus* sp.) woodlands predominate on both alluvial and residual soils. Several types of deciduous shrubs grow in the uplands, especially on northward-facing slopes.

Rabbitbrush *(Chrysothamnus* sp.) and greasewood *(Sarcobatus vermiculatus)* grow locally in and along stream channels in the alluvium and in places on the valley floor (Stephens 1976). These shrubs are limited primarily to areas of sandy soils that absorb precipitation and runoff readily and temporarily store it as soil moisture for subsequent plant use. Where moisture is perennially available in the vicinity of certain springs and in areas where the water table is shallow, meadowgrasses, saltgrass *(Distiahlis striata),* greasewood, rabbitbrush, willow *(Salix* sp.), and other phreatophytes are common. Cottonwood *(Populus* sp.) and saltcedar *(Tamarix* sp.) grow as phreatophytes at a few locations. Cattail *(Typha latifolia),* watercress *(Rorippa nasturtium-aquatiaum)*, and other hydrophytes grow locally in areas of spring discharge.

3.6 GEOLOGY

Structurally, Pine and Wah Wah Valleys are eastward-tilted graben fault blocks that are bounded on each side by normal faults associated with basin and range tectonic extension in the Basin and Range physiographic province (Gardner *et al*. 2020). Faulting extends along the length of each of the mountain ranges that divide the basins, including the San Francisco Mountains and Wah Wah Mountains on the east and west side of Wah Wah Valley, respectively, and the Needle Mountains on the west side of Pine Valley. Additional complex folding, faulting, and fracturing has been observed, especially in rocks of Paleozoic age (Stephens 1976). Lithologic units in the Pine Valley and Wah Wah Valley HAs range in age from Precambrian to Quaternary and are shown on the geologic map of the Study Area (Figure 3-4).

Early hydrologic reconnaissance studies of Pine and Wah Wah Valleys described the basin-fill alluvium and stated that the maximum thickness of the basin fill was unknown (Stephens 1974, 1976). Gardner's hydrologic and geochemical characterization study (Gardner *et al*. 2020) was more focused on the regional carbonate aquifer and discharge from springs. Gardner described the "thick basin-fill deposits" as coarse gravels and sands interlayered with fine-grained sediment (referencing Stephens) and stated that "groundwater levels are deep throughout the basin-fill aquifers" but did not discuss the thickness of the basin fill. As part of the setup and verification of the GBCAAS-PV model for this study, available geologic, hydrogeologic and geophysical studies, including published geologic maps, cross sections, and well boring logs, were examined, digitized, and entered into a three-dimensional geodatabase to verify that the regional alluvial and carbonate aquifer representation in the model is consistent with geologic mapping and geophysical studies. Additional details regarding this conceptual model verification are discussed in Section 3.8.1. The maximum alluvial basin-fill thicknesses interpreted from the cross sections are 10,000 feet in Pine Valley and 4,000 feet in Wah Wah Valley.

The Precambrian and Paleozoic units in the Study Area consist of quartzites and carbonates with lesser amounts of shales, siltstones, and sandstones (Gardner *et al.* 2020), and are the dominant lithologies that crop out on the western slopes of the San Francisco Mountains and in the Wah Wah Mountains, House Range, Confusion Range, and the northern portion of the Needle Mountains. These rocks are generally subdivided into a lower siliciclastic unit that is overlain by a lower carbonate unit, an upper siliciclastic

unit, and an upper carbonate unit. The lower siliciclastic unit comprises Precambrian to Ordovician siliciclastic rocks consisting mainly of quartzites with some phyllites and phyllitic shales that are generally resistant, cliff-forming strata (Stephens 1976). The subsurface thickness of these lower siliciclastic rocks varies from 5,000 to more than 10,000 feet and they underlie most of Pine and Wah Wah Valleys at depth. Overlying these lower siliciclastic rocks are Cambrian to Devonian carbonate rocks, Mississippian siliciclastic rocks, and Pennsylvanian to Permian carbonates. The lower carbonate rocks consist mainly of limestone and dolomite and have been altered by contact metamorphism adjacent to the intrusive rocks in the Needle Mountains in the southern portion of the area (Stephens 1976). The maximum thickness of the Cambrian to Devonian carbonate sequence is more than 15,000 feet and these rocks underlie most of the valleys at depth. Based on the published cross sections used to verify the hydrogeologic conceptual model, the Mississippian (upper) siliciclastic rocks are sandwiched between the two carbonate rock sequences and vary from 0 to 5,000 feet in thickness. In the Study Area, they are found primarily east of the axis of Pine Valley and are truncated by the range-bounding fault on the east side of the valley. Pennsylvanian to Permian carbonate rocks include limestones and dolomites that crop out mainly in the northern mountains and are overlain by extrusive igneous rocks. These younger carbonate rocks are not found in the subsurface in Pine or Wah Wah Valleys but crop out in the northern portion of the Needle Mountains, Burbank Hills, and Confusion Range and other mountain ranges to the north of Pine Valley and occur in the subsurface in Snake Valley.

The Cenozoic bedrock units consist of both intrusive and extrusive igneous rocks. Tertiary intrusive rocks are composed mainly of porphyritic quartz monzonite and small outcrops of diabase and granite in the southern Needle Mountains, southern Wah Wah Mountains and San Francisco Mountains (Stephens 1974 and 1976). Tertiary extrusive volcanic units are comprised of thick sequences of tuffs and ignimbrites that dominate the bedrock sequence in the southern portion of the Needle Mountains and Pine Valley and are associated with the Indian Peak-Caliente caldera complex (Best *et al*. 2013). Multiple eruptive events created nine partly exposed, separate to overlapping calderas and surrounding outflow ignimbrite sheets. The Indian Peak-Caliente ignimbrite field migrated southward throughout the Great Basin through time in response to rollback of the subducting lithosphere (Best *et al.* 2013). The tuffs and ignimbrites extend into the subsurface and are interbedded with the older alluvium in the southern portions of Pine Valley (Stephens 1976).

Tertiary and Quaternary older alluvium comprises sediments ranging in size from clay through boulders that are intermixed and interbedded range from unconsolidated to locally well cemented (Stephens 1976). The sequence may include some lacustrine deposits at the valley centers and colluvium at the valley margins, but consists primarily of alluvium deposited in alluvial fans and along the valley axis. Well-cemented gravel beds crop out locally along the margins of the valley. The older alluvium underlies the younger alluvium and is interbedded with extrusive igneous rocks in the southern portion of Pine and Wah Wah Valleys. The thickness of the older alluvium ranges from a few tens or hundreds of feet near the margins of Pine Valley to more than 3,500 feet near the center.

The maximum thickness of the Quaternary alluvium is approximately 6,500 feet in the Study Area. Quaternary alluvium and colluvium is composed of mainly of sand, gravel and boulders, but includes some intermixed and interbedded clay and silt (Stephens 1976). The alluvium was primarily deposited on steeply

sloping fans at the base of the mountains and grades laterally into finer grained alluvium toward the valley center; whereas, colluvium locally covers the bedrock slopes adjacent to the mountains. The alluvium near the center of the valleys includes distal fan deposits and valley axial deposits of sandy and gravelly clay. It also occurs as a thin veneer overlying and adjacent to modern lakebed silts and clays, which grade into the coarser alluvium along the valley margins. The Pine Valley structural basin is asymmetrical, and the alluvial valley fill thins abruptly toward the eastern margin of the valley and may be truncated by the range-bounding fault on that side of the valley. Based on the published cross sections, the alluvium thins more gradually to the west, where it abuts a more gradually tilted bedrock of the mountain front on the west side of the valley.

Modern stream channel alluvium is deposited along the valley axis and the dominant alluvial fan drainages emerging from the mountains. It is composed of mainly sand and gravel but includes some clay and silt (Stephens 1976). The alluvium is present as channel fill along larger streams and is probably less than 20 feet thick (Stephens 1976).

Quaternary lacustrine deposits consist of lakebed clay and silt and include the playa deposits near the north end of Pine Valley and Wah Wah Valley (Stephens 1976, 1974). Lacustrine deposits may underlie the more gently sloping alluvial deposits of the valley floor, particularly in the northern portion of the valleys. The lacustrine deposits are expected to thin laterally from the center of the valley toward the valley margins.

3.7 SURFACE WATER RESOURCES

The PVWS Project is located in the Pine Valley HA (HA 255); however, Wah Wah Valley (HA 256), Snake Valley (including Hamlin Valley, HA 254), Tule Valley (HA 257), Sevier Desert (HA 287), Milford Area (HA 284), and Beryl-Enterprise Area (HA 280) are considered in the Study Area. The potential for surface water resources to be affected by pumping for the PVWS Project is generally limited to the area within the APE identified in Figure 3-1, and the discussion of surface water resources below is focused on these areas.

3.7.1 STREAMS, PONDS AND LAKES

3.7.1.1 PINE VALLEY HA

There is no surface water outflow from the Pine Valley HA (Figure 3-5). A well-developed network of intermittent to ephemeral stream channels leads onto the playa from the surrounding mountains. Stephens (1976) observed that runoff seldom reaches the playa except during intense local storms. Most runoff from the southern portion of the HA is dissipated by infiltration and evaporation before it reaches the playa. Sheep Creek and Indian Creek in the southeastern Needle Mountains and Pine Grove Creek in the west central Wah Wah Mountains are perennial in higher elevation reaches but become ephemeral in lower reaches as they approach the valley (Gardner *et al*. 2020). These streams probably do not represent discharge from a regional water table; instead, they appear to be perched zones resulting from the accumulation of groundwater in permeable unconsolidated deposits underlain by less permeable, unsaturated consolidated rocks (Gardner *et al*. 2020). As such, they are not expected to be affected by groundwater level drawdown from pumping associated with the PVWS Project.

Pine Valley Wash, the principal drainage for the southern portion of the HA, is ephemeral through its entire course from the southern drainage divide to the playa. Estimates of runoff in this wash ranged from 350 to 1,200 acre-feet per year (AFY) (Stephens 1976). An average annual runoff of 1,200 AFY from the 192 square mile drainage area equals about 1% of the average annual precipitation on the drainage area. Field examination of the dry washes by Stephens (1976) indicates that as these channels become progressively smaller, the mean volume of runoff becomes progressively less with decreasing altitude. Based on these observations, Stephens (1976) estimated that runoff reaching the Pine Valley playa averages less than 500 AFY, or about 0.1% of the total precipitation on the HA.

Surface water development and use in the Pine Valley HA is insignificant (Stephens 1976). Several small stock ponds and reservoirs intercept local runoff or stream flow in Pine Valley. At times during the fall, winter, and spring these reservoirs store small quantities of water for livestock, but during summer most of them are dry. The total storage capacity of these impoundments is probably less than 100 acre-feet. At least two stream impoundments are reported to store water for diversion to off-stream uses (Stephens 1976). Water from Pine Grove Creek is diverted intermittently from one reservoir by an open unlined ditch to East Pine Reservoir, a stock pond. Water has also been pumped from an impoundment on Sheep Creek for use in nearby mining operations. Total volume of water diverted from these impoundments is unknown, but probably small.

3.7.1.2 WAH WAH VALLEY HA

There is no surface water outflow from the Wah Wah Valley HA (Figure 3-5). All the washes and streams in Wah Wah Valley are intermittent or ephemeral. The more prominent stream channels and washes in the valley include Wah Wah Wash, Grover Wash, Willow Creek, Quartz Creek, and Frisco Wash. Streamflow has been historically observed in these channels during large, high-intensity precipitation events, but does not persist for great distances due to streambed seepage (Gardner *et al*. 2020). Wah Wah Wash is the predominant wash that drains into the Wah Wah Valley playa, which is a sink at the northern end of the Wah Wah Valley HA.

Total runoff in the Wah Wah Valley HA reportedly averages about 7,800 AFY (Stephens 1974). Because the average annual precipitation in Wah Wah Valley is low (less than 10 inches), air temperatures and soil-moisture requirements in this area are generally high and surficial deposits in the valley portion of the HA are generally unconsolidated, runoff is negligible. Total annual runoff below an altitude of 5,600 feet is estimated to average less than 500 AFY, even though one-half of the total precipitation falls there (Stephens 1974).

Runoff estimates from Grover Wash, Willow Creek, Frisco Wash, Quartz Creek, and other unnamed tributaries ranged from 240 to 1,890 AFY (Stephens 1974). Runoff estimates for Wah Wah Wash range from 100 to 580 AFY. Most of this runoff never reaches the valley floor because it is lost by evaporation and infiltration on the lower slopes of the surrounding mountains. These streams are losing and not groundwater connected, and therefore are not expected to be affected by potential groundwater drawdown associated with pumping for the PVWS Project.

Several small stock ponds and reservoirs have been constructed in Wah Wah Valley to intercept local runoff (Stephens 1974). These reservoirs store small quantities of water for livestock use during the fall and spring, but during much of the summer they are dry. A reservoir at Wah Wah Ranch, which reportedly has a surface area of about 60 acres and storage capacity of about 200 acre-feet, stores water diverted by pipeline from Wah Wah Springs. Dutchman Reservoir and Newhouse Reservoir, two ponds located north of Wah Wah Ranch, also store water diverted from the springs.

3.7.1.3 OTHER HAS

The only other surface water body within the APE shown on Figure 3-5 that has a potential to be groundwater connected is Sevier Lake, located in the southern portion of the Sevier Desert HA, approximately 50 miles north-northeast of the proposed PVWS Project wellfield. No other interconnected surface water bodies have been identified in the Study Area (Brooks 2017). Although Sevier Lake receives significant runoff in some years that results in the formation of a large, shallow playa lake, recent investigations for the Crystal Peak Minerals (CPM) Sevier Playa Potash Project (CPM Project) determined that the shallow brine system at Sevier Lake occurs in relatively low permeability playa sediments that impede communication with the underlying regional aquifer system (Whetstone Associates and ENValue 2019). GBCAAS v. 3.0 incorporated the assumption that Sevier Lake is disconnected from the regional aquifer (Brooks 2017).

3.7.2 SPRINGS AND SEEPS

A total of 268 springs and seeps are reported in the USGS National Hydrography Dataset (NHD) as being located within the APE of the Proposed Action in the mountains surrounding Pine Valley. In the APE for the ANWS Alternative, 230 springs and seeps are reported. The locations of these springs and seeps are identified in Figure 3-6 and Figure 3-7. The identified springs include one suspected regional spring (Wah Wah Springs) that is assumed to discharge water from, and be hydraulically connected with, the regional aquifer. An additional four regional springs (Big Springs (2 outlets), Dearden Spring Group, and Clay Spring) were identified within the Study Area but outside the APE. The remaining springs are suspected to discharge water from local perched aquifers that are not connected to the regional aquifer system. Most of the local springs and seeps in the NHD dataset do not have associated discharge data and are relatively small. Available information regarding the regional and local springs within the Study Area that are of interest to this project is summarized in Table 3-3 and discussed below.

TABLE 3-3. SELECTED REGIONAL AND LOCAL SPRINGS IN THE STUDY AREA

Spring Name	Hydrographic Area	Easting 1983 (m, UTM11N)	Northing 1983 (m, UTM11N)	Elevation (ft)	Discharge (AFY)
Antelope Spring	Wah Wah Valley	818887.327805	4253858.24992	5,554	4.8
Big Basket Spring	Hamlin Valley	774795.171024	4226537.06418	7,662	NA
Big Springs	Snake Valley	749412.6352	4287274.699	5,578	7,404**
Big Springs	Snake Valley	749475.00	4287141.00	5,568	
Biting Spring	Pine Valley	774596.243971	4250913.19185	6,590	1.6

Spring Name	Hydrographic Area	Easting 1983 (m, UTM11N)	Northing 1983 (m, UTM11N)	Elevation (ft)	Discharge (AFY)
Clay Spring	Snake Valley	760860.5591	4306141.779	5,442	257**
Dearden Spring Group (Stateline Springs)	Snake Valley	756308	4295437	5,443	4,833**
Fish Springs - House Spring	Fish Springs Flats	808385.043	4417322.7731	4,315	26,019**
Fish Springs - Lost Spring	Fish Springs Flats	808772.6819	4415979.1316	4,310	
Fish Springs - Middle Spring	Fish Springs Flats	808542.5115	4416371.5192	4,315	
Fish Springs - North Spring	Fish Springs Flats	806650.0583	4421392.1306	4,303	
Fish Springs - Percy Spring	Fish Springs Flats	808773.8853	4415361.4197	4,315	
Fish Springs - South Spring	Fish Springs Flats	808813.916	4415548.4205	4,310	
Fish Springs - Thomas Spring	Fish Springs Flats	808478.826	4416770.5196	4,315	
Kiln Spring	Wah Wah Valley	804171.375894	4255465.43486	5,846	12.9
Meadow Spring	Pine Valley	773424.057312	4247616.20346	6,842	NA
Meadow Spring	Beryl Enterprise	794267.75	4218116.90	5,806	80.7
Muddy Spring	Pine Valley	774115.563727	4257735.4641	6,660	1.2
Pots Sum Pa Spring	Pine Valley	775455.050823	4258312.94091	6,334	30.2
Scraper Spring	Snake Valley	766534.15426	4257659.48304	7,122	NA
Sheep Creek Spring	Pine Valley	781811.904489	4230571.10301	6,914	17.7
Unnamed Spring	Pine Valley	778025.835921	4241684.25965	6,784	NA
Upper Pine Spring	Pine Valley	774039.006652	4269485.31064	6,558	0.4
Unnamed Spring reported by Gardner (2020) as Wah Wah Springs	Wah Wah Valley	806167.746522	4265332.74994	5,487	1,800*
Water Hollow Spring	Pine Valley	793743.243761	4242467.82333	7,322	44.4
Warm Springs	Pine Valley	754812.00	4371945.00	5,248	9,375
Willow Spring	Pine Valley	776168.012571	4256309.72019	6,283	7.3

Notes: m = meters, ft = feet, AFY = acre-feet per year, NA = not available
Source: R. Smith (2019) Bureau of Land Management Personal communication, except * as described in Section 3.7.2.1, and ** from Brooks (2017) GBCAAS v. 3.0 calibration targets.

3.7.2.1 KNOWN OR SUSPECTED REGIONAL SPRINGS

Regional springs in the GBCAAS are typically associated with relatively high discharge rates from regionally connected carbonate aquifers as reported in Mathey (1998) and described by Harrill and Prudic (1998). These springs can have discharges from several hundred to over 1,000 gpm (Harrill and Prudic 1998). As shown on Figure 3-5, regional springs in the Study Area are located in the Snake Valley HA northwest of the proposed PVWS Project wellfield and include Big Springs, Dearden Spring Group, and Clay Spring. Fish Springs is located a greater distance to the north-northwest. Wah Wah Springs is the closest identified (although suspected) regional spring to the proposed PVWS wellfield. It is located in the Wah Wah Valley HA approximately 17 miles northwest of the proposed PVWS Project wellfield under the Proposed Action

and 10 miles west of the wellfield under the ANWS Alternative. These springs were simulated in GBCAAS v. 1.0 groundwater flow model (Brooks *et al*. 2014).

Wah Wah Springs is the only regional spring identified within the APE and is the most well-known spring in Wah Wah Valley. Rather than being a single spring, it is a complex of springs on the west side of the valley just south of State Route 21 at the base of the Wah Wah Mountains. The springs discharge from Paleozoic carbonate rocks with secondary solution permeability along bedding planes, fractures, and faults (Stephens 1974). Water from Wah Wah Springs was used in early mining operations in the late 1800s in the San Francisco Mountains and at a mill in the now abandoned town of Newhouse. The springs are the sole source of water to Wah Wah Ranch. Water discharged from the springs is diverted to Wah Wah Ranch for irrigation, stock and potable use. A small hydroelectric turbine has been installed in the diversion pipeline and has been used to generate electricity for the ranch since 1988.

Stephens (1974) reported that discharge at Wah Wah Springs was measured at about 500 gpm or 800 AFY from at least 10 individual springs, and that an additional 600 AFY of groundwater was discharged annually by ET in the immediate vicinity of the springs for a total estimated discharge of approximately 1,400 AFY. About 380 gpm or 600 AFY was also reported to be diverted by pipeline to other parts of the valley, but it is not clear whether this amount was accounted for in Stephen's discharge measurement. The discharge from Wah Wah Springs was measured by Gardner *et al*. (2020) at approximately 1,000 gpm (1,600 AFY). This discharge was measured through a rectangular weir in a collection box and thought to represent nearly all of the spring flow from the complex. Irrespective of this measurement, however, the amount of discharge simulated in GBCAAS v. 3.0 was 800 AFY (Brooks 2017). An analysis of ET conducted for this GRIA indicated that the average annual ET in the vicinity of Wah Wah Springs between 2005 and 2014 was approximately 200 AFY (Section 3.9.3). For development of the GBCAAS-PV model, the amount was added to the discharge measured by Gardner *et al*. (1,600 AFY) for a total estimated spring discharge of 1,800 AFY.

Consistent with Stephens (1974), Gardner *et al*. (2020) describes Wah Wah Springs as issuing from the base of the carbonate aquifer unit in the Wah Wah Mountains and draining a mountain aquifer unit perched on a siliciclastic unit. Recharge is interpreted to infiltrate into the exposed consolidated rocks upslope from the springs and to be transmitted downward and laterally down dip toward Wah Wah Valley. The springs issue from fractures and solution channels in Paleozoic carbonate rocks and from tufa deposits in an area where the land surface transects a structurally controlled, permeable fracture zone. However, it is also acknowledged that water discharged at the springs includes a "thermal" component indicative of deeper circulation. Geochemical groundwater age dating information reported by Gardner *et al*. supports the presence of modern water; however, a fraction of pre-modern water is also interpreted to be present and the discharge from Wah Wah Springs is therefore interpreted as a mixture of modern and Late Holocene groundwater. A principal uncertainty is the fraction of modern vs. pre-modern water in the spring discharge, which would shed light on the amount of discharge derived from recent recharge to a perched mountain aquifer vs. more deeply circulating groundwater from the regional aquifer system that could be affected by Project pumping. In GBCAAS v. 3.0 Wah Wah Springs is modeled as discharging from the regional aquifer system. In the absence of data to the contrary, this interpretation has been adopted in the GBCAAS-PV model, which may lead to an over-estimation of spring flow depletion by the PVWS

Project because the perched aquifer component is not accounted for. It is likely infeasible to address this data gap prior to project implementation, and it will need to be considered in the Project mitigation and monitoring approach.

3.7.2.2 KNOWN OR SUSPECTED LOCAL (PERCHED) SPRINGS AND SEEPS

Most of the local springs in the mountains surrounding the Pine Valley HA are in the Needle Mountains and are associated with mid-Tertiary extrusive igneous rocks, primarily ignimbrites and lava flows. These rocks typically have low primary permeability and only localized, near-surface secondary permeability. Stephens (1976) reported that these conditions created perched (or semi-perched) mountain aquifers where significant discharge occurs to mountain springs. Stephens (1976) also noted that the springs issue either from a surficial weathered zone or from permeable interbeds within the volcanic rocks.

Paleozoic carbonate rocks yield water to a few springs and a few small ephemeral springs discharge from talus below Paleozoic quartzite outcrops and directly from fractured quartzite (Stephens 1976). Several of these springs were monitored by Gardner *et al*. (2020), including Pots Sum Pa Spring and Willow Spring on the west side of Pine Valley, and Sheep Creek Spring near the southern end of the Pine Valley HA. A few local springs and seeps discharge from breccias and interflow zones of mid-Tertiary extrusive igneous rocks, especially in the southern part of the Wah Wah Valley HA where they are fractured and broken by faulting (Stephens 1974). As in Pine Valley, a few local small ephemeral springs discharge from talus below Paleozoic quartzite outcrops and from fractured quartzite. All known springs in the mountains surrounding Pine Valley are at elevations above 6,200 feet amsl, which is above the mountain bedrock-basin fill transition zone, and further suggests that the springs are perched.

Historical discharge rates for the springs in the Pine Valley HA are less than 60 gpm (Stephens 1976). Spring discharge generally increases following wet periods when recharge exceeds discharge for a period of time. Discharge from Pots Sum Pa Spring, which was measured from 2013 to 2016 as part of the USGS study (Gardner *et al*. 2020), was about 15 gpm.

Similar to Pine Valley, local springs in the mountains surrounding Wah Wah Valley are at elevations above 5,400 feet amsl, which is above the mountain bedrock-basin fill transition zone and suggests that the springs are perched (Stephens 1974). Spring discharge generally increases when recharge exceeds discharge for a period of time and results from increased precipitation.

Water samples collected from 12 springs in the mountains surrounding Pine and Wah Wah Valleys were analyzed for overall water chemistry, geochemical and isotopic indicators of water age (time of recharge), recharge elevation and temperature, and the influence of evaporation (Gardner *et al.* 2020). The results were compared to similar analyses of groundwater samples collected from wells completed in Pine and Wah Wah Valleys and support the conclusion that the springs are associated with perched or semi-perched mountain aquifers which are hydraulically separate from groundwater in the valleys, which tends to be significantly older and different geochemically.

Based on the above information, both the hydrogeologic and geochemical data support the interpretation that, with the exception of Wah Wah Springs, springs in the mountains surrounding Pine and Wah Wah

Valleys are connected only to local perched or semi-perched mountain aquifers and not to the regional aquifer system. While this interpretation is supported by the available data, the potential for regional flow contribution to some of the springs, and hence for groundwater extraction related to the PVWS Project to affect spring discharge, probably cannot be conclusively ruled out without significantly stressing the adjacent regional aquifer system. It is not feasible to test each spring, and even completion of long-term pumping tests proximal to selected springs is not likely to eliminate this uncertainty. As such, while it is reasonable to assume these springs are not regionally connected, the possibility of a regional connection should be addressed in the adaptive management program that is included in the PVWS, and mitigation and monitoring program adopted under NEPA.

3.8 HYDROGEOLOGIC SETTING

The PVWS Project is located in the eastern portion of the GBCAAS, which is a regionally-connected aquifer system that spans a large portion of the Basin and Range physiographic province from western Utah across eastern and southern Nevada and into southeastern California. The proposed project is located in Pine Valley (HA 255), but considers hydrogeologic and drawdown effects in adjacent HAs, including Wah Wah Valley (HS 256), Snake Valley (HA 254), Tule Valley (HA 257), Sevier Desert (HA 287), Milford Area (HA 284), and Beryl-Enterprise Area (HA 280), which are in the Great Salt Lake Desert and Sevier Lake Desert groundwater flow systems (Heilweil and Brooks 2011).

The groundwater system in the Study Area consists of water in unconsolidated alluvial deposits in the valleys and water in consolidated rock (bedrock) underlying the valleys and in the adjacent mountain blocks (Gardner *et al*. 2020). Groundwater levels in adjacent wells completed in the alluvial valley fill and underlying carbonate aquifers were found to be similar, supporting the conclusion that the aquifers are hydraulically connected (Gardner *et al.* 2011). Most of the recharge occurs in bedrock mountain blocks and adjacent mountain front areas. Water discharges to gaining streams and springs in mountain areas. Regionally, groundwater has been interpreted to flow north-northeastward out of Pine and Wah Wah Valleys and discharge via evapotranspiration in Tule Valley and the area surrounding Sevier Lake (Gardner *et al*. 2020).

3.8.1 HYDROSTRATIGRAPHY

The hydrogeologic units (HGUs) in the Study Area, are described by Gardner *et al.* (2020) using the three-dimensional hydrogeologic framework of the eastern Great Basin (Cederberg *et al.* 2011; Sweetkind *et al.* 2011). An HGU has considerable lateral extent and reasonably distinct physical characteristics that may be used to infer the capacity of a sediment or rock to transmit water (Sweetkind *et al.* 2011). Stephens (1974, 1976) and Sweetkind *et al.* (2011) describe the water-bearing characteristics of HGUs occurring in the Study Area as follows:

Non-Carbonate Confining Unit (NCCU) – This unit consists of low-to-moderate permeability Precambrian-age siliciclastic formations as well as intrusive igneous rocks that are locally exposed in mountain ranges and underlie parts of the project area. Primary permeability is generally low; however, surficial weathered zones and fractured zones may have moderate permeability. This unit is not known to yield significant groundwater in the Pine Valley HA.

Lower Carbonate Aquifer Unit (LCAU) – The Lower Carbonate Aquifer Unit is a relatively thick succession of predominantly high-to-moderate permeability Cambrian to Devonian-age carbonate rocks that are locally exposed in mountain ranges, and present beneath most of the valleys within the Study area. Primary permeability is generally low; however, secondary solution permeability is moderate to high, especially along bedding planes, fractures, and faults.

Upper Siliciclastic Confining Unit (USCU) – This unit consists of low-permeability Mississippian-age siliciclastic rocks, predominantly shales, that are limited in extent within the Study Area.

Upper Carbonate Aquifer Unit (UCAU) – The Upper Carbonate Aquifer Unit is a relatively thick succession of low-to-high permeability Pennsylvanian- and Permian-age carbonate rocks that are locally exposed in the mountain ranges and exist beneath some of the valleys within the Study Area. As with the Lower Carbonate Aquifer Unit, primary permeability is generally low; however, secondary solution permeability is moderate to high, especially along bedding planes, fractures, and faults. This unit yields water to some springs in the Pine and Wah Wah Valley HAs.

Volcanic Unit (VU) – The Volcanic Aquifer Unit consists of large volumes of low-to-high permeability Cenozoic-age volcanic rocks that are locally exposed in mountain ranges and exist beneath some of the valleys in the Study Area. Primary permeability is generally low. Where fractured and broken by faulting, secondary permeability in some breccias and interflow zones may locally be high. Numerous springs, seeps, and a few abandoned mine workings discharge water from perched groundwater zones in these rocks in the southern part of the mountains surrounding Pine Valley, especially the Needle Range. Surficial weathered zones, especially on the ignimbrite sheets associated with the Indian Peak-Caliente caldera complex in the Needle Range, readily absorb precipitation and runoff.

Lower Basin-Fill Aquifer Unit (LBFAU) – The Lower Basin-Fill Aquifer Unit represents approximately the lower one-third of the Cenozoic basin fill and, in addition to thick sands and gravels, includes (1) generally thick sequences of welded ash-flow tuff with a high relative permeability in well-developed fracture networks (permeability may be reduced somewhat inside calderas due to lithologic heterogeneity); and (2) local lava flows of moderate to high permeability that can be highly fractured (but the fracture pattern is typically disorganized and fractures are short), particularly in the southern part of Wah Wah Valley.

Upper Basin-Fill Aquifer Unit (UBFAU) – The Upper Basin-Fill Aquifer Unit consists of low-to-high permeability Tertiary and Quaternary valley-fill sediments, includes both older alluvium and younger alluvial and lacustrine deposits and represents the upper two-thirds of the basin fill. The Upper Basin-Fill Aquifer Unit is slightly to highly permeable. Permeability is dependent upon grain size and sorting of materials and the amount of cementation in individual strata. Some of the wells in Pine and Wah Wah Valley are reported to yield water from sand beds at depths of 1,500 to 2,000 feet bgs. This unit forms the bulk of the valley fill, which is the major groundwater reservoir in the Pine Valley HA.

The surface outcrop areas of the above HGUs are shown on Figure 3-8. The HGUs are represented in a three-dimensional (3D) hydrostratigraphic framework within the GBCAAS model, which defines the distribution of HGUs and major structure of the GBCAAS (Cederberg *et al*. 2011), and is used to assign horizontal hydraulic conductivity and vertical anisotropy to the GBCAAS model. As described in Section

3.6, for this GRIA the published geologic maps and cross sections available for the Study Area were digitized and entered into a three-dimensional geodatabase and used to verify that the vertical and horizontal distribution of HGUs was adequately represented in the Study Area. Geologic maps and cross sections were obtained from Budding (1984), Harrill *et al.* (1988), Peltz *et al.* (2005), Sweetkind *et al*. (2011), Cederberg *et al*. (2011, Auxiliary 1), Horton *et al*. (2017), and Rowley (2017) and entered into this database, and were systematically compared to verify that the framework of hydrostratigraphic units in GBCAAS v. 3.0 and GBCAAS-PV is consistent with the published data.

Figure 3-9 and Figure 3-10 present geologic and hydrostratigraphic cross sections through the Study Area. The following key information is presented in these figures:

- The location of the geologic and hydrostratigraphic cross section is shown on an inset view of the HGU map presented in Figure 3-8 and presenting the following information: The location of the GBCAAS model row; the location of the published geologic cross section represented by the model row; the mapped distribution of HGUs attributed to the GBCAAS grid; and the location of additional published geologic sections in the area.
- A plan view closeup is presented showing the location of the geologic and hydrostratigraphic section, and including the following data: The GBCAAS model grid row represented by the cross section with labeled grid column numbers; a closeup of the mapped HGUs attributed to the GBCAAS grid cells in the area around the section; any structural features represented as hydrologic flow barriers in the model; and simulated groundwater water levels.
- A cross-sectional view of the subsurface distribution of HGUs along the grid row is presented and shows the following: The model grid column numbers; digitized outlines of the HGUs interpreted from the published cross section and included in GBCAAS; and simulated groundwater levels interpolated along the section.
- A cross-sectional view of the published cross section is presented and includes the following: The model grid column numbers; the vertical distribution of geologic formations interpreted along cross section; and digitized outlines of HGUs interpreted from published section.

Based on the hydrostratigraphic analysis, the available data from published geologic maps and cross sections is accurately represented by the three-dimensional framework of HGUs included in GBCAAS v. 3.0 and GBCAAS-PV.

3.8.2 EXISTING GROUNDWATER WELLS IN THE PINE AND WAH WAH VALLEY HAS

There are 15 existing wells in the Pine Valley HA and nine wells in the Wah Wah Valley HA, as shown on Figure 3-11. Well completion details for the production wells are listed in. Table 3-4, and the screen depths were attributed to the appropriate aquifer units based on information provided in the Well Driller's Reports and Well Log Information Listing available for the respective wells from the DWRi website. Although most of the wells extract water from the unconfined basin-fill aquifer, some of the wells are completed in deeper bedrock of the volcanic aquifer unit. The types of wells in the project area include domestic, irrigation, and stock watering wells.

TABLE 3-4. COMPLETION DETAILS FOR EXISTING WELLS IN THE PINE VALLEY AND WAH WAH VALLEY HAS

Water Right	Type	Well Diameter (in)	Depth (ft bgs)	Screen Interval (ft bgs)	Aquifer Unit
Pine Valley HA					
14-121	Well	4	430	390-430	Basin-fill
14-89	Well	6	340	Open hole 320-TD	Basin-fill
14-27	Well	4-1/2	801	737-798	Bedrock (VU)
14-28	Tunnel	NA	200	NA	Bedrock (VU)
14-42	Well	6	340	Open hole 320-TD	Basin fill
14-43	Well	4	393	373-393	Basin-fill
14-44	Well	8	628	482-628	Basin-fill
14-45	Well	6	340	300-340	Bedrock
14-47	Drain	NA	NA	NA	Bedrock
14-48	Tunnel	NA	NA	NA	Bedrock
14-108	Well	6	385	365-385	Basin-fill
14-109	Well	6	250	100-250	Basin-fill
14-114	Well	6	385	365-385	Basin-fill
71-2820	Well	12	160	unknown	unknown
71-2882	Well	NA	NA	NA	unknown
Wah Wah Valley HA					
69-25	Well	6	294	238-294	Basin-fill
69-41	Tunnel	NA	NA	NA	Bedrock
69-42	Tunnel	NA	NA	NA	Bedrock (VU)
69-46	Tunnel	NA	NA	NA	Bedrock
69-64	Well	6	218	100-200	Basin-fill
69-85	Well	7	194	60-194	Bedrock (VU)
69-86	Well	3	50	unknown	unknown
71-1386	Well	NA	NA	NA	unknown
71-1927	Well	NA	NA	NA	unknown

Notes: in = inches, ft bgs = feet below ground surface, NA = not available; VU = volcanic unit
Source: https://www.waterrights.utah.gov/search/?q=

3.8.3 AQUIFER PROPERTIES FROM PUMPING TESTS

As part of the study by Gardner *et al*. (2020), aquifer properties for the basin-fill aquifers in the Pine and Wah Wah Valley HAs were estimated from 10 single-well pump tests. Pumping test locations are illustrated in Figure 3-12. Transmissivities were estimated from specific-capacity values by considering a range of storage coefficients representing unconfined to confined conditions (Driscoll 1986). The estimated transmissivities ranged from approximately 400 to 9,000 square feet per day (ft^2/d) (Table 3-5). For this GRIA, Formation verified the estimated transmissivity ranges from Gardner *et al*. (2020) using the specific-capacity method, compared the results to historical pump test analysis data for the wells, and performed a more refined aquifer test analysis for four wells for which time-series drawdown or recovery data of suitable quality were available. The aquifer test analyses were conducted using a more detailed curve matching evaluation, based on confined Theis recovery and confined Cooper-Jacob Agarwal methods, and the transmissivities calculated from this evaluation were approximately 30 to 150% higher

than values calculated by Gardner *et al*. (2020) and are considered more reliable estimates. The methods and results of this analysis are included in Appendix B ()

For further insight, transmissivities estimated by Gardner *et al*. (2020) and Formation (2020) were compared to historical transmissivity estimates as summarized in Table 3-6. Phelps Dodge (1980) performed single-well pumping tests on three wells in Pine Valley and estimated transmissivity values similar to Gardner *et al.* (2020) for those wells. The USGS (2013) also performed a single-well pumping test at Phelps Dodge #19 in Pine Valley and estimated transmissivity using the specific capacity method assuming confined conditions (Driscoll 1986), producing results similar Gardner *et al.* (2020). However, they suggested their estimate was low due to well efficiency issues and estimated a transmissivity of 1,000 ft^2/d at Phelps Dodge #19 based on a Cooper-Jacob straight line analysis. This estimate is more consistent with Formation's estimated range for that well (897 to 949 ft^2/d). Earth Sciences, Inc. (1975) performed pumping tests on three wells in Wah Wah Valley. The range of estimated transmissivities was similar to Gardner *et al.* (2020). USGS (2013) estimated a range (Driscoll 1986) of transmissivities at Wah Wah #29, which was also similar to Gardner *et al.* (2020), but again suggested that the estimates were low due to well efficiency issues. Based on a Cooper-Jacob straight line analysis, revised transmissivity estimates of 30,000 to 60,000 ft^2/d were developed (USGS 2013). Again, these estimates were more consistent with Formation's estimates (66,830 to 70,460 ft^2/d).

TABLE 3-5. ESTIMATED AQUIFER PROPERTIES OF BASIN-FILL AND BEDROCK AQUIFERS IN PINE AND WAH WAH VALLEYS FROM SPECIFIC CAPACITY DATA

Well Name	Date of Test	Well Diameter (in)	Screen Interval (ft bgs)	Aquifer Unit	Pumping Rate (gpm)	Duration (hours)	Draw-down (ft)	Specific Capacity (gpm/ft)	Trans-missivity (ft^2/d)[1]
CICWCD #6	11/4/16	6	60 - 1,000	Basin-fill	168	NR	69	2.4	400 - 580
CICWCD #7	2/2/17	6	250 - 1,000	Bedrock	198	30	82	2.4	410 - 580
CICWCD #8	10/31/16	6	550 - 1,000	Basin-fill	168	NR[2]	58	2.9	490 - 690
CICWCD #11	11/9/16	6	500 - 1,000	Basin-fill	189	NR[2]	0.5	380	94,000 – 120,000[3]
CICWCD #18	11/2/16	6	440 - 880	Bedrock	4	NR	57	0.1	7 - 13
CICWCD #12	1/24/17	6	550- 1,000	Basin-fill	168	29	24	7.0	1,300 – 1,800
CICWCD #25	10/16/16	6	700 - 1,000	Basin-fill	10	NR	61	0.2	20 - 30
Phelps Dodge #19	6/12/78	12	ND - 970	Basin-fill	402	44	139.5	2.9	450 - 650
Phelps Dodge #27	6/12/78	8	ND - 2,006	Basin-fill	503	44	35.2	14.3	2,800 – 3,800
Wah Wah #1	12/13/74	12	680 - 1,475	Basin-fill / bedrock	1,353	28	113	12	2,100 – 2,900
Wah Wah #26	6/4/75	16	800 - 970	Basin-fill / bedrock	1,281	72	73	18	3,200 – 4,500
Wah Wah #29	2/14/75	12	700 - 1,480	Basin-fill / bedrock	1,401	48	44	32	6,300 – 8,500

Notes: Modified from Table 1 in Gardner *et al.* (2020); in = inches, ft bgs = feet below ground surface, gpm = gallons per minute, ft = feet, gpm/ft = gallons per minute per foot drawdown, ft^2/d = square feet per day, NR = Not Reported

[1] Range of transmissivity (T) based on a range of storage coefficients representing unconfined (0.075) and confined (0.001) aquifer conditions.

[3] Actual drawdown reported as zero which results in unrealistic transmissivity (T). This result should be considered suspect.

[4] Results from drawdown associated with highest pumping rate and longest duration during step test by Phelps Dodge.

TABLE 3-6. COMPARISON OF RECENT AND HISTORICAL TRANSMISSIVITY ESTIMATES

Well Name	Earth Sciences Inc. (1974 & 1975) Wah Wah Valley Pumping Tests	Phelps Dodge (1980) Pine Valley Pumping Tests	USGS (2013) Pine Valley Pumping Tests	Gardner *et al.* (2020)	Formation (2020)
CICWCD #6	---	---	---	400 - 580	667 - 744[1]
CICWCD #7	---	---	---	410 - 580	1,020 – 1,036[1]
CICWCD #8	---	---	---	490 - 690	637 - 800[1]
CICWCD #11	---	---	---	94,000 - 120,000[3]	---
CICWCD #18	---	---	---	7- 13	---
CICWCD #12	---	---	---	1,300 - 1,800	3,023 - 3,306[1]
CICWCD #25	---	---	---	20 - 30	---
Phelps Dodge #13	---	1,569 - 1,177	---	---	---
Phelps Dodge #19	---	578 - 770	531 – 708; 1,000	450 - 650	897 - 949[2]
Phelps Dodge #27	---	2,865 - 3,824	---	2,800 - 3,800	---
Wah Wah #1	3,200	---	---	2,100 - 2,900	---
Wah Wah #26	4,300	---	---	3,200 - 4,500	---
Wah Wah #29	8,500	---	5,600 - 7,400; 30,000 - 60,000	6,300 - 8,500	66,830 - 70,460[2]

Notes:

--- Indicates the well test was not evaluated in the reference presented in that column

Transmissivity in ft^2/d = square feet per day

[1] Range of transmissivity based on confined Theis recovery and unconfined Cooper-Jacob Agarwal methods.

[2] Range of transmissivity based on confined Theis recovery and confined Cooper-Jacob Agarwal methods

[3] Gardner *et al.* (2020) considered this estimate to be potentially erroneous due to reporting of zero drawdown.

It should be noted that the pumping test for well CICWCD #11 indicated a very high transmissivity, but because the drawdown was reported as zero, transmissivity was calculated based on an assumed drawdown of 0.5 foot, yielding a transmissivity estimate of 94,000 to 120,000 ft^2/d (Gardner *et al.* (2020). USGS considered this result to be potentially erroneous and it was not considered representative during development of GBCAAS v. 3.0 (Brooks 2017). Drawdown and recovery data for CICWCD #11 were not of sufficient quality to conduct more detailed analyses; however, evaluation of the driller's log indicates a thick section of interbedded medium to coarse sand and gravel, which suggests the alluvial sediments along the axis of Pine Valley are at least locally relatively highly transmissive.

Gardner *et al.* (2020) estimated the transmissivity for bedrock in Pine Valley from two single-well pump tests at wells CICWCD #7 and #18 (see Figure 3-12). They stated that it is unclear from the driller's logs what rock type the wells were screened in; however, based on the location of these wells and review of the 3D hydrogeologic framework model (see Section 3.8.1), it is likely they are located in an area underlain by the non-carbonate confining unit (NCCU). The transmissivity calculated from these two tests ranged

from about 10 to 580 ft^2/day. It should be noted that transmissivities estimated for the carbonate aquifers underlying Pine Valley from aquifer tests performed in the surrounding area are several orders of magnitude higher, and these values are reflected in the GBCAAS parameter attribution for the regional carbonate aquifers (see Brooks 2017, table 2-4).

Hydraulic conductivity (K) was estimated based on the transmissivity ranges presented in Table 3-6 and the minimum saturated well screen lengths for the wells, where known. Hydraulic conductivity estimates are presented in Table 3-7.

Based on these analyses, there is uncertainty regarding the transmissivity and hydraulic conductivity of the basin fill in both Pine and Wah Wah Valleys based on the type of aquifer test analyses performed (specific capacity tests) and a lack of reliable long-term aquifer test data. Analyses using a curve matching approach by both Formation and USGS indicated the values presented in Gardner *et al.* (2020) appear to be biased low. During development of GBCAAS v. 3.0, hydraulic conductivities assigned to the alluvial basin -aquifers were decreased below the values estimated by Gardner *et al.* (Brooks 2017). The above data suggest that increasing the hydraulic conductivities of these materials in GBCAAS-PV is justified provided the increased values are consistent with water budget estimates and result in reasonable calibration results.

TABLE 3-7. HYDRAULIC CONDUCTIVITY[1] COMPARISON

Well Name	USGS (2013) Pumping Test Analyses	Gardner *et al*. (2020) Specific Capacity Analyses [1]	Formation (2020) Pumping Test Analyses[1]
CICWCD #6	---	1.0 – 1.5	1.7 – 1.9
CICWCD #7	---	0.6 – 0.8	1.5
CICWCD #8	---	1.1 – 1.5	1.4 – 1.8
CICWCD #12	---	2.9 – 4.0	6.7 – 7.3
Phelps Dodge #19	1	0.6 – 0.9	1.3 – 1.4
Wah Wah #29	40 – 70	8.3 – 11.2	88 – 93

Notes: Hydraulic conductivity in ft/d = feet per day
[1] Hydraulic conductivity based on estimated transmissivity range (see Table 3-6) and minimum length of saturated well screen during pumping test.

3.8.4 GROUNDWATER LEVELS AND FLOW

Groundwater occurs in alluvial basin-fill and bedrock aquifers in the Study Area under confined and unconfined conditions. In the alluvial basin-fill aquifer, unconfined conditions occur in the upper portions of alluvial fans, and confined conditions exist in areas where fine-grained distal fan and lacustrine sediment is interlayered with coarser gravels and sands near the centers of the valleys (Gardner *et al.* 2020). Both Stephens (1974, 1976) and Gardner *et al*. (2020) indicated that many of the shallow bedrock aquifers in the surrounding mountains are perched and are not connected to the basin-fill aquifers. This is especially true in the upland areas underlain by igneous rocks associated with the Indian Peak Caldera Complex.

When compared to other HAs in this portion of the Great Basin, the Pine Valley HA and the Wah Wah Valley HA are unique because the depth to groundwater in the regional aquifer system precludes the possibility of natural groundwater discharge in these basins, except from perched mountain aquifers. By comparison, other valleys in the eastern Great Basin have extensive areas of lowland discharge where groundwater levels are near the land surface and the bulk of the groundwater discharge occurs through springs and by phreatophyte evapotranspiration. A consequence of the deep groundwater levels is that all discharge from the basin-fill aquifers in both valleys must occur through the subsurface where it is not observable and cannot be measured.

In 2011, the USGS prepared a potentiometric-surface map of the carbonate and alluvial basin-fill aquifer system roughly centered on Pine Valley and encompassing the Study Area for this GRIA (Gardner *et al*. 2011). Groundwater levels in adjacent wells completed in the alluvial basin-fill and underlying carbonate aquifers were found to be similar, supporting the conclusion that the aquifers are hydraulically connected. As shown in Figure 3-14, the groundwater flow direction was generally northward out of Pine Valley and then north-northeast toward Sevier Lake. A groundwater divide is inferred to exist between the Pine Valley and Beryl-Enterprise Area HAs, dividing northward from southward flow in this area. Groundwater flow from Sevier Lake was westward toward Tule Valley and then north toward Fish Springs Flat. Groundwater flow from Wah Wah Valley was also northward toward Sevier Lake and then eastward toward Tule Valley. Groundwater flow was also northward in Snake Valley and then northeastward and eastward toward Fish Springs Flat. In each valley, differences in groundwater levels between adjacent valleys are consistent with the presence of bounding faults along the intervening mountain ranges. Where both sides of a valley are fault bounded, flow within the valleys is interpreted to be toward the valley axis and away from the mountain ranges, where much of the recharge is inferred to occur. Strongly converging groundwater contours in the vicinity of Sevier Lake, Tule Valley and Fish Springs Flat are consistent with groundwater discharge in these areas. In summary, the general groundwater flow direction in the vicinity of the Pine Valley HA is northward to discharge areas in the vicinity of Sevier Lake and Tule Valley, and from there (and the surrounding valleys) northward to a discharge area near Fish Springs Flat.

The USGS constructed a water-level surface map for the unconfined alluvial basin-fill aquifer in Snake, Pine and Wah Wah Valleys using water-level measurements from wells and elevations of springs in the surrounding mountains (Figure 3-14) (Gardner *et al*. 2020). Groundwater occurs relatively deep below the ground surface in the basin-fill aquifers in the center of the valleys. In Pine Valley, water-level depths range from about 300 to 620 feet bgs. In Wah Wah Valley, groundwater is slightly deeper than in Pine Valley with observed water-level depths ranging from about 210 to 750 feet bgs. Shallower water levels were observed in volcanic rocks at higher elevations along the margins of both valleys as well as in local mountain bedrock areas.

The mapped groundwater gradients are generally consistent with the regional groundwater flow directions discussed above; however, relatively steep eastward gradients are interpreted near the western edge of Pine Valley. These gradients are consistent with existence of a fault that is interpreted in this area and is assumed to represent an impediment to local groundwater flow. The existence of a fault is also supported by the observed differences in groundwater elevations in adjacent areas of Pine and Snake Valleys. An alternative or perhaps contributing factor may also be a difference in sediment types

that comprise the basin-fill aquifer. The southern and western sides of Pine Valley likely contain fine-grained sediment that is a weathering product of the volcanic rocks that dominate the Needle Mountains and southern portions of the Wah Wah Mountains, whereas the eastern side of Pine Valley likely contains more coarse-grained sediment derived from quartzites that outcrop on the western slopes of the Wah Wah Mountains (Gardner *et al.* 2020).

A second zone with a steep north-northeast groundwater gradient trends across the southern portion of the Pine Valley HA in a west-northwest direction. Similar to the steepened gradients along the west side of the valley, this area of steepened gradients may also be caused, or contributed to, by differences in the permeability of the basin fill sediments derived from the surrounding mountains. Faults in the region generally do not trend along this alignment; however, it is located near the inferred edge of the Indian Peak-Caliente caldera complex based on gravity data (Best *et al*. 2013). This suggests that subsurface structural or stratigraphic changes could also be contributing to a groundwater flow impediment in this area. It should be noted that the location and steepness of this gradient change is inferred based on a very limited number of data points, and the available data are not considered sufficient to confirm its location or the existence of a flow impeding zone.

3.8.5 GROUNDWATER LEVEL TRENDS

Long-term water-level hydrographs are presented for seven wells in Pine and Wah Wah Valleys in Figure 3-15, and spring discharge fluctuations for two springs are shown in Figure 3-16. All water-level and discharge data were downloaded from the USGS National Water Information System database.[5] Six of the wells with long-term water-level data are completed in the deep basin-fill aquifers of Pine and Wah Wah Valleys; the remaining well (381911113200201, (C-28-13)32cdd- 1) (hydrograph 7, Figure 3-15) is a shallow well completed in the volcanic-rock aquifer in the mountains of southeastern Wah Wah Valley HA. Both springs where discharge was measured are in bedrock aquifers in the mountains.

Groundwater levels in most of the wells were generally stable for the period of record. Groundwater levels in four of the basin-fill aquifer wells did not fluctuate by more than approximately 1 to 2 feet. In one basin fill aquifer well (382113113435401, (C-28-17)22dda- 1), groundwater levels rose steadily by approximately 3 feet between 2011 and 2018; whereas, in the remaining deep aquifer well (383131113214301, (C-26-14)25aad- 1), groundwater levels dropped by approximately 2 to 2.5 feet between 2012 and 2014. These groundwater level fluctuations appear to be within the reasonable range of variability and may be related to fluctuations in recharge. A steady decline in groundwater levels was observed from 2008 to 2017 in well (C-28-13)32cdd- 1 located in the southeastern part of Wah Wah Valley and screened in the volcanic rock aquifer. Gardner *et al*. (2020) suggested that this decline in water levels could represent an immediate response to drier than normal conditions that occurred during this time.

In both springs, discharge was generally stable for the period of record, and discharge measured by Gardner *et al*. (2020) remained stable from 2013 to 2016 (Figure 3-16). Discharge from Pots Sum Pa Spring was relatively constant at about 15 gpm. Wah Wah Springs exhibited only a slight decrease in discharge

[5] https://waterdata.usgs.gov/nwis

from about 2.3 cubic feet per second (ft^3/s) in early 2013 to about 2.2 ft^3/s in 2016. This decrease is the result of drier than normal conditions that occurred during the period of record.

3.8.6 GROUNDWATER QUALITY

The USGS collected water samples in 2008, and from 2011 through 2013 from 24 locations: 13 wells and springs in Pine Valley and 11 wells and springs in Wah Wah Valley. Water samples were analyzed for major ions, nutrients, selected trace metals, and a suite of environmental tracers. Geochemistry data were reported in Gardner *et al*. (2020).

Dissolved major-ion, nutrient, and trace-metal concentrations in groundwater samples were analyzed to assess general water-quality conditions in Pine and Wah Wah Valleys (Gardner *et al*. 2020; Table 6). Concentrations of total dissolved solids (TDS) ranged from 120 to 1,290 milligrams per liter (mg/L) and exceeded the recommended secondary Maximum Contaminant Level (MCL) of 500 mg/L for drinking water at approximately one quarter of the wells and springs. Groundwater samples from wells in Pine Valley had generally lower TDS concentrations than almost all groundwater samples from wells and springs in the surrounding mountains. Manganese concentrations exceeded the secondary MCL of 0.05 mg/L at two springs, and sulfate concentrations exceeded the secondary MCL of 250 mg/L at one spring. Arsenic exceeded the primary MCL of 0.01 mg/L in a water supply well at the Desert Experimental Range and an observation well in Pine Valley, as well as in one stock well in the volcanic bedrock hills of southwestern Wah Wah Valley. Arsenic is likely derived from alluvial sediments eroded from volcanic rocks in the surrounding mountains.

Environmental tracers and major-ion chemistry were used to investigate sources of recharge, groundwater flow paths, and groundwater ages to refine the conceptual understanding of the groundwater systems (Gardner *et al*. 2020; Figures 10 and 11). Mountain groundwaters were sampled from springs and from wells screened in bedrock or shallow alluvium in the foothills or mountains adjacent to the valleys and well above the valley floors. Basin-fill groundwaters were sampled from relatively deep alluvial wells with long screens that were generally located near the axis of each valley. The Pine Valley HA mountain groundwater was found to be dominantly calcium-bicarbonate water, whereas the Pine Valley HA basin-fill groundwater was found to be dominantly sodium-bicarbonate or calcium-sodium-bicarbonate water (Gardner *et al*. 2020). The Wah Wah Valley HA mountain groundwater on the west side of the HA was also found to be calcium bicarbonate water, whereas springs and wells in the hills that bound Wah Wah Valley to the southeast were found to yield calcium-chloride or sodium-calcium-chloride water (Gardner *et al*. 2020). The Wah Wah Valley HA basin-fill groundwater was found to be dominantly sodium-chloride water, likely from dissolution of evaporite minerals below the surface of the playa.

Groundwater samples were analyzed for tritium and helium in order to differentiate “modern” water (less than about 60 years old) from pre-modern water (Gardner *et al*. 2020). The combined analysis of tritium and helium clearly identifies a component of “modern” water at half of the wells and springs sampled. All these locations are in the mountains surrounding the valleys. Some mountain samples appear to be pre-modern (more than 60 years old) or mixtures of modern and pre-modern water, indicating areas of mountain residence times of 60 years or more. None of the basin-fill samples contained even a fraction of modern water (Gardner *et al*. 2020; Table 7).

General age categories were assigned to 24 groundwater samples from Pine and Wah Wah Valleys using carbon-14 activity and helium isotope data (Gardner *et al*. 2020; Tables 7 and 8). The categories include Modern (post 1950s), Mixture (modern and Late Holocene), Late Holocene (>60 years and <2,000 years), Holocene (>2,000 years and <11,700 years), and Pleistocene (>11,700 years). All modern and mixed groundwater is found in the mountains surrounding the valleys at springs that discharge from volcanic bedrock or from a well in alluvium eroded from volcanic rocks in the hills and mountains bordering the valleys. The presence of water this young in the mountains indicates that these are areas of low bedrock permeability, that they receive little recharge, or both. No modern groundwater or mixtures containing modern water were reported in wells in either valley (Gardner *et al*. 2020). Pine Valley valley groundwater was classified as Holocene or Pleistocene and Wah Wah Valley valley groundwater was classified as Late Holocene or Pleistocene. In both HAs, the youngest samples are from high-elevation mountain locations and valley groundwater increases in age downgradient from south to north.

Stable-isotopes (oxygen-18 and deuterium) were measured in groundwater sampled from the Pine and Wah Wah Valley HAs (Gardner *et al*. 2020; Table 7). There were no significant differences between samples collected from Pine or Wah Wah Valleys or between samples collected from mountain or valley locations. Most of the samples from Pine and Wah Wah Valleys were isotopically heavier than cumulative winter precipitation and fell within the range of cumulative annual precipitation, indicating that precipitation falling at lower elevations or during the summer months is the dominant source of recharge in Pine and Wah Wah Valleys.

Noble gas and water-table temperatures (NGTs) represent estimates of recharge temperature (the water-table temperature at the location of recharge), and were compared to valley water-table temperatures to evaluate whether samples represent mountain or valley recharge (Gardner *et al*. 2020; Table 10). In many parts of the eastern Great Basin, mountain water-table temperatures are notably cooler than valley water-table temperatures, providing a clear contrast between the two (Gardner and Heilweil 2014). And because of the conservative nature of dissolved noble gases in saturated freshwater systems, NGTs can be used to identify continuous groundwater flow between recharge and sample locations. For example, if samples collected from valley wells have NGTs that are clearly cooler than valley water-table temperatures, then they likely originated as mountain recharge and moved into the valley aquifer through the subsurface along a continuous flow path.

Groundwater temperatures measured near the water table from 20 valley wells in Pine and Wah Wah Valleys ranged from 14.5 to 24.9 degrees Celsius (°C) with an average of 18.9°C (Gardner *et al*. 2020; Table 10). Mountain water-table temperatures in Pine and Wah Wah Valleys ranged from 9.3 to 16.7 °C with an average of 11.6°C. Because the mountain and valley water-table temperature ranges overlapped, the contrast between mountain and valley water-table temperatures is not as clear in Pine and Wah Wah Valleys as in other HAs in the region. Computed average NGTs ranged from 7.5 to 16.6°C and were cooler than measured water temperatures at all but two locations (Gardner *et al.* 2020; Table 10 and Figure 14). Typically, NGTs are cooler than measured water temperatures because recharge areas are higher in elevation and, therefore, are generally cooler at the water table than the corresponding sample locations. Except for Wah Wah Springs, which are classified as “thermal” or “warm” by Stephens (1974), most mountain waters have cooler NGTs than most valley waters. Only one groundwater sample collected from

a valley well in Pine Valley had a cool NGT that fell in the range of NGT values for mountain wells and springs. At this well location, mountain recharge does contribute to a fraction of valley groundwater (Gardner *et al*. 2020).

The data presented in Gardner *et al*. (2020) support an overall interpretation that the geochemistry of the basin groundwater indicates limited influence from mountain precipitation and a generally low recharge rate; however, an important limitation that is not discussed in the report is the collection of samples from wells with long screen intervals or wells screened below the water table (tables 1 and 5 of the report). In addition, several different methods were used to collect the well samples, and the differences in the methods in terms of the well purging approach, pumping rates and pump intake depths are not discussed. As a result, with the exception of a few short-screened monitoring wells near the valley margins or in bedrock areas, the results from the well samples may be more representative of a homogenized water column that includes a significant fraction of deeper groundwater. Younger groundwater typically occurs along shallow flow lines near the water table that were more recently recharged, and groundwater age usually increases with depth. Although the general conclusions presented in the report are reasonable, the inability to distinguish potentially younger groundwater near the water table limits the ability to understand the contribution of recent mountain recharge to the regional aquifer system.

3.9 GROUNDWATER BUDGET

3.9.1 BACKGROUND

Groundwater resources in the Pine and Wah Wah Valley HAs and surrounding basins have been very sparsely developed, and significant data gaps, therefore, exist in the hydrogeologic understanding of the area. The stability of groundwater levels in the area (Section 3.8.5) indicates that the amount of groundwater in storage is not currently changing, and recharge is therefore equal to discharge. Furthermore, since Pine and Wah Wah Valleys are topographically closed basins with relatively deep groundwater levels, the amount of groundwater underflow leaving the valleys is equal to the amount of recharge, which in turn is equal to the difference between HA-wide precipitation and ET.

Several key prior studies resulted in the following recharge estimates:

Stephens 1974 and 1976. Recharge in the Pine Valley HA was originally estimated by Stephens (1976) to be 21,000 AFY. Stephens used the Maxey-Eakin method, which uses empirically-derived recharge coefficients (percentages) applied to precipitation within designated rate ranges in a basin and the surrounding mountains (Maxey and Eakin 1949). This approach has been widely used to characterize recharge in other basins in the Basin and Range physiographic province in Nevada. Of this amount, 3,000 AFY was assumed to flow directly into Wah Wah Valley because of the bedrock structure of the southern Wah Wah Mountains. Recharge in Wah Wah Valley was estimated to be 7,000 AFY, plus an additional 3,000 AFY of recharge from precipitation falling within a portion of the Pine Valley HA that drains directly into Wah Wah Valley HA (Stephens 1974).

Brooks *et al*. 2014. In 2014, the USGS developed a regional steady-state numerical groundwater flow model of the GBCAAS, referred to as GBCAAS v. 1.0 (Brooks *et al.* 2014). In this model, the recharge

component of the groundwater budget for the Pine Valley HA was increased to 24,000 AFY based on additional regional studies to characterize the GBCAAS aquifer system by Harrill and Prudic (1998) as well as Heilweil and Brooks (2011), and model calibration. The recharge to Wah Wah Valley was estimated to be 5,000 AFY. No accounting was made for the accrual of recharge from precipitation falling in the Pine Valley HA to the Wah Wah Valley HA, and this transfer is presumed to have been considered as part of the modeled inter-basin flows.

Gardner *et al*. 2020. The purpose of the recent investigation by Gardner *et al.* (2020) was to gather additional data to help refine the conceptual hydrogeologic model and water budget for the area; however, because the scope of the study was limited, it left significant uncertainties in the amount and distribution of groundwater recharge and discharge, as well as aquifer properties. The study focused on improving characterization of groundwater discharge by evaluating ET from phreatophytes (ET discharged from groundwater, or ETg) in the Tule Valley and Sevier Lake areas based on a limited dataset, but did not include estimation of total ET or ETg for Pine and Wah Wah Valleys. In terms of precipitation, the report presented a 30-year average precipitation volume of 510,000 AFY for Pine Valley and 320,000 AFY for Wah Wah Valley based on information derived by the Parameter-Elevation and Regression of Independent Slopes Model (PRISM), but used the precipitation estimates of Stephens (1974 and 1976) when calculating the water budgets for the Pine and Wah Wah Valley HAs (410,000 and 290,00 AFY, respectively).

Brooks 2017. Using the data gathered by Gardner *et al*. (2020), the USGS updated and recalibrated the GBCAAS v. 1.0 model for the area surrounding the Pine and Wah Wah Valley HAs and published GBCAAS v. 3.0 which evaluates the theoretical effects of very long-term groundwater extraction (Brooks 2017). In this model, recharge to the Pine and Wah Wah Valley HAs was decreased to 11,000 and 3,200 AFY, respectively, based on the ETg discharge analysis in the Tule Valley HA and the area around Sevier Lake performed by Gardner *et al* (2020). Similar to GBCAAS v. 1.0, there was no attribution of recharge from precipitation in the Pine Valley HA to the Wah Wah Valley HA, and this transfer is presumed to be part of the modeled inter-basin flows. Notably, the model could not be adequately calibrated without decreasing the hydraulic conductivity of the aquifer layers significantly below the values determined from well testing data in the region.

The following sections present a re-examination and update of the groundwater budgets for the Pine and Wah Wah Valley HAs. Both Pine and Wah Wah Valley are topographically closed basins and, therefore, all precipitation that falls within their respective HAs is either discharged as ET (total ET, including ETg as well as ET from non-phreatophyte vegetation, soil moisture and surface water) or recharges groundwater and flows out of the basins in the subsurface. Because of this, groundwater recharge can be reliably estimated if precipitation and total ET are known; however, Gardner *et al.* (2020) did not include an evaluation of total ET or ETg in the Pine Valley or Wah Wah Valley HAs or otherwise constrain local recharge estimates. To accomplish this, a more rigorous analysis of precipitation and ET is presented in the following sections to further constrain estimates of recharge and discharge. In addition, the amount of ETg in Tule Valley and around Sevier Lake was evaluated, and the uncertainty of ETg estimates is discussed. Finally, although groundwater is sparsely developed in the area, an updated analysis of groundwater demand is provided. The following approach was implemented:

1. A long-term (10-year) dataset of ET was developed for the area surrounding Pine and Wah Wah Valleys using remote sensing and meteorological data. The time period from 2005 to 2014 was selected as hydrologically representative and was utilized in this analysis. The ET dataset was validated by comparing it to available observations from eddy covariance (EC) stations in the general area during the period of the analysis.

2. Precipitation data available from the PRISM were compared to data measured at precipitation stations in the area. Both data sets were evaluated, and an appropriate approach was developed for their use in this water balance study.

3. Recharge estimates were developed for Pine and Wah Wah Valleys by subtracting the refined 10-year average ET from a conservative (low) estimate of precipitation. The refined recharge estimate was compared to historical water budgets for these valleys and an updated water budget was developed.

4. Estimated ETg discharge in Tule Valley and around Sevier Lake was compared to USGS estimates (Gardner *et al*. 2020). Uncertainties in ETg estimates were evaluated and an appropriate approach to groundwater budget refinement in these ETg discharge areas was developed.

3.9.2 PRECIPITATION

3.9.2.1 BACKGROUND AND APPROACH

Several types of precipitation data are available to characterize spatial and temporal variability in precipitation. These include data collected by rain gauges at a specific point (station), often in combination with other climatic data, and "gridded data products" that model the spatial distribution of precipitation, taking the gauge data, orographic effects, and other landscape and climatic factors that influence precipitation into consideration. The types of precipitation data are described further below.

Gauge Data. Gauge measurements collect precipitation data over a period of time and allow evaluation of temporal variability and statistics, including long-term averages (normals) and depth-intensity-frequency relationships for storm recurrence. Measurements taken by different types of gauges at similar locations sometimes yield different results depending on the type of gauge used. Local variability in topography, variability in ground cover and elevation can also influence measurement results.

Gridded Data Products (GDP). In mountainous areas especially, measurements taken at weather stations are typically not dense enough to allow the spatial distribution of precipitation to be evaluated by simple contouring. For this reason, precipitation measurements are interpolated between stations using models that consider additional factors such as elevation, slope orientation, prevailing wind directions and historically observed weather patterns and spatial trends. These data are analyzed with computer models and used to derive spatially continuous gridded data products that provide contoured actual and average precipitation .

To evaluate the input of precipitation into the groundwater budgets for the Pine and Wah Wah Valley HAs, GDP that provide contoured average precipitation across the project area was compared to

precipitation measured by rain gauges across the area. Based on this comparison, an appropriate precipitation dataset for the groundwater budget analysis was developed.

3.9.2.2 GRIDDED PRECIPITATION DATA

Three available PRISM precipitation GDP were analyzed for the Study Area: (1) 800-meter monthly normal data for 1981 to 2010; (2) 4-kilometer monthly normal data for 1981 to 2010; and (3) 4-kilometer 30-year monthly data. Analysis of these data sets shows that the three precipitation GDP from PRISM do not show any significant difference on a 30-year average annual scale for the project area (Table 3-8). The PRISM 4-kilometer monthly data and 30-year normal data are therefore used in this analysis.

TABLE 3-8. SPATIALLY AGGREGATED AVERAGE ANNUAL PRECIPITATION VALUES FROM PRISM FOR THE STUDY AREA

Hydrologic Area	PRISM 800 m Normal, 1981–2010 (in)	PRISM 4 km Normal, 1981–2010 (in)	PRISM 4 km Monthly, 1981–2010 (in)
Pine Valley	13.0	12.9	13.1
Wah Wah Valley	10.1	10.3	10.4
Tule Valley	9.9	9.9	9.9

Notes: in = inches; km = kilometers; m = meters

3.9.2.3 COMPARISON OF PRISM AND RAIN GAUGE DATA

Rain gauge data from stations in the Study Area maintained by the local BLM field office and at weather stations managed by the RAWS network were compiled for comparison with PRISM precipitation data. PRISM monthly precipitation was extracted at each rain gauge station location for comparison and further analysis. After extraction, data were aggregated to annual time steps and the station data were quality checked. Station and PRISM data were compared only during years when station data were available. Table 3-9 lists the comparison of the 17 stations with rain gauges in the Study Area. The locations of these stations are shown on Figure 3-17. A graph comparing the two datasets is presented as Figure 3-18.

TABLE 3-9. COMPARISON OF PRISM DATA AND RAIN GAUGE STATION AVERAGE ANNUAL PRECIPITATION OBSERVATIONS

Station Name	Years Station Data Available	Elevation (ft amsl)	PRISM (in)	Station (in)	Difference (in)
Indian Peak	1963–2018	7,615	22.1	15.5	6.6
South Hamlin Valley	1963–2018	6,696	13.3	11.7	1.6
Jockeys	1982–2018	6,575	17.5	11.2	6.2
Wood and Eyres	1983–2018	6,526	15.6	9.1	6.5
Wintch	1982–2018	6,467	14.5	10.6	3.8
Pine Valley	1963–2018	6,296	14.5	9.3	5.2
Big Wash	1988–2018	6,171	12.3	7.0	5.2
North Hamlin Valley	1963–2018	6,043	12.9	9.0	3.9

Station Name	Years Station Data Available	Elevation (ft amsl)	PRISM (in)	Station (in)	Difference (in)
Bible Springs	1963–2018	5,794	12.9	12.4	0.4
Jensen Spring	2000–2018	5,738	12.4	10.3	2.1
Brimstone Reservoir	2000–2018	5,623	11.3	6.8	4.5
Willow Creek	1988–2018	5,509	9.2	7.3	1.8
Guyman Fence	1981–2018	5,358	10.5	7.6	2.9
North Pine Valley	1989–2018	5,299	7.6	6.3	1.3
Desert Experimental	1950–1984	5,246	8.2	7.8	0.4
Wah Wah Cove	1988–2018	4,948	7.5	6.8	0.8
Wah Wah Ranch	1955–2007	4,885	7.3	6.6	0.7
	Average		**12.3**	**9.1**	**3.2**

Notes: ft amsl = feet above mean sea level, in = inches

Comparison of average annual precipitation from the PRISM and rain gauge datasets indicates they are moderately well correlated with an R-square of 0.72 (Figure 3-18); however, PRISM values were consistently higher than rain gauge data. A recent study compared precipitation GDP, including PRISM, to rain gauge observation networks in the Snake Range and Sheep Range in eastern Nevada and found similar results (McEvoy *et al.* 2014). This study examined rain gauge stations along orographic transects across the mountain ranges and found that rain gauges tended to under-measure solid precipitation (snow). As a result, the difference between measured precipitation and GDP-predicted precipitation increased with elevation. In addition, differences were more pronounced during the cool season (October to March) than during the warm season (April to September).

To investigate whether similar under-measurement of solid precipitation could be affecting rain gauges in the Study Area, the difference between average annual rain gauge and PRISM data (PRISM minus rain gauge) at each location was plotted against station elevation (Figure 3-18) and further examined by dividing average precipitation into cool season (October through March) and warm season (April through September) periods, and computing the difference between PRISM and station data for these periods (Table 3-10, plotted in Figure 3-19).

TABLE 3-10. COOL SEASON AND WARM SEASON COMPARISON OF PRISM AND RAIN GAUGE DATA

Station Name	Elevation (ft amsl)	Cool Season PRISM (in)	Cool Season Station (in)	Difference (in)	Warm Season PRISM (in)	Warm Season Station (in)	Difference (in)
Indian Peak	7,615	12.03	7.92	4.11	9.84	7.54	2.3
South Hamlin Valley	6,696	7.82	5.86	1.96	5.49	5.7	-0.21
Jockeys	6,575	10.6	5.74	4.86	6.88	5.51	1.38

Station Name	Elevation (ft amsl)	Cool Season PRISM (in)	Cool Season Station (in)	Difference (in)	Warm Season PRISM (in)	Warm Season Station (in)	Difference (in)
Wood and Eyres	6,526	9.65	4.01	5.64	5.94	5.05	0.89
Wintch	6,467	8.42	5.16	3.26	6.02	5.47	0.55
Pine Valley	6,296	8.52	4.18	4.34	5.94	5.14	0.79
Big Wash	6,171	6.77	3.17	3.61	5.41	3.86	1.55
North Hamlin Valley	6,043	7.26	4.06	3.21	5.6	4.91	0.69
Bible Springs	5,794	7.43	6.76	0.68	5.42	5.81	-0.38
Jensen Spring	5,738	7.17	5.02	2.15	5.24	5.24	-0.01
Brimstone Reservoir	5,623	6.5	2.7	3.8	4.79	4.03	0.75
Willow Creek	5,509	4.87	3.62	1.26	4.26	3.74	0.52
Guyman Fence	5,358	5.76	3.52	2.24	4.66	4.06	0.61
North Pine Valley	5,299	3.6	2.67	0.93	3.94	3.45	0.49
Desert Experimental	5,246	2.71	2.57	0.14	5.59	5.57	0.02
Wah Wah Cove	4,948	3.54	3.02	0.52	3.98	3.78	0.2
Wah Wah Ranch	4,885	2.85	2.65	0.2	4.25	4.21	0.04
Average		**6.79**	**4.27**	**2.52**	**5.49**	**4.89**	**0.60**

Notes: ft amsl = feet above mean sea level, in = inches

Figure 3-18 shows that the difference between average annual PRISM and rain gauge precipitation tends to increase with station elevation (R-square = 0.56), *i.e.*, the higher the elevation, the more the rain gauge-data tend to decrease relative to PRISM data. Further examination of Figure 3-19 reveals that rain gauge data tend to be lower than PRISM data during the cool season (October to March) (R-square = 0.62), but are closer to PRISM data during the warm season (April to September) (R-square = 0.62). Similarly, the difference between PRISM data and rain gauge data tends to increase with elevation during the cool season (R-square = 0.54), but not during the warm season (R-square = 0.15). These observations are consistent with McEvoy's findings that rain gauge data tends to under-report snow and total precipitation, with the degree of under-reporting increasing with elevation and during the cool season. As such, it is likely that rain gauge precipitation data in the project area are biased low, especially at higher elevations. Critical assessment of PRISM data was beyond the scope of this analysis.

As is typical of mountainous areas, precipitation in the Study Area is closely correlated with elevation. Therefore, depending on the distribution of rain gauges, averaged gauge data may or may not adequately represent spatial precipitation averages in the Study Area. For example, higher elevation areas could be under-represented if most of the precipitation stations are in valley areas. To further assess the appropriateness and limitations of using rain gauge data to evaluate the groundwater budgets of the Pine

and Wah Wah Valley HAs, the distribution and representativeness of the rain gauge data was compared to the spatial distribution of precipitation reported by PRISM. The spatial distribution of average precipitation in Pine and Wah Wah Valleys derived from PRISM 30-year normal precipitation is presented in Figure 3-20. In the Pine Valley HA, 53 percent of the land lies at elevations sufficient to receive over 12 inches of precipitation annually. In contrast, only 22 percent of the land in the Wah Wah Valley HA lies at elevations sufficient to receive over 12 inches of precipitation per year. The distribution of rain gauge stations generally follows a similar pattern, with four of six stations in Pine Valley lying in the higher precipitation area, compared with one of five stations in Wah Wah Valley. As such, the available rain gauge data appears to be representative of the spatial distribution of rain in the Pine and Wah Wah Valley HAs, but likely underestimates the total amount of precipitation.

The annual average precipitation data from rain gauge stations and corresponding PRISM data in the Pine and Wah Wah Valley HAs is presented below in Table 3-11 and segregated into spatial averages for areas receiving greater than and less than 12 inches per year of average precipitation. When the percentage of the HA area receiving more than 12 inches of precipitation is multiplied by the average PRISM and gauge-measured precipitation for those areas, the total precipitation is close to the average of all the stations. This indicates the average rain gauge data are a reasonable approximation of spatial precipitation conditions across the Pine and Wah Wah Valley HAs, but, as noted above, tend to underestimate the total precipitation as reported by PRISM.

For example, for Wah Wah Valley, the calculations are as follows:

For PRISM data: (0.22 of area x 14.48 in) + (0.78 of area x 8.76 in) = 10.01 in; compared to 9.91 in average for overall HA

For station data: (0.22 of area x 10.63 in) + (0.78 of area x 6.86 in) = 7.69 in; compared to 7.62 average for overall HA

For Pine Valley, the calculations are as follows:

For PRISM data: (0.53 of area x 17.40 in) + (0.47 of area x 7.89 in) = 12.93 in; compared to 14.23 average for overall HA

For station data: (0.53 of area x 11.28 in) + (0.47 of area x 7.02 in) = 9.28 in; compared to 9.86 average for overall HA

TABLE 3-11. ANNUAL AVERAGE PRECIPITATION DATA AND SPATIAL AVERAGES, PINE AND WAH WAH VALLEY HAS

Hydrologic Area	Station Name	Elevation (ft amsl)	PRISM (in)	Rain Gauge (in)	PRISM Spatial Averages (in)	Rain Gauge Spatial Averages (in)
Pine Valley	Indian Peak	7,615	22.09	15.50	17.40	11.28
	Jockeys	6,575	17.45	11.22		
	Wood and Eyres	6,526	15.60	9.09		
	Pine Valley	6,296	14.48	9.32		

Hydrologic Area	Station Name	Elevation (ft amsl)	PRISM (in)	Rain Gauge (in)	PRISM Spatial Averages (in)	Rain Gauge Spatial Averages (in)
	North Pine Valley	5,299	7.60	6.28	7.89	7.02
	Desert Experimental Station	5,246	8.18	7.77		
	All Stations Average		**14.23**	**9.86**		
Wah Wah Valley	Wintch	6,467	14.48	10.63	14.48	10.63
	Brimstone Reservoir	5,623	11.30	6.76	8.76	6.86
	Willow Creek	5,509	9.15	7.33		
	Wah Wah Cove	4,948	7.30	6.76		
	Wah Wah Ranch	4,885	7.30	6.61		
	All Stations Average		**9.91**	**7.62**		

Notes: Blue color indicates stations in areas designated by PRISM as receiving over 12 inches of precipitation per year. Burnt orange color indicates station in areas designated by PRISM as receiving less than 12 inches of precipitation per year.

The above analysis indicates that the rain gauge station data provide a relatively good spatial representation of precipitation across the entire Pine Valley and Wah Wah Valley HAs, including both valley and mountain areas. Precipitation data for rain gauges in the mountain areas tend to be biased low, indicating that use of these data should provide a conservative (*i.e.*, low) estimate of precipitation volume from a water budget perspective.

3.9.2.4 Estimate of Precipitation in the Pine and Wah Wah Valley HAs

The spatially weighted average annual precipitation calculated from rain gauge data in the Pine and Wah Wah Valley HAs is 9.86 and 7.62 inches, respectively (Table 3-11). As discussed above, this represents a conservative estimate of true precipitation. Multiplying this amount by the areas of the Pine and Wah Wah Valley HAs (472,200 and 386,971 acres, respectively) yields an average annual estimated precipitation volume of 387,991 and 245,727 AFY, respectively. For perspective, this is considerably less than precipitation volumes assumed by Stephens (410,000 and 290,000 acre-feet, respectively), or the PRISM precipitation estimates cited by Gardner *et al*. (2020) (510,000 and 320,000 AFY, respectively), which suggests it represents the low end of the reasonable range and a conservative value for water budget calculations.

3.9.3 Evapotranspiration

3.9.3.1 Background and Approach

Regionally, groundwater has been interpreted to flow north-northeast out of the Pine and Wah Wah Valley HAs, and ultimately discharge via ET in Tule Valley and around Sevier Lake, approximately 50 to 75 miles to the north-northeast of the proposed PVWS Project wellfield. The USGS (Gardner *et al.* 2020)

developed estimates for ETg in Tule Valley and around Sevier Lake using the methods described below. The revised ETg estimates incorporated into GBCAAS v. 3.0 were lower than estimates incorporated in the prior versions of the model. As reported by Brooks (2017) ETg in the Tule Valley HA was decreased from 41,900 to 33,900 AFY, and ETg in the Sevier Desert HA was decreased from 61,700 to 34,500 AFY. To help balance this decrease in the ETg estimates, recharge in the Pine Valley and Wah Wah Valley HAs was decreased and the GBCAAS v. 3.0 hydraulic conductivity was decreased as described in Brooks (2017), below the measured values reported by Gardner *et al*. (2020) and the refined values calculated as discussed in Section 3.8.3.

Both Pine and Wah Wah Valleys are topographically closed HAs and, therefore, all precipitation that falls within their respective boundaries is either discharged as ET or recharges groundwater and flows out of the HAs in the subsurface. Because of this, groundwater recharge can be reliably estimated if precipitation and total ET are known; however, Gardner *et al*. (2020) did not include an evaluation of total ET in the Pine Valley or Wah Wah Valley HAs or otherwise constrain local recharge estimates. Rather, the USGS incorporated the water budget estimates developed by Stephens (1974, 1976) and adjusted the water budgets assuming, among other things, that discharge from springs which ring Pine Valley at the surrounding mountain fronts is completely consumed by ET (based on reconnaissance-level calculations by Stephens), that deep percolation from semi-perched mountain aquifers does not occur, and that 3,000 AFY of recharge from precipitation falling within the Pine Valley HA drains in the subsurface to the Wah Wah Valley HA due to an eastward dip in the carbonate aquifer system of the Wah Wah Mountains. The net result was a decrease in recharge by 13,000 AFY in the Pine Valley HA in GBCAAS v. 3.0 compared to the prior version of the model. In addition, recharge in the Wah Wah Valley HA was decreased by 2,200 AFY during model calibration.

As noted above, Gardner *et al*. (2020) did not include an evaluation of ET in Pine or Wah Wah Valleys. In addition, ETg for Tule Valley and the area around Sevier Lake was evaluated by indirectly applying a single year of data from several eddy-covariance (EC) stations in eastern Nevada to ETg discharge areas determined based on estimated groundwater depths and field mapping. Uncertainty in the USGS computation of average annual ETg? is addressed in this GRIA by adopting a more rigorous analysis method. An analysis of total ET was conducted using the surface energy balance method to calculate ET on a 30-meter grid using remote sensing data generated by the Landsat Satellite mission and local meteorological data (Paul *et al*. 2011, 2018). The analyzed Landsat scene (path row 39-33) measures approximately 180 by 185 kilometers and encompasses the Pine and Wah Wah Valley HAs, Sevier Lake, most of the Tule Valley HA, and much of the surrounding area. Landsat imagery is available every 8 to 14 days and is usable when cloud cover is not extensive. Information between overflights is extrapolated using local meteorological data, resulting in daily ET estimates for a multi-year period. Thus, the resulting analysis was both temporally and spatially robust. The period selected for detailed ET analysis was 2005 to 2014, and as summarized by the precipitation data presented in Table 3-12 and shown in Figure 3-21, the data include average, dry and wet years. This is important because it is therefore considered a representative hydrologic period for this analysis.

TABLE 3-12. COMPARISON OF 2005-2014 PRECIPITATION TO LONG-TERM AVERAGES FROM PRISM

Data Period	Pine Valley (in)	Wah Wah Valley (in)	Tule Valley (in)
30-Year Normal (1981-2010)	12.9	10.3	9.9
Average (1981-2018)	12.8	10.3	9.7
Average (2005-2014)	12.7	10.5	9.5

Remote sensing algorithms based on the equilibrium between the radiation balance and energy balance at the surface of the earth are the only viable means to map regional patterns of ET. The energy balance method is accepted as being among the most reliable and defensible methods for evaluating ET (Allen *et al.* 2011; Paul *et al.* 2011; 2018; Su 2002) and has been widely applied by Formation. Accuracy achieved in estimating ET using this method can be on par with the Lysimeter method, widely regarded as the most accurate (Allen *et al.* 2011). In addition, the energy balance method has approximately half the error of estimates made using comparable approaches based on remote sensing vegetation indices, such as those used by the USGS (Gardner *et al.* 2020). In this study, the Surface Energy Balance System, a peer reviewed extensively applied algorithm (Paul *et al.* 2011, 2018; Su 2002), was used for regional-scale mapping of ET. The algorithm uses local weather information and visible, near-infrared, shortwave infrared, and thermal infrared reflectance data acquired by sensors onboard the Landsat satellite to generate ET estimations. The modeling framework includes a set of automated routines (scripts) to download satellite imagery, filter-out clouds, convert imagery to reflectance (using an atmospheric correction model), derive physical and biophysical variables, and ultimately produce daily evaporation estimates on a 30-meter scale. The number of usable Landsat scenes for each year in the representative hydrologic period is presented in Table 3-13, and the location of the Landsat scenes and meteorological stations used are shown in Figure 3-22.

TABLE 3-13. USABLE LANDSAT SCENES IN EACH OF THE 10 YEARS FOR WHICH ET ESTIMATES WERE DEVELOPED

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Number of Scenes	30	24	30	27	30	23	24	12	22	29

3.9.3.2 ESTIMATE OF EVAPOTRANSPIRATION IN THE PINE AND WAH WAH VALLEY HAS

Maps showing the calculated annual ET distribution are shown in Figure 3-23. The annual spatially averaged ET for the Pine Valley and Wah Wah Valley HAs are presented in Figure 3-24. The results indicate that higher ET is correlated with elevation, the presence of springs, seeps and irrigated agriculture, and Sevier Lake, which receives significant runoff during some years. Irrigated areas in Snake and Wah Wah Valleys are clearly visible, with the calculated actual ET generally consistent with agronomic practices for local crops. ET is variable from year to year, with 2011 standing out as a high ET year and 2005 as a low ET year. Interestingly, annual precipitation (Figure 3-21) and annual ET do not necessarily correlate directly, suggesting that not only total annual precipitation, but the seasonality of precipitation, plays a significant role in ET.

The spatially weighted average annual evapotranspiration calculated from 2005 to 2014 remote sensing data in Pine and Wah Wah Valley HAs is 9.41 and 7.46 inches, respectively. Multiplying this rate by the areas of the Pine and Wah Wah Valley HAs (472,200 and 386,971 acres, respectively) yields an average annual estimated evapotranspiration volume of 370,284 and 244,567 AFY, respectively.

3.9.3.3 VALIDATION

Devitt and Bird (2016) monitored ET using EC intrumentation at a station in Snake Valley (Figure 3-25) from 2007 to 2013. This data overlapped with the analysis period for this study and represents the closest EC data to Pine Valley and the longest available ET dataset measured by this method. Vegetation at the EC site is reported to consist of desert shrubland, primarily greasewood. As shown in Table 3-14, measured ET was variable from year to year and agreed relativley closely with the remote sensing-based ET estimate from the present study. The difference in the long-term average annual ET between the two methods is slightly over 1 percent.

TABLE 3-14. COMPARISON OF REMOTE-SENSING ET ESTIMATES TO 7-YEAR EC DATA IN SNAKE VALLEY (DEVITT AND BIRD 2016)

Year	Devitt and Bird (2016) EC Measured (in)	Remote Sensing Based ET Estimate (in)
2007	7.80	7.76
2008	7.80	7.62
2009	8.76	8.77
2010	8.88	9.19
2011	12.20	12.25
2012	7.80	8.4
2013	8.64	8.72
Average	**8.84**	**8.96**

Notes: in = inches

In another study by Devitt *et al.* (2011), ET data were collected in 2006 for two sites. This data also overlapped for the region and period for which an ET dataset was developed in this study. The 2006 annual ET values for stations SNV-1W and WRV-1W (Figure 3-26) were 9.46 and 16.70 inches, respectively. The corresponding remote sensing-based ET values were 9.08 and 16.82 inches for SNV-1W and WRV-1W, respectively, or about 4 percent lower and 1 percent higher, respectively.

The USGS collected ET data from six EC stations in eastern Nevada from September 2005 through August 2006 (Moreo *et al.* 2007). These data were used by Gardner *et al.* (2020) to derive ET and ETg estimates in Tule Valley and at Sevier Lake. Table 3-15 and Figure 3-27 show a comparison of the USGS data and the remote sensing-derived data developed in this study.

TABLE 3-15. COMPARISON OF ET ESTIMATES DEVELOPED IN THIS STUDY TO SEPTEMBER 2005–AUGUST 2006 EC DATA

Station Name	USGS – EC Measured (in)	Remote Sensing Based ET Estimate (in)
SNV1	10.03	8.17
SPV1	10.02	9.05
SPV2	12.07	9.33
SPV3	26.94	25.51
WRV1	12.77	12.70
WRV2	12.18	11.41
Average	14.00	12.70

Notes: in = inches

The USGS estimated their measurements to be within approximately 10 percent of actual values. As shown in Table 3-15, the remote sensing-derived ET values for the station locations were generally within this error range. Figure 3-27 illustrates that monthly ET values from the EC stations were generally relatively well correlated with ET estimates calculated form remote sensing data for this study. For stations with lower annual ET, the remote sensing-derived values were generally lower than the EC-measured values during the months with higher ET. It should be noted that a single year is not a sufficient time frame to estimate long-term average ET and cannot adequately capture changes on plant phenology, the extent of vegetation or climatic variation. The longer-term data from Devitt and Bird (2016) suggest that the September 2005 to August 2006 data could represent a temporary bias in either the EC measurements or the remote sensing data that does not exist for longer-term data.

3.9.4 ETG ESTIMATE IN THE TULE VALLEY AND SEVIER DESERT HAS

3.9.4.1 BACKGROUND

The Pine and Wah Wah Valley HAs are part of a regional groundwater flow system with ETg from vegetation in low-lying areas in Tule Valley and the area surrounding Sevier Lake. Regional groundwater flow patterns are north-northeasterly out of Pine Valley and northerly out of Wah Wah Valley, into the area surrounding Sevier Lake and north-westerly to Tule Valley. Gardner *et al.* (2020) identified Groundwater Discharge Areas (GDAs) comprising 81,659 acres in the Tule Valley HA and 143,239 acres in the Sevier Desert HA (Figure 3-28). The GDAs were identified based on interpolated depths to groundwater supplemented by aerial imagery interpretation and field reconnaissance. Five GDA land cover classes were mapped, including open water, very sparse desert shrub, sparse-to-dense desert shrub, grassland, and marshland. Each land use class was assigned a range of ET rates based on published literature and ET was interpolated spatially across the GDAs using remote sensing-derived reflectance indices. Finally, measured precipitation at a meteorological station in Tule Valley was subtracted from the calculated ET rates to develop ETg rates. These revised ETg rates were then applied to designated ETg discharge cells in GBCAAS v. 3.0 and an extinction depth was established for the water table, below which ETg by phreatophytes would not occur.

A significant additional change to the simulation of ETg between GBCAAS v. 1.0 and v. 3.0 was the elimination of ETg discharge from the regional aquifer within the Sevier Lake playa area. Investigations for the CPM Project determined that the shallow brine system at Sevier Lake occurs in relatively low permeability playa sediments that impede communication with the underlying regional aquifer system (Whetstone Associates and ENValue 2019). Thus, although our analysis indicates that significant ET occurs from Sevier Playa, GBCAAS v. 3.0 incorporates the assumption that this discharge does not involve the regional aquifer. Finally, the investigations for the Sevier Playa Potash Project also generated additional groundwater level data that were used to calibrate GBCAAS v. 3.0.

There are several uncertainties related to the ETg estimates discussed in Gardner *et al.* (2020) and incorporated into GBCAAS v. 3.0. Uncertainties are related to the conceptual model for ETg discharge and how it is incorporated into GGBCAAS v. 3.0, and the reliability of the ETg estimates. The conceptual model followed to assess the ETg areas and simulate ETg in the identified GDAs includes the following uncertainties:

It is unclear how Sevier Playa is different from other wet playas in the Great Basin that are regarded as regional groundwater discharge points. The fact that fine grained terminal playa sediments will largely isolate the shallow brine systems does not mean these systems are not terminal discharge points for regional aquifers in areas where the regional water table is relatively shallow. Generally speaking, all that is required for discharge to occur is a continuous saturated zone from the regional aquifer to a depth that is close enough to ground surface for phreatic rise to occur. Fine grained sediments will slow, but not stop this process. The presence of high concentrations of TDS and stable isotope concentrations indicative of evaporation (Gardner *et al*. 2020) are expected at wet playas, and do not disprove the occurrence of discharge.

The groundwater resource studies completed for the Sevier Playa Project indicate the presence of local perched aquifers in the alluvial fans surrounding Sevier Lake that may support discharge to phreatophytes ringing the playa (Whetstone Associates and ENValue 2019). As such, there is uncertainty regarding the correct conceptual model for groundwater discharge at Sevier Lake, and its relation to the regional aquifer system. ETg discharge could be occurring from perched aquifers at some locations.

GBCAAS v. 3.0 models ETg discharge areas in Sevier and Tule Valleys using the MODFLOW Evapotranspiration (EVT) package, which assigns ET rates to saturated intervals above an assigned extinction depth. A recent study near Baker Ranch in Snake Valley demonstrated that greasewood shrubs (*S. vermiculatus*) were able to maintain groundwater connectivity during a period of steady, pumping-induced groundwater level decline from 2007 to 2013 (Devitt and Bird 2016). During this time, groundwater levels in the area declined by approximately 1.3 meters (4.3 feet) and the plants were able to adapt and maintain groundwater connectivity without decline in plant health. A study of Rabbitbrush (*C. nauseosus*) in the Mono Lake region of California indicated that groundwater level declines in the range of 1 to 2 feet did not affect plant canopy density (Toft and Fraizer 2003). The available MODFLOW EVT package cannot simulate the ability of local phreatophytes to adapt to gradual drawdown induced by the Sevier Playa Project, and thus will tend to overpredict impacts.

As shown in Figure 3-29, EVT discharge cells have been added around Sevier Lake in a similar elevation range around the edges of the playa, but groundwater levels are several feet deeper on the west side of the playa than on the east side. As a result, EVT cells on the northwest side of the playa produce little to no ETg discharge. This ET pattern does not match the spatial distribution of ET measured by our remote sensing analysis (, which would be expected to be greater in ETg discharge areas.

ETg estimates for the phreatophyte discharge areas in Tule Valley and surrounding Sevier Lake were developed using the following process:

Step 1: A vegetation cover map of the GDAs was generated with five classes: open water, very sparse desert shrub, sparse-to-dense desert shrub, grassland, and marshland.

Step 2: ET rates for each of the five land-use classes and playa, were taken from the literature (Garcia *et al.* 2014; Moreo *et al*. 2007; Berger *et al*. 2016; Welch *et al.* 2007; Huntington and Allen 2010).

Step 3: ET measurements from a single year (September 2005 to August 2006) of observations using EC systems installed at six sites in eastern Nevada (Figure 3-26) (Moreo *et al.* 2007) were used to establish a relationship between annual ET and several remotely-sensed vegetation indices, and the best performing index was selected and applied to two satellite images to represent the spatial distribution of ET in the mapped GDAs. Nine Landsat images spread across seven years were used to calculate indices. It was determined that Modified Soil Adjusted Vegetation Index (MSAVI) for images taken July 18, 2007 and August 21, 2008 provided the best correlation. The average MSAVI derived from these images was therefore used in the final step of the process to represent the spatial distribution of ET in the GDA.

Step 4: Spatially distributed ET for each GDA class from Step 1 was developed by scaling the ET-rate range from Step 2 based on the range of average vegetation index values from Step 3.

Step 5: ETg was estimated by subtracting local precipitation from the spatially-distributed ET estimates, based on the assumption that ET that exceeds local precipitation must be met by groundwater.

The limitations of this approach are briefly discussed in Gardner *et al*. (2020) and include spatial variability in surface and weather conditions, differences in elevation between the GDAs and EC stations used to select the vegetation index approach, potential image processing errors and the effect of localized precipitation events. The following additional factors contribute to the uncertainty of the ETg estimate results:

- A fixed ET rate (literature-derived ET values from Step 2) cannot capture inter-annual changes in vegetation growth dynamics and climate variability, on which actual ET is highly dependent.
- Phreatophytic vegetation growth and establishment is highly dynamic across space and time, and landuse maps prepared from a single image and field surveys do not capture this variability. The single average vegetation index value represented by the July 18, 2007 and August 21, 2008 images from which ETg was calculated provides the average condition of the vegetation during

two satellite overpasses, and does not capture plant phenological variations over time. The calculated ETg values are thus representative of the vegetation condition at a single point in time and not average annual conditions.

- Six EC stations were used to build a correlation between estimated ET and remotely sensed vegetation indices, and to select satellite imagery dates for which the correlation is strongest, and these are asymmetrically distributed. Five of the data points are clustered in the low ET range, and a single value is in the higher ET range. Applying a linear fit to this dataset suggests a strong correlation between vegetative index and ET measurements, when in fact the correlation is relatively poor. When all six data points are used, the correlation coefficient (R-square) is 0.98, suggesting there is a strong correlation. However, when the highest value is dropped, R-square drops to 0.64, indicating considerably lower correlation. For other images, the correlation drops as low as 0.08 when the single high value is dropped. The highly variable correlation for the five clustered ET values suggests the criteria used to select the aerial imagery used for ET calculation in the GDA is more random than the reported statistics based on all six points implies.

- The value of ETg from playa surfaces was assumed based on unpublished communication and a single published value for Dixie Valley in west central Nevada (Garcia *et al.* 2014), and was not quantitatively derived or supported using local information. Given the large area of playa in the GDAs, even a small error in this estimate could lead to significant changes in regional groundwater discharge estimates.

- To develop ETg estimates, local precipitation was subtracted from the spatial ET estimates for the GDAs derived using the above approach. To do this, the annual average of four years (2006 to 2009) of precipitation data from a single station (the Tule Valley RAWS station) were subtracted from the estimated ET values. The locations of the Tule Valley RAWS station and other nearby rain gauge stations are shown in Figure 3-30. The BLM Filmore Field Office operates a total of 10 additional rain gauge stations with long-term records in this area. In addition, the Tule Valley RAWS station has a precipitation record spanning 30 years. Use of 4 years of precipitation records from a single station introduces considerable uncertainty into the ETg analysis in Gardner et al. (2020).

3.9.4.2 APPROACH

To further evaluate potential ETg in the mapped the GDAs, the following evaluation was undertaken.

- Long-term ET volumes derived from 2005 to 2014 remote sensing data using the surface energy balance method were extracted for the EVT cells designated around Sevier Lake and in Tule Valley in GBCAAS v. 3.0.
- The potential range of precipitation amounts in the area was evaluated by calculating long-term average precipitation for the Tule Valley RAWS station, for Tule Valley RAWS combined with long-term averages from three other stations at similar elevations around the GDAs, and for all of the available rain gauge stations in this area. These values were compared to 2006 to 2009 Tule Valley RAWS averages.

- The precipitation volumes were subtracted from the extracted ET volumes to evaluate the potential range of ETg discharge form the GDAs.

The results of this comparison are presented in Table 3-16**.**

TABLE 3-16. FURTHER EVALUATION OF POTENTIAL ETG IN GROUNDWATER DISCHARGE AREAS IN TULE VALLEY AND AROUND SEVIER LAKE

ET Discharge Area Precipitation Data Source	Precipitation (in)	Precipitation (AFY)	Total ET (AFY)	ETg Groundwater Discharge (AFY)
USGS: 4-Year Average for Tule Valley RAWS	5.52	75,700	142,900	67,300
Long-Term Average for Tule Valley RAWS	6.62	90,700	142,900	52,200
Long-Term Average for all BLM Stations	9.1	124,700	142,900	18,200
Average for Tule and Sevier Lake Valley Floor Stations	7.85	107,600	142,900	35,300

Notes: in = inches; AFY = acre feet per year

For comparison, the estimate of ETg for these areas in Gardner *et al.* (2020) is 45,500 AFY, and Brooks (2017) indicates the calibrated ETg simulated in GBCAAS v. 3.0 is 38,200 AFY. The findings of the above calculations span these USGS estimates. The ETg discharge in these areas was further evaluated during calibration of the GBCAAS-PV model (Appendix A). The ETg from these areas in the calibrated GBCAAS-PV model was found to be 38,100 AFY from the GDA in the Tule Valley HA and 4,200 AFY from the GDA around Sevier Lake, for a total ETg of 42,400 AFY. This is in the range presented in Figure 3-16, above and between the estimated values presented by Gardner *et al.* (2020) and Brooks (2017).

3.9.5 GROUNDWATER DEMAND

3.9.5.1 PINE AND WAH WAH VALLEY HAS

The Pine Valley HA includes no permanent residences or other development. Groundwater pumping is, therefore, limited to few domestic and stock wells. Stephens (1976) reported that groundwater demand within the Pine Valley HA is negligible and Gardner *et al*. (2020) did not report significant current groundwater development. Pumping from basin-fill aquifer wells in the northern part of the valley was estimated at less than 5 AFY and was considered an insignificant part of the total discharge (Stephens 1976). Future groundwater demand increases in Pine Valley are related to the PVWS Project which would withdraw up to 15,000 AFY from the basin-fill aquifer.

Similar to Pine Valley, Wah Wah Valley is sparsely inhabited, and groundwater pumping is limited to a few domestic and stock wells. Pumping from basin-fill aquifer wells was estimated at 1 to 2 AFY (Stephens 1974). The water supply for Wah Wah Ranch, which is located near the center of the valley, is derived by diverting water from Wah Wah Springs. As discussed in Section 3.7.2.1, Stephens (1974) indicated that about 600 AFY of the spring discharge is diverted for irrigation use at the ranch. The diversion estimate is

similar to the average annual ET estimate for the irrigated area at Wah Wah Ranch derived from our ET analysis (Section 3.9.3), which is 570 AFY for the period from 2005 to 2014. There are no currently planned developments that would increase future groundwater demand.

With the exception of Wah Wah Springs, the springs in the Pine Valley and Wah Wah Valley HAs are presumed to discharge groundwater from local perched mountain aquifers. Flow from several springs in the mountains surrounding Pine and Wah Wah Valleys is diverted by BLM to provide water sources (guzzlers) for wildlife, and as discussed above, some discharge from Wah Wah Springs is diverted for irrigation use at Wah Wah Ranch. Ultimately, all of the spring discharge in the Pine and Wah Wah Valley HAs is either consumed by ET from crops or vegetation, or re-infiltrates to recharge the regional aquifer system. As such, it is accounted for in the balance between precipitation and ET in these basins.

Estimates of historical, current, and future groundwater withdrawals (and year withdrawal was reported, estimated, or projected) for the HAs in the Study Area are summarized in Table 3-17.

TABLE 3-17. HISTORICAL, CURRENT AND FUTURE GROUNDWATER PUMPING IN HAS IN THE STUDY AREA

Hydrographic Area	Historical Groundwater Pumping (AFY)	Current Groundwater Pumping (AFY)	Projected Future Groundwater Pumping (AFY)
Pine Valley	5 (1976)	5	15,005
Wah Wah Valley	2 (1974)	2	2
Sevier Desert (southern portion within APE)	None reported	None reported	1,500
Snake Valley / Hamlin Valley	5,500 (1945) - 21,600 (2004)	28,700	28,700
Beryl-Enterprise Area	3,000 (1937) - 92,000 (1974)	95,000 (2016)	34,000 (2130)

Notes: Snake Valley estimates represent net pumping based on an analysis of discharge. Beryl-Enterprise estimates represent gross pumping. AFY = acre feet per year

3.9.5.2 OTHER HAS IN THE STUDY AREA

Information regarding historical, current, and projected future groundwater pumping for the remaining HAs in the Study Area is discussed below and summarized in Table 3-17, above.

Sevier Desert HA. The portion of the Sevier Desert HA that lies within the APE for the PVWS Project includes areas to the south and west of Sevier Lake playa (Figure 3-1). Similar to the Pine and Wah Wah Valley HAs, this area includes, a broad, sparsely inhabited valley surrounded by mountains that is generally undeveloped with no reported current or historical groundwater development (Whetstone and ENValue 2019). Centrally located in this area is Sevier Lake, a large terminal playa that is intermittently filled with runoff and changes in size from year to year, disappearing altogether for some periods. The area that lies to the north of Sevier Lake playa includes land that is used for crop cultivation and irrigated pasture, but

this area lies outside the APE and is therefore not evaluated in detail in this GRIA (except to the extent that it is included in the area simulated by the GBCAAS model).

CPM has proposed to develop and operate potassium mineral leases on and adjacent to Sevier Lake playa (Whetstone and ENValue 2019). Potash-bearing brines would be extracted from trenches and wells on the playa and processed in adjacent facilities. Studies conducted by CPM have reportedly determined that the shallow groundwater brines beneath the playa are not hydrologically connected to the underlying regional aquifer system, and Brooks (2017) updated GBCAAS v. 3.0 with the assumption that no recharge or discharge occurs to/from the regional aquifer system within the playa boundaries. In keeping with this assumption, the proposed brine extraction is not accounted as groundwater pumpage in this analysis. However, CPM has proposed to develop a groundwater supply wellfield in the Cambrian Prospect Mountain Quartzite to provide freshwater for the potash processing operations. The well field would produce a total of 1,500 AFY of groundwater from Cambrian- to Precambrian-age quartzite bedrock that is considered part of the regional aquifer system (Whetstone and ENValue 2019).

Snake Valley HA (including Hamlin Valley). The Snake Valley HA is located along the Utah-Nevada border in White Pine and Lincoln Counties in eastern Nevada and Tooele, Millard, Juab, Beaver, and Iron Counties in western Utah. It is relatively sparsely developed with approximately 10,000 acres of land under agricultural use (BLM 2012) and several small rural communities, including Garrison and Baker, among others. Almost all the consumptive water use in the Snake Valley HA is for the irrigation of crops and pasture (SNWA 2009). Sources of water for irrigation include precipitation, surface water and groundwater, with surface and groundwater being used conjunctively to irrigate some parcels. Irrigated agricultural areas can be supplied by both surface water and groundwater.

Estimates for historical groundwater pumpage were derived by SNWA (2009) from 1945 through 2004. Because of a lack of historical water-use records, estimates of historical consumptive water use for irrigation were derived using a combination of data from historical records, Nevada DWR and Utah DWRi water right databases, land use analysis using aerial imagery, and crop demand factors for the area.

Average annual crop consumptive groundwater-use rate was estimated as follows:

- Areas under agricultural land use were identified from aerial imagery.
- For crop areas where only groundwater irrigation was assumed to occur (based on place-of-use data from Nevada DWR and Utah DWR) the area of the irrigated cropland was multiplied by a crop demand factor of 3.1 feet of water per year for alfalfa.
- For crop areas where both surface water and groundwater were used conjunctively (based on place-of-use data from Nevada DWR and Utah DWRi), the area of irrigated cropland was multiplied by a crop demand factor of 3.1 feet of water per year for alfalfa, and an adjustment factor of 0.5 to reflect the intermittent use of supplemental groundwater. The 0.5 adjustment factor was based on Nevada State Engineer's Ruling #5726 (Spring Valley) which stated that the maximum supplemental use in Spring Valley was 49.8 percent of the regular annual duty (Nevada State Engineer 2007; BLM 2012).

Using this approach, it was found that the area of land under agricultural production increased from 1,890 acres in 1945 to 8,222 acres in 2004. In the period from 1945 to 1955, about 87% of irrigated land was

estimated to be irrigated with groundwater exclusively, and the remainder by a combination of surface water and groundwater. By 2001 to 2004, about 70% of the land was estimated to be irrigated exclusively with groundwater, and the remainder by a combination of surface water and groundwater. Application of the assumed crop demand factor and adjustment factor, historical groundwater pumping in the Snake Valley HA was estimated to have been approximately 5,469 AFY in 1945-1955, and to have increased to 21,649 AFY in 2001-2004. For perspective, Utah DWRi reported that municipal and private domestic groundwater pumping in the portions of the Snake Valley HA (including Hamlin Valley) within Utah was 80 AFY in the year 2000 (BLM 2012). This confirms that agricultural irrigation accounts for the vast majority of groundwater pumping in this area.

To estimate current groundwater pumping in the Snake Valley HA, the analysis performed by SNWA was updated using the following approach:

- Areas under agricultural land use were identified from satellite imagery and ET distribution maps were developed for 2004 through 2015 and extrapolated to the present time based on historical land use trends.
- For crop areas where only groundwater irrigation is assumed to occur (based on place-of-use data from Nevada DWR and Utah DWRi) the area of the irrigated cropland was multiplied by the long-term average ET rate for irrigated land in the valley.
- For crop areas where both surface water and groundwater were used conjunctively (based on place-of-use data from Nevada DWR and Utah DWRi), the area of irrigated cropland was multiplied by the long-term average ETa rate and a factor of 0.5 to reflect the intermittent use of supplemental water.

Based on this analysis approach, the total estimated groundwater pumping for agricultural irrigation under current conditions is estimated to be 28,655 AFY. The actual amount of pumping may vary from year to year based on climatic conditions and actual cropping patterns.

Masbruch (2019) performed a study to assess long-term groundwater level and discharge effects if all available groundwater rights in the Utah and Nevada portions of Snake Valley HA were to be exercised. The study considered potential pumping associated with all approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in the Snake Valley HA, which were determined to comprise about 55,272 AFY as of February 2018. Available online water-right data for Snake Valley from Utah DWR and Nevada DWR were updated in August 2020; and the total water rights falling into the above categories were approximately 53,383 AFY. The small difference was the result of new permitted applications and cancelled (or terminated) applications since 2018. Approximately 41,927 AFY of this total comprised perfected or certificated water rights. It is important to note that current pumping represents about 68 percent of these water rights, and it appears unlikely they will ever be fully exercised. The rate at which irrigated acreage has been added in the basin has decreased significantly since 2000 (BLM 2012). At the same time, the proportion of surface water used conjunctively with groundwater for irrigation was reported to increase from 1990 to 2004, and review of aerial imagery suggests that the estimated percentage of surface water use in the basin may be low. Thus, in the absence of projections that would indicate planned or anticipated agricultural expansion in the Snake Valley HA, it is assumed that groundwater demand will remain relatively constant at current levels.

Beryl-Enterprise Area HA. The Beryl-Enterprise Area HA consists of open rangeland and agricultural areas in Iron and Washington Counties in the Escalante Valley of southwest Utah. Crops irrigated with groundwater from wells in the Escalante Valley include alfalfa, barley, corn, grass hay, potatoes, and canola (Keith 2008). Utah DNR (Mower 1982) estimated the natural groundwater recharge of the Beryl-Enterprise Area to be about 31,820 AFY. Greer (2008) calculated the return flow from surface irrigation at about 1,300 AFY and added that to the estimated recharge to determine a safe yield of approximately 34,000 AFY. The current average depletion from the basin-fill aquifer is estimated at approximately 65,000 AFY, which represents consumptive use of applied water (Greer 2008). Groundwater withdrawals in this area have exceeded the safe yield of the aquifer for more than 40 years, causing a long-term decline in groundwater levels and local subsidence.

As a result, a GMP was adopted by Utah DNR DWRi to bring the basin groundwater extraction into safe yield over a period of time through the sequential retirement of existing groundwater rights from October 31, 2030 to October 31, 2130 (DWRi 2012). Historical groundwater extraction by pumping of irrigation wells was reported as 3,000 acre-feet in 1937 and increased to 92,000 acre-feet by 1974 (Mower 1982). In 2016, Utah DNR, Utah Department of Environmental Quality and the USGS estimated the current withdrawal of groundwater from wells in the Beryl-Enterprise Area to be approximately 95,000 acre-feet (LaBonte 2017). These estimates are shown on Table 3-17 and represent gross pumping of groundwater. Under the GMP, the safe yield of approximately 34,000 AFY is projected to be achieved by 2130. The vast majority of the current and projected groundwater demand in the Beryl-Enterprise HA, as well as the documented historical drawdown, occurs south of the area that is projected to be affected by the proposed PVWS Project. Current groundwater pumping within the PVWS Project APE is assumed to be based on full exercise of the available groundwater rights, or 1,396 acre-feet.

3.9.6 Refined Groundwater Budgets for the Pine and Wah Wah Valley HAs

3.9.6.1 Inflows

3.9.6.1.1 Recharge from Precipitation

Based on the results of the precipitation and ET analysis discussed in Sections 3.9.2 and 3.9.3, a refined recharge estimate was developed using a water balance approach for the 10-year representative hydrologic period from 2005 to 2014. First, an average precipitation rate was calculated from rain gauge data in Pine and Wah Wah Valleys. Second, the average annual ET rate calculated from Landsat remote sensing data using the surface energy balance method was subtracted from precipitation to assess net recharge rates in the two HAs. Finally, the net recharge rate was multiplied by the area of the HA to calculate the recharge volume. This approach relies on the following inputs and assumptions:

- The average annual precipitation rate calculated from rain gauge data in the Pine and Wah Wah Valley HAs is 9.86 and 7.62 inches, respectively (refer to Table 3-11). The precipitation volume calculated for the Pine and Wah Wah Valley HAs based on these precipitation rates is 387,991 and 245,727 AFY, respectively. This represents a conservative estimate of true precipitation and is considerably less than the precipitation volumes assumed by Stephens (410,000 and 290,000 AFY, respectively), or PRISM precipitation estimates cited in Gardner *et al*. (2020) (510,000 and

320,000 AFY, respectively). The USGS did not directly consider precipitation in the revision of the Pine and Wah Wah Valley HA water budgets for the development of GBCAAS v. 3.0.

- The calculated spatially-weighted average annual ET rate for the Pine and Wah Wah Valley HAs is 9.41 and 7.46 inches, respectively. This equates to an average annual estimated ET volume of 370,284 and 244,567 AFY, respectively. These values are based on the most spatially and temporally robust analysis of ET in the area currently available.

- Net average annual recharge rates across the Pine and Wah Wah Valley HAs are 0.45 and 0.16 inches, respectively. Multiplying this rate by the areas of the HAs, 472,200 and 386,971 acres, respectively, yields net recharge estimates of 17,700 AFY in Pine Valley and 5,160 AFY in Wah Wah Valley.

The use of a conservative precipitation estimate coupled with the most reliable ET estimate represents a reasonable approach to establishment of a refined water budget for impact analysis. Note that these estimates are based on basin-wide assessment of total ET, including all ET losses in both the mountain and valley areas. For development of a net recharge estimate, therefore, it was not necessary to separately consider recharge to perched mountain aquifers or discharge to springs.

For perspective, the refined recharge estimates for the Pine and Wah Wah Valley HAs are compared below in Table 3-18 to the historical estimates from Stephens (1974 and 1976), Brooks *et al.* (2014) and Brooks (2017).

TABLE 3-18. HISTORICAL RECHARGE ESTIMATES FOR PINE AND WAH WAH VALLEYS

Hydrologic Area	Formation 2020	Stephens (1974 and 1976)	Brooks *et al*. GBCAAS v. 1.0 (2014)	Brooks GBCAAS v. 3.0 (2017)
Pine Valley	17,700	21,000	24,000	11,000
Wah Wah Valley	5,160	7,000	5,000	3,200[1]

Notes: Estimates in acre-feet per year (AFY)

[1] Brooks (2017) reduced the volume of recharge applied to Wah Wah Valley HA during model calibration to cause simulated water levels on the west side of Sevier Lake to more closely match recent observed water levels.

3.9.6.1.2 OTHER INFLOWS

It should be noted that the groundwater budgets reported by Stephens (1974 and 1976) did not include interbasin flows (IBFs), with one exception. Due to the presence of a fault along the eastern margin of Pine Valley that is assumed to act as a groundwater divide and eastward dipping bedding in the carbonate aquifers of the Wah Wah Mountains, approximately 3,000 AFY of recharge from precipitation falling on 28,000 acres in the eastern portion of the Pine Valley HA actually flows in the subsurface to the Wah Wah Valley HA and recharges that basin. Brooks (2017) discusses IBFs simulated by GBCAAS v. 1.0 and 3.0, but does not explicitly mention this component. This component, however, is presumed to be included in the

overall estimate of IBF between Pine and Wah Wah Valley (Gardner *et al.* 2020) and is retained in our analysis of the groundwater budget.

No water is imported into Pine or Wah Wah Valleys; therefore, there are no other inflows. Stephens (1976) states that 160 AFY of groundwater discharge to streams in Pine Valley percolates back into the basin fill, although much of it is believed also be lost to ET. Since this exfiltration, re-infiltration and ET of groundwater occurs within the Pine Valley HA, it is not accounted as a component of the water budget in this study. IBF into and out of the various HAs in the Study Area were estimated using GBCAAS-PV and are discussed in Section 3.9.6.2.

3.9.6.2 OUTFLOWS

The groundwater budgets presented by Stephens (1974 and 1976) list several outflows that are internal to Pine and Wah Wah Valley, including groundwater discharges to springs, streams and phreatophyte ET from perched aquifers. Some of the groundwater discharge from Wah Wah Springs is diverted to Wah Wah Ranch, where it is used for irrigation and a portion returns to groundwater through deep percolation. These components are internal to the Pine Valley and Wah Wah Valley HAs and represent recharge to perched aquifers that is consumed within the basin and accounted for in the basin-wide balance between precipitation and ET. This information provides insight into the hydrologic processes in the basins, but does not represent actual groundwater inflows or outflows from the HAs. In this GRIA, these internal groundwater budget outflow components are accounted for when basin-wide ET is subtracted from basin-wide precipitation during development of refined groundwater recharge estimates. The only exception is a negligible amount of consumptive groundwater use from springs and wells for domestic and stock water supply, estimated to be 5 AFY in the Pine Valley HA and 2 AFY in the Wah Wah Valley HA. These components are neglected in the refined groundwater budgets.

A unique characteristic of the Pine and Wah Wah Valley HAs is a lack of areas where the regional water table is shallow enough for natural discharge to occur (Gardner *et al.* 2020). Most comparable valleys in the eastern Great Basin have areas where the depth to the regional water table is shallow enough for groundwater discharge to occur from springs, seeps and/or phreatophytes (ETg), which typically represents a significant component of the groundwater budget in such basins. Groundwater levels in Pine and Wah Wah Valleys, however, are hundreds of feet below land surface, even beneath the dry playas at the lowest valley elevations. A consequence of these deep groundwater levels is that all discharge from the basin-fill aquifers in both HAs must occur through the subsurface where it is not observable and cannot be measured.

Because groundwater in the Pine Valley and Wah Wah Valley HAs is sparsely developed and groundwater levels are relatively stable, the basins may be considered in equilibrium, meaning that inflows approximately equal outflows. For the purposes of the present analysis, net underflows out of the basins as determined by various historical studies are summarized below in Table 3-19. These net underflows out of the basins are assumed to be equal to local recharge because the Pine and Wah Wah Valley HAs are currently in hydrologic balance. The current net outflow estimates determined based on the recharge analysis conducted for this study (listed as Formation 2020) are presented below in Table 3-19 and compared to historical estimates by Stephens (1974 and 1976), Brooks *et al.* (2014) and Brooks (2017).

TABLE 3-19. NET GROUNDWATER OUTFLOWS FROM PINE AND WAH WAH VALLEYS

Hydrographic Area	Stephens (1974 and 1976)	Brooks *et al*. (2014) GBCAAS v. 1.0*	Brooks (2017) GBCAAS v. 3.0*	Formation (2020)
Pine Valley	3,000 to Wah Wah Valley; 11,000 mostly northward	24,000 mostly northward	11,000 mostly northward	3,000 to Wah Wah Valley; 14,700 mostly northward
Wah Wah Valley	8,450 mostly northward	4,230 mostly northward	2,450** mostly northward	8,160 mostly northward

Notes: Outflows in acre-feet per year (AFY)

* Presented values are net outflows. A complete accounting of modeled IBFs simulated in GBCAAS v. 1.0 and 3.0 is provided by Brooks 2017.

** Brooks (2017) reduced the volume of recharge applied to Wah Wah Valley HA during model calibration to cause simulated water levels on the west side of Sevier Lake to more closely match recent observed water levels.

3.9.6.3 SUMMARY

3.9.6.3.1 PINE VALLEY HA

Historical and refined groundwater budgets for the Pine Valley HA are presented graphically in Figure 3-31. The original groundwater budget developed for the Pine Valley HA (Stephens 1976) includes an inflow component of 21,000 AFY including approximately 7,000 acre-feet that is recharged to perched aquifers and assumed to be consumed through discharge to springs, seeps, and ET within the basin. Of the remaining 14,000 AFY of recharge, 3,000 is assumed to flow into Wah Wah Valley and 11,000 flows out of the basin as subsurface underflow, mostly to the north toward Tule Valley and Sevier Lake.

Stephens' groundwater budget, including 21,000 AFY of recharge, was incorporated into GBCAAS v. 1.0 and increased to 24,000 AFY during model calibration. The model documentation did not distinguish between recharge to perched aquifers or regional aquifers as Stephens had done. An accounting of IBFs by Brooks (2017) indicates that all 24,000 acre-feet were assumed to recharge the regional aquifer system. This was updated in GBCAAS v. 3.0.

The refined water budget for Pine Valley includes a calculation of net basin recharge derived by subtracting ET from precipitation, which accounts for the local intra-basin discharge and recharge components associated with springs, seeps and ET that were enumerated separately by Stephens. Discharge to Wah Wah Valley HA by IBF is assumed to be Stephens' original 3,000 AFY.

3.9.6.3.2 WAH WAH VALLEY HA

Historical and refined groundwater budgets for the Wah Wah Valley HA are presented graphically in Figure 3-31. The original groundwater budget by Stephens (1974) includes an inflow of 10,000 AFY, including approximately 1,500 acre-feet recharged to perched aquifers and assumed to be consumed by discharge to springs, seeps, and ET. An additional 3,000 acre-feet of inflow to the regional aquifer system is derived from recharge that occurs in the Pine Valley HA-. Finally, 5,500 acre-feet results from intra-basin recharge of precipitation. A total of 8,500 AFY flows out of the basin as subsurface underflow, mostly to the north toward Tule Valley and Sevier Lake.

GBCAAS v. 1.0 only accounted for the 5,500 AFY of regional aquifer recharge in Stephens' groundwater budget as recharge and did not include recharge to perched aquifers (1,500 AFY) assumed to be consumed by ET within the basin. The remaining 3,000 acre-feet of underflow from Pine Valley was assumed to be included in modeled IBFs. Local recharge to the regional aquifer system was decreased to 5,000 AFY during model calibration, as reflected in the accounting of IBFs by Brooks (2017). Recharge to the regional aquifer system within Wah Wah Valley was further decreased to 3,200 AFY during calibration of GBCAAS v. 3.0. Both GBCAAS v. 1.0 and 3.0 simulate the consumptive use of diverted water from Wah Wah Springs to Wah Wah Ranch as a discharge component of the regional aquifer system (770 and 750 AFY, respectively).

The refined water budget for Wah Wah Valley HA includes a calculation of net basin recharge derived by subtracting ET from precipitation, which accounts for local intra-basin discharge and recharge components associated with springs, seeps, irrigation, and ET that were enumerated separately by Stephens and the GBCAAS water budgets. Because the groundwater budgets for the Pine and Wah Wah Valley HAs are being evaluated together in this study, the outflow of 3,000 AFY from the Pine Valley HA is being accounted as inflow in the groundwater budget for the Wah Wah Valley HA.

3.10 SUBSIDENCE

Land subsidence can occur when compressible clays are depressurized as a result of groundwater extraction. Clay sediments in alluvial systems are deposited as open frameworks of very fine grained, plate-like clay mineral grains stacked at opposing angles due to electrical attractions on the mineral surfaces. When groundwater is extracted from adjacent sandy aquifers, the water pressure decreases, inducing water to flow from the clays into the surrounding aquifer. Decreases pore water pressure causes the clay framework to consolidate under pressure from the overlying sediments. This can happen especially in confined aquifer conditions such as below laterally extensive lacustrine clays at basin centers, where the head loss resulting from groundwater extraction is greater than in unconfined aquifers and clay units may be more abundant. Younger, poorly consolidated clays are more susceptible than older formations. The process of subsidence is reversible when granular aquifer materials compress and expand under changing pressure conditions, but irrecoverable when clay frameworks are compressed and reoriented. Irrecoverable subsidence can result in decreased storage capacity within the aquifer, settlement of the ground surface and formation of fissures. In general, most subsidence occurs when an aquifer is initially depressurized, but can continue for months, or even years, after clays slowly dewater and adjust to the new pressure regime. If groundwater levels subsequently recover, subsidence generally does not resume (or does not progress as rapidly), until groundwater levels fall below historical low levels.

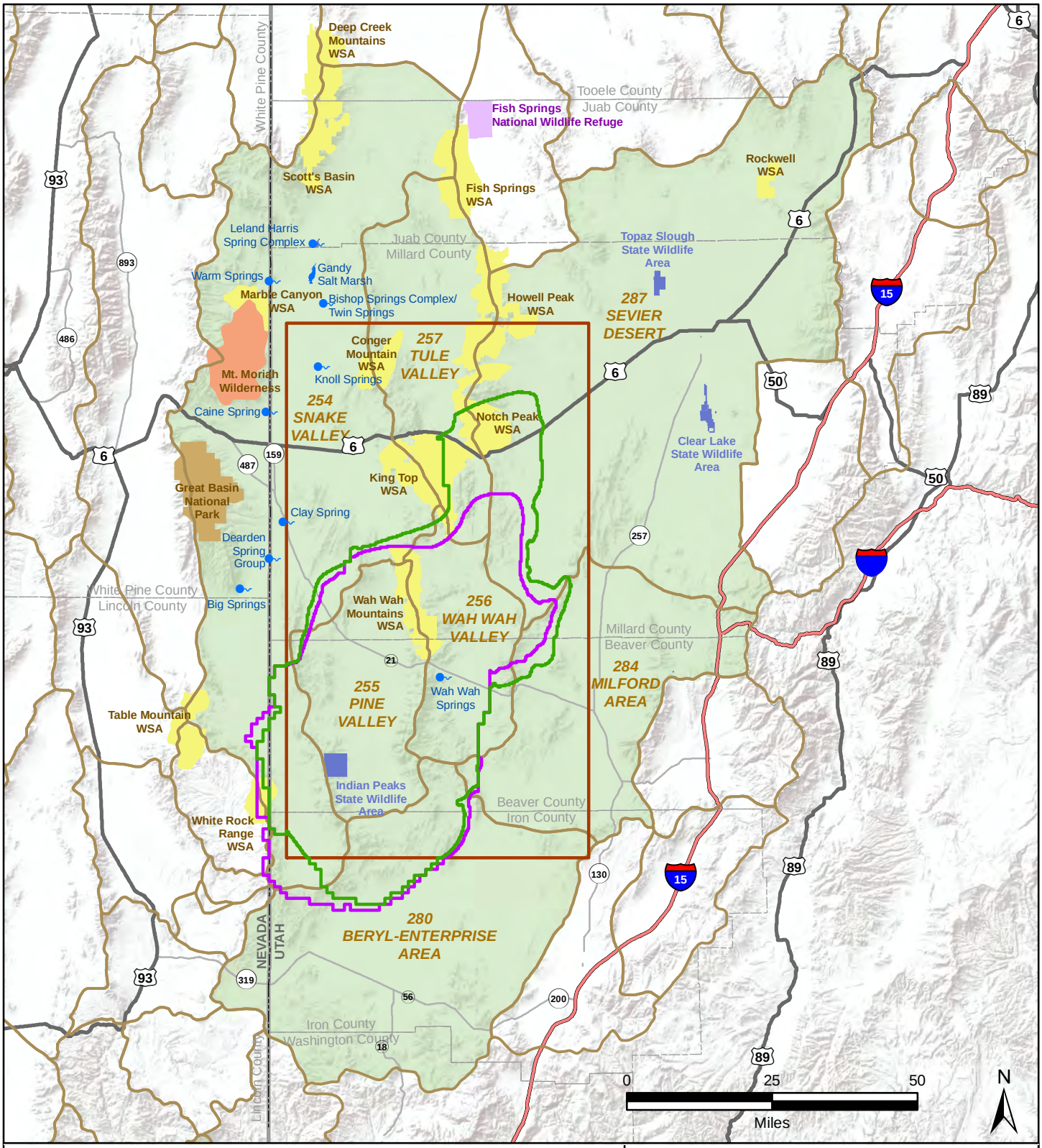
Groundwater levels are relatively stable in Pine Valley, and no subsidence has been reported or would be expected. The nearest continuous geodetic monitoring station is P081, located near Garrison, Utah, in Snake Valley, about 20 miles northwest of Pine Valley (UNAVCO 2020). Monitoring data from this station indicates elastic movement of the ground surface occurs in annual cycles with an amplitude of approximately 30 millimeters. This likely represents a cyclical deflection of the ground surface in response to annual groundwater withdrawal and soil moisture cycles. No irrecoverable land subsidence has occurred as a result of groundwater level declines in Snake Valley to date.

In the geologic setting of Pine Valley, areas underlain by lacustrine clay deposits in the subsurface basin fill would be the most susceptible to future subsidence as a result of groundwater level decline. The presence and extent of such materials has not been determined; however, the presence of at least some lacustrine deposits is likely. They would be most likely to occur in the lowest parts of the basin near the northern end of the valley. Clay deposits susceptible to subsidence are unlikely to occur in the alluvial fan deposits that ring the valley, or in valley axial stream deposits in the southern portion of the valley, since these are expected to be coarser grained and heterogeneous. The subsurface extent and thickness of lacustrine clays in the sedimentary basin fill of Pine Valley is unknown; however, the potential susceptibility of the basin to future subsidence may be inferred from the response of similar nearby basins to groundwater level decline.

Forster (2006) measured surface displacement in Escalante Valley with interferometric synthetic aperture radar (InSAR) and investigated other areas of potential subsidence in the Milford area and in Parowan Valley. The InSAR data used in Forster's study were acquired by the European Space Agency's ERS-1 and ERS-2 satellites for 1993 to 1996, and 1996 to 1998. The maximum total subsidence measured with InSAR in the Escalante Valley was 17 centimeters from February 1993 to March 1998, which is equivalent to a subsidence rate of 3 to 4 centimeters per year (cm/yr). This subsidence rate is consistent with a GPS-based subsidence rate estimate of 3 cm/yr near Beryl Junction for the period 1941 to 1972 (Lund *et al*. 2005). Groundwater level measurements indicate groundwater elevations have declined by as much as 95 to 105 feet in an area that extends from near Beryl Junction to Enterprise. Lund *et al.* (2005) attributed the formation of a series of earth fissures with as much as 12 inches of displacement to lateral stresses resulting from differential aquifer compaction and subsidence as a result of long-term groundwater level decline. Subsidence was measured from InSAR data in the Milford area but at a lower rate (< 1.5 cm/yr) and with a smaller spatial extent than in Escalante Valley (Forster 2006).

Similar evidence of subsidence was found in the southeastern and northeastern parts of Cedar (City) Valley, where groundwater levels have declined by as much as 114 feet since 1939 (Knudsen *et al*. 2014). During an investigation by the Utah Geological Survey (UGS), the basin fill sediments in portions of Cedar Valley were found to contain a high percentage of fine-grained material susceptible to compaction. As of 2014, the most displacement due to subsidence was about 1 foot near Enoch City; however, vertical displacement across the Enoch-graben-west fissure zone was as much as 3 feet (Knudsen *et al*. 2014).

The above data indicate that other basins in the region contain sedimentary fill that is potentially susceptible to subsidence. By inference, therefore, this could also be the case in Pine Valley; however, these basins are located at lower elevations, which could result in their containing greater accumulations of lacustrine sediments. The presence and extent of subsurface lacustrine sediments in Pine Valley has not been determined, though it seems likely that at least some lacustrine clay deposits exist, especially in the north-central part of the valley beneath the playa.



Legend

- Regional Spring
- State Wildlife Management Area
- National Park NPS
- Wilderness FS
- Wilderness Study Area (WSA) BLM
- National Wildlife Refuge
- Study Area
- Hydrographic Area
- Focused Model Area
- Simulated Area of Project Effects for Proposed Action
- Simulated Area of Project Effects for ANWS Alternative

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-1

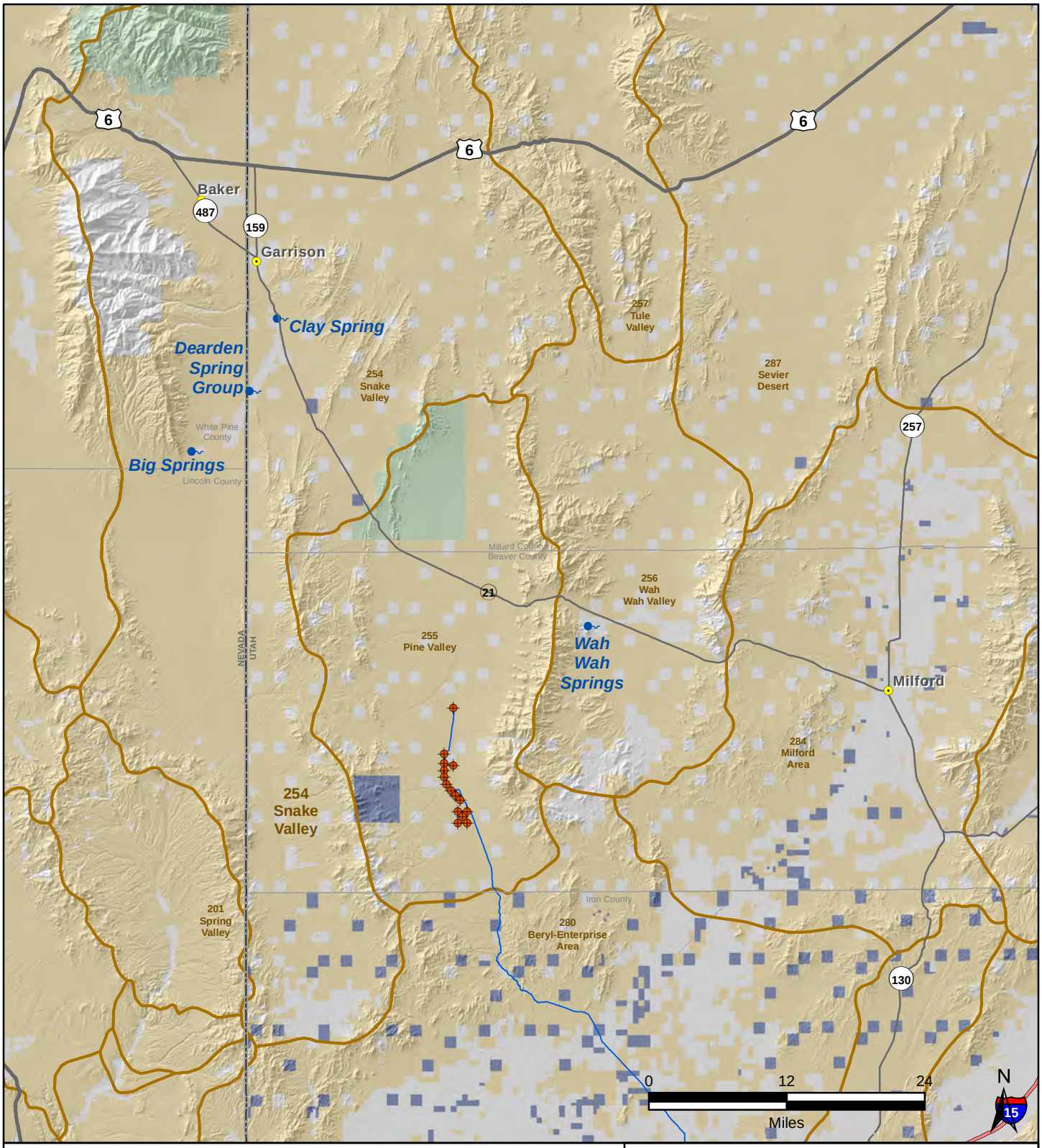
PROJECT STUDY AREA FOR GROUNDWATER RESOURCES EFFECTS

DATE: FEB 26, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRI\Fig3_01_EffectsArea_v2.mxd



Legend

- PVWS Project Well
- Regional Spring
- Interstate
- US Route
- State Route
- Project Pipeline Alignment
- Hydrographic Area
- Private
- Bureau of Land Management
- Forest Service
- State Parcel

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-2

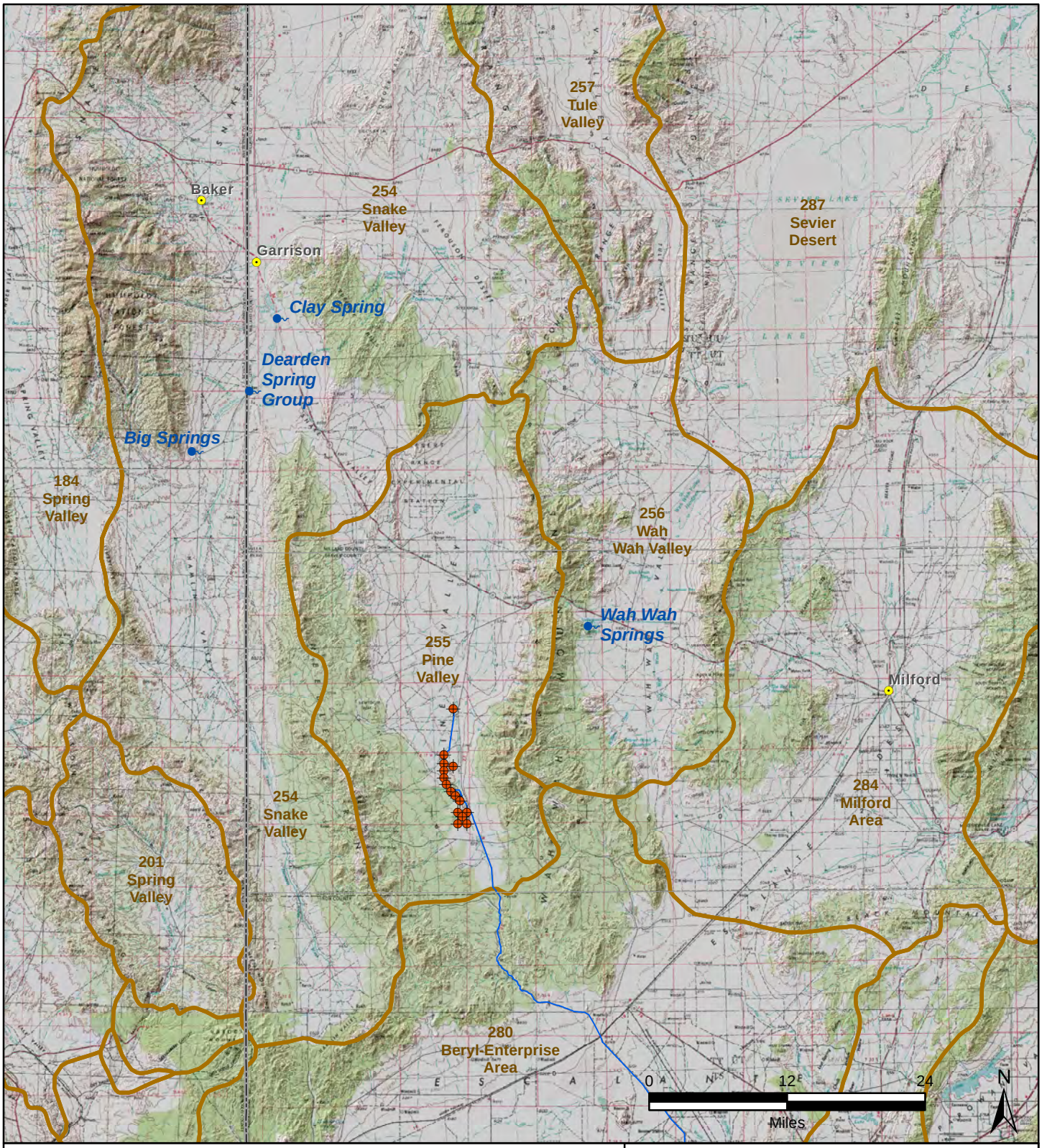
LAND OWNERSHIP IN THE PINE VALLEY REGION

DATE: MAY 18, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- PVWS Project Well
- Regional Spring
- Hydrographic Area
- Project Pipeline Alignment

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-3

PHYSIOGRAPHIC MAP OF THE PINE VALLEY REGION

DATE: MAY 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- PVWS Project Well
- Project Pipeline Alignment
- Hydrographic Area

Geology (SGMC)

- Igneous, intrusive
- Igneous, volcanic
- Igneous, undifferentiated
- Igneous and Sedimentary, undifferentiated
- Metamorphic, sedimentary clastic
- Metamorphic and Sedimentary, undifferentiated
- Sedimentary, carbonate
- Sedimentary, clastic
- Sedimentary, undifferentiated
- Unconsolidated and Sedimentary, undifferentiated
- Unconsolidated, undifferentiated
- Water
- Fault, unknown type, approximate
- Fault, unknown type, certain
- Fault, unknown type, concealed
- Fault, unknown type, inferred or queried
- Thrust fault, approximate (teeth on right from origin)
- Thrust fault, certain (teeth on right from origin)

from Horton et. al. (2017)

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-4

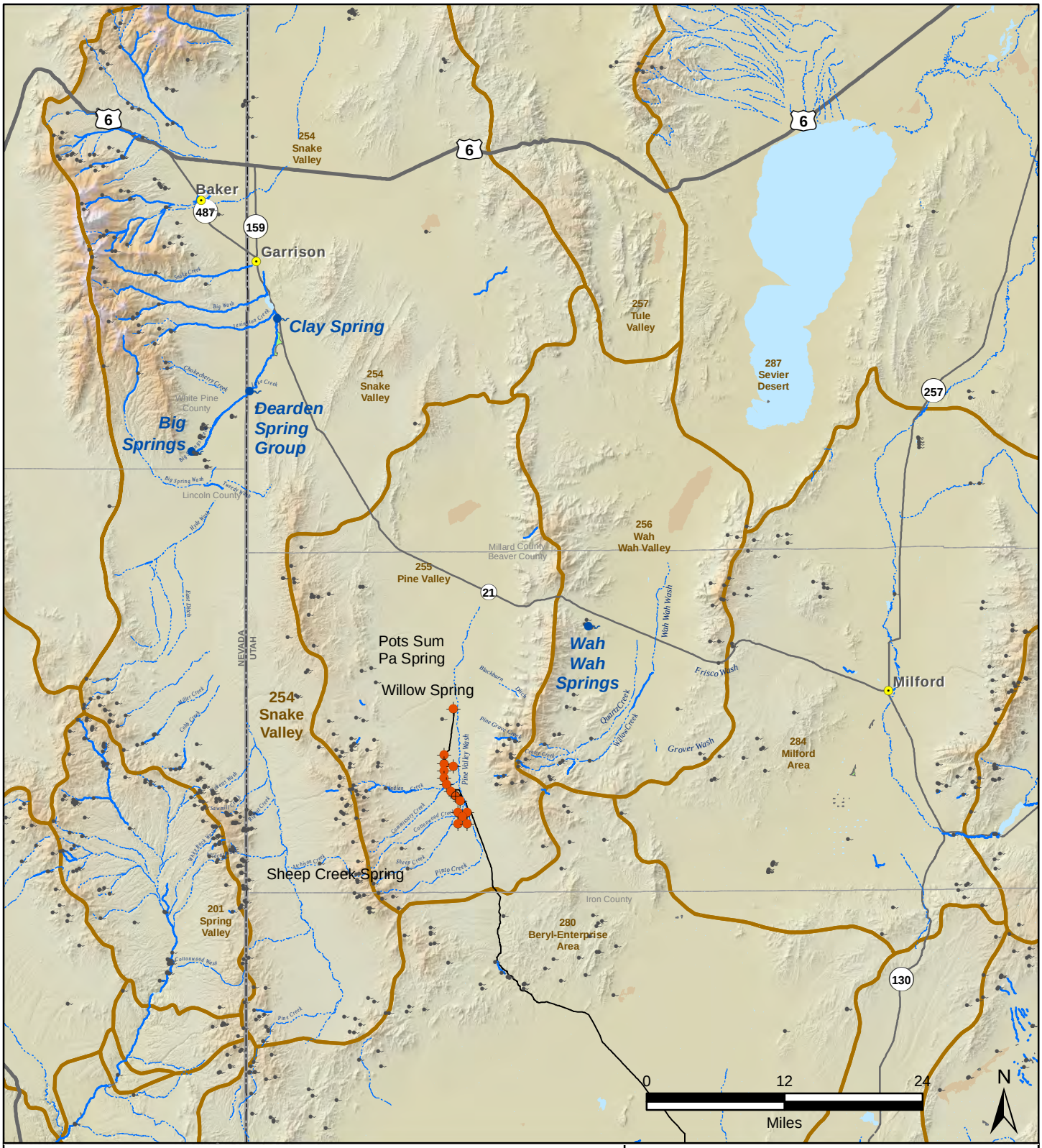
GEOLOGIC MAP OF THE PINE VALLEY REGION

DATE: DEC 29, 2020

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig3_04_Geo.mxd



Legend

- PVWS Project Well
- Regional Spring
- Local Spring or Seep
- Stream/River
- Stream/River - Perennial
- Stream/River - Intermittent
- Project Pipeline Alignment
- US Route
- State Route
- Hydrographic Area
- Lake/Pond
- Playa
- Reservoir
- Swamp/Marsh

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-5

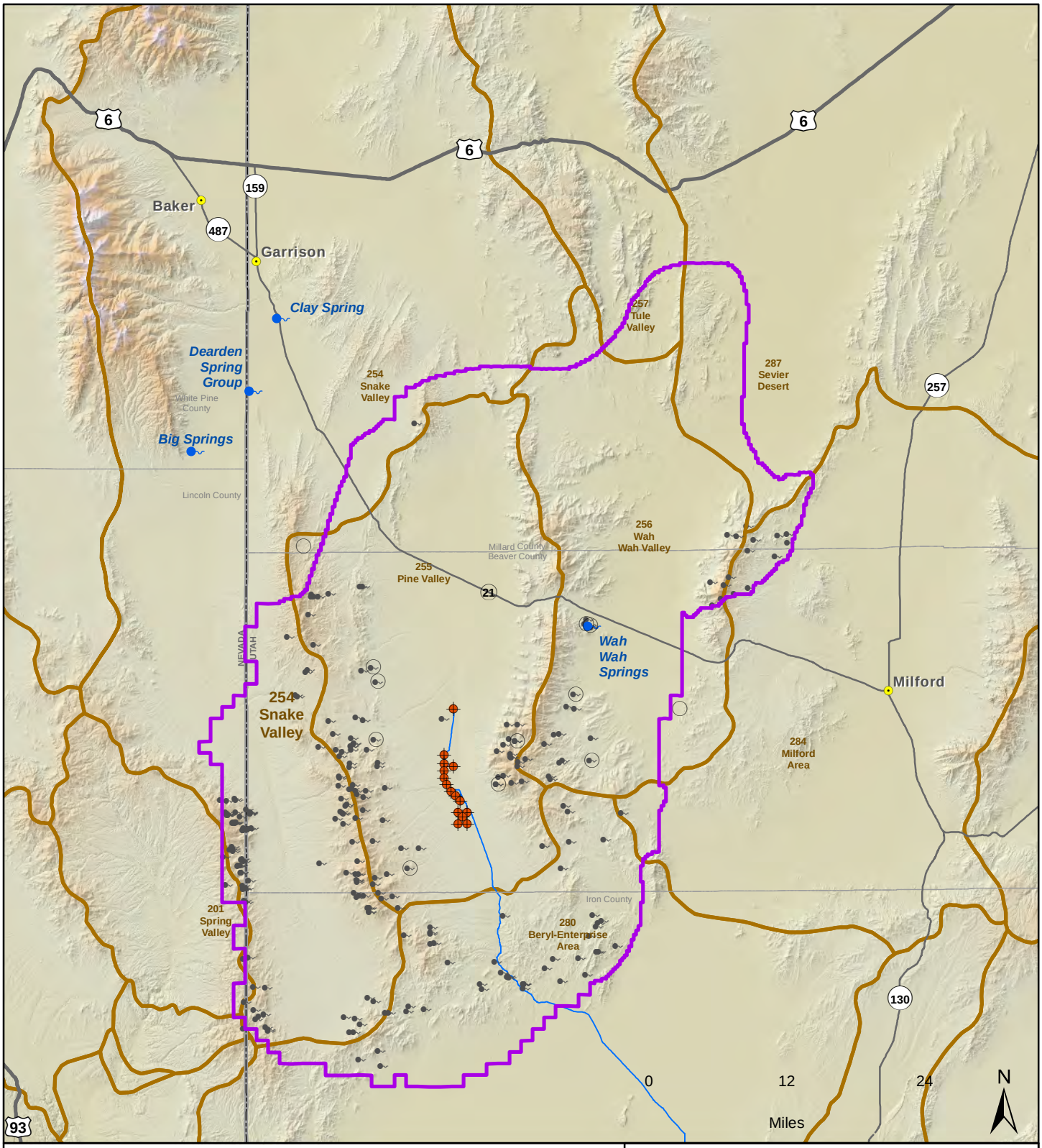
HYDROGRAPHY OF THE PINE VALLEY REGION

DATE: MAY 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRI\Fig3_05_Hydrography.mxd



Legend

- PVWS Project Well
- Springs and Seeps
- Regional Spring
- Gardner et al. (2020) Spring Sample Locations
- Simulated Area of Project Effects for Proposed Action
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

-(Maximum predicted extent of 1-foot drawdown in GBCAAS Layer 1 [Appendix A])
-Springs from USGS National Hydrography Dataset

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-6

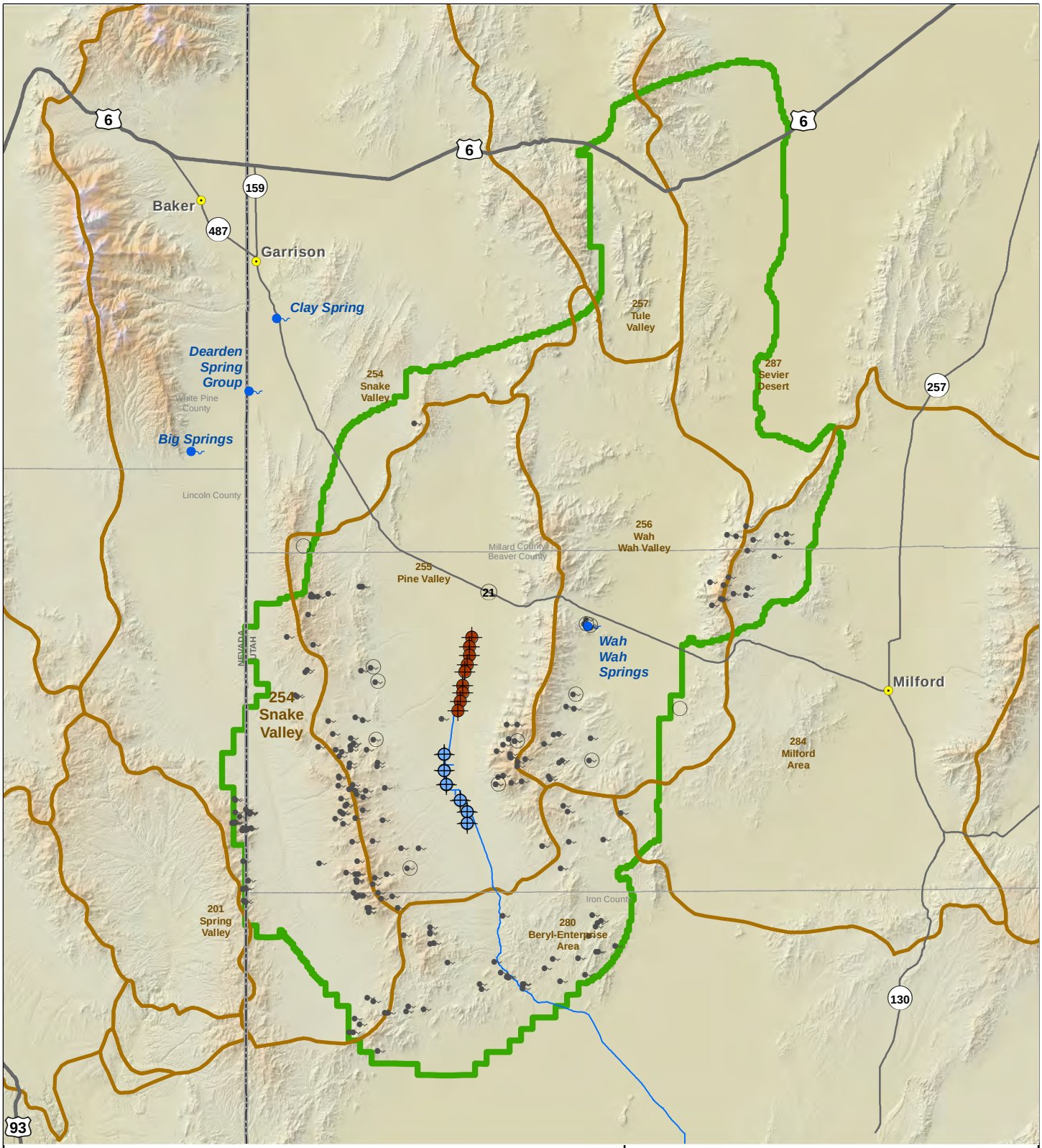
LOCATION OF SPRINGS AND SEEPS IN THE AREA OF PROJECT EFFECTS FOR PROPOSED ACTION

DATE: DEC 30, 2020

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRI\Fig3_06_NHD_Springs_PropArea.mxd



Legend

- Startup pumping well
- ANWS Alternative Well
- Regional Spring
- Springs and Seeps
- Gardner et al. (2020) Spring Sample Locations
- Simulated Area of Project Effects for Adaptive Northern Well Sites Alternative
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

-(Maximum predicted extent of 1-foot drawdown in GBCAAS Layer 1 [Appendix A])
-Springs from USGS National Hydrography Dataset

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-7

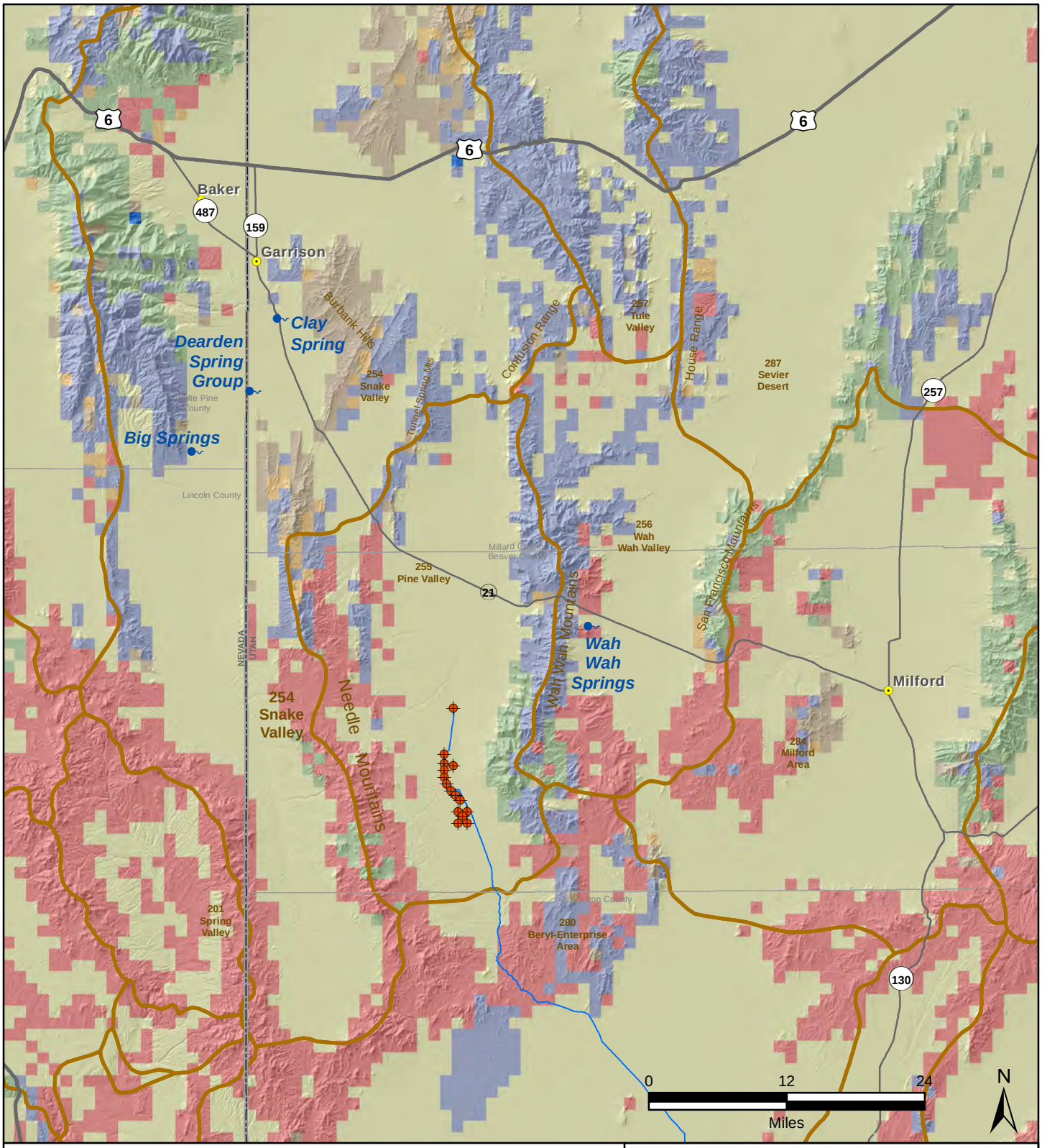
LOCATION OF SPRINGS AND SEEPS IN THE AREA OF PROJECT EFFECTS FOR ANWS ALTERNATIVE

DATE: DEC 30, 2020

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRI\Fig3_07_NHD_Springs_AltArea.mxd



Legend

- PVWS Project Well
- Regional Spring
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

Hydrogeologic Units

- Upper Basin-Fill Aquifer Unit
- Lower Basin-Fill Aquifer Unit
- Volcanic Unit
- Upper Carbonate Aquifer Unit
- Upper Siliciclastic Confining Unit
- Lower Carbonate Aquifer Unit
- Non-Carbonate Confining Unit

from Brooks (2017)

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-8

HYDROGEOLOGIC UNIT MAP OF THE PINE VALLEY REGION

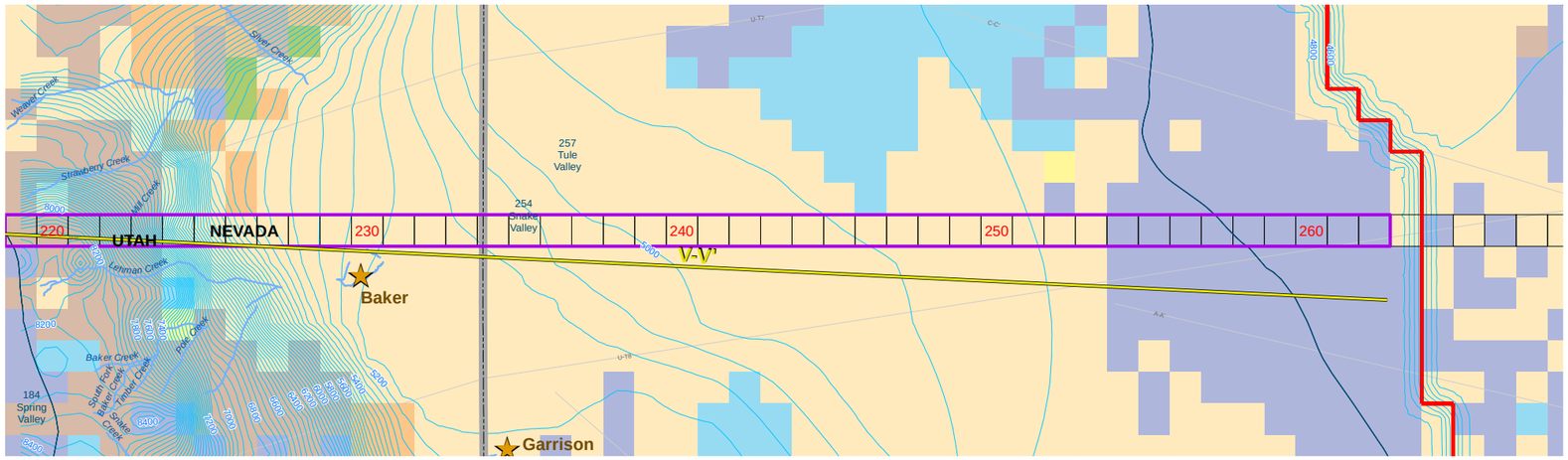
DATE: MAY 19, 2021

BY: CRL | FOR: PHT

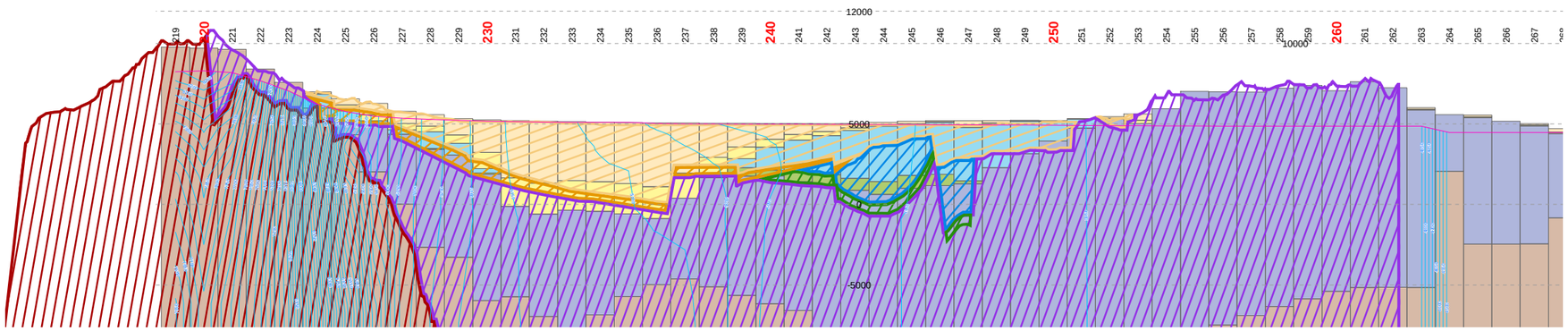
FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig3_08_HGU.mxd

PLAN VIEW: Geology / HGU



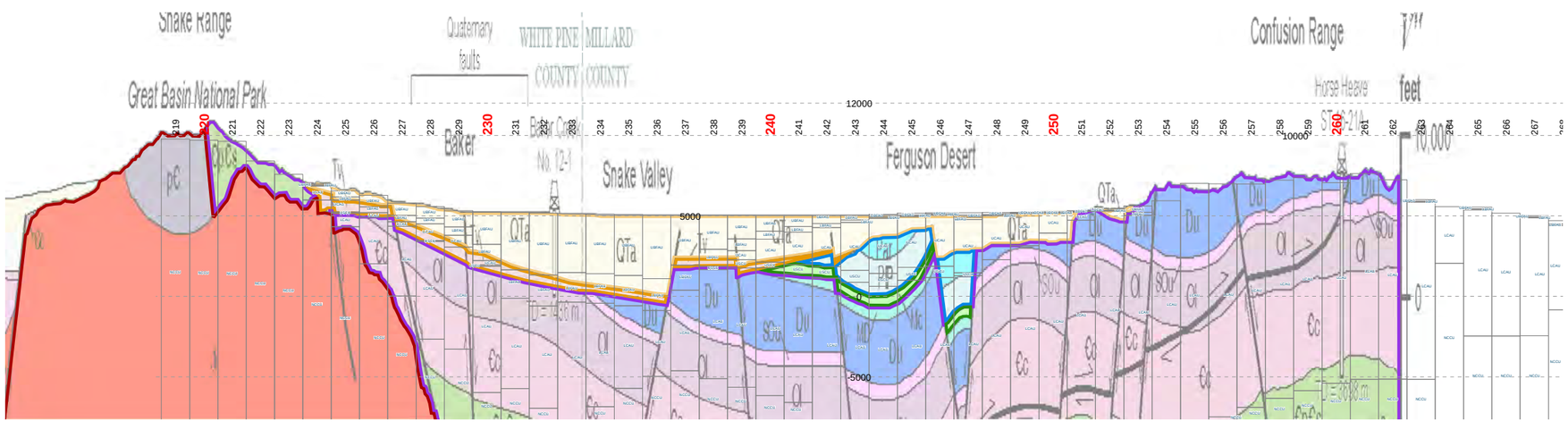
SECTION VIEW: Geology / HGU



VE: 3x

Water table
Head
5-ft
50-ft
HGU
1, UBFAU
2, LBFAU
3, VU
6, UCAU
7, USCU
8, LCAU
9, NCCU

SECTION VIEW: Published Geology



VE: 3x

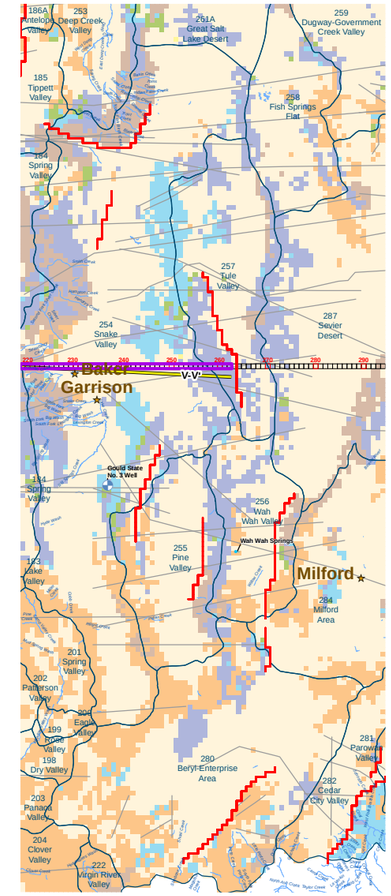
HGU
1, UBFAU
2, LBFAU
3, VU
6, UCAU
7, USCU
8, LCAU
9, NCCU

Gould State No. 3 Well
Town
HFB
Focus model columns for this map
Hydrographic Area (sir20105193_ha1000_p)
Focus model row for this map
XS Shown
XS (SIR2010-5193)
Regional Spring
NHD Perennial Streams

LAY, GEO
1, UBFAU. Upper Basin-Fill Aquifer Unit
2, LBFAU. Lower Basin-Fill Aquifer Unit
3, VU. Volcanic Unit
6, UCAU. Upper Carbonate Aquifer Unit
7, USCU. Upper Siliciclastic Confining Unit
8, LCAU. Lower Carbonate Aquifer Unit
9, NCCU. Noncarbonate Confining Unit

0 10 20 Miles

N



PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-9 ROW: 246

PLAN AND SECTION
PUBLISHED GEOLOGY MAP
(Rowley 2017)
V-V'

DATE: MAY 20, 2021

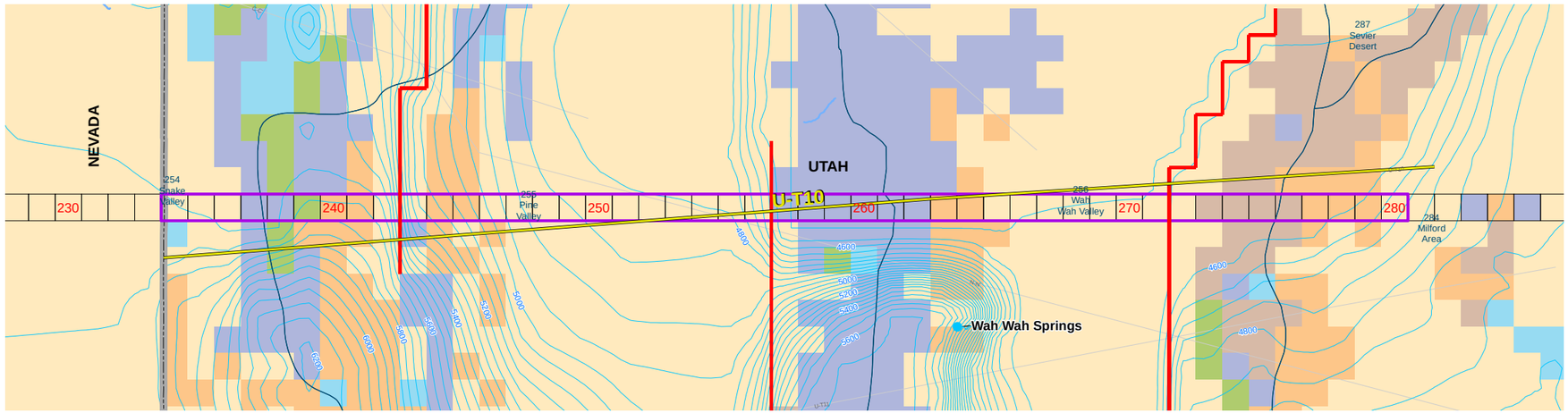
BY: CFJ FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig3_09_10_XS_PubGeo_VE3_1x03XS_v2_forGRIA.mxd

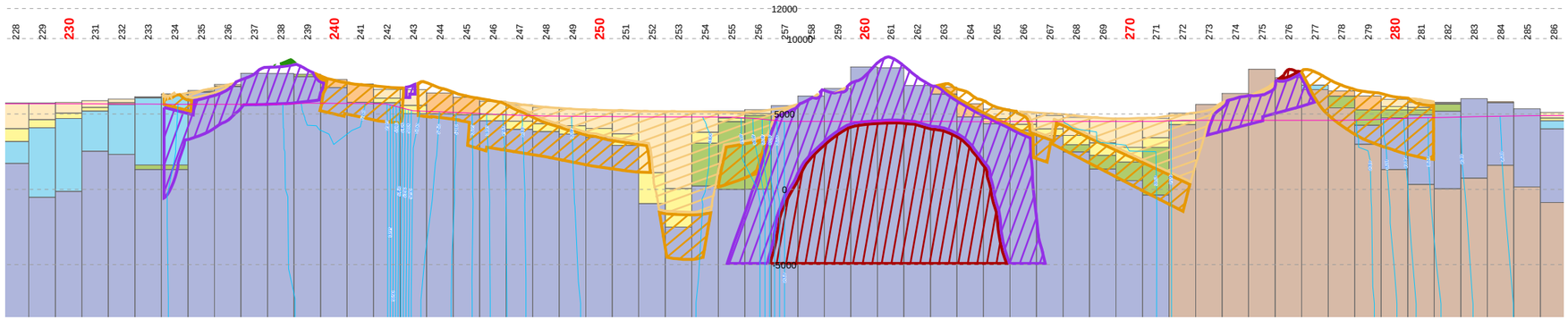
DRAFT

PLAN VIEW: Geology / HGU



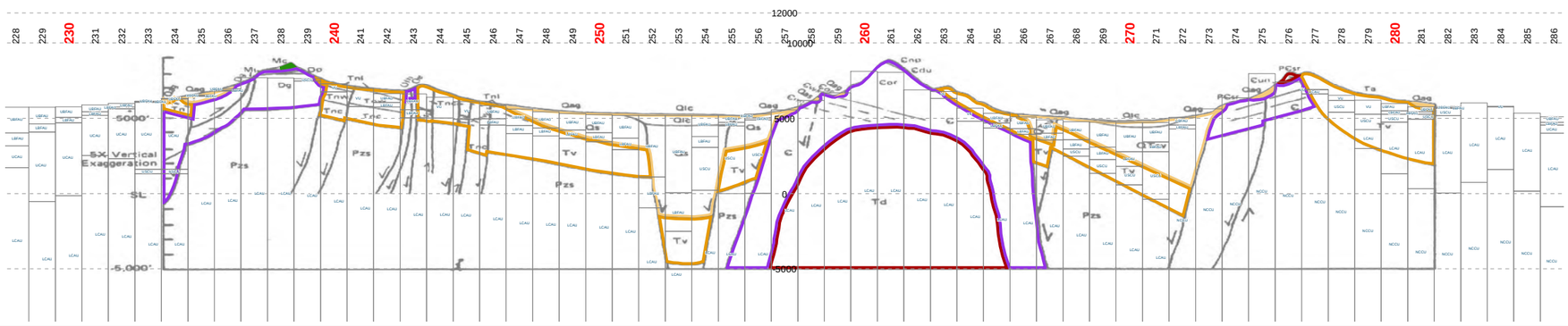
ROW: 280

SECTION VIEW: Geology / HGU



VE: 3x

SECTION VIEW: Published Geology



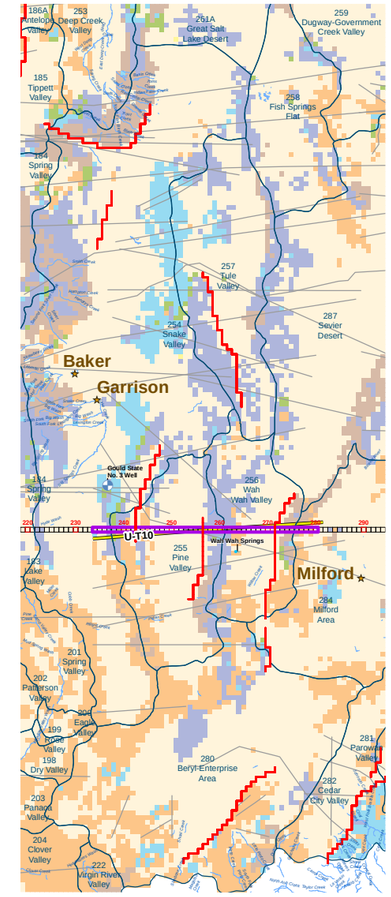
VE: 3x

Gould State No. 3 Well
Town
HFB
Focus model columns for this map
Hydrographic Area (sir20105193_ha1000_p)
Focus model row for this map
XS Shown
XS (SIR2010-5193)
Regional Spring
NHD Perennial Streams

LAY, GEO
1, UBFAU. Upper Basin-Fill Aquifer Unit
2, LBFAU. Lower Basin-Fill Aquifer Unit
3, VU. Volcanic Unit
6, UCAU. Upper Carbonate Aquifer Unit
7, USCU. Upper Siliciclastic Confining Unit
8, LCAU. Lower Carbonate Aquifer Unit
9, NCCU. Noncarbonate Confining Unit

0 10 20 Miles

N



PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-10 ROW: 280

PLAN AND SECTION PUBLISHED GEOLOGY MAP (Budding 1984) U-T10

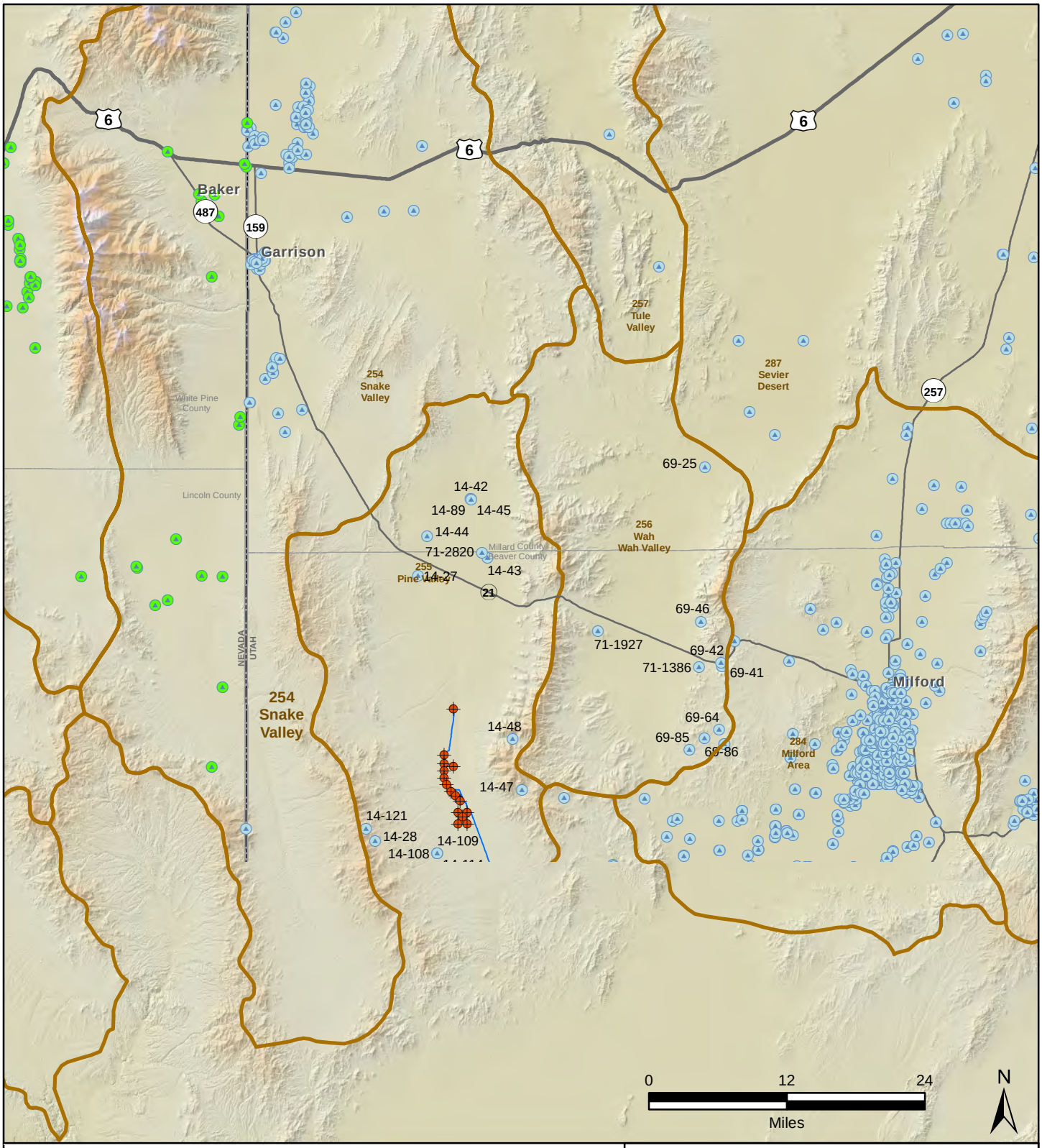
DATE: MAY 20, 2021

BY: CFJ FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\pltGRIA\Fig3_09_10_XS_PubGeo_VE3_1x03XS_v2_forGRIA.mxd

DRAFT



Legend

- PVWS Project Well
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route
- NV Certificated Underground POD
- UT Perfected Underground POD

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-11

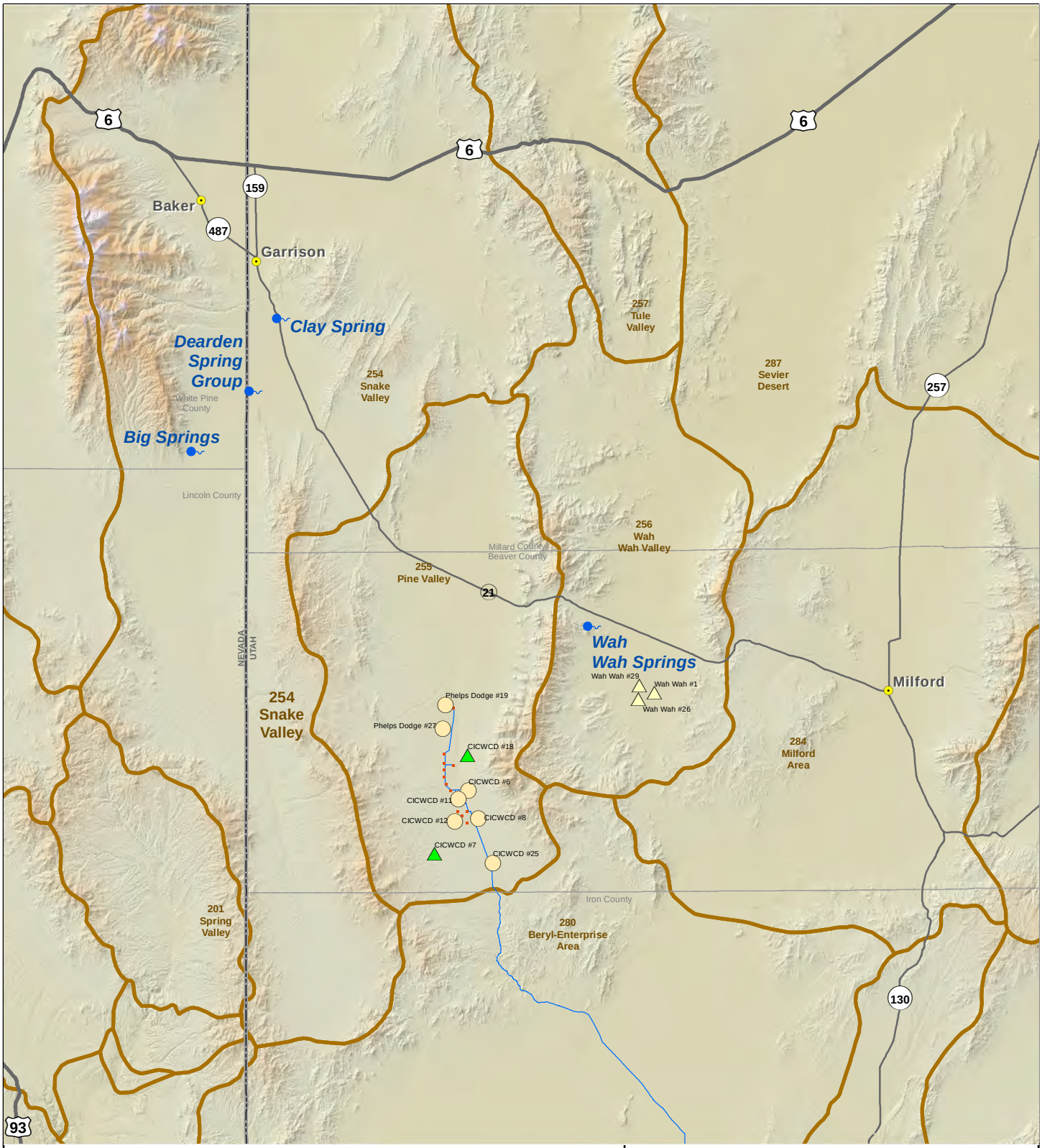
LOCATION OF EXISTING WELLS IN THE PINE VALLEY REGION

DATE: MAY 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig3_11_WellsInProjArea.mxd



Legend

- Regional Spring
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

Pumping Test Locations

- basin-fill
- basin-fill / bedrock
- bedrock

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-12

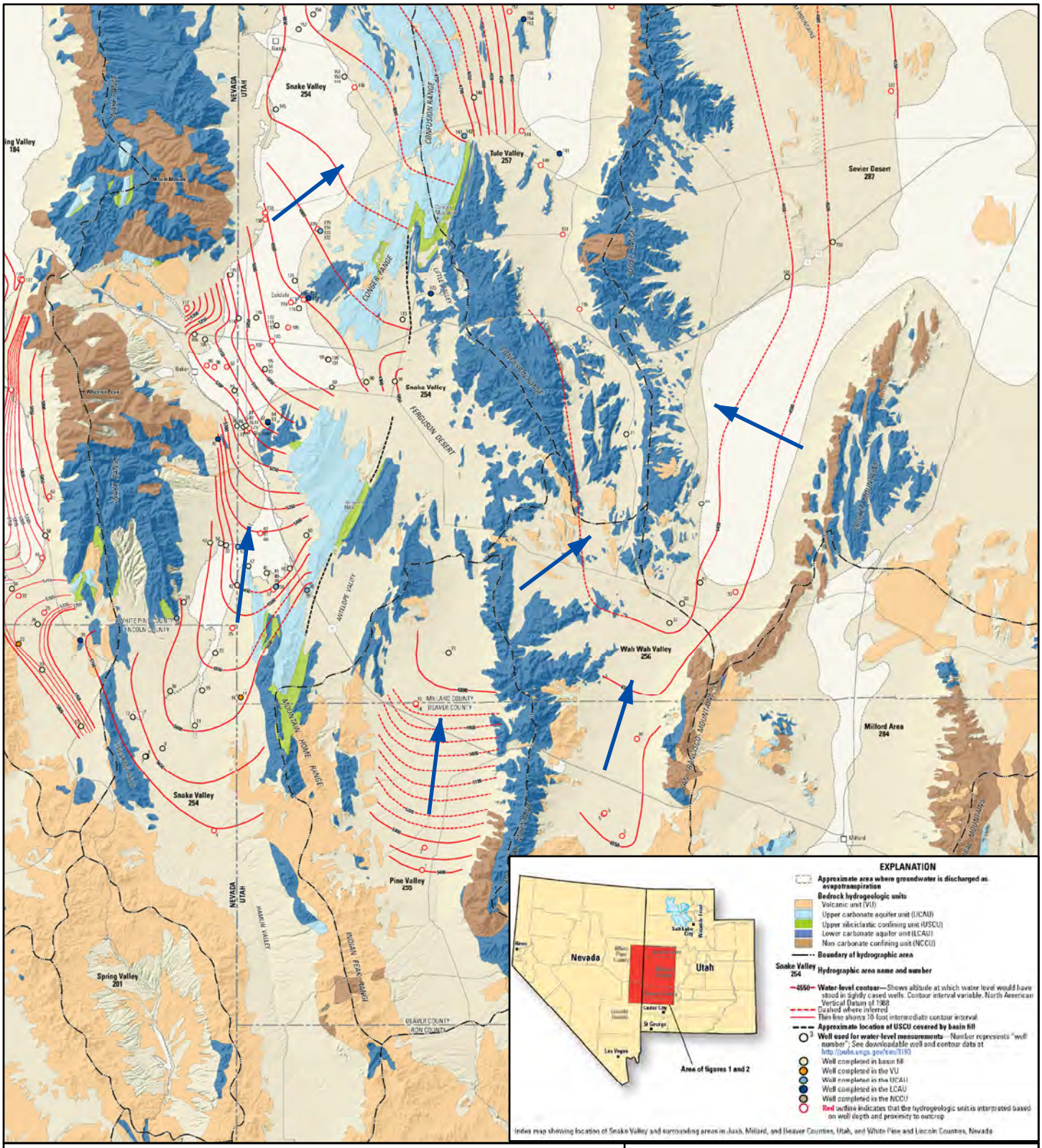
PUMPING TEST LOCATIONS IN THE PINE AND WAH WAH VALLEY HAs

DATE: DEC 29, 2020

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRI\Fig3_12_PumpTestLocs.mxd



Legend

Gardner, P.M., M.D. Masbruch, R.W. Plume and S.G. Buto. 2011. Regional potentiometric-surface map of the Great Basin carbonate and alluvial aquifer system in Snake Valley and surrounding areas, Juab, Millard, and Beaver Counties, Utah, and White Pine and Lincoln Counties, Nevada: USGS Scientific Investigations Map 3193, 2 sheets. https://doi.org/10.3133/sim3193

Groundwater Flow Direction

PINE VALLEY WATER SUPPLY PROJECT

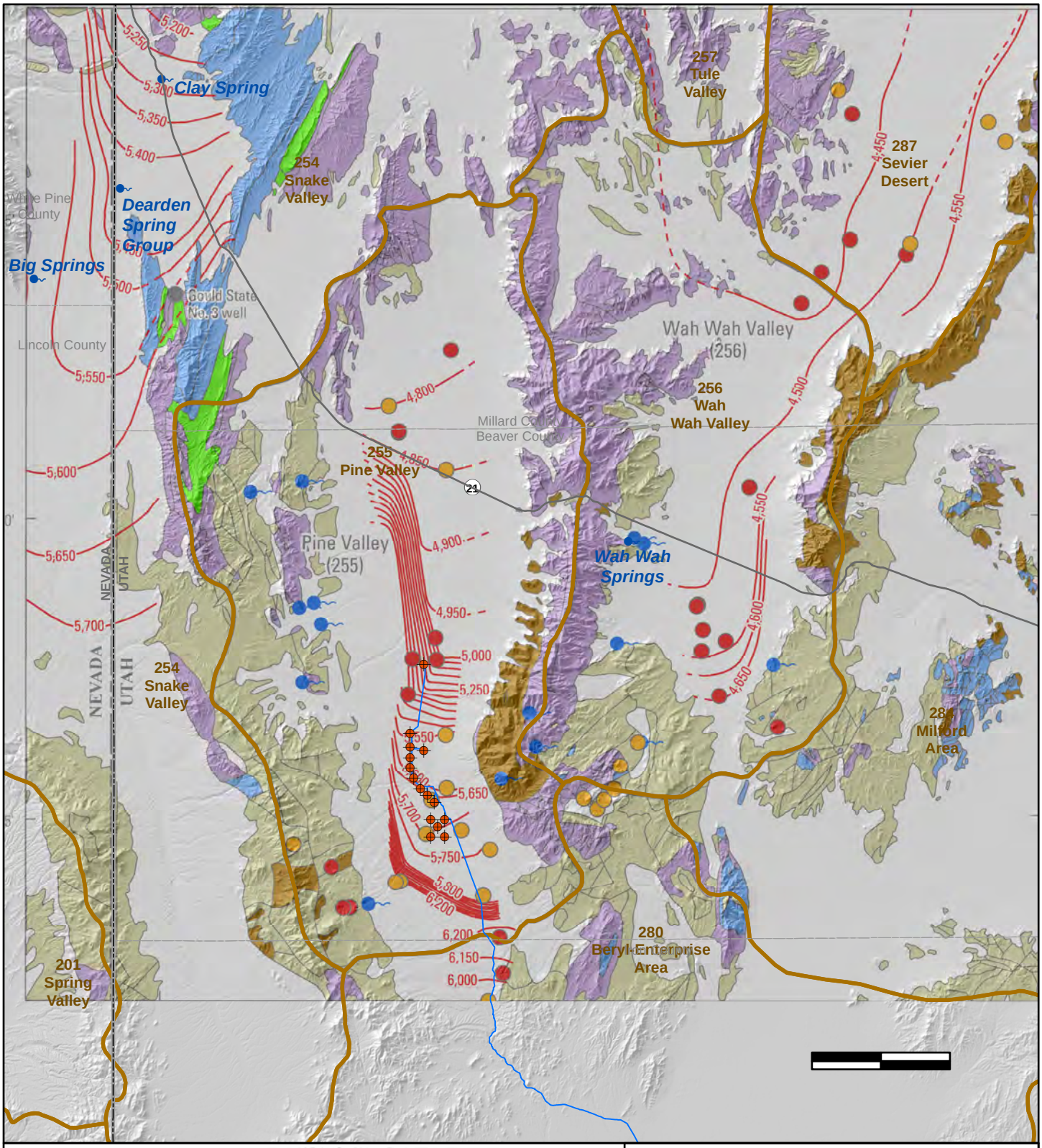
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-13

WATER-LEVEL SURFACE OF THE REGIONAL CARBONATE AND ALLUVIAL AQUIFER

DATE: MAY 20, 2021	FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT

S:\GIS\a5\Transcon_PineValley\plt\GRI\Fig3_13_USGS_SIM_PotMap.mxd



Legend

- Hydrographic Area
- Regional Spring
- Project Pipeline Alignment

Hydrogeologic Units

- Vulcanic Unit (VU)
- Lower carbonate aquifer unit (LCAU)
- Upper siliciclastic confining unit (USCU)
- Non-carbonate confining unit (NCCU)
- Upper carbonate aquifer unit (UCAU)

Water-level contour
Contour interval at 50 feet.
Water-level contours in Snake Valley (upper left in figure) are from Gardner and others (2011).

Dashed contours are less certain

Water level measured by U.S. Geological Survey during this study

Water level reported on driller's log or by other entity

Spring
Locations and identifier of well or spring with time-series of water levels or discharge measurements shown in figures 6 and 7.

From Gardener et. al. (2020)

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-14

WATER LEVEL SURFACE OF THE UNCONFINED BASIN-FILL AQUIFER

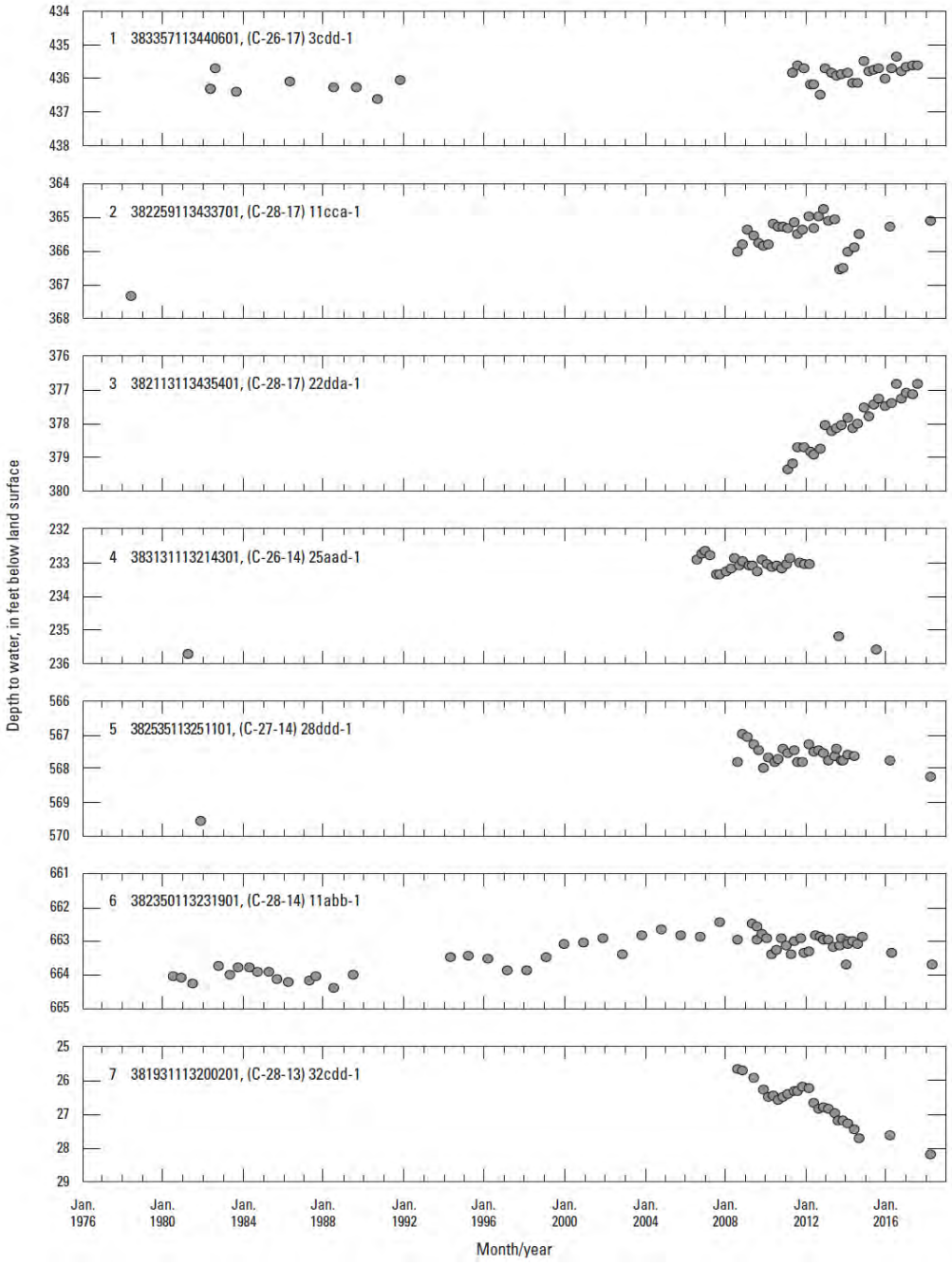
DATE: MAY 20, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig3_14_UBF_PotMap.mxd

S:\GIS\A5\TRANSCON_PINEVALLEY\PLT\GRIA\FIG3_12_PRISM_SEASONS.PPTX



Notes:

Gardner, P.M., Marston, T.M., Buto, S.G., and Brooks, L.E., 2020. Hydrogeologic and Geochemical Characterization of Groundwater Resources in Pine and Wah Wah Valleys, Iron, Beaver, and Millard Counties, Utah. U.S. Geological Survey Scientific Investigations Report 2019-5139, 49p.

PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-15

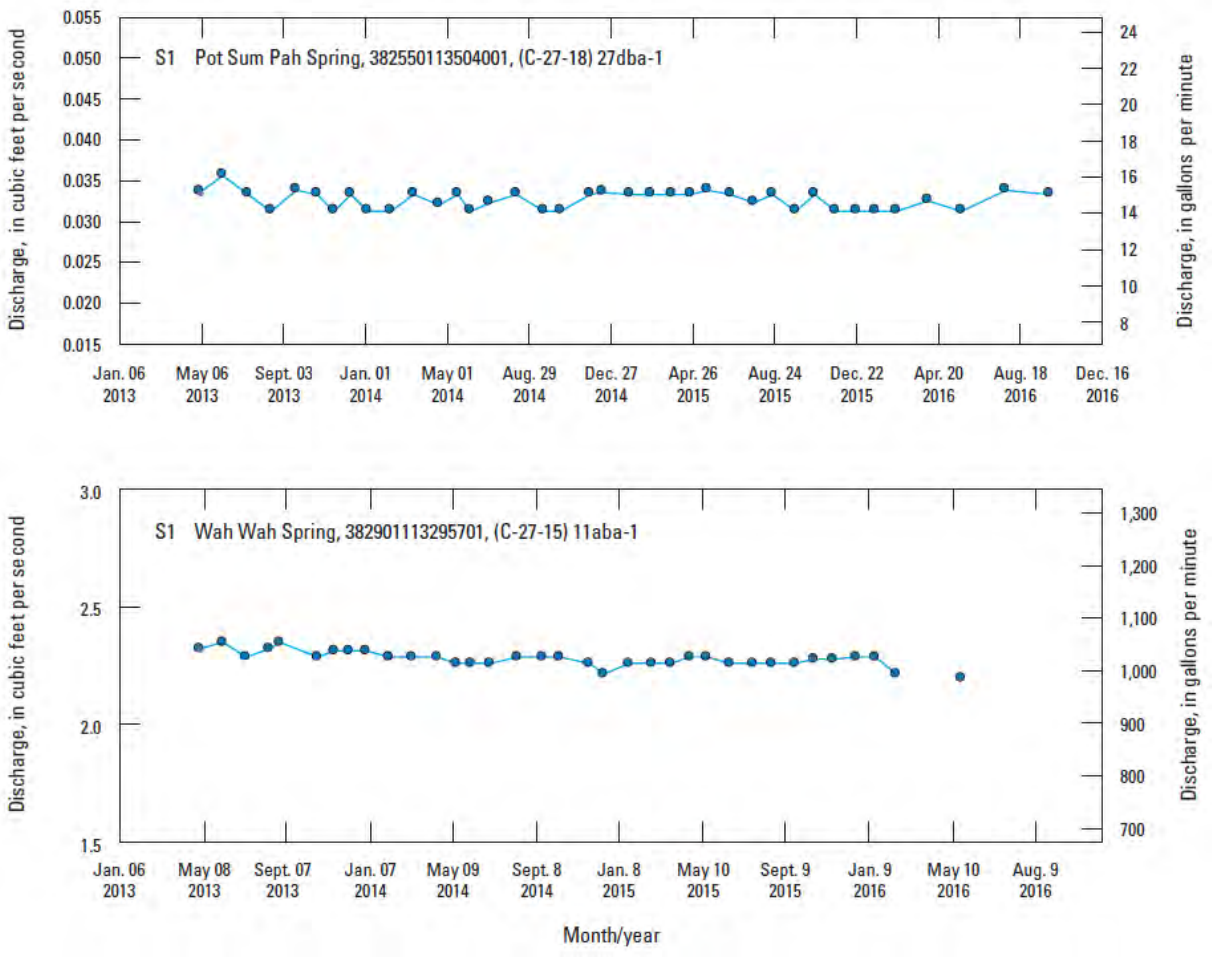
LONG-TERM WATER-LEVEL FLUCTUATIONS IN SELECTED WELLS IN PINE AND WAH WAH VALLEYS (from Gardner et al. 2020)

DATE: SEPTEMBER 2020

BY: PHT | FOR: MT

FORMATION ENVIRONMENTAL

S:\GIS\A5\TRANSCON_PINEVALLEY\PLT\GRIA\FIG3_13_PRISM_SEASONS.PPTX



Notes:

Gardner, P.M., Marston, T.M., Buto, S.G., and Brooks, L.E., 2020. Hydrogeologic and Geochemical Characterization of Groundwater Resources in Pine and Wah Wah Valleys, Iron, Beaver, and Millard Counties, Utah. U.S. Geological Survey Scientific Investigations Report 2019-5139, 49p.

PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

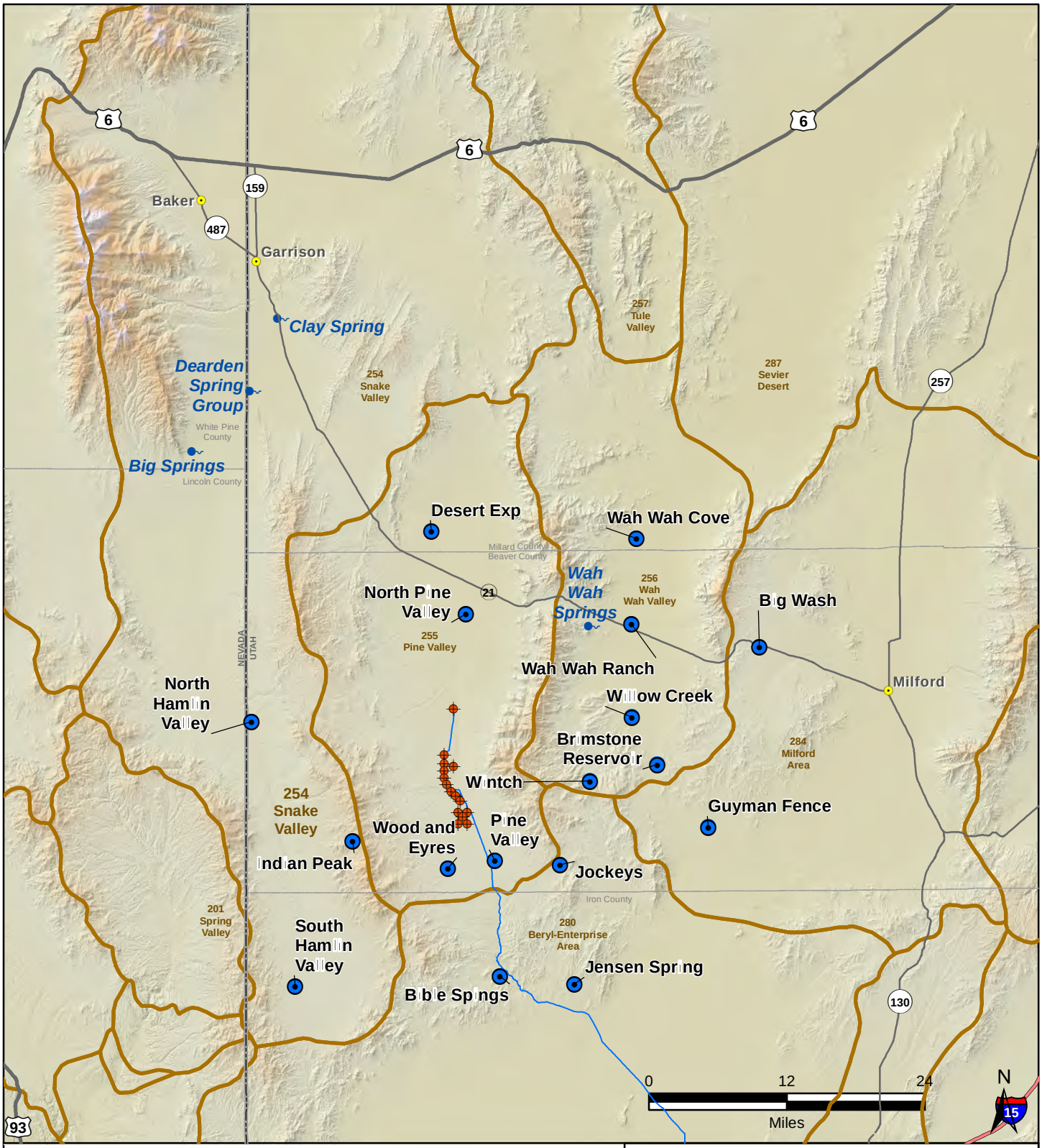
FIGURE 3-16

DISCHARGE AT SPRINGS IN MOUNTAINS SURROUNDING PINE AND WAH WAH VALLEY BASINS (from Gardner et al. 2020)

DATE: SEPTEMBER 2020

BY: PHT | FOR: MT

FORMATION ENVIRONMENTAL



Legend

- PVWS Project Well
- Rain Gauge Location
- Hydrographic Area
- Project Pipeline Alignment
- Interstate
- US Route
- State Route

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-17

LOCATION OF RAIN GAUGE STATIONS IN THE PINE VALLEY REGION

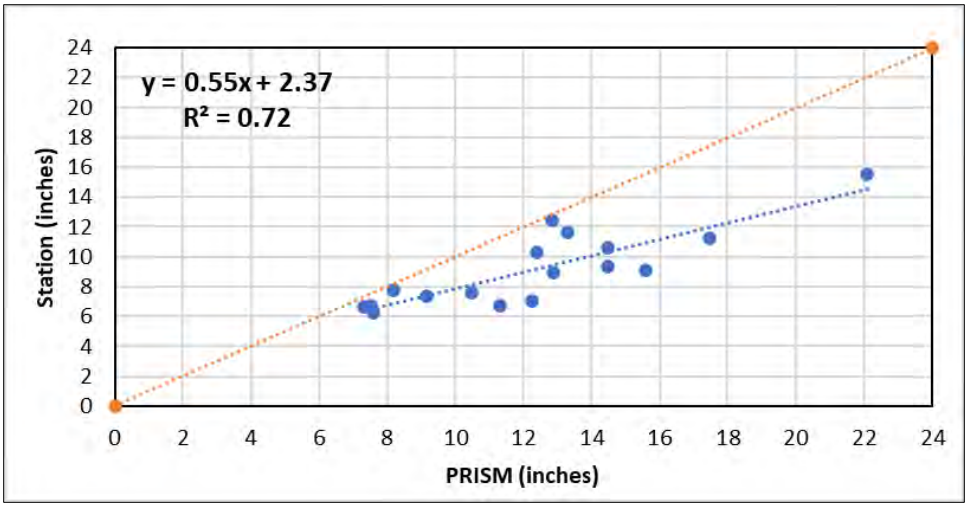
DATE: DEC 29, 2020

BY: CRL | FOR: PHT

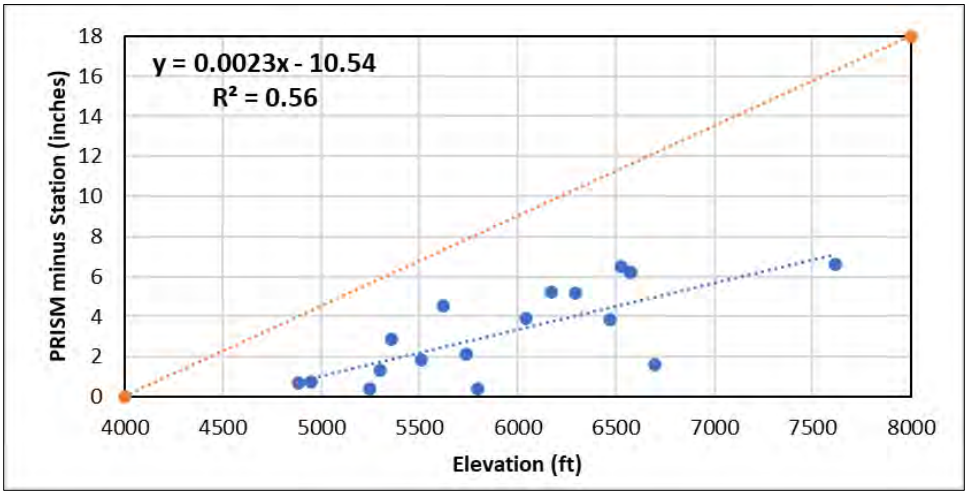
FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig3_17_RainGauge.mxd

I) Graphical Comparison of PRISM and Rain Gauge Precipitation Data



II) Graphical Comparison of PRISM Minus Rain Gauge Precipitation Data vs. Station Elevation



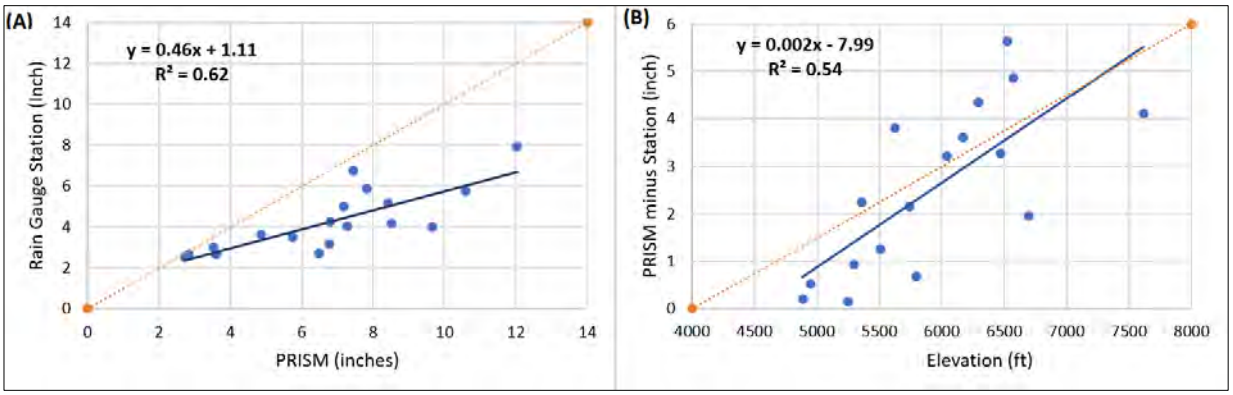
PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-18

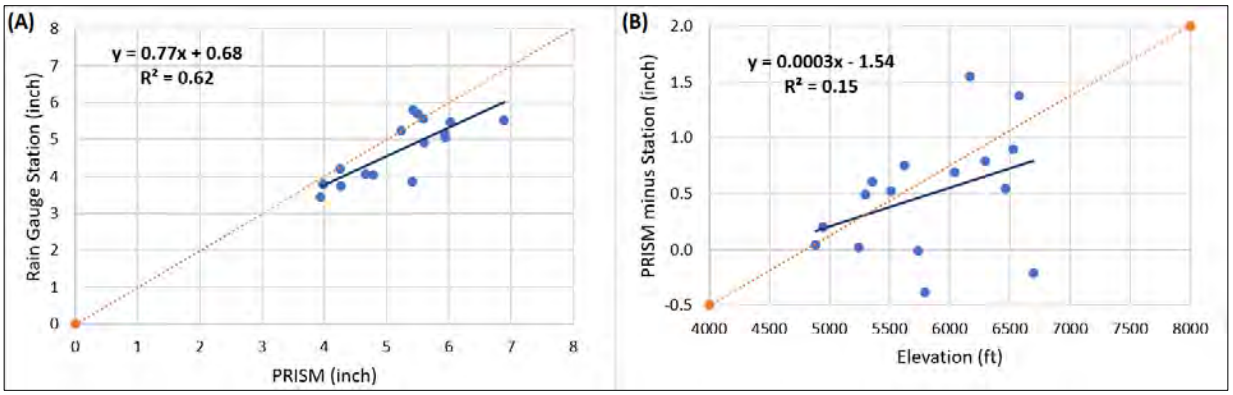
COMPARISON OF PRISM AND RAIN GAUGE PRECIPITATION DATA VS. STATION ELEVATION

DATE: SEPTEMBER 2020		FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT	

I) Cool season (Oct-Mar) comparison of PRISM and Rain Gauge Data. (A) PRISM versus Rain Gauge Data and (B) Elevation versus Difference between PRISM and Rain Gauge Data



II) Warm season (Oct-Mar) Comparison of PRISM and Rain Gauge Data. (A) PRISM versus Rain Gauge Data and (B) Elevation versus Difference between PRISM and Rain Gauge Data



PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

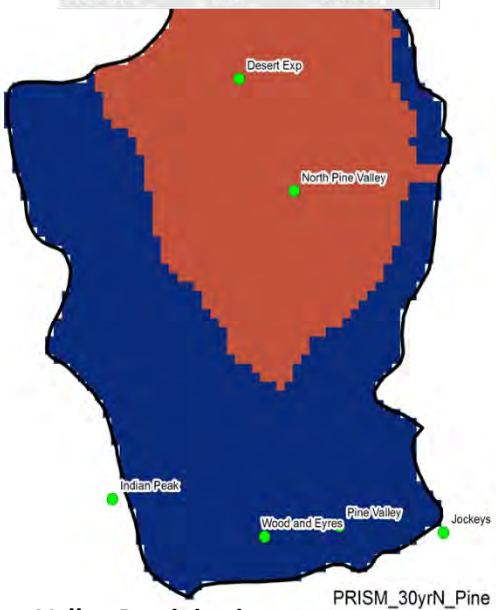
FIGURE 3-19

COOL AND WARM SEASON COMPARISON OF PRISM AND RAIN GAUGE DATA

DATE: SEPTEMBER 2020		FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT	

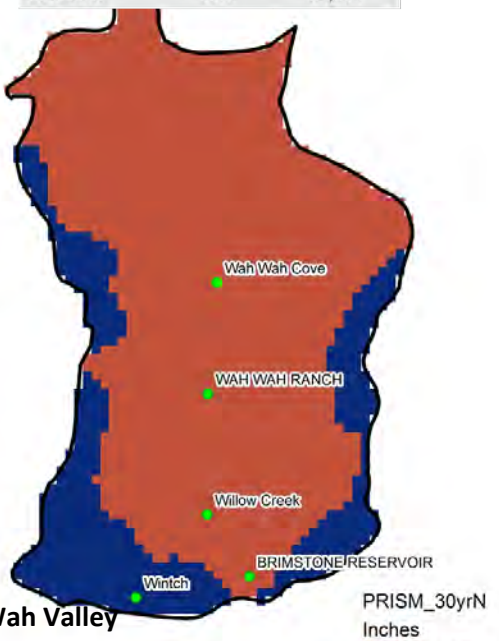
"S:\GIS\A5\TRANSCON_PINEVALLEY\PLT\GRIA\FIG3_17NEW_PRECIPDISTRIBUTION.PPTX"

Precip (inches)	%Area	Area (acres)
6.8-12	47.0	223034
12.1-23.9	53.0	249165



Pine Valley Precipitation Distribution and Rain Gauge Locations

Precip (inches)	%Area	Area (acres)
6.8-12	78.0	302,046
12.1-22.8	22.0	84,924



Wah Wah Valley Precipitation Distribution and Rain Gauge Locations

PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

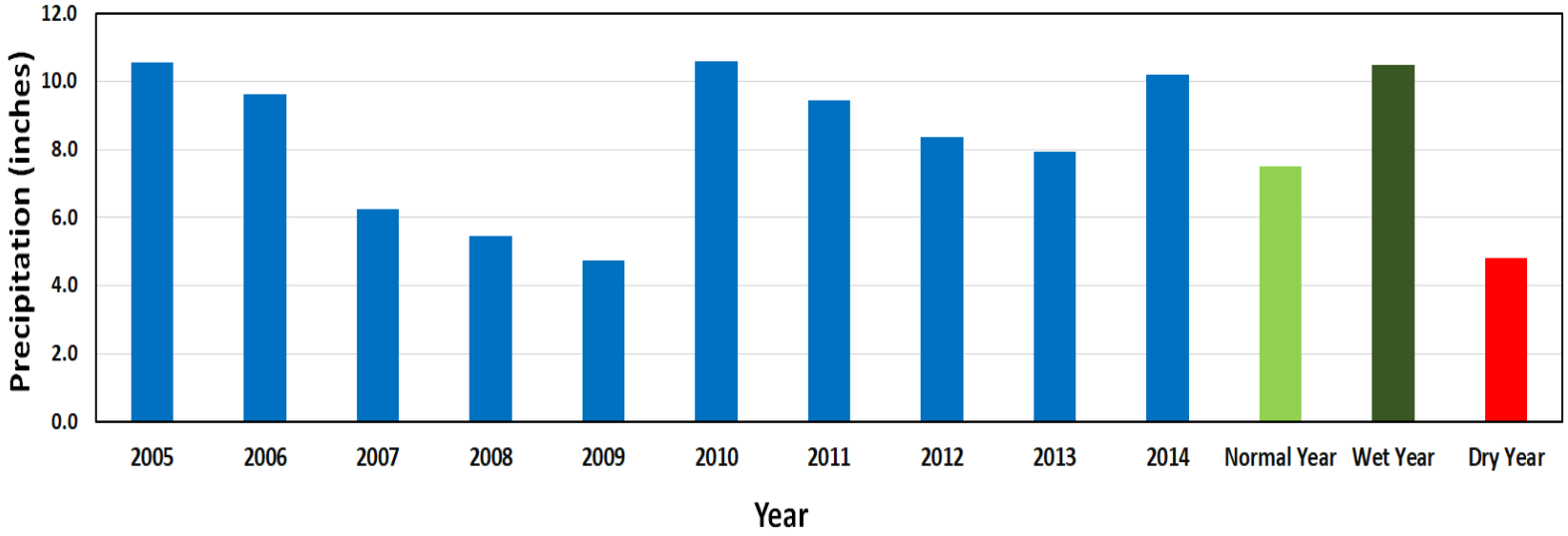
FIGURE 3-20

DISTRIBUTION OF PRECIPITATION AND RAIN GAUGE STATIONS IN PINE AND WAH WAH VALLEYS

DATE: DECEMBER 2020	
BY: PHT	FOR: MT

FORMATION ENVIRONMENTAL

"S:\GIS\A5\TRANSCON_PINEVALLEY\PLT\GRIA\FIG3_18_PRECIPITATION ANALYSIS.XLSX"

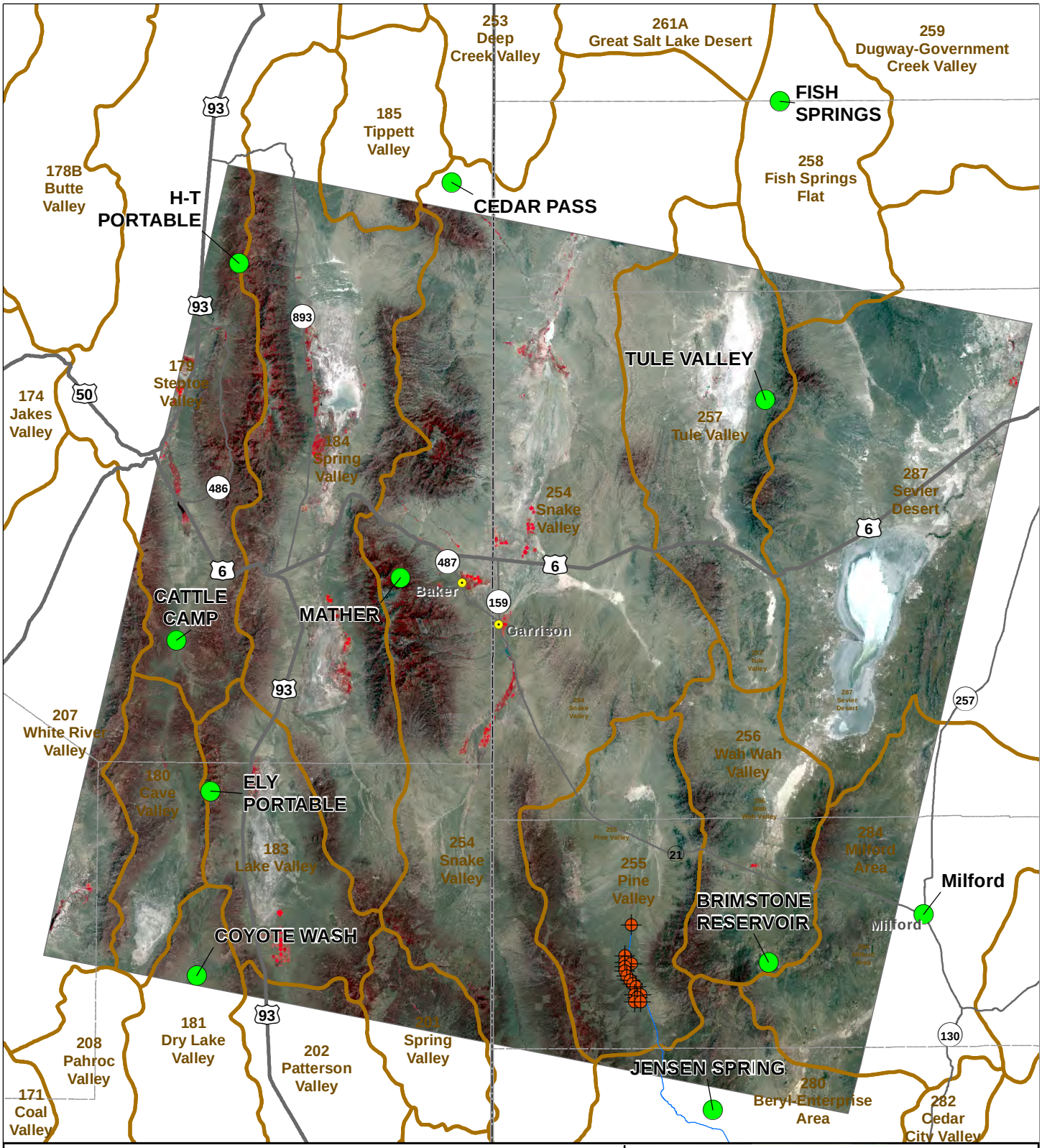


PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-21

AVERAGE PRECIPITATION 2005-2014 AT METEROLOGICAL STATIONS IN PINE AND WAH WAH VALLEYS

DATE: DEC 2020		FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT	



Legend

- Weather Station
- PVWS Project Well
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

0 8 16
Miles

N

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-22

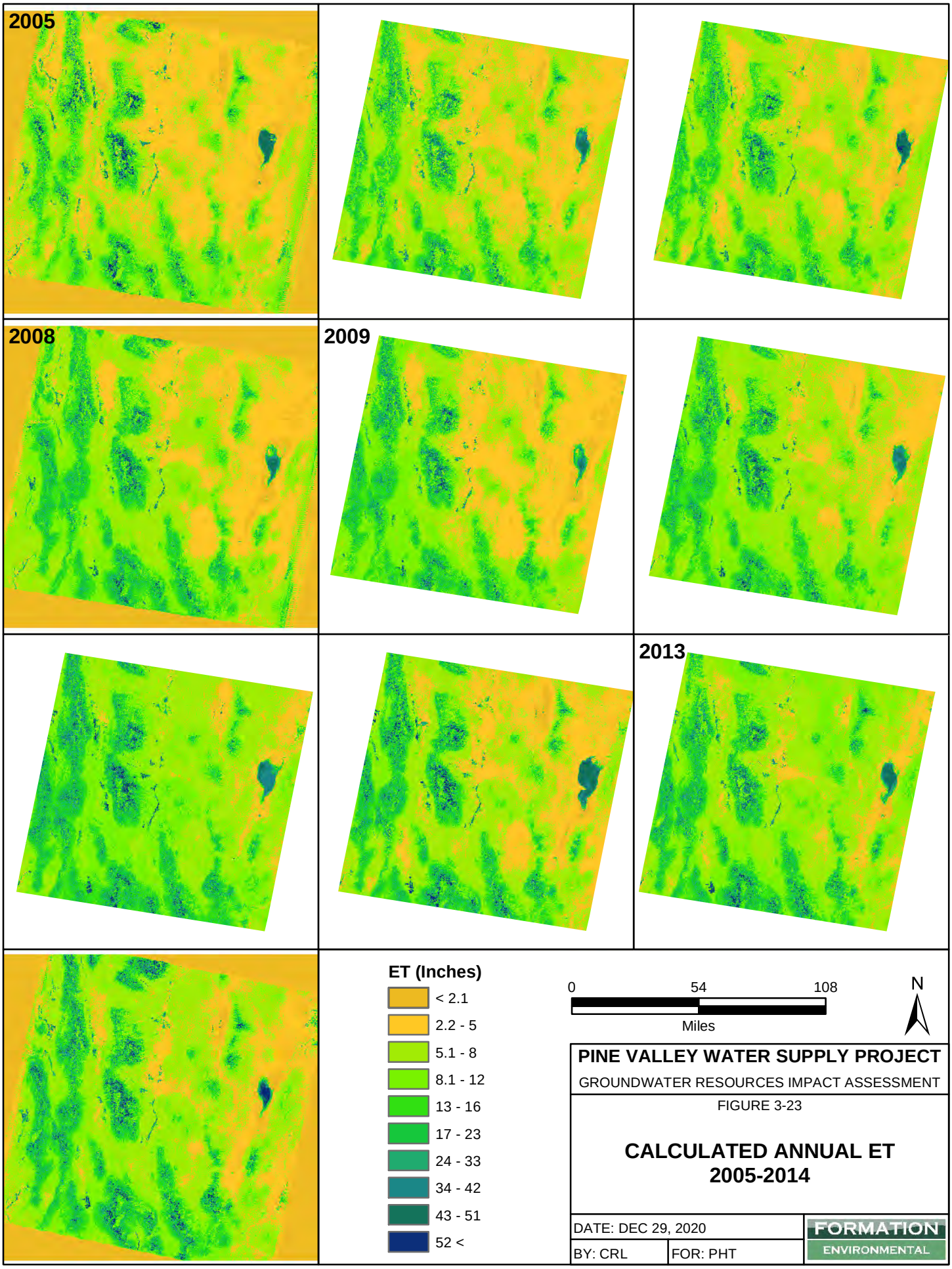
WEATHER STATIONS IN THE VICINITY OF THE STUDY AREA

DATE: DEC 30, 2020

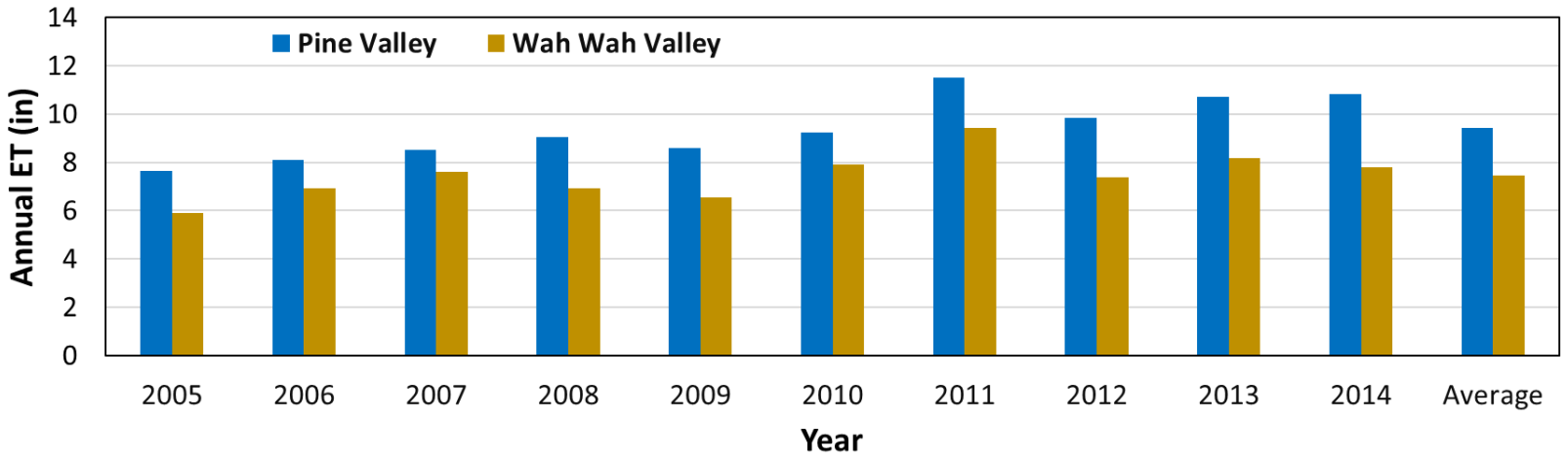
BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig3_22_Landsat_WeatherStations.mxd


2005
2008
2009
2013
ET (Inches)
< 2.1
2.2 - 5
5.1 - 8
8.1 - 12
13 - 16
17 - 23
24 - 33
34 - 42
43 - 51
52 <
0
54
108
Miles
N
PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT
FIGURE 3-23
CALCULATED ANNUAL ET
2005-2014
DATE: DEC 29, 2020
BY: CRL
FOR: PHT
FORMATION
ENVIRONMENTAL
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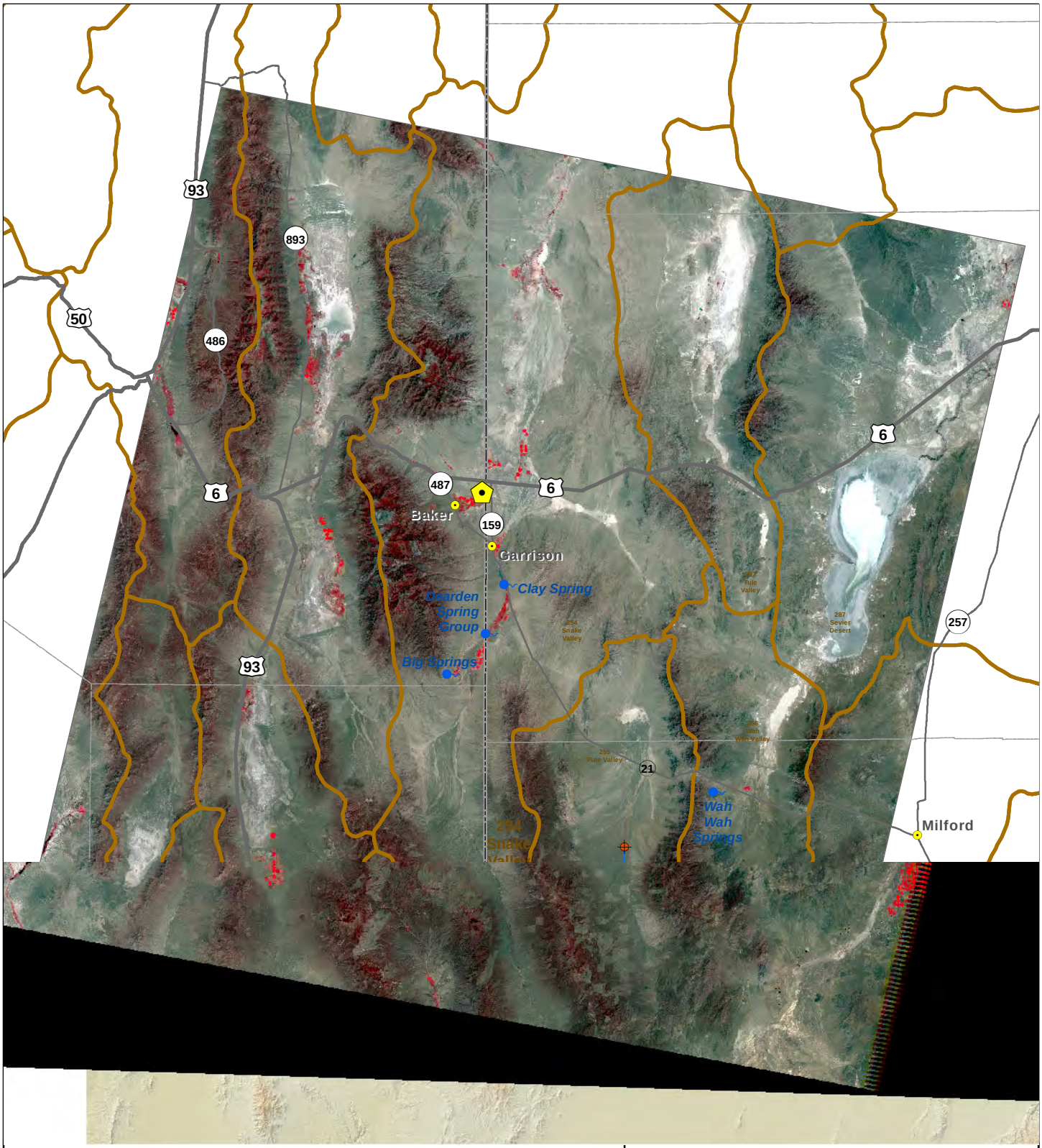


PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-24

SPATIALLY AVERAGED ANNUAL ET IN PINE AND WAH WAH VALLEY HAs

DATE: MAY 2021		FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT	



Legend

- Devitt and Bird, 2016
- PVWS Project Well
- Regional Spring
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

PINE VALLEY WATER SUPPLY PROJECT

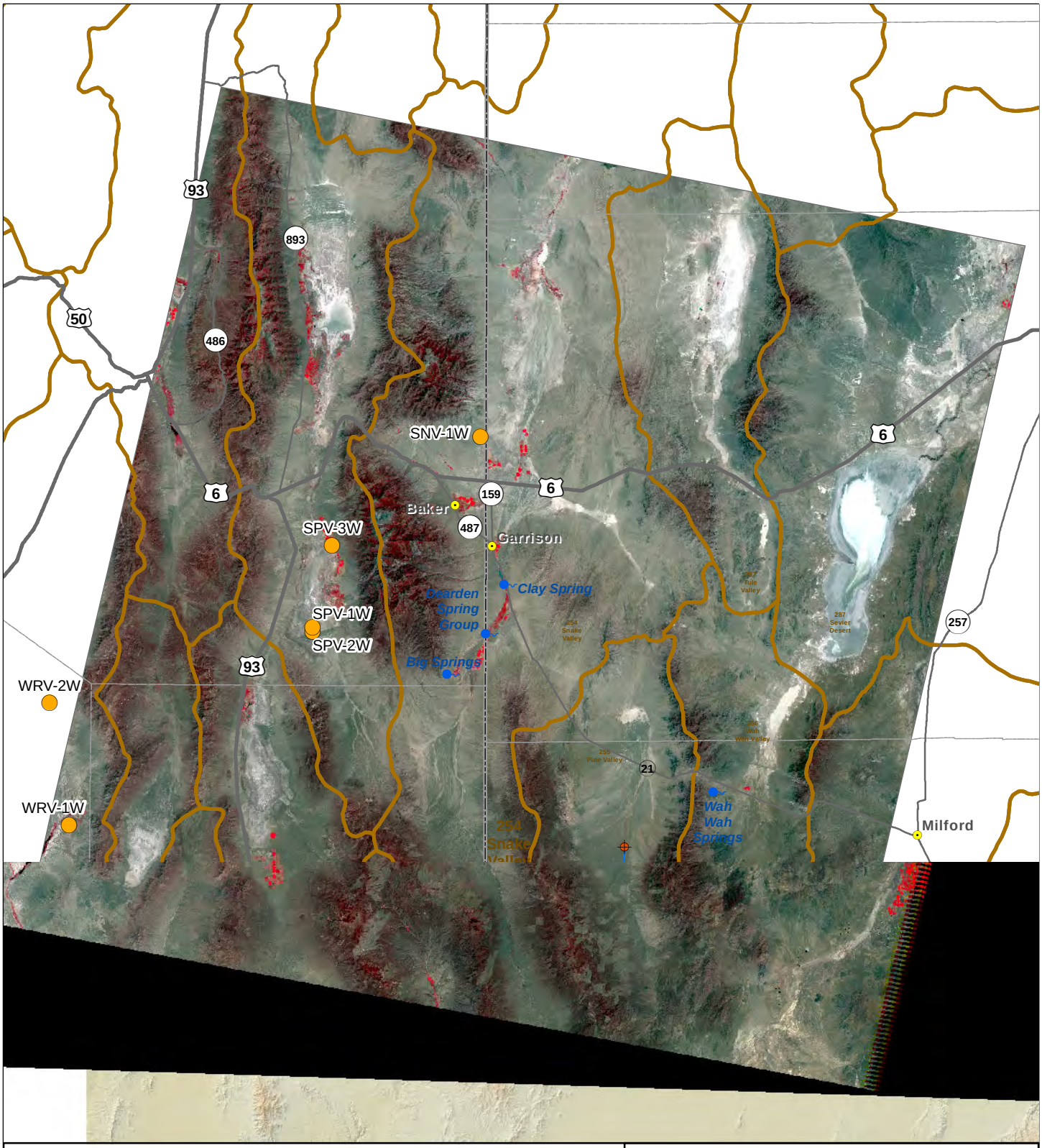
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-25

LOCATION OF EC DATA STATION IN SNAKE VALLEY HA

DATE: DEC 29, 2020		FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT	

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Legend

- ET_sites
- PVWS Project Well
- Regional Spring
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-26

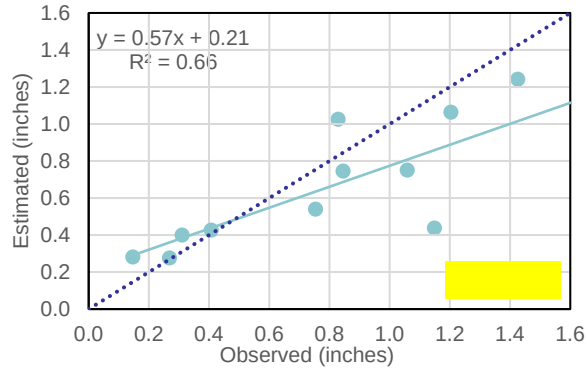
LOCATIONS OF EC STATIONS STUDIED BY USGS FROM SEPTEMBER 2005 TO AUGUST 2006

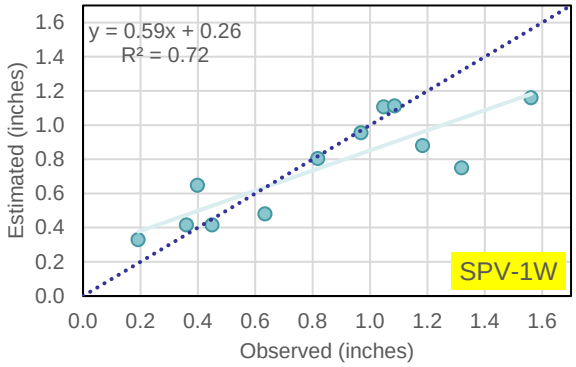
DATE: DEC 29, 2020

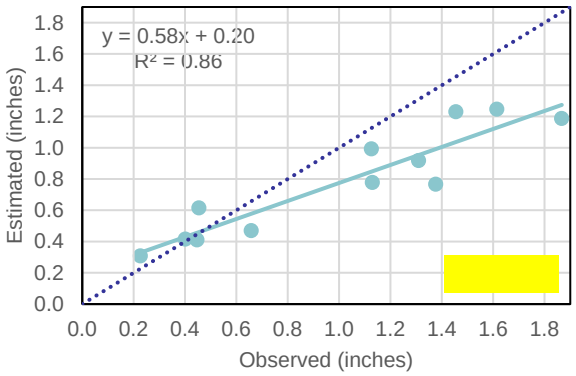
BY: CRL | FOR: PHT

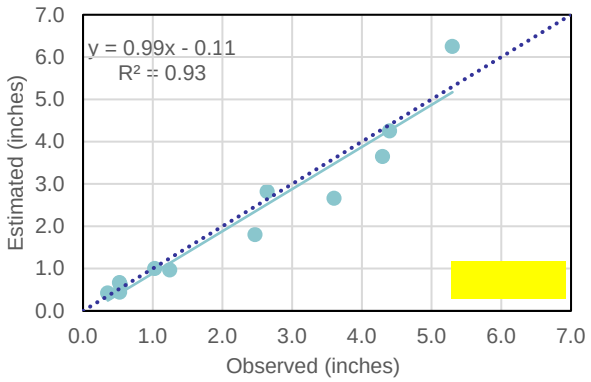
FORMATION ENVIRONMENTAL

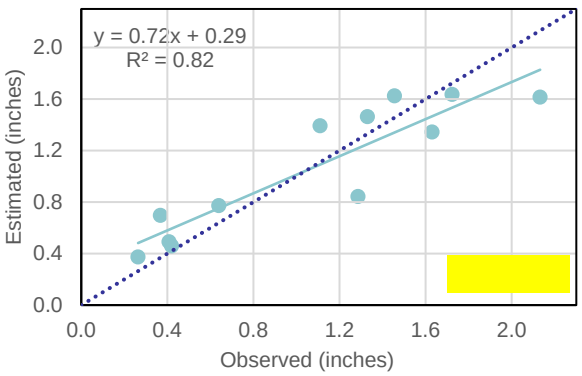
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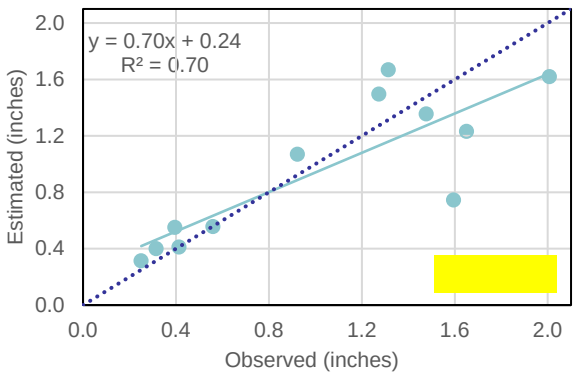












Notes:

Comparison of monthly et estimates developed in this study to eddy covariance data collected by USGS from September 2005 through August 2006 from six locations in eastern Nevada

PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-27

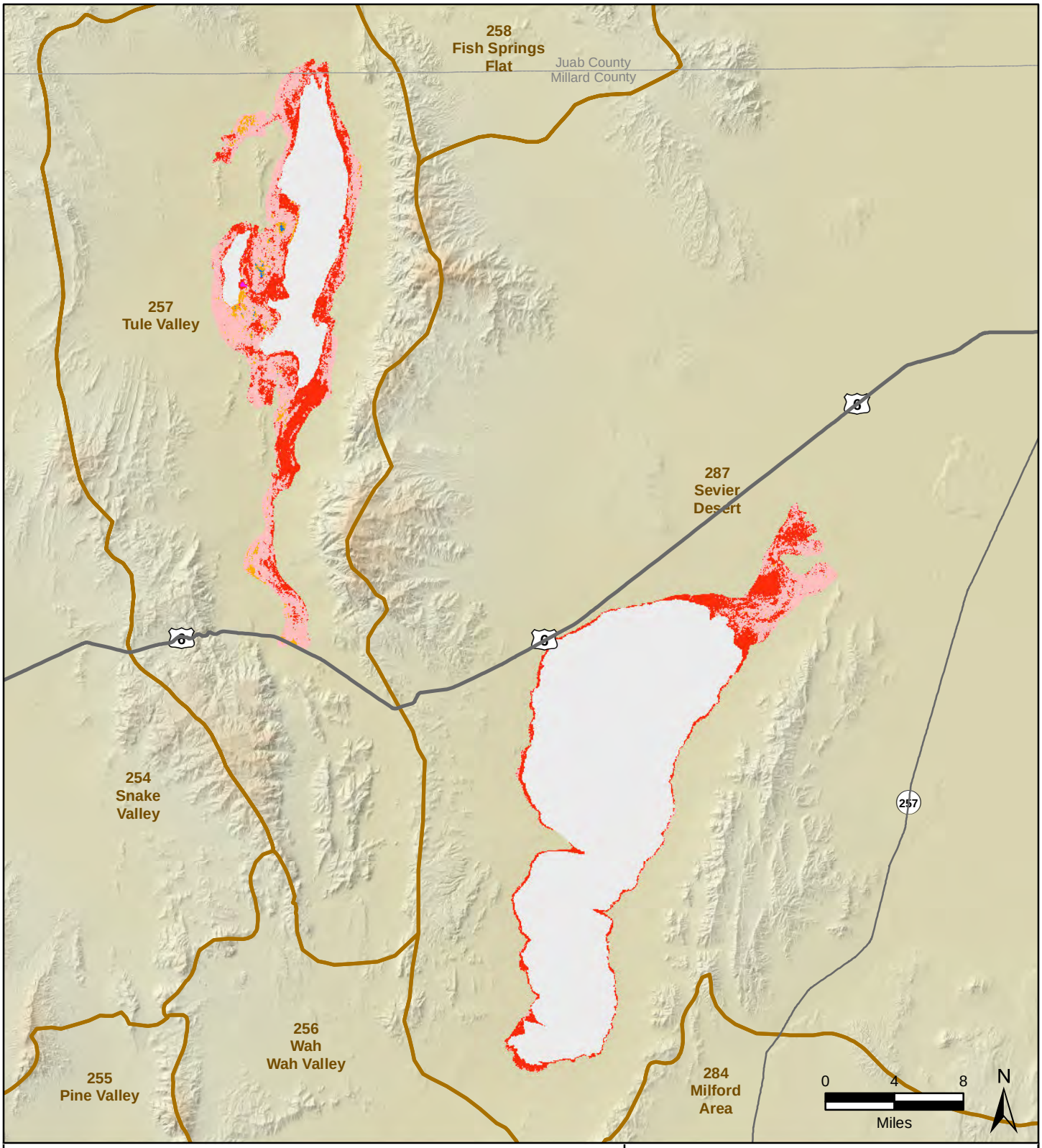
COMPARISON OF MONTHLY ET ESTIMATES TO EDDY COVARIANCE DATA COLLECTED BY USGS

DATE: JANUARY 2021

BY: PHT | FOR: MT

FORMATION ENVIRONMENTAL

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Legend

- Hydrographic Area
- US Route
- State Route

ET Unit (from Gardner et al. 2020)

- Dense meadow and marshland
- Grassland
- Open water
- Playa
- Sparse-to-dense desert shrub
- Very sparse desert shrub

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-28

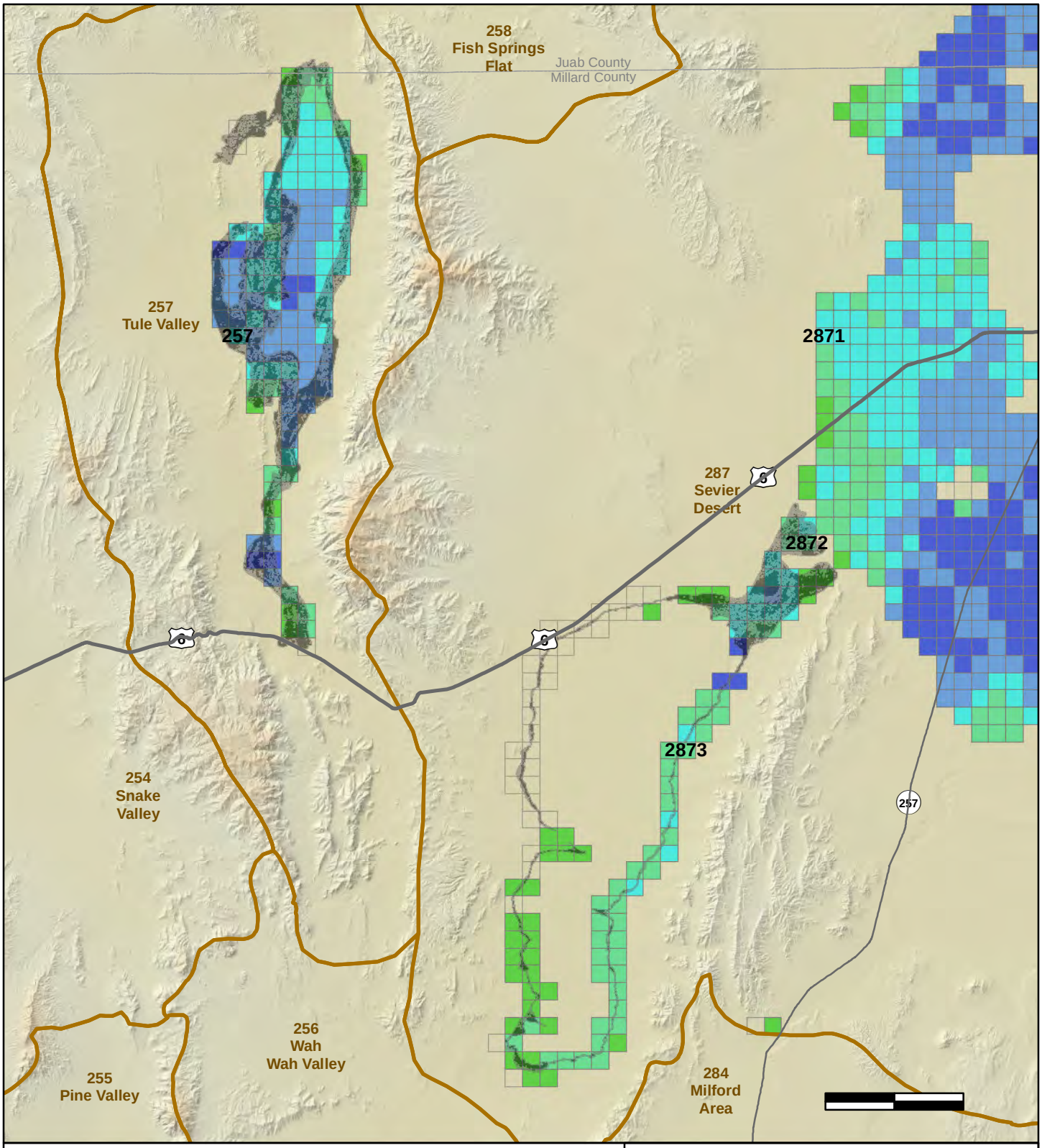
MAPPED GDAs AND GBCAAS V. 3.0 ET DISCHARGE ZONES

DATE: DEC 30, 2020

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig3_28_GDAS_zones.mxd



Legend

- Hydrographic Area
- US Route
- State Route
- GBCAAS v3 ET Cells
- Mapped ET Units (from Gardner et al. 2020)

Thickness of zone from which ET is derived (ft)

- 0.3 - 10.0
- 10.1 - 20.0
- 20.1 - 30.0
- 30.1 - 40.0
- >40 ft

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-29

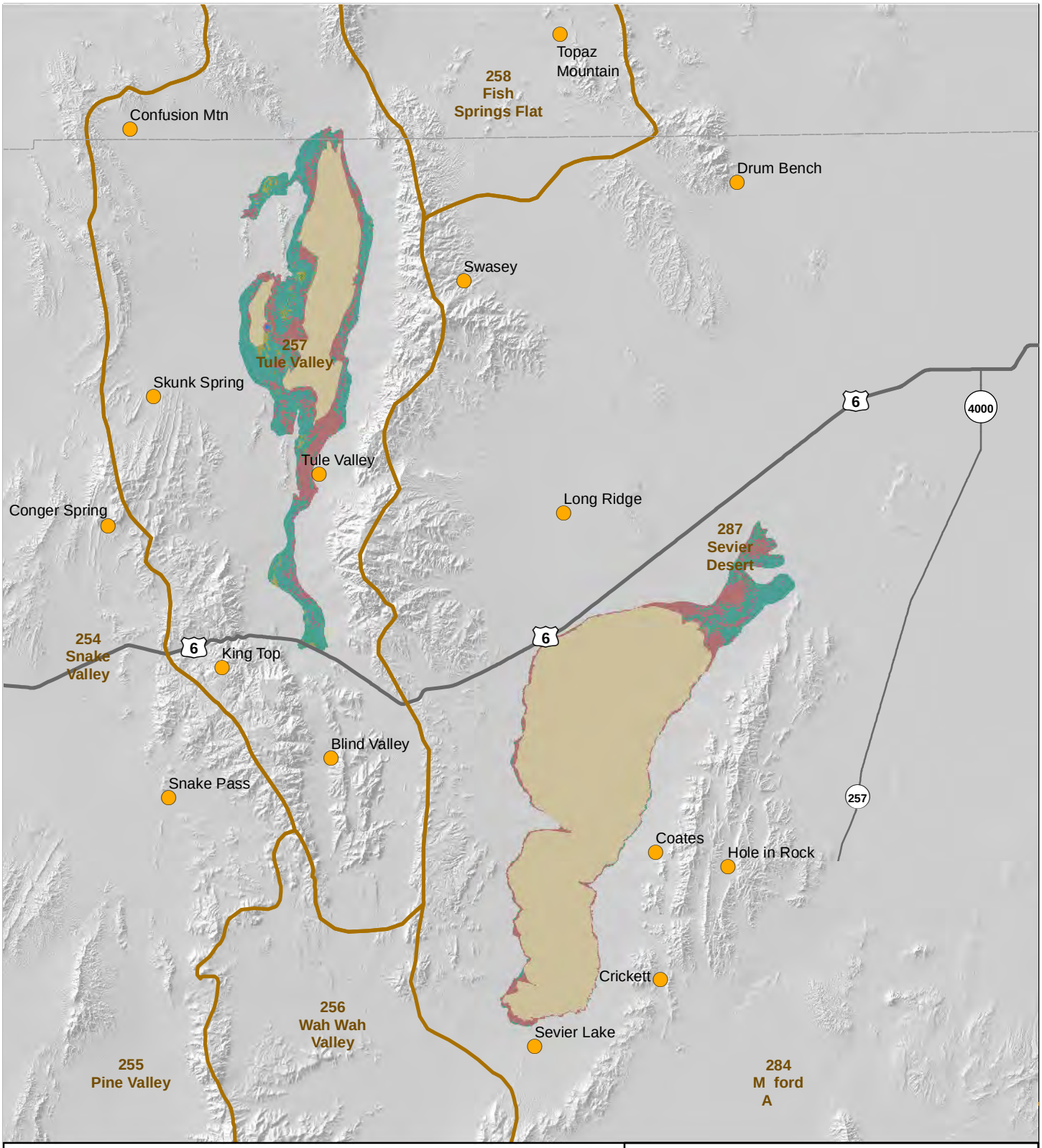
MODEL EVT CELLS AND AQUIFER THICKNESS FROM WHICH ET IS DERIVED

DATE: DEC 30, 2020

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig3_29_EVT_Cells.mxd



Legend

- Rain Gauge
- Hydrographic Area
- US Route
- State Route

ET Unit (from Gardner et al. 2020)

- Dense meadow and marshland
- Grassland
- Open water
- Playa
- Sparse-to-dense desert shrub
- Very sparse desert shrub

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-30

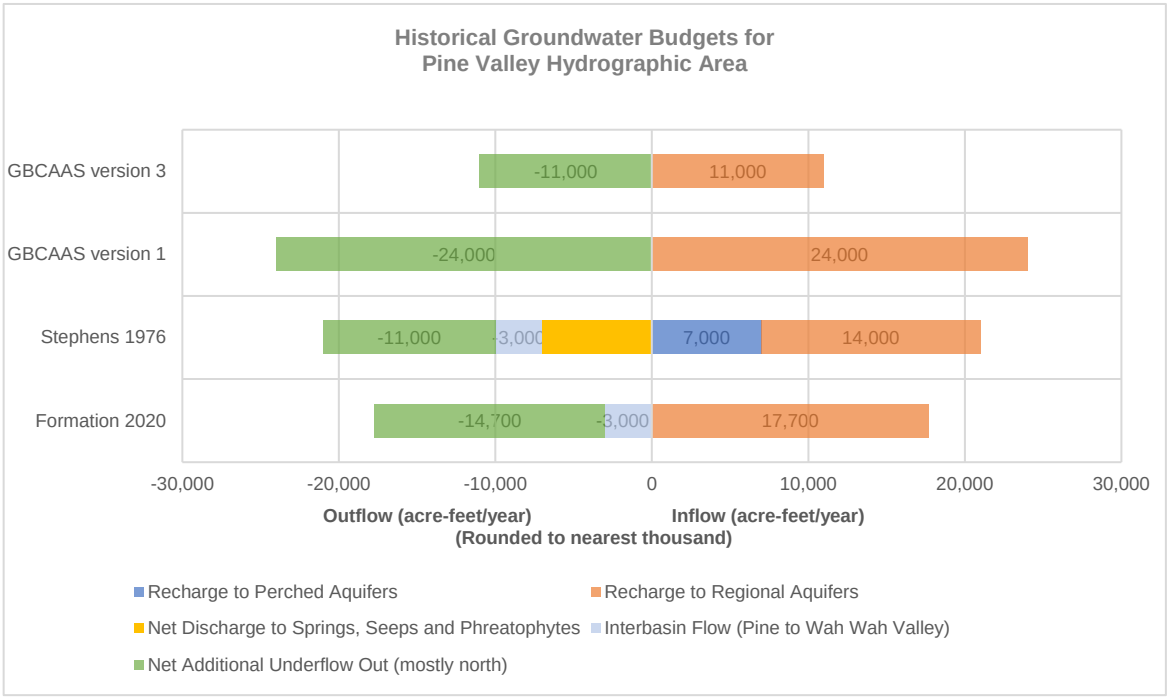
GDAs AND NEARBY RAIN GAUGE STATIONS

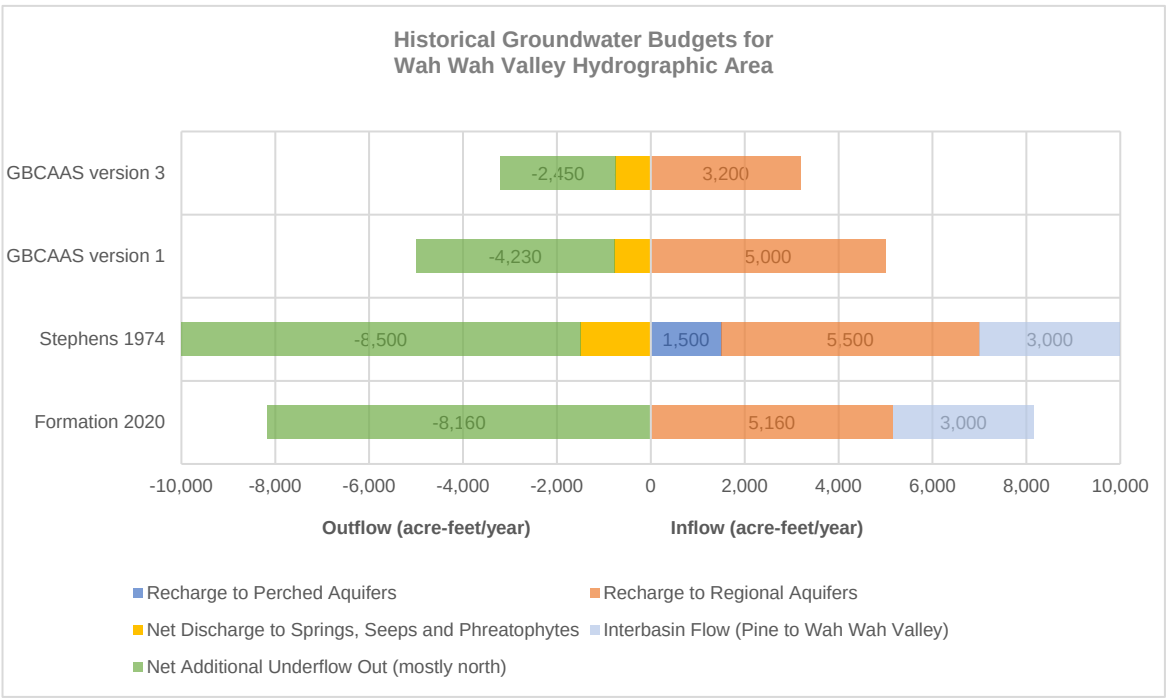
DATE: DEC 30, 2020

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 3-31

HISTORICAL AND REFINED GROUNDWATER BUDGETS FOR THE PINE AND WAH WAH VALLEY HAs

DATE: SEPTEMBER 2020	FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT

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4 POTENTIAL PROJECT AND CUMULATIVE EFFECTS

4.1 BACKGROUND AND APPROACH

This section includes a description of potential project effects induced by the PVWS Project. Also included is a discussion regarding the potential cumulative effects of the PVWS Project combined with other planned and reasonably foreseeable groundwater extraction in the Study Area. Potential effects that could occur in the Study Area as a result of groundwater extraction include the following:

- Groundwater level drawdown will occur as a result of groundwater extraction for the proposed PVWS Project and is the primary effect that would result from the project.
- Groundwater level drawdown may affect the operation of existing wells in the area around the proposed wellfield. This is referred to as interference drawdown.
- Regional groundwater level drawdown and flow changes will decrease the amount of groundwater in storage and change the groundwater balance in the surrounding area. This may affect the amount of groundwater available for other future beneficial uses.
- Groundwater level drawdown and water balance changes may deplete the flow of springs connected to the regional aquifer system within the APE.
- Groundwater extraction will change the regional water balance by intercepting water that currently discharges to areas of phreatophytes and other groundwater-dependent vegetation in Tule Valley and around Sevier Lake.
- Drawdown in Pine Valley could result in the depressurization and consolidation of clay sediments and result in subsidence.

The GBCAAS-PV numerical flow model was developed to evaluate the reasonable range of effects that could occur from groundwater extraction related to the PVWS Project. As described in Appendix A, GBCAAS-PV is a refined version of GBCAAS v.3.0 (Brooks 2017). The focus of the model is around Pine Valley and Wah Wah Valley, but the entire GBCAAS v.3.0 model and model area is still evaluated. Modifications to GBCAAS v. 3.0 allow the simulation of the large regional groundwater system with added details and refinement within the Study Area.

Consistent with the modeling objectives described in Appendix A, a superposition modeling approach was used for assessment of project effects. “Superposition” or “impact modeling” is a robust modeling approach that focuses on evaluating drawdown and flow changes induced by a project rather than actual predicted groundwater levels and flows (Reilly, Franke, and Bennett 1987). All models of natural systems are limited by inherent inaccuracies, and by subtracting a no-project baseline model from model cases that simulate project pumping, the potential effects of model inaccuracies on evaluation of project effects can, to some extent, be subtracted out. The use of superposition modeling in hydrogeologic literature is well established, and this approach has been widely used to evaluate the impacts of water supply pumping under NEPA. The GBCAAS-PV consists of (1) a calibrated historical model that simulates groundwater and surface water conditions; (2) a baseline forecast model without project pumping; (3) 250-year forecast scenarios (including 50 years of project pumping and 200 years of recovery) to establish the aquifer response under the Proposed Action and the ANWS Alternative; and (4) 250-year to 500-year forecast scenarios (including 50 years of project pumping and 200 to 450 years of recovery) to establish the

cumulative aquifer response under both project and existing and reasonably foreseeable pumping in the area that may be affected by the project.

This section presents the potential project effects based on the understanding of the affected environment summarized in Section 3 and using the GBCAAS-PV groundwater flow model described in Appendix A. The effects analysis presented herein is based on a number of prior studies, available data from investigations and public sources, and the evaluations presented in Section 3 and Appendix A. The data used are believed to represent the most comprehensive and up-to-date data currently available, and are judged to be adequate to support the effects and impact analysis described herein. Nevertheless, because the Study Area is relatively large, hydrogeologically complex and only sparsely developed in terms of groundwater supply, significant uncertainties remain. In addition, modeling of natural systems entails inherent uncertainties that limit the appropriate interpretation and application of the modeling results. These limitations are described throughout this report, and accounted for by describing the remaining uncertainties, adopting a conservative approach to impact assessment, disclosing the implications of potential risks, and addressing potential risks of significant impacts through appropriately designed monitoring and mitigation. Water budget numbers derived from the PVCAAS-PV model and discussed herein should be understood in this context and should not be taken as absolute predictions.

4.2 POTENTIAL PROJECT EFFECTS

4.2.1 GROUNDWATER LEVEL DRAWDOWN

4.2.1.1 DESCRIPTION OF POTENTIAL EFFECTS

Drawdown occurs as a result of groundwater extraction and decreases with distance from a pumping well, creating a cone of depression with the gradients needed to direct flow toward the well in the extracted amount. During the early stages of well operation, groundwater is taken out of storage and the cone of depression expands until sufficient sources of recharge are captured (or discharge is intercepted) to supply the well, and drawdown reaches a new equilibrium. Initially the water levels drop rapidly, but as pumping continues, the rate of drawdown decreases geometrically as the cone of depression expands to draw water from a larger area. The cone of depression eventually stabilizes when the rate of withdrawal equals the amount of captured recharge and intercepted discharge.

The PVWS Project proposes to use groundwater pumped from production wells in a well field in Pine Valley as water supply for CICWCD for a period of 50 years. The water supply wells would extract groundwater from the basin-fill aquifer within the valley and are anticipated to be completed to depths ranging from approximately 500 to 2,000 feet bgs. The proposed well layout for the Proposed Action is shown on Figure 2-1. The proposed layout for the ANWS Alternative is shown on Figure 2-2.

Groundwater levels in the Pine Valley HA are hundreds of feet below the ground surface and, therefore, hydrologically disconnected from local recharge and discharge sources. As a result, while groundwater level drawdown will slow over time and reach a state of pseudo-equilibrium as the cone of depression expands into the surrounding HAs, true steady state equilibrium would not be achieved unless pumping continues for several thousand years (Brooks 2017). The PVWS Project proposes to extract groundwater for only 50 years, so a state of equilibrium is not expected to be reached during pumping. During the

pumping period, a relatively deep cone of depression would form in Pine Valley. When pumping ceases after 50 years, groundwater would continue to flow into this cone of depression from the surrounding area as it is filled. As a result, the shallow portion of the cone of depression in the HAs surrounding Pine Valley would continue to expand for some time after pumping ceases, while groundwater levels recover in the wellfield area. Over time, groundwater levels in the outlying areas would also recover.

4.2.1.2 PREDICTED EFFECTS OF THE PROPOSED ACTION

Simulation of pumping for the PVWS Project Proposed Action indicates that during the initial 50-year pumping period, a cone of depression would form around the wellfield in the southern part of Pine Valley with predicted drawdowns over 100 feet covering an area measuring approximately 7 by 12 miles (Figure 4-1). Maximum drawdowns in the wellfield are predicted to approach 350-400 feet within approximately 500 feet of four wells; decreasing to between 50 and 100 feet after 150 years' recovery. Predicted drawdown between 50 and 100 feet covers an area of about 10 by 16 miles; and, predicted drawdown exceeding 10 feet covers an area measuring approximately 17 by 25 miles in southern Pine Valley HA and extending up to 3 miles into the northern area of the Beryl-Enterprise Area HA and up to 2 miles into the Snake (Hamlin) Valley HA. Drawdown between 1 and 10 feet is predicted to extend up to approximately 6 miles into the Snake (Hamlin) Valley HA, 10 miles into the northern area of the Beryl-Enterprise Area HA, and 8 miles into the southern area of the Wah Wah Valley HA, south of Wah Wah Springs. Much of the northern portion of Pine Valley is also predicted to experience drawdown between 1 and 10 feet.

After pumping ceases, drawdown in the wellfield area is predicted to decrease to between 50 and 100 feet in 75 to 150 years (Figure 4-1). At the same time, the area where drawdown exceeds 10 feet is predicted to increase to approximately 20 by 50 miles by 150 years post pumping, covering most of the Pine Valley HA, and extending up to about 4.5 miles into the eastern part of the Snake (Hamlin) Valley HA, 10 miles into the Beryl-Enterprise Area HA, and encompassing a small area in the southern part of the Wah Wah Valley HA. The area underlain by drawdown exceeding 1 foot is predicted to expand up to 12 miles into the Snake (Hamlin) Valley HA and 16 miles into the northern area of the Beryl-Enterprise Area HA, and approximately 20 to 25 miles across the northern part of the Wah Wah Valley HA and into the southern part of the Tule Valley HA and southwestern part of the Sevier Desert HA around Sevier Lake.

Approximately 200 years after pumping is discontinued, the lateral extent of the 1-foot and 10-foot drawdown contours is predicted to be relatively unchanged; however, the area of drawdown exceeding 50 feet in southern Pine Valley is predicted to decrease to approximately 7 by 10 miles (Figure 4-1).

4.2.1.3 PREDICTED EFFECTS OF THE ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

Under the ANWS Alternative, about 60% of wellfield pumping would be shifted northward and spread out over a greater distance in a north-south direction (Figure 4-2). As a result, the area of maximum predicted drawdown in the wellfield would be smaller and would occupy a narrower area, and the area of drawdown effects would be generally shifted northward. Predicted drawdowns exceeding 100 feet after 50 years of pumping occupy two smaller areas in southern and central Pine Valley measuring about 4 by 7 miles and 4 by 5 miles, respectively. Maximum drawdowns in the wellfield are predicted to approach 200 feet within approximately 500 to 2,500 feet of pumping wells after 50 years of pumping; decreasing to 100 feet within

20 years and 50 feet within 150 years' recovery. Predicted drawdown between 50 and 100 feet covers an area of about 7 by 20 miles; and, predicted drawdown exceeding 10 feet covers an area measuring approximately 12 by 40 miles entirely within the Pine Valley HA and occupying most of the valley floor. Drawdown between 1 and 10 feet is predicted to extend up to 5 miles into the Snake (Hamlin) Valley HA, 9 miles into the northern part of the Beryl-Enterprise HA, and 7 miles into the southwest part of the Wah Wah Valley HA. In addition, an area with between 1 and 5 feet of drawdown is predicted to extend approximately 20 miles across from the Pine Valley HA, across the northern part of the Wah Wah Valley HA and into the southern part of the Tule Valley HA and southwestern part of the Sevier Desert HA.

After pumping ceases, drawdown in the wellfield area is predicted to decrease to less than 100 feet in 20 years and to be less than 50 feet in 150 years (Figure 4-2). The area where drawdown exceeds 10 feet is predicted to increase to approximately 17 by 50 miles within 75 years after pumping ceases. The extent of this area remains relatively stable during the rest of the simulation period, covering most of the Pine Valley HA and extending up to 3 miles into the Snake Valley HA and up to 9 miles into the Beryl-Enterprise Area HA. The area underlain by drawdown over 1 foot is predicted to expand farther into the southern Tule Valley HA and around Sevier Lake after pumping stops. It is predicted to stabilize at a maximum extent of approximately 30 to 45 miles northwest of the Pine Valley HA about 150 years after pumping stops.

4.2.2 Storage Depletion and Water Budget Effects

4.2.2.1 Description of Potential Effects

Regional drawdown and changes in groundwater flow will be induced by the PVWS Project, and will result in a decrease in groundwater storage, especially in the Pine Valley HA. Groundwater level declines can also make future groundwater development in a region more difficult or expensive by increasing the depth to which wells must be drilled and/or from which groundwater must be pumped. In addition, changes in groundwater flow will affect the water budgets of the adjacent HAs by causing changes in underflow between these basins and Pine Valley. The hydrologic effects related to this potential impact are discussed in the following sections, and potential impacts are discussed in Section 5.2.

4.2.2.2 Predicted Effects of the Proposed Action

The effect of groundwater pumping for the Proposed Action on groundwater storage in the HAs in the Study Area is summarized below in Table 4-1.

Table 4-1. Predicted Storage Depletion in Study Area HAs Under the Proposed Action

Hydrographic Area	Groundwater Storage Depletion after 50 Years of Pumping (acre-feet)	Groundwater Storage Depletion 200 Years Post Pumping (acre-feet)
Pine Valley	-717,100	-412,200
Wah Wah Valley	-3,800	-21,800
Snake Valley	-2,500	-43,300
Beryl-Enterprise Area	-21,700	-79,200
Tule Valley	-200	-4,600
Milford Area	-100	-3,600
Sevier Desert	-500	-11,900
Total	**-745,900**	**-576,600**

The proposed groundwater extraction rate for the PVWS Project is 15,000 AFY, which equates to extraction of 750,000 over the 50-year project operational period. As is evident from the information in the table above, most of this groundwater will removed from storage in the Pine Valley HA, with a smaller amount coming from storage in the surrounding HAs. During the 200 years after pumping ceases, groundwater will flow from the surrounding HAs into the Pine Valley HA, restoring approximately 305,000 acre-feet of storage while further depleting storage in the surrounding HAs. During this time period, the net storage recovery due to decreases in discharge is predicted to be approximately 170,000 acre-feet.

A map view of predicted changes in IBF rates between the HAs in the Study Area under the Proposed Action is presented in Figure 4-3 and graphs of the changes in IBF between the HAs in the Study Area are included in Figure 4-5. These are net changes in total groundwater exchange across the HA boundaries, and the actual quantities and directions of flow are likely to be variable across HA boundaries. The following IBF effects are predicted using the GBCAAS-PV model:

- **Pine Valley HA to Beryl-Enterprise Area HA.** The Pine Valley and Beryl-Enterprise Area HAs are separated by an inferred hydraulic divide. The exact location and elevation of this divide cannot be precisely constrained by the available groundwater elevation data and is inferred from modeling. Under current (or pre-Project pumping) conditions, net IBF is simulated by the GBCAAS-PV model from the Pine Valley HA into the Beryl-Enterprise Area HA at a rate of approximately 800 AFY based on the inferred position of the groundwater divide relative to the established HA boundary. However, the actual amount and direction of IBF across this HA boundary depends on the actual location of the divide and local hydraulic gradients, and is therefore uncertain. Only net volume change can be predicted at this time. IBF is predicted to begin to decrease a few years after pumping starts and about 20 years after pumping ceases, a maximum underflow depletion of about 1,300 AFY would occur. From this point, IBF would begin to slowly recover. Approximately 80% of the recovery would occur within about 180 years of stopping pumping.

- **Pine Valley HA to Wah Wah Valley HA.** Under current (or pre-Project pumping) conditions, net IBF is simulated by the GBCAAS-PV model from the Pine Valley HA to the Wah Wah Valley HA at a rate of approximately 15,900 AFY. IBF is predicted begin to decrease about 10 years after pumping starts and after 50 years of pumping, IBF would be decreased by about 300 AFY. The maximum underflow depletion of about 700 AFY would occur about 125 years after pumping ceases. From this point, IBF would begin to recover slowly, with about 40% of the recovery occurring by 450 years after pumping stops.

- **Pine Valley HA to Snake Valley HA.** Under current (or pre-Project pumping) conditions, net IBF is simulated by the GBCAAS-PV model from the Pine Valley HA to the Snake Valley HA at a rate of approximately 1,100 AFY. Most of this interchange likely to the north due to the presence of flow impediments underlying the Needle Range to the west. IBF is predicted begin to decrease about 10 years after pumping starts and after 50 years of pumping, IBF would decrease by about 100 AFY. The maximum underflow depletion of about 200 AFY would occur about 60 years after pumping ceases. From this point, IBF would begin to recover slowly, with about 65% of the recovery occurring by 450 years after pumping stops.

- **Wah Wah Valley HA to Sevier Desert HA.** Under current (or pre-Project pumping) conditions, net IBF is simulated by the GBCAAS-PV model from the Wah Wah Valley HA to the Sevier Desert HA at a rate of approximately 9,800 AFY. IBF is predicted to begin to decrease slowly about 25 years after pumping starts and after 50 years of pumping, IBF would decrease by about 50 AFY. The maximum underflow depletion of about 300 AFY would occur about 250 years after pumping ceases. From this point, IBF would begin to recover very slowly, with about one-third of the recovery occurring by 450 years after pumping stops.

- **Sevier Desert HA to Tule Valley HA.** Under current (or pre-Project pumping) conditions, net IBF is simulated by the GBCAAS-PV model from the Sevier Desert HA to the Tule Valley HA at a rate of approximately 19,700 AFY. No change in IBF is predicted to occur until about 50 years after beginning pumping. IBF would decrease very slowly for about 250 years, when a maximum depletion of about 100 AFY would occur about 250 years. From this point, IBF would begin to recover slowly, with about 20% of the recovery having occurred by 450 years after pumping stops.

- **IBF Between Other HAs.** IBF between the other HAs in the Study Area are predicted to experience minor changes in underflow ranging from approximately 2 to 20 AFY. Most of these changes at more distant interbasin boundaries will occur very slowly over periods of several hundreds of years as the region equilibrates to groundwater extraction by the PVWS Project.

The above changes in IBF reflect a gradual, long-term re-equilibration of regional groundwater flows as a result of pumping for the Proposed Action. In general, the magnitude and timing of changes in IBF induced by the PVWS Project is consistent with the distance of the affected interbasin boundaries from the well field and in some cases the presence of faults and other flow impediments. The most pronounced changes in IBF are between the Pine Valley HA and the Beryl Enterprise HA (increased underflow in of 1,300 AFY), and between the Pine and Wah Wah Valley HAs (decreased underflow out of about 700 AFY). Hydrologic interaction with the Snake Valley HA appears to be limited by range front faults and steeply tilted siliciclastic rocks. IBF changes between more distant basins are more dampened and delayed. The maximum changes in IBF are predicted to occur decades to several hundreds of years after pumping ceases, and residual changes are predicted to persist for hundreds of years. The IBF changes between the Beryl-Enterprise Area HA and the Pine Valley HA are not only the largest, but are also the first to reach a maximum (approximately 20 years after pumping ceases) and the first to substantially recover (approximately 200 years after pumping ceases).

As noted above, the Proposed Action will induce relatively limited drawdown in the Snake Valley HA, focused primarily in Hamlin Valley. This drawdown will induce a small change in the net groundwater flow that currently takes place across the border between Nevada and Utah. To estimate this change, the change in groundwater flow across the refined (child) model boundary west of the project wellfield within the Snake Valley HA was evaluated. Net changes in flow across this model boundary are expected to reflect most change in flow induced in Snake Valley by pumping for the Proposed Action. The magnitude of this change over time is shown graphically in Figure 4-6. As shown, the amount of net groundwater flow across the state boundary from Nevada into Utah is predicted to increase relatively shortly after pumping begins. After 50 years of pumping, net groundwater underflow across the state line is predicted

to increase by approximately 20 AFY. The maximum predicted net underflow increase would occur approximately 170 years after pumping ceases and is approximately 200 AFY. After this time, groundwater underflow would gradually decrease, recovering by approximately 25 percent 450 years after pumping ceases. It should be noted that these numbers represent net changes in groundwater flow across the interstate border within Snake Valley. Actual flow directions across the border within Snake Valley are expected to be variable and induced by pumping centers located on either side of the border. As such, they may include increases in flow where the flow across the state border is eastward, and decreases where flow is westward.

4.2.2.3 PREDICTED EFFECTS OF THE ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

The effect of groundwater pumping for the ANWS Alternative on groundwater storage in the HAs in the Study Area is summarized below in Table 4-2.

TABLE 4-2. PREDICTED STORAGE DEPLETION IN STUDY AREA HAS UNDER THE ANWS ALTERNATIVE

Hydrographic Area	Groundwater Storage Depletion after 50 Years of Pumping (acre-feet)	Groundwater Storage Depletion 200 Years Post Pumping (acre-feet)
Pine Valley	-715,700	-397,900
Wah Wah Valley	-9,800	-30,400
Snake Valley	-1,900	-33,800
Beryl-Enterprise Area	-9,400	-41,200
Tule Valley	-2,200	-7,800
Milford Area	-300	-3,200
Sevier Desert	-4,600	-21,300
Total	**-743,900**	**-535,600**

Groundwater storage depletion under implementation of the ANWS Alternative will be similar to, but slightly less, than the Proposed Action. Storage depletion in the Wah Wah Valley HA would be higher than under the alternative and storage depletion in the Beryl-Enterprise Area HA would be lower. This is because the wellfield would be expanded to the north, farther from the Beryl Enterprise HA. An additional result is that after 200 years of recovery, regional storage recovery would be over 40,000 acre-feet greater. Only 13,000 of this additional storage recovery would occur in Pine Valley, and the remainder is likely due to the interception of additional discharge by shifting drawdown effects northward.

A map view of predicted changes in IBF rates between the HAs in the Study Area under the ANWS Alternative is shown in Figure 4-3, and graphs of the changes in IBF between the HAs in the Study Area are included in Figure 4-7. The following IBF effects are predicted using the GBCAAS-PV model:

- **Pine Valley HA to Beryl-Enterprise Area HA.** The Pine Valley and Beryl-Enterprise Area HAs are separated by an inferred hydraulic divide. The exact location and elevation of this divide cannot be precisely constrained by the available groundwater elevation data and is inferred from modeling. Under current (or pre-Project pumping) conditions, net IBF is simulated by the GBCAAS-PV model from the Pine Valley HA into the Beryl-Enterprise Area HA at a rate of approximately 800 AFY based on the inferred position of the groundwater divide relative to the established HA

boundary. However, the actual amount and direction of IBF across this HA boundary depends on the actual location of the divide and local hydraulic gradients, and is therefore uncertain. Only net volume change can be predicted at this time. The amount of change in IBF predicted by the GBCAAS-PV model under the ANWS Alternative would be about 40% of the flow depletion under the Proposed Action. IBF is predicted to decrease by approximately 550 AFY approximately 20 years after pumping stops. From this point, IBF would begin to increase, with the almost all the recovery having occurred 450 years after pumping ceases.

- **Pine Valley HA to Wah Wah Valley HA.** Under the ANWS Alternative, the depletion of IBF predicted by the GBCAAS-PV model would be about twice as much as under the Proposed Action. Under current (or pre-Project pumping) conditions, IBF is simulated from the Pine Valley HA to the Wah Wah Valley HA at a rate of approximately 15,900 AFY. IBF is predicted to decrease steadily after pumping starts, and after 50 years of pumping, IBF would be decreased by about 1,000 AFY. The maximum underflow depletion of about 1,300 AFY would occur about 30 years after pumping ceases. From this point, IBF would begin to recover slowly, with about 70% of the recovery having occurred by 450 years after pumping stops.

- **Pine Valley HA to Snake Valley HA.** The amount of IBF depletion under the ANWS Alternative would be a little lower than under the Proposed Action. Under current (or pre-Project pumping) conditions, net IBF is simulated by the GBCAAS-PV model from the Pine Valley HA to the Snake Valley HA at a rate of approximately 1,100 AFY. Most of this interchange likely to the north due to the presence of flow impediments underlying the Needle Range to the west. IBF is predicted to begin to decrease about 10 years after pumping starts and after 50 years of pumping, IBF would be decreased by about 100 AFY. The maximum underflow depletion of about 200 AFY would occur about 70 years after pumping ceases. From this point, IBF would begin to recover slowly, with about 60% of the recovery occurring by 450 years after pumping stops.

- **Wah Wah Valley HA to Sevier Desert HA.** Under the ANWS Alternative, IBF depletion is predicted by the GBCAAS-PV model to be about twice as high as under the Proposed Action, and the maximum depletion would occur about 200 years sooner. Under current (or pre-Project pumping) conditions, IBF is simulated from the Wah Wah Valley HA to the Sevier Desert HA at a rate of approximately 9,800 AFY. The maximum underflow depletion of about 500 AFY is predicted to occur about 60 years after pumping ceases. From this point, IBF would begin to recover slowly, with approximately 60% of the recovery occurring by 450 years after pumping stops.

- **Sevier Desert HA to Tule Valley HA.** The amount of IBF depletion under the ANWS Alternative is predicted by the GBCAAS-PV model to be about 100 AFY higher than under the Proposed Action and the maximum depletion would occur about 100 years sooner. Under current (or pre-Project pumping) conditions, IBF is simulated from the the Sevier Desert HA to the Tule Valley HA at a rate of approximately 19,700 AFY. IBF is predicted begin to decrease about 30 years after pumping starts. The maximum underflow depletion of about 200 AFY would occur about 150 years after pumping stops. From this point, IBF would begin to recover slowly, with about half of the recovery occurring by 450 years after pumping ceases.

- **IBF Between Other HAs.** IBF between the other HAs in the Study Area are predicted to experience minor changes in underflow ranging from approximately 2 to 20 AFY. Most of these changes at more distant interbasin boundaries will occur very slowly over periods of several hundreds of years as the region equilibrates to groundwater extraction by the PVWS Project.

As with the Proposed Action, the above changes in IBF reflect a gradual, long-term re-equilibration of regional groundwater flows as a result of pumping for the ANWS Alternative; however, the magnitude and timing of changes in IBF induced by the pumping reflect the northward shift in the wellfield. The most pronounced changes in underflow under this alternative would be northward, between the Pine and Wah Wah Valley HAs, where net underflow out would decrease by 1,300 AFY (compared to a decrease of 700 AFY under the Proposed Action). In addition, net IBF depletion between the other basins located north of Pine Valley would increase and would happen sooner. Conversely, net underflow depletion between the Pine Valley HA and the Beryl Enterprise Area HA would decrease from 1,300 AFY to 550 AFY. Hydrologic interaction with the Snake Valley HA would remain limited, with a minor decrease in the amount of IBF depletion. Recovery timeframes would be generally similar.

The ANWS Alternative would induce more limited drawdown in the Snake Valley HA, which would increase the net groundwater flow from Nevada into Utah, but at a lower magnitude than under the Proposed Action. Under the alternative, drawdown is predicted to be more dispersed along the eastern edge of the Snake Valley HA than under the Proposed Action (Figure 4-2), and this drawdown would therefore induce a smaller change in net interstate groundwater flow. The magnitude of this change over time is shown graphically in Figure 4-7. As shown in this figure, the amount of net groundwater flow across the state boundary from Nevada into Utah is predicted to increase relatively shortly after pumping begins. After 50 years of pumping, net groundwater underflow across the state line would increase by approximately 10 AFY. The maximum predicted net underflow increase would occur from approximately 150 to 250 years after pumping ceases and is approximately 135 AFY. After this time, net groundwater underflow would gradually decrease, recovering by approximately 15% 450 years after pumping ceases. As such, the effects of the ANWS Alternative would be a somewhat smaller increase in net interstate groundwater flows to Utah over a longer period of time. It should be noted that these numbers represent net changes in groundwater flow across the interstate border within Snake Valley. Actual flow directions across the border within Snake Valley are expected to be variable.

4.2.3 INTERFERENCE DRAWDOWN TO EXISTING WELLS

4.2.3.1 DESCRIPTION OF POTENTIAL EFFECTS

Existing wells within the area of predicted drawdown resulting from the PVWS Project will experience "interference drawdown" or "well interference." The primary effects will be in the Pine Valley HA and to a lesser extent in the surrounding basins (Figures 4-1 and 4-2). Drawdown imposed by a well on another nearby pumping well changes the conditions under which that well operates, which can affect its performance. This effect is shared between nearby wells, i.e., each well both receives and induces interference effects. In severe cases, well interference can cause a well to go dry. In other cases, a well's capacity may be diminished, or expenses related to well pumping and maintenance may increase. More limited interference drawdown is an expected and acceptable consequence of using groundwater as a

water supply. The extent and type of well interference is dependent on hydrogeologic conditions in the aquifer as well as the characteristics of the affected well and may include the following:

- The amount of interference drawdown that is applied in the aquifer surrounding the well (which varies with the distance of the impacted well from the PVWS Project wellfield);
- The depth and screened interval of the affected well;
- The thickness of saturated sediments penetrated by the affected well;
- Local variations in transmissivity of saturated sediments in which the well is completed, if any;
- The condition and efficiency of the affected well, and resulting pumping water level in the well;
- Pump specifications of the affected well, including the rating curve, the depth at which the pump intake is set and the condition of the pump; and
- The required water production rate and operating schedule to meet the existing demand.

The above conditions are specific to individual wells, making them either more or less susceptible to well interference. They are unknown at this time and cannot be reliably ascertained without a well inspection program. For this reason, the sections below focus on identifying the amount of aquifer drawdown that may be experienced by existing wells in the area potentially affected by the PVWS Project pumping. The nature and potential significance of interference drawdown impacts that may be experienced by these wells is discussed in Section 5.3.

The Utah DWRi has not published specific guidance or regulations regarding interference drawdown; however, two existing groundwater management plans for areas that are still open to limited new appropriation (i.e., Bountiful Sub-area of the East Shore area and Weber River Delta Sub-area of the East Shore area) set forth the State Engineer's policy concerning the management of interference drawdown and establish a maximum of 15 feet of interference drawdown as acceptable (DWRi 1995a, 1995b). The plans state that "[w]*ells shall be spaced so that under unconfined conditions they do not cause more than 15 feet of drawdown on any well with an earlier priority date*." The discussion of hydrologic effects in the subsections below therefore provides a special focus on wells that may experience interference drawdown considered under this standard as a potential impairment to prior water rights.

An additional consideration is the reasonably expected service life of an existing well. New wells drilled in the area affected by PVWS Project drawdown will presumably be constructed to adapt to the current and anticipated groundwater conditions and avoid adverse effects from interference drawdown. The service life of a well depends on the methods and materials used in its construction, water quality, aquifer conditions, operational practices and intended use (Driscoll 1986), and can range from approximately 25 to over 100 years (Glotfelty 2017). During a well's operational life, well yield may be expected to decrease, but can often be restored periodically using chemical or physical rehabilitation techniques (Driscoll 1986). However, rehabilitation techniques often decrease in their effectiveness over time. Some causes of well yield depletion ultimately result in well failure. The estimate of reasonably anticipated well life adopted

in some NEPA analyses is as little as 20 years. For this GRIA, an anticipated well service life of 50 years has been adopted to account for the range in potential well conditions and the amount of time that existing wells in the area have been under production.

Appendix B includes a table summarizing information regarding the underground Points of Diversion located in the APE for the Proposed Action and the ANWS Alternative. The tables in this appendix include information regarding these Points of Diversion derived from the Utah DWRi water rights database, and drawdowns predicted by the GBCAAS-PV model over a 50-year PVWS Project pumping period. Locations where drawdown over the first 50 years of PVWS operation is predicted to exceed 15 feet are discussed further below. Because groundwater development in Pine Valley is relatively sparse, there are not many of these. Additional wells are located in more outlying areas in the Snake Valley HA and the Beryl Enterprise Area HA, but these would experience less drawdown.

4.2.3.2 PREDICTED EFFECTS OF THE PROPOSED ACTION

The area predicted to be affected by more than 15 feet of drawdown after 50 years of pumping under the Proposed Action is shown on Figure 4-8. Also shown are the locations of underground Points of Diversion within this area identified in the Utah DWRi water rights database. The drawdown predicted at these Points of Diversion after 50 years of pumping is summarized below in Table 4-3. Six existing wells represented by these Points of Diversion are expected to experience 15 feet or more interference drawdown during the 50-year review period. All six of these wells are located in the Pine Valley HA. The predicted drawdown at these locations ranges from about 20 to 120 feet.

TABLE 4-3. PREDICTED DRAWDOWN AT UNDERGROUND POINTS OF DIVERSION UNDER THE PROPOSED ACTION

Water Right	Drawdown During 50 Years Pumping (feet)				
	10 Years	20 Years	30 Years	40 Years	50 Years
14-121	0	0	0	16	23
14-28	0	0	0	18	25
14-47	0	0	0	19	25
14-108	0	40	68	95	119
14-109	0	40	68	95	119
14-114	0	40	68	95	119

As summarized in Appendix B, existing wells within the APE but outside the Pine Valley HA may experience lesser amounts of interference drawdown. This includes four wells located in the northern Beryl Enterprise Area HA that are predicted to experience less than 15 feet of drawdown during the review period but may experience additional drawdown exceeding 15 feet after the review period as a result of latent drawdown.

4.2.3.3 PREDICTED EFFECTS OF THE ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

The area predicted to be affected by more than 15 feet of drawdown after 50 years of pumping under the Proposed Action is shown on Figure 4-9. Also shown are the locations of underground Points of Diversion

within this area identified in the Utah DWRi water rights database. The drawdown predicted at these Points of Diversion after 50 years of pumping is summarized below in Table 4-4.

Approximately 10 Points of Diversion are expected to experience 15 feet or more interference drawdown during the review period in the Pine Valley HA. Ten existing wells represented by these Points of Diversion are expected to experience 15 feet or more interference drawdown during the 50-year review period. All ten of these wells are located in the Pine Valley HA. In general, the area in which existing wells will be affected under this alternative is shifted farther north. The predicted drawdown at these locations ranges from approximately 20 to 50 feet in Pine Valley HA.

TABLE 4-4. PREDICTED DRAWDOWN AT UNDERGROUND POINTS OF DIVERSION UNDER THE ANWS ALTERNATIVE

Water Right	Drawdown During 50 Years Pumping (feet)				
	10 Years	20 Years	30 Years	40 Years	50 Years
14-89	0	0	0	15	21
14-27	0	0	0	19	25
14-42	0	0	0	15	21
14-43	0	0	0	18	23
14-44	0	0	0	15	21
14-45	0	0	0	15	21
14-108	0	16	28	39	50
14-109	0	16	28	39	50
14-114	0	16	28	39	50
71-2820	0	0	0	17	23

As summarized in Appendix B, existing wells within the APE but outside the Pine Valley HA may experience lesser amounts of interference drawdown. This includes several wells located in the northern part of the Beryl-Enterprise Area HA that are predicted to experience less than 15 feet of drawdown during the review period. Under this alternative, drawdown in these wells during the simulated 200-year recovery period will also remain less than 15 feet.

4.2.4 SPRING FLOW DEPLETION

4.2.4.1 DESCRIPTION OF POTENTIAL EFFECTS

Spring flow depletion can occur when drawdown induced by the PVWS Project decreases pressure gradients that drive groundwater discharge at springs and seeps. The amount of spring flow depletion is dependent on the amount of drawdown compared to gradients that drive the discharge, and the existence and degree of hydraulic connection between the aquifer in which the drawdown occurs and the aquifer from which the spring discharge issues. Springs discharging from perched aquifers would not be expected to be affected by drawdown that occurs in underlying regional aquifers.

Based on studies performed by Gardner *et al.* (2020) that are discussed in Section 3.9.1, hydrogeologic and geochemical data support the interpretation that with the exception of Wah Wah Springs, springs and seeps in the mountains surrounding Pine and Wah Wah Valleys are connected only to local perched or semi-perched mountain aquifers and not to the regional aquifer system. As such, these local springs

and seeps are not expected to be affected by pumping for the PVWS Project. While this interpretation is supported by the available data, the potential for a regional flow contribution to some of the springs and, hence, for groundwater extraction related to the PVWS Project to affect spring discharge, probably cannot be conclusively ruled out without significantly stressing the adjacent regional aquifer system. It is not feasible to test each spring, and even completion of long-term pumping tests proximal to selected springs is not likely to eliminate this uncertainty. As such, the analysis of effects below focuses on the identified regional springs, but also considers identified mountain springs and seeps within the area where drawdown induced by the PVWS at the water table is predicted to exceed 1 foot. Both regional and local springs are considered in the analysis of potential impacts discussed in Section 5.4.

4.2.4.2 PREDICTED EFFECTS OF THE PROPOSED ACTION

As discussed in Section 3.7.2.1, regional springs in the GBCAAS are typically associated with relatively high discharge rates from regionally connected carbonate aquifers as reported in Mathey (1998) and described by Harrill and Prudic (1998). These springs can have discharges from several hundred to over 1,000 gpm (Harrill and Prudic 1998). As shown on Figure 3-5, regional springs in the Study Area are located in the Snake Valley HA northwest of the proposed PVWS Project wellfield and include Big Springs, Dearden Spring Group, and Clay Spring. Fish Springs is located a greater distance to the north-northwest.

Figure 4-10 shows regional and local springs relative to the extent of the area predicted to be affected by more than 1 foot of drawdown and the change in that area over time. A total of 268 springs and seeps are reported in the USGS NHD as being located within the APE of the Proposed Action in the mountains surrounding Pine Valley. Three additional regional springs are located in the Study Area in the Snake Valley HA but are outside of the APE (Dearden Spring Group, Clay Spring, and Big Springs). In addition, Fish Springs, an important regional groundwater discharge point, is located north of the Study Area. Information regarding Points of Diversion associated with springs in the APE in the Utah DWRi water rights database is presented in Appendix C. Most of the local springs and seeps in the NHD dataset do not have associated discharge data and are relatively small. The identified NHD springs include one suspected regional spring in the APE (Wah Wah Springs) that is assumed to discharge water from, and be hydraulically connected with, the regional GBCAAS. This is the closest identified regional spring to the proposed PVWS wellfield. It is located in the Wah Wah Valley HA approximately 18 miles northwest of the proposed PVWS Project wellfield under the Proposed Action.

The predicted effects from the Proposed Action on the identified regional springs are discussed below. Based on the available data, it is not anticipated that the project will affect any local springs or seeps, but this possibility cannot be completely ruled out at this time. Therefore, Section 5.4 considers potential impacts to both local and regional spring resources.

A map view of predicted flow depletion effects on regional springs in the Study Area is presented as Figure 4-4. Graphs of the potential spring flow depletion effects over time from pumping for the Proposed Action are shown graphically in Figure 4-11. The following spring flow depletion effects are predicted using the GBCAAS-PV model:

- **Wah Wah Springs.** Under current (or pre-Project pumping) conditions, Wah Wah Springs discharges at about 1,800 AFY (Section 3.7.2.1). Assuming that spring flow from Wah Wah Springs is derived entirely from the regional aquifer system, as has been assumed in the GBCAAS-PV model, discharge begins to decrease a few years after pumping starts, and after 50 years of pumping, the flow would be about 1,650 AFY. About 40 years after pumping stops, spring flow depletion would be greatest and Wah Wah Springs would discharge at about 1,550 AFY. The maximum spring flow depletion is predicted to be about 14% of the total discharge. From this point, spring flow would begin to slowly recover, and approximately 40% of the recovery would occur within about 200 years after pumping stops. As discussed in Section 3.7.2.1, geochemical analyses performed by the USGS (Gardner *et al.* 2020) support the interpretation that only a portion of the discharge from Wah Wah Springs is derived from the regional aquifer system; therefore, the above depletion estimates may be considered conservative overestimates.

- **Big Springs.** Under current (or pre-Project pumping) conditions, the groundwater discharge rate at Big Springs is reported to be about 7,400 AFY (Table 3-3). Big Springs is located about 37 miles northwest of the proposed wellfield. Due to the distance of Big Springs and its location in the Snake Valley HA, which is in limited hydrogeologic communication with the Pine Valley HA, flow at Big Springs would not be affected by the PVWS Project until after pumping stops. Flows are projected to decrease slightly beginning about 20 years after pumping stops. The maximum projected discharge depletion during the simulation period is about 70 AFY, approximately 200 years after pumping ceases. This depletion represents about 0.9% of the total discharge from the spring, and would not be measurable or observable.

- **Dearden Spring Group.** Under current (or pre-Project pumping) conditions, Dearden Spring Group is reported to discharge at about 4,800 AFY (Table 3-3). Dearden Spring Group is located about 39 miles northwest of the proposed wellfield in Snake Valley. Spring flow would not be affected by project pumping until about 25 years after pumping stops and would slowly decrease over time. The maximum projected discharge depletion during the simulation period is about 6 AFY, approximately 200 years after pumping ceases. This depletion represents about 0.1% of the total discharge from the spring, and would not be measurable or observable.

- **Clay Spring.** Under current (or pre-Project pumping) conditions, the reported discharge rate at Clay Spring is about 260 AFY (Table 3-3). Clay Spring is located about 44 miles northwest of the proposed wellfield in Snake Valley. Spring flow would not be affected by project pumping until about 25 years after pumping stops and would slowly decrease over time. The maximum projected discharge depletion during the simulation period is about 0.5 AFY, approximately 200 years after pumping stops. This depletion represents about 0.2% of the total discharge from the spring, and would not be measurable or observable.

- **Fish Springs ET Area.** Under current (or pre-Project pumping) conditions, the reported discharge rate at the Fish Springs ET area is about 26,000 AFY (Table 3-3). Fish Springs is located about 100 miles northwest of the proposed wellfield in the Fish Springs Flat HA. Due to the distance of the spring from the well field, flow at Fish Springs would not be affected by the

PVWS Project until after pumping stops. Flows would begin to decrease about the time pumping stops and continue to slowly decrease for at least the next 200 years. The maximum projected discharge depletion during the simulation period is about 60 AFY, approximately 200 years after pumping ceases. This depletion represents about 0.2% of the total discharge from the spring, and would not be measurable or observable.

4.2.4.3 PREDICTED EFFECTS OF THE ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

Figure 4-12 shows regional and local springs relative to the extent of the area predicted to be affected by more than 1 foot of drawdown and the change in that area over time. As shown on the figure, regional springs in the Study Area are located in the Snake Valley HA northwest of the proposed PVWS Project wellfield and include Big Springs, Dearden Spring Group, and Clay Spring. Fish Springs is located a greater distance to the north-northwest. A total of 230 springs and seeps are reported in the USGS NHD as being located within the APE of the ANWS Alternative in the mountains surrounding Pine Valley. As stated above, most of the local springs and seeps in the NHD dataset do not have associated discharge data and are relatively small. Of the identified springs in the APE, only Wah Wah Springs is assumed to discharge water from, and be hydraulically connected with, the regional GBCAAS. This is the closest identified regional spring to the proposed PVWS wellfield. It is located in the Wah Wah Valley HA approximately 10 miles east of the proposed PVWS Project wellfield under the ANWS Alternative.

The predicted effects from the ANWS Alternative on the identified regional springs are discussed below. Based on the available data, it is not anticipated that the project will affect any local springs or seeps, but this possibility cannot be completely ruled out at this time. Therefore, Section 5.4 considers potential impacts to both local and regional spring resources.

A map view of predicted flow depletion effects on regional springs in the Study Area is presented as Figure 4-4. Graphs of the potential spring flow depletion effects of pumping for the ANWS Alternative are shown graphically in Figure 4-13. The following spring flow depletion effects are predicted using the GBCAAS-PV model:

- **Wah Wah Springs.** Under the ANWS Alternative, the wellfield would be shifted northward and projected spring flow depletion at Wah Wah Springs would be about 25 AFY greater than under the Proposed Action. Spring flow depletion would occur over roughly the same time period. The maximum projected spring flow depletion would be about 15% of the total spring discharge. As discussed in Section 4.2.4.2, only a portion of the discharge from Wah Wah Springs is likely derived from the regional aquifer, so the above estimates are likely conservative over-predictions.

- **Big Springs, Dearden Spring Group, Clay Spring and Fish Springs ET Area.** The predicted spring discharge depletion for the remaining regional springs in the Study Area and Fish Springs ET area is essentially the same as for the Proposed Action. Spring flow depletion at these springs would not be measurable or observable.

4.2.5 ET DISCHARGE DEPLETION

4.2.5.1 DESCRIPTION OF POTENTIAL EFFECTS

Groundwater extraction from new wells changes the groundwater budget in a basin, which must then adjust to a new equilibrium. The specific effect of introducing groundwater extraction from wells as a new discharge component is that ultimately groundwater discharge to other groundwater budget components must decrease. As discussed previously, groundwater levels in the Pine and Wah Wah Valley HAs are too deep for groundwater to discharge locally. Groundwater flows northward out of these basins in the subsurface and ultimately discharges by ET from phreatophytes and other groundwater-dependent vegetation around Sevier Lake and in the Tule Valley HA, where groundwater levels are closer to the ground surface. As groundwater level drawdown propagates northward from the proposed PVWS Project wellfield over time, groundwater levels would be expected to decline and ET discharge to decrease.

The PVWS Project will capture groundwater that would otherwise flow northward from the Pine and Wah Wah Valley HAs to Sevier Lake and the Tule Valley HA and discharge as ETg from phreatophytes and wet meadows. The GDAs around Sevier Lake and in the Tule Valley HA are shown on Figure 3-28 and were simulated in the GBCAAS-PV model as shown in Figure 3-29 and discussed in Appendix A. These GDAs are generally within the designated APE that is predicted to be affected by 1 foot or more of drawdown induced by the project. A recent study near Baker Ranch in Snake Valley demonstrated that greasewood shrubs (*S. vermiculatus*) were able to maintain groundwater connectivity during a period of steady, pumping-induced groundwater level decline from 2007 to 2013 (Devitt and Bird 2016). During this time, groundwater levels at the study site declined by approximately 1.3 meters (4.3 feet) and the plants were able to adapt and maintain groundwater connectivity without decline in plant health. Alkaline meadows represent a relatively small portion of the GDA in Tule Valley that may be in or near the APE, but may be more sensitive to drawdown. A compilation of studies conducted by TNC in the western United States that examined plant response of 17 herbaceous species (11 common and six rare) to groundwater drawdown indicated gradual loss of indicator species starting with as little as 0.66 feet (0.2 meters) of drawdown, with a median of 2.99 feet (0.91 meters), and complete loss at 6.23 feet (1.9 meters) (Gerla *et al.* 2015). A study of the effects of regulatory drawdown thresholds on inundation area and plant community composition in southeast Australia suggested that drawdowns from 0.82 feet (0.25 meters) to 0.98 feet (0.3 meters) represent a threshold where community composition is likely to change (Deane *et al.* 2017). The study setting was a regional unconfined aquifer with shallow groundwater levels and wetlands dependent on groundwater discharge, and included wetlands considered sensitive to even small declines in groundwater level. Thresholds were assigned based on ecological value, with higher functioning wetlands sensitive to changes assigned a threshold of up to 0.82 feet (0.25 meters) of acceptable drawdown over the course of five years; regional triggers were set at 1.64 feet (0.50 meters) over five years. This information indicates that a threshold of 1 foot of drawdown over a long period of time should be adequate to assess potential adverse effects to GDEs, including alkaline meadows.

In the model, ETg discharge from the modeled GDAs is decreased as groundwater levels fall until a preset extinction depth is reached that represents the assumed maximum rooting depth of the phreatophytes. Once groundwater levels fall below the extinction depth, the GDAs are assumed to be disconnected from

the aquifer and ETg is assumed to cease. It should be noted that use of a single extinction depth in the model does not account for the ability of phreatophytes to adjust to changing groundwater levels. This suggests that the GBCAAS-PV model may overpredict the rate and timing of ETg depletion.

4.2.5.2 PREDICTED EFFECTS OF THE PROPOSED ACTION

The predicted decrease in ETg discharge from the GDAs around Sevier Lake and in the Tule Valley HA due to implementation of the Proposed Action is graphed over time in Figure 4-14. The following ETg discharge effects are predicted using the GBCAAS-PV model:

- **Sevier Desert HA.** Under current (or pre-Project pumping) conditions, modeled ETg discharge from phreatophytes around Sevier Lake is about 1,500 AFY. ETg discharge would begin to decrease after about 50 years of pumping. The predicted decrease is expected to be gradual, and the depletion in ETg discharge would reach a maximum of 70 AFY about 300 years after project pumping stops, then begin to slowly recover. The maximum predicted depletion represents about 5% of the total annual modeled ETg discharge around Sevier Lake.

- **Tule Valley HA.** Under current (or pre-Project pumping) conditions, modeled ETg discharge in the Tule Valley HA is about 38,200 AFY. As in the Sevier Desert HA, ETg discharge would begin to decrease after pumping stops. For the next 250 years, ETg discharge would gradually increase until about 250 years after pumping stops, then begin to slowly recover. The maximum ETg discharge depletion would be about 300 AFY, which represents about 0.9% of the total modeled ETg discharge from phreatophytes and alkaline meadows in Tule Valley.

- **Milford Area HA.** Under current (or pre-Project pumping) conditions, the modeled ETg discharge in the Milford Area HA is about 32,000 AFY. ETg discharge would begin to decrease about 10 years after pumping stops. For the next 250 years, the area would experience a gradual depletion in ETg discharge. The maximum predicted ETg discharge depletion is about100 AFY, which represents 0.2% of the total ETg discharge in the Milford Area HA.

- **Snake Valley HA.** Under current (or pre-Project pumping) conditions, the modeled ETg discharge from phreatophytes in the Snake Valley is about 68,500 AFY. ETg discharge would begin to decrease about 30 years after pumping ceases. The predicted decrease would be negligible, with a maximum depletion of 12 AFY (0.02%) about 400 years after pumping stops.

4.2.5.3 PREDICTED EFFECTS OF THE ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

The predicted decrease in ETg discharge from the GDAs around Sevier Lake and in the Tule Valley HA due to implementation of the ANWS Alternative is graphed over time in Figure 4-15. The following ETg discharge effects are predicted using the GBCAAS-PV model:

- **Sevier Desert and Tule Valley HAs.** Under the ANWS Alternative, the wellfield would be shifted northward. As a result, g depletion in the Sevier Desert and Tule Valley HAs would be greater and would occur sooner. The predicted ETg discharge depletion around Sevier Lake would begin after about 30 years of pumping, would reach a maximum of 120 AFY (about 50 AFY more than under

the Proposed Action) about 100 years sooner. The maximum projected depletion would be about 8% of the total annual ETg discharge around Sevier Lake. Similarly, ETg depletion in the Tule Valley HA would begin after about 20 years of pumping and would increase to a maximum of about 600 AFY (almost twice as much as the Proposed Action) about 150 years sooner. The maximum ETg depletion in the Tule Valley HA would be about 1.5% of the total annual modeled ETg discharge.

- **Milford Area HA.** Under the ANWS Alternative, the projected ETg discharge depletion in the Milford Area HA would be less and would occur later than under the Proposed Action. Depletion amounts would represent less than 0.5% of the total ETg discharge from phreatophytes in this HA.

- **Snake Valley HA.** The maximum predicted ETg discharge depletion in the Snake Valley HA would remain negligible at less than 0.02% of the total ETg discharge in this area.

4.2.6 WATER QUALITY DEGRADATION

Development of a cone of depression in and around Pine Valley as a result of the PVWS Project would create a groundwater flow system centered on the Pine Valley HA that is internally drained. Such flow systems can foster a long-term increase in the concentration of TDS in the local aquifer system if the net inflow of solutes increases. Gardner *et al*. (2020) indicates that the TDS concentration of groundwater within the valley alluvial aquifer in the Pine Valley HA is higher than in the mountain aquifers. A net increase in solute inflow could occur if the balance between the amount of inflow from the regional aquifer system in adjacent HAs and potential recharge from mountain aquifers were to shift as a result of the PVWS Project. Given that groundwater extraction will result in a net increase in IBF into the Pine Valley HA, it is unlikely that TDS concentrations in the aquifer will increase as a result of proposed pumping.

Groundwater quality effects can also occur if zones or pockets of lower quality groundwater or degraded groundwater are induced to migrate as a result of groundwater extraction. It is likely that the Pine Valley Hardpan is underlain by salt accumulations from evaporative concentration, as is the case for numerous playas in the Great Basin. However, this portion of the valley is also most likely to be underlain by the greatest accumulation of fine-grained sediments in the basin, which would impede recharge and degradation of the underlying aquifer. Recharge from the Pine Valley Hardpan was assumed to be negligible and was neglected in GBCAAS v. 1.0 and 3.0. In addition, Gardner *et al*. (2020) found no evidence of zonal groundwater degradation or pockets of degraded groundwater in the basin fill aquifer in Pine Valley. As noted in Section 3.8.6, groundwater containing constituents in excess of their respective MCLs for drinking water has been identified in several wells in Pine Valley, but the detections were not spatially distributed in a way that suggests an area of degraded groundwater that could be mobilized by the PVWS Project. Groundwater extracted for the PVWS Project will be treated as necessary to comply with drinking water regulations.

The available data do not suggest groundwater quality would change as a result of implementing the PVWS Project. Nevertheless, in order to further characterize groundwater flow and recharge in the Pine Valley HA, groundwater quality monitoring for general mineral constituents, major anions and cations, deuterium and oxygen-18 will be conducted as part of the PVWS Wellfield Operation Monitoring and

Adaptive Management Program as discussed in Section 6.1.3. In addition, CICWCD will conduct water quality monitoring in accordance with applicable State and Federal requirements for its municipal water supply system.

4.2.7 SUBSIDENCE

4.2.7.1 DESCRIPTION OF POTENTIAL EFFECTS

Land subsidence can occur when compressible clays are depressurized as a result of groundwater extraction, triggering water to flow from the clays into the surrounding aquifer. Aquifers below laterally extensive lacustrine clay units are more susceptible to subsidence than unconfined aquifers because the head loss resulting from groundwater extraction is greater and clay units may be relatively more abundant. Younger, poorly consolidated clays are more susceptible than older formations. In general, most subsidence occurs when an aquifer is initially depressurized, but can continue for months, or even years, after clays slowly dewater and adjust to the new pressure regime. If groundwater levels subsequently recover, subsidence generally does not resume (or does not progress as rapidly), until groundwater levels fall below historical low levels.

The extent, distribution, and continuity of clay deposits in the basin fill sediments within Pine Valley has not been extensively characterized; however, inferences can be made regarding their likely distribution. In the geologic setting of Pine Valley, laterally extensive lacustrine clay deposits are most likely to be found in the northern portion of the valley, which represents the depositional low point of the basin and has the thickest accumulations of basin-fill sediment. The presence of at least some lacustrine deposits that accumulated during historically wetter time periods is likely in this area. Extensive clay deposits susceptible to subsidence are unlikely to occur in the alluvial fan deposits that ring the valley, or in valley axial stream deposits that underly the southern portion of the valley, because these are expected to be coarser grained and heterogeneous. However, during more extensive lacustrine depositional phases, lacustrine sediments could have been deposited farther south in the valley. In addition, it has been inferred that fine grained sediments weathered from the volcanic rocks of the southern Needle Range could have contributed more extensive fine-grained sediments to the southwestern portion of the valley. As such, the sediments underlying the north-central and southwest-central portions may be more susceptible to future subsidence than other areas of the valley.

In Escalante Valley and Cedar (City) Valley, subsidence was reported to be associated with groundwater level drawdowns somewhat exceeding 100 feet (Lund *et al*. 2005; Forster 2006; Knudsen *et al*. 2014). Based on available data for Escalante Valley and Cedar (City) Valley, the maximum subsidence reported in these valleys was about 3 feet, which is roughly 1 foot of subsidence per 30 feet of drawdown. The data are insufficient to establish a reliable correlation between predicted drawdowns and subsidence in Pine Valley, as such correlations depend on local geologic and geotechnical conditions that vary between basins and from place to place within a basin. Nevertheless, the subsidence history of nearby basins in a similar geologic setting provides a useful perspective regarding the general subsidence risk in the area.

4.2.7.2 PREDICTED EFFECTS OF THE PROPOSED ACTION

Wellfield Area. Simulation of pumping for the Proposed Action indicates that during the 50-year pumping period, a cone of depression would form around the wellfield in the southern portion of Pine Valley with predicted drawdowns exceeding 100 feet covering an area measuring approximately 7 by 12 miles, and predicted drawdowns between 50 and 100 feet covering an area of about 10 by 16 miles (Figure 4-1). These drawdowns are in the range of reported groundwater level declines associated with subsidence in other nearby basins. They occur in an area of Pine Valley where subsidence is relatively less likely; however, the possibility of some subsidence near the center of the valley where at least some lacustrine sediments may occur, or along the southwestern side of the valley where finer grained sediments from weathered volcanic rock may be present, cannot be ruled out, especially given the magnitude of the maximum drawdowns near the wellfield in this area. Groundwater levels in this area would reach a minimum after about 50 years and then recover after the pumps are turned off. It is possible that some residual subsidence could occur for a period of a few years after the cessation of pumping as subsurface materials and pressures equilibrate.

Northern Pine Valley. The amount of drawdown in the north-central part of Pine Valley, where the likelihood of significant accumulations of lacustrine clay strata susceptible to subsidence is the greatest, is predicted to be approximately 1 to 20 feet when pumping ceases. After pumping ceases, equilibration of the water table would result in additional drawdown in this area for a period of time. Maximum drawdowns of about 10 to 30 feet are possible, and minimum groundwater levels may not occur in some areas until over 100 years after the cessation of pumping. Thus, drawdown would be more limited in the portion of the valley where the potential for subsidence is judged to be greatest; however, with maximum drawdowns approaching 30 feet, the potential for some subsidence cannot be ruled out. The timing of such subsidence would be latent relative to the pumping period, and because the rate of groundwater level decline is predicted to be very slow in this area, the rate of subsidence may also be very slow.

4.2.7.3 PREDICTED EFFECTS OF THE ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

Wellfield Area. Simulation of pumping for the ANWS Alternative indicates that during the 50-year pumping period, an elongated cone of depression would form around the wellfield in the southern and central portions of Pine Valley with predicted drawdowns exceeding 100 feet covering two smaller areas measuring approximately 4 by 7 miles and 4 by 5 miles, and predicted drawdowns between 50 and 100 feet covering an area of about 7 by 20 miles (Figure 4-2). Because the wellfield would be more dispersed than under the Proposed Action, predicted maximum wellfield drawdowns would not be as great. However, these drawdowns would still be in the range of reported groundwater level declines associated with subsidence in other nearby basins. In addition, they would occur farther north than under the Proposed Action, and closer to the portion of the valley where the presence of more extensive lacustrine clays is more likely. The effects of this alternative near the wellfield would be to (1) lessen the maximum predicted drawdown, (2) induce greater drawdown in the central portion of Pine Valley, closer to the area of increased subsidence risk in the northern portion of the valley; and (3) decrease the extent of drawdown somewhat in the southern portion of the valley, where the risk of subsidence is lower, but cannot be ruled out due to the potential presence of at least some lacustrine sediments and the potential for finer grained sediments derived from weathered volcanic rocks. Similar to the Proposed Action,

groundwater levels near the wellfield area would reach a minimum after about 50 years and then recover after the pumps are turned off. It is possible that some residual subsidence could occur for a period of a few years after the cessation of pumping as subsurface materials and pressures equilibrate.

Northern Pine Valley. The amount of drawdown in the north-central part of Pine Valley, where the likelihood of significant accumulations of lacustrine clay strata susceptible to subsidence is the greatest, is predicted to be approximately 10 to 50 feet when pumping ceases. After pumping stops, equilibration of the water table would result in additional drawdown in the northern portion of this area for a period of time while groundwater levels would tend to recover relatively quickly in the southern portion of the area. Minimum groundwater levels may not occur in some of the northern areas until nearly 100 years after the cessation of pumping. Thus, drawdown would be greater under this alternative in the portion of the valley where the potential for subsidence is judged to be greatest, making subsidence more likely. In the northern portion of this area, the timing of such subsidence would be latent relative to the pumping period and may persist at a slow rate for a long period of time.

4.3 POTENTIAL CUMULATIVE EFFECTS

4.3.1 BACKGROUND AND APPROACH

NEPA requires federal agencies to consider the cumulative effects of proposals under their review. Cumulative effects are defined by the CEQ as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7).

This section describes the anticipated cumulative effects of the proposed PVWS Project and other historical, ongoing, and reasonably foreseeable groundwater extraction in nearby HAs in the Study Area. The rationale for the amount of groundwater pumping included in the cumulative effects analysis for each of these other HAs is summarized in Table 4-5. The derivation and application of specific pumping rates is further discussed in Appendix A.

TABLE 4-5. HYDROGRAPHIC AREAS AND PROJECTS INCLUDED IN CUMULATIVE EFFECTS ANALYSIS

Hydrographic Area	Rationale for Groundwater Extraction Rates Included in Cumulative Effects Analysis	Groundwater Demand
Pine Valley	Proposed PVWS Project has an approved water right of 15,000 AFY to develop a groundwater supply for CICWCD. Existing pumping in the Pine Valley HA is estimated to be 5 AFY (Stephens 1976).	15,005 AFY
Wah Wah Valley	Pumping from basin-fill aquifer wells is estimated at 1 to 2 AFY (Stephens 1974). There is no planned or reasonably foreseeable change in pumping in this HA.	2 AFY
Sevier Desert	Groundwater is relatively undeveloped in this HA within the APE of the PVWS Project. The CPM Project is approved to appropriate groundwater from a well field to supply water for potash processing facilities, administration facilities and dust suppression for a period of 30 years.	1,500 AFY

Hydrographic Area	Rationale for Groundwater Extraction Rates Included in Cumulative Effects Analysis	Groundwater Demand
Snake Valley / Hamlin Valley	An extensive modeling study of this area was recently completed (Masbruch 2019); therefore, pumping in the entire HA is simulated for the cumulative effects analysis using the model that was developed for this study. Total 2020 groundwater extraction for irrigation was estimated based on the methodology discussed in Section 3.9.5.2 and Appendix A, and was simulated at a constant rate for a period of 50 years as discussed further below. This estimate does not consider the net offsetting effect of deep percolation from applied irrigation water, and its application therefore allows for some future growth in groundwater demand.	28,700 AFY
Beryl-Enterprise Area	Total current and projected future pumping data for the HA were derived from the Utah DWRi water right database and reports prepared for the adopted GMP. A separate groundwater model of the area is not available, and the model developed by Masbruch (2019) was therefore used to simulate pumping from wells located within the APE. These simulated wells are located well north of the primary pumping center and cone of depression that lies in the Beryl-Enterprise HA. Perfected water rights for groundwater Points of Diversion within the APE are simulated in the cumulative effects analysis and total 3,196 AFY. The GMP for the Beryl-Enterprise HA decreases pumping in increments of 3,500 AFY until a safe yield of 34,000 AFY is reached in 2130; however, pumping in the APE is assumed not to decrease during the simulation period. This estimate does not consider the net offsetting effect of deep percolation from applied irrigation water, and its application therefore allows for some future growth in groundwater demand.	3,200 AFY
Other HAs	Pumping in Parowan Valley and in the Milford Area HA was assessed based on review of simulated drawdown presented in Brooks 2017. Drawdown associated with pumping in these areas did not intersect with predicted drawdown associated with the PVWS Project within the time frame of the cumulative impact analysis. For this reason, pumping in Parowan Valley and Milford Area HA was not considered in the cumulative impact analysis for this project	NA

The most extensive drawdown from non-project pumping that may interact with drawdown from pumping by the PVWS Project is expected to occur in Snake Valley. Masbruch (2019) performed a study to assess long-term groundwater level and discharge effects if all available groundwater rights in the Utah and Nevada portions of the Snake Valley HA were to be exercised. The study considered potential pumping associated with all approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in the Snake Valley HA, which were determined to comprise about 55,272 AFY as of February 2018. The study was performed on behalf of BLM and the National Park Service (NPS) to assess the potential ultimate long-term impacts to sensitive groundwater-dependent resources including key water supply wells, springs, spring complexes and mountain streams. Groundwater extraction was simulated assuming full utilization of all available groundwater rights for a sufficient time to reach steady state conditions. Brooks (2017) found that steady state conditions in response to pumping in the Pine and Wah Wah Valley HAs take a very long time to achieve (simulations were conducted for 1,000 to 5,000) because these valleys are located remote from recharge and discharge sources or are separated from them by hydrologic flow barriers. Snake Valley is located closer to both groundwater

recharge and discharge areas. The length of time to reach simulated steady state conditions in the Snake Valley HA is not known, but is likely shorter than in the Pine and Wah Wah Valley HAs; however, it may still take centuries to achieve. The report therefore states that "[t]his assessment provides a general understanding of the relative susceptibility of the groundwater resources of interest to the NPS and BLM, and the groundwater system in general, to existing and future groundwater development in the study area." As discussed in Section 1.2.3, such studies provide useful perspective on the general relative susceptibility of resources to drawdown impacts, but are too speculative to predict impacts. Drawdown impacts simulated by Masbruch (2019) ranged up to 649 feet in Snake Valley, and simulated drawdowns at sensitive sites ranged up to 159 feet. Significant groundwater discharge depletions were predicted at the majority of sensitive sites. Four regional springs were predicted to dry up completely. Of the three springs in Snake Valley located near the APE, Clay Spring was predicted to dry up completely, and discharge from Dearden Spring Group and Big Springs was predicted to be depleted by up to 81 and 46 percent, respectively.

Based on the study by Masbruch (2019), continuing pumping at the currently approved rates in Snake Valley will result in significant and irreversible adverse impacts to groundwater-dependent spring, wetland, stream and riparian resources. However, the timeframe of Masbruch's analysis is speculative because management intervention by the State of Utah and the State of Nevada to curtail pumping to rates that avoid, lessen or recover from such impacts would be reasonably expected to occur. The same conclusion was reached for a theoretical analysis based on 200 years of pumping at current rates in Snake Valley performed to provide perspective on scoping the impact analysis in this GRIA, as discussed in Section 1.4.3. For this reason, the cumulative impact analysis presented herein limits the duration of pumping in Snake Valley to the same duration and planning horizon as pumping for the PVWS Project – 50 years. In addition, our estimate of actual pumping in Snake Valley (Section 3.9.5.2) indicates that only about 68 percent of the available water rights were actually being exercised as of 2020. Because planning data that prescribe future pumping rates in Snake Valley were not available, for the cumulative impact modeling scenarios it was assumed that pumping would continue at 2020 rates for 50 years. As discussed in the subsequent sections, this rate and duration of pumping is still predicted to result in significant adverse impacts to groundwater-discharge-dependent resources in Snake Valley and may result in significant subsidence impacts. As such the cumulative impact analysis presented herein focuses on evaluating whether pumping for the PVWS project would potentially contribute to or expand such impacts in a cumulatively considerable way. This approach is consistent with the 50-year planning horizon within which mitigation or management actions must be implemented, if needed, for the PVWS Project to minimize or avoid potential groundwater-related impacts.

Cumulative pumping was simulated using the GBCAAS-PV model for pumping in the Pine Valley HA and the southern Sevier Desert HA. To simulate cumulative pumping in the Snake Valley HA and the Beryl Enterprise HA, the recently updated version of GBCAAS with refinements focused on Snake Valley and Hamlin Valley (Masbruch 2019) was utilized and was thought to represent the most refined modeling tool available to evaluate the effects of cumulative pumping in that area and in the northern portion of the Beryl-Enterprise Area HA. Pumping drawdown from multiple sources was considered additive, and drawdown predicted by these models at any particular point was summed to produce the cumulative

drawdown analysis. These drawdown analyses were conducted using a 50-year pumping period (30 years in the case of the CPM Project) and a 200-year recovery period. To capture the latency effect of pumping effects on spring flow and ETg discharge depletion, these effects were considered over a 450-year recovery period. The following specific additional assumptions were made:

- **Snake Valley HA.** It is reasonable to assume that changes in pumping in the Snake Valley HA will occur within the next 50 years to avoid potentially significant impacts to spring resources of regional environmental significance. A number of studies have been completed that indicate the potential for such impacts, and they are confirmed by a 200-year pumping simulation performed in support of scoping this GRIA as discussed in Section 1.4.3, as well as the cumulative effects analysis discussed below. For the cumulative impact analysis described herein, it was assumed that 2020 extraction rates will be held constant throughout the 50-year simulation period, but it is possible that future extraction rates will change to adapt to information from future studies regarding the long-term sustainability of groundwater supplies in the region. Thus, although groundwater pumping in the surrounding HAs is expected to persist for longer than 50 years, simulation of a specific extraction rate beyond this time frame was considered speculative.

  The assumed long-term pumping rate does not account for the net effect of groundwater recharge form the deep percolation of applied irrigation and assumes that all historically cultivated agricultural parcels will be irrigated every year. As such, it likely overestimates the current groundwater demand in the Snake Valley HA and may be considered to account for some future expansion.

- **Beryl-Enterprise Area HA.** Groundwater extraction in the northern portion of this HA is associated with irrigation at several isolated ranches. The total perfected water rights associated with this extraction are for approximately 3,200 AFY. These water rights are not scheduled to be retired under the GMP. For consistency with the simulation of groundwater extraction in the Snake Valley HA, these water rights were simulated for a period of 50 years. The assumed long-term pumping rate does not account for the net effect of groundwater recharge form the deep percolation of applied irrigation. As such, it likely overestimates the groundwater demand in the northern Beryl-Enterprise Area HA and may be considered to account for some future expansion.

- **Sevier Desert HA.** The CPM Project is permitted to extract groundwater for 30 years at a rate of 1,500 AFY, and was assumed to be pumping for that period and then cease pumping.

- **Other HAs.** Cumulative pumping in other HAs in the Study Area is anticipated to produce negligible effects. As such, it is neglected in the modeling of potential cumulative effects.

4.3.2 CUMULATIVE GROUNDWATER LEVEL DRAWDOWN

4.3.2.1 DESCRIPTION OF POTENTIAL CUMULATIVE EFFECTS

Because the aquifer system in the Study Area is regionally connected, drawdown at any particular point in the aquifer system is the sum of drawdowns imposed by all the cumulative pumping in the area. As such, pumping for the PVWS Project in Pine Valley would incrementally increase the drawdown related to

other nearby regional pumping. This increase would occur within the APE of the project. Similarly, other nearby regional pumping would incrementally increase the predicted drawdown induced by the PVWS Project within the Pine Valley HA. These incremental changes in the drawdown effects would change the total effects related to groundwater storage, IBF, interstate groundwater flows, spring discharge, ETg discharge, and potentially water quality and subsidence.

To evaluate the cumulative effects of regional groundwater pumping, cumulative drawdowns were simulated for the Proposed Action and the ANWS Alternative and are described in the following subsections. The implications of these drawdowns for other cumulative effects are discussed in subsequent sections. Consistent with the evaluation of the effects of the PVWS Project, drawdowns were assessed for a 50-year pumping period followed by 200 years of recovery.

4.3.2.2 PREDICTED CUMULATIVE EFFECTS OF THE PROPOSED ACTION

The distribution of drawdown over time associated with the Proposed Action is presented in Figure 4-1 and the distribution of drawdown associated with the Proposed Action and other cumulative pumping in the area is presented in Figure 4-16. By comparing the two figures, the following conclusions may be made about cumulative drawdown effects:

- **Pine Valley HA.** While it is true that cumulative pumping in the surrounding HAs would be expected to incrementally increase the drawdown within the Pine Valley HA, there is no observable change in the predicted drawdown in this area. This is because the Snake Valley HA is bounded to the east (toward the Pine Valley HA) by range front faults, volcanic rocks and steeply tilted siliciclastic rocks that impede groundwater exchange between these basins (USGS 2011). Pumping by wells in the northern portion of the Beryl-Enterprise Area HA is only about 3,000 AFY and affects a limited area. Similarly, pumping for the CPM Project affects a limited area in the southern Sevier Desert HA and the northern Wah Wah Valley HA.

- **Snake Valley HA.** Pumping in Snake Valley will result in a relatively large cone of depression in the Snake Valley HA around pumping centers located in agricultural areas around the communities of Baker and Garrison, and extending southward approximately to Big Spring Wash in Lincoln County, Nevada. Predicted drawdown between 10 and 50 feet underlies an area measuring approximately 10 by 35 miles. A small area within this depression measuring about 3 by 1 miles is predicted to experience drawdown between 100 and 500 feet. Recovery is predicted to be relatively rapid after pumping ceases, and the residual drawdown is predicted to be less than 10 feet within 75 years. The recovery of groundwater levels in Snake Valley is predicted to be more rapid than in Pine Valley because the pumping centers are relatively close to both recharge sources and discharge areas. The drawdown cone at the end of the simulated pumping is outside the area of drawdown that would be induced by the Proposed Action. Therefore, the Proposed Action would not add incrementally to the predicted drawdown in this area.

  A cone of depression is projected to form in southern Hamlin Valley with drawdown between 10 and 50 feet beneath an area measuring approximately 5 by 3 miles. Drawdown is predicted to recover to less than 10 feet within approximately 50 years after simulated pumping ceases. This

area lies outside the initial area of projected drawdown associated with the Proposed Action; however, as drawdown associated with the Proposed Action spreads laterally into southern Hamlin Valley after pumping ceases, it would commingle with residual drawdown in the local cone of depression and slow its recovery. In addition, drawdown in eastern Hamlin Valley would be about 1 to 5 feet greater as a result of the cumulative contribution from the Proposed Action.

- **Beryl-Enterprise Area HA.** A cone of depression is projected to be centered in the northern portion of the Beryl-Enterprise Area HA about 12 miles south of the Pine Valley HA due to local agricultural pumping. Drawdown is predicted to be between 10 and 50 feet beneath an area measuring about 1 by 3 miles. Groundwater drawdown in this area is predicted to recover to less than 10 feet within 10 years after pumping ceases. Published hydrographs for wells in the Beryl-Enterprise Area HA from USGS National Water Information System (NWIS) show that groundwater levels in the central area of the basin, south of the APE of the Proposed Action, have been declining since the 1940s. Drawdown induced by the Proposed Action after 50 years of pumping may add about a foot to the drawdown at the northern fringe of this cone of depression, about 6 miles south of the Pine Valley HA. As drawdown associated with the Proposed Action spreads southward into the northern Beryl-Enterprise Area HA during the recovery period, it may somewhat slow the recovery of residual drawdown induced by local pumping in this area, and add about 1 to 5 feet to the local drawdown.

- **Sevier Desert HA.** A cone of depression is projected to form in the southern portion of the Sevier Desert HA about 20 miles east of the Pine Valley HA due to pumping for the CPM Project. Drawdown is predicted to be between 10 and 50 feet beneath an area measuring about 8 by 4 miles at the end of 30 years of pumping. Several small areas where drawdown is predicted to be between 50 and 100 feet are located around the proposed well sites for this project. Groundwater drawdown in this area is predicted to recover to less than 10 feet within 70 years after pumping ceases. Drawdown associated with the Proposed Action is predicted to expand into this area about 150 to 200 years after pumping for the PVWS Project ceases, and would add about 1 to 2 feet of drawdown in this area.

- **Wah Wah Valley HA.** The Wah Wah Valley HA will be affected by drawdown associated with the the PVWS Project and the CPM Project; however, the two cones of depression are not predicted to intersect under the Proposed Action. For this reason, no cumulative effects will occur.

4.3.2.3 PREDICTED CUMULATIVE EFFECTS OF THE ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

The distribution of drawdown over time associated with the ANWS Alternative is presented in Figure 4-2 and the distribution of drawdown associated with the alternative and other cumulative pumping in the area is presented in Figure 4-17. By comparing the two figures, the following conclusions may be made about cumulative drawdown effects:

- **Pine Valley HA.** Similar to the Proposed Action, with the addition of cumulative pumping to the analysis of drawdown, there is no observable change in the predicted drawdown in Pine Valley.

- **Snake Valley HA.** As under the cumulative analysis for the Proposed Action, pumping in Snake Valley would result in a relatively large cone of depression near the communities of Baker and Garrison, which is predicted to recover relatively rapidly after pumping ceases. There is no observable difference in the extent or rate of recovery of this cone of depression between the cumulative analysis for the Proposed Action or the ANWS Alternative. Under the ANWS Alternative, the western fringe of the cone of depression resulting from pumping for the PVWS Project is predicted to interact with the eastern fringe of the cone of depression associated with pumping in Snake Valley, resulting in about 1 to 2 feet of additional cumulative drawdown near the boundary between the two HAs than when only PVWS pumping is considered.

  Similar to the cone of depression in Snake Valley, the cone of depression associated with pumping in Hamlin Valley may impose about 1 to 2 feet of additional drawdown in the southwest portion of the cone of depression that would form as a result of PVWS Project pumping near the boundary between the two HAs. The cumulative drawdown effect in this area would be less than under the Proposed Action.

- **Beryl-Enterprise Area HA.** Under the ANWS Alternative, 60% of the pumping is shifted farther to the north and, consequently, cumulative drawdowns in the northern portion of the Beryl-Enterprise Area HA would be less. The cone of depression associated with pumping in the northern portion of the Beryl-Enterprise Area HA would interact with the cone of depression resulting from PVWS pumping to add about a foot to the drawdown predicted in the area within about 6 miles south of the Pine Valley HA boundary.

- **Sevier Desert and Wah Wah Valley HAs.** Under the ANWS Alternative, the cone of depression associated with the PVWS Project would begin to interact with the cone of depression related to pumping for the CPM Project to produce about 1 foot of cumulative drawdown across northern Wah Wah Valley HA after about 30 years of pumping. The cone of depression associated with pumping for the CPM Project would remain relatively stable after this time and begin to decline; however, the cone of depression resulting from the PVWS Project would continue to expand northward and produce approximately 1 to 3 feet of additional drawdown across the northern Wah Wah Valley HA and the southern Sevier Desert HA. Cumulative drawdown exceeding 1 foot would extend approximately 3 to 5 miles farther to the north in the southern portion of the Sevier Desert HA.

4.3.3 Cumulative Storage Depletion and Water Budget Effects

4.3.3.1 Description of Potential Cumulative Effects

Regional drawdown and changes in groundwater flow induced by groundwater extraction can decrease the available groundwater storage, especially in the basin from which extraction occurs. Groundwater level declines can also make future groundwater development in a region more difficult or expensive by increasing the depth to which wells must be drilled and/or from which groundwater must be pumped. In addition, changes in groundwater flow would affect the water budgets of the adjacent HAs by causing changes in underflow between these basins and Pine Valley. The hydrologic effects related to regional

drawdown induced by the PVWS Project are discussed in the following sections, and potential impacts are discussed in Section 5.2.

4.3.3.2 PREDICTED CUMULATIVE EFFECTS OF THE PROPOSED ACTION

The effect of cumulative groundwater pumping for the Proposed Action on groundwater storage in the HAs in the Study Area is summarized below in Table 4-6. The contribution of the PVWS Project to cumulative depletion is also shown.

TABLE 4-6. CUMULATIVE GROUNDWATER STORAGE DEPLETION FOR THE PROPOSED ACTION

Hydrographic Area	Groundwater Storage Depletion After 50 Years Pumping			Groundwater Storage Depletion After 200 Years Recovery		
	PVWS Project (acre-feet)	Cumulative (acre-feet)	PVWS Project Percent of Cumulative	PVWS Project (acre-feet)	Cumulative (acre-feet)	PVWS Project Percent of Cumulative
Pine Valley	-717,100	-719,200	100%	-412,200	-417,400	99%
Wah Wah Valley	-3,800	-9,300	40%	-21,800	-23,700	92%
Snake Valley	-2,500	-450,300	1%	-43,300	-90,700	48%
Beryl-Enterprise Area *	-21,700	-57,200	38%	-79,200	-86,100	92%
Tule Valley	-200	-3,900	6%	-4,600	-5,900	79%
Milford Area	-100	-6,300	1%	-3,600	-4,700	78%
Sevier Desert	-500	-32,200	1%	-11,900	-14,400	83%
Total	**-745,900**	**-1,278,400**	**58%**	**-576,600**	**-642,900**	**90%**

* The cumulative storage depletion calculation for the Beryl-Enterprise Area HA includes only storage depletion from pumping in the northern portion of the area that is affected by the PVWS Project. The actual basin-wide storage depletion is much greater.

Approximately 56% of the cumulative storage depletion at the end of pumping would occur in the Pine Valley HA, 35% would occur in the Snake Valley HA, and the remaining 9% would occur in other HAs. The PVWS Project would account for almost all the groundwater taken out of storage in the Pine Valley HA during the pumping period; 96% of the groundwater taken out of storage by the PVWS Project would be removed from the Pine Valley HA and only 4% from the surrounding HAs. Conversely, pumping from sources other than the PVWS Project accounts for 95% of the cumulative storage depletion in the surrounding HAs. PVWS pumping would account for approximately 40% of the groundwater predicted to be taken out of storage in the Wah Wah Valley and Beryl-Enterprise HAs, and much lower percentages of the groundwater storage removed from the other HAs.

During the 200 years of recovery after pumping ceases, about 50% of the total projected cumulative storage depletion would be recovered. Approximately 53% of this recovery would occur in the HAs surrounding the Pine Valley HA, and 47% (about 300,000 acre-feet) would occur in Pine Valley. The water for the storage recovery in Pine Valley would be derived primarily by inflow of groundwater from the surrounding HAs as drawdown would continue to propagate into the surrounding area. This inflow would further deplete groundwater storage in the surrounding HAs while local groundwater depressions that

were formed by non-PVWS Project pumping are projected to recover relatively rapidly because they are located closer to recharge sources and discharge areas. The net result is that after 200 years, an increasing percentage of the total residual storage depletion would be attributable to the PVWS Project.

Predicted cumulative changes in IBF rates between the HAs in the Study Area under the Proposed Action were evaluated using the GBCAAS-PV model with the following conclusions:

- **Pine Valley HA to Beryl-Enterprise Area HA.** Pumping in the northern portion of the Beryl-Enterprise Area HA is relatively limited and wells are located several miles from its boundary with the Pine Valley HA. As a result, the cumulative pumping effects in this area would not substantially change the effects induced by pumping for the PVWS Project – the effects would be decreased by a maximum of about 6 AFY.

- **Pine Valley HA to Wah Wah Valley HA.** Pumping for the CPM Project will occur near the southern end of the Sevier Desert HA, approximately 20 miles east of the Pine Valley HA and across northern Wah Wah Valley. Pumping for this project will result in a slight offset of the IBF depletion predicted as a result of implementing the Proposed Action for the first 100 years after pumping starts. The maximum offset of IBF depletion would be about 30 AFY after 30 years of pumping. The net cumulative effect would be an IBF depletion of about 300 AFY 50 years after pumping starts. The maximum underflow depletion would remain about 700 AFY about 125 years after pumping ceases.

- **Pine Valley HA to Snake Valley HA.** IBF would begin to decrease about 10 years after pumping starts and after 50 years of pumping, IBF would decrease by about 100 AFY. The maximum underflow depletion of about 200 AFY would occur about 70 years after pumping ceases. From this point, IBF would begin to recover slowly, with about 65% of the recovery occurring by 450 years after pumping stops.

- **Wah Wah Valley HA to Sevier Desert HA.** IBF from the Wah Wah Valley HA into the Sevier Desert HA would increase as a result of CPM pumping by a maximum rate of approximately 400 AFY 30 years after pumping begins. After pumping ceases, IBF would decrease rapidly as a result of PVWS Project pumping and be depleted by a maximum of approximately 300 AFY about 250 years after pumping stops. From this point, IBF would begin to recover very slowly, with about one-third of the recovery occurring by 450 years after pumping stops.

- **IBF Between Other HAs.** Cumulative IBF between other HAs in the Study Area is not expected to be substantially different from IBF changes induced by the Proposed Action.

The above cumulative changes in IBF are only slightly different from the effects predicted for the Proposed Action alone. This is because hydraulic communication between the Snake Valley HA and the Pine Valley HA is likely impeded by the presence of range front faults, volcanic rocks, and a band of steeply tilted siliciclastic rocks (USGS 2011), and pumping in the northern Beryl-Enterprise Area HA and the southern Sevier Desert HA is relatively limited and located 10 to 20 miles from the Pine Valley HA boundaries.

With respect to interstate groundwater flow, as noted in Section 4.3.2.2, pumping in Snake Valley will produce a relatively large cone of depression along the center of the valley northwest of the Pine Valley HA. This cone of depression is predicted to extend for about 40 miles in a north-south direction and would affect both sides of the border between Nevada and Utah – groundwater may be drawn either eastwards or westwards across the state boundary by pumping in either state. The local effects of this pumping have not been evaluated, and are beyond the scope of analysis of this GRIA. It is unclear how interstate flows would be affected by this cone of depression, but the gradients, and hence the flows, that would be induced are expected to be much greater than those induced by the PVWS Project. As such, local pumping contributes to a much greater extent to the direction and extent of groundwater flow across the state boundary than the relatively small amount of drawdown predicted to be induced by the PVWS Project in Snake Valley. Because the effects of local pumping within Snake Valley on interstate flow have not been established, it is not clear whether flow changes induced by the PVWS Project would incrementally increase or decrease the locally-induced flow.

4.3.3.3 PREDICTED CUMULATIVE EFFECTS OF THE ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

The effect of cumulative groundwater pumping for the ANWS Alternative on groundwater storage in the HAs in the Study Area is summarized below in Table 4-7. The contribution of the PVWS Project to cumulative depletion is also shown.

TABLE 4-7. CUMULATIVE GROUNDWATER STORAGE DEPLETION FOR THE ANWS ALTERNATIVE

Hydrographic Area	Groundwater Storage Depletion After 50 Years Pumping			Groundwater Storage Depletion After 200 Years Recovery		
	PVWS Project (acre-feet)	Cumulative (acre-feet)	PVWS Project Percent of Cumulative	PVWS Project (acre-feet)	Cumulative (acre-feet)	PVWS Project Percent of Cumulative
Pine Valley	-715,700	-717,700	100%	-397,900	-403,000	99%
Wah Wah Valley	-9,800	-15,400	64%	-30,400	-32,300	94%
Snake Valley	-1,900	-449,600	0%	-33,800	-81,300	42%
Beryl-Enterprise Area *	-9,400	-44,900	21%	-41,200	-48,100	86%
Tule Valley	-2,200	-5,900	38%	-7,800	-9,100	86%
Milford Area	-300	-6,400	4%	-3,200	-4,300	75%
Sevier Desert	-4,600	-36,300	13%	-21,300	-23,700	90%
Total	**-743,900**	**-1,276,200**	**58%**	**-535,600**	**-601,800**	**89%**

* The cumulative storage depletion calculation for the Beryl-Enterprise Area HA includes only storage depletion from pumping in the northern portion of the area that is affected by the PVWS Project. The actual basin-wide storage depletion is much greater.

Under the ANWS Alternative, cumulative storage depletion at the end of the pumping period would be similar to the Proposed Action. The amount of storage depletion predicted for the Pine and Snake Valley HAs would be unchanged from the Proposed Action; however, the distribution of the storage depletion

in the surrounding HAs, which accounts for 9% of the total forecasted storage depletion volume, would be shifted northward. Under this alternative, more storage depletion would be experienced by the Wah Wah and Tule Valley HAs, and less by the Beryl-Enterprise Area HA.

During the 200 years after pumping ceases, the amount of storage recovery would be slightly greater than under the Proposed Action (53% vs. 50%); however, the amount of storage recovery in Pine Valley would only increase slightly (13,000 acre-feet). The remainder of the storage recovery would occur as a result of the northward shift of drawdown effects under this alternative.

Predicted cumulative changes in IBF rates between the HAs in the Study Area under the ANWS Alternative were evaluated using the GBCAAS-PV model with the following conclusions:

- **Pine Valley HA to Beryl-Enterprise Area HA.** Pumping in the northern portion of the Beryl-Enterprise Area HA is relatively limited and would not substantially change the effects induced by pumping for the PVWS Project – the effects would be decreased by a maximum of about 6 AFY.

- **Pine Valley HA to Wah Wah Valley HA.** Pumping for the CPM Project would result in a slight offset of the IBF depletion predicted as a result of implementing the ANWS Alternative for the first 100 years after pumping starts. The maximum offset of IBF depletion would be about 30 AFY after 30 years of pumping. The net cumulative effect would be an IBF depletion of about 975 AFY 50 years after pumping starts. The maximum underflow depletion would be about 1,200 AFY about 30 years after pumping ceases.

- **Pine Valley HA to Snake Valley HA.** IBF would begin to decrease about 10 years after pumping starts and after 50 years of pumping, IBF would be decreased by about 100 AFY. The maximum underflow depletion of about 200 AFY would occur about 70 years after pumping ceases. From this point, IBF would begin to recover slowly, with about 65% of the recovery occurring by 450 years after pumping stops.

- **Wah Wah Valley HA to Sevier Desert HA.** IBF from the Wah Wah Valley HA into the Sevier Desert HA would increase as a result of CPM pumping by a maximum rate of approximately 400 AFY 30 years after pumping begins. This increase would offset some of the early decrease in IBF depletion induced by the ANWS Alternative. After pumping ceases, IBF would decrease rapidly as a result of PVWS Project pumping and be depleted by a maximum of approximately 500 AFY about 60 years after pumping stops. From this point, IBF would begin to recover very slowly, with about 60% of the recovery occurring by 450 years after pumping stops.

- **IBF Between Other HAs.** Cumulative IBF between other HAs in the Study Area is not expected to be substantially different from IBF changes induced by the Proposed Action.

The above cumulative changes in IBF are only slightly different from the effects predicted for the Proposed Action.

With respect to the potential cumulative effect of the ANWS Alternative on interstate groundwater flow, as noted in Section 4.3.2.2, pumping in Snake Valley would produce a relatively large cone of depression

along the center of the valley northwest of the Pine Valley HA. This cone of depression is predicted to extend for about 40 miles in a north-south direction and would affect both sides of the border between Nevada and Utah – groundwater may be drawn either eastwards or westwards across the state boundary by pumping in either state. The local effects of this pumping have not been evaluated, and are beyond the scope of analysis of this GRIA. It is unclear how interstate flows would be affected by this cone of depression, but the gradients, and hence the flows, that would be induced are expected to be much greater than those induced by the PVWS Project. As such, local pumping contributes to a much greater extent to the direction and extent of groundwater flow across the state boundary than the relatively small amount of drawdown predicted to be induced by the ANWS Alternative in Snake Valley. Because the effects of local pumping within Snake Valley on interstate flow have not been established, it is not clear whether flow changes induced by the ANWS Alternative would incrementally increase or decrease the locally-induced flow.

4.3.4 CUMULATIVE INTERFERENCE DRAWDOWN TO EXISTING WELLS

4.3.4.1 DESCRIPTION OF POTENTIAL CUMULATIVE EFFECTS

Interference drawdown is a cumulative effect that is the sum of drawdown induced by all nearby wells whose radius of influence extends to a well location. Cumulative interference drawdown would be greater than the drawdown predicted for the PVWS Project alone in areas where the cones of depression for pumping in adjacent HAs intersect with the cone of depression for the PVWS Project wellfield. The discussion below is focused on identifying wells where cumulative interference drawdown may exceed 15 feet within 50 years of beginning pumping.

4.3.4.2 PREDICTED CUMULATIVE EFFECTS OF THE PROPOSED ACTION

Drawdown predicted to be induced by the Proposed Action is presented in Figure 4-1. Cumulative drawdown associated with the Proposed Action and other nearby pumping is shown on Figure 4-16. Drawdown under the Proposed Action in individual wells within the Pine Valley HA is predicted to range from 20 to as much as 120 feet (Table 4-3). Drawdown induced by simulated pumping in the Snake Valley HA, the Beryl-Enterprise Area HA and the Sevier Desert HA is not predicted to reach identified well locations within the Pine Valley HA. Therefore, these wells would only be affected by drawdown from the PVWS Project.

The Proposed Action would induce a drawdown cone that intersects with the eastern flank of a cone of depression predicted to form in the center of the Snake Valley HA and near the southern end of Hamlin Valley and several smaller cones of depression predicted to form in the northern part of the Beryl-Enterprise Area HA. The cumulative drawdown in the areas of intersection, shown on Figure 4-18, is predicted to be less than 15 feet in Snake and Hamlin Valleys, as shown by the yellow shading. The drawdown is predicted to be greater than 15 feet in the Beryl-Enterprise Area HA as shown by the red shading. Three wells within the northern Beryl-Enterprise Area HA are predicted to be affected, and estimated drawdowns for these wells are listed in Table 4-8. A cone of depression is projected to form in the southern portion of the Sevier Desert HA east of the Pine and Wah Wah Valley HAs due to pumping for the CPM Project. The cumulative drawdown in the area of intersection between the cone of depression

for this pumping and drawdown induced by the PVWS Project is predicted to be less than 15 feet (Figure 4-18).

TABLE 4-8. PREDICTED CUMULATIVE DRAWDOWN AT UNDERGROUND POINTS OF DIVERSION FOR PROPOSED ACTION

Water Right	Drawdown During 50 Years Pumping (feet)				
	10 Years	20 Years	30 Years	40 Years	50 Years
71-271	1.66	4	8	8	17
71-1083	6.95	10	12	12	17
71-2264	6.95	10	12	12	17

4.3.4.3 PREDICTED CUMULATIVE EFFECTS OF THE ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

Drawdown predicted to be induced by the ANWS Alternative is presented in Figure 4-2. Cumulative drawdown associated with the ANWS Alternative and other nearby pumping is shown on Figure 4-17. Drawdown induced by simulated pumping under the ANWS Alternative in individual wells within the Pine Valley HA is predicted to range from 20 to as much as 50 feet (Table 4-4). Drawdown predicted to be induced by simulated pumping in the Snake Valley HA, the Beryl-Enterprise Area HA and the Sevier Desert HA is not predicted to reach identified well locations within the Pine Valley HA. Therefore, these wells would only be affected by drawdown from the PVWS Project.

The ANWS Alternative would induce the drawdown cone that intersects with the eastern flank of a cone of depression predicted to form near the southern end of Hamlin Valley, but to a lesser extent than the Proposed Action. In addition, drawdown associated with the ANWS Alternative would extend into the Snake Valley HA and interact with the eastern flank of a cone of depression predicted to form there. As shown on Figure 4-19, the cumulative drawdown in both areas of intersection is predicted to be less than 15 feet. Because 60% of the groundwater production wells would be shifted northward under this alternative, cumulative drawdown in the northern Beryl-Enterprise Area HA is also predicted to be less than 15 feet. The intersections of the drawdown cones are shown on Figure 4-19. Because the well field would be shifted northward under the ANWS Alternative, the drawdown cone for the PVWS Project would intersect the cone of depression in the southern portion of the Sevier Desert HA projected to form due to pumping for the CPM Project to a larger extent than under the Proposed Action. However, the cumulative drawdown is predicted to be less than 15 feet in the Sevier Desert HA (Figure 4-19). No existing wells are predicted to be affected by cumulative interference drawdown under the ANWS Alternative.

4.3.5 CUMULATIVE SPRING FLOW DEPLETION

4.3.5.1 DESCRIPTION OF POTENTIAL CUMULATIVE EFFECTS

Regional springs in the Study Area may experience cumulative discharge depletion effects from pumping in the area. The most pronounced effects will be in the areas within the extents of measurable predicted drawdown (about 1 foot); however, spring discharge can be affected even outside these areas, so regional springs throughout the Study Area are considered. Of special interest to the cumulative effects evaluation are regional springs in the Snake Valley HA because they are located within the area of predicted drawdown from pumping in Snake Valley, and so may experience measurable drawdown. Fish Springs and Wah Wah Springs are located at greater distance from the pumping centers outside of the Pine Valley HA

that are evaluated in the cumulative effects analysis, and are less likely to be affected. Based on the available data, local springs are not anticipated to be affected by cumulative drawdown in the regional aquifer system; however, this cannot be conclusively established until the aquifer system is stressed by pumping for the PVWS Project.

4.3.5.2 PREDICTED CUMULATIVE EFFECTS OF THE PROPOSED ACTION

The predicted cumulative effects under the Proposed Action on the identified regional springs are discussed below. As shown on Figure 4-16, Big Springs, Dearden Spring Group, and Clay Spring in Snake Valley are located within the predicted area of cumulative drawdown in a groundwater depression that is projected to form as a result of future groundwater pumping in that area. Comparison of Figure 4-1 and Figure 4-16 indicates that Wah Wah Springs is located well outside the area predicted to be affected by cumulative drawdown changes. Fish Springs is a regionally important spring discharge area located north of the Study Area. The potential cumulative spring flow depletion effects to these springs is discussed below. Cumulative spring flow depletion effects to Big Springs, Dearden Spring Group, and Clay Spring that were predicted using the GBCAAS-PV model are shown graphically in Figure 4-20. The effects of PVWS pumping and cumulative project pumping on spring flow depletion are shown separately with separate scales to provide insight into the cumulative contribution of each depletion source.

- **Wah Wah Springs.** Wah Wah Springs is located remote from groundwater pumping centers in the Snake Valley HA, the northern part of the Beryl-Enterprise Area HA and southern part of the Sevier Desert HA. As such, it is not predicted to experience drawdown effects associated with pumping in these areas and cumulative spring flow depletion will be the same as discussed in Section 4.2.4.2.

- **Clay Spring.** Under current conditions, the discharge rate at Clay Spring is about 300 AFY (Table 3-3). Stresses from nearby pumping in Snake Valley are predicted to decrease discharge from this spring relatively rapidly, beginning when pumping starts and drying up the spring after about 50 years of pumping. Discharge would begin to recover relatively rapidly after simulated pumping ceases, with about 90% of the recovery occurring within 50 years. Spring flow depletion predicted to be induced by the PVWS Project would begin slowly after pumping ceases and would not be measurable or observable (approximately 0.5 AFY or 0.2% of total discharge after 200 years).

- **Dearden Spring Group.** Under current conditions, Dearden Spring Group discharges at about 4,800 AFY (Table 3-3). Stresses from nearby pumping in Snake Valley are predicted to decrease discharge from this spring relatively rapidly, beginning when pumping starts and reaching a maximum depletion of approximately 2,500 AFY after 50 years of pumping. This represents about 52% of the total reported discharge. Discharge would begin to recover relatively rapidly after simulated pumping ceases, with over 90% of the recovery occurring within 50 years. Spring flow depletion predicted to be induced by the PVWS Project would begin slowly after pumping ceases and would not be measurable or observable (approximately 6 AFY or 0.1% of total discharge after 200 years).

- **Big Springs.** Under current conditions, the reported discharge rate at Big Springs is about 7,400 AFY (Table 3-3). Stresses from nearby pumping in Snake Valley are predicted to decrease discharge from this spring relatively rapidly, beginning when pumping starts and reaching a maximum depletion of approximately 1,600 AFY after 50 years of pumping. This represents about 22% of the total reported discharge. Discharge would begin to recover relatively rapidly after simulated pumping ceases, with about 75% of the recovery occurring within 50 years. Spring flow depletion predicted to be induced by the PVWS Project would begin slowly after pumping ceases and would not be measurable or observable (approximately 75 AFY or 1% of total discharge after 200 years).

- **Fish Springs Area.** Under current conditions, the discharge rate at the Fish Springs Area is about 26,000 AFY (Table 3-3). Stresses from nearby pumping in Snake Valley are predicted to decrease discharge from this spring relatively rapidly, beginning when pumping starts and reaching a maximum depletion of approximately 60 AFY after 50 years of pumping. Recovery would begin after simulated pumping ceases and would be about 80% complete after 200 years. Spring flow depletion predicted to be induced by the PVWS Project would begin slowly after pumping ceases and increase to about 50 AFY after 200 years. The cumulative spring flow depletion from pumping in Snake Valley and the Proposed Action would be less than 0.2% of the total reported spring discharge and would not be measurable or observable.

4.3.5.3 Predicted Cumulative Effects of the Adaptive Northern Well Sites Alternative

The predicted cumulative effects under the ANWS Alternative on the identified regional springs would be similar to the cumulative effects under the Proposed Action. Depletion of Wah Wah Springs discharge would be dominated by pumping by the PVWS Project and would be somewhat greater under this alternative as discussed in Section 4.2.3.3. The contribution of the PVWS Project to discharge depletion at Big Springs, Dearden Spring Group, Clay Spring and the Fish Springs would be similar to that discussed for the Proposed Action and would not be measurable or observable.

4.3.6 Cumulative ET Discharge Depletion

4.3.6.1 Description of Potential Cumulative Effects

Regional ETg discharge in the Study Area occurs via phreatophytes and local alkali meadows, and may experience cumulative discharge depletion effects from pumping in the area. The most pronounced effects will be in the areas within the extents of measurable predicted drawdown (about 1 foot) from pumping within the HAs in which they occur, and to a lesser extent from pumping in nearby basins. The locations of ETg discharge areas included in the GBCAAS-PV model are shown on Figure 3-29.

4.3.6.2 Predicted Cumulative Effects of the Proposed Action

The predicted cumulative decrease in ETg discharge from the GDAs around Sevier Lake and in the Tule Valley and Snake Valley HAs due to implementation of the Proposed Action is graphed over time in Figure 4-21. The following ET discharge effects are predicted:

- **Sevier Desert HA.** Under current conditions, modeled ETg discharge from phreatophytes around Sevier Lake is about 1,500 AFY. ETg discharge in this area would be affected by the PVWS Project and pumping for the CPM Project. ETg discharge decline induced by the PVWS Project would begin about 20 years after pumping stops and would reach a maximum depletion of 100 AFY about 300 years after project pumping stops, then begin to slowly recover. ETg depletion associated with the CPM Project would begin shortly after pumping starts. The maximum predicted depletion induced by the CPM Project would occur about 10 years after pumping stops. This would represent the maximum cumulative depletion, and would be about 8% of the total annual modeled ETg discharge around Sevier Lake.

- **Tule Valley HA.** Under current conditions, modeled ETg discharge in the Tule Valley HA is about 38,000 AFY. ETg discharge in this area would be affected by the PVWS Project and, to a lesser extent, by pumping for the CPM Project and in the Snake Valley HA. ETg discharge decline induced by the PVWS Project would begin about 20 years after pumping stops and would reach a maximum depletion of 400 AFY about 250 years after project pumping stops, then begin to slowly recover. ETg depletion associated with the CPM Project and pumping in Snake Valley would begin about 10 years after pumping starts and reach a maximum of about 150 and 100 AFY, respectively, about 20 years after pumping stops. The predicted cumulative depletion at this time would be about 300 AFY and would increase to about 400 AFY 250 years after pumping stops. The maximum cumulative depletion represents about 1% of the total annual modeled ETg discharge in the Tule Valley HA.

- **Snake Valley HA.** Under current conditions, the modeled ETg discharge from phreatophytes in the Snake Valley HA is about 68,500 AFY. ETg discharge in this area would be affected primarily by pumping in Snake Valley. The maximum predicted ETg depletion effect from the PVWS Project would be 10 AFY approximately 400 years after pumping stops, which is a negligible contribution. ETg depletion induced by local pumping is predicted to begin shortly after pumping begins and increase relatively rapidly to a maximum of 15,000 AFY after 50 years of pumping, after which it would recover relatively rapidly. Over 90% of recovery is predicted to occur within 50 years after stopping pumping.

- **Milford Area HA.** Based on the distance between the cumulative pumping evaluated in this study and the Milford Area HA, and considering regional groundwater flow patterns, cumulative ETg depletion effects are not expected in this HA, and were not evaluated.

4.3.6.3 Predicted Cumulative Effects of the Adaptive Northern Well Sites Alternative

The predicted decrease in ETg discharge from the GDAs around Sevier Lake and in the Tule Valley and Snake Valley HAs due to implementation of the ANWS Alternative graphed over time in Figure 4-21. The following ETg discharge effects are predicted:

- **Sevier Desert HA.** Under the ANWS Alternative, ETg depletion by the PVWS Project would begin earlier and be greater than under the Proposed Action. ETg discharge decline induced by the PVWS Project would begin after about 40 years of pumping and would reach a maximum

depletion of 100 AFY about 200 years after project pumping stops, then begin to slowly recover. The net effect of this change would be to increase the maximum cumulative ETg depletion slightly, to about 130 AFY. The maximum cumulative ETg depletion would still occur about 10 years after pumping stops.

- **Tule Valley HA.** Similar to the Sevier Desert HA, under the ANWS Alternative, ETg depletion by the PVWS Project would begin earlier and be greater than under Proposed Action. ETg discharge decline induced by the PVWS Project would begin after about 30 years of pumping and would reach a maximum depletion of 600 AFY about 150 years after project pumping stops, then begin to slowly recover. The net effect would be an increase in the cumulative ETg depletion to about 500 AFY 20 years after pumping stops, increasing to a maximum of about 700 AFY 150 years after pumping stops. The maximum cumulative depletion would increase to about 2% of the total annual modeled ETg discharge in the Tule Valley HA.

- **Snake Valley HA.** Under the ANWS Alternative, the amount of ETg depletion predicted to be induced by the PVWS Project would be similar to the Proposed Action and also negligible (approximately 20 AFY). As such, the predicted cumulative ETg depletion effects would be the same as under the Proposed Action.

- **Milford Area HA.** Based on the distance between the cumulative pumping evaluated in this study and the Milford Area HA, and considering regional groundwater flow patterns, cumulative ETg depletion effects are not expected in this HA, and were not evaluated

4.3.7 CUMULATIVE WATER QUALITY DEGRADATION

Cumulative pumping for the PVWS Project, combined with pumping for agriculture or water supply projects in other HAs would develop individual cones of depression in each of the HAs that would merge over time resulting in increased cumulative drawdown in the areas of intersection and either increased or decreased gradients, depending on the interaction. The distribution of cumulative drawdown shown in Figure 4-16 and Figure 4-17 does not indicate the formation of any gradients that would mobilize or capture known or suspected areas of degraded water quality, such as groundwater underlying salt playas. No cumulative water quality effects are anticipated to occur.

4.3.8 CUMULATIVE SUBSIDENCE EFFECTS

Cumulative pumping for the PVWS Project, combined with pumping for agriculture and water supply projects in other HAs would develop individual cones of depression in each of the HAs that would merge over time resulting in increased cumulative drawdown in the areas of intersection. Greater drawdown would potentially make these areas of intersection more vulnerable to subsidence if compressible clays are present in the subsurface. The distribution of predicted drawdown induced by the PVWS Project under the Proposed Action and the ANWS Alternative is presented in Figure 4-1 and Figure 4-2, respectively, and the distribution of predicted cumulative drawdown is presented in Figure 4-16 and Figure 4-17, respectively. The magnitude and distribution of cumulative drawdown is discussed in Section 4.3.2.

Areas of groundwater level depression from pumping in other HAs are predicted to interact with groundwater drawdown induced by the PVWS project to produce cumulative drawdowns that are mostly in the range of 1 to 10 feet, but may be greater in some locations. Induced cumulative drawdowns exceeding 10 feet are predicted to occur in the regional aquifer beneath the mountain blocks and in the upper to middle portions of the alluvial fans. In the valley floor areas of the HAs surrounding the Pine Valley HA, the PVWS Project might increase drawdown by 1 to 3 feet in some areas. Similarly, drawdown induced in the Pine Valley HA by pumping in the surrounding HAs is predicted to be 1 to 5 feet beneath some of the mountain block areas in the Needle Range.

Based on the information above, cumulative drawdown that could cause subsidence is expected to be confined to areas where sediments potentially susceptible to subsidence are not expected to occur. Similarly, incremental cumulative drawdown increases in areas where such sediments may be present are insufficient to change the amount of subsidence that would result from locally caused drawdown. As such, no cumulative subsidence effects are expected.

Well & Spring Locations

10 Years Pumping

20 Years Pumping

30 Years Pumping

40 Years Pumping

50 Years Pumping

10 Years Recovery

20 Years Recovery

50 Years Recovery

75 Years Recovery

150 Years Recovery

200 Years Recovery

Legend

- Regional Spring
- PVWS Project Well
- Hydrographic Area
- Project Pipeline Alignment
- Focused Model Area
- ET Zones

0 12.5 25 50 Miles

N

Maximum drawdown (ft)

- < 1'
- 1' - 2'
- 2' - 3'
- 3' - 5'
- 5' - 10'
- 10' - 50'
- 50' - 100'
- 100' - 500'
- > 500'

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-1

SIMULATED DRAWDOWN AND RECOVERY FOR PROPOSED ACTION

DATE: DEC 29, 2020

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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Well & Spring Locations

10 Years Pumping

20 Years Pumping

30 Years Pumping

40 Years Pumping

50 Years Pumping

10 Years Recovery

20 Years Recovery

50 Years Recovery

75 Years Recovery

150 Years Recovery

200 Years Recovery

Legend

- Regional Spring
- Hydrographic Area
- Focused Model Area
- ET Zones
- Startup pumping well
- ANWS Alternative Well
- Project Pipeline Alignment

0 12.5 25 50 Miles

N

Maximum drawdown (ft)

- < 1'
- 1' - 2'
- 2' - 3'
- 3' - 5'
- 5' - 10'
- 10' - 50'
- 50' - 100'
- 100' - 500'
- > 500'

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-2

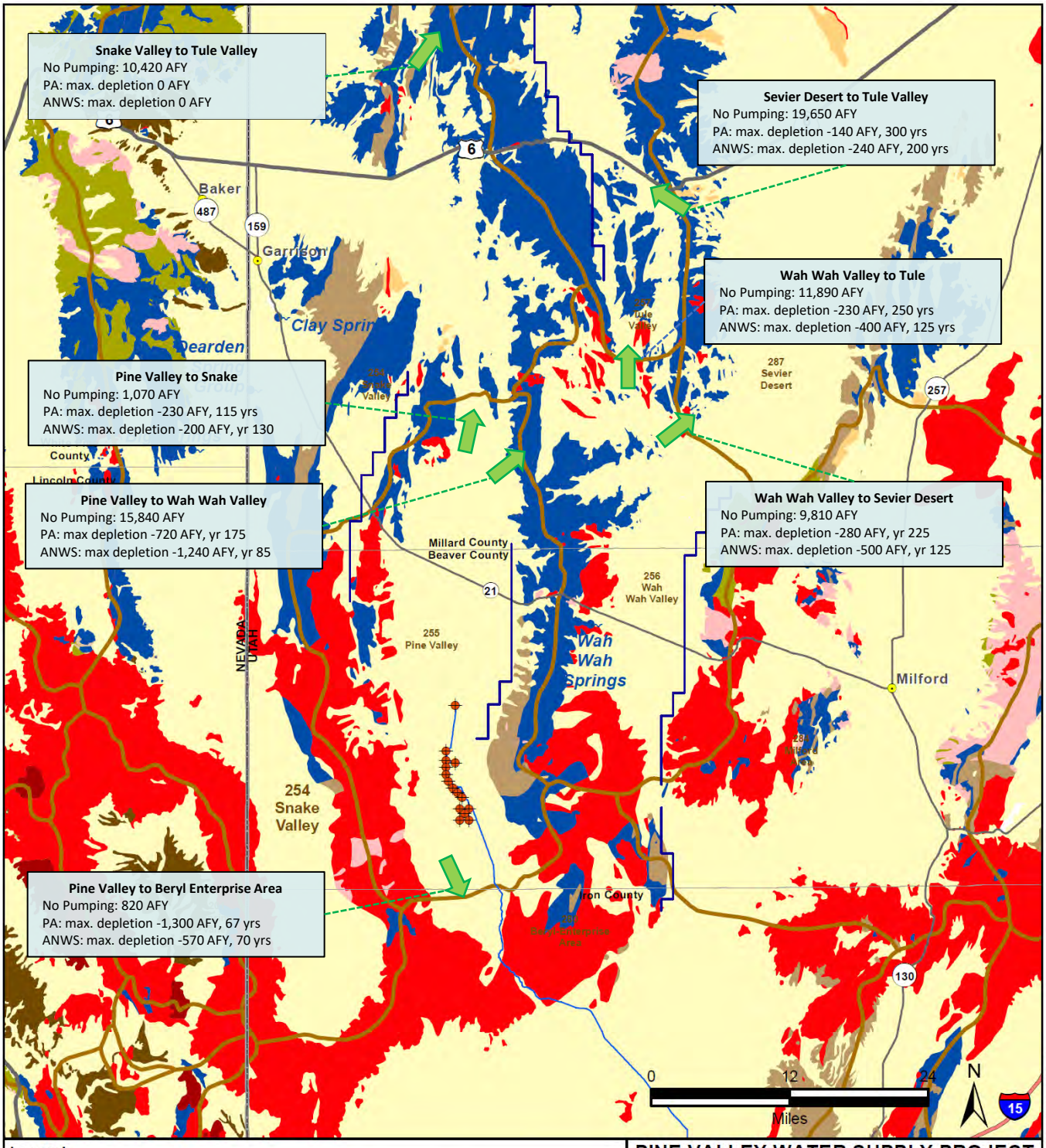
SIMULATED DRAWDOWN AND RECOVERY FOR ANWS ALTERNATIVE

DATE: DEC 29, 2020

BY: CRL FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- PVWS Project Well
- Project Pipeline Alignment
- GBCAAS v. 3.0 Fault/Flow Barrier
- Hydrographic Area
- Volcanic unit
- Carbonate aquifer unit
- Non-carbonate confining unit
- Upper siliciclastic confining unit

PA: Proposed Action
ANWS: Adaptive Northern Well Field

DRAFT

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-3

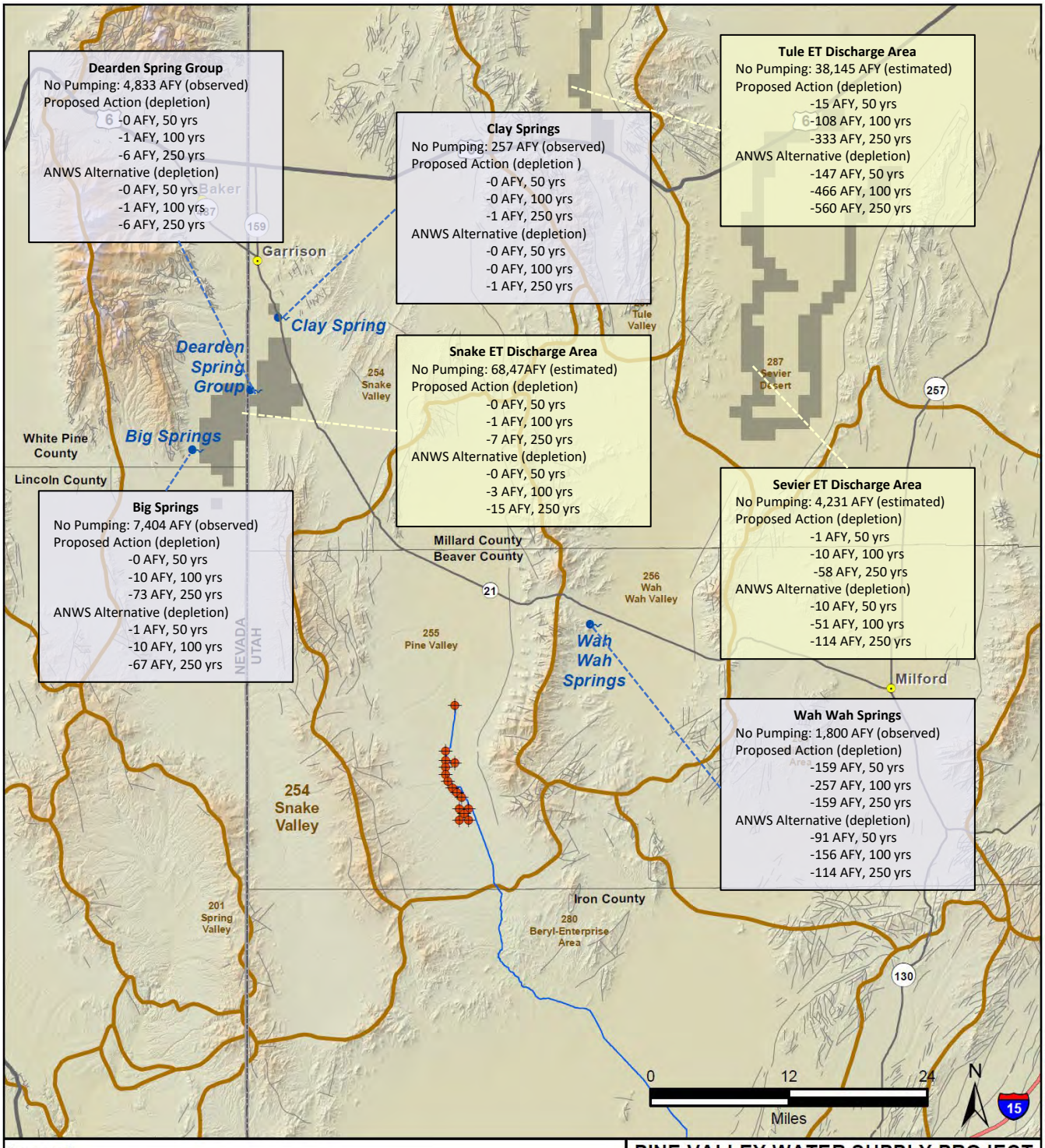
PROPOSED ACTION AND ANWS ALTERNATIVE EFFECTS ON INTER-BASIN FLOWS

DATE: MAY 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- PVWS Project Well
- Regional Spring
- Project Pipeline Alignment
- Faults (Horton et al. 2017)
- Hydrographic Area

ANWS: Adaptive Northern Well Field

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PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-4

PROPOSED ACTION AND ANWS ALTERNATIVE EFFECTS ON DISCHARGE

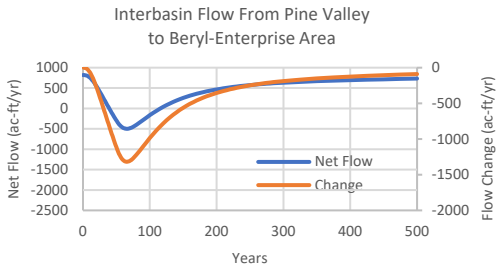
DATE: MAY 19, 2021

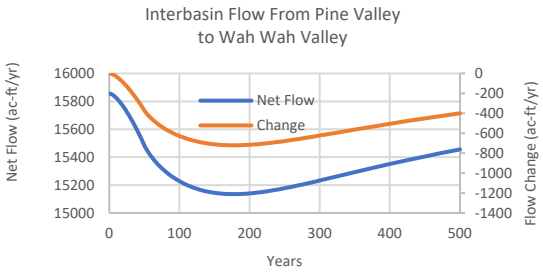
BY: CRL | FOR: PHT

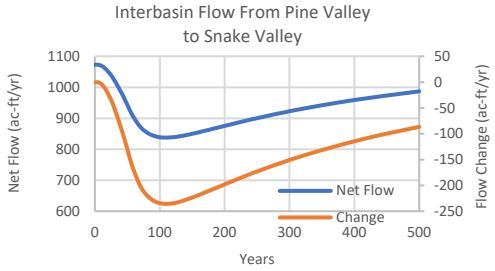
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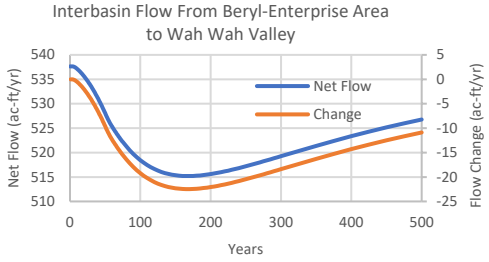
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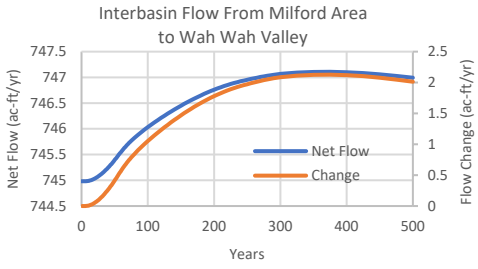
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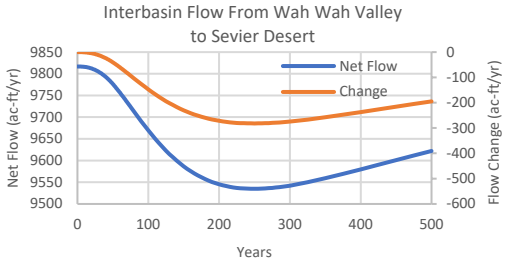


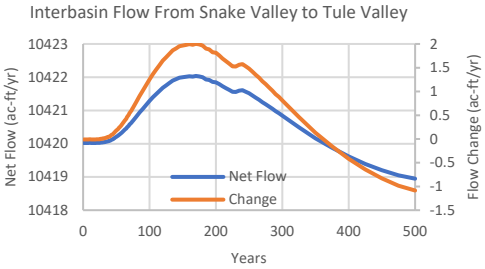


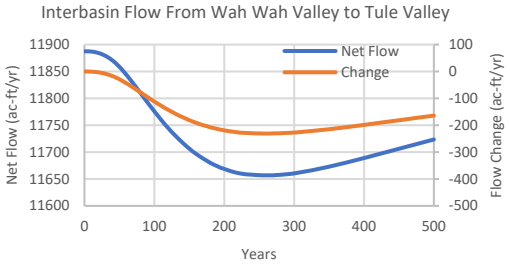


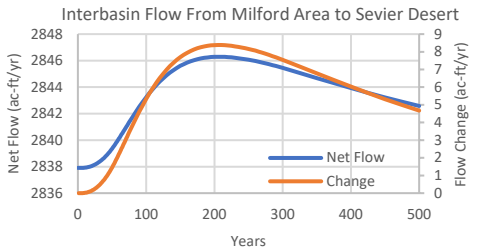


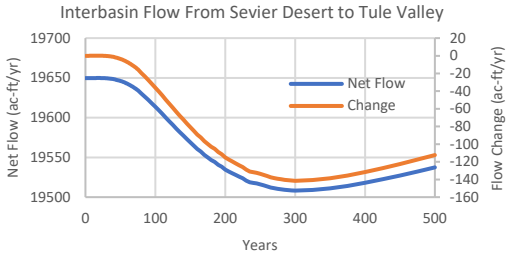












PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-5

CHANGES IN INTERBASIN FLOW UNDER PROPOSED ACTION

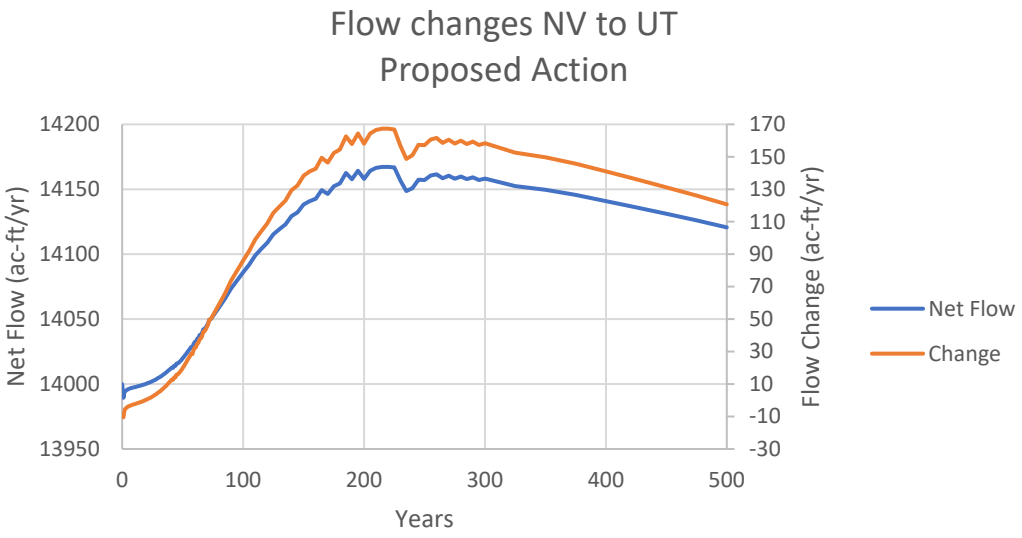
DATE: MAY 2021

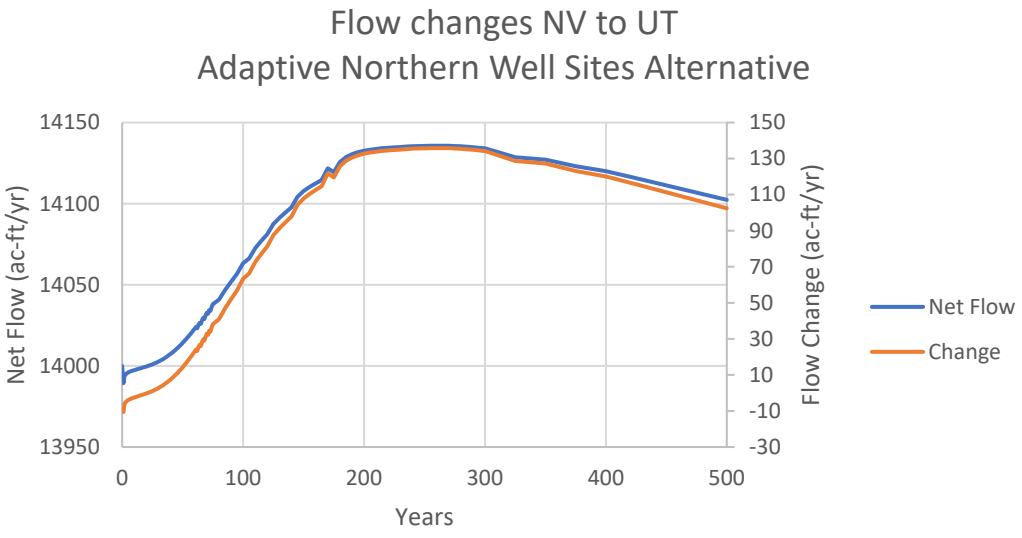
BY: PHT | FOR: MT

FORMATION ENVIRONMENTAL

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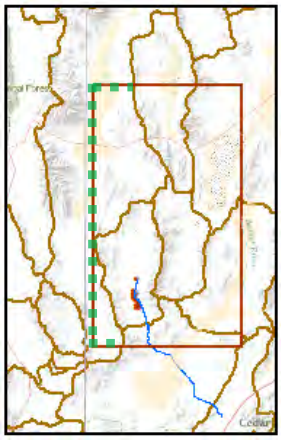
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Notes:

Child model boundary used for face flow calculations



PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-6

ESTIMATED CHANGES IN INTERSTATE GROUNDWATER FLOWS

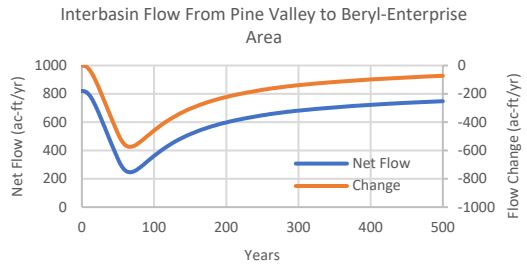
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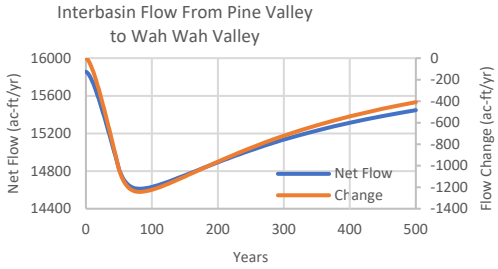
BY: PHT | FOR: MT

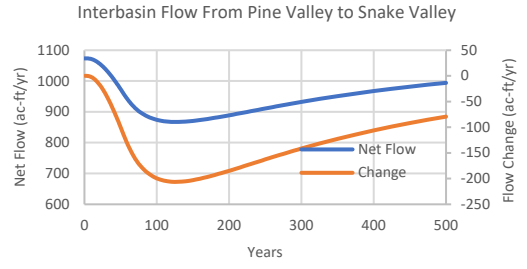
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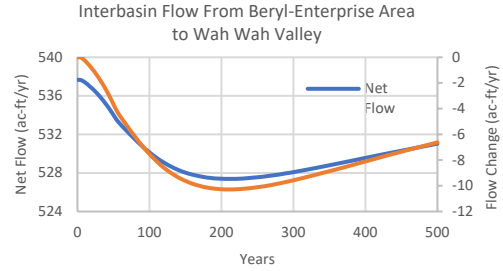
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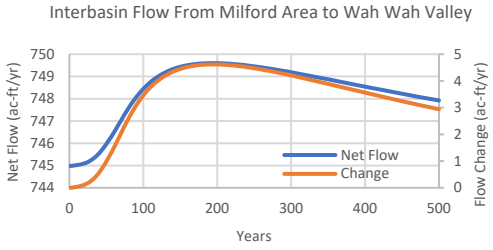
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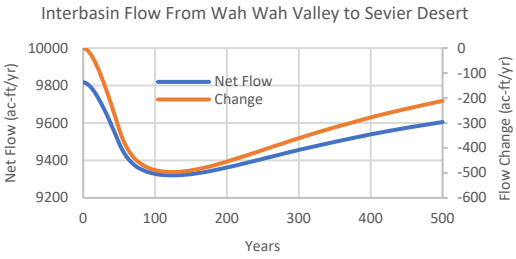


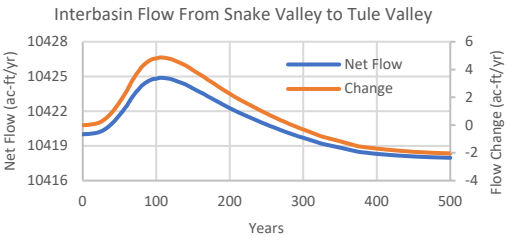


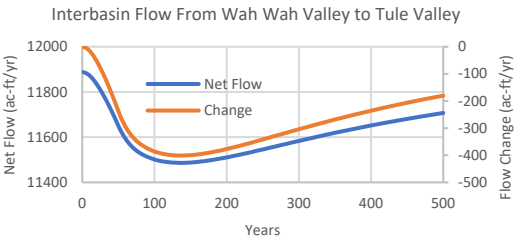


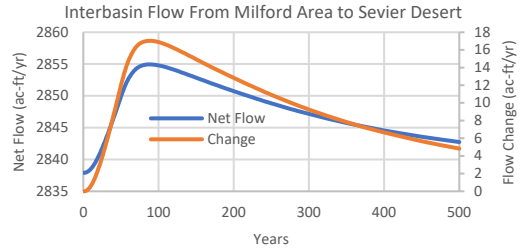


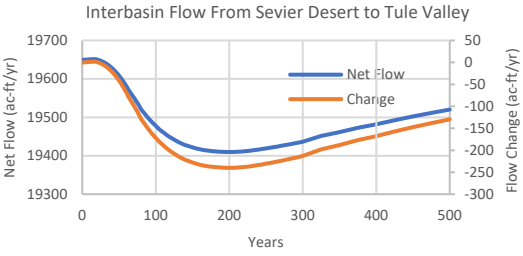












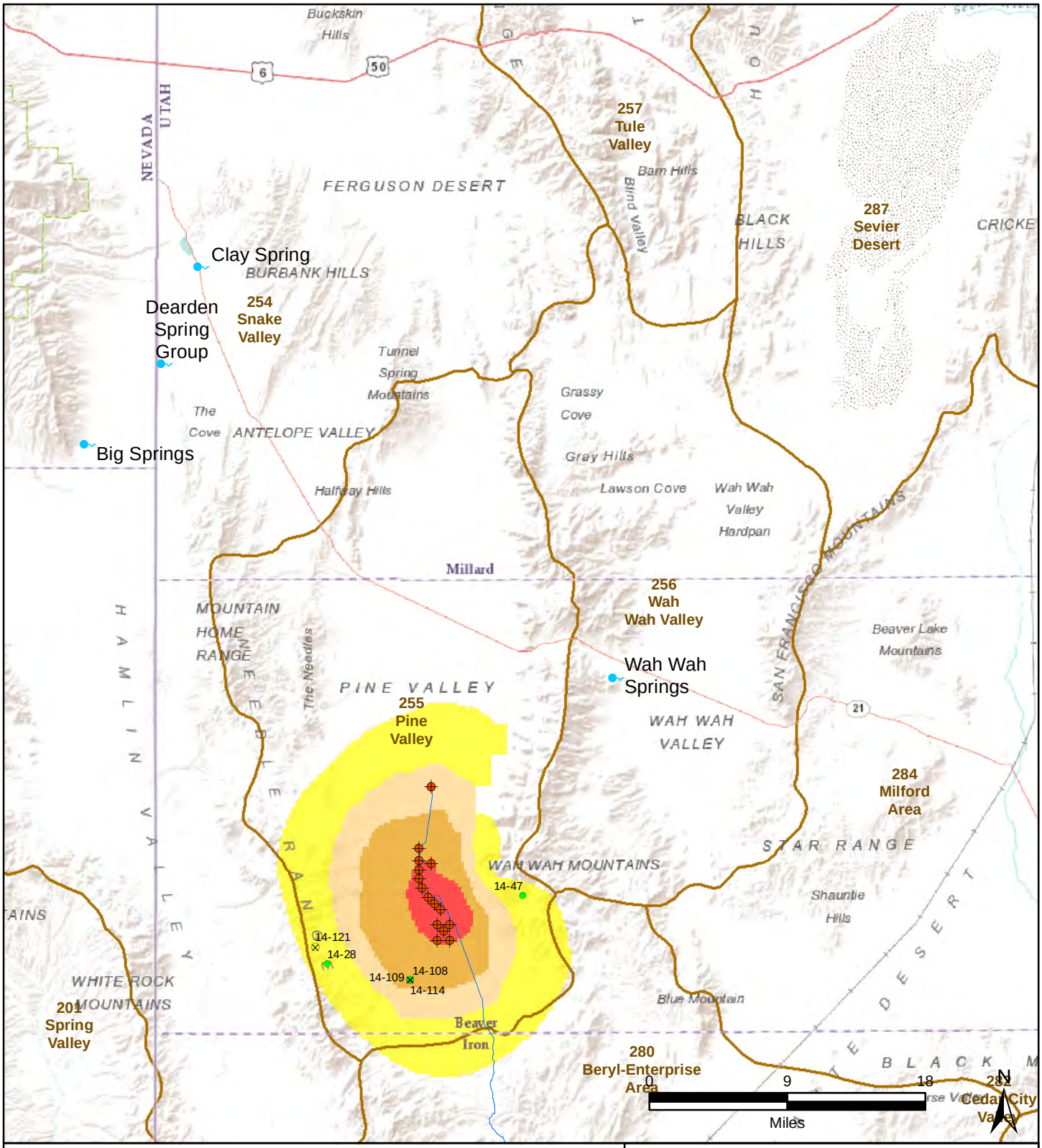
PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-7

CHANGES IN INTERBASIN FLOW UNDER ANWS ALTERNATIVE

DATE: MAY 2021	FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT

S:\GIS\a5\Transcon_PineValley\cov\AquaGeo\PineValley_Dist\Model\2020\predictions\PV19PV_pred_conf_99b\TransientObsAndBudgets_v3_north.xlsx



Legend

- Perfected Underground POD (senior)
- Perfected Underground POD (junior)
- Well log available
- PVWS Project Well
- Project Pipeline Alignment
- Hydrographic Area

Drawdown >15ft after 50 years pumping

Drawdown (feet)

- < 50
- 50 - 100
- 100 - 250
- > 250

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-8

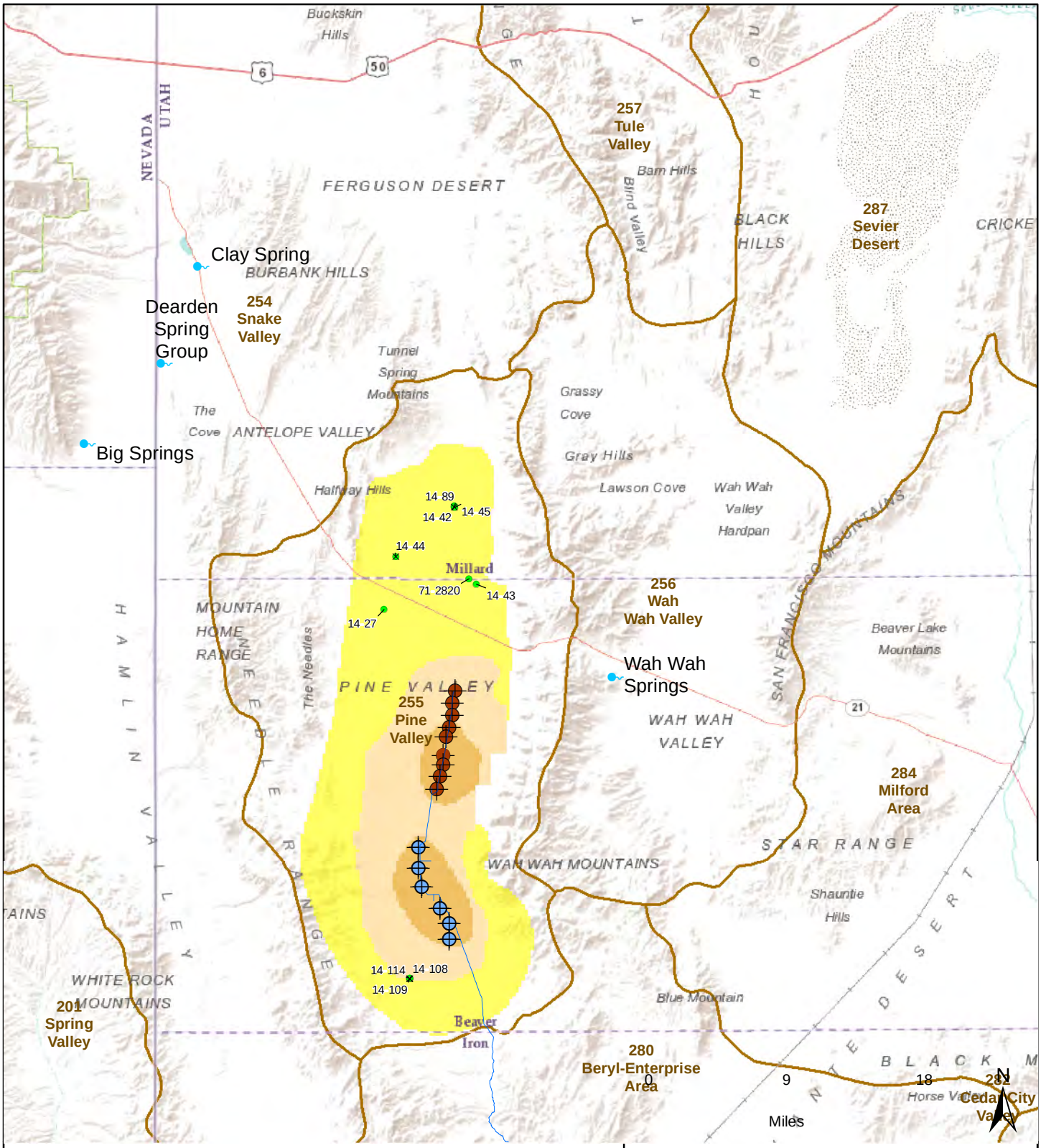
EXISTING WELLS IN THE PREDICTED DRAWDOWN AREAS (>15FT) FOR PROPOSED ACTION

DATE: MAY 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRI\Fig4_08_UndergroundPOD_15ft_DD_Prop.mxd



Legend

- Perfected Underground POD (junior)
- Perfected Underground POD (senior)
- Well log available
- Startup pumping well
- ANWS Alternative Well
- Project Pipeline Alignment
- Hydrographic Area

Drawdown >15ft after 50 years pumping

Drawdown (feet)

- < 50
- 50 - 100
- 100 - 250
- > 250

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-9

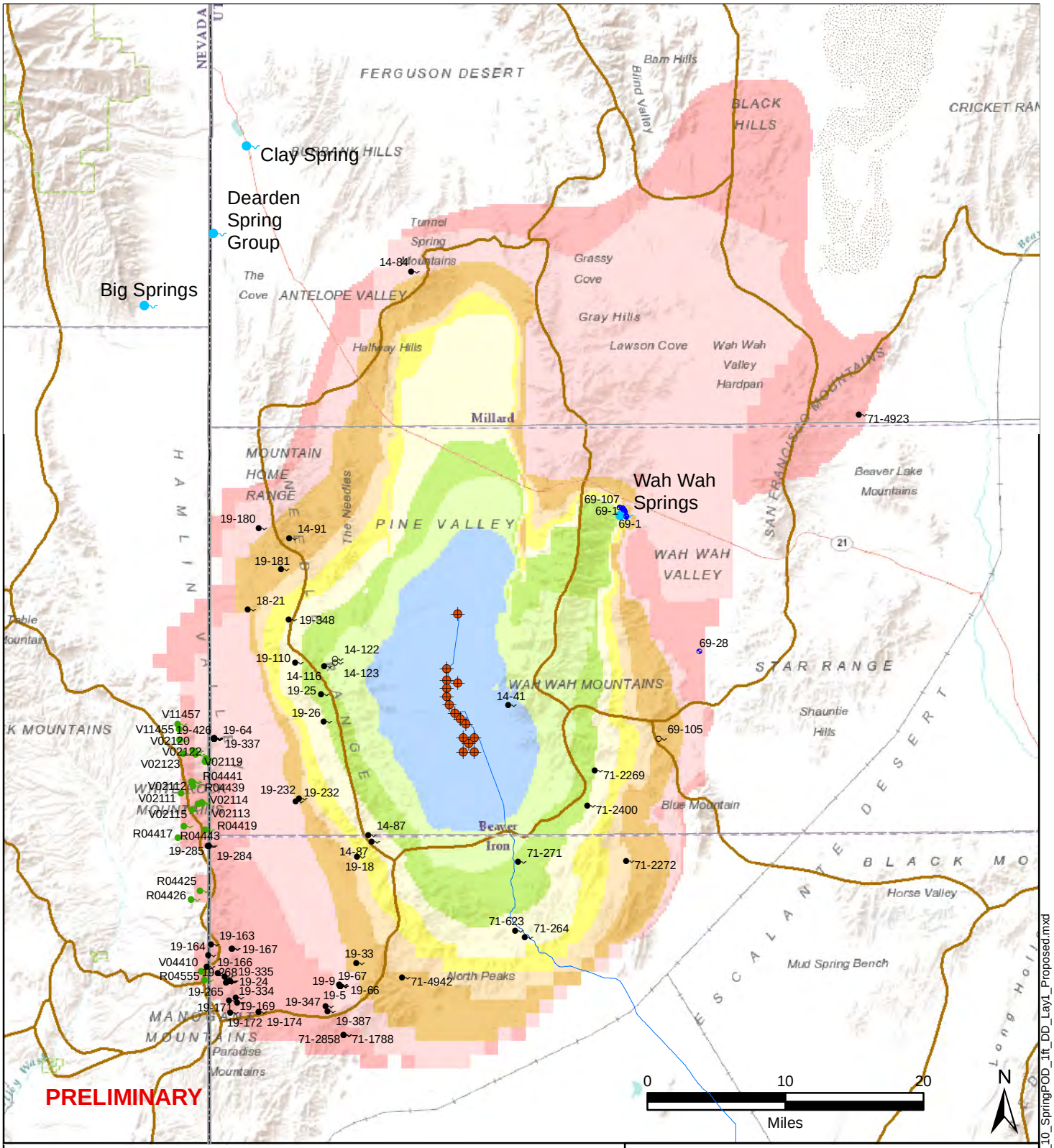
EXISTING WELLS IN THE PREDICTED DRAWDOWN AREAS (>15FT) FOR ANWS ALTERNATIVE

DATE: MAY 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRI\Fig4_09_UndergroundPOD_15ft_DD_North.mxd



Legend

- PVWS Project Well
- Regional Spring (NHD)
- Utah Perfected Surface POD (Wah Wah Spring)
- Utah Perfected Spring POD (junior)
- Utah Perfected Spring POD (senior)
- Nevada Spring POD
- Project Pipeline Alignment
- Hydrographic Area

Model Period

- Pumping yr 10
- Pumping yr 20
- Pumping yr 30
- Pumping yr 40
- Pumping yr 50
- Post Pumping yr 10
- Post Pumping yr 50
- Post Pumping yr 100
- Post Pumping yr 200

PINE VALLEY GROUNDWATER DEVELOPMENT AND TRANSMISSION PIPELINE PROJECT

FIGURE 4-10

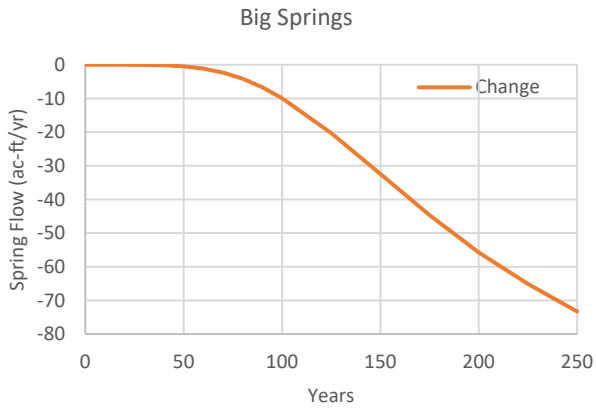
REGIONAL AND LOCAL SPRINGS IN PREDICTED DRAWDOWN AREAS (>1FT) FOR PROPOSED ACTION

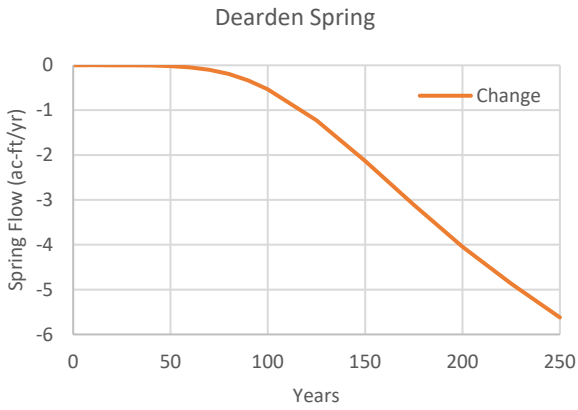
DATE: MAY 19, 2021	FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT

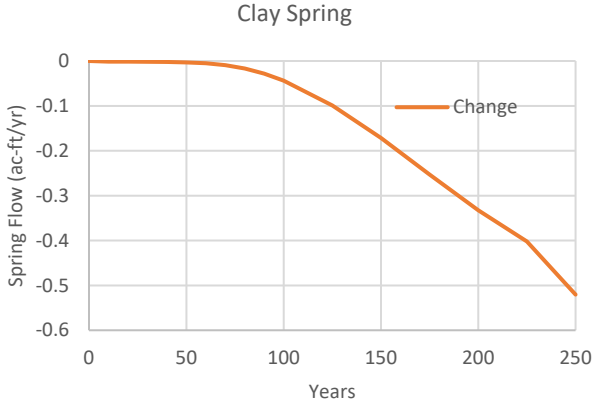
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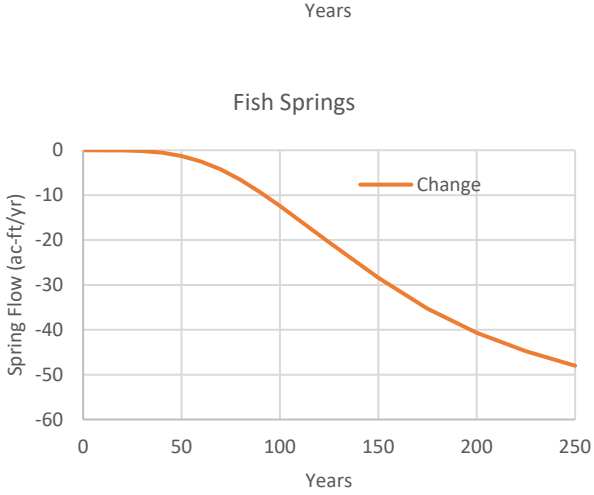
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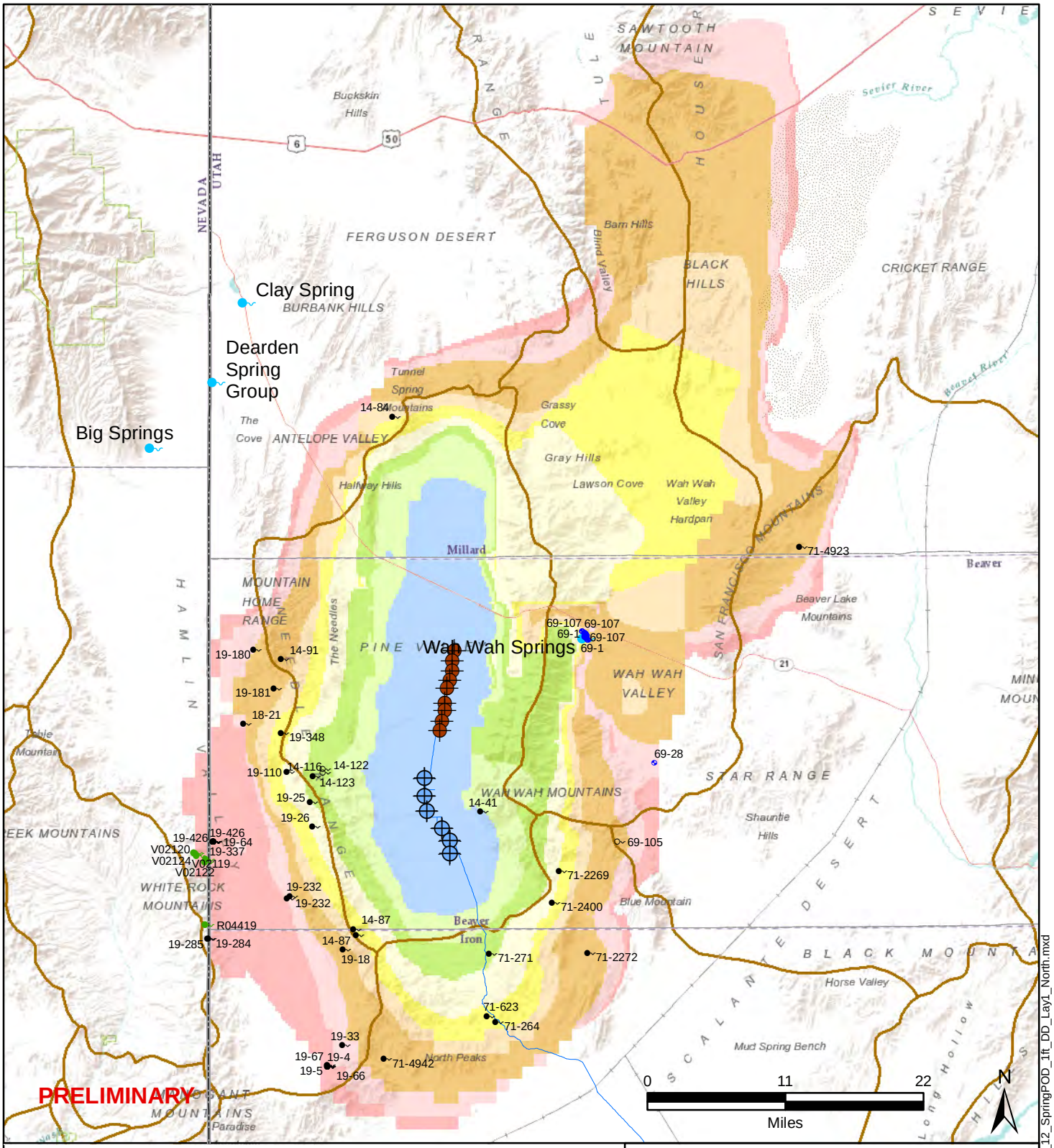
PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-11

SPRING FLOW DEPLETION EFFECTS OF PUMPING FOR PROPOSED ACTION

DATE: MAY 2020	FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT

"S:\GIS\a5\Transcon_PineValley\cov\AquaGeo\PineValley_DistModel\2020predictions\PV19\PV_pred_conf_99a\KeySpringFlowChanges_prop.xlsx"



Legend

- Regional Spring (NHD)
- Utah Perfected Surface POD (Wah Wah Spring)
- Utah Perfected Spring POD (junior)
- Perfected Spring POD (senior)
- Nevada Spring POD
- Startup pumping well
- ANWS Alternative Well
- Project Pipeline Alignment
- Hydrographic Area

Model Period

- Pumping yr 10
- Pumping yr 20
- Pumping yr 30
- Pumping yr 40
- Pumping yr 50
- Post Pumping yr 10
- Post Pumping yr 50
- Post Pumping yr 100
- Post Pumping yr 200

PINE VALLEY GROUNDWATER DEVELOPMENT AND TRANSMISSION PIPELINE PROJECT

FIGURE 4-12

REGIONAL AND LOCAL SPRINGS IN PREDICTED DRAWDOWN AREAS (>1FT) FOR ANWS ALTERNATIVE

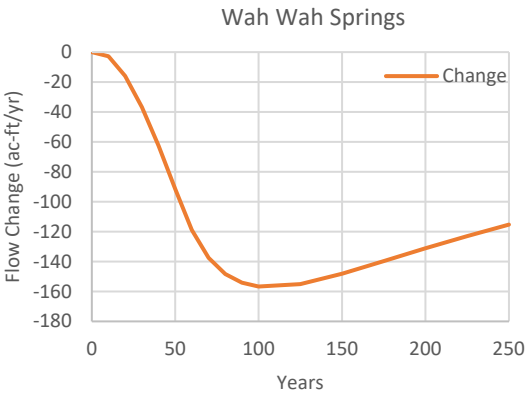
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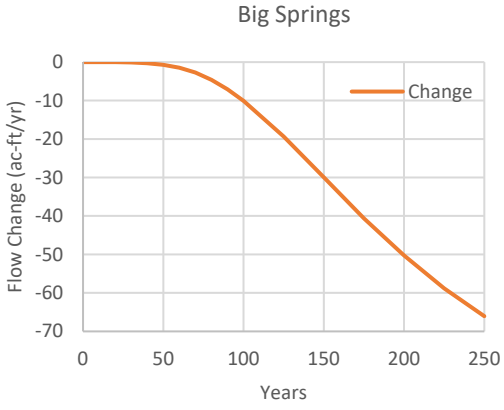
BY: CRL | FOR: PHT

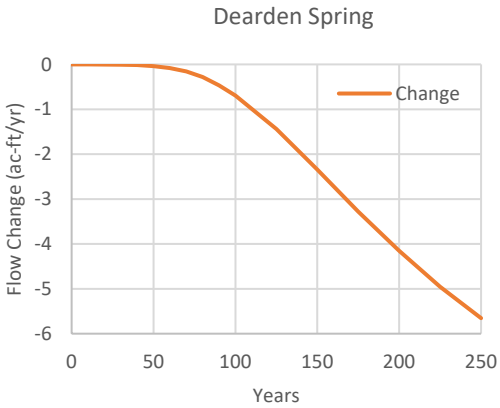
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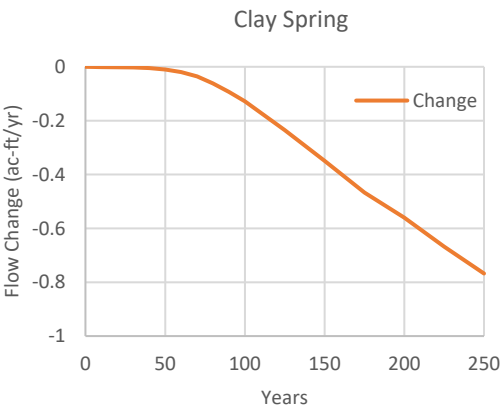
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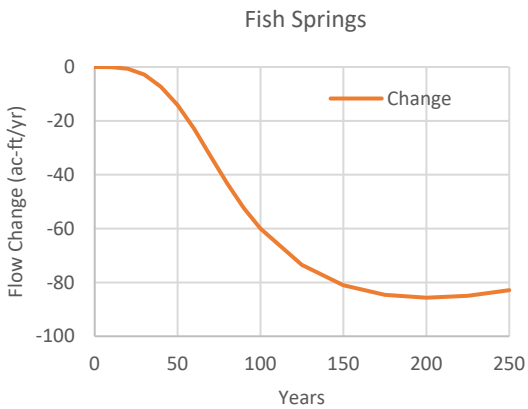
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PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

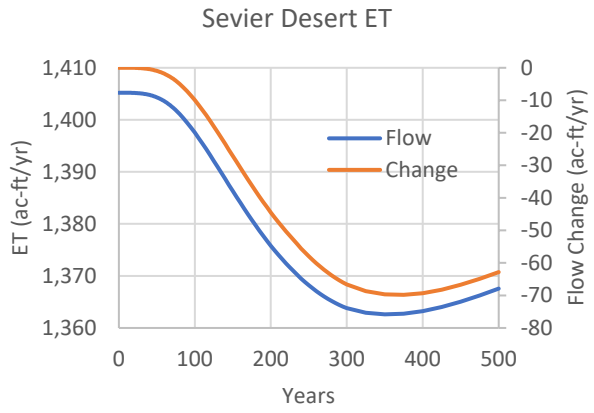
FIGURE 4-13

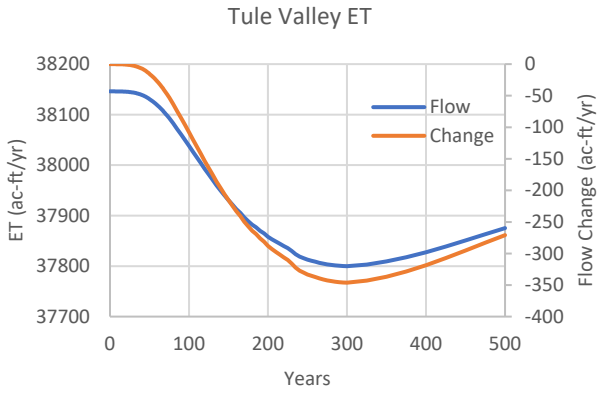
SPRING FLOW DEPLETION EFFECTS OF PUMPING FOR ANWS ALTERNATIVE

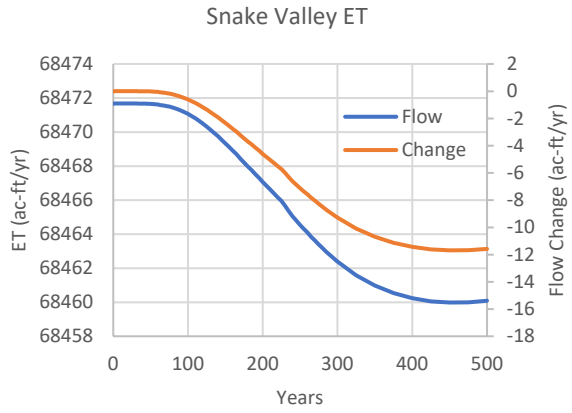
DATE: MAY 2020	FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT

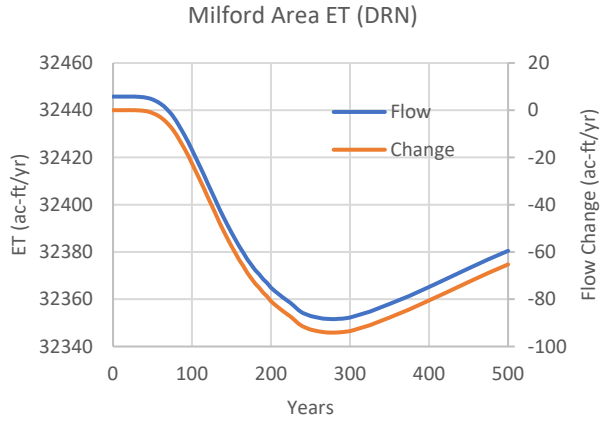
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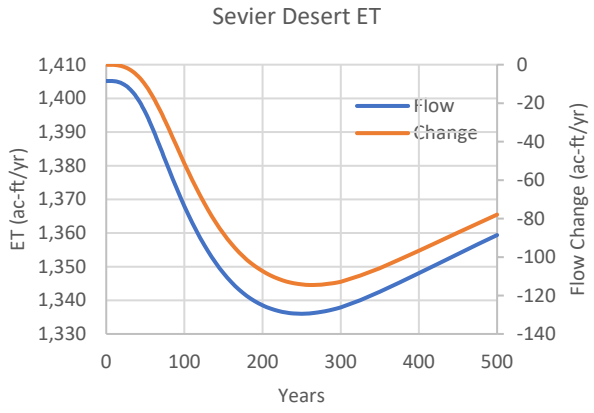
PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

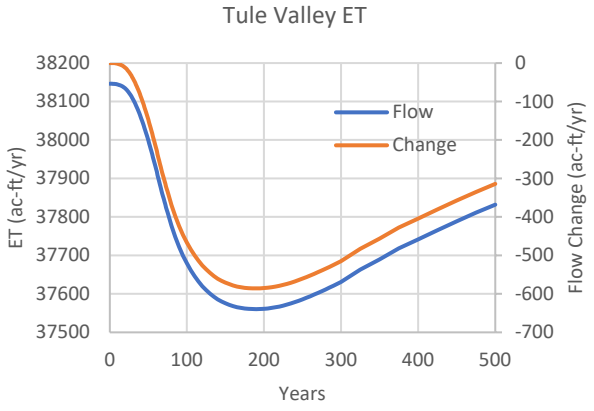
FIGURE 4-14

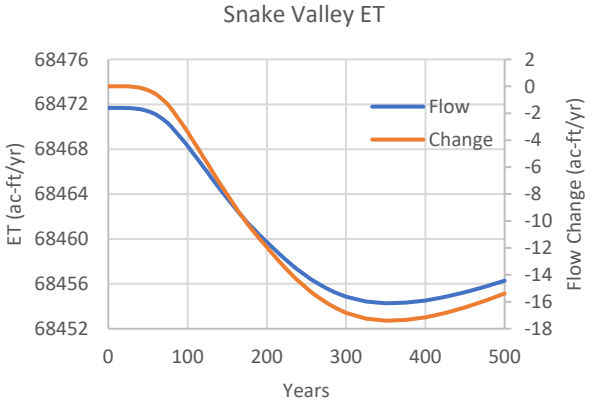
ET DISCHARGE EFFECTS OF PUMPING FOR PROPOSED ACTION

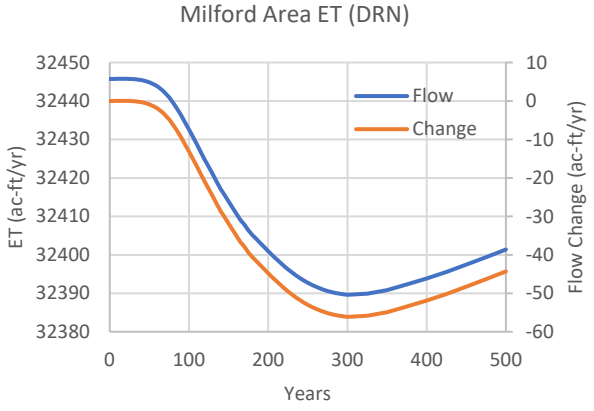
DATE: MAY 2020	FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT

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PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-15

ET DISCHARGE EFFECTS OF PUMPING FOR ANWS ALTERNATIVE

DATE: MAY 2020	FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT

"S:\GIS\a5\Transcon_PineValley\cov\AquaGeo\PineValley_DistModel\2020\predictions\PV19\PV_pred_conf_99b\TransientObsAndBudgets_v3_north.xlsx"

Well & Spring Locations

10 Years Pumping

20 Years Pumping

30 Years Pumping

40 Years Pumping

50 Years Pumping

10 Years Recovery

20 Years Recovery

50 Years Recovery

75 Years Recovery

150 Years Recovery

200 Years Recovery

Legend

- Regional Spring
- PVWS Project Well
- ET Zones
- Project Pipeline Alignment
- Focused Model Area
- Hydrographic Area

Maximum drawdown (ft)

Layer 1 Drawdown (feet)

- < 1'
- 1' - 2'
- 2' - 3'
- 3' - 5'
- 5' - 10'
- 10' - 50'
- 50' - 100'
- 100' - 500'
- > 500'

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-16

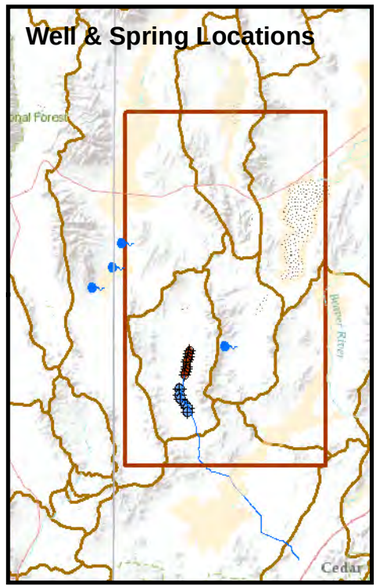
SIMULATED CUMULATIVE DRAWDOWN FOR PROPOSED ACTION

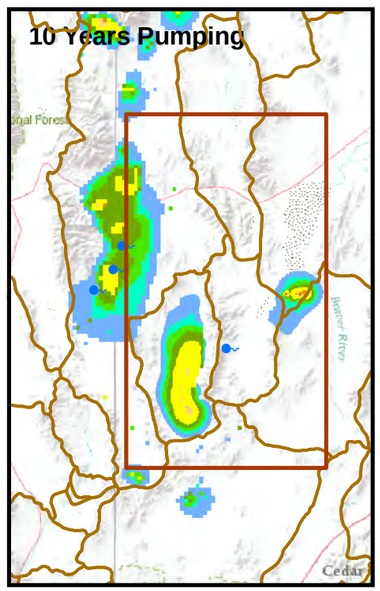
DATE: MAY 19, 2021

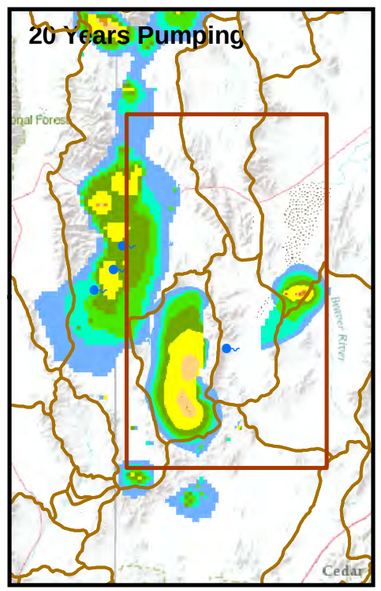
BY: CRL | FOR: PHT

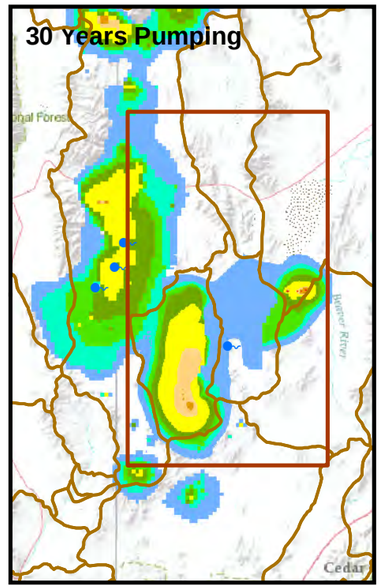
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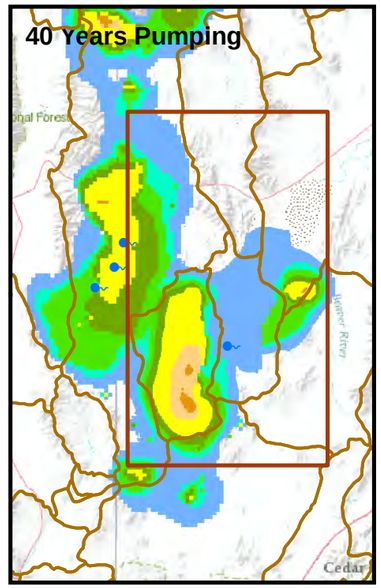
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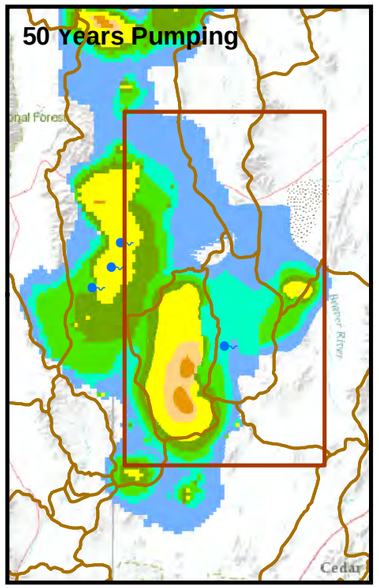


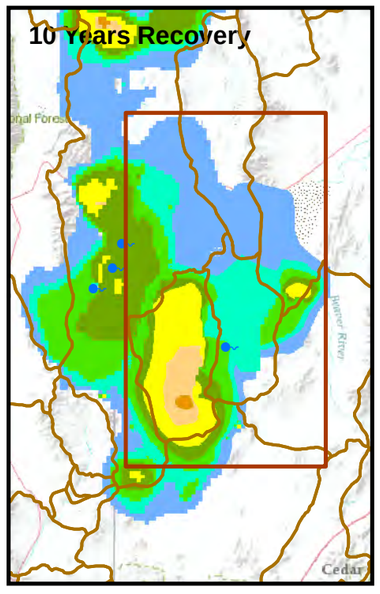


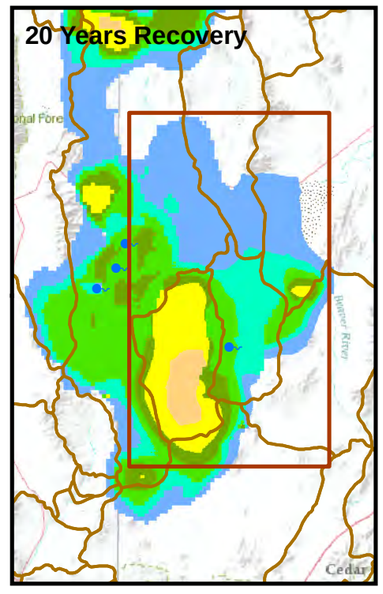


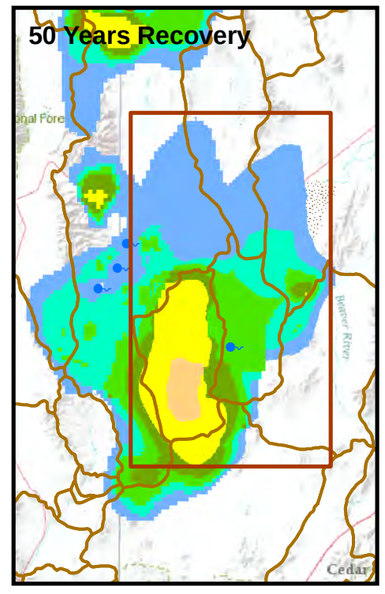


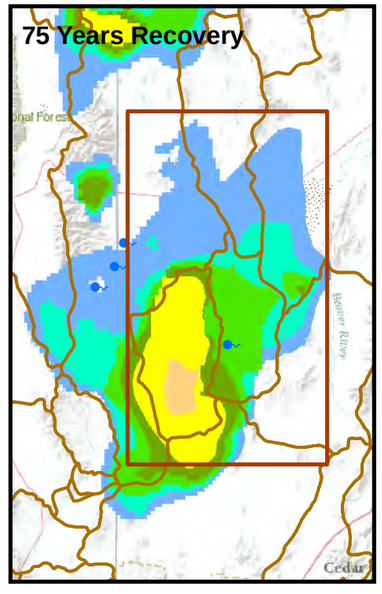


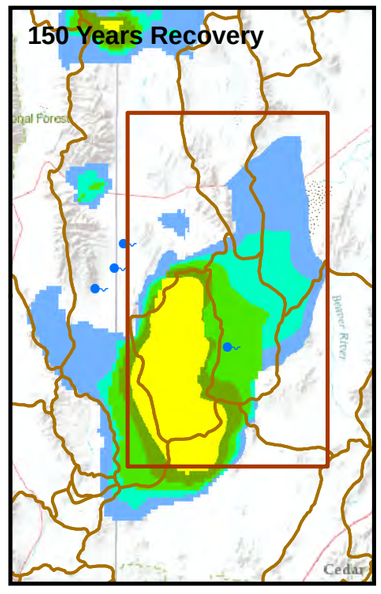


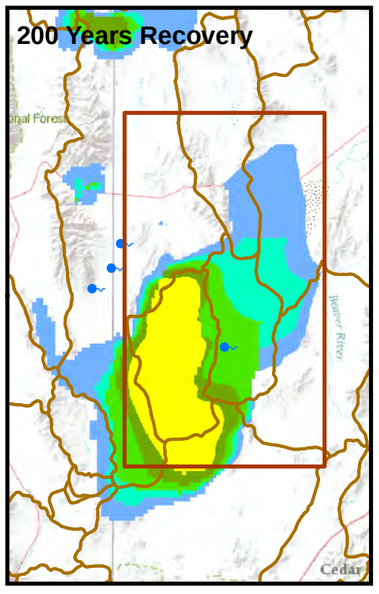












Legend

- Regional Spring
- ET Zones
- Focused Model Area
- Hydrographic Area
- Startup pumping well
- ANWS Alternative Well
- Project Pipeline Alignment

Maximum drawdown (ft)

Layer 1 Drawdown (feet)

- < 1'
- 1' - 2'
- 2' - 3'
- 3' - 5'
- 5' - 10'
- 10' - 50'
- 50' - 100'
- 100' - 500'
- > 500'

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-17

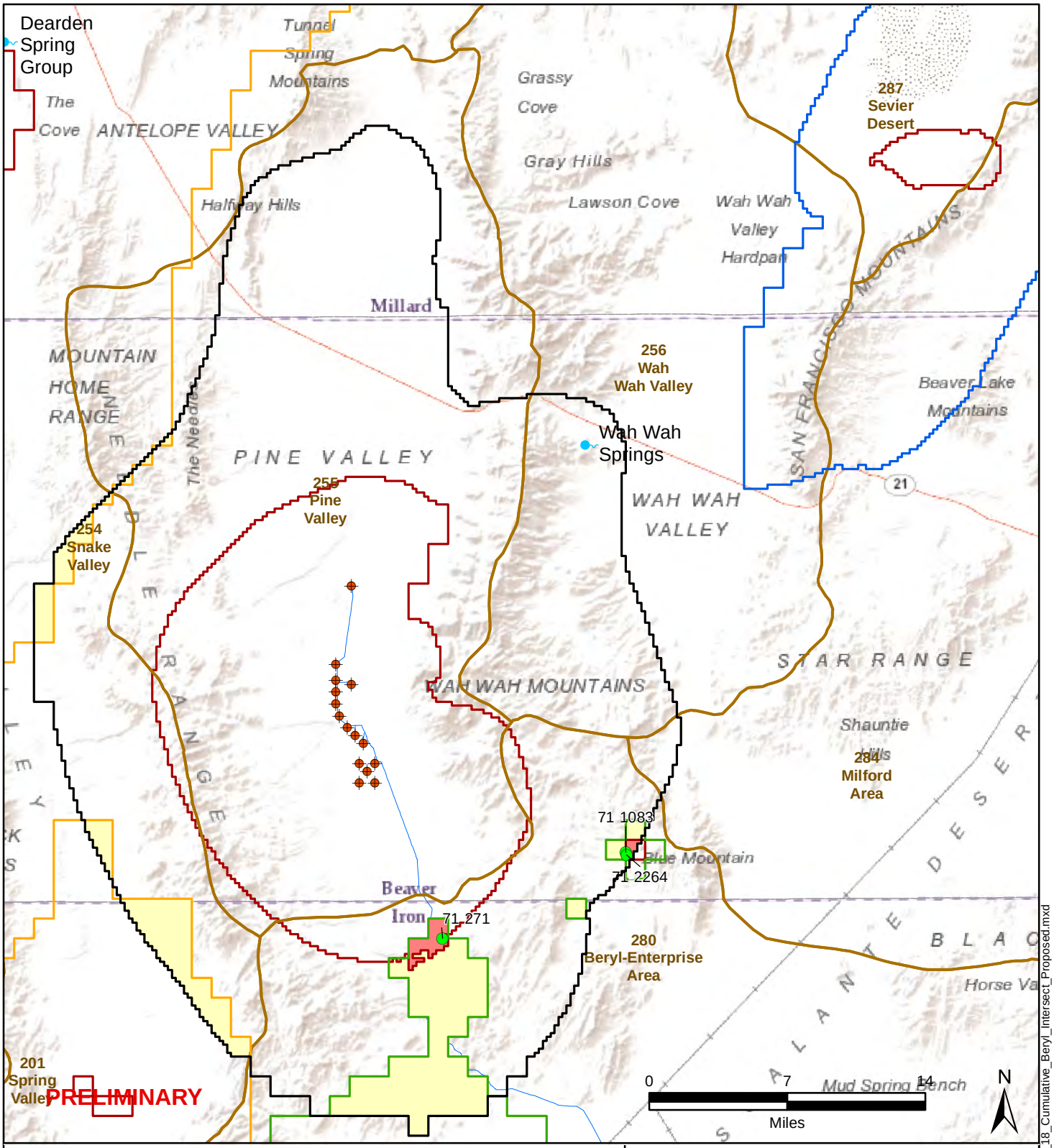
SIMULATED CUMULATIVE DRAWDOWN FOR ANWS ALTERNATIVE

DATE: MAY 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\sa5\Transcon_PineValley\plt\GRIA\Fig4_17_PumpRecov_Cumul_North.mxd



Legend

- PVWS Project Well
- Perfected Underground POD (senior)
- Hydrographic Area
- Cumulative > 15 ft DD
- PVWS Project >=1 ft
- Snake Valley HA > 1 ft
- CPM Project > 1ft
- Beryl-Enterprise Area HA > 1ft
- Intersection of >1 ft Areas
- Total predicted cumulative drawdown > 15 ft

PINE VALLEY GROUNDWATER DEVELOPMENT AND TRANSMISSION PIPELINE PROJECT

FIGURE 4-18

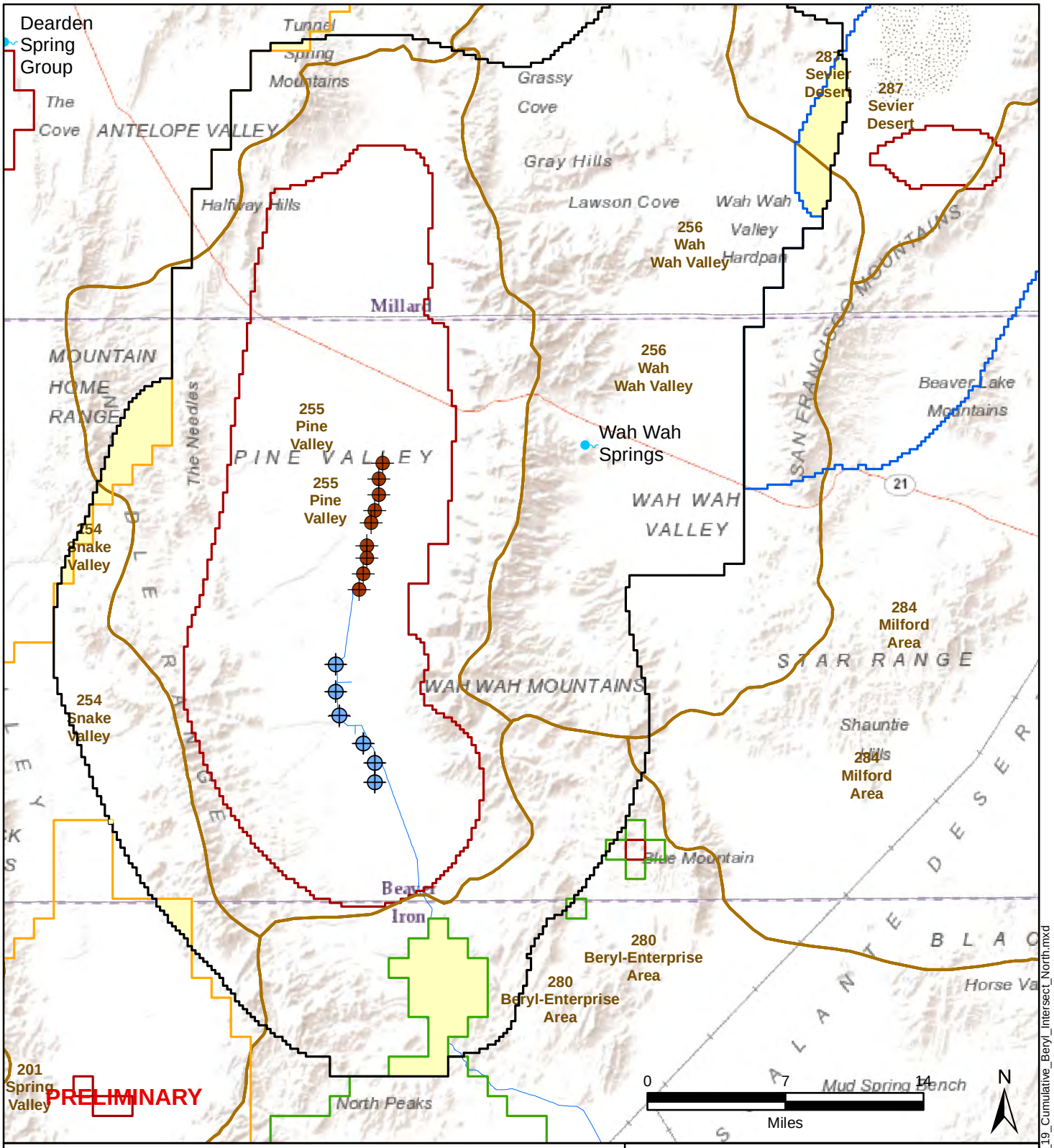
WELLS PREDICTED TO EXPERIENCE CUMULATIVE DRAWDOWN, PROPOSED ACTION

DATE: MAY 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a51Transcon_PineValley\plt\GRI\Fig4_18_Cumulative_Beryl_Intersect_Proposed.mxd



Legend

- Startup pumping well
- ANWS Alternative Well
- Hydrographic Area
- North Alt. DD >= 1 ft
- Snake >= 1ft
- Peak Snake >= 1ft
- Beryl >= 1ft
- Cumulative > 15 ft DD
- Intersection of >1 ft Areas
- Total predicted cumulative drawdown > 15 ft

PINE VALLEY GROUNDWATER DEVELOPMENT AND TRANSMISSION PIPELINE PROJECT

FIGURE 4-19

SIMULATED INTERFERENCE DRAWDOWN IN OUTLYING HAS FOR ANWS ALTERNATIVE

DATE: MAY 19, 2021

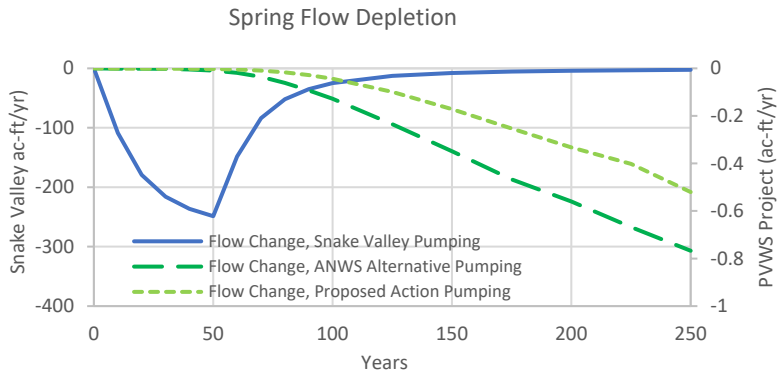
BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

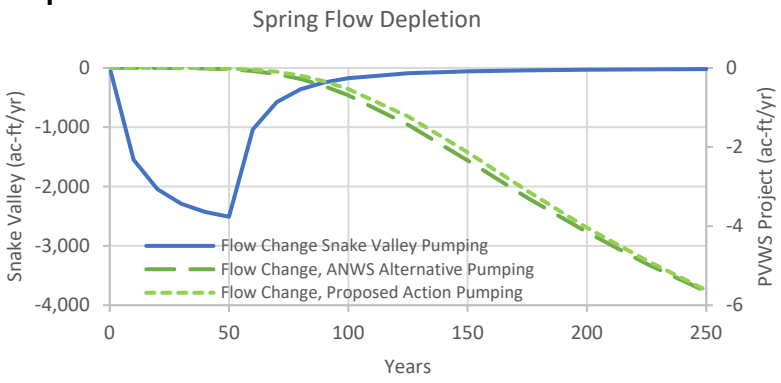
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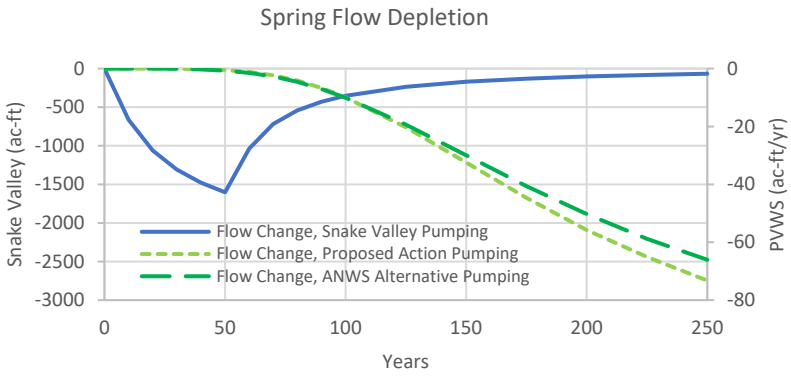
Clay Spring



Dearden Spring Group



Big Springs



PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-20

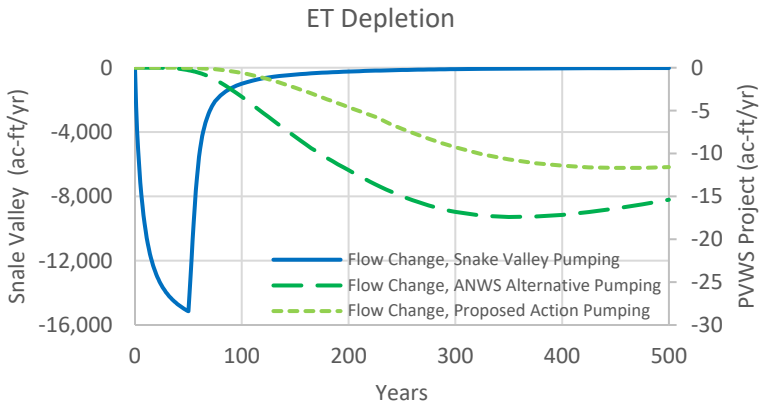
CUMULATIVE SPRING FLOW DEPLETION EFFECTS

DATE: MAY 2021	FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT

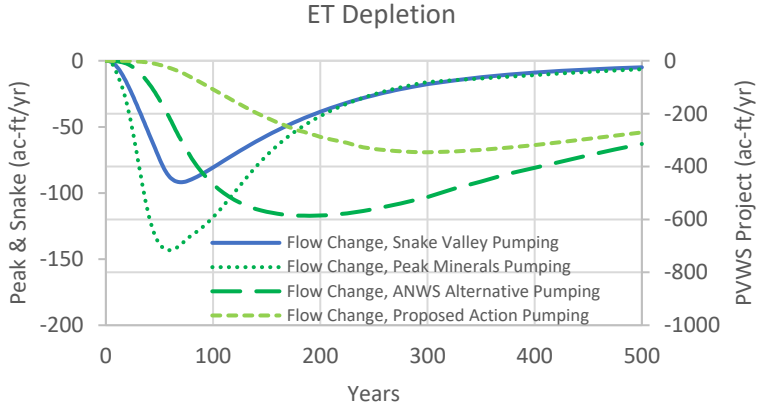
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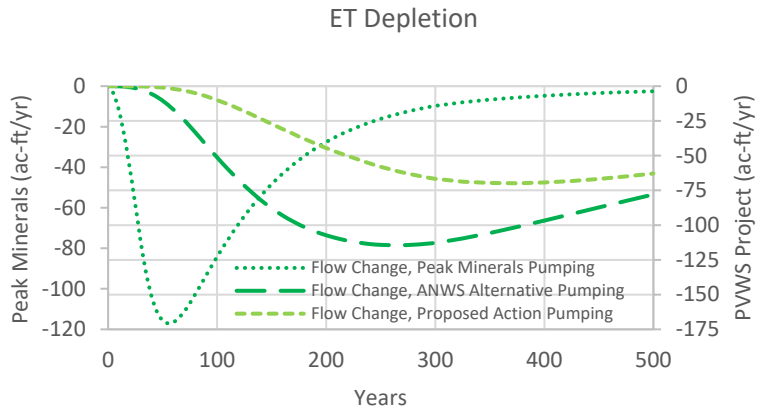
Snake Valley



Tule Valley



Sevier Desert



PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 4-21

CUMULATIVE ET DISCHARGE DEPLETION EFFECTS

DATE: MAY 2020	FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT

S:\GIS\a5\Transcon_PineValley\cov\AquaGeo\SnakeValley_Dist\output\output.SV.scenarioB4\CompareETChanges_Project.xlsx

5 POTENTIAL ENVIRONMENTAL IMPACTS

5.1 BACKGROUND AND APPROACH

This section presents an analysis of the potential environmental impacts that could result from extraction of groundwater in the Pine Valley HA from the proposed PVWS Project. A reasoned analysis of the potential significance, likelihood, timing, and extent of impacts is presented based on the project description in Chapter 2, the available setting information presented in Chapter 3, and the effects analysis presented in Chapter 4. Also included is a discussion regarding the potential cumulative impacts of the PVWS Project combined with other planned and reasonably foreseeable groundwater extraction in the Study Area. The discussion below focuses on potential impacts resulting from groundwater extraction, and is divided into the following general areas:

- Regional groundwater storage depletion and water budget changes, and their potential impacts to future availability of groundwater for beneficial uses in the area;
- Interference drawdown to existing wells that could impair the exercise of prior water rights;
- Spring flow depletion and potential impacts to groundwater dependent ecosystems, wildlife and prior water rights;
- ETg discharge depletion and potential impacts to groundwater-dependent vegetation, erosion and air quality;
- Water quality degradation and potential impacts to aquifer chemical integrity, beneficial users and spring discharge; and
- Land subsidence and potential impacts to surface infrastructure, public health and safety, wildlife and stock.

The discussions of each area below present the following:

- A summary of the kinds of potential adverse impacts that could occur;
- An evaluation of the likelihood and severity of the potential impacts; and
- A discussion regarding potential data gaps, uncertainties and risks.

5.2 STORAGE DEPLETION AND WATER BUDGET IMPACTS

5.2.1 DESCRIPTION OF POTENTIAL IMPACTS

Regional drawdown and changes in groundwater flow will be induced by the PVWS Project, and will result in a decrease in groundwater storage and changes to the groundwater budget, especially in the Pine Valley HA and to a lesser extent in the surrounding basins. Declines in groundwater storage and increased groundwater flow out of a basin can result in less groundwater being available for beneficial use. Groundwater level declines can also make future groundwater development more difficult or expensive by increasing the depth to which wells must be drilled and/or from which groundwater must be pumped. Potential impacts related to regional drawdown, storage depletion and groundwater budget changes include the following:

- Increased well drilling expenses and pumping costs due to declining groundwater levels;
- Potential reduction in the water supply available to senior water right holders; and/or

- Reduced long-term groundwater storage that could be available to supply future regional needs, such as during extended drought conditions.

5.2.2 LIKELIHOOD, EXTENT AND TIMING OF POTENTIAL IMPACTS

The 2014 DWRi Order approving Application to Appropriate Water Number 14-118 (A76676) (DWRi 2014b) says the State Engineer believes 16,650 AFY of groundwater is available for appropriation in the Pine Valley HA, including the 15,000 AFY appropriated under CICWCD's water right for the PVWS Project. It further states this estimate is based on currently available data, and that if in the future Pine Valley HA groundwater should prove to be over-appropriated as a result of exercising CICWCD's or other water rights granted for the basin, the State Engineer may adopt a GMP to address this issue. To support the appropriate management and implementation of CICWCD's water right for the project, the Order requires CICWCD to develop a monitoring program that ensures no prior water rights are impaired and that the aquifer system in the Pine Valley HA is not exceeding safe yield. The Utah Code defines safe yield as "*the amount of groundwater that can be withdrawn from a groundwater basin over a period of time without exceeding the long-term recharge of the basin or unreasonably affecting the basin's physical and chemical integrity"* (Utah Code §73-5-15(1)(b)). If Utah DWRi determines that the basin's safe yield is being exceeded, or more than 1/3 of the water rights holders in the Pine Valley HA request it, a GMP would be adopted that limits groundwater extractions to the safe yield (Utah Code §73-5-15(2)). The GMP would specify allowable pumping rates for each water right holder that are protective of the physical and chemical integrity of the basin.

To address the requirements of the Utah DWRi's 2014 Order, CICWCD will implement several "Applicant-Provided Measures" as part of the PVWS Project to verify the basin's safe yield is not being exceeded. These include the following:

- A Wellfield Construction Monitoring and Adaptive Management Program will be implemented as described in Section 6.1.2 to collect data during construction and initial operation of the first six wells. The aquifer and drawdown data collected during this time will be used to adjust the wellfield configuration as needed so drawdown and water budget impacts to the Beryl-Enterprise Area HA do not exceed those forecast in Section 4.2.2.1.
- A Wellfield Operation Monitoring and Adaptive Management Program will be implemented as described in Section 6.1.3 to collect data during long-term operation of the wellfield. The drawdown and water quality data will be used to help ensure that exceedances of the safe yield are pre-emptively identified and avoided.
- The data from these monitoring programs will be used to support implementation of the storage depletion and water budget impact mitigation measures described in Section 6.2.4 to help ensure that potential adverse impacts are recognized in a timely manner and appropriately mitigated.

As summarized in Sections 4.2.1 and 4.2.2, under both the Proposed Action and the ANWS Alternative, groundwater level drawdown, storage depletion and water budget impacts will be most pronounced in the Pine Valley HA and reach a maximum at the end of the PVWS Project 50-year operational period and recover slowly after that time. In the surrounding HAs, groundwater level drawdown, storage depletion, and water budget impacts will be much less and will reach a maximum after pumping ceases and then recover very slowly.

The following conclusions may be drawn regarding potential storage depletion and water budget impacts in the Pine Valley HA:

- Groundwater drawdown would increase the cost of groundwater supply development and pumping for the foreseeable future. In some areas around the PVWS Project wellfield, these effects would persist over 200 years after groundwater extraction under CICWCD's water right ceases. Potential adverse impacts to senior water right holders would be mitigated under the Interference Drawdown Monitoring and Mitigation Program described in Section 6.2.5. Potential impacts to junior water right holders are a normal and expected result of prior groundwater supply development and are required to be borne by them under Utah water law.
- Groundwater storage in the upper portion of the carbonate and alluvial aquifer system would be depleted by approximately 700,000 acre-feet after 50 years of project pumping, recovering slowly to approximately 400,000 acre-feet approximately 200 years after pumping ceases. This finding is not inconsistent with DWRi's conclusion that sufficient water is available for appropriation in the Pine Valley HA, provided that the Applicant Provided Measures described in Sections 6.1.2 and 6.1.3, and the mitigation measures described in Section 6.2.4 are implemented and exceedance of safe yield is avoided through implementation of the remaining mitigation measures described in Section 6.2.
- Net IBF into the Pine Valley HA will increase as a result of the PVWS Project, and net IBF out will decrease, which would not result in adverse impacts to the Pine Valley HA. Potential adverse impacts to the surrounding HAs as a result of these changes are discussed further below.

The following conclusions may be drawn regarding potential storage depletion and water budget impacts in the Beryl-Enterprise Area HA:

- Groundwater drawdown would somewhat increase the cost of groundwater supply pumping for a few wells in the northern part of the Beryl-Enterprise Area HA. Because drawdown will be relatively limited, future groundwater supply development costs are not expected to be significantly increased. Potential adverse impacts to senior water right holders for affected wells would be mitigated under the Interference Drawdown Monitoring and Mitigation Program described in Section 6.2.5. Potential impacts to junior water right holders are a normal and expected result of prior groundwater supply development and are required to be borne by them under Utah water law.
- Under the Proposed Action, groundwater storage in the uppermost portion of the aquifer system underlying the northern part of the Beryl Enterprise Area HA would be decreased by about 22,000 acre-feet after 50 years of PVWS Project pumping and by about 79,000 acre-feet 200 years after pumping ceases. IBF into the Beryl-Enterprise Area HA from the Pine Valley HA would decrease by up to about 1,300 AFY, with the maximum depletion occurring about 20 years after pumping ceases. The predicted storage depletion is a relatively small percentage of the total groundwater in storage in the Beryl-Enterprise Area HA, and the total IBF depletion is relatively small compared to the current net estimated groundwater demand (approximately 65,000 AFY); however, this HA operates under a GMP that will sequentially retire existing water rights until average annual groundwater extractions are decreased from a current estimated net value of 65,000 AFY to 34,000 AFY by October 31, 2130. Although depletion in underflow and basin storage will make it more difficult for the senior water right holders in the Beryl-Enterprise Area HA, these factors were presumably considered by DWRi when it issued the 2014 Order approving CICWCD's water right application based on the Points of Diversion included in the Proposed Action. Therefore, as long as IBF and storage depletion do not exceed these predicted values, the PVWS Project is not

expected to interfere with implementation of the GMP for the Beryl-Enterprise Area HA, and no impairment of prior water rights will occur.

- Under the ANWS Alternative, groundwater extraction would be shifted farther north and potential impacts to the Beryl-Enterprise Area HA would be less. Groundwater storage would be depleted by about 9,000 acre-feet after 50 years of pumping, and about 41,000 acre-feet 200 years after pumping ceases. IBF would be decreased by up to a maximum of about 550 AFY approximately 20 years after pumping ceases. Because the magnitude of the impact is less than the Proposed Action, no impairment of prior water rights is expected to occur.

The following conclusions may be drawn regarding potential storage depletion and water budget impacts in other HAs surrounding the Pine Valley HA:

- Predicted drawdown under the Proposed Action and the ANWS Alternative in other HAs adjacent to Pine Valley HA would be limited to drawdown beneath the mountain blocks at the edges of the HAs or broader areas with less than 5 feet of drawdown. The amount and distribution of drawdown is not expected to lead to a significant increase in groundwater development or pumping costs.
- Due to the effect of local pumping, cumulative groundwater storage depletion under the Proposed Action is forecast to be much greater than the amount of storage depletion caused by the PVWS project at the end of the pumping period. Local pumping would account for approximately 99% of the forecast storage depletion in the Snake Valley, Sevier Desert and Milford Area HAs, 94% of the forecast depletion in the Tule Valley HA, and about 60% of the forecast depletion in the Wah Wah Valley HA. With the exception of Snake Valley, where the cumulative storage depletion would exceed 450,000 acre-feet, these forecast depletion volumes are a very small percentage of the total groundwater in storage in these basins. After 200 years of recovery, the forecast storage depletion induced by local pumping would be significantly recovered, and the remaining depletion would be largely due to the residual effects of the PVWS Project. Cumulative IBF depletion is predicted to be similar to depletion under the Proposed Action alone. None of these HAs currently operates under a GMP and the predicted storage and IBF depletions are expected effects for the exercise of groundwater rights that are within the safe yield stipulated in the DWRi's 2014 Order. As discussed in Section 5.3, potential significant well interference impacts to existing wells located in and near the Pine Valley HA will be addressed or offset through the Well Interference Monitoring and Mitigation Program described in Section 6.2.5. For these reasons, we conclude the forecasted cumulative storage and IBF depletions will not impair prior groundwater rights in these HAs.
- The ANWS Alternative will shift the contribution of PVWS Project-induced groundwater storage depletion to cumulative storage depletion northwards. This would result in a greater cumulative groundwater storage depletion impact in the Wah Wah and Tule Valley HAs. Cumulative IBF depletion impacts will be generally similar to those forecast for the Proposed Action. As such, cumulative impacts to the Wah Wah and Tule Valley HAs would be somewhat greater than under the Proposed Action at the end of the pumping period, and somewhat less 200 years after pumping ceases. These forecast depletion volumes are a very small percentage of the total groundwater in storage in these basins. None of these HAs currently operates under a GMP and the predicted IBF and storage depletions are expected effects that were presumably considered in the DWRi's 2014 Order. For these reasons, we conclude the forecasted storage and IBF depletions will not impair prior groundwater rights in these HAs.

5.2.3 UNCERTAINTIES, DATA NEEDS AND RISKS

Because groundwater has been sparsely developed in the Pine Valley HA, the response of the aquifer system to larger scale pumping is uncertain. As discussed in Section 2.3.1, some data suggest the potential presence of groundwater flow impediments in the aquifer system beneath the southern portion of Pine Valley that could cause higher-than-expected drawdown, storage depletion and water budget impacts in that area and extending southwards into the Beryl-Enterprise Area HA. The PVWS Project will implement the Wellfield Construction Monitoring and Adaptive Management Program described in Section 6.2.2 to shift components of the wellfield northward if monitoring during initial startup pumping indicates this may be the case. The aim of this program is to maintain impacts to the Beryl-Enterprise Area HA to no more than those forecast for the Proposed Action. In addition, during operation of the PVWS Project, the Wellfield Operation Monitoring and Adaptive Management Program described in Section 6.2.3 will be implemented to ensure the project operates within the safe yield of the aquifer system in compliance with the DWRi's 2014 Order. If future monitoring and analysis indicate that storage or IBF depletion impacts to the Beryl-Enterprise Area HA will exceed those currently forecast under the Proposed Action, the mitigation measure described in Section 6.2.4 will be implemented to offset potential increases in these depletions above currently forecast levels. With the implementation of this measure, the potential impairment of prior water rights in the Beryl-Enterprise Area HA would be mitigated.

5.3 WELL INTERFERENCE IMPACTS

5.3.1 DESCRIPTION OF POTENTIAL IMPACTS

As discussed in Section 4.2.3, drawdown induced by the PVWS Project will affect existing groundwater supply wells in the Pine Valley HA, and to a lesser extent, wells in the surrounding HAs. Drawdown imposed by a pumping well on another nearby pumping well can have adverse effects on the operation and performance of that well, and is referred to as interference drawdown or well interference. Well interference effects are mutual; that is, each well imposes drawdown that affects the other well's performance. In an impact assessment, however, impacts are discussed in terms of potential adverse effects that a new well imposes on an existing well with senior water rights. The specific potential adverse effects of interference drawdown evaluated in this GRIA include the following:

- The groundwater level in the aquifer could be drawn down below the screened or perforated interval of a well so that the well goes dry and must be deepened or replaced;
- The pumping water level in a well could be drawn down so that the pump intake needs to be lowered in order for the well to remain operational or to maintain the well's pumping capacity;
- The pumping water level in a well could be drawn down below the top of the well's screened or perforated interval, causing cascading of the water down the inside of the well screen, potentially causing damage and increasing well maintenance costs, causing premature corrosion of the well or pump, or creating problems with entrained air in irrigation systems;
- The pumping capacity of a well could be diminished to a point where the well can no longer produce the amount of water needed for a particular use and the well must be deepened or replaced ; and/or

- A well may be able to continue operating and produce adequate amounts of water, but pumping must occur at either greater frequency or duration, and/or water must be lifted to a greater height, resulting in greater operational costs.

5.3.2 LIKELIHOOD, EXTENT AND TIMING OF POTENTIAL IMPACTS

The Utah DWRi has not published specific guidance or regulations regarding interference drawdown; however, two existing groundwater management plans for areas that are still open to limited new appropriation (i.e., Bountiful Sub-area of the East Shore area and Weber River Delta Sub-area of the East Shore area) set forth the State Engineer's policy concerning the management of interference drawdown and establish a maximum of 15 feet of interference drawdown as acceptable (DWRi 1995a, 1995b). The plans state the following:

> *Wells shall be spaced so that under unconfined conditions they do not cause more than 15 feet of drawdown on any well with an earlier priority date. Users in a particular area may enter into an agreement to provide a variance from this requirement if it does not interfere with third party rights and also subject to approval by the State Engineer.*

Consistent with this policy, since groundwater level fluctuations in the range of 15 feet or less are not uncommon as a result of regional groundwater level trends and pumping patterns, they may be reasonably expected by well drillers and operators. As such, groundwater level declines of less than 15 feet are not likely to result in a well going dry, a significant decrease in pumping capacity, or a change in the operating or maintenance costs of a well that is not reasonably anticipated. Based on this information, interference drawdowns of less than 15 feet are not considered sufficient to impair the reasonable exercise of an existing groundwater right and are not considered an adverse impact in this GRIA.

An additional consideration is the reasonable expected service life of an existing well. New wells drilled in the area affected by PVWS Project drawdown will presumably be constructed to adapt to the current and anticipated groundwater conditions and would be constructed to avoid adverse effects from interference drawdown. The service life of a well depends on the age of the well, the methods and materials used in its construction, water quality, aquifer conditions, operational practices and intended use (Driscoll 1986), and can range from approximately 25 to over 100 years (Glotfelty 2017). During a well's operational life, well yield may be expected to decrease, but can often be restored periodically using chemical or physical rehabilitation techniques (Driscoll 1986). Eventually, rehabilitation techniques decrease in their effectiveness over time and wells may fail. The reasonable planning estimate of well life adopted in some NEPA analyses is as little as 20 years. For this GRIA, an anticipated well service life of 50 years after the start of PVWS Pumping has been adopted to account for the range in potential well conditions and the amount of time that existing wells in the area have been under production.

As discussed in Sections 4.2.3.2 and 4.2.3.3, a number of existing wells in the Pine Valley HA are predicted to experience well interference drawdown induced by the PVWS Project that would adversely affect their capacity, increase operating or maintenance costs, or cause them to go dry. Under the Proposed Action, six existing wells are predicted to experience interference drawdown ranging from approximately 20 to 120 feet. The locations of these wells are shown on Figure 4-8 and the amount of drawdown predicted at

the well locations is presented in Table 4-3. The onset of this drawdown is predicted to occur between 10 and 20 years of wellfield operation in some wells, and between 30 and 40 years of wellfield operation in others. Under the ANWS Alternative, 10 existing wells are predicted to experience interference drawdown ranging from approximately 20 to 50 feet. The locations of these wells are shown on Figure 4-9 and the amount of drawdown predicted at the well locations is presented in Table 4-4. The onset of this drawdown is predicted to occur between 10 and 20 years of wellfield operation in some wells, and between 30 and 40 years of wellfield operation in others.

Based on the available data, it is likely that the wells identified in Table 4-3 and Table 4-4 would experience adverse impacts during their operational life, including potential loss of use, loss of productivity or increased operating or maintenance costs. It is important to note that one of the wells projected to be impacted under the Proposed Action (Point of Diversion 14-121) is operated under a water right that is junior to the water right held by CICWCD for the PVWS Project. Under Utah water law, the operator of this well must accept any adverse impacts resulting from operation of the PVWS Project. The remaining water right holders would be eligible to participate in the Well Interference Drawdown Monitoring and Mitigation Program discussed in Section 6.2.5. This program would ensure any impaired groundwater right holder whose well is adversely affected is compensated for the cost of well replacement, modification, maintenance or operation, or is provided with an alternative water supply. In cases where multiple causes adversely affect a well (e.g., well interference from other wells), reimbursement would be provided to the extent that adverse impacts are attributable to the PVWS Project. With the implementation of this measure, adverse interference drawdown effects to senior water right holders resulting from the PVWS Project are expected to be fully mitigated.

5.3.3 Uncertainties, Data Needs and Risks

The location and completion details of existing wells are available from the DWRi; however, the existing condition and use of the wells is not known in most cases, and this includes whether wells have been abandoned, or whether they currently require rehabilitation or replacement. Documentation will be collected during the early stages of project implementation as part of the Well Interference Monitoring and Mitigation Program described in Section 6.2.5.

Because the aquifer system in the Pine Valley HA has not been extensively developed or stressed, the GBCAAS-PV model used to predict drawdown at existing underground Points of Diversion entails inherent uncertainties. As described in Sections 6.1.2 and 6.1.3, data will be gathered during implementation of the PVWS Project and the model will be updated as warranted. In the event additional underground Points of Diversion are projected to be impacted by interference drawdown exceeding 15 feet during the first 50 years after pumping starts, the holders of any senior water rights that may be adversely affected will be notified and invited to participate in the Well Interference Monitoring and Mitigation Program as described in Section 6.2.5.

5.4 POTENTIAL IMPACTS TO SPRING RESOURCES

5.4.1 DESCRIPTION OF POTENTIAL IMPACTS

As discussed in Section 4.2.4, drawdown induced by the PVWS Project in the regional GBCAAS will extend beneath the mountains surrounding Pine Valley in into the adjacent alluvial basins. Local mountain springs and seeps that rely on groundwater discharge from perched aquifers would not be affected by drawdown in the regional aquifer system, but springs that are hydraulically connected to the regional aquifer system may experience a decline in discharge as groundwater levels decline, groundwater flow directions change, and groundwater discharge is intercepted by project pumping. Decreased discharge from these regional springs could adversely impact vegetation and habitat areas that have developed around them and the species that depend on them. In addition, decreased spring flow could impair the beneficial use of spring water by senior water right holders. The specific potential adverse effects of spring flow depletion evaluated in this GRIA include the following:

- Reduction or loss of spring discharge availability for beneficial use by senior water right holders for stock, domestic or irrigation use, or for wildlife guzzlers;
- Decline in wetland area, functional components and primary productivity;
- Degradation or loss of groundwater-dependent ecosystems (GDEs), including:
    - Decline or loss of groundwater-dependent vegetation, or shift in species composition leading to habitat degradation;
    - Diminished water sources for aquatic habitat, species and bottom-up food webs;
    - Decline or loss of nesting, roosting, or foraging habitat for avian species;
    - Decline or loss of habitat, forage and refugia for mammals and reptiles;
    - Decline or loss of water supplies used by terrestrial wildlife for drinking, bathing or basking;
- Loss of sensitive or protected animal and plant species; and/or
- Changes in wetland water chemistry and water quality.

5.4.2 LIKELIHOOD, EXTENT AND TIMING OF POTENTIAL IMPACTS

The only regional spring predicted to potentially experience a measurable or observable decline in discharge is Wah Wah Springs, which is further discussed below. The GBCAAS-PV model predicts a slight theoretical decrease in discharge from Dearden Spring Group, Big Springs, and Clay Spring in the Snake Valley HA and Fish Springs in the Fish Springs Flat HA; however, the modeled decreases range from approximately 0.1 to 0.9% of the total discharge at these springs and would not be measurable or observable. Based on the available data, the remaining springs within the area of predicted drawdown induced by the PVWS Project are assumed to discharge water from local perched or semi-perched aquifer systems and are unlikely to be affected by project pumping. However, some uncertainty remains in this conclusion due to the lack of aquifer stress and groundwater supply development in the Study Area. This uncertainty is further discussed in Section 5.4.3.

5.4.2.1 POTENTIAL IMPACTS TO WAH WAH SPRINGS

The predicted depletion of Wah Wah Springs discharge under the Proposed Action is approximately 14% of the total estimated discharge, and the predicted depletion under the ANWS Alternative is

approximately 15%. This amount of spring flow depletion would likely be observable and measurable. Wah Wah Springs consists of a group of springs and seeps within an approximately 380-acre ET discharge area along the mountain front on the eastern slope of the Wah Wah Mountains. The location of the springs and seeps is thought to follow a structural contact of the carbonate and siliciclastic rocks prevalent in the northern portion of the range (Stephens 1974). In this setting, spring flow depletion in the range of 14% to 15%, or similar values, would be most likely to manifest itself either as a depletion of outlying springs and seeps that are in more vulnerable positions along the discharge structure and therefore more vulnerable to groundwater level decline, or as a decrease in overflow from the spring areas to the surrounding groundwater-dependent phreatophyte vegetation. Potential adverse impacts could include the following:

- Declines in wetland area, aquatic habitat, emergent wetland vegetation and phreatophyte vegetation surrounding more vulnerable spring areas;
- Decrease in the area, vigor and composition of phreatophyte and other groundwater-dependent vegetation around the edges of the ET discharge area; and/or
- Decreased availability of water for diversion to Wah Wah Ranch if diversions under the existing senior water right are curtailed to preserve the ecological integrity of the spring system.

The Spring Flow Monitoring and Mitigation Program presented in Section 6.2.6 was developed to identify the potential effects of spring flow depletion, focus investigation on areas of uncertainty and risk, and present an escalating framework of mitigation measures to address potential adverse impacts. With implementation of these measures, the above potential impacts of spring flow depletion are expected to be mitigated. The program allows for collection and evaluation of remote sensing data to support program implementation if the current property owner does not allow access.

5.4.3 UNCERTAINTIES, DATA NEEDS AND RISKS

5.4.3.1 WAH WAH SPRINGS

Consistent with Stephens (1974), Wah Wah Springs is described by Gardner *et al*. (2020) as issuing from the base of the carbonate aquifer unit in the Wah Wah Mountains and draining a mountain aquifer unit perched on a siliciclastic unit; however, it is also acknowledged that water discharged at the springs includes a "thermal" component indicative of deeper circulation. The geochemical groundwater age dating information supports the presence of modern water; however, a fraction of pre-modern water is also interpreted to be present and the discharge from Wah Wah Springs is, therefore, interpreted as a mixture of modern and Late Holocene groundwater (Gardner *et al*. 2020). A principal uncertainty is the fraction of modern versus pre-modern water in the spring discharge, which would provide evidence of the amount of discharge derived from recent recharge to a perched mountain aquifer versus more deeply circulating groundwater from the regional aquifer system that could be affected by project pumping.

In GBCAAS-PV Wah Wah Springs is modeled as discharging entirely from the regional aquifer system. The modeling approach has been refined from GBCAAS v. 3.0 (Brooks 2017) as described in Appendix A, which included the same assumption. This would appear to be a conservative assumption and could lead to over-estimating the amount of spring flow depletion that could result from pumping of the regional aquifer. However, the approach used to simulate discharge from Wah Wah Springs in the GBCAAS v. 3.0 and

GBCAAS-PV models cannot be tested until the PVWS Project is implemented, and thus includes inherent uncertainties typical of modeling simulations. The monitoring and mitigation measures described for spring flow depletion in Section 6.2.6 would identify and appropriately respond to either over-or under-prediction of the potential impacts to discharge at Wah Wah Springs. The program includes direct monitoring of key spring resources as well as monitoring of sentinel wells located between the PVWS wellfield and the springs. With the implementation of these measures, potential adverse impacts to spring resources at Wah Wah Springs will be adequately mitigated.

5.4.3.2 LOCAL MOUNTAIN SPRINGS

The best available geochemical and geologic data indicate that springs in the mountains surrounding Pine Valley discharge groundwater from local perched or semi-perched aquifers and would not be affected by groundwater pumping from the regional aquifer system (Stephens 1976; Brooks 2017; Gardner *et al*. 2020); however, this cannot be conclusively verified until the aquifer is significantly stressed by PVWS Project drawdown. For this reason, Section 6.2.6 includes implementation of a Spring Discharge Monitoring and Mitigation Program that would identify potential changes in spring discharge, ET, vegetation, and habitat quality that could occur if the assumption of discharge from a regionally-disconnected aquifer system is not correct or not completely correct. The program is designed to provide timely warning of potential impacts, identify areas of risk and uncertainty that warrant more detailed investigation, and implement an escalating system of mitigation measures to protect spring-related resources. With implementation of the Spring Discharge Monitoring and Mitigation Program, potential adverse impacts to spring resources would be identified and mitigated.

5.5 POTENTIAL IMPACTS TO GROUNDWATER ET DISCHARGE AREAS

5.5.1 DESCRIPTION OF POTENTIAL IMPACTS

ETg discharge occurs in areas of a groundwater flow system where the depth to groundwater is shallow enough for plant rooting depths to utilize groundwater to meet vegetation water demand. Groundwater levels in the Pine and Wah Wah Valley HAs are too deep for groundwater to discharge locally. Groundwater flows northward out of these basins in the subsurface and ultimately discharges by ETg from phreatophytes and other groundwater-dependent vegetation around Sevier Lake and in the Tule Valley HA, where groundwater levels are closer to the ground surface. As groundwater level drawdown propagates northward from the proposed PVWS Project wellfield over time, groundwater levels would be expected to decline and ETg discharge to decrease. Potential impacts related to groundwater level decline and depletion of ETg discharge include the following:

- Decline or loss of groundwater-dependent phreatophyte species and changes in shrub density or composition;
- Decline or loss of alkali meadow areas;
- Loss or degradation of wildlife foraging, nesting, roosting and refugia habitat;
- Increased erosion due to declining vegetation; and/or
- Air quality degradation due to increased wind erosion.

5.5.2 LIKELIHOOD, EXTENT AND TIMING OF POTENTIAL IMPACTS

In the Study Area, ETg discharge occurs at the northern extent of the regional groundwater flow system in the southern portion of the Sevier Desert HA around Sevier Lake, and in the Tule Valley HA. In these areas, the USGS has mapped GDAs consisting of phreatophyte shrubs and, in a small portion of Tule Valley, alkali meadows (see Figure 3-28). These areas are located remotely from the proposed well field, and ETg depletion effects are expected to be delayed, to increase gradually over a long period of time, and to be associated with small amounts of drawdown in the range of 1 foot or less. Under the Proposed Action ETg depletion is predicted to begin after the end of the 50-year pumping period and to increase slowly over a period of about 250 to 300 years to a maximum of about 70 AFY around Sevier Lake and 340 AFY in the Tule Valley HA (Figure 4-14). The forecast depletion represents about 5% of the total estimated ETg around Sevier Lake and 0.9% of the total ETg in the Tule Valley HA.

GBCAAS v. 3.0 and GBCAAS-PV models simulate ETg discharge areas in Sevier and Tule Valleys using the MODFLOW EVT package, which assigns ET rates to saturated intervals above a static extinction depth. A recent study near Baker Ranch in Snake Valley demonstrated that phreatophyte shrubs were able to adapt and maintain groundwater connectivity and plant vigor during a 6-year period of steady, pumping-induced groundwater level decline of over 4 feet (Devitt and Bird 2016). Since the EVT package cannot simulate the ability of phreatophytes to adapt to changing groundwater conditions, it will tend to over-predict ETg depletion. It is reasonable to expect that ETg depletion would, therefore, be less in magnitude and spread over a larger area than simulated.

The GBCAAS v. 3.0 and GBCAAS-PV models have also adopted the assumption that the ETg demand of phreatophyte shrubs around Sevier Lake is met entirely by groundwater from the regional aquifer system. Recent investigations for the CPM Project at the Sevier Lake playa concluded that phreatophyte shrubs in this area derive at least part of their ETg demand from local perched aquifers and would not be affected by local groundwater pumping for this project (Whetstone Associates and ENValue 2019). Given the geologic setting of this playa, this interpretation seems plausible and, if correct, would further decrease the potential for ETg depletion in this area.

Under the ANWS Alternative, ETg depletion is predicted to begin sooner and to be somewhat greater. ETg depletion is predicted by the GBCAAS-PV model to begin after about 20 years of pumping and to increase slowly over a period of about 150 to 200 years to a maximum of about 110 AFY around Sevier Lake and 590 AFY in the Tule Valley HA (Figure 4-15). The forecast depletion represents about 8% of the total estimated ETg around Sevier Lake and 1.5% of the total ETg in the Tule Valley HA. While this is somewhat greater than the predicted ETg depletion under the Proposed Action, is still represents a relatively small amount of the total ETg theorized for the area and would likely be spread over a larger area.

Based on the available information, the probability that drawdown associated with the PVWS Project would result in a widespread measurable decline in groundwater-dependent vegetation or habitat quality in the GDAs mapped around Sevier Lake and in Tule Valley is low. Correspondingly, increased erosion and air quality degradation impacts are also unlikely. If future monitoring (Sections 5.5.3 and 6.2.7) or other studies were to identify a potential concern related to ETg discharge at the GDAs in Tule Valley and around Sevier Lake, under Utah water law, the junior groundwater right recently granted to the CPM project

would be curtailed prior to the right granted to CICWCD. Since pumping for the CPM project is more proximal to the GDAs, curtailment of pumping at this location would be expected to have a greater and more immediate effect, further decreasing the chances of an adverse ETg depletion impact related to the PVWS Project.

5.5.3 UNCERTAINTIES, DATA NEEDS AND RISKS

The conceptual hydrogeologic model for ETg discharge in GBCAAS v. 3.0 and GBCAAS-PV includes the following uncertainties:

- Sevier Lake Playa may be partially connected to the regional flow system, but is assumed to be completely disconnected;
- A local perched system that discharges to phreatophytes around Sevier Lake has been identified but is not included; and
- The mapping of ETg discharge areas, assumed extinction depths and estimated ET discharge rates include inherent uncertainties and are likely overly conservative.

Implementation of the Wellfield Operation Monitoring and Adaptive Management Program described in Section 6.1.3 will help to ensure that drawdown induced by the PVWS Project is similar to what was predicted in the GRIA and that adaptive modifications are implemented as may be required. In addition, ETg depletion monitoring by remote sensing and documentation of photo points will be conducted as described in Section 6.2.7 to document long-term conditions in the ETg discharge areas and the impact conclusions in the previous section are correct.

5.6 POTENTIAL WATER QUALITY IMPACTS

5.6.1 DESCRIPTION OF POTENTIAL IMPACTS

Groundwater extraction from wells changes regional groundwater gradients and flow patterns, and can cause the migration, capture or trapping of dissolved solutes, contamination and water with inferior water quality, leading to water quality degradation. In addition, groundwater wells can create pathways for vertical migration of contaminants and solutes through intra-borehole flow. Any of these effects can affect the "chemical integrity" of a groundwater basin and, if widespread, severe and pervasive, could potentially violate the definition of safe yield in the Utah Code. Potential groundwater quality impacts in the setting of the PVWS Project include the following:

- Development of a cone of depression in and around Pine Valley could lead to long-term increasing solute concentrations in the local aquifer system through internal trapping of salt loading from recharge sources;
- Zones or pockets of lower quality groundwater or degraded groundwater could migrate into unaffected areas as a result of groundwater extraction;
- Construction of wells with long screen intervals that cross regional aquitards could potentially serve as pathways for vertical migration of groundwater of different quality via intra-borehole flow under ambient (non-pumping) conditions;
- Capture of degraded groundwater by supply wells could result in the requirement for additional treatment; and/or

- Changes in regional groundwater quality could change the quality of groundwater discharged from springs, resulting in potential impacts to aquatic habitat, groundwater-dependent vegetation, and phreatophytes.

5.6.2 LIKELIHOOD, EXTENT AND TIMING OF IMPACTS

A large cone of depression will form around the PVWS Project wellfield; however, this cone of depression will capture only existing long term precipitation recharge sources to the aquifer system and is not expected to capture sources with elevated solute concentrations or other contaminants. No water is imported to Pine Valley for irrigation purposes, and no fertilizers are applied. The only known source of potential solute loading would be the Pine Valley Hardpan which occasionally receives surface water with elevated solute concentrations as a result of evaporation and is located at the northern end of Pine Valley. The Pine Valley Hardpan is not considered as a significant source of recharge to the groundwater system under GBCAAS v. 1.0 (Brooke et al. 2014), GBCAAS v. 3.0 (Brooks 2017) or in water budget studies performed for Pine Valley (Stephens 1976 Gardner *et al.* 2020). In addition, groundwater flow from this area will continue in a northward direction under both the Proposed Action and the ANWS Alternative. For these reasons, groundwater quality degradation through the internal trapping of salt loading sources is not expected to occur.

Although groundwater quality is somewhat variable throughout the Pine Valley HA (Gardner *et al*. 2020; Ensign 2018), likely depending on the age of groundwater in the aquifer system and the parent material of the aquifer sediments (i.e., volcanic rocks vs. carbonate or siliciclastic rocks), no distinct pockets or zones of impacted or inferior quality groundwater have been identified and the groundwater generally meets Primary and Secondary MCLs for drinking water established by the U.S. Environmental Protection Agency (EPA). It is likely that the Pine Valley Hardpan is underlain by salt accumulations from evaporative processes, as is the case for numerous playas in the Great Basin. However, this portion of the valley is also most likely to be underlain by the greatest accumulation of fine-grained sediments in the basin, and it is expected that the net groundwater flow beneath the hardpan will continue to be northward.

Individual wells, and the PVWS wellfield as a whole, will draw water from a wide source area in all directions from the extraction well or area. If local water quality variations exist, they are unlikely to result in distinct water quality impacts that violate water quality standards. In addition, there are no known lateral or vertical migration pathways from degraded groundwater sources that would affect existing wells, and no data that would suggest vertical zonation of water quality that could be mobilized or cross connected by new well completions for the PVWS Project.

As noted in Section 5.4, with the possible exception of Wah Wah Springs, is it unlikely that the project will affect the springs surrounding Pine Valley. Wah Wah Springs could experience a measurable change in water quality if the regional aquifer component of the spring discharge is depleted while the local perched aquifer component remains; however, there are no data to suggest that adverse water quality changes would occur.

Based on the available information, adverse water quality changes are not anticipated as a result of the PVWS Project. Water quality monitoring will be conducted as discussed in Section 5.6.3 below to address potential data gaps and uncertainties, and address potential risks.

5.6.3 Uncertainties, Data Needs and Risks

Based on the available data, potential sources of salt loading and poor-quality groundwater pockets or zones appear to be limited and adverse water quality impacts are not likely. However, the following uncertainties and data needs exist:

- Recharge from the Pine Valley hardpan playa is neglected in GBCAAS v. 3.0 and has not been estimated; and
- The vertical and lateral zonation of groundwater quality in the regional aquifer system is not extensively characterized.

Groundwater quality monitoring will be conducted as part of the Wellfield Operation Monitoring and Adaptive Management Program to help assess groundwater source and migration patterns (Section 6.1.3) and spring discharge monitoring will include water quality analysis as discussed in Section 6.2.6. In addition, CICWCD will conduct water quality monitoring in accordance with applicable State and Federal requirements for its municipal water supply system. With the implementation of these monitoring programs, the risk of encountering unanticipated water quality issues during operation of the PVWS Project is considered low.

5.7 Potential Subsidence Impacts

5.7.1 Description of Potential Impacts

Land subsidence may result from groundwater level decline in the alluvial aquifer systems underlying Pine Valley in areas where significant thicknesses of potentially compressible clays occur. Potential impacts of land subsidence include:

- Changes in elevation and slope of the ground surface, possibly affecting drainage patterns and creating new playa areas or areas prone to flooding;
- Damage to existing linear surface infrastructure, such as roads, pipelines and buried utilities;
- Damage and diminished or loss of function of surface conveyance infrastructure such as ditches, drains, storm sewers or sanitary sewers;
- Damage to buildings, pavements and other surface infrastructure;
- Failure of well casings due to compaction of the basin-fill alluvium;
- Reduced long-term storage capacity; and/or
- Formation of fissures that damage infrastructure or are a hazard to public health, stock or wildlife.

5.7.2 Likelihood, Extent and Timing of Impacts

Based on the available information regarding the geology of Pine Valley, the area most susceptible to subsidence is the north-central portion of the valley in the vicinity of the playa. This area appears to have

served as a depo-center throughout the geologic history of the basin and is a location where significant thicknesses of lacustrine clay strata susceptible to subsidence are likely to occur. The amount of drawdown predicted in the northern and central portions of Pine Valley under the Proposed Action reaches a maximum of about 10 to 20 feet about 75 to 200 years after pumping ceases (Figure 4-1). Under the ANWS Alternative, the maximum drawdown in the northern and central portions of Pine Valley is predicted to be about 10 to 50 years at the end of the 50-year pumping period (Figure 4-2). Based on available data for Escalante Valley and Cedar Valley, groundwater drawdowns of as much as 100 feet have been reported as being associated with up to approximately 3 feet of subsidence, which is roughly 1 foot of subsidence per 30 feet of drawdown. Although there is insufficient information to establish a reliable correlation between predicted drawdowns and subsidence in Pine Valley, the subsidence history of nearby basins in a similar geologic setting provides a useful perspective regarding the general subsidence risk in the area.

Based on this information, engineering judgment, and the predicted drawdown for the PVWS Project compared to drawdown experienced in Escalante Valley and Cedar Valley, pumping of groundwater for the PVWS Project may cause on the order of a few inches to 2 feet of subsidence in northern and central Pine Valley. Depending on the thickness and compressibility of the sediments underlying the wellfield areas in the southern portion of Pine Valley, subsidence in this area could locally range from a few inches to 3 feet or more. However, significant subsidence is less likely in the wellfield area because, even though the predicted drawdown is greater, lacustrine sediments are probably less extensive. In general, based on the available data, the subsidence risk associated with the Proposed Action is less than the ANWS Alternative. The significant depth to groundwater and the actual compressed sediments will decrease and delay the effect of subsidence at the ground surface. Drawdown in the adjacent HAs will primarily affect bedrock, upper alluvial fan and middle alluvial fan areas, which are generally not susceptible to subsidence.

Surface infrastructure in Pine Valley potentially sensitive to damage from subsidence is relatively limited due to a general lack of development in the area. Potential infrastructure that could be damaged includes State Route 21, which is the only paved road in Pine Valley and bisects the north-central portion, the Desert Experimental Range station which is located in the north-central portion of the valley and includes several buildings and dirt roads, other various dirt roads, and ditches that lead to stock ponds and East Pine Reservoir in the northern portion of the valley where subsidence is more likely, but drawdown will be more limited. Potential impacts include local damage to roads and other infrastructure, local fissure formation, and local changes in drainage patterns. The subsidence monitoring and mitigation program described in Section 6.2.8 is expected to identify the effects of subsidence in a timely fashion and effectively mitigate the limited anticipated infrastructure and surface damage that may result.

5.7.3 UNCERTAINTIES, DATA NEEDS AND RISKS

The distribution and extent of unconsolidated clay sediments that may be susceptible to subsidence has not been established, but they are likely to be most extensive in the north-central portion of Pine Valley in the vicinity of the playa. Compressible clays could also occur farther south in the central portion of the valley, and potentially beneath the southwest portion of the valley, where finer-grained sediments

associated with weathering of volcanic rocks may be more prevalent. Additional information on the composition of the basin-fill aquifer will be collected during drilling of wells for the PVWS Project. Lithologic logs will be created during drilling and downhole geophysical logs will be run in the open borehole prior to well completion. These logs will provide geologic data regarding the composition, thickness, and extent of unconsolidated clay sediments in the vicinity of the wellfield in Pine Valley. In addition, the subsidence monitoring and mitigation program will give a more definitive indication as to the distribution and magnitude of potential subsidence impacts.

5.8 POTENTIAL CUMULATIVE IMPACTS

5.8.1 APPROACH

The following subsections present a reasoned assessment of the potential for cumulative adverse impacts that could result from regional groundwater pumping and water budget effects to which the PVWS Project may incrementally contribute. The following topics are discussed:

- An overview of the cumulative effects and individual contributions;
- An assessment of the potential for impacts that are cumulatively adverse; and
- An assessment of uncertainties, data needs and risks.

5.8.2 CUMULATIVE STORAGE DEPLETION AND WATER BUDGET IMPACTS

As discussed in Sections 4.3.3.2 and 4.3.3.3, over 99% of the storage depletion and water budget impacts in the Pine Valley HA under the Proposed Action and the ANWS Alternative are the result of the PVWS Project. Based on this finding, cumulative impacts in the Pine Valley HA are not substantially different from the potential PVWS Project impacts discussed in Section 5.2.

By comparison, only a fraction of the storage depletion in the surrounding HAs at the end of the pumping period would be caused by the PVWS Project. During recovery after pumping, inflow from the surrounding HAs into the Pine Valley HA would increase, while storage depletion from pumping within these HAs would recover. Therefore, the contribution of project-induced effects to cumulative storage depletion is predicted to increase in the 200 years after pumping ceases.

The following conclusions may be made regarding cumulative storage depletion and water budget impacts in the Beryl-Enterprise Area HA:

- In the northern part of the Beryl-Enterprise Area HA, local pumping would add to cumulative drawdown near a cone of depression about 12 miles south of the Pine Valley HA with drawdown predicted to be between 10 and 50 feet beneath an area measuring about 1 by 3 miles. Groundwater drawdown in this area is predicted to recover to less than 10 feet within 10 years after pumping ceases. Under the Proposed Action, the contribution of drawdown to the northern part of the Beryl-Enterprise Area HA is predicted to be about 1 to 30 feet during project pumping, increasing to about 1 to 50 feet in the following 200 years as local groundwater levels recover. The greatest drawdown contribution would occur beneath undeveloped public land well to the north of private agricultural land and groundwater pumping in the area. The contribution to drawdown beneath private agricultural land is predicted to be less than 5 feet. Under the ANWS Alternative, this contribution would decrease to about 1 foot.

- Local drawdown will somewhat increase the cost of groundwater supply pumping for a few wells; however, based on the amount of cumulative drawdown, it is not anticipated that the cost of groundwater supply development and pumping would impair the exercise of prior water rights. Potential adverse impacts to senior water right holders experiencing more than 15 feet of cumulative drawdown (see Table 4-8 in Section 4.3.4.2) would be mitigated under the Interference Drawdown Monitoring and Mitigation Program described in Section 6.2.5. Potential impacts to junior water right holders are a normal and expected result of prior groundwater supply development and are required to be borne by them under Utah water law.
- Accounting for cumulative storage depletion from local pumping in the northern part of the Beryl-Enterprise Area HA and the PVWS Project, cumulative storage depletion at the end of pumping would be approximately 27% higher under the Proposed Action than under the ANWS Alternative. Storage depletion due to PVWS pumping would account for approximately 38% of total depletion in the northern Beryl-Enterprise Area HA under the Proposed Action and 21% under the ANWS Alternative. Storage depletion would continue to increase after pumping stops. After 200 years of recovery, the total predicted storage depletion under the Proposed Action would be approximately 50% higher than when pumping stopped, and the total predicted storage depletion under the ANWS Alternative would be approximately 7% higher than when pumping stopped. Local pumping would account for only about 10 to 14% of the remaining storage depletion and residual drawdown from the PVWS Project would account for the rest. The potential for interaction between drawdown in these basins to produce cumulative storage depletion is a hydrogeologic principal underlying local groundwater management decisions, including adoption of the GMP for the Beryl Enterprise HA and in the approval of CICWCD's water right application in Pine Valley HA. The effects of cumulative well interference drawdown will be addressed through the Well Interference Drawdown Monitoring and Mitigation Program described in Section 6.2.5. As such, the predicted cumulative storage depletion under the Proposed Action or the ANWS Alternative does not impair prior water rights or interfere with implementation of the GMP.
- Cumulative IBF depletion would be somewhat less than depletion predicted to result from PVWS Project pumping only. This is because pumping in the northern part of the Beryl-Enterprise Area HA will somewhat offset the gradient changes by the PVWS Project. Cumulative impacts to IBF under both the Proposed Action and the ANWS Alternative are presumed to have been considered during adoption of the GMP and approval of the CICWCD's water right application, and therefore would not impair prior water rights or interfere with implementation of the GMP.

The following conclusions may be drawn regarding potential cumulative storage depletion and water budget impacts in other HAs surrounding the Pine Valley HA:

- Predicted drawdown under the Proposed Action and the ANWS Alternative in other HAs adjacent to Pine Valley HA would be limited to drawdown beneath the mountain blocks at the edges of the HAs or broader areas with less than 5 feet of drawdown. At their fringes, these areas are predicted to interact with drawdown cones associated with pumping in the Snake Valley (including Hamlin Valley) and southern Sevier Desert HAs. The amount and distribution of drawdown is not expected to lead to a significant increase in groundwater development or pumping costs within the APE for the PVWS Project.
- Cumulative groundwater storage depletion under the Proposed Action is forecast to range from less than 100 to about 4,000 acre-feet at the end of the 50-year pumping period, and about 4,000 to 43,000 acre-feet 200 years after pumping ceases. These volumes are a very small percentage of the total groundwater in storage in these basins. Net IBF is predicted to be depleted by

approximately 2 to 700 AFY, which represents a relatively small component of the groundwater budgets for these HAs. None of these HAs currently operates under a GMP and the predicted IBF and storage depletions are expected effects that were presumably considered in the DWRi's 2014 Order. For these reasons, we conclude the forecasted storage and IBF depletions will not impair prior groundwater rights in these HAs.

- Groundwater storage depletion under the ANWS Alternative is forecast to range from less than 300 to about 10,000 acre-feet at the end of the 50-year pumping period, and about 3,000 to 34,000 acre-feet 200 years after pumping ceases. As such, these impacts would be somewhat greater than the Proposed Action at the end of the pumping period, and somewhat less 200 years after pumping ceases. These volumes are a very small percentage of the total groundwater in storage in these basins. Net IBF is predicted to be depleted by approximately 2 to 1,300 AFY, which represents a relatively small component of the groundwater budgets for these HAs. None of these HAs currently operates under a GMP and the predicted IBF and storage depletions are expected effects that were presumably considered in the DWRi's 2014 Order. For these reasons, we conclude the forecasted storage and IBF depletions will not impair prior groundwater rights in these HAs.

Cumulative effects in the Snake Valley HA (including Hamlin Valley) were simulated using the recent update to the USGS GBCAAS v. 3.0 model developed by Masbruch (2019) in order to assess the long-term effects of pumping in Snake Valley. This was thought to represent the most refined modeling tool available to evaluate the effects of cumulative pumping in that area. This model is considered to provide an adequate perspective for the evaluation of cumulative impacts associated with the PVWS Project; however, further refinement of the model and the underlying water budget and demand assumptions may be needed in order to utilize it as a definitive tool to guide groundwater management decisions in that basin.

5.8.3 CUMULATIVE WELL INTERFERENCE DRAWDOWN IMPACTS

The cumulative effects of drawdown induced by the PVWS Project and local pumping in the HAs surrounding the Pine Valley HA are shown graphically in Figure 4-18 and Figure 4-19 for the Proposed Action and the ANWS Alternative, respectively. As shown in these figures and presented in Table 4-8 of Section 4.3.4.2, under the Proposed Action cumulative drawdown exceeding 15 feet after 50 years is predicted to be induced at three additional Points of Diversion in the northern part of the Beryl-Enterprise Area HA. No other Points of Diversion are predicted to be impacted by cumulative drawdown exceeding 15 feet under either alternative. Potential adverse well interference impacts to the senior water rights associated with these Points of Diversion would be mitigated under the Interference Drawdown Monitoring and Mitigation Program described in Section 6.2.5. With implementation of this program, no impairment of prior water rights would occur.

5.8.4 CUMULATIVE SPRING FLOW DEPLETION IMPACTS

Because Wah Wah Springs is located remotely from existing local pumping in the Snake Valley, Beryl-Enterprise Area and Sevier Desert HAs, no cumulative contribution to the depletion of flow from this spring would occur. Cumulative impacts would be identical to those discussed for the Proposed Action and the ANWS Alternative in Section 5.4.2.1.

The converse is true for the contribution of the PVWS Project to other regional springs in the Study Area. As discussed in Section 4.3.5, the following cumulative spring flow depletions are predicted for regional springs in Snake Valley, primarily as a result of local pumping:

- **Big Springs.** Discharge from Big Springs is predicted to decrease by about 22% from 7,400 AFY to approximately 5,800 AFY after 50 years of pumping. Discharge begins to recover relatively rapidly after simulated pumping ceases, with about 75% of the recovery occurring within 50 years. The component of the cumulative spring flow depletion induced by the PVWS Project would begin slowly after pumping ceases and would not be measurable or observable (approximately 75 AFY or 1% of total discharge after 200 years).

- **Dearden Spring Group.** Discharge from Dearden Spring Group is predicted to decrease by about 52% from 4,800 AFY to approximately 2,300 AFY after 50 years of pumping. Discharge begins to recover relatively rapidly after simulated pumping ceases, with over 90% of the recovery occurring within 50 years. The component of the cumulative spring flow depletion predicted to be induced by the PVWS Project would begin slowly after pumping ceases and would not be measurable or observable (approximately 6 AFY or 0.1% of total discharge after 200 years).

- **Clay Spring.** Discharge from Clay Spring (currently reported as 257 AFY) is predicted to decrease approximately 250 AFY after about 50 years of pumping. Discharge begins to recover relatively rapidly after simulated pumping ceases, with about 90% of the recovery occurring within 50 years. The component of the cumulative spring flow depletion predicted to be induced by the PVWS Project would begin slowly after pumping ceases and would not be measurable or observable (approximately 0.5 AFY or 0.2% of total discharge after 200 years).

- **Fish Springs Area.** Discharge from the Fish Springs area is currently reported as 26,000 AFY and is predicted to decrease by about 60 AFY after 50 years of simulated pumping in Snake Valley. Recovery would occur slowly and would be approximately 80% complete 200 years after simulated pumping ceases. The component of spring flow depletion predicted to be induced by the PVWS Project would begin slowly after simulated pumping ceases, increase to about 50 AFY after 200 years ,then slowly decrease. The net result would be a long-term cumulative depletion of about 50 to 60 AFY for about 250 years. The cumulative spring flow depletion from pumping in Snake Valley and the PVWS Project would be less than 0.2% of the total reported spring discharge and would not be measurable or observable.

Based on the above information, it is likely that Big Springs, Dearden Spring Group and Clay Spring would experience adverse impacts including:

- Loss of wetland area;
- Loss and degradation of aquatic habitat and food webs;
- Loss of habitat, forage and water sources for terrestrial and avian species;
- Loss and degradation of groundwater-dependent vegetation; and
- Impairment of prior water rights.

Based on the available data, the contribution to these impacts from the PVWS project would not be measurable or observable; that is, the same type and severity of impacts would occur regardless of whether the PVWS Project is implemented.

As stated previously, cumulative effects in the Snake Valley HA were simulated using a recent update to the USGS GBCAAS v. 3.0 model developed by Masbruch (2019), which was thought to represent the most refined modeling tool available to evaluate the effects of pumping in that area. The spring flow depletions simulated using this model provide an adequate basis to conclude that significant adverse impacts to regional spring resources should be considered likely as a result of current and foreseeable groundwater pumping in Snake Valley for the purposes of the present impact assessment and pending completion of more definitive studies to inform local groundwater management. Further refinement of the model and the underlying water budget and demand assumptions may be needed in order to utilize it as a definitive tool to guide groundwater management decisions in that basin, and the information provided in this report should not be used for that purpose. Specifically, the current groundwater demand may be over-estimated. Demand estimates and water budget calculations could be refined by additional land and water use analysis, remote sensing and GIS evaluation. Forecast demand trends are similarly uncertain. Finally, the scope of this GRIA did not include a critical analysis of potential static and dynamic model refinements outside the detailed model area of the GBCAAS-PV model. Further analysis would be needed to develop a reliable tool to support a better understanding of local groundwater management options and their potential impacts to springs and other resources.

5.8.5 CUMULATIVE GROUNDWATER ET DEPLETION IMPACTS

Regional ETg discharge in the Study Area occurs via phreatophytes and local alkali meadows, primarily in the area around Sevier Lake and in the Tule Valley HA, and within the Snake Valley HA. As discussed in Section 4.3.6, cumulative ETg depletion in these areas results from a combination of pumping for the PVWS Project and the CPM Project, and agricultural pumping in Snake Valley. The following summary information regarding potential ETg depletion effects informs the analysis of cumulative ETg discharge impacts:

- **Sevier Desert HA.** ETg depletion around Sevier Lake would be dominated by near-term effects caused by groundwater extraction for the CPM Project, followed by latent effects due to the PVWS Project. Under the Proposed Action, cumulative ETg depletion would begin shortly after pumping starts for the CPM Project and reach a maximum of about 100 AFY (8% of the total ETg discharge around Sevier Lake) about 10 years after the 50-year pumping period ceases. ETg discharge decline induced by the PVWS Project would reach a maximum depletion of 70 AFY (about 5% of the total ETg discharge) roughly 300 years after project pumping stops. Under the ANWS Alternative, ETg depletion by the PVWS Project would reach a maximum of about 100 AFY about 200 years after project pumping stops. Under this alternative, overlap between the effects of the CPM Project and the PVWS Project would increase the maximum cumulative ETg depletion slightly, to about 130 AFY (about 9% of total ETg discharge) roughly 10 years after pumping stops.

- **Tule Valley HA.** Cumulative ETg discharge in this HA would be affected by the PVWS Project and, to a lesser extent, by pumping for the CPM Project and agricultural pumping in the Snake Valley HA. Under the Proposed Action, cumulative depletion would reach a maximum of 400 AFY 250 years after pumping stops. Of this total, ETg depletion induced by the PVWS Project would account for up to about 350 AFY. This represents about 1% of the total annual ETg discharge in the Tule Valley HA. Similar to the Sevier Desert HA, under the ANWS Alternative, ETg depletion by the PVWS Project would begin earlier and be greater than under the Proposed Action. Cumulative ETg discharge would increase to about 500 AFY 20 years after pumping stops and would reach a maximum of about 700 AFY 150 years after pumping stops. Of this total, ETg depletion induced by the PVWS Project would account for up to 600 AFY about 150 years after project pumping stops. The maximum cumulative depletion would increase to about 2% of the total ETg discharge in the Tule Valley HA.

- **Snake Valley HA.** ETg discharge in this HA would be affected primarily by pumping in Snake Valley. Under both the Proposed Action and the ANWS Alternative, the contribution of the PVWS Project to ETg discharge depletion in Snake Valley would be less than 0.02%, which is negligible. ETg depletion induced by local agricultural pumping is predicted to begin shortly after pumping begins and increase relatively rapidly to a maximum of 15,000 AFY after 50 years of pumping. This represents about 22% of the total annual ETg discharge in the Snake Valley HA.

The above cumulative ETg depletion estimates for the Sevier Desert and Tule Valley HAs are somewhat higher than the estimates for the PVWS Project alone. However, they are still relatively limited and, as noted in Section 5.5, actual ETg depletion effects are likely to be more spread out in space and time. Furthermore, phreatophyte shrubs in this area have been found to be able to adapt to gradual declines in groundwater levels of over 4 feet, which is greater than the predicted groundwater level declines in this part of the Study Area. Finally, effects related to the CPM Project will occur earlier than the effects of the PVWS Project, giving added opportunity for potential course corrections relative to the curtailment of junior water rights if the monitoring program presented in Section 6.2.7 suggests that measurable ETg depletion is occurring. For these reasons, we conclude that adverse cumulative impacts to phreatophytes and other groundwater dependent vegetation in the GDAs around Sevier Lake and in the Tule Valley HA are unlikely.

The predicted cumulative ETg depletion in GDAs in the Snake Valley HA are over 2 to 20 times higher than those predicted for the Sevier Desert and Tule Valley HAs, respectively. Based on this information, we conclude that adverse impacts to phreatophytes and other groundwater-dependent vegetation are possible in the Snake Valley HA, but pumping for the PVWS Project would not contribute cumulatively to such impacts. As stated above, while the USGS GBCAAS model developed by Masbruch (2019) provides an adequate basis to conclude significant adverse impacts to phreatophytes and other groundwater-dependent vegetation are possible as a result of current and foreseeable groundwater pumping in Snake Valley, further refinement of the model, the underlying water budget and assumptions used to model GDAs may be needed before it can be utilized as a definitive tool to guide groundwater management decisions.

5.8.6 CUMULATIVE GROUNDWATER QUALITY IMPACTS

Cumulative groundwater quality impacts could occur when (1) a cumulative action or project releases contamination or causes water quality impacts that are then acted upon by groundwater extraction associated with the new project; (2) multiple groundwater extraction projects act together to change groundwater flow patterns and capture contamination, draw it into uncontaminated areas, or trap degraded groundwater; or (3) a project interferes or conflicts with an existing or planned cleanup, waste management strategy, or water quality management plan.

As discussed in Section 5.6, groundwater quality effects or impacts are not anticipated to be associated with the PVWS Project. No cumulative pumping is planned that would cause recharge from the Pine Valley Hardpan to be internally trapped in the basin. There are no other known releases or areas of contaminated or degraded groundwater that could be acted upon by the PVWS Project either by itself or in combination with other pumping. The project will not conflict with any known or planned groundwater cleanups, waste management plans or water quality management plans. Based on this information, adverse cumulative water quality impacts are not anticipated.

5.8.7 CUMULATIVE SUBSIDENCE IMPACTS

Drawdown effects are additive in an aquifer, and cumulative increases in subsidence impacts can occur when the effects from multiple pumping wells or centers combine to increase the drawdown in an area underlain by potentially compressible deposits. As described in Section 3.10, areas susceptible to subsidence are expected to occur in the central portions of alluvial valleys where the thickness of compressible clay may be greater and the continuity of fine grained layers leads to a greater level of aquifer confinement. As discussed in Section 4.3.8, areas of groundwater drawdown induced by pumping in the HAs surrounding the Pine Valley HA are predicted to interact with groundwater drawdown induced by the PVWS Project to produce cumulative drawdowns that are mostly in the range of 1 to 10 feet. Induced cumulative drawdowns exceeding 10 feet are predicted to occur in the regional aquifer beneath the mountain blocks and in the upper to middle portions of the alluvial fans. In the valley floor areas of the HAs surrounding the Pine Valley HA, the PVWS Project might increase drawdown by 1 to 3 feet in some areas. Similarly, drawdown induced in the Pine Valley HA by pumping in the surrounding HAs is predicted to be 1 to 5 feet beneath some of the mountain block areas in the Needle Range, but is negligible beneath the valley floor.

Based on the information above, cumulative drawdown that could cause subsidence is expected to be confined to areas where sediments potentially susceptible to subsidence are not expected to occur. Similarly, incremental cumulative drawdown increases in areas where such sediments may be present are insufficient to change the amount of subsidence that would result from locally caused drawdown. As such, no adverse cumulative subsidence impacts are expected that are different from the subsidence impacts described in Section 5.7.

5.8.8 CLIMATE CHANGE

Climate change may affect and magnify the cumulative impacts of the proposed PVWS Project due to factors such as declines in snowpack; changes in the timing, amount and intensity of precipitation;

increased climatic variability and drought frequency; and increased temperatures and ET. Warmer temperatures may cause more rainfall because warmer air holds more water vapor than colder air. Climate change may result in increased average temperatures and corresponding increases in precipitation, but this may be offset by increased evapotranspiration. In addition, there may be more rainfall and less mountain snow. Finally, changing weather patterns may cause changes in the amount (increases or decreases) of precipitation, longer periods without storms or changes in storm intensity. Because Utah's climate is generally very dry, the area is susceptible to strong thunderstorms that cause flash floods, and these storms may become more frequent and more intense as a result of climate change. The underlying concern for all of these scenarios from a groundwater management perspective is the potential for decreased groundwater recharge and increased groundwater discharge.

As described in Section 3.5, average temperatures in St. George, in southwestern Utah, have been steadily warming since 1895 and have increased by approximately 3°F during the period of record (DPS 2019). The temperature record for Cedar City indicates more variable average temperatures, but also with an overall increasing trend of about 0.5°F since 1950. No long-term trends in precipitation were observed at either location during the periods of record. The long-term average annual precipitation is approximately 11 inches for Cedar City and 8 inches for St. George. Significant periods of drought occurred in the 1930s in St. George and in the 1950s and early 2000s in both locations.

Temperatures are projected to warm by 2.5 to 5.5°F over the next 50 years (DPS 2019). Long-range climate models do not provide clear projections of how precipitation will change in southwestern Utah, and do not predict an increase in precipitation. However, increased temperatures would be expected to raise potential ET, and may decrease the amount of precipitation that falls as snow, with both effects depending upon the timing of storm events. Gardner *et al*. (2020) collected geochemical data from wells within the Pine and Wah Wah Valley HAs that indicates snowfall is a less important source of groundwater recharge than higher temperature storms (Section 3.8.6), so the effect of climate change on groundwater recharge in these basins is not clear. It is likely that increased potential ET will result in some decrease in the amount of groundwater available for mountain recharge, but the distribution, magnitude and timing of this effect is uncertain.

Based on this information, assessment of cumulative impacts related to climate change is somewhat speculative. The following cumulative effects on impacts may be considered:

- It is unlikely that pumping-related impacts from the PVWS Project would be significantly affected by climate change. The amount of municipal pumping associated with the PVWS Project is limited by water right and does not change with climate. Pumping for irrigation uses in the Snake Valley and Beryl-Enterprise Area HAs could increase somewhat, causing greater cumulative drawdown or storage depletion in these areas, but this effect is expected to be limited during the pumping period.
- Water budget effects related to changes in recharge and discharge are expected to take a substantial amount of time to manifest themselves and propagate through the groundwater flow system in the Study Area, where the groundwater table occurs hundreds of feet below the ground surface and recharge areas are 50 miles or more from the discharge areas. Such changes are unlikely to affect the maximum predicted impacts or their timing, which are based on

groundwater extraction during the pumping period and aquifer conditions but could affect the time for conditions to recover from impacts induced by the PVWS Project. This would include recovery of drawdown, storage depletion, spring flow depletion and ET depletion.

- Increased ET and changes in precipitation and temperature could induce long-term stress that leads to changes in plant composition and vigor. These changes could affect vegetation in GDAs and could work cumulatively with groundwater discharge changes, or independent of them. Long-term climate and remote sensing based ET and Leaf Area Index (LAI) monitoring data will help to distinguish these effects.
- Changes in mountain snowpack temporal and spatial patterns could lead to near-term changes in the discharge of local springs, which have shorter response times than regional flow systems. Long-term spring discharge, climate, ET and LAI monitoring data will help to distinguish these effects.

6 ADAPTIVE MANAGEMENT, MONITORING, MITIGATION MEASURES AND REPORTING

To address uncertainty in the aquifer response to pumping, the applicant will implement an adaptive management strategy during construction and operation of the PVWS Project wellfield that is intended to maintain drawdown effects within those predicted by the analysis discussed in Section 4. This strategy will be implemented as an applicant-provided measure that is part of the project, and is required under the 2014 Order issued by DWRi that grants the water right under which the project will operate. In addition, the applicant will be required to implement a monitoring, mitigation and reporting program to prevent potential significant environmental impacts pursuant to BLM's authority under NEPA to require mitigation of potentially significant environmental impacts as condition to approving the right-of-way for the project. These measures are described in detail in Appendix F of the EIS and are summarized briefly in the sections below to provide a context for how the uncertainties and impacts described in Section 5 will be addressed.

6.1 APPLICANT-PROVIDED MEASURES AS PART OF THE PVWS PROJECT

The Wellfield Construction Adaptive Management Program and Wellfield Operation Adaptive Management Program proposed to be implemented by CICWCD are discussed in Sections 2.3.1 and 2.3.2 of this report, and specific monitoring, management action and reporting obligations and requirements are outlined in Appendix F of the EIS for the project. These programs are included as part of the PVWS Project to comply with the 2014 DWRi Order approving Application to Appropriate Water Number 14-118 (A76676) (DWRi 2014b). Specifically, this order states the following:

> *"There has been very little actual pumping of groundwater in Pine Valley to stress the groundwater system such that recharge estimates can be verified through a quantitative analysis. Although the state engineer believes there is water available for appropriation, estimates of the amount of water should be considered preliminary at this time. Applicant should understand that this decision is based on the information and data currently available. Should the groundwater resource prove to be over appropriated as diversions under this and other applications are made, a groundwater management plan could be formulated in the future to address that issue."*
>
> *"Along with this approval, the applicant shall develop a monitoring program to ensure that no prior rights are being impaired and that the aquifer system is not exceeding safe yield. Plans for this monitoring program must be submitted to and approved by the State Engineer prior to diversion of any water from the proposed sources."*

The following subsections include a description of the specific measures proposed by the applicant to address these requirements and to avoid or minimize the likelihood of adverse impacts that would trigger a finding that the safe yield of the aquifer system is being exceeded. The discussions below focus on an overview of the measures and how they will comply with the DWRi requirement to implement a program that assures prior water rights will not be impaired and the aquifer system is not exceeding safe yield.

6.1.1 PVWS PROJECT GROUNDWATER DIVERSION ACCOUNTING

The Utah DWRi's 2014 Order (DWRi 2014b) requires the following:

> *"Each well under this application is to be individually metered and a permanent record of the water diverted from each well shall be maintained. The applicant shall make those records of the diversions made available for inspection by personnel of the Division of Water Rights upon reasonable request.* ***An annual report of all water diversions under this approval shall be submitted to the Division of Water Rights.****"*

CICWCD will implement a water diversion accounting program to meet this requirement as described in detail in Appendix F of the EIS.

6.1.2 PVWS PROJECT WELLFIELD CONSTRUCTION MONITORING AND ADAPTIVE MANAGEMENT PROGRAM

In compliance with with 2014 DWRi Order (DWRi 2014b), a data collection, groundwater monitoring and adaptive management program will be implemented during development of the wellfield to help assure that the configuration of the wellfield will not adversely affect senior water right holders in the Pine Valley HA and the Beryl-Enterprise Area HA beyond the levels considered in Section 4.2.2 and Section 5.1. As described in Section 2.3.1, there is uncertainty about the potential existence of groundwater flow impediments in the aquifer system underlying the southern portion of Pine Valley. If present, such impediments could lead to greater water budget impacts or well interference impacts in this area, as discussed in Sections 5.3.2 and 5.3.3, respectively. Under the Wellfield Construction Monitoring and Adaptive Management Program, construction of the project wellfield will proceed in phases, allowing monitoring data to be collected to assess the aquifer response to the first phase to be assess and the wellfield design to be adjusted so that drawdown and groundwater budget impacts remain within the predicted ranges evaluated in this GRIA.

The program is outlined in detail in Appendix F of the EIS for the project, and will include the following components:

- A Wellfield Construction Monitoring and Adaptive Management Plan will be submitted to DWRi and BLM for review and approval prior to any groundwater extraction from the wells.
- Four wellfield monitoring wells will be fitted with transducers in the southern portion of the proposed wellfield. These monitoring wells will include one existing well and three new wells to be installed for the project, located as shown on Figure 2-3.
- Lithologic and aquifer parameter data will be collected during construction and testing of the first six production wells and the new monitoring wells.
- During initial pumping of the first six wells, over a period of about three to 12 months, well yield and drawdown data will be collected to assess the aquifer response to the stress of production-scale pumping. This will include comparing the the observed drawdown to the predicted drawdown in the monitoring wells shown in Figure 2-4.
- If the drawdown response is greater than that predicted in this GRIA, the GBCAAS-PV model will be updated. The updated model will be used to assess modifications to the wellfield so that long-

term groundwater budget and drawdown impacts remain similar to or less than those predicted in this GRIA.

- Wellfield expansion would then occur in a subsequent phase, during which some or all of the remaining wells would be shifted to alternative locations located further north in Pine Valley. These alternative locations are shown on Figure 2-2.

6.1.3 PVWS PROJECT WELLFIELD OPERATION MONITORING AND ADAPTIVE MANAGEMENT PROGRAM

As described earlier and stated in the DWRi 2014 Order granting the water right for the PVWS Project (DWRi 2014b), because groundwater development and aquifer stress is currently very limited in the Pine Valley HA, predicting the aquifer response to PVWS Project pumping entails inherent uncertainties. This includes not only the drawdown and groundwater budget changes discussed in the previous sections, but potential impacts to spring resources (discussed in Section 5.4.3) and ETg discharge areas and related groundwater-dependent vegetation (discussed in Section 5.5.3). Much valuable information will be obtained by monitoring the groundwater level response to the long-term operation of the project wells. Under the Wellfield Operation Monitoring and Adaptive Management Program, nearfield and farfield monitoring data will be collected to assess the aquifer response during long-term pumping assess and allow wellfield operation to be adjusted so that drawdown, groundwater budget, spring discharge and ETg impacts remain within the levels predicted in this GRIA.

The program is outlined in detail in Appendix F of the EIS for the project, and will include the following components:

- A Wellfield Operation Monitoring and Adaptive Management Plan will be submitted to DWRi and BLM for review and approval prior to any groundwater extraction from the wells.
- Nine or 10 nearfield or far field monitoring wells (depending on the wellfield configuration implemented during the second phase of project wellfield construction) will be fitted with transducers in the area surrounding the proposed wellfield. These monitoring wells will include five or six existing wells and four new wells to be installed for the project, located as shown on Figures 6-1 and 6-2.
- Lithologic and aquifer parameter data will be collected during construction and testing of the production and new monitoring wells.
- During long-term operation of the well field, well yield and drawdown data will be collected to assess the aquifer response to the stress of long-term production-scale pumping. This will include comparing the the observed drawdown to the predicted drawdown in Figures 4-1 and 4-2.
- If the drawdown response is greater than that predicted in this GRIA, the GBCAAS-PV model will be updated. The updated model will be used to assess modifications to wellfield operation so that long-term groundwater budget, drawdown, spring discharge and ETg impacts remain similar to or less than those predicted in this GRIA.

6.2 MONITORING AND MITIGATION

6.2.1 APPROACH

In addition to the monitoring and adaptive management programs adopted as part of the PVWS Project to meet the requirements of the Utah DWRi's 2014 Order and described in Section 6.1, several monitoring and mitigation programs will be adopted and enforceable by the BLM under NEPA. The purpose of these programs is to further assess the effects of implementing the PVWS Project on resources that may be affected by changes in the regional groundwater flow system, and inform the timely and effective implementation of mitigation measures to prevent or offset any significant environmental impacts. These monitoring and mitigation requirements are discussed in detail in Appendix F of the EIS and will focus on the following:

- Collection and reporting of long-term groundwater level and quality data to assess groundwater level impacts by the project;
- Collection and reporting of remotely sensed ET and Leaf Area Index (LAI) data to assess landscape-scale surface water budget and vegetation changes that may be related to the project;
- Monitoring and mitigation of groundwater storage and IBF depletion based on analysis of groundwater level, groundwater quality and modeling data;
- Well interference monitoring and mitigation to address potential adverse impacts to senior underground water right holders;
- Monitoring and mitigation of potential impacts related to spring flow depletion and potentially resulting adverse impacts to habitat, wildlife and senior water right holders;
- Monitoring and mitigation of ETg discharge depletion and potentially resulting adverse impacts related to vegetation, habitat, wildlife, erosion and air quality; and
- Monitoring and mitigation of potential land subsidence and potentially resulting impacts related to surface infrastructure damage and flooding.

As described in detail in Appendix F of the EIS, each monitoring program will be implemented in a stepwise and escalating fashion, as determined by the data collected. Implementation will start with baseline characterization of potentially affected resources, followed by implementation of a routine (Tier I) monitoring program to assess whether adverse effects may be occurring as a result of the PVWS Project. If the Tier I monitoring data indicate that potentially adverse effects could be occurring as a result of the PVWS Project based on review by BLM or its designated representative, monitoring will escalate to Tier II. In this phase, focused investigations and monitoring will be conducted to confirm whether adverse impacts are occurring or likely. If so, the programs escalate to Tier III, which includes implementation of mitigation measures to prevent or offset potential significant impacts and implementation of targeted monitoring programs to assure their effectiveness.

6.2.2 GROUNDWATER LEVEL AND QUALITY MONITORING DATA

Groundwater level data reflect the extent and magnitude of hydrologic effects related to groundwater extraction and are key indicators for understanding potential adverse effects related to storage depletion, interference drawdown, spring flow depletion, ETg depletion, groundwater quality degradation and

subsidence. Data regarding general groundwater quality and stable isotope composition, distribution and trends are also useful for understanding basin-wide groundwater flow dynamics. The data generated by the monitoring programs described in Section 6.1 are necessary to inform the timely and effective implementation of the required mitigation measures. For these reasons, submittal of the monitoring work plans and reports discussed in Section 6.1 to BLM is included as part of the required project monitoring program. In addition, BLM review and approval of these documents prior to finalization will be required.

6.2.3 EVAPOTRANSPIRATION AND LEAF AREA INDEX MONITORING

Remote sensing data will be used to monitor potential water budget and vegetation changes indicative of potential impacts to a variety of resources, including spring resources, ETg discharge areas, GDEs, habitat, protected species and water rights. Remote sensing algorithms based on the equilibrium between the radiation balance and energy balance at the surface of the earth are the only viable, robust means to map regional patterns of ET. The Surface Energy Balance System, a peer reviewed extensively applied algorithm (Paul *et al*. 2011; Paul *et al.* 2018; Su 2002) can be used for reliable regional-scale mapping of ET and ETg (Beamer *et al*. 2013). The accuracy achieved in estimating ETa using this method can be on par with the Lysimeter method, widely regarded as the most accurate (Allen *et al*. 2011), and the energy balance method is accepted as being among the most reliable and defensible methods for evaluating ETa and ETg at the landscape scale. In addition, the energy balance method has approximately half the error of estimates made using comparable approaches based on simple remote sensing vegetation indices based on empirical ratios between different remotely-sensed electromagnetic (EM) band widths, such as Enhanced Vegetation Index (EVI), and Normalized Difference Vegetation Index (NDVI) (Allen *et al*. 2011).

The energy balance algorithm uses local weather information and visible, near-infrared, shortwave infrared, and thermal infrared reflectance data acquired by sensors onboard the Landsat satellite to generate ETa calculations. These data are available for each Landsat overpass, on average every 8 to 16 days, and after removing data affected by cloud cover and pixel artifacts, are extrapolated to daily values using meteorological data. The modeling framework employed for this GRIA includes a set of automated routines (scripts) to download satellite imagery, filter-out clouds, convert imagery to reflectance (using an atmospheric correction model), derive spatially-distributed physical and biophysical variables, and ultimately produce daily ETa estimates on a 30-meter scale.

ETa is reflective of consumptive surface and groundwater use, and in vegetated areas, it is closely correlated with biomass productivity. For additional insight, Leaf Area Index (LAI), which is a by-product of the energy balance algorithm, can be used for assessing vegetation growth dynamics. LAI (in units of area/area) represents the amount of green leaf material in an ecosystem and is geometrically defined as the total one-sided area of photosynthetic tissue per unit of ground surface area. LAI represents an important vegetation biophysical parameter that can be monitored with Landsat satellite imagery to quantify changes in photosynthetic leaf material over time. LAI is sensitive to photosynthetic activity and is an important metric for assessing growth, biomass, and vigor of vegetation.

The continuity of water columns from soil pores through the plant to leaf cells is linked to the evaporative flux creating the soil-plant-atmosphere continuum. Maintenance of this hydraulic system in vegetation is needed to ensure a continuous water supply to leaves. Under conditions of drought or groundwater

stress, leaf area growth, leaf area duration, and leaf photosynthesis are affected at different spatial and temporal scales. In natural vegetation systems, water stress will modify many of the canopy characteristics which could result in significant losses of LAI. Because LAI incorporates physical processes it provides a robust direct measure of seasonally adjusted vegetation health and vigor (Hoyos *et al*. 2016). Formation has applied LAI to monitor vegetation health at a landscape scale in groundwater discharge areas occupied by alkali meadows and phreatophyte desert shrubs in the Great Basin in the Owens Valley, California. The method was adopted for monitoring groundwater dependent ecosystems (GDEs) and peer reviewed by a broad group of stakeholders as well as Federal, State and local agencies (Eamus *et al*. 2016). It was found to be a much better indicator of vegetation health and vigor than empirically derived ratios based on remotely-sensed EM band widths, such as NDVI (Santin-Janin *et al.* 2009), EVI or MSAVI.

In several of the monitoring programs described below, remote sensing data will be used to determine whether future LAI observations at a particular location are within the range of expected naturally occurring variability, or whether it is likely they are being affected by other factors, such as a decline in groundwater levels induced by the PVWS Project or other groundwater pumping. The energy balance method will be used to calculate an ETa and LAI value for each 30-meter by 30-meter grid cell in the Study Area. These data have currently been developed for 2005 through 2014 (Section 3.9.3), but can be analyzed for any period from 1985 through 2020 to provide a robust baseline that reflects the natural range in ETa and vegetative vigor at a 30-meter scale over variable climatic conditions. The approach to using these data for monitoring variation in vegetation health and vigor is illustrated in Figure 6-3, and includes the following steps:

- A historical dataset of ETa and LAI is developed for the Study Area using remote sensing and weather station data, as described above.
- Synoptic precipitation data are compiled from nearby weather stations or rain gauges and assessed to characterize dry, normal, and wet years and their associated ET responses.
- The temporal variability of LAI is analyzed over the baseline period to derive a probability-density curve for each 30-meter by 30-meter grid cell that characterizes the natural range of LAI due to climatic fluctuations during the baseline period.
- Future LAI values for the same grid cell calculated from monitoring data are assigned a quantile score based on the likelihood that an equal or lower value would occur under natural conditions.
- Quantile scores are evaluated in terms of their relationship to a threshold value that identifies them as outliers, their spatial continuity (*i.e.*, the number of cells with low quantile scores that occur in an area) and their persistence over time (number of years) to assess appropriate mitigation actions.

6.2.4 STORAGE DEPLETION MONITORING AND MITIGATION

Data from the Wellfield Construction Monitoring and Adaptive Management Program and Wellfield Operation Monitoring and Adaptive Management Program will be assessed every five years to determine whether operating the PVWS Project wellfield is likely to deplete groundwater storage in the Beryl-Enterprise Area HA or IBF between the Beryl-Enterprise Area HA and the Pine Valley HA above the amounts predicted for the Proposed Action in Section 4.2.2.2. Operation of the actual constructed project wellfield will be simulated using the updated GBCAAS-PV model for the entire 50-year operating period and a 200-year recovery period. If the forecast aquifer storage depletion in the Beryl-Enterprise Area HA

after 50 and 250 years, or the predicted IBF depletion between Beryl-Enterprise HA and the Pine Valley HA, exceed the amounts predicted for the Proposed Action, then appropriate mitigation measures will be implemented as discussed in Appendix F of the EIS, potentially including pumping redistribution and/or acquisition and retirement of water rights.

6.2.5 INTERFERENCE DRAWDOWN MONITORING AND MITIGATION PROGRAM

To mitigate the potential adverse impacts of interference drawdown resulting from the PVWS Project on existing wells operated by prior (senior) water rights holders, an interference drawdown monitoring and mitigation program will be implemented. The program will reimburse senior water right holders for potential expenses associated well interference associated with drawdown induced by the PVWS Project. The program is described in detail in Appendix F of the EIS and will include the following components:

- The program would be administered by BLM or a designated third party.
- Senior water right holders in the area projected to be impacted by 15 feet or more of project-induced drawdown would be identified and notified regarding the program and the opportunity to participate (see Tables 4-3, 4-4 and 4-8 for a preliminary assessment of potentially eligible wells).
- Potentially-affected wells of parties that agree to participate would be inspected and their current condition documented.
- If a participating well owner experiences expenses associated with pumping, rehabilitating, modifying, deepening or replacing their well as a result of the project, they would submit a claim and under the program. Based on review of the claim by BLM or a designated third party, the well owners would be reimbursed for the reasonable and customary cost of these actions.

6.2.6 SPRING FLOW DEPLETION MONITORING AND MITIGATION

Wah Wah Springs is the only spring resource anticipated to experience a measurable effect as a result of groundwater extraction for the PVWS Project. As discussed in Section 4.2.4, if Wah Wah Springs receives all of its discharge from the regional aquifer and operates as simulated in the GBCAAS-PV model, spring flow depletions of 14 to 15% may be anticipated as a result of implementing the Proposed Action and the ANWS Alternative, respectively. The remaining regional springs, Clay Spring, Dearden Spring Group, and Big Springs, are located outside the APE and are not reasonably expected to experience measurable or observable effects as result of project pumping (predicted flow depletions are well under 1%). As such, the only identified regional spring to be included in the monitoring program will be Wah Wah Springs.

The remaining springs in the mountains surrounding Pine Valley are believed to derive their discharge from perched mountain aquifers and, based on investigations performed by the USGS (Gardner *et al*. 2020), are not expected to be affected by pumping from the regional aquifer (Sections 3.7.2 and 4.2.4). Nevertheless, because a potential connection between some of these springs and the regional aquifer system cannot be conclusively ruled out without verifying whether they respond to significant stresses to the regional aquifer system, the spring flow depletion monitoring program will include a number of key local springs. The locations of springs proposed to be included in the monitoring program and progression of simulated drawdown effects at the water table in the underlying regional aquifer are shown on Figure

6-4 for the Proposed Action and the ANWS Alternative. Figure 6-5 highlights the selected spring areas with color infrared imagery details. These springs were selected based on the following criteria:

- They are located near the contact between valley-fill alluvium and bedrock of the surrounding mountain fronts (however, in some cases, important springs at somewhat higher elevations were selected);
- They are generally predicted to experience 1 foot or more of drawdown in the regional aquifer within approximately 10 to 50 years after pumping begins;
- They are associated with a measurable area of ET influence;
- They generally surround the area of predicted wellfield drawdown effects; and
- Data are available for the springs from other studies, such as biological resource surveys and monitoring for the PVWS Project, or prior investigations by the USGS.

Information regarding the springs adopted under the monitoring program for the Proposed Action and ANWS Alternative is summarized in Table 6-5.

TABLE 6-1. LOCATIONS PROPOSED FOR SPRING FLOW DEPLETION MONITORING PROGRAM

Name (NHD Number)	HA	Elevation (ft)	Discharge (AFY)	Prior Investigations	Comments
Meadow Spring (79033322)	Beryl-Enterprise	5,806	80.7	BLM (2010); Transcon (2020)	On BLM Land; Associated with an area of ET discharge near the head of a broad swale and extending about 2,000 feet downstream.
Sheep Creek Spring (81421683)	Pine Valley	6,914	17.7	Gardner *et al*. (2020), BLM (2010)	On BLM Land; Located in a drainage and associated with an area of ET discharge extending about ½ mile downstream.
Water Hollow Spring (81421789)	Pine Valley	7,322	44.4	Gardner *et al*. (2020), BLM (2010)	On BLM Land; Higher elevation, but close to wellfield; Located in a drainage and associated with an area of ET discharge extending about ½ mile downstream.
Unnamed Spring (81421751)	Pine Valley	6,784	NA	None known	State of Utah Land; Located near the head of drainage swale with an area of ET discharge extending about 1,000 feet downstream.
Meadow Spring (81421743)	Pine Valley	6,842	NA	Transcon (2020)	On BLM Land; Located in a swale and in an area of ET discharge measuring about 500 by 1,000 feet.
Biting Spring (81421725)	Pine Valley	6,590	1.6	BLM (2010)	On BLM Land; Located in a hollow at the head of a small drainage with an ET discharge area measuring about 100 by 200 feet.
Pots Sum Pa Spring (81421767)	Pine Valley	6,334	30.2	Gardner *et al*. (2020), BLM (2010)	Private Land; Located in a hollow at the head of a swale, with an ET discharge area measuring about 500 by 1,000 feet
Kiln Spring (75959491)	Wah Wah Valley	5,846	12.9	Gardner *et al*. (2020), BLM (2010)	On BLM Land; Located in a hollow at the head of a drainage swale, with an ET discharge area extending about 250 feet downstream.
Unnamed Spring but reported by Gardner (2020) as	Wah Wah Valley	5,487	1,800	Gardner *et al*. (2020), BLM (2010)	Private Land; Spring complex located on a side slope near the contact between carbonate and underlying siliciclastic

Wah Wah Springs (75959455)					rock near the alluvial valley fill boundary; The ET area around Wah Wah Springs measures about 380 acres.
Big Basket Spring (86909851)	Snake Valley	7,662	NA	Transcon (2020)	On BLM Land; Located in a drainage swale with ET areas extending for over 1,000 feet downstream and encompassing Unnamed Spring 869099581.
Scraper Spring (86909895)	Snake Valley	7,122	NA	Transcon (2020)	On BLM Land; Located in a drainage containing ET discharge areas about 1 mile upstream and ½ mile downstream.
Unnamed Spring (79032388)	Hamlin Valley	Pete/Chad	NA	Transcon (2020)	On BLM Land; Located in a drainage saddle on volcanic bedrock near the crest of the southern Needle Range. Reported moderate flow and found to contain springsnails

Notes: NA = not available

Unnamed spring 79032388 did not meet all of the selection criteria (it is located on volcanic bedrock near the crest of the Needle Range, is not predicted to experience drawdown for 50 to 100 years, and is unlikely to be connected to the regional aquifer system); however, it is included because it is the only spring found to support a population of living springsnails during the surveys conducted by Transcon (2020).

The monitoring and mitigation program is discussed in Appendix F of the EIS and will include the following components:[6]

- Baseline spring characterization;
- Development and submittal of a Spring Resource Monitoring and Mitigation Plan for BLM review and approval;
- Implementation of the Spring Resource Monitoring and Mitigation Plan, including monitoring and reporting;
- Monitoring of ET and LAI changes using remote sensing data;
- Periodic monitoring of spring discharge, vegetation changes, and (if applicable) springsnail population changes; and
- Escalation of the monitoring program, completion of supplemental investigations, and/or implementation of spring discharge mitigation as required under the Plan.

The locations of springs designated for monitoring and average annual ETa from 2005 to 2014 for both the Proposed Action and the ANWS Alternative are shown in Figure 6-4. Information regarding local conditions at each designated spring is shown on Figure 6-5.

6.2.7 GROUNDWATER ET DISCHARGE DEPLETION MONITORING AND MITIGATION

ETg discharge areas for the groundwater flow system that includes Pine Valley occur around Sevier Lake and in Tule Valley. These areas are located remotely from the proposed PVWS Project wellfield, and drawdown effects, if they were to occur, are predicted to be limited to about 1 foot or less, would take

[6] Because Unnamed spring 79032388 does not meet all of the monitoring criteria and is the only spring located outside of the Landsat satellite scene used to develop ET data in this GRIA, it will not be monitored for ET and LAI changes but will be visited periodically to assess potential spring discharge, vegetation and springsnail population changes.

decades or longer to begin, and progress slowly over a period of years. The amount of ETg depletion that could be induced by the PVWS Project around Sevier Lake is predicted to be less than 5% and the amount of ETg depletion predicted in the Tule Valley HA is less than 1%. This assumes that all of the ETg from phreatophytes in this area is derived from the regional aquifer, which is a conservative assumption. A recent study near Baker Ranch in Snake Valley demonstrated that greasewood shrubs (*S. vermiculatus*) were able to maintain groundwater connectivity during a period of steady, pumping-induced groundwater level decline of more than 4 feet between 2007 and 2013 (Devitt and Bird 2016). This suggests the GBCAAS-PV model may overpredict the rate and timing of ETg depletion and that actual impacts may be less and spread over a broader area.

Based on the information above, significant ETg depletion impacts are not anticipated. The PVWS Project will include a Wellfield Operation Adaptive Management Program that includes long-term monitoring of drawdown responses in wells north of the wellfield to help assure that drawdown and ETg depletion are similar to or less than predicted amounts. If this program were to identify a potential concern related to ETg discharge at the GDAs in Tule Valley and around Sevier Lake, it is assumed that the water rights recently granted to the CPM project would be curtailed, further decreasing the chances of an adverse ETg depletion effect. These facts serve to further reduce the extent of the already less-than-significant impacts related to ETg discharge depletion. Nevertheless, ETg depletion monitoring is proposed to document long-term conditions in the ETg discharge areas and verify these assumptions are correct. ETg discharge areas selected for monitoring are discharge areas around Sevier Lake and in Tule Valley. Locations that will be used for ETg discharge depletion monitoring are the GDAs and ET Units mapped by the USGS and shown on Figure 6-6 (Gardner *et al*. 2020).

Due to size of the mapped GDAs and the relatively diffuse nature of the predicted ETg depletion effects, the monitoring program will focus on the use of remote sensing derived ETa and LAI measurements. The monitoring and mitigation program will include the following components discussed in detail in Appendix F of the EIS:

- Baseline GDA characterization;
- Development and submittal of a GDA Resource Monitoring and Mitigation Plan for BLM review and approval;
- Implementation of the GDA Resource Monitoring and Mitigation Plan, including monitoring and reporting; and
- Escalation of the monitoring program, completion of supplemental investigations, and/or implementation of mitigation as required under the Plan.

6.2.8 SUBSIDENCE MONITORING AND MITIGATION

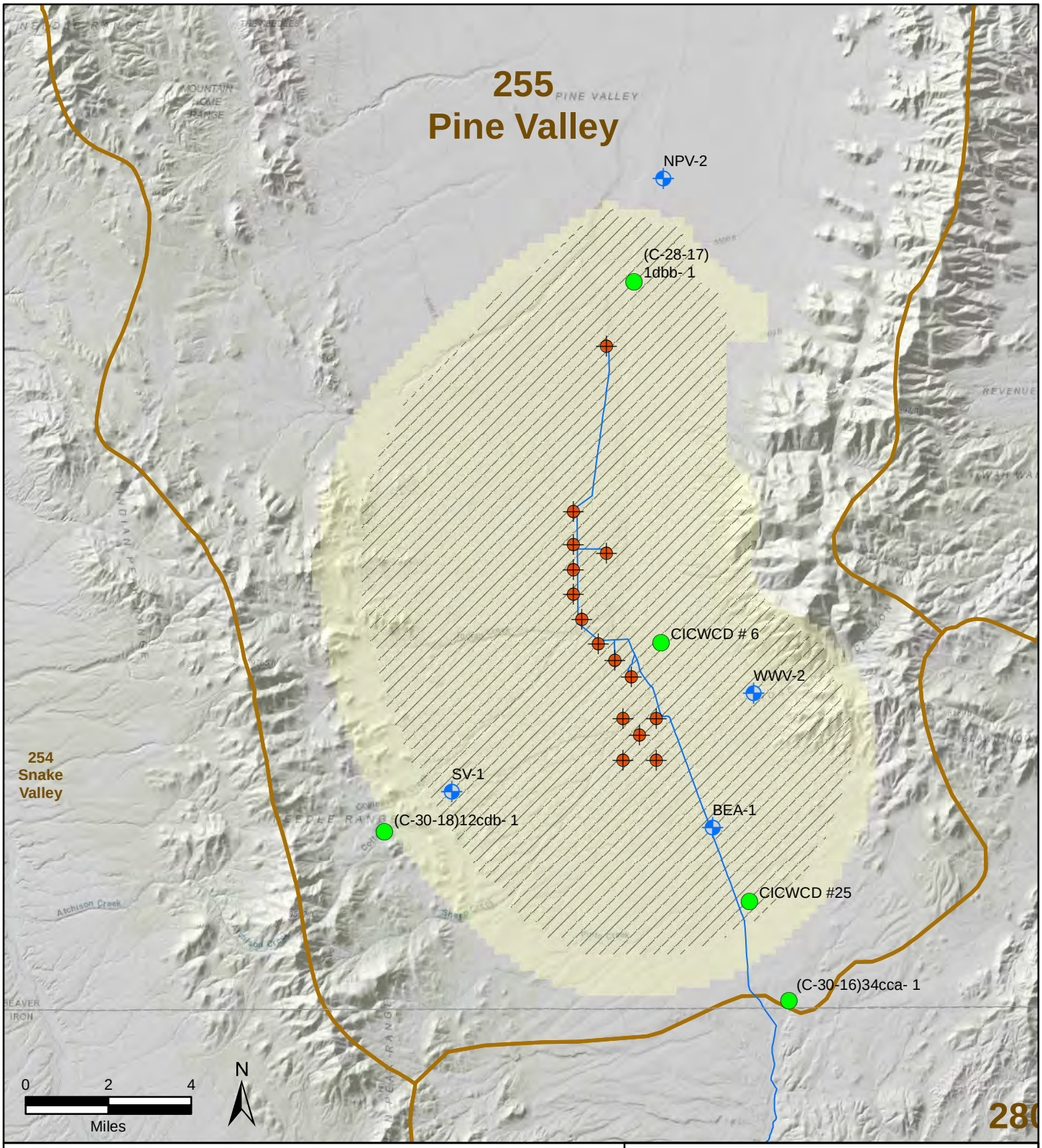
The distribution and extent of unconsolidated clay sediments in Pine Valley that may be susceptible to subsidence has not been established, but they are likely to be most extensive in the north-central portion of Pine Valley. Compressible clays could also occur farther south in the central portion of the valley, and potentially beneath the southwest portion of the valley, where finer-grained sediments may be more prevalent at some locations. Permanent development and infrastructure that could be adversely impacted by subsidence is relatively sparse in Pine Valley, and limited to State Route 12, a network of dirt

roads, and a few permanent structures at the US Forest Service Desert Research Station in the northern portion of the valley that are occasionally occupied.

The Subsidence Monitoring and Mitigation program would focus on monitoring of surface elevations and infrastructure conditions, re-distribution of pumping as may be needed to avoid potentially damaging impacts, and implementation of remedial grading or infrastructure repair as may be needed. A network of 12 subsidence monitoring monuments will be required to be installed throughout the valley floor by the applicant and will serve as the primary basis for subsidence monitoring. The locations of these monuments are shown on Figure 6-7 relative to drawdown predicted for implementation of the Proposed Action, and on Figure 6-8 relative to drawdown predicted or the ANWS Alternative. Field adjustments may be made in the selection of final monument locations.

The Subsidence Monitoring and Mitigation Program will include the following components discussed in detail in Appendix F of the EIS:

- Development and submittal of a Subsidence Monitoring and Mitigation Plan for BLM review and approval;
- Baseline elevation, drainage and infrastructure characterization;
- Implementation of the Subsidence Monitoring and Mitigation Plan, including routine monitoring and reporting;
- Escalation of the monitoring program to focused monitoring, elevation surveys and/or implementation of supplemental geotechnical investigations if evidence of subsidence is observed; and
- Implementation of mitigation as required under the Plan if needed, including re-distribution of pumping as may be needed to decrease subsidence and avoid potentially damaging impacts, and, if damaging subsidence has occurred, implementation of remedial grading or infrastructure repair as needed.



Legend

- PVWS Project Well
- Monitoring Wells (New)
- Monitoring Wells (Existing)
- Hydrographic Area
- Predicted Drawdown >5 ft after 10 years pumping
- Predicted Drawdown >10 ft after 20 years pumping

PINE VALLEY WATER SUPPLY PROJECT

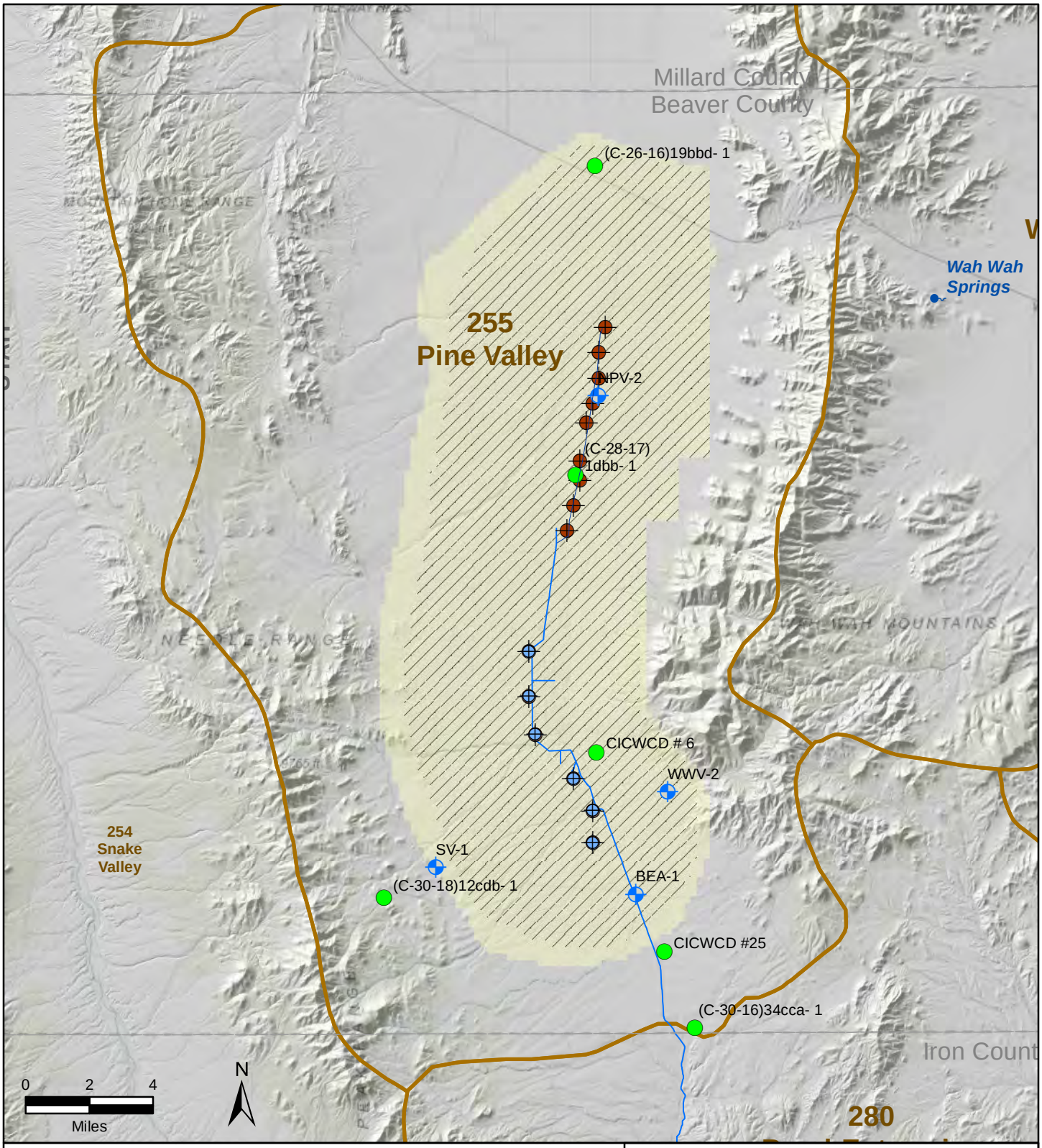
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 6-1

NEARFIELD AND FARFIELD MONITORING WELL LOCATIONS FOR PROPOSED ACTION

DATE: DEC 29, 2020		FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT	

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Legend

- ANWS Alternative Well
- Startup pumping well
- Monitoring Well (New)
- Monitoring Well (Existing)
- Hydrographic Area
- Drawdown >5 ft after 10 years pumping
- Drawdown >10 ft after 20 years pumping

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 6-2

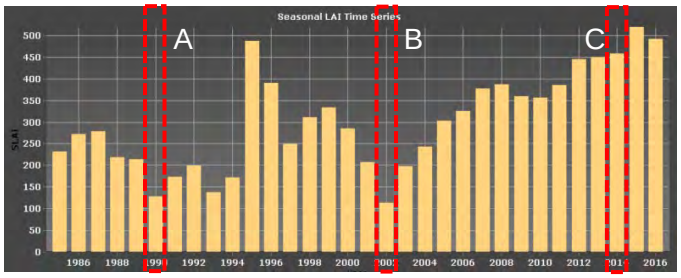
PROPOSED NEARFIELD AND FARFIELD MONITORING WELL LOCATIONS FOR ANWS ALTERNATIVE

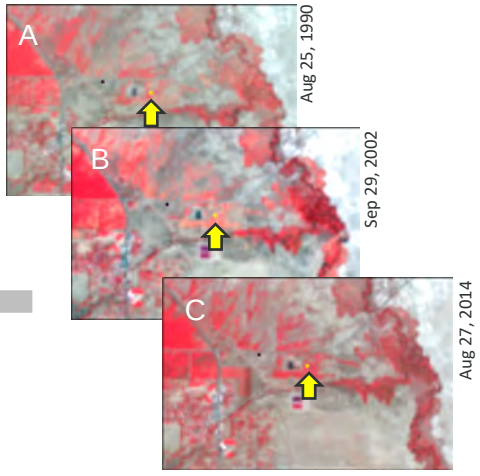
DATE: DEC 29, 2020		FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT	

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LAI Trend Analysis

Temporal ETa dataset is generated per 30m x 30m pixel. Seasonal leaf area index (LAI) time-series is developed as part of analysis.

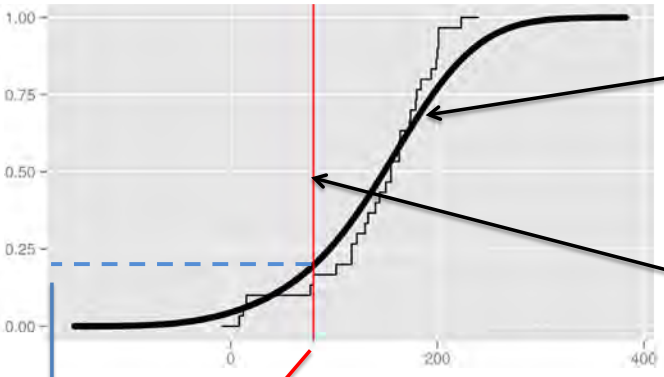




False Color Composites

LAI Statistical Baseline Development

An Example Landsat Pixel Cumulative Probability Density



Estimated probability density curve. All Landsat pixels have a unique cumulative probability density curve specific to that pixel's historical seasonal LAI.

An individual Landsat pixel's single year seasonal LAI value is compared to the historical curve to produce a "Quantile Score" for a given year. A quantile score is a measure of how unusually low a cell's seasonal LAI is, in a given year. It's the probability of seeing a given seasonal LAI value or lower in a randomly selected year.

80 (.20)	203 (.44)	189 (.31)
154 (.28)	65 (.78)	87 (.65)
133 (.77)	50 (.83)	33 (.85)

An example 3x3 Landsat pixel matrix with a single year's seasonal LAI values and associated quantile scores (quantile scores in blue)

PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

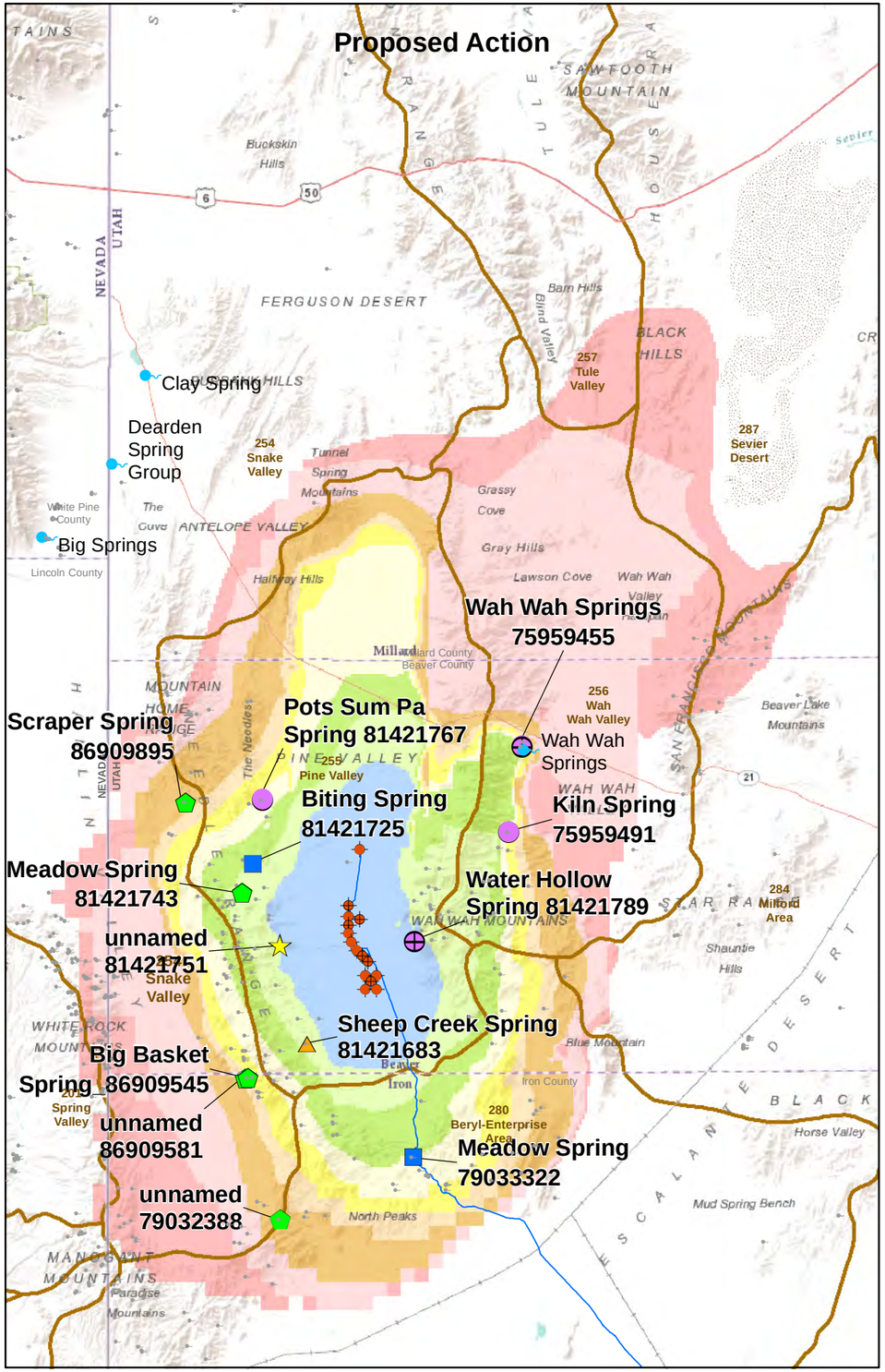
FIGURE 6-3

APPROACH FOR USE OF EVAPOTRANSPIRATION AND LEAF AREA INDEX MONITORING DATA

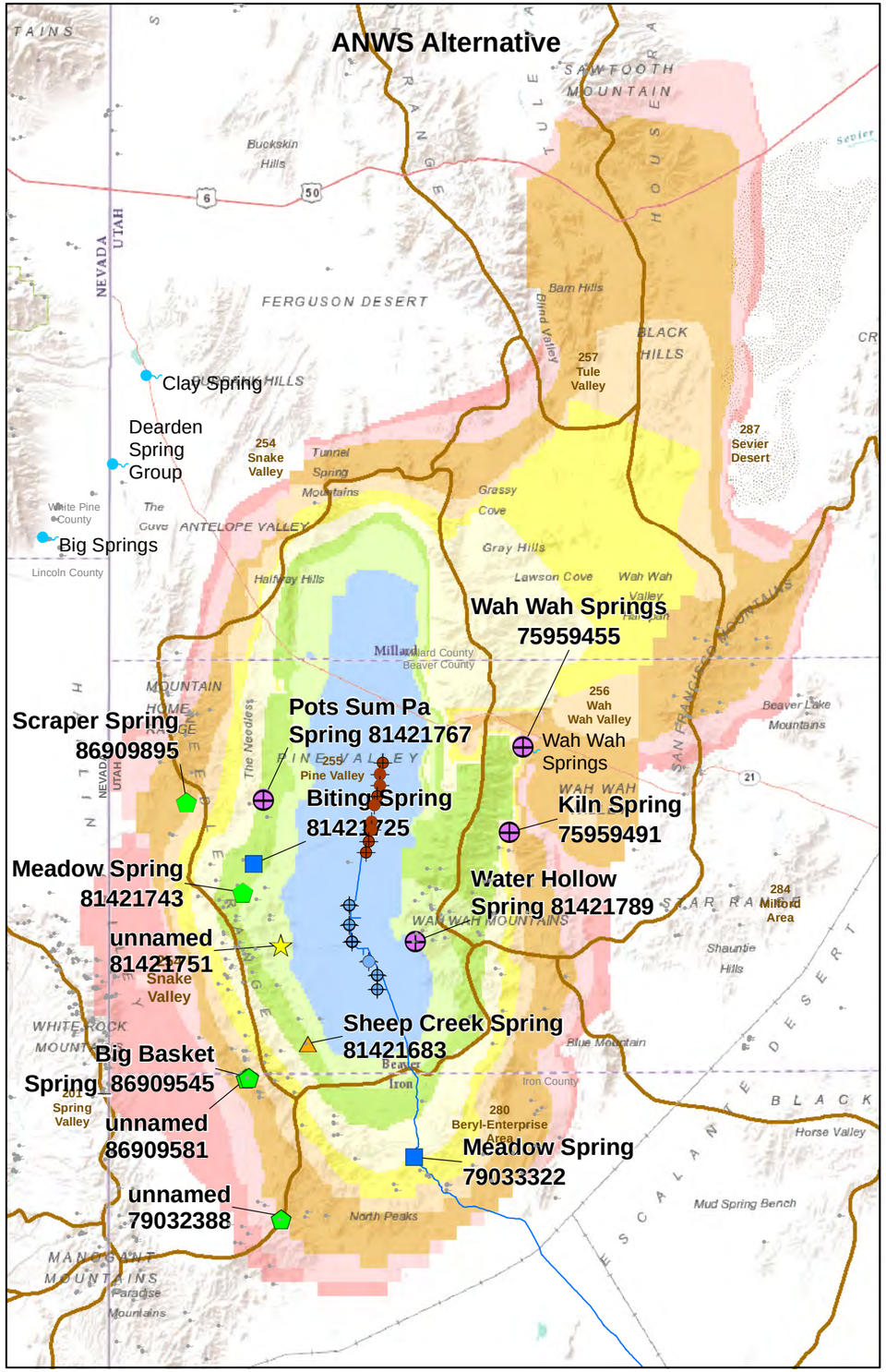
DATE: DECEMBER 2020
BY: PHT
FOR: MT

FORMATION ENVIRONMENTAL

Proposed Action



ANWS Alternative



Legend

- Local Spring
- PVWS Project Well

Proposed Spring Monitoring and Previous Characterization Studies

- Gardner et. al. (2020)
- BLM (2010)
- Gardner et. al. (2020) and BLM (2010)
- Transcon (2020)
- No Previous Studies
- Project Pipeline Alignment
- Hydrographic Area

Drawdown (1 ft)

Model Period

- Pumping yr 10
- Pumping yr 20
- Pumping yr 30
- Pumping yr 40
- Pumping yr 50
- Post Pumping yr 10
- Post Pumping yr 50
- Post Pumping yr 100
- Post Pumping yr 200

0 10 20
Miles

N

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 6-4

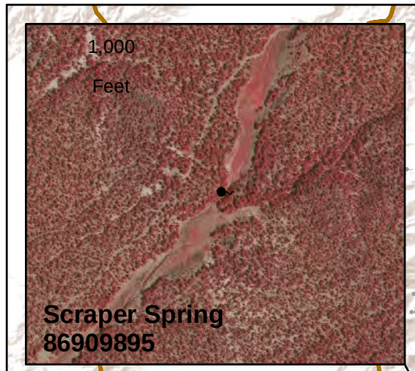
SPRING MONITORING LOCATIONS AND PREDICTED DRAWDOWN TIMING

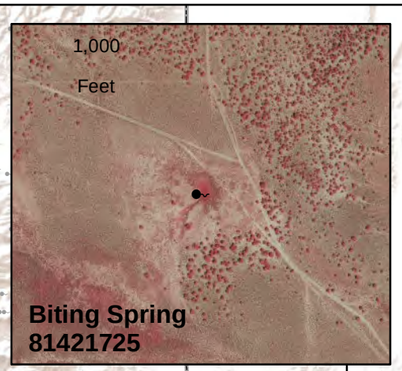
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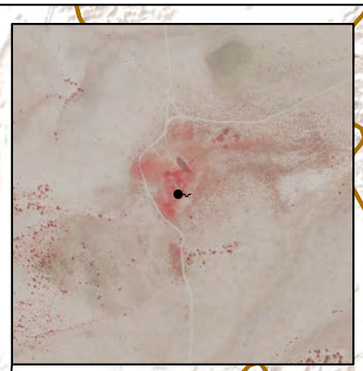
BY: CRL FOR: PHT

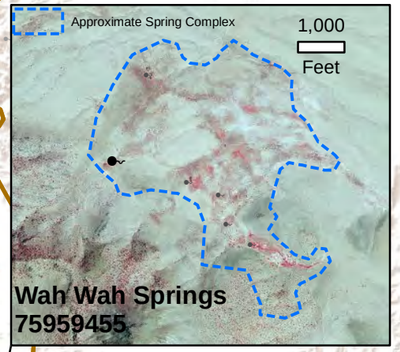
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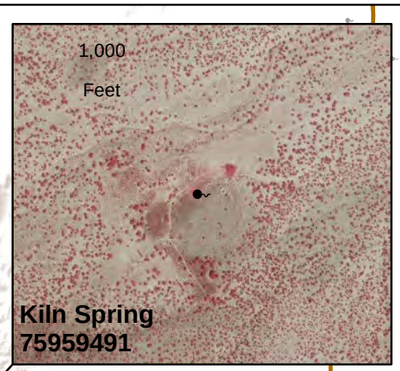
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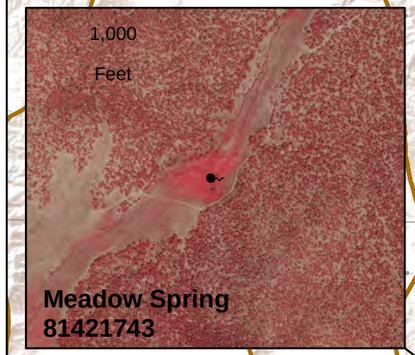


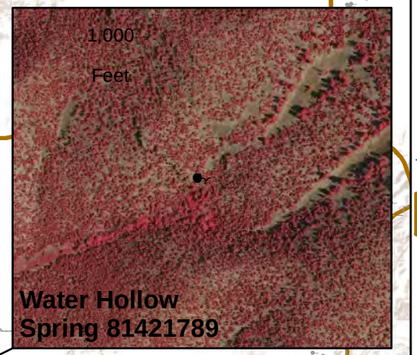


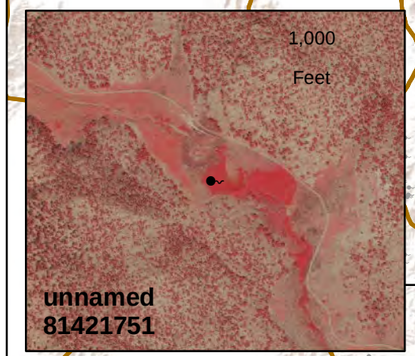


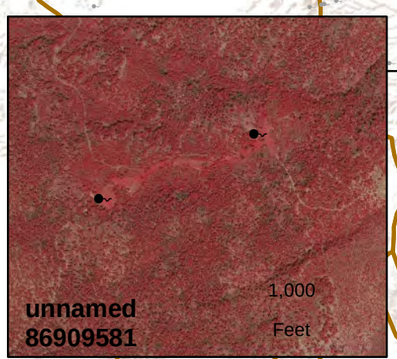


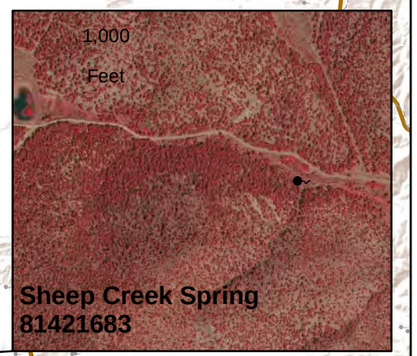


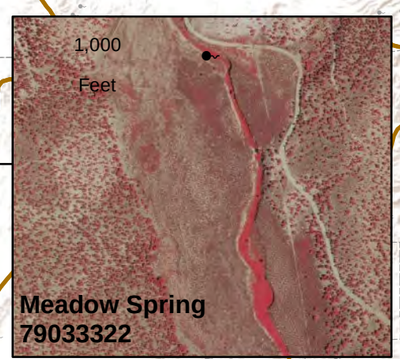












Clay Spring

Dearden Spring Group

Big Springs

White Pine County

Lincoln County

Millard County

Beaver County

Iron County

NEVADA

UTAH

257 Tule Valley

254 Snake Valley

287 Sevier Desert

256 Wah Wah Valley

Wah Wah Springs

255 Pine Valley

284 Milford Area

280 Beryl-Enterprise Area

201 Spring Valley

Legend

- Local Spring
- PVWS Project Well

Proposed Spring Monitoring and Previous Characterization Studies

- Gardner et. al. (2020)
- BLM (2010)
- Gardner et. al. (2020) and BLM (2010)
- Transcon (2020)
- No Previous Studies
- Project Pipeline Alignment
- Hydrographic Area

0 10 20

Miles

N

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 6-5

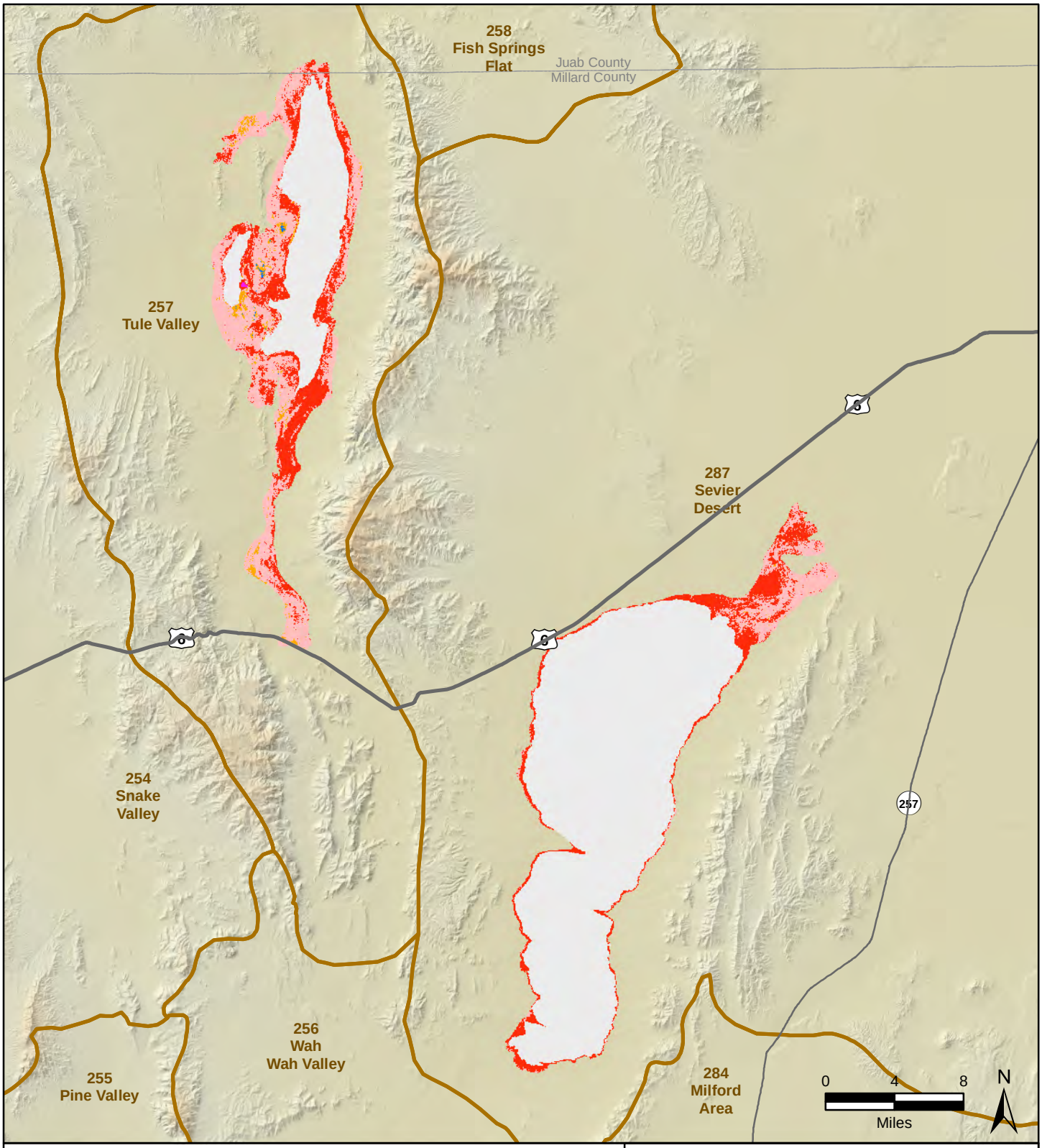
SELECTED SPRING AREAS WITH COLOR INFRARED IMAGERY

DATE: DEC 29, 2020

BY: CRL FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig6_05_PropSpringDetails.mxd



Legend

- Hydrographic Area
- US Route
- State Route

ET Unit (Gardner et al. 2020)

- Dense meadow and marshland
- Grassland
- Open water
- Playa
- Sparse-to-dense desert shrub
- Very sparse desert shrub

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 6-5

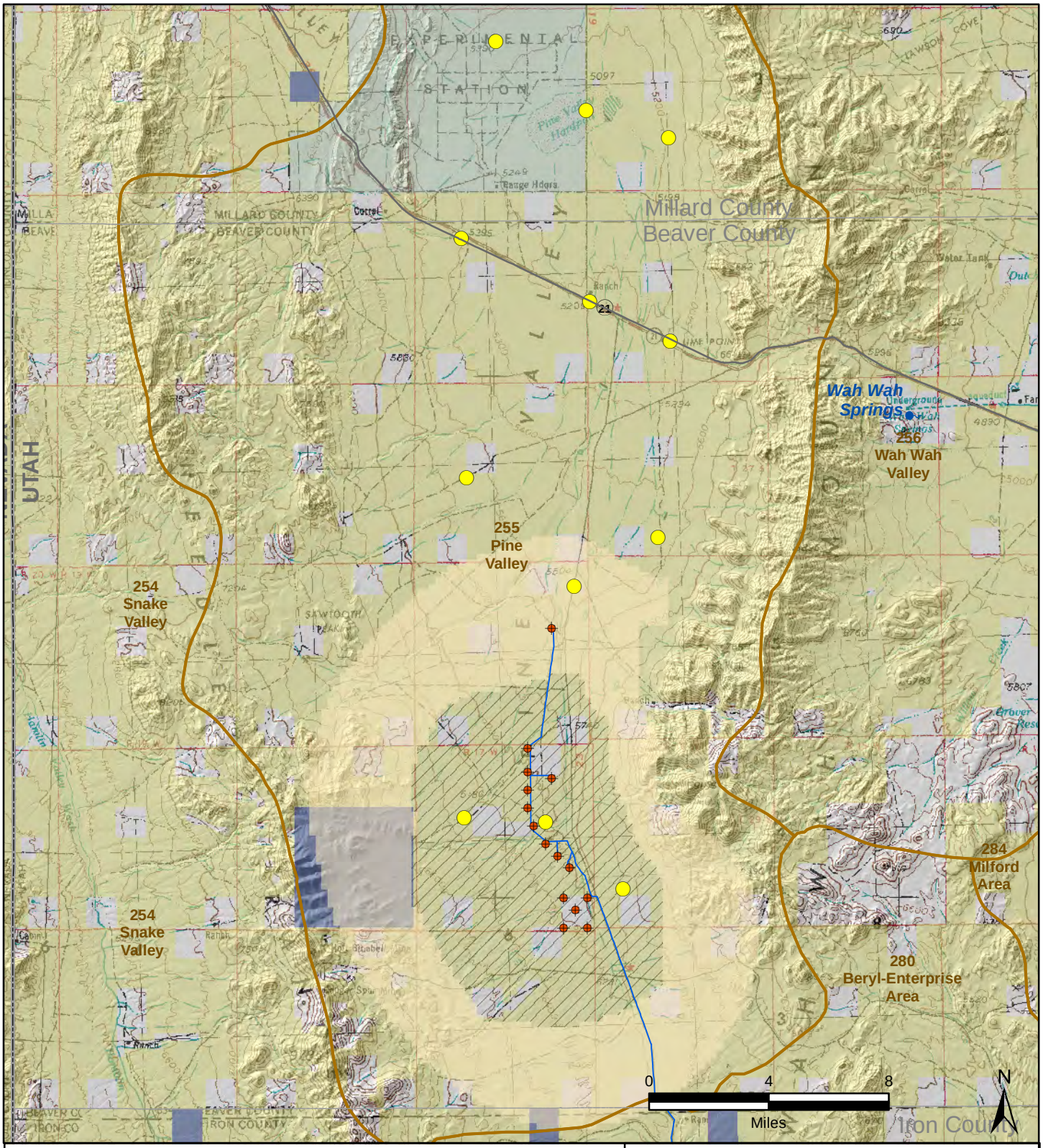
ET DISCHARGE DEPLETION MONITORING AREAS

DATE: DEC 29, 2020

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- Subsidence Survey Monument
- PVWS Project Well
- Project Pipeline Alignment
- State Route

Drawdown after 50 years pumping (feet)

- 30-100
- 100-391
- Hydrographic Area
- Private

- BLM
- Forest Service
- State Parcel

PINE VALLEY WATER SUPPLY PROJECT

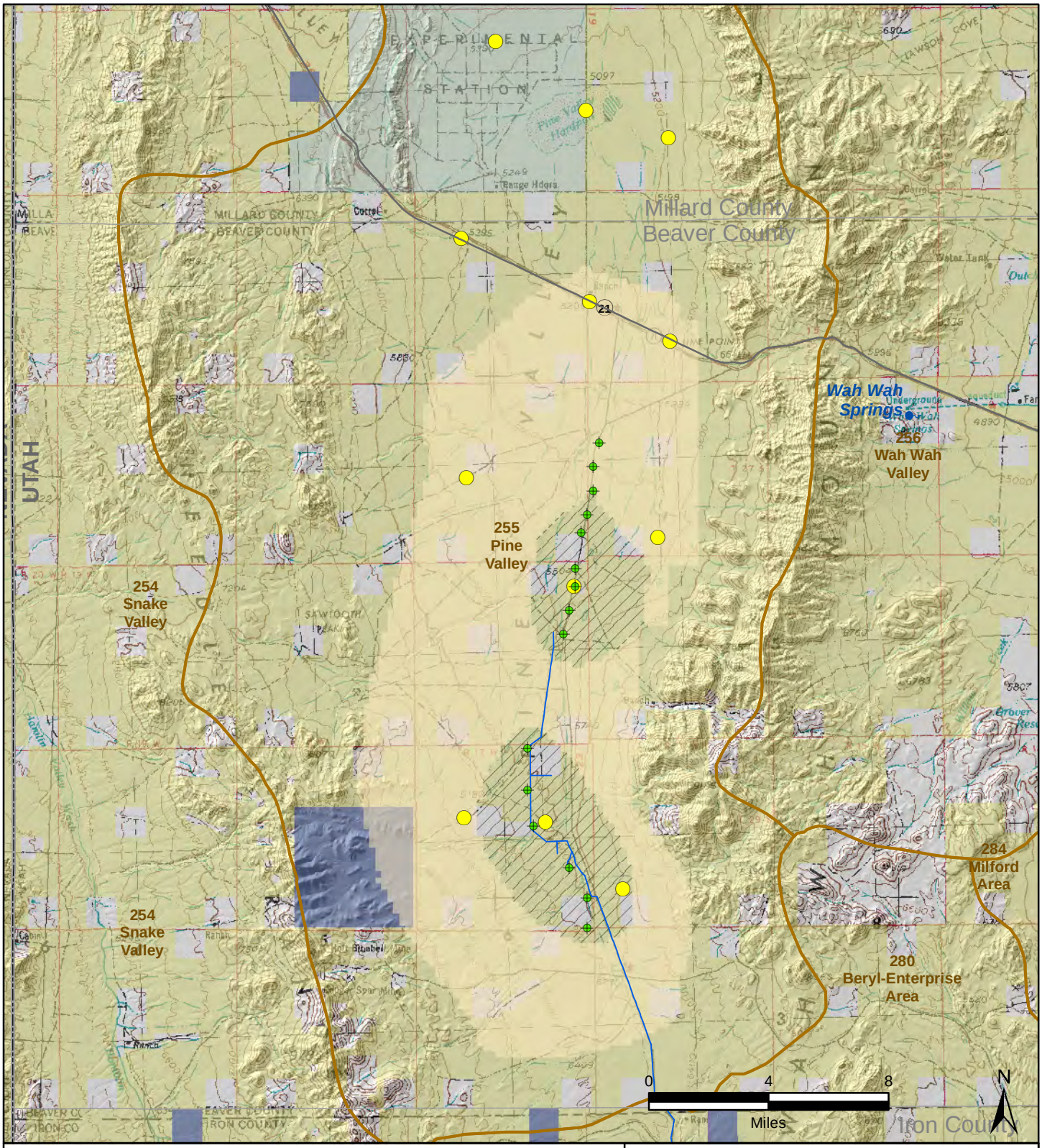
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 6-7

SUBSIDENCE MONITORING MONUMENT LOCATIONS AND MAXIMUM PREDICTED DRAWDOWN FOR PROPOSED ACTION

DATE: DEC 30, 2020	FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT

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Legend

- Subsidence Survey Monument
- ANWS Alternative Well
- Project Pipeline Alignment
- State Route

Drawdown after 50 years pumping (feet)

- 30-100
- 100-196
- Hydrographic Area
- Private

- BLM
- Forest Service
- State Parcel

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE 6-8

SUBSIDENCE MONITORING MONUMENT LOCATIONS AND MAXIMUM PREDICTED DRAWDOWN FOR ANWS ALTERNATIVE

DATE: DEC 30, 2020	FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Fig6_08_SubsSurvMon_ANWS.mxd

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APPENDIX A– DEVELOPMENT OF THE GBCAAS-PV GROUNDWATER FLOW MODEL

Groundwater Resources Impact Assessment

Iron and Beaver Counties, Utah

APPENDIX A

Development of the GBCAAS-PV Groundwater Flow Model

Prepared for:

Transcon Environmental and
Central Iron County Water Conservancy District

Prepared by:

Formation Environmental

SEPTEMBER 2021

PROFESSIONAL CERTIFICATION

The following professionals have reviewed the report entitled Groundwater Resources Impact Assessment, Pine Valley Water Supply and Conservation Project, Iron and Beaver Counties, Utah. Their signatures appear below.

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Attachments

ATTACHMENT A1 – WELL DATA, WATER-LEVEL OBSERVATIONS, AND UNCERTAINTY IN THE GBCAAS-PV MODEL

ATTACHMENT A2 – BERYL-ENTERPRISE AREA, UNDERGROUND, PERFECTED POINTS OF DIVERSION (PODS) USED IN CUMULATIVE ANALYSIS SIMULATIONS

LIST OF ABBREVIATIONS

%	percent
3D	Three dimensional
AFY	acre-feet per year
AMSL	above mean sea level
APE	Area of Potential Effects
BCM	Basin Characterization Model
bgs	below ground surface
BLM	Bureau of Land Management
CEQ	Council on Environmental Quality
CICWCD	Central Iron County Water Conservancy District
cm/yr	centimeters per year
CPM	Crystal Peak Minerals
DNR	Department of Natural Resources
DWR	Division of Water Resources
EC	Eddy Covariance
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ET	Evapotranspiration
ETa	Actual Evapotranspiration
ETg	Groundwater Discharge by Evapotranspiration
EVT	Evapotranspiration Package
ft/day	foot per day
ft^2/day	square feet per day
ft^3/s	cubic feet per second
GBCAAS	Great Basin Carbonate and Alluvial Aquifer System
GDA	Groundwater Discharge Area
GDE	Groundwater Dependent Ecosystem

GDP	Gridded Data Products
gpd/ft^2	gallon per day per square foot
gpm	gallon per minute
gpm/ft	gallon per minute per foot
GMP	Groundwater Management Plan
HGU	Hydrogeologic Unit
in	inches
InSAR	Interferometric Synthetic Aperture Radar
km	kilometers
LAI	Leaf Area Index
LGR	Local Grid Refinement
m	meters
mg/L	milligrams per liter
MSAVI	Modified Soil Adjusted Vegetation Index
NEPA	National Environmental Policy Act
NHD	National Hydrography Dataset
NWIS	National Water Information System
POD	Point of Diversion
PRISM	Parameter-elevation Relationships on Independent Slopes Model
PVWS	Pine Valley Water Supply
RAWS	Remote Automatic Weather Stations
SNWA	Southern Nevada Water Authority
UGS	Utah Geological Survey
USGS	U.S. Geological Survey

A1 INTRODUCTION

A1.1 PROJECT BACKGROUND

Central Iron County Water Conservancy District (CICWCD) proposes to develop the Pine Valley Water Supply (PVWS) Project to extract groundwater from a wellfield in Pine Valley in Iron and Beaver Counties in southwest Utah. CICWCD proposes to beneficially use the water in its service territory in Cedar Valley, approximately 40 miles to the southeast (the PVWS Project or Project) (Figure A1-1). The proposed PVWS Project involves the exercise of a water right granted to CICWCD for the appropriation of 15,000 acre-feet per year (AFY) of groundwater from beneath Pine Valley. CICWCD proposes to install and operate a wellfield with production and monitoring wells in the Pine Valley Hydrographic Area (HA) to extract the water.

The potential environmental impacts of the PVWS Project are being evaluated in an Environmental Impact Statement (EIS) that is being prepared by Transcon Environmental, Inc. (Transcon) under the National Environmental Policy Act (NEPA) on behalf of the Bureau of Land Management (BLM). Two project alternatives are being evaluated, including a southern wellfield alternative and pipeline (the Proposed Action), and a northern wellfield alternative and pipeline (the Adaptive Northern Well Sites Alternative or ANWS Alternative). Under the Proposed Action, a wellfield is proposed to be constructed in the southern portion of Pine Valley. Under the ANWS Alternative, all but the first six of the production wells would be shifted farther to the north in Pine Valley. The water supply wells for both alternatives are anticipated to be completed to depths ranging from approximately 500 to 2,000 feet below ground surface (bgs) to extract water from the alluvial aquifer beneath the valley. At this time, it is anticipated that approximately 15 production wells will be completed. The proposed well layout for the Proposed Action is shown on Figure A1-2 and the proposed layout for the ANWS Alternative is shown on Figure A1-3.

The proposed PVWS Project is located in the southeast portion of the Basin and Range physiographic province (Fenneman and Johnson 1946), which consists of a system of fault-bounded, north-northeast trending alluvial basins that are separated by uplifted bedrock mountain ranges. The Great Basin Carbonate and Alluvial Aquifer System (GBCAAS) covers an area within the Basin and Range province where the alluvial basins are underlain and separated by carbonate bedrock that act together as a regional aquifer system. These regional carbonate aquifers allow groundwater to flow between the individual alluvial basins in the GBCAAS and permit groundwater effects to be regionally transmitted over wide areas.

Formation Environmental, Inc. (Formation) and AquaGeo, Ltd. (AquaGeo) have prepared this appendix to document the development of a refined numerical groundwater flow model to assess the potential groundwater resources-related impacts associated with the PVWS Project alternatives in support of the EIS. The U.S. Geological Survey (USGS) GBCAAS groundwater flow model v. 3.0 (Brooks 2017) was used as a starting point for the refined model that is adequate to evaluate the potential impacts of the PVWS Project, and the refined model is referred to as the GBCAAS-PV model.

A1.2 MODELING OBJECTIVES

The GBCAAS-PV model was developed as a key tool to support assessment of groundwater resources-related impacts that could result from implementation of the PVWS Project, compare the environmental effects of the Project alternatives, develop appropriate monitoring strategies, identify measures that could minimize or avoid Project impacts, and to designate appropriate mitigation measures when potentially significant impacts cannot be completely avoided. The model is needed to address the following potential effects that could occur as a result of groundwater extraction for the PVWS Project:

- Groundwater level drawdown would occur as a result of groundwater extraction for the proposed PVWS Project and is the primary effect that would result from the project.
- Groundwater level drawdown may affect the operation of existing wells in the area around the proposed wellfield. This is referred to as interference drawdown and could impair the exercise of prior water rights by drying up a well, decreasing its capacity, shortening its usable life, and/or increasing maintenance and operational costs.
- Regional groundwater level drawdown and flow changes would decrease the amount of groundwater in storage and change the groundwater balance in the area. This may affect the amount of groundwater available for future beneficial uses or interfere with the implementation of GMPs.
- Groundwater level drawdown and water balance changes may deplete the flow of springs connected to the regional aquifer system within the Area of Project Effects (APE).[1] Spring flow depletion may result in potential adverse impacts to groundwater dependent ecosystems, wildlife and prior water rights.
- Groundwater extraction will change the regional water balance and intercept water that currently discharges to areas of phreatophytes and other groundwater-dependent vegetation through evapotranspiration (ETg) in Tule Valley and around Sevier Lake. ETg discharge depletion could result in stress and decline of groundwater-dependent vegetation, habitat degradation or succession, loss of forage or habitat, increased soil erosion and/or air quality degradation.
- Water quality degradation can occur from changes in groundwater gradients or the migration of water of differing quality through wells when they are not being pumped. The formation of large cones of depression can trap salt loading from recharge containing high concentrations of dissolved solids. Gradients induced by wells can cause the migration or capture of contaminated or lower quality groundwater. These effects can impair the exercise of water rights and harm the chemical integrity of the basin by rendering the water unusable for certain beneficial uses, increasing treatment costs, or damaging environmental resources.

[1] The APE is defined as the area where drawdown induced by the Project is predicted to exceed 1 foot. Initially, the APE was estimated using the GBCAAS v. 3.0 model and later refined using the GBCAAS-PV model.

- Drawdown in Pine Valley could result in the depressurization and consolidation of clay sediments, leading to land subsidence. Land subsidence and fissure formation can damage surface infrastructure, change drainage patterns and increase flooding, and/or pose a risk to public health and safety, wildlife and livestock.

Based on the potential impacts listed above, the specific objectives of the groundwater resources impact assessment (GRIA) supported by the GBCAAS-PV model include the following:

1. Develop a refined understanding of aquifer conditions and groundwater flow in the vicinity of the Pine Valley HA;
2. Refine the groundwater budget in the area surrounding the Pine Valley HA, including recharge, discharge and inter-basin flows;
3. Identify the Area of Potential Effects (APE) induced by groundwater extraction for the PVWS Project;
4. Identify and characterize resources that could be adversely affected by groundwater extraction for the PVWS Project, including springs, groundwater-dependent vegetation and evapotranspiration discharge areas, existing groundwater wells, existing water rights, areas regulated under a Groundwater Management Plan, and areas that are potentially vulnerable to subsidence;
5. Assess the timing and extent of groundwater-resources-related effects induced by the PVWS Project including the following:
    - Drawdown;
    - Groundwater storage depletion;
    - Changes in inter-basin flows;
    - Spring discharge depletion;
    - Groundwater evapotranspiration (ETg) discharge depletion; and
    - Groundwater drawdown-related subsidence;
6. Assess the timing and extent of cumulative groundwater resources effects induced by the PVWS in combination with existing and projected future pumping in Pine Valley HA and adjacent HAs;
7. Based on the predicted effects, evaluate the potential environmental impacts related to groundwater extraction that could result from implementing the PVWS Project;
8. Characterize potential uncertainties inherent in the predicted environmental consequences of the PVWS Project; and
9. Provide recommendations for monitoring and mitigation measures to avoid, minimize or mitigate potential significant adverse impacts associated with the PVWS Project, and to address potential risks and uncertainties.

To support the GRIA, development of the GBCAAS-PV model was guided by the following objectives:

1. Extensive regional groundwater basin characterization and modeling studies have been completed in the GBCAAS by the USGS and others. The GBCAAS-PV should not duplicate this work, and to the extent possible, should leverage previous work for the model-development effort.

2. In the GBCAAS, the effects of groundwater withdrawal can extend across large areas including multiple alluvial basins. Discretization should be more refined/detailed within the area surrounding the Pine Valley HA where the effects of the PVWS Project are anticipated to be the greatest, but the model should extend to include all of the surrounding basins in which water budget effects are anticipated.

3. Past groundwater studies (Brooks 2017; Gardner et al. 2020) have shown that the groundwater flow system in the vicinity of Pine Valley receives relatively limited recharge and groundwater discharge areas are located at a considerable distance away from the valley. As a result, the effects of groundwater pumping take a long time to equilibrate and persist for long periods of time. Transient simulations of PVWS pumping should include a reasonably foreseeable pumping period and a long enough post-pumping period to assess latent effects and recovery trends.

4. Boundary locations and conditions for the model should be established with the goal of minimizing the size of the model, to the extent possible, while not introducing artificial boundary effects within the area of greatest interest.

5. The model was developed to be able to evaluate issues related to groundwater levels, flow, boundary conditions, inter-basin underflow, regional spring flow discharge and ETg at a level of detail sufficient to recognize potential issues for project impact assessment. To accomplish this, the GBCAAS v. 3.0 model was updated and refined in the area encompassing the APE.

6. Groundwater resources are sparsely developed in Pine Valley and its vicinity, which means that stress data from which aquifer properties can be characterized are limited. In addition, available groundwater level monitoring data are limited to a few wells that are relatively widely spaced. This leads to an inherent uncertainty in modeling predictions that cannot be practically resolved until groundwater supplies are further developed during implementation of the PVWS Project. The modeling approach should recognize these limitations. In light of the uncertainty in existing aquifer conditions and groundwater levels, a "superposition" approach is appropriate to evaluate the impacts of the PVWS Project. As explained further in Section 2.0, in superposition modeling, the differences between a baseline and forecast scenario can be compared without the need to accurately quantify existing or future heads and flows, since these are essentially subtracted out. This approach is widely used in impact assessment, and tends to reduce the effect of model uncertainty on model outputs. In addition, as also discussed in Section 2.0, use of the GBCAAS-PV model should be supplemented by monitoring, verification of predicted results, and adaptive management to adapt the PVWS Project to actual aquifer safe yield conditions.

A1.3 REGULATORY CONTEXT

The GBCAAS-PV model supports the analysis of the PVWS Project as part of the preparation of an EIS under NEPA. As such, it must be adequate to support assessment of groundwater resources-related impacts that could result from implementation of the project, compare the environmental effects of the project alternatives, develop appropriate monitoring strategies, identify measures that could minimize or avoid project impacts, and to designate appropriate mitigation measures when potentially significant impacts cannot be completely avoided. Evaluation of impacts to natural systems in general, and modeling of groundwater systems in particular, is an inherently uncertain science. Groundwater resources in Pine Valley have been relatively sparsely developed. As a result, the forecasts made using the GBCAAS-PV model include inherent uncertainties that cannot be resolved until the aquifer system is stressed by implementation of the PVWS Project. These uncertainties, their importance to understanding the environmental consequences of the project, and the probability that adverse environmental impacts could occur must be adequately described.

The fact that the safe yield of the Pine Valley HA is, by necessity, somewhat uncertain prior to development of the project is addressed in the DWRi 2014 Order granting CICWCD's right to appropriate and divert groundwater from Pine Valley. The Order says the State Engineer believes 16,650 AFY of groundwater are available for appropriation in the Pine Valley water right area (Water Right Area 14), including the 15,000 AFY appropriated under CICWCD's water right for the PVWS Project. It further states this estimate is based on currently available data and if in the future Pine Valley groundwater should prove to be over-appropriated because of CICWCD or other water rights exercised in the basin, the State Engineer may adopt a Groundwater Management Plan (GMP) to address the issue. The Order requires that CICWCD develop and implement a monitoring program that ensures no prior water rights are impaired and the aquifer system in Pine Valley is not exceeding safe yield. The Utah Code defines safe yield as "the amount of groundwater that can be withdrawn from a groundwater basin over a period of time without exceeding the long-term recharge of the basin or unreasonably affecting the basin's physical and chemical integrity" (Utah Code §73-5-15(1)(b)).

To comply with the requirements of the DWRi's 2014 Order, CICWCD will implement a monitoring and adaptive management program as part of the PVWS Project. These measures are intended to address the uncertainty inherent in the GBCAAS-PV model and provide critical context for the establishment of the model performance objectives. As described in greater detail in Sections 2 and 6 of the GRIA Report and summarized below, the monitoring and adaptive management program will respond to information gathered during implementation of the PVWS Project, update the GBCAAS-PV model, address new findings, and adapt wellfield operations as needed so that impacts do not exceed the impacts identified by the model. These measures include the following:

- A Wellfield Construction Monitoring and Adaptive Management Program will be implemented to collect data during initial construction and operation of the first six wells to verify model assumptions and performance in the southern portion of Pine Valley, where groundwater level and geologic data suggest unrecognized flow impedances may exist. The aquifer and drawdown data collected during this time will be used to adjust the wellfield configuration as needed so

drawdown and water budget impacts to the Beryl-Enterprise Area HA do not exceed those forecast by the GBCAAS-PV model.

- A Wellfield Operation Monitoring and Adaptive Management Program will be implemented to collect data during long-term operation of the wellfield. The water level and water quality data will be used to help ensure that any exceedance of the impacts identified in this EIS is pre-emptively identified and avoided, and that long-term extraction remains within the safe yield of the basin.

For the EIS, the USGS GBCAAS v. 3.0 model was updated and further refined to serve as an adequate tool to evaluate the potential impacts of the PVWS Project consistent with the modeling objectives described above. A superposition modeling approach was used for assessment of project effects. "Superposition" or "impact modeling" is a robust modeling approach that focuses on evaluating drawdown and flow changes induced by a project rather than actual predicted groundwater levels and flows (Reilly, Franke, and Bennett 1987). All models of natural systems are limited by inherent inaccuracies, and by subtracting a no-Project baseline model from model cases that simulate Project pumping, the potential effects of model inaccuracies on evaluation of Project effects can, to some extent, be subtracted out. The use of superposition modeling in hydrogeologic literature is well established, and this approach has been widely used to evaluate the impacts of water supply pumping under NEPA.

A1.4 PROJECT TECHNICAL REVIEW COMMITTEE

Development of the GBCAAS-PV model was performed through a collaborative process that was implemented by Transcon and included participants representing the BLM and a diverse group of agencies, technical experts and stakeholders. The Groundwater Technical Team included biologists, hydrologists and NEPA experts with BLM, hydrogeologists from the USGS, CICWCD, CICWCD's District Engineer (Ensign Engineering (Ensign)), Barnett Intermountain, Transcon, AquaGeo, and Formation. Representatives from the Utah State Engineer's office were also invited to participate. A series of 24 web-based meetings were held from May 2019 through November 2020. These Groundwater Technical Team meetings provided a forum for discussion of information regarding the development of the model and its use for impact assessment.

A1.5 REPORT ORGANIZATION

This Model Development Report includes the following chapters:

- Chapter 1, *Introduction,* which describes the project background and objectives of the modeling tasks and acknowledges the role and contributions of the technical review committee for the GRIA.

- Chapter 2, *Hydrogeologic Setting*, which provides a brief overview of the physical setting, the groundwater system in the unconsolidated alluvial deposits in Pine and Wah Wah Valleys, and the sources and amounts of recharge and discharge that are components of the water budget.

- Chapter 3, *Model Overview and Refinement Approach*, which summarizes the approach to development of the groundwater flow model, including the concept and approach, modeling code selection, model selection and refinement approach.

- Chapter 4, *Model Development and Calibration,* which describes the approach and methods used for local grid refinement, boundary conditions, hydraulic properties, model observations, and calibration.

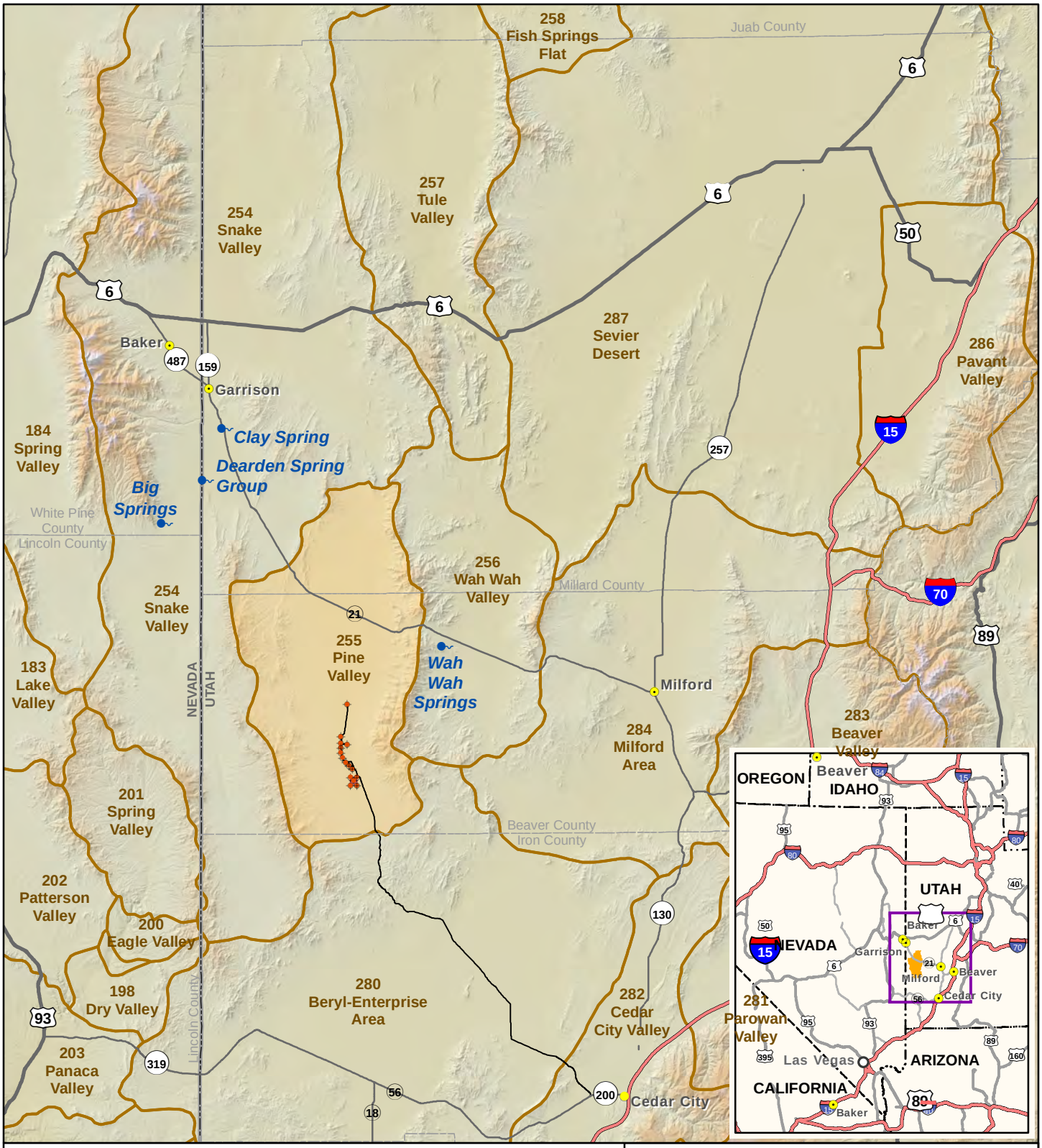
- Chapter 5, *Model Predictions*, which describes the approach used in applying the model to predict the changes in groundwater conditions resulting from implementation of the PVWS Project alternatives, during initial period of wellfield operation, and as a result of cumulative Project and regional pumping.

- Chapter 6, *Summary,* which provides a brief summary of the modeling task.

- Chapter 7, *References,* which includes a list of documents cited in this report.

Attachment 1 includes water-level observations and uncertainties in the GBCAAS-PV model.

Attachment 2 includes a list of the underground and perfected Points of Diversion (PODs) used in the Beryl-Enterprise Area cumulative effects simulation.



Legend

- PVWS Project Well
- Regional Spring
- Hydrographic Area
- CICWCD Parcel
- Project Alignment
- Interstate
- US Route
- State Route

N

0 8.5 17

Miles

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A1-1

LOCATION OF PINE VALLEY WATER SUPPLY PROJECT

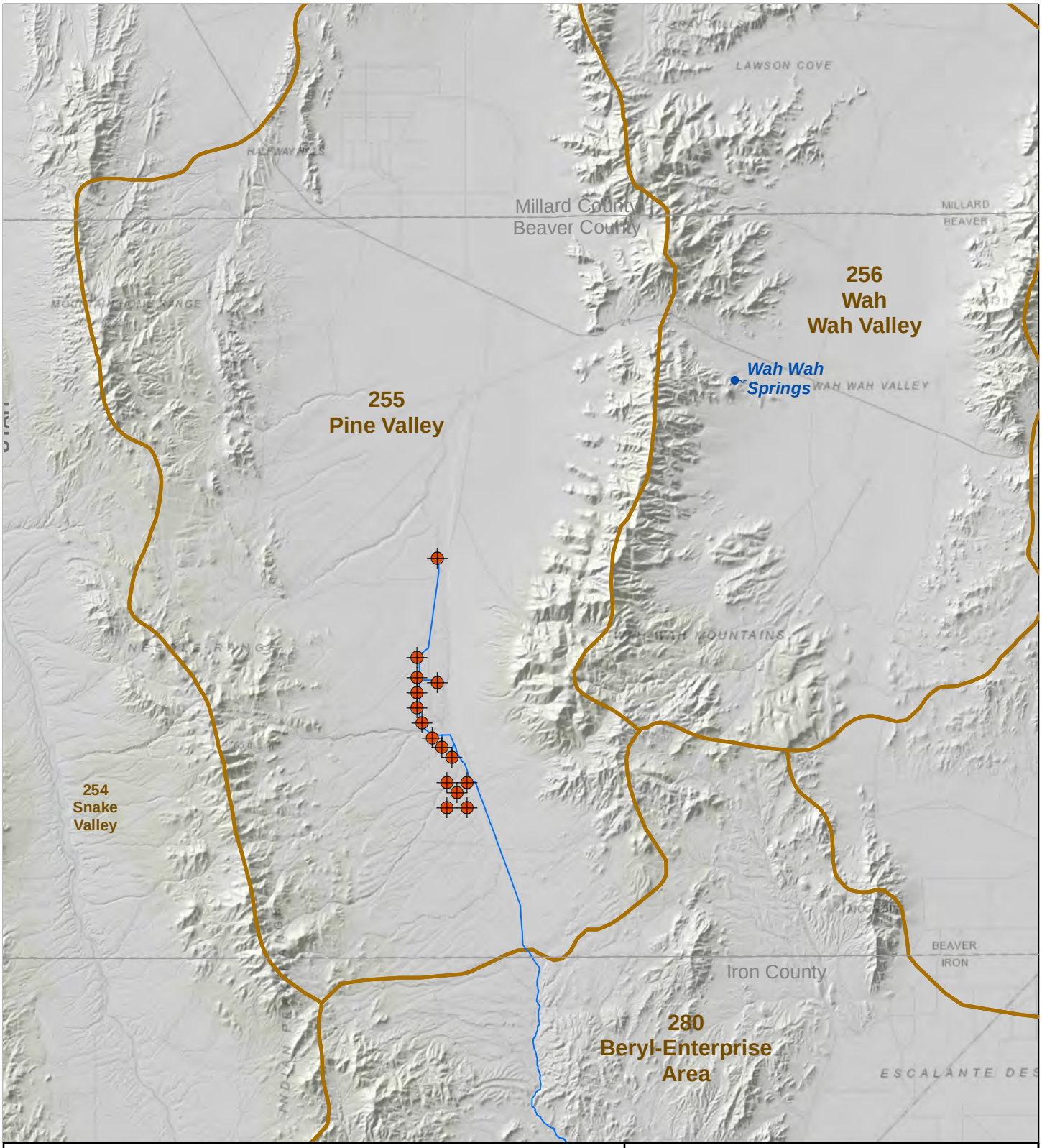
DATE: FEB 16, 2021

BY: CRL

FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- Regional Spring
- PVWS Project Well
- Hydrographic Area
- Project Pipeline Alignment

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PINE VALLEY WATER SUPPLY PROJECT

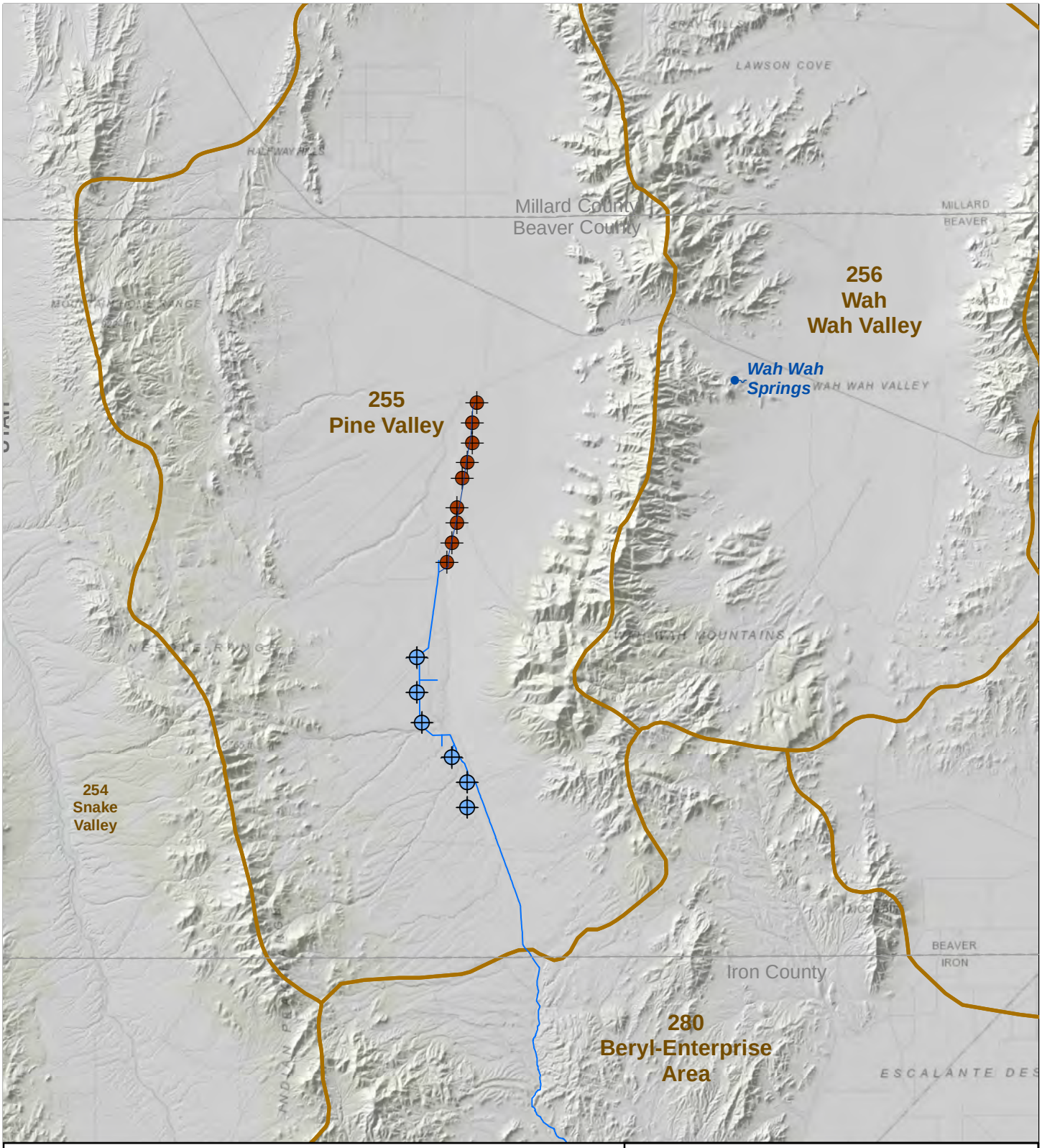
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A1-2

WELLFIELD LAYOUT FOR PROPOSED ACTION

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Legend

- Regional Spring
- ANWS Alternative Well
- Startup pumping well
- Hydrographic Area
- Project Pipeline Alignment

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0 4 8

Miles

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A1-3

WELLFIELD LAYOUT FOR ADAPTIVE NORTHERN WELL SITES ALTERNATIVE

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A2 HYDROGEOLOGIC SETTING

A2.1 OVERVIEW AND PREVIOUS WORK

The PVWS Project is located in the Pine Valley HA in the southeastern portion of the GBCAAS. Modeling for this GRIA, therefore, includes evaluation of hydrogeologic effects across a broad area encompassing several adjacent HAs, including the Snake Valley (including Hamlin Valley), Tule Valley, Sevier Desert, Wah Wah Valley, Milford Area and Beryl-Enterprise Area HAs. The Study Area for this GRIA is shown in Figure A2-1 and was established based on the extent of reasonably anticipated PVWS Project hydrogeologic and groundwater budget effects. The area predicted to experience drawdown induced by pumping for the PVWS Project falls within this area and is considered the Area of Project Effects (APE). Hydrogeologic conditions in this area were evaluated in greater detail, and refinements during development of the GBCAAS-PV model were focused primarily on this area. Of these areas, the most pronounced effects induced by the PVWS Project would occur in the Pine Valley HA, and to a lesser extent in the Wah Wah Valley HA and northern portion of the Beryl-Enterprise Area HA. Lesser effects would extend into the surrounding portions of the Study Area and attenuate with distance.

The first comprehensive study of groundwater resources in the Pine Valley HA was conducted by Stephens (1976). The estimated recharge component of the groundwater budget for the Pine Valley HA was 21,000 AFY, 3,000 AFY of which was accounted as recharge to the Wah Wah Valley HA due to local hydrostratigraphic conditions. This amount was used to inform the regulation of water rights in the basin and remains the technical basis for the understanding of the water volume available for appropriation determined by the DWRi. To help address the potential implications of groundwater supply development in the GBCAAS, the USGS developed a regional steady-state numerical groundwater flow model referred to as GBCAAS v. 1.0 (Brooks *et al*. 2014). In this model, the recharge component of the groundwater budget for the Pine Valley HA was simulated as 24,000 AFY.

To provide additional scientific context for the potential development of groundwater supplies in the southeastern portion of the GBCAAS in Utah, the USGS performed additional hydrogeologic studies and updated GBCAAS v. 1.0 to provide perspective on the potential effects of groundwater supply development in the Pine Valley, Wah Wah Valley and Parowan Valley HAs. The subregionally-updated version of the steady state GBCAAS model was referred to as GBCAAS v. 3.0. To support this update, Gardner *et al.* (2020) conducted a hydrogeologic and geochemical investigation of the Pine and Wah Wah Valley HAs to further characterize aquifer conditions, groundwater occurrence and flow, groundwater recharge and discharge volume estimates, and the source and age of aquifer water and spring discharge. The investigation included pump testing of several wells to better characterize aquifer conditions; sampling and geochemical analysis of groundwater samples from wells to assess the nature, age and source of the water; sampling and geochemical analysis of water from springs to determine whether they are connected to the regional aquifer system or discharge water from perched aquifers; and an evaluation of evapotranspiration in groundwater discharge areas in the Tule Valley and Sevier Desert HAs and further constrain groundwater budget estimates. GBCAAS v. 3.0 incorporated changes to the groundwater budget and recalibrated basin fill hydraulic conductivities based on the assumed water budget changes. Notably, the simulated groundwater recharge component of the groundwater budget for the Pine Valley HA was

decreased to 11,000 AFY; however, hydraulic conductivities of the alluvial aquifer were reduced below recently measured conductivites to meet calibration targets. The GBCAAS v. 3.0 model was used to evaluate the aquifer response to long-term pumping stresses in the Pine Valley and Wah Wah Valley HAs. The study included a theoretical analysis of drawdown impacts that would result if groundwater pumping were continued for 62 years, 1,000 years, and 5,000 years. While simulations of 1,000 and 5,000 years can provide valuable scientific context to understand the nature of the aquifer system, they are too speculative and hypothetical to be considered for use in assessing the actual effects of a project.

A2.2 PHYSIOGRAPHY AND GEOLOGY

Pine Valley is a relatively undeveloped rural valley located approximately 50 miles northwest of Cedar City in southwest Utah and encompasses approximately 730 square miles. Wah Wah Valley lies immediately to the east of Pine Valley and encompasses about 600 square miles. The Pine and Wah Wah Valley HAs are sparsely inhabited. There is one ranch with irrigated land in Wah Wah Valley. The primary land use in Pine Valley is open range used for livestock grazing and recreational activities on federally owned lands.

Pine Valley is an elongate topographically closed basin bounded by the Wah Wah Mountains to the east and the Needle Range to the west as shown in Figure A2-2. The valley extends about 40 miles from north to south and is about 20 miles wide. There is a dry playa near the northern end of the valley. The southern end of Pine Valley is separated from Escalante Valley by a low divide. Wah Wah Valley is also a closed basin with a dry playa near the northern end. The valley is bounded by the Wah Wah Mountains to the west, the Confusion Range and House Range to the north, and the San Francisco Mountains to the east. A broad low divide between the House Range and the San Francisco Mountains separates the northeastern end of Wah Wah Valley from the Sevier Desert.

Structurally, Pine and Wah Wah Valleys are eastward-tilted graben fault blocks that are bounded on each side by normal faults associated with basin and range tectonic extension (Gardner *et al.* 2020). These range bounding faults may be impediments to groundwater flow. Bedrock consists of Precambrian and Paleozoic quartzites and carbonates with lesser amounts of shales, siltstones, and sandstones. The maximum thickness of the lower carbonate sequence is more than 15,000 feet and these rocks underlie most of the valleys at depth. The carbonates are overlain in places by Cenozoic intrusive and extrusive igneous rocks. Some of the tuffs and ignimbrites extend into the subsurface and are interbedded with alluvium in the southern portions of Pine Valley (Stephens 1976). The valley fill consists of Tertiary and Quaternary alluvium with maximum thicknesses interpreted from geologic cross sections of 10,000 feet in Pine Valley and 4,000 feet in Wah Wah Valley. Lithologic units and interpreted faults are shown on the surficial geologic map of the Study Area (Figure A2-3).

A2.3 SURFACE WATER RESOURCES

There is no surface water outflow from the Pine Valley HA. A well-developed network of intermittent to ephemeral stream channels leads onto the playa from the surrounding mountains (Figure A2-4). Stephens (1976) observed that runoff seldom reaches the playa except during intense local storms because most runoff from the southern portion of the HA is dissipated by infiltration and evaporation before it reaches the playa. The only perennial streams in the Pine Valley HA consist of a few short headwater reaches that

appear to be perched zones (Gardner *et al.* 2020). As such, they are not expected to be affected by groundwater level drawdown due to pumping associated with the PVWS Project. Pine Valley Wash is the predominant wash that drains to the playa. Stephens (1976) estimated that runoff reaching the Pine Valley playa averages less than 500 AFY, or about 0.1% of the total precipitation on the HA.

Similarly, there is no surface water outflow from the Wah Wah Valley HA. All the washes and streams in Wah Wah Valley are intermittent or ephemeral. Streamflow has been historically observed in the more prominent channels during large high-intensity precipitation events but does not persist for great distances due to streambed seepage (Gardner *et al.* 2020). These streams are losing and not connected to the regional groundwater table by a continuous saturated zone and, therefore, are not expected to be affected by potential groundwater drawdown associated with pumping for the PVWS Project. Wah Wah Wash is the predominant wash that drains into the Wah Wah Valley playa, which is a sink at the northern end of the Wah Wah Valley HA. Total annual runoff below an altitude of 5,600 feet is estimated to average less than 500 AFY, even though one-half of the total precipitation in the valley falls below this altitude (Stephens 1974).

The only other surface water body within the APE shown on Figure A2-4 that has a potential to be groundwater-connected is Sevier Lake, located in the southern portion of the Sevier Desert HA, approximately 50 miles north-northeast of the proposed PVWS Project wellfield. No other interconnected surface water bodies have been identified in the Study Area (Brooks 2017). Although Sevier Lake receives significant runoff in some years that results in the formation of a large, shallow playa lake, recent investigations for the Crystal Peak Minerals (CPM) Sevier Playa Potash Project (CPM Project) determined that the shallow brine system at Sevier Lake occurs in relatively low permeability playa sediments that impede communication with the underlying regional aquifer system (Whetstone Associates and ENValue 2019). Brooks (2017) made the assumption that Sevier Lake is disconnected from the regional aquifer.

A total of 268 springs and seeps are reported in the USGS National Hydrography Dataset (NHD) as being located within the APE for the Proposed Action in the mountains surrounding Pine Valley. In the APE for the ANWS Alternative, 230 springs and seeps are reported. Most of these springs are at elevations over 5,400 feet above mean sea level, which is above the mountain bedrock-basin fill transition zone and suggests that the springs are perched (Stephens 1974, 1976). Gardner *et al.* (2020) collected water samples from springs in the mountains surrounding Pine and Wah Wah Valleys and the results were compared to similar analyses of groundwater samples collected from wells completed in Pine and Wah Wah Valleys. The results support the conclusion that the springs are associated with perched or semi-perched mountain aquifers that are hydraulically separate from groundwater in the valleys, which tends to be significantly older and different geochemically. Most of the local springs and seeps in the NHD dataset do not have associated discharge data.

The identified springs include one suspected regional spring (Wah Wah Springs) that is assumed to discharge water from, and be hydraulically connected with, the regional GBCAAS. Three regional springs (Big Springs, Dearden Spring Group and Clay Spring) were identified within the Study Area but outside the APE. In addition, Fish Springs, an important regional groundwater discharge point, is located north of the Study Area. Stephens (1974) reported that discharge at Wah Wah Springs was measured at 500 gallons

per minute (gpm) (800 AFY), and that an additional 600 AFY of groundwater was discharged annually by evapotranspiration (ET) in the immediate vicinity of the springs for a total estimated discharge of approximately 1,400 AFY. The discharge from Wah Wah Springs was measured by Gardner *et al.* (2020) at approximately 1,000 gpm (1,600 AFY). An analysis of ET conducted for this GRIA indicated that the average annual groundwater ET (ETg) in the vicinity of Wah Wah Springs between 2005 and 2014 was approximately 200 AFY. For development of the GBCAAS-PV model, the ETg amount was added to the spring discharge measured by Gardner *et al.* (1,600 AFY) for a total estimated spring discharge of 1,800 AFY. Wah Wah Springs is modeled as discharging from the regional aquifer system in the GBCAAS-PV model. Reported discharges at the other regional springs from Brooks (2017) are: 7,404 AFY at Big Springs, 4,833 AFY at Dearden Spring Group, 257 AFY at Clay Spring, and 26,019 AFY at the Fish Springs ETg area.

A2.4 HYDROSTRATIGRAPHY

The hydrogeologic units (HGUs) in the Study Area (Figure A2-5), are described by Gardner *et al.* (2020) using the three-dimensional (3D) hydrogeologic framework of the eastern Great Basin (Cederberg *et al.* 2011; Sweetkind *et al.* 2011). An HGU has considerable lateral extent and reasonably distinct physical characteristics that may be used to infer the capacity of a sediment or rock to transmit water (Sweetkind *et al.* 2011). Stephens (1974, 1976) and Sweetkind *et al.* (2011) describe the water-bearing characteristics of HGUs occurring in the Study Area as follows:

Non-Carbonate Confining Unit (NCCU) – The NCCU consists of low-to-moderate permeability Precambrian-age siliciclastic formations as well as intrusive igneous rocks that are locally exposed in mountain ranges and underlie parts of the Project area. Primary permeability is generally low; however, surficial weathered zones and fractured zones may have moderate permeability. This unit is not known to yield significant groundwater in the Pine Valley HA.

Lower Carbonate Aquifer Unit (LCAU) – The LCAU is a relatively thick succession of predominantly high-to-moderate permeability Cambrian to Devonian-age carbonate rocks that are locally exposed in mountain ranges, and present beneath most of the valleys within the Study area. Primary permeability is generally low; however, secondary solution permeability is moderate to high, especially along bedding planes, fractures, and faults.

Upper Siliciclastic Confining Unit (USCU) – The USCU consists of low-permeability Mississippian-age siliciclastic rocks, predominantly shales, that are limited in extent within the Study Area.

Upper Carbonate Aquifer Unit (UCAU) – The UCAU is a relatively thick succession of low-to-high permeability Pennsylvanian- and Permian-age carbonate rocks that are locally exposed in the mountain ranges within the Study Area. As with the LCAU, primary permeability is generally low; however, secondary solution permeability is moderate to high, especially along bedding planes, fractures, and faults. This unit yields water to some springs in the Pine and Wah Wah Valley HAs.

Volcanic Unit (VU) – The VU consists of large volumes of low-to-high permeability Cenozoic-age volcanic rocks that are locally exposed in mountain ranges and exist beneath some of the valleys in the Study Area. Primary permeability is generally low. Where fractured and broken by faulting, secondary permeability in

some breccias and interflow zones may locally be high. Numerous springs, seeps, and a few abandoned mine workings discharge water from perched groundwater zones in these rocks.

Lower Basin-Fill Aquifer Unit (LBFAU) – The LBFAU represents approximately the lower one-third of the Cenozoic basin fill and in addition to thick sands and gravels, includes thick sequences of welded ash-flow tuff with a high relative permeability in well-developed fracture networks and local lava flows of moderate to high permeability that can be highly fractured.

Upper Basin-Fill Aquifer Unit (UBFAU) – The UBFAU consists of low-to-high permeability Tertiary and Quaternary valley-fill sediments that represents the top two-thirds of the Cenozoic basin fill and includes both older alluvium and younger alluvial and lacustrine deposits. The UBFAU is slightly to highly permeable. Permeability is dependent upon grain size and sorting of materials and the amount of cementation in individual strata. Some of the wells in Pine and Wah Wah Valley are reported to yield water from sand beds at depths of 1,500 to 2,000 feet bgs. This unit forms the bulk of the valley fill, which is the major groundwater reservoir in the Pine Valley HA.

A2.5 AQUIFER PROPERTIES

As part of the Gardner *et al.* (2020) study, aquifer properties for the basin-fill aquifers in the Pine Valley and Wah Wah Valley HAs were estimated from 10 single-well pump tests. Transmissivities were estimated from specific-capacity values by considering a range of storage coefficients representing unconfined to confined conditions (Driscoll 1986). The estimated transmissivities ranged from approximately 400 to 9,000 square feet per day (ft^2/day). Estimates of transmissivity from specific capacity were made using empirical equations developed from the modified nonequilibrium (Jacob) equation: Q/s = T/2000 (confined) and Q/s = T/1500 (unconfined) (Q in gpm, s in ft, T in gallons per day/ft). The equations are derived by assuming an average well diameter, average duration, and typical values of storage coefficient (Driscoll 1986, Appendix 16.D).

Formation verified the estimated transmissivity ranges from Gardner *et al.* (2020) using the specific-capacity method, compared the results to historical pump test analysis data for the wells, and performed a more refined aquifer test analysis for four wells for which time-series drawdown or recovery data of suitable quality were available. The aquifer test analyses by Formation used a more detailed curve matching evaluation, based on confined Theis recovery and confined Cooper-Jacob Agarwal methods. The transmissivities calculated from this evaluation were approximately 30 to 150 percent higher than values calculated by Gardner *et al.* (2020). Curve matching methods are considered more accurate as the underlying equations are based on well hydraulics and have been developed for different types of aquifers and a variety of drawdown behaviors. For further insight, transmissivities estimated by Gardner *et al.* (2020) and Formation were compared to historical transmissivity estimates as summarized in Table A1.

Based on these analyses, there is uncertainty regarding the transmissivity and hydraulic conductivity of the basin fill in both Pine and Wah Wah Valleys depending on the type of aquifer test analyses performed (specific capacity tests) and a lack of reliable long-term aquifer test data. Analysis using a curve matching approach by both Formation and the USGS indicated the values presented in Gardner *et al.* (2020) appear to be biased low. During development of GBCAAS v. 3.0, hydraulic conductivities assigned to the alluvial

basin-fill aquifers were decreased below the values estimated by Gardner *et al.* (Brooks 2017). The above data suggest that increasing the hydraulic conductivities of these materials in GBCAAS-PV is justified provided the increased values are consistent with water budget estimates and result in a reasonable calibration.

Hydraulic conductivity (K) was estimated based on the transmissivity ranges presented in Table A1 and the minimum saturated well screen lengths for the wells, where known. Hydraulic conductivity estimates are presented in Table A2.

TABLE A1. COMPARISON OF RECENT AND HISTORICAL TRANSMISSIVITY ESTIMATES (FT^2/D)

Well Name	Earth Sciences Inc. (1974 & 1975) Wah Wah Valley Pumping Tests	Phelps Dodge (1980) Pine Valley Pumping Tests	USGS (2013)[3] Pine Valley and Wah Wah Valley Pumping Tests	Gardner *et al.* (2020)	Formation (2020)
CICWCD #6	---	---	---	400 - 580	667 - 744[1]
CICWCD #7	---	---	---	410 - 580	1,020 – 1,036[1]
CICWCD #8	---	---	---	490 - 690	637 - 800[1]
CICWCD #12	---	---	---	1,300 - 1,800	3,023 - 3,306[1]
Phelps Dodge #19	---	578 - 770	531 – 708; 1,000	450 - 650	897 - 949[2]
Wah Wah #29	8,500	---	5,600 - 7,400; 30,000 - 60,000	6,300 - 8,500	66,830 - 70,460[2]

Notes:

[1] Range of transmissivity based on confined Theis recovery and unconfined Cooper-Jacob Agarwal methods.

[2] Range of transmissivity based on confined Theis recovery and confined Cooper-Jacob Agarwal methods.

[3] C. Nielson, Ensign Engineering, pers. comm., June 24, 2019. Unpublished data and analyses (October 2013) from P. Gardener.

TABLE A2. HYDRAULIC CONDUCTIVITY[1] COMPARISON (FT/D)

Well Name	USGS (2013) Pumping Test Analyses	Gardner *et al.* (2020) Specific Capacity Analyses [1]	Formation (2020) Pumping Test Analyses[1]
CICWCD #6	---	1.0 – 1.5	1.7 – 1.9
CICWCD #7	---	0.6 – 0.8	1.5
CICWCD #8	---	1.1 – 1.5	1.4 – 1.8
CICWCD #12	---	2.9 – 4.0	6.7 – 7.3
Phelps Dodge #19	1	0.6 – 0.9	1.3 – 1.4
Wah Wah #29	40 – 70	8.3 – 11.2	88 – 93

Notes:

[1] Hydraulic conductivity based on estimated transmissivity range (see Table A1) and minimum length of saturated well screen during pumping test.

A2.6 GROUNDWATER LEVELS AND FLOW

Groundwater occurs in alluvial basin-fill and bedrock aquifers in the Study Area under confined and unconfined conditions. Groundwater levels in adjacent wells completed in the alluvial basin-fill and underlying carbonate aquifers were found to be similar, supporting the conclusion that the aquifers are hydraulically connected (Gardner *et al.* 2011). In the alluvial basin-fill aquifer, unconfined conditions occur in the upper portions of alluvial fans, and confined conditions exist in areas where fine-grained distal fan and lacustrine sediment is interlayered with coarser gravels and sands near the centers of the valleys (Gardner *et al.* 2020). In Pine Valley, water-level depths range from about 300 to 620 feet bgs. In Wah Wah Valley, groundwater is slightly deeper than in Pine Valley with observed water-level depths ranging from about 210 to 750 feet bgs. Groundwater levels are relatively stable in both valleys.

Similar to other basins in the area, most of the recharge in the Pine Valley and Wah Wah Valley HAs occurs in bedrock mountain blocks and adjacent mountain front areas. Recharge to perched mountain aquifers discharges to gaining streams or to mountain springs or seeps, and otherwise percolates into the underlying regional aquifer system. With respect to discharge, the Pine Valley HA and Wah Wah Valley HA are unique when compared to other HAs in this portion of the Great Basin because the depth to groundwater in the regional aquifer system precludes the possibility of natural groundwater discharge in these basins. By comparison, other valleys in the eastern Great Basin have extensive areas of lowland discharge where groundwater levels are near the land surface and the bulk of the groundwater discharge occurs through springs and by phreatophyte evapotranspiration. A consequence of the deep groundwater levels is that all discharge from the basin-fill aquifers in both valleys must occur through the subsurface where it is not observable and cannot be measured. Groundwater levels from Gardner *et al.* (2020) indicate that groundwater moves northward from Pine Valley into the Snake Valley HA, and groundwater in Wah Wah Valley flows north into the Tule Valley HA and the area surrounding Sevier Lake. The USGS has mapped groundwater discharge areas (GDAs) in these basins consisting of phreatophyte shrubs and a few alkali meadow areas in Tule Valley.

The mapped groundwater gradients are generally consistent with the regional groundwater flow directions; however, relatively steep eastward gradients are interpreted near the western edge of Pine Valley. These gradients are consistent with existence of a fault that is interpreted in this area and is assumed to represent an impediment to local groundwater flow. An alternative or perhaps contributing factor may also be a difference in sediment types that compose the basin-fill aquifer. The southern and western sides of Pine Valley likely contain fine-grained sediment that is a weathering product of the volcanic rocks that dominate the Needle Range and southern portions of the Wah Wah Mountains, whereas the eastern side of Pine Valley likely contains more coarse-grained sediment derived from quartzites that outcrop on the western slopes of the Wah Wah Mountains (Gardner *et al.* 2020).

A second zone with a steep north-northeast groundwater gradient trends across the southern portion of the Pine Valley HA in a west-northwest direction. Similar to the steepened gradients along the west side of the valley, this area of steepened gradients may also be caused or contributed to by differences in the permeability of the alluvial sediments derived from the surrounding mountains. Faults in the region generally do not trend along this alignment; however, it is located near the inferred edge of the Indian

Peak-Caliente caldera complex based on gravity data (Best *et al.* 2013). This suggests that subsurface structural or stratigraphic changes could be contributing to a groundwater flow impedance in this area.

A2.7 REFINED GROUNDWATER BUDGET

A2.7.1 GROUNDWATER RECHARGE IN THE PINE VALLEY AND WAH WAH VALLEY HAS

The GRIA Report presents a refined analysis of the groundwater budgets for the Pine Valley and Wah Wah Valley HAs. Groundwater resources in the Pine Valley and Wah Wah Valley HAs and surrounding basins have been very sparsely developed, and significant data gaps, therefore, exist in the hydrogeologic understanding of the area. The stability of groundwater levels indicates the amount of groundwater in storage is not currently changing, and recharge is therefore equal to discharge. Furthermore, since Pine and Wah Wah Valleys are topographically closed basins with relatively deep groundwater levels, the amount of groundwater underflow leaving the valleys is equal to the amount of recharge. Recharge to the groundwater system is equal to HA-wide precipitation minus ET.

A refined recharge estimate was developed using a water balance approach for a representative 10-year hydrologic period from 2005 to 2014. The following approach was utilized:

- First, the average annual precipitation was calculated for the Pine Valley and Wah Wah Valley HAs using data from 17 stations (period of record 18 to 55 years). The data were evaluated by comparing them to 30-year average annual gridded precipitation data from the Parameter-elevation Relationships on Independent Slopes Model (PRISM) and assessing trends and differences related to station elevation and cool vs. warm season precipitation. Based on this analysis, the long-term average annual precipitation for the Pine Valley and Wah Wah Valley HAs was calculated using an approach that was spatially representative. The calculated average annual precipitation in the Pine Valley and Wah Wah Valley HAs is 9.86 and 7.62 inches, respectively. The corresponding average annual precipitation volume in the Pine Valley and Wah Wah Valley HAs is 387,991 and 245,727 AFY, respectively. This represents a more conservative estimate than the average annual precipitation volumes for the Pine Valley and Wah Wah Valley HAs calculated by Stephens (410,000 and 290,000 AFY, respectively), or cited in Gardner *et al.* (2020) (510,000 and 320,000 AFY, respectively).
- Second, the average annual ET rate was calculated from Landsat remote sensing data. The Surface Energy Balance System, a peer reviewed extensively applied algorithm (Paul *et al.* 2011, 2018; Su 2002), was used for regional-scale mapping of ET on a 30-meter grid. The algorithm uses local weather information and visible, near-infrared, shortwave infrared, and thermal infrared reflectance data to generate ET estimations. The modeling framework includes a set of automated routines (scripts) to download satellite imagery, filter-out clouds, convert imagery to reflectance (using an atmospheric correction model), derive physical and biophysical variables, and ultimately produce daily evaporation estimates. The data were derived from 251 satellite flyovers of one Landsat scene (path row 39-33) that measures approximately 180 by 185 kilometers and encompasses the Pine Valley and Wah Wah Valley HAs, Sevier Lake, most of the Tule Valley HA, and much of the surrounding area. The calculated spatially weighted annual ET rate for the Pine Valley and Wah Wah Valley HAs is 9.41 and 7.46 inches, respectively. This equates to an average annual estimated actual evapotranspiration (ETa) volume of 370,284 and 244,567 AFY, respectively. These values are based on the most spatially and temporally robust analysis of ETa in the area currently available.

- Recharge was calculated by subtracting average annual ETa from precipitation. The calculated average annual net recharge rates across the Pine Valley and Wah Wah Valley HAs are 0.45 and 0.16 inches per year, respectively. Multiplying this rate by the areas of the HAs, 472,200 and 386,971 acres, respectively, yields net average annual recharge estimates of 17,700 AFY in the Pine Valley HA and 5,160 AFY in the Wah Wah Valley HA.

Based on this information, the net groundwater outflows resulting from local recharge in the Pine Valley and Wah Wah Valley HAs are summarized in Table A3. Note that this table is not intended to present a complete water budget of all basin inflows and outflows, but focuses on the local recharge component and its flow from the basin, primarily to discharge areas to the north.

TABLE A3. NET GROUNDWATER OUTFLOWS RESULTING FROM RECHARGE IN PINE VALLEY AND WAH WAH VALLEY (AFY)

Hydrographic Area	Stephens (1974 and 1976)	Brooks *et al.* (2014) GBCAAS v. 1.0	Brooks (2017) GBCAAS v. 3.0	Formation (2020)
Pine Valley	3,000 to Wah Wah Valley; 11,000 mostly northward	24,000 mostly northward	11,000 mostly northward	3,000 to Wah Wah Valley; 14,700 mostly northward
Wah Wah Valley	8,450 mostly northward	4,230 mostly northward	2,450 mostly northward[1]	8,160 mostly northward

Notes:

[1] Brooks (2017) reduced the volume of recharge applied to Wah Wah Valley HA during model calibration to cause simulated water levels on the west side of Sevier Lake to more closely match recent observed water levels.

A2.7.2 GROUNDWATER ET DISCHARGE

The Pine Valley and Wah Wah Valley HAs are part of a regional groundwater flow system with groundwater discharge via ET from vegetation in low-lying areas in Tule Valley and the area surrounding Sevier Lake. Gardner *et al.* (2020) mapped Groundwater Discharge Areas (GDAs) based on interpolated depths to groundwater supplemented by aerial imagery interpretation and field reconnaissance. Five GDA land cover classes were mapped, including open water, very sparse desert shrub, sparse-to-dense desert shrub, grassland, and marshland. Each land use class was assigned a range of ET rates based on published literature and ET was interpolated spatially across the GDAs using remote sensing-derived reflectance indices. Finally, measured precipitation for a period of 4 years at the Tule Valley RAWS station was subtracted from the calculated ET rates to develop groundwater ET rates. These revised groundwater ET rates were then applied to designated groundwater ET discharge cells in GBCAAS v. 3.0 and an extinction depth was established for the water table, below which groundwater ET by phreatophytes was assumed not to occur.

For this EIS, an updated analysis of ETg rates was conducted by calculating the average total ET rates in the GDAs for a 10-year representative hydrologic period using the surface energy balance method and subtracting the fraction of the total ET demand met by local precipitation to estimate the fraction of total ET derived from groundwater (ETg) (Section 3.11.1.8 of the GRIA Report). A reasonable range of ETg was estimated by subtracting precipitation data from four precipitation stations in the area analyzed in several different ways. The alternative approaches to calculating the precipitation rate included (1) using the 4-year period of data from the Tule Valley RAWS station analyzed by Gardner *et al.* (2020); (2) using the full long-term record (30 years) from the Tule Valley RAWS station; (3) using the full long-term record from all four stations in the vicinity of Tule Valley and Sevier Lake; and (4) using the long-term record from the two lowest elevation stations in Tule Valley and Sevier Lake. The estimated ETg using these methods ranged from approximately 18,000 AFY to 67,000 AFY, reflecting considerable uncertainty regarding the amount of vegetation ET demand met by precipitation in this area. For comparison, the estimate of ETg for these areas in Gardner *et al.* (2020) is 45,500 AFY, and Brooks (2017) indicates the calibrated ETg simulated in GBCAAS v. 3.0 is 38,200 AFY. The findings of the above calculations span these USGS estimates. The ETg discharge in these areas will, therefore, be further evaluated and adjusted during calibration of the GBCAAS-PV model.

A2.7.3 GROUNDWATER PUMPING

Information regarding historical, current and projected future groundwater demand and existing well locations in the Pine Valley HA and surrounding basins is discussed in detail in the GRIA Report and summarized briefly below and in Table A4.

- The Pine Valley HA includes no permanent residences or other development. Groundwater pumping is, therefore, limited to a few domestic and stock wells. Stephens (1976) reported that groundwater demand was estimated at less than 5 AFY and was considered an insignificant part of the total discharge (Stephens 1976). Future groundwater demand increases in Pine Valley related to the PVWS Project would withdraw up to 15,000 AFY from the basin-fill aquifer.
- Similar to Pine Valley, Wah Wah Valley is sparsely inhabited, and groundwater pumping is limited to a few domestic and stock wells. Pumping from basin-fill aquifer wells was estimated at 1 to 2 AFY (Stephens 1974). There are no currently planned developments that would increase future groundwater demand in Wah Wah Valley.
- Water demand for agricultural irrigation in Snake Valley is currently estimated to be nearly 30,000 AFY and supplied by groundwater pumping and surface water diversion. The groundwater demand in this valley was evaluated by analyzing land use, ET and information regarding existing water right Points of Diversion and Places of Use. Using this approach, current demand may be somewhat over-estimated and is assumed to remain constant for the foreseeable future.
- Groundwater demand in the Beryl-Enterprise Area HA is managed under a GMP and therefore is well documented and was recently estimated to be approximately 95,000 AFY. Under the GMP, pumping will be sequentially reduced through 2130 in order to bring pumping to levels that are consistent with the estimated safe yield.
- No groundwater demand is reported in the Tule Valley HA or the area around Sevier Lake. In the future, industrial supply water demand for the proposed CPM project will be met through the installation of wells south of the playa.

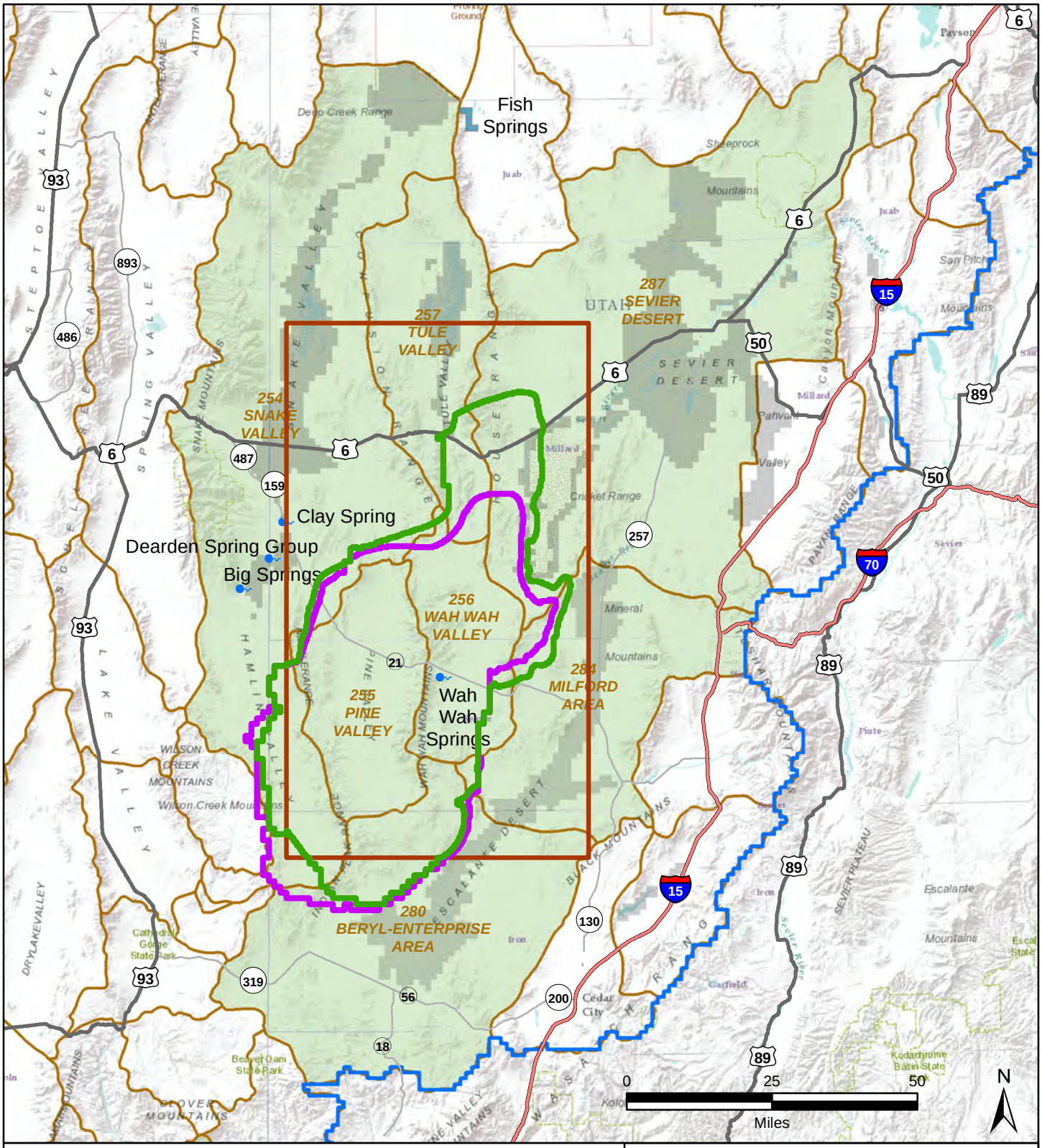
TABLE A4. HISTORICAL, CURRENT AND FUTURE GROUNDWATER PUMPING IN HYDROGRAPHIC AREAS IN THE STUDY AREA

Hydrographic Area	Historical Groundwater Pumping (AFY)	Current Groundwater Pumping (AFY)	Projected Future Groundwater Pumping (AFY)
Pine Valley	5 (1976)	5	15,005
Wah Wah Valley	2 (1974)	2	2
Sevier Desert (southern portion within APE)	None reported	None reported	1,500
Snake Valley / Hamlin Valley[1]	5,469 (1945) - 21,649 (2004)	28,655	28,655
Beryl-Enterprise Area[2]	3,000 (1937) - 92,000 (1974)	95,000 (2016)	34,000 (2130)

Notes:

[1]Snake Valley estimates represent net pumping based on an analysis of ET discharge. Refer to Section 3.9.5.2 of the GRIA Report for details.

[2]Beryl-Enterprise Area current estimates represent gross pumping and do not account for deep percolation of applied water; however, the projected future pumping considers deep percolation from irrigation. Refer to Section 3.9.5.2 of the GRIA Report for details.



Legend

- Regional Spring
- Interstates
- US Route
- State Route
- Study Area
- ET Zones
- Hydrographic Area
- Focused Model Area
- GBCAAS Model Boundary
- Simulated Area of Project Effects for Proposed Action
- Simulated Area of Project Effects for Adaptive Northern Well Sites Alternative

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A2-1

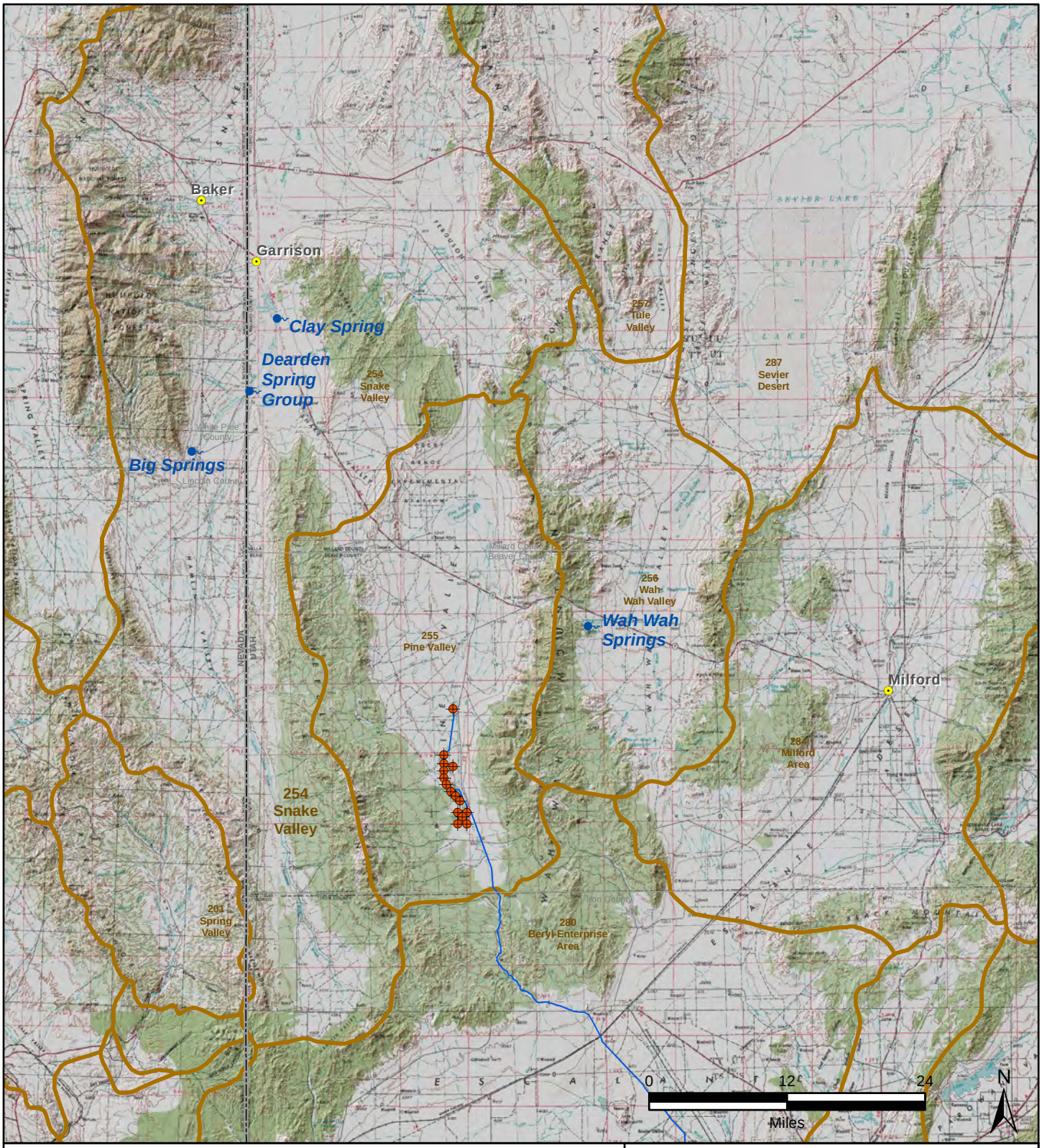
PROJECT STUDY AREA FOR GROUNDWATER RESOURCES EFFECTS

DATE: FEB 16, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- PVWS Project Well
- Regional Spring
- Hydrographic Area
- Project Pipeline Alignment

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A2-2

PHYSIOGRAPHIC MAP OF THE PINE VALLEY REGION

DATE: FEB 11, 2021	FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT

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Legend

- Regional Spring
- PVWS Project Well
- Project Pipeline Alignment
- Hydrographic Area

Geology (SGMC)

- Igneous, intrusive
- Igneous, volcanic
- Igneous, undifferentiated
- Igneous and Sedimentary, undifferentiated
- Metamorphic, sedimentary clastic
- Metamorphic and Sedimentary, undifferentiated
- Sedimentary, carbonate
- Sedimentary, clastic
- Sedimentary, undifferentiated
- Unconsolidated and Sedimentary, undifferentiated
- Unconsolidated, undifferentiated
- Water
- Fault, unknown type, approximate
- Fault, unknown type, certain
- Fault, unknown type, concealed
- Fault, unknown type, inferred or queried
- Thrust fault, approximate (teeth on right from origin)
- Thrust fault, certain (teeth on right from origin)

from Horton et. al. (2017)

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A2-3

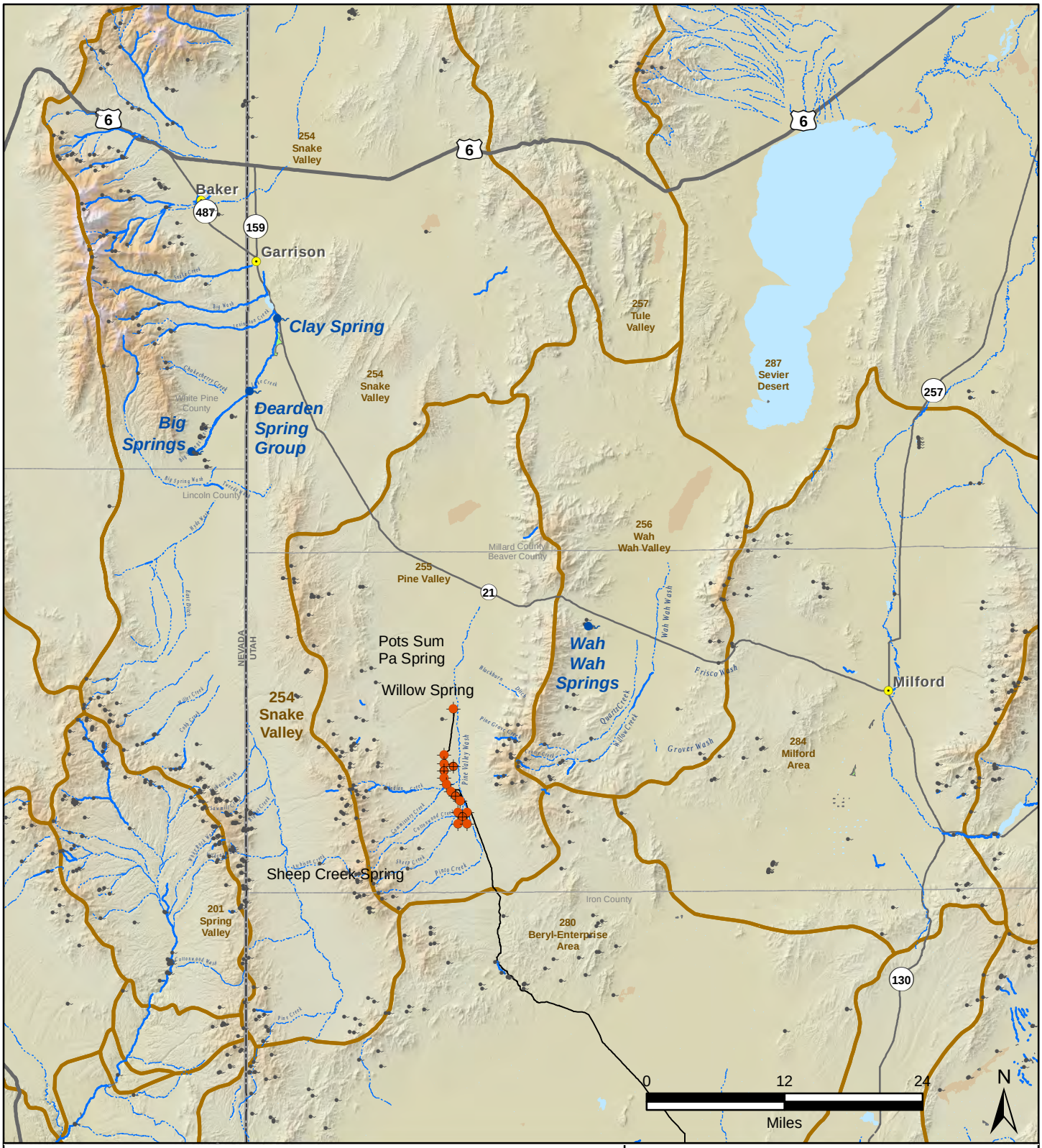
SURFICIAL GEOLOGIC MAP OF THE PINE VALLEY REGION

DATE: FEB 18, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- PVWS Project Well
- Regional Spring
- Local Spring or Seep
- Stream/River
- Stream/River - Perennial
- Stream/River - Intermittent
- Project Pipeline Alignment
- US Route
- State Route
- Hydrographic Area
- Lake/Pond
- Playa
- Reservoir
- Swamp/Marsh

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A2-4

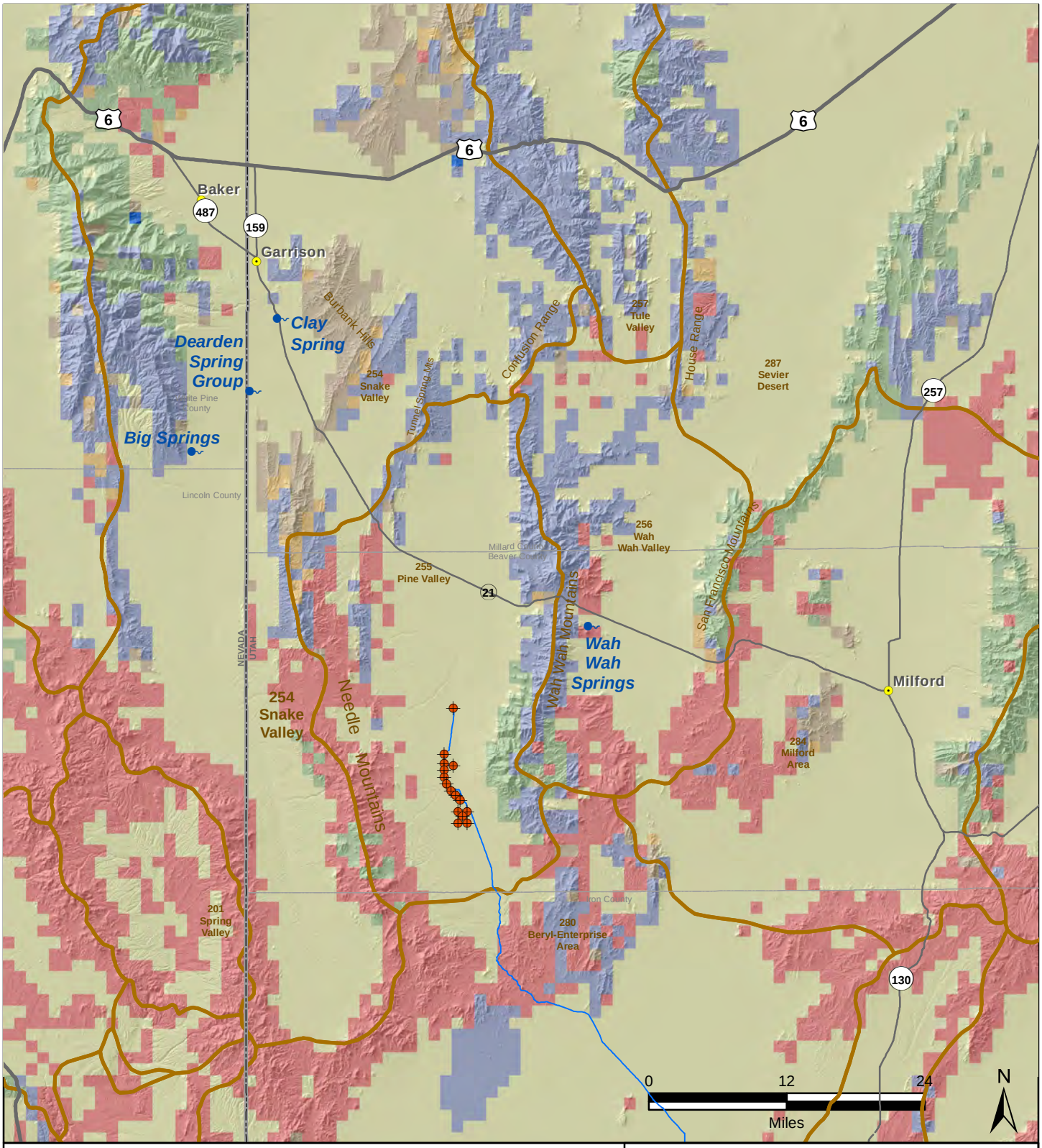
HYDROGRAPHY OF THE PINE VALLEY REGION

DATE: MAY 20, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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Legend

- PVWS Project Well
- Regional Spring
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

Aquifer Units

- Upper Basin-Fill Aquifer Unit
- Lower Basin-Fill Aquifer Unit
- Volcanic Unit
- Upper Carbonate Aquifer Unit
- Upper Siliciclastic Confining Unit
- Lower Carbonate Aquifer Unit
- Non-Carbonate Confining Unit

from Brooks (2017)

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A2-5

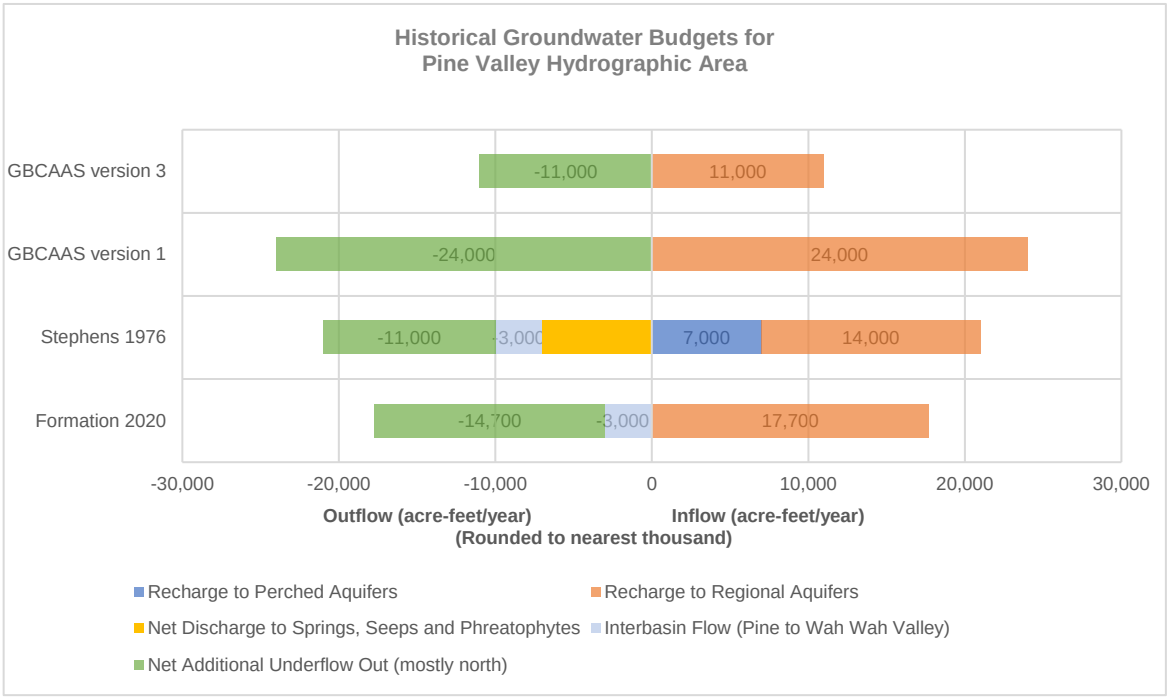
HYDROGEOLOGIC UNIT MAP OF THE PINE VALLEY REGION

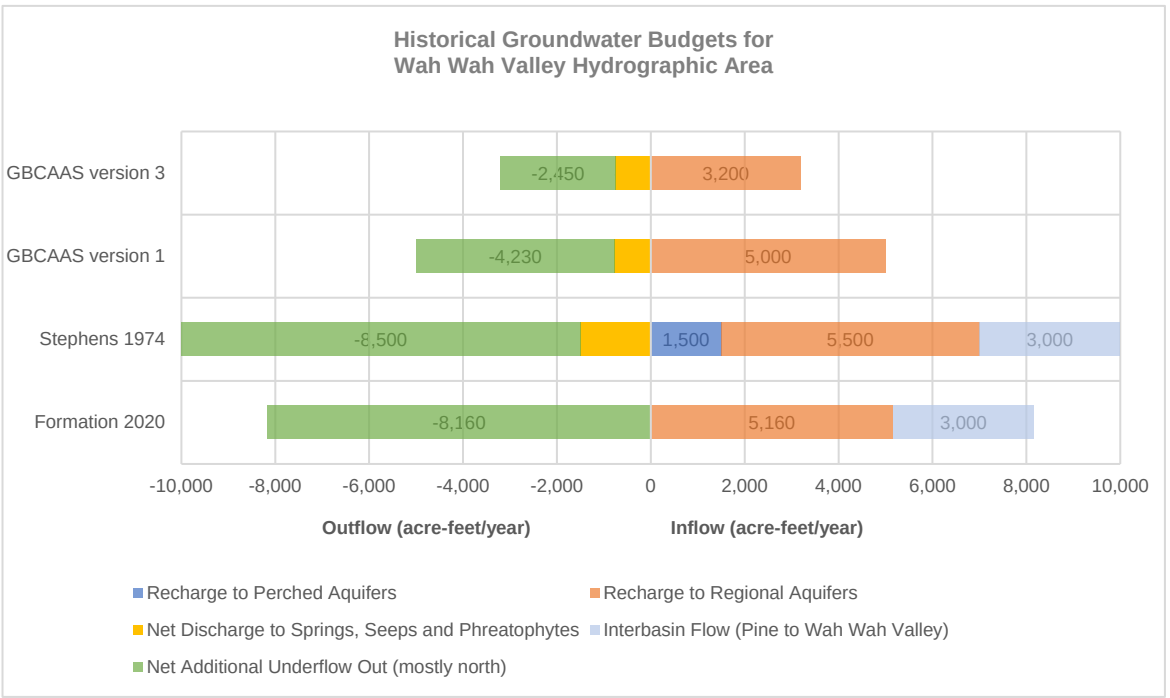
DATE: FEB 20, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A2-6

HISTORICAL AND REFINED GROUNDWATER BUDGETS FOR THE PINE AND WAH WAH VALLEY HAs

DATE: FEB 24, 2021	FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT

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A3 MODEL DEVELOPMENT OVERVIEW AND APPROACH

A3.1 OVERVIEW

Development of the GBCAAS-PV groundwater flow model followed the steps outlined in the proposal for the PVWS Project and discussed in the monthly Groundwater Technical Team Meetings, and included model setup and verification, focused refinement and calibration, and impact analysis as summarized below.

Model Selection and Refinement Approach

- **Conceptual Model.** The available information was compiled into a summary of key components to form the conceptual understanding of the groundwater flow system that underlies model development.
- **Model Selection.** GBCAAS v. 3.0, which represents the culmination of over 30 years of local and regional hydrogeologic studies, was selected as a starting point for development of the GBCAAS-PV model.
- **Model Refinement Approach.** Development of a locally-refined child model within GBCAAS v. 3.0 was the selected modeling approach. GBCAAS v. 3.0 is based on MODFLOW-LGR, which provides the functionality to refine the model in the project Study Area.

Initial Model Setup and Verification

- **Data Compilation**. Available information regarding the project and project area was compiled and included reports prepared by the USGS, State Engineer, BLM, and others. Executable model files and data input files for GBCAAS v. 3.0 were acquired from the USGS. Supporting unpublished data and studies were obtained from the USGS and BLM. Data regarding water right applications, permitted wells, and monitoring wells were downloaded from the Utah Division of Water Rights Database. Unpublished pumping test data from CICWCD wells were obtained from the USGS.
- **Verification of GBCAAS v. 3.0**. GBCAAS v.3.0 (Brooks 2017) model files were executed, post-processed, and verified against published model results. Published geologic maps and cross sections were digitized and entered in a 3D geodatabase and used to verify that the vertical and horizontal distribution of HGUs was adequately represented in the Study Area. Using a project area focus, the 3D hydrogeologic unit model was verified as well as each unit property representation on the model grid.
- **Study Area and APE**. The preliminary area of interest was evaluated using the existing USGS GBCAAS v. 3.0 model and was used to develop the boundaries of the Study Area and an Area of Potential Effects (APE).

Focused Refinement and Calibration of GBCAAS-PV

- **Local grid refinement**. The horizontal grid spacing and model layers of the child model grid were refined to better represent potential effects associated with project pumping. The final child grid dimensions are 16 layers, 460 rows, and 260 columns, replacing 8 layers, 92 rows, and 52 columns of the parent model. The horizontal grid spacing of the child model grid was subdivided by 1/5 or 0.2 mi on each side with a grid-cell area of 0.04 mi^2 ($1/25^{th}$ of the original cell area) to better represent potential effects associated with Project pumping.

- **Boundary Condition Assignment.** Hydrologic boundaries in the Pine Valley child model include specified-flux boundaries (recharge and pumping wells) and head-dependent flow boundaries (evapotranspiration and springs). Wells occur in the model to represent Project pumping.
- **Hydraulic Property Assignment.** Hydrogeologic units (HGUs) represented in GBCASS v. 3.0 and associated hydraulic properties were attributed to the refined child model grid.
- **Model Observation Development.** Model observations including water levels at wells, groundwater discharge as ET, and discharge to springs, were used to calibrate the Pine Valley child model. Observation statistics were recalculated for the child model for consistency with methods described in Brookes et al. (2014) and Brooks (2017). Observations are considered representative of steady-state conditions.
- **Model Calibration.** Model calibration was performed to reasonably represent groundwater recharge, movement, groundwater levels, and discharge as ET and at springs in the GBCAAS-PV focus area.

Impact Analysis

- **Scenario Development**. Alternatives evaluated using the GBCAAS-PV model include the PVWS Proposed Action and the ANWS Alternative. Each consists of 15 wells each pumping 1,000 AFY for 50 years. A startup production period using six wells each pumping 1,000 AFY with a focus on the initial pumping period was simulated to support the development of a wellfield monitoring plan. Project effects were simulated for a 50-year project pumping period and 450-year recovery period to assess latent effects and recovery trends. A cumulative pumping scenario was also developed, and included pumping for the PVWS Project alternatives combined with existing and anticipated future pumping in the surrounding HAs.
- **Characterization of Affected Environment**. GBCAAS-PV was used to evaluate groundwater flow and discharge conditions without Project pumping to further characterize the affected environment and serve as baseline for impact analysis.
- **Impact Analysis**. GBCAAS-PV was used to predict changes in groundwater levels, storage, well interference drawdown, spring flow, and ETg discharge as a result of implementing pumping for the PVWS Project Proposed Action and ANWS Alternative. In addition, the cumulative impacts of PVWS Project pumping and other existing and anticipated future pumping in the surrounding area were simulated and evaluated.

A3.2 CONCEPTUAL MODEL

The conceptual model for development of the groundwater flow model consists of the principal components summarized below.

- The area of interest for this study is the Pine Valley HA and the extent of reasonably anticipated PVWS Project hydrogeologic and groundwater budget effects which includes the Snake Valley (including Hamlin Valley), Tule Valley, Sevier Desert, Wah Wah Valley, Milford Area and Beryl-Enterprise Area HAs. The area predicted to experience drawdown induced by pumping for the PVWS Project falls within this area and is considered the APE.

- Pine Valley and Wah Wah Valley are elongate topographically closed basins. There is no surface water outflow from either valley and runoff seldom reaches the playas.

- Structurally, Pine and Wah Wah Valleys are eastward-tilted graben fault blocks bounded by normal faults. Bedrock consists of carbonates that underlie the valleys at depth with a maximum

thickness of more than 15,000 feet. The valley fill consists of alluvium with a maximum thickness of 10,000 feet in Pine Valley and 4,000 feet in Wah Wah Valley. Intrusive and extrusive igneous rocks are interbedded with alluvium in the southern portion of Pine Valley.

- Most springs and seeps in the mountains surrounding Pine Valley are assumed to discharge water from local perched aquifers that are not connected to the regional aquifer system. Wah Wah Springs is assumed to discharge water from, and be hydraulically connected with, the regional carbonate aquifer. In addition, three regional springs in Snake Valley (Big Springs, Dearden Spring Group and Clay Spring) are located within the Study Area but outside the APE. In addition, Fish Springs, an important regional groundwater discharge point, is located north of the Study Area.

- Groundwater occurs in alluvial basin-fill and bedrock aquifers in the Study Area under confined and unconfined conditions. Based on available groundwater level data, the alluvial and carbonate aquifers operate as one contiguous aquifer system. In the alluvial basin-fill aquifer, unconfined conditions occur in the upper portions of alluvial fans, and confined conditions exist in areas where fine-grained distal fan and lacustrine sediment is interlayered with coarser gravels and sands near the centers of the valleys.

- Hydraulic conductivities of the basin fill alluvium determined from analysis of single well pumping tests range from approximately 0.6 to 93 feet/day. These values are approximately 30% to 10 times higher than values incorporated into GBCAAS v. 3.0.

- Range front faults and lower permeability siliciclastic and volcanic bedrock units in portions of the mountain blocks in the Study area represent significant flow impedances that limit interbasin flows between Pine Valley and Snake Valley, and between Pine Valley and Wah Wah Valley.

- Mapped groundwater gradients are generally consistent with regional groundwater flow directions. Relatively steep eastward gradients are interpreted near the western edge of Pine Valley consistent with existence of a fault interpreted in this area. This feature represents recognized potential impedance to interbasin flow between Pine and Snake Valley and is simulated in GBCAAS v. 3.0. A second zone with a steep north-northeast groundwater gradient trends across the southern portion of the Pine Valley HA along the inferred edge of the Indian Peak-Caliente caldera complex. The data are insufficient to substantiate the existence of a structural flow impedance in this area so it is not simulated in GBCAAS v. 3.0; however, a structural flow impedance could exist in this area.

- Groundwater levels in Pine and Wah Wah Valleys are hundreds of feet below land surface, even beneath the playas. A consequence of these deep groundwater levels is that all discharge from the basin-fill aquifers in both HAs must occur through the subsurface where it is not observable and cannot be measured. Groundwater has been interpreted to flow northeastward out of Pine and Wah Wah Valleys and discharge via ET in Tule Valley and in the area surrounding Sevier Lake. Some interbasin flow also occurs from Pine Valley to northward into the Snake Valley HA. A relatively limited amount of groundwater flow is believed to exit Pine Valley to the south and flow into the northern portion of the Beryl-Enterprise Area HA.

- Groundwater recharge to the Pine Valley HA is estimated to average at least approximately 17,700 AFY. Of this total, approximately 3,000 AFY is assumed to flow into the Wah Wah Valley HA due to a fault interpreted to underly the southeastern margin of Pine Valley and an eastward

structural dip in the carbonate rocks of the Wah Wah Mountains. Groundwater recharge to Wah Wah Valley (not accounting for this additional 3,000 AFY) is estimated to average 5,160 AFY.

- Groundwater discharge by ET around Sevier Lake and in Tule Valley is subject to considerable uncertainty and is estimated to average between 18,000 AFY to 67,000 AFY.

- Pine Valley HA includes no permanent residences or other development. Groundwater pumping is limited to a few domestic and stock wells and is considered negligible from a modeling perspective. Future groundwater demand increases in Pine Valley related to the PVWS Project would withdraw up to 15,000 AFY from the basin-fill aquifer.

- Current and projected pumping in Wah Wah and Tule Valleys is considered negligible from a modeling perspective. Effects resulting from agricultural pumping in Snake Valley and the northern portion of the Beryl-Enterprise Area HA could interact with drawdown induced by the PVWS Project. Current pumping in the southern portion of the Sevier Desert HA is currently negligible, but pumping proposed for the Crystal Peak Minerals project south of Sevier Lake could interact with drawdown induced by the PVWS Project.

A3.3 MODEL SELECTION AND REFINEMENT APPROACH

A3.3.1 MODEL SELECTION

Consistent with the objectives discussed in Section 1.2, the most recent update of the USGS GBCAAS model (v. 3.0) was selected as a starting point for development of the GBCAAS-PV model. The GBCAAS models (Brooks *et al.* 2014, Stolp *et al.* 2014; and Brooks 2017) developed by the USGS cover all of the Study Area and are pertinent to this modeling effort. A description of studies to characterize groundwater in the GBCAAS and the development and refinement of the GBCAAS model are summarized below.

The USGS performed studies to characterize groundwater supplies and provide information that would aid in understanding the future implications of expanding groundwater demand in the GBCAAS in California, Nevada, Utah and Arizona. The USGS published several studies characterizing the GBCAAS aquifer system, including a characterization of the aquifer systems in the Great Basin region of Nevada, Utah, and adjacent states (Harrill and Prudic 1998) and a characterization of the GBCAAS (Heilweil and Brooks 2011). As a culmination of these studies, in 2014 the USGS published a regional steady state numerical groundwater flow model of the GBCAAS, referred to as GBCAAS v. 1.0 (Brooks *et al.* 2014). GBCAAS v. 1.0 spans 110,000 square miles in Utah, Nevada, California, Idaho, and Arizona (Figure A3-1). The numerical model uses MODFLOW-2005 and simulates the complex hydrogeologic system of the GBCAAS. The level of detail in this model had not been previously available throughout the study area (Brooks *et al.* 2014). The model consists of 509 rows, 389 columns, and 8 layers; grid rows are aligned in an east-west direction; grid columns are aligned in a north-south direction; grid spacing is 1 mile in the north-south and east-west directions.

A second version (GBCAAS v. 2.0) of the model (Stolp *et al.* 2017) included local grid refinement (i.e., "child model") in the Malad-Lower Bear River Area in northern Utah using MODFLOW-LGR (Mehl and Hill, 2013). GBCAAS v. 2.0 includes the "parent model" that incorporates the rest of the GBCAAS area. Few modifications were made in the parent model and the changes occurred near the child model. As a result,

most of the GBCAAS v. 2.0 parent model is generally the same as GBCAAS v. 1.0 near the Pine Valley Study Area.

To provide additional scientific context for the potential development of groundwater supplies in the southeastern portion of the GBCAAS in Utah, the USGS performed additional hydrogeologic studies and updated GBCAAS v. 2.0 to provide perspective on the potential effects of groundwater supply development in the Pine Valley, Wah Wah Valley and Parowan Valley HAs. The subregionally-updated version of the steady-state GBCAAS model (Brooks 2017) was referred to as GBCAAS v. 3.0.

To update the GBCAAS v. 2.0 model, Gardner *et al.* (2020) conducted a hydrogeologic and geochemical investigation of the Pine Valley and Wah Wah Valley HAs to further characterize aquifer conditions, groundwater occurrence and flow, groundwater recharge and discharge volume estimates, and the source and age of aquifer water and spring discharge. The investigation included pump testing of several wells to better characterize aquifer conditions; sampling and geochemical analysis of groundwater samples from wells to assess the nature, age and source of the water; sampling and geochemical analysis of water from springs to determine whether they are connected to the regional aquifer system or discharge water from perched aquifers; and an evaluation of evapotranspiration in groundwater discharge areas in the Tule Valley and Sevier Desert HAs and further constrain groundwater budget estimates.

Using the data developed by Gardner, Brooks (2017) updated and recalibrated the area surrounding Pine Valley and Wah Wah Valley. GBCAAS v. 3.0 incorporated changes to the groundwater budget and recalibrated basin-fill hydraulic conductivities based on the assumed water budget changes. Notably, the groundwater recharge component of the groundwater budget for the Pine Valley HA was decreased to 11,000 AFY; however, simulated hydraulic conductivities of the basin-fill aquifer had to be decreased below recently measured levels to adequately meet calibration targets.

GBCAAS v. 3.0 was calibrated to transient conditions in Parowan Valley. Simulated storage properties outside of Parowan Valley were set the same as the Parowan Valley properties and are not considered calibrated. In other words, the model may not accurately represent transient conditions outside of Parowan Valley. GBCAAS v. 3.0, however, is considered most representative to simulate the GBCAAS during pre-development steady-state conditions. The updated model was used to evaluate the aquifer response to long-term pumping stresses in the Pine Valley and Wah Wah Valley HAs. The study included a theoretical analysis of drawdown impacts that would result if groundwater pumping were continued for 62 years, 1,000 years, and 5,000 years.

Brooks (2017) is the culmination of over 30 years of research and represents the state-of-the-science for the regional flow system; however, it remains a relatively coarse regional model with a grid cell size of 1 square mile, a somewhat regionalized conceptual approach to groundwater recharge and discharge representation, and uncertainty in some of its local calibration statistics and simulation accuracy. Specific uncertainties remain around the recharge and ETg discharge rates simulated in the model, which do not correlate with the observed aquifer hydraulic conductivity data.

A3.3.2 MODEL REFINEMENT APPROACH

The Groundwater Technical Team discussed several groundwater modeling approaches capable of supporting the GRIA for the PVWS Project. Three general modeling approaches were discussed, including development of a separately-constructed model, a GBCAAS child model, and a GBCAAS hybrid model. These approaches are summarized below.

A3.3.2.1 SEPARATELY CONSTRUCTED MODEL

Under this approach, a MODFLOW-based model would be developed using a standard graphical pre- and post-processing application, such as Groundwater Vistas, Groundwater Modeling System (GMS), or Visual MODFLOW. The approach would focus only on the region affected by project pumping and enough of the surrounding area to provide a buffer for boundary effects. The conceptual numerical representation of the model would rely in large part on numerous studies published by the USGS to provide the basis for the model hydrostratigraphy, material properties, boundary conditions, recharge and discharge areas, etc.

Because GBCAAS v. 3.0 represents a current understanding of conditions in Pine and Wah Wah Valleys and is an accepted regional groundwater flow model, the separately constructed model would be based primarily on its contents. Additional data and information local to Pine Valley and its vicinity would provide the basis for further refinement, as needed, to assess the potential impacts of the proposed Project. An approach to establish and justify boundary conditions for the model would be required.

Advantages of a separately constructed model include the following: (1) Use of a standard pre- and post-processing application enables use of familiar tools for model development, and is easily exchangeable with third parties for review; (2) model calibration within a smaller, focused domain may potentially be less complicated; and (3) potentially reduced model run times.

Disadvantages include the following: (1) Simulated Project effects and associated inter-basin flows are more likely to be influenced by inappropriate or simplified boundary effects (for example, a no-flow boundary could artificially increase the simulated drawdown and effects on natural discharge while a constant head could artificially decrease the simulated drawdown and effects on natural discharge within the study area); (2) the potential need for additional regional model calibration outside the study area would be obscured; (3) the transient effect of simulated Project and cumulative pumping in the model area on boundary conditions likely cannot be accurately evaluated; and (4) model boundary conditions cannot be easily updated if future refinements to GBCAAS v. 3.0 are implemented.

A3.3.2.2 GBCAAS CHILD MODEL

GBCAAS v. 3.0 uses MODFLOW-LGR (Mehl and Hill 2013), which allows for local grid refinement (LGR) within a larger regional model. MODFLOW-LGR simulates groundwater flow using one or more higher resolution local grids (child models) within the coarser model grid (parent model). Thus, recharge, discharge, and aquifer properties can be represented in greater detail within a child model in an area of interest without separating it from the parent.

Advantages of using the child model approach within GBCAAS v. 3.0 versus a separately constructed model of the Project study area include the following: (1) The coarse-grid regional model automatically accounts for subsurface inflow to and outflow from the Study Area – development and justification of boundary conditions is not necessary; (2) simulated Project effects and associated inter-basin flows are less likely to be influenced by inappropriate or simplified boundary conditions; (3) simulated Project effects outside the child model domain could be identified by activating the parent model, and any need for recalibration outside the domain can be accounted for; (4) future work with the GBCAAS model would be able to utilize changes made for the Project analysis; and (5) future changes to the GBCAAS model could be used to update the Project analysis.

Disadvantages included the following: (1) Larger numerical run times can occur because of multiple models; and (2) Custom programming and additional software is required for pre- and post-processing for both parent and child models.

Refinement of the child model could lead to cascading effects outside the child model domain, potentially revealing inconsistencies with the parent model and the need for further calibration in areas that are beyond the scope of the Project effects analysis. We believe that the ability of the LGR modeling approach to reveal such inconsistencies is a benefit as it would lead to a more robust and defensible analysis. Any inconsistencies between the parent and child models would be evaluated in terms of their ability to affect the use of the model for the proposed Project and cumulative impact analysis. Calibration needs that do not affect these model uses would be identified as potential future regional model improvements.

A3.3.2.3 GBCAAS HYBRID MODEL

The hybrid approach was considered as a potential compromise alternative to the above approaches. The hybrid model would modify GBCAAS v. 3.0 to deactivate the portion of the regional flow systems that are not relevant to the GRIA or proposed project. The numerical grid representing the active flow systems would be refined using standard grid refinement techniques in the area of interest. Conceptually, this approach would assume a no-flow boundary would be adequate to divide flows in the Great Salt Lake Flow System from the other flow systems represented in GBCAAS v. 3.0. Simulated flows and regional groundwater flow system boundaries (see Brooks *et al.* 2014, Figure 39) suggests there is not a clear division between the Great Salt Lake Flow System. Thus, a no-flow boundary condition would be difficult to justify. Moreover, potential boundary effects may arise in the vicinity of Pine Valley due to inadequate simulation of boundary flows to the west and southwest.

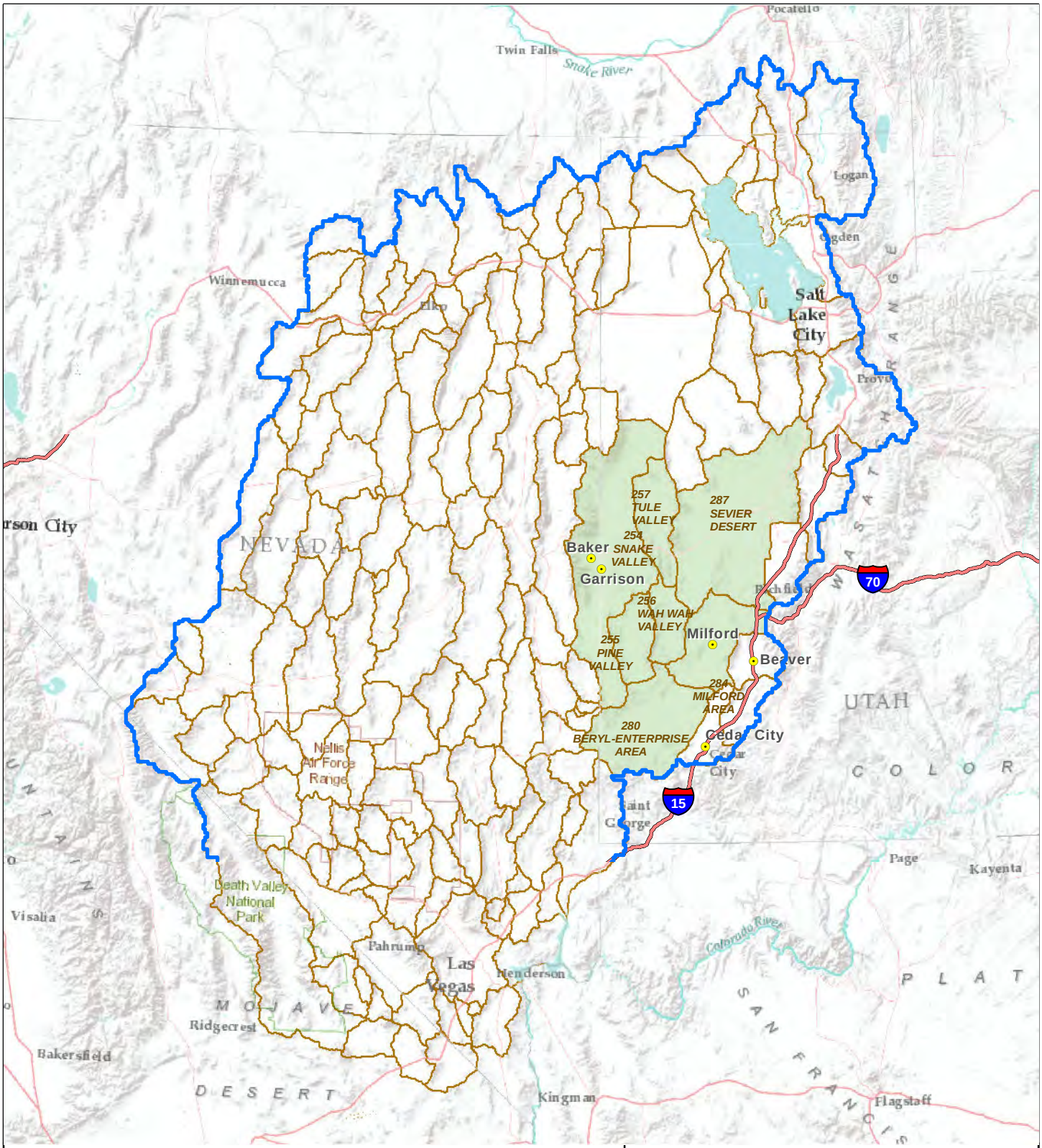
Advantages of using a hybrid approach include the following: (1) the GBCAAS regional model framework is maintained as a single model with grid refinements in the area of interest; and (2) potential numerical run times associated with parent/child models are decreased compared to a child model approach.

Disadvantages include: (1) Potentially inappropriate boundary conditions and associated effects.

A3.3.2.4 SELECTED APPROACH

Based on the evaluation of modeling approaches and discussion with the Groundwater Technical Team, development of a child model within GBCAAS v. 3.0 was the selected modeling approach. We believe

approaches that can introduce and/or obscure potential boundary effects should be avoided as they could create future issues for defensibility of the GRIA. As described above, boundary effects could artificially increase or decrease the simulated drawdown and effects on natural discharge within the study area. While the identification of model calibration issues outside the area of interest for the GRIA could potentially lead to additional questions about the model's adequacy, it would be better to identify and address such questions when the model is first developed. Moreover, MODFLOW-LGR provides the functionality to refine the GBCAAS v. 3.0 model in the Project Study Area.



Legend

- Interstates
- Hydrographic Area
- Study Area
- GBCAAS Model Boundary

0 25 50
Miles

N

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A3-1

GBCAAS MODEL DOMAIN AND STUDY AREA

DATE: FEB 11, 2021

BY: CRL | FOR: PHT

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A4 MODEL DEVELOPMENT AND CALIBRATION

The selected model used for this analysis is a locally refined version of GBCAAS v. 3.0 (Brooks 2017). GBCAAS v. 3.0 was developed with MODFLOW-LGR (Mehl and Hill 2013), which supports local grid refinement (LGR) within a larger regional model. Modifications to GBCAAS v. 3.0 allow the simulation of the large regional groundwater system with added details of recharge, discharge, and aquifer properties within in the Project study area. MODFLOW-LGR allows one or more, higher resolution, local grids (child models) within the coarser grid (parent model) by iteratively coupling separate MODFLOW-2005 models, thereby balancing heads and fluxes across the shared boundaries. The parent and child models can be run either as a coupled system of models or separately as independent models (Stolp *et al.* 2017).

A4.1 HYDROGRAPHIC AREAS

Consistent with Brooks (2017) and previously published reports about the GBCAAS (Heilweil and Brooks, 2011; Brooks *et al.*, 2014), this analysis uses hydrographic areas (HAs) to describe locations, name model observations, and present groundwater budgets. The original HA publication by the USGS was in paper map form (Harrill and others, 1988) and later released in digital GIS format (Buto, 2009). The dataset was downloaded for this analysis from the WRD NSDI node at https://water.usgs.gov/GIS/metadata/usgswrd/XML/sir2010_5193_ha1000.xml.

A4.2 CHILD MODEL DOMAIN

The GBCAAS-PV model is a refined version of GBCAAS v. 3.0. The focus of the model is around Pine Valley and Wah Wah Valley. GBCAAS-PV incorporates a child model within the GBCAAS v. 3.0 parent model using the LGR technique. The child model, incorporated within a parent model, allows more detail to be defined in the focus area, while representing more realistic boundary conditions with the coupled regional parent model.

Figure A4-1 illustrates the GBCAAS-PV model domain and the GBCAAS parent model grid. The extent of the child model (i.e., focus area) was chosen in consultation with the Groundwater Technical Team to incorporate drawdown from project pumping and key discharge areas potentially influenced by Project effects and where greater resolution would be helpful for impact assessment, including Wah Wah Springs, Sevier Desert, and Tule Valley. Positioning of the child model boundary considered hydraulic flow barriers (faults) and materials with large hydraulic conductivity contrasts. Boundaries were placed to avoid these features to gain numerical stability. This was balanced with selecting the domain boundary far enough away from the focus area so that minimal flow changes could be expected across the parent/child model boundary and while minimizing the size of the child model and simulation run-times.

A4.3 LOCAL GRID REFINEMENT

GBCAAS v. 3.0 was developed with MODFLOW LGR (Mehl and Hill, 2013). LGR supports grid refinements in odd or even integer factors of the parent grid, such as 1/2, 1/3, 1/4, etc. The horizontal grid spacing of the child model grid was subdivided by 1/5 or 0.2 mi on each side with a grid-cell area of 0.04 mi^2 ($1/25^{th}$ of the original cell area) to better represent potential effects associated with Project pumping.

Grid refinement requires adjusting the top of the model, the bottom and thicknesses of model layers, the top of each hydrogeologic unit (HGU) in the model, and the thickness of the bottom HGU to reflect the finer discretization of the land surface (Stolp *et al.* 2017). Eight additional model layers (Figure A4-2) were added to the GBCAAS-PV child model to improve vertical discretization of the HGUs in the flow model (see section A4.5). The final child grid dimensions are 16 layers, 460 rows, and 260 columns. This replaces 8 layers, 92 rows, and 52 columns from the parent model.

Refinement of model layer top and bottom elevations was performed by linear interpolation from parent grid cell values to 5x5 cells. Where an original parent cell was adjacent to the parent/child boundary, the two rows or columns in the 5x5 grid nearest the boundary were fixed to the original parent cell value. This representation supported overall numerical stability and alignment between the parent and child model. Additional adjustments were made to layer elevations at some locations during model calibration. This process is described further in section A4.8.

A4.4 BOUNDARY CONDITIONS

A boundary condition describes mathematically how the simulated groundwater system interacts with the surrounding hydrologic system. Hydrologic boundaries in the GBCAAS-PV child model include specified-flux boundaries (recharge and pumping wells) and head-dependent flow boundaries (evapotranspiration and springs). The following sections describe the representation of boundary conditions in the GBCAAS-PV. Section A5 describes the simulation of pumping wells.

A4.4.1 RECHARGE FROM PRECIPITATION

GBCAAS v. 3.0 simulates recharge from precipitation, irrigation, and streams as a specified-flux boundary with the MODFLOW Recharge Package (see Harbaugh, 2005). Recharge is applied to the highest active cell (layer 1 in the GBCAAS models) and is defined using multiplier arrays, zones, and parameters. GBCAAS v. 3.0 uses multiplier arrays to define four components of recharge:

- **In-place**. Recharge that occurs in the cell in which the rainfall and snowmelt originally occurred;
- **Runoff**. Recharge that is transferred from the location where the precipitation fell to the recharge location in perennial, intermittent, and ephemeral streams, or is derived from irrigation with surface water;
- **Base**. Recharge that occurs from mountain-stream baseflow in streams that enter the basins, and from irrigation with mountain-stream baseflow; and
- **Import**. Recharge that occurs from imported water delivered in rivers or canals of from irrigation with imported water (Brooks *et al.* 2014).

GBCAAS v. 3.0 recharge zones intersecting Pine Valley and Wah Wah Valley were subdivided to allow the adjustment of recharge necessary to apply refined estimates of recharge in Pine and Wah Wah Valleys (see section A2.7.1). The redefined zones include smaller versions of the original zones (254 and 255) and their corresponding parameters (rech254c and rch255c), and newly defined sub-zones 2542 (rch2542c), 2551 (rch2551c), and 2831 (rch2831c) (see Figure A4-3). As shown in Figure A4-3, zones 2451, 2542, and 2551 extend into the adjacent HAs to avoid sharp transitions in recharge at HA boundaries. In other words, the higher estimated recharge rate in mountain block areas in Pine Valley and Wah Wah Valley was

assumed to also occur in the portion of the mountain block area in the adjacent HA. Recharge zone 2552 was added to simulate irrigation return flow to the Upper Basin-Fill Aquifer at Wah Wah Ranch (see GRIA Section 3.9 for additional discussion). The rate was applied to ten model cells at the center pivot area.

The GBCAAS-PV child model utilized the same base, in-place, and runoff arrays that were used in GBCAAS v3.0 (Figure A4-4). Note that there was no imported water in the child model area. The sum of these rates is the initial total recharge estimate per cell. In GBCAAS v3.0 and most of the child model, these individual cell rates were multiplied by recharge parameter values assigned to different zones (Figure A4-3). The parameter acts as a scaler:

Cell Recharge = (BASE + IN_PLACE + RUNOFF) * Parameter Value

In GBCAAS-PV this same approach was used. Because recharge in Pine Valley and Wah Wah Valley were estimated to be larger (see GRIA Section 3.9), the parameter values were increased locally to increase total recharge proportionally across the model cells.

The factors IP_FACTOR and RO_FACTOR were added as fixed variables to adjust the proportion of in-place recharge to runoff recharge to limit potential groundwater mounding effects. These values were scaled so the total recharge in Pine Valley and Wah Wah Valley was unchanged; only the location of the recharge was shifted. The resulting recharge per cell was calculated as follows:

Cell Recharge = (BASE + (IN_PLACE * IP_FACTOR) + (RUNOFF * RO_FACTOR)) * Parameter Value

The Base recharge component is negligible in Pine Valley and Wah Wah Valley (see Figure A4-4) and was, therefore, not adjusted. IP_FACTOR and RO_FACTOR were not tested for sensitivity nor estimated using UCODE (Poeter, 2104). These factors were adjusted manually to match estimated recharge for Pine Valley and Wah Wah Valley and to maintain consistency with estimates of the proportion of recharge as runoff (≈10%) for HAs not highly irrigated with surface water (see Masbruch et al. 2011, p. 86). Adjustment of IP_FACTOR and RO_FACTOR was combined with material property (e.g., VU and LCAU hydraulic conductivities) adjustments to reduce mounding. See section A4.8 for the further calibration discussion.

A4.4.2 WELLS

Calibration of the GBCAAS-PV model was performed for steady-state, pre-development conditions. Transient pumping wells represented in the Parowan Valley evaluation in GBCAAS v. 3.0 were disabled in the parent model as (1) they are outside the APE; and (2) their effects within the simulation time frame do not interact or overlap with drawdown induced by the Project. Representation of Project pumping wells is described in section A5.

A4.4.3 EVAPOTRANSPIRATION OF GROUNDWATER

Discharge as evapotranspiration of groundwater (ETg) occurs from three key areas in the GBCAAS-PV domain. These areas are in Snake Valley, Tule Valley, and the Sevier Desert (see Figure A4-5). GBCAAS v. 3.0 simulates ETg at these areas using the Evapotranspiration (EVT) Package (see Harbaugh, 2005). The required information to simulate ETg using the EVT package is the estimated rate of ETg, the extinction

depth, and the depth below land surface at which the observed ETg is assumed to occur (see Brooks et. al, 2014, figure 15). These inputs were not modified in the Pine Valley child model. Parent cells were converted to 5x5 child cells. The EVT (see Harbaugh, 2005) surface elevation was set to the parent model value.

GBCAAS v. 3.0 simulates evapotranspiration in the Milford and Beryl-Enterprise Area HAs using the Drain Package (see Harbaugh, 2005). Drain elevation was maintained in the child model cells (i.e., linear interpolation was not performed). Drain conductance was divided by 25 (5x5 sub-cells per parent cell) to maintain the same total conductance as the parent model.

A4.4.4 SPRINGS

Regional springs in the GBCAAS are typically associated with relatively high discharge rates from regionally connected carbonate aquifers as reported in Mathey (1998) and described by Harrill and Prudic (1998). These springs can have discharges from several hundred to over 1,000 gpm (Harrill and Prudic 1998). As shown on Figure A4-5, four regional springs in the Study Area are located in the Snake Valley HA northwest of the proposed PVWS Project wellfield and include Big Springs, Dearden Spring Group, and Clay Spring. Fish Springs is located a greater distance to the north-northwest (see Figure A2-1). Wah Wah Springs is the closest identified regional spring to the proposed PVWS wellfield.

Wah Wah Springs and Clay Spring occur in the GBCAAS-PV domain and are simulated using the Drain package. These springs areas were reduced from 1 square mile areas to 0.04 (0.2 x 0.2 mile) square mile areas. Consistent with GBCAAS v. 3.0, drain elevations for Wah Wah Springs and Clay Spring were set to 5,640 ft and 5,381 ft, respectively. The conductances of drains representing springs are defined as parameters in the groundwater flow model. Drain conductance is defined by the conductance factor multiplied by the parameter value. Drain boundaries for these springs were simulated in layer 1 in GBCAAS v. 3.0. Springs were simulated in layers 1 and 2 in the GBCAAS-PV model. This modification was necessary to achieve a closer match to observed spring discharge and is consistent with methods used in prior investigations (see Stolp *et al.* 2017). As these springs are artesian and pull water from depth, this is a reasonable approximation.

A4.5 HYDRAULIC PROPERTIES

Nine hydrogeologic units (HGUs) described in Sweetkind *et al.* (2011) occur in GBCAAS-PV (see Figure A2-5) and provide the basis for assigning horizontal hydraulic conductivity and vertical anisotropy to the model layers. The HGUs are simulated with the Hydrogeologic-Unit Flow (HUF) Package (Anderman and Hill, 2000; 2003), which can represent the complexities of the geology (see Brooks and others, 2014, fig. 3). Horizontal hydraulic conductivity and vertical anisotropy (the ratio of horizontal to vertical hydraulic conductivity) are defined for each HGU with parameters and zones. The HUF Package determines the HGUs that apply to each model cell (Anderman and Hill, 2000, fig. 1C) and calculates the effective hydraulic conductivity in both the vertical and horizontal directions for each cell (Anderman and Hill, 2000, p. 7).

HGUs defined in the HUF package represent the 3D hydrogeologic framework for the model (see Cederberg *et al.* 2010). The HUF package defines the distribution of HGUs and major structure of the

GBCAAS (Cederberg *et al.* 2011). The 3D hydrogeologic framework provides the basis for assigning horizontal hydraulic conductivity and vertical anisotropy to the GBCAAS model. The published geologic maps and cross sections available for the Study Area (Sweetkind *et al.* 2011; Cederberg *et al.* 2011, Auxiliary 1; Rowley 2017) were digitized and entered into a 3D geodatabase and used to systematically verify that the vertical and horizontal distribution of HGUs was adequately represented in GBCAAS v. 3.0 (see section 3.8.1 of the GRIA). Subsequently, the compiled geodatabase was used to refine the distribution of HGUs and associated aquifer properties in the more finely discretized GBCAAS-PV child model as described below.

The geometry of the HGUs in this system is complex due to folding, faulting, and other processes. HGUs are not continuous across the parent model. Where an HGU is not present, it is represented as zero thickness. For this case, a simple interpolation for estimating HGU thicknesses horizontally from a cell containing an HGU, to a cell not containing the HGU (zero thickness), produced a non-zero thickness in the refined grid where the HGU should be absent. Therefore, a multi-step interpolation process was used to attribute the refined grid while maintaining layer thickness consistency with the parent model.

For each HGU, the top elevation and thickness was defined using linear interpolation (see section A4.2). Where a parent cell had zero thickness, the child cell thickness was set to zero. These steps could result in overlaps or gaps, vertically, in the model where a zero thickness HGU was defined which must then be corrected in a subsequent step. To ensure that zero thickness and vertical continuity were maintained in the refined grid, additional adjustments were made. Iterating from top to bottom, underlying HGU top elevations were evaluated for an overlap. If an overlap occurred, the underlying HGU top elevation was lowered. Finally, HGU thicknesses were recalculated based on the top elevations. Consistent with GBCAAS v. 3.0, the base elevation of the model (-12,000 feet) was maintained.

Manual adjustments were made to the distribution of the HGUs in the vicinity of Wah Wah Springs to reflect interpreted geologic unit contacts more accurately on the refined grid. This change was required to achieve spring discharge consistent with observations.

A4.6 STRUCTURES SIMULATED AS BARRIERS

Hydrogeologic structures acting as barriers to groundwater flow (faults) are simulated with the Horizontal-Flow Barrier (HFB) Package (Harbaugh 2005). The geometry of faults is represented in the hydrogeologic framework (Cederberg *et. al.* 2011). The locations of HFBs in the GBCAAS-PV model are consistent with the parent model (see Figure A2-5). The hydraulic characteristics of HFBs are defined using parameters which represent hydraulic conductivity of the barrier divided by the width of the barrier. Fault width is assumed to 1 ft (Brooks 2017).

A4.7 MODEL OBSERVATIONS

Model observations used to calibrate the GBCAAS-PV model are water levels at wells, discharge as ETg, and discharge to springs. Observations are considered representative of steady-state conditions and are used in calibration, sensitivity analyses, and parameter estimation. Observation uncertainties were estimated as variances and used as part of model input, which UCODE_2005 (Poeter *et al.* 2008) uses to

define weights (1 divided by the variance). Weights are applied to the observations for calibration statistics, sensitivity analyses, and parameter estimation. The term "simulated equivalent" denotes the simulated value compared to the observation (Brooks 2017).

Parent model observations were not statistically evaluated in the GBCAAS-PV calibration. Parent model observations were maintained and followed the original GBCAAS v. 3.0 specifications.

A4.7.1 WATER LEVELS IN WELLS AND UNCERTAINTY

The water levels used as observations in GBCAAS v. 3.0 are documented in Brooks (2017) and Brooks *et al.* (2014). Water-level observations located in the parent model were not modified. Water-level observations from GBCAAS v. 3.0 located within the child model domain and additional water-level observations from Gardener *et al.* (2020) were included in the GBCAAS-PV observation data set.

Uncertainty associated with water-level observations in the GBCAAS-PV observation data set includes multiple potential sources of error. Potential error was accounted for in estimating simulated weighted residuals used for error analysis, parameter sensitivity analysis, and model regression (Brooks 2014). Potential errors that contribute to uncertainty include potential inaccuracies in the elevation and location of a well, in the measurement of water levels, in model discretization, and in fluctuations introduced by variations in climate or any other non-simulated transient stresses (San Juan *et. al.* 2004, p. 128).

These potential errors were assessed from available information for the refined GBCAAS-PV grid to quantify the uncertainty of each water-level observation (see Attachment 1). Well information was verified using the USGS National Water Information System (NWIS; Mathey 1998). Verified water level observations were assigned model positions. Reported open intervals of wells were used to associate observations to model layers. Wells were assumed open/screened from the ground surface to the bottom of the well when specific screen-interval data was not available. For wells with open intervals in multiple model layers, simulated water levels were a weighted average calculated by the MODFLOW-2005 Head Observation Package (HOB) based on the length of opening in each layer (Harbaugh and Hill 2009, p. 5). The total variance for each observation was estimated as follows:

Total variance = variance caused by water level measurement data error +
variance caused by well location data error +
variance caused by well altitude data error +
variance caused by model discretization error+
variance caused by depth of well data error

Finally, de-clustering (Deutsch and Journel 1998) was applied to observations to reduce the weight where refined grid cells contained multiple observations or "clusters" of observations. A base weight was divided by the count of the number of observations in any row/column cell (observations spanning multiple layers were treated as a single observation). For example, if one observation occurred in a cell, it received the full base weight; if two observations occurred in a cell, each received ½ the base weight. This method does not adjust weights for two observations in close proximity, but in different cells. The resulting water-level observation variance used was:

Variance used = de-cluster weight * Total variance

or

Variance used = Total variance / (number of observations in cell)

Consistent with GBCAAS v. 3.0 (Brooks 2017, p. 18), the layers to which observations were assigned were not redefined when layering was adjusted during the calibration process to keep the top of the model approximately equal to the regional groundwater surface (see Section 4.8.1.4).

A total 127 water-level observations are included in GBCAAS-PV (Figure A4-6). Thirty-five additional observations were suspected to represent perched water-levels and were not included in nonlinear regression using UCODE_2014 (Poeter *et al.* 2014) and were not included in the calibration statistics. This is consistent with calibration methods used by Brooks (2017). Observations were defined as perched or possibly perched when one or more of the following conditions applied:

- GBCAAS v. 1.0 or v. 3.0 defined the observations as possibly perched;
- Groundwater levels were associated with springs included in the NWIS database (excluding Wah Wah Springs and Clay Spring, which are regional springs) and occur in mountain block areas with an orifice elevation hundreds of feet above the top of the predicted carbonate aquifer flow system; and/or
- Groundwater levels were associated with shallow wells in mountain block areas.

A4.7.2 GROUNDWATER DISCHARGE AND UNCERTAINTY

Groundwater discharge observations in the child model include discharge to springs and ETg. Discharge data generally have larger uncertainty compared to water-level data due to measurement error and because seasonal or annual changes may not be well represented (Brooks 2017). Discharge observations and uncertainty are consistent with GBCAAS v. 3.0 with the exception of Wah Wah Springs. The discharge at Wah Wah Springs was revised to 1,800 AFY (see section 3.8.1 of GRIA). Discharge locations are illustrated in Figure A4-5.

A4.8 CALIBRATION

The purpose of the model calibration was to define reasonable base conditions, particularly in Pine Valley and Wah Wah Valley, so changes to groundwater level, flow, storage, spring discharge and ETg area discharge in the carbonate and alluvial aquifer system in response to proposed water supply pumping in Pine Valley by the PVWS Project can be more accurately evaluated. During model calibration, model parameters representing the value and distribution of recharge, horizontal hydraulic conductivity, vertical anisotropy, and conductance terms at drains representing spring discharge were adjusted. Manual changes were applied iteratively in the parent model in the vicinity of the refined GBCAAS-PV model area.

Manual changes were applied iteratively in the parent model in the vicinity of the refined GBCAAS-PV model area with a focus on errors in observed water levels and spring flows. Similar to GBCAAS v. 3.0, automated calibration methods using UCODE 2014 (Poeter *et al.*, 2014) were used in the GBCAAS-PV child model in combination with iterative manual calibration. Observations evaluated included weighted well

water levels, spring flows, and ETg discharges. Parent model observations were not used in the UCODE optimization process.

The calibration was based on steady-state pre-project conditions. A long-term equilibrium (LTEQ) transient stress period (1,000 years) was used to develop a better steady-state solution between the parent and child models using MODFLOW LGR. The LTEQ solution, which represented initial conditions for predictive simulations, resulted in a more stable numerical solution for subsequent simulations. GBCAAS-PV observations were evaluated at the end of the LTEQ stress period to determine whether additional calibration was needed.

A4.8.1 METHOD

GBCAAS v. 3.0 used an abbreviated version of the calibration methods described for GBCAAS v. 1.0 (Brooks *et al.*, 2014, p. 38–40). The approach used in GBCAAS v.3.0 included nonlinear regression using UCODE_2014 (Poeter *et al.*, 2014) and iterative manual adjustment of parameter zones and selected parameter values, following the examination of nonlinear regression results (Brooks 2017). This approach was applied in the GBCAAS-PV calibration. Parameter values from GBCAAS v.3.0 (Brooks 2017, tables 4 and 5) were used as initial estimates. Unless there was specific data to justify large parameter changes, hydraulic conductivity parameters were not allowed to vary by more than one order of magnitude; generally, changes were kept in the range of 1/3 to 3 times the GBCAAS v. 3.0 estimate.

Observation weights were generally calculated in a fashion similar to GBCAAS v.3.0 (Brooks 2017; see Section 4.7.1). The weight of water level observation C390656cb1 (see section A4.7.1) was modified to provide a more balanced representation of observation groups in the calibration process. The calculated variance for the water level observation C390656cb1 (see Figure A4-6), which is in the northern part of GBCASS-PV in Snake Valley, resulted in approximately 15% of the total error in the GBCAAS-PV calibration. Its variance was manually adjusted to give it less influence on the calibration process. The absolute error of this observation, however, is still reported. Note that this well had similarly large errors during calibration of GBCAAS v. 3.0 (see Brooks *et al.* 2017, Figures 15 and 20).

A4.8.1.1 MODEL SENSITIVITIES

Model parameter and observation sensitivities were used to guide the model calibration. Parameter sensitivities are useful for identifying which parameters will change model results the most, and which parameters have little or no effect on observations. Sensitivities can be evaluated for the total solution, or for individual observations. Modifying the most sensitive parameters correctly generally improves model fit to observations; however, modifications can impact local model results in both a positive and negative manner. Less sensitive parameters can also have a significant impact for smaller portions of a model. During calibration, it is important to keep in mind that automated parameter optimization can produce a numerically improved solution that is unrealistic for the hydrogeologic setting. Thus, automated methods using UCODE were used to guide initial gross model calibration and were followed up by targeted manual calibration to fine-tune areas of importance.

Composite scaled sensitivities were routinely calculated for all model parameters to identify the most sensitive parameters. The 10 to 15 most sensitive parameters were the focus of the automated calibration

effort, which consisted primarily of UBFAU and LCAU hydraulic conductivity parameters (see Figure A4-7A). Some sensitive parameters, however, were not adjusted. For example, testing of estimated values for NCCU17hkc did not benefit model calibration, so its initial value was not changed. Estimates of the basin fill vertical hydraulic conductivity anisotropy ratio, parameter BFAU_VNC, tended toward values of 300 or more, which was larger than the anisotropy ratio of playa units. Because this is a model-wide parameter, the estimated solution was not applied and its initial value was not changed. BFAU_VNC was suspected to be influenced by water-level observations in southern Pine Valley in an area of a relatively steep gradient. The steep gradient suggests the possible presence of a flow-impeding structure. The presence of such a structure, and its effect if present, cannot be assessed based on the existing data, and is best verified by monitoring during significant aquifer stresses (see section A5.2).

GBCAAS v. 3.0 estimated recharge parameters during model calibration. This approach, however, was not used during GBCAAS-PV calibration. GBCAAS-PV used the refined estimates of recharge developed for Pine Valley and Wah Wah Valley (see section A2.7.1). These estimates were not modified. Thus, sensitive recharge parameters illustrated in Figure A4-7A are not estimated in the calibration process. The scaling process to adjust recharge to match these estimates (see section A4.4.1 and A4.8.1.2) was performed manually.

One-percent scaled sensitivities were used to identify parameters that affected observations when adjusted. An example is shown in Figure A4-7B for flow from Wah Wah Springs (observation gha256_1). Besides recharge (rch2551c), carbonate aquifer zones LCAU516hks and LCAU5241hkc are the primary parameters affecting discharge at Wah Wah Springs.

The leverage statistic (Hill and Tiedeman, 2007) was also used to evaluate model sensitivity (Figure A4-7C). This statistic shows which observations most influence the weighted sum of square residuals. Reducing errors at these observations improve the general model fit. The leverage statistic was also used to identify observations impacting automated parameter estimation. C383825ell, in northern Pine Valley (Figure A4-6), is an example of an observation with a large leverage statistic. This area of Pine Valley has a relatively small water-table gradient, resulting in an estimation variance of 3 ft^2 at C383825ell. This is the smallest water level estimation error in GBCAAS-PV. Thus, small changes in simulated head in this area of the model had a large effect on model calibration statistics.

A4.8.1.2 MANUAL ADJUSTMENTS

Consistent with techniques applied by Brooks (2017) to calibrate GBCAAS v. 3.0, improvement in GBCAAS-PV calibration considered not only the objective function (sum of squared residuals), but also hydrogeologic judgement.

For example, parameter values that resulted in a simulated water table above ground surface were not accepted even if they reduced the residual of specific simulated equivalents (Brooks 2017). An effect of a larger recharge rate applied in Pine Valley, Wah Wah Valley, and the mountain blocks in adjacent HAs valleys was higher water levels that sometimes resulted in mounding. Groundwater mounding above ground surface was usually the result of higher recharge on low hydraulic conductivity materials. During the calibration process this was addressed by manually increasing hydraulic conductivities (e.g., VU2_hkc

(sub-zone 12), LCAU5112hkc, and LCAU6181hkc). The proportion of in-place and runoff recharge components (see section A4.4.1) was also modified to limit the magnitude of hydraulic conductivity adjustments required to address groundwater mounding. An increase of hydraulic conductivity of roughly one order of magnitude were considered acceptable.

Increased recharge along the Needle Mountains between Pine Valley and southern Snake Valley (i.e., Hamlin Valley) resulted in increased water levels in southern Snake Valley. Manual adjustment of hydraulic conductivity to parent model parameter LCAU4191hkp maintained water levels in southern Snake Valley to values more consistent with GBCAAS v. 3.0 estimates. Adjustment to LCAU4191hkp is the one case in the GBCAAS-PV model where a parent model parameter was modified outside the child model without a corresponding change in the child model. In this case LCAU4191hkp is located completely outside the child model (see Figure A4-10, "Parent Model Zone 4191").

A4.8.1.3 HYDROLOGIC UNIT ZONE SUB-DIVISIONS

HGU zone identification numbers (IDs) adopted a "1", "2", etc., at the end of zone IDs used in GBCAAS v. 3.0. HGU zone subdivisions were necessary to perform refinements specific to Pine Valley and Wah Wah Valley. For example, the upper basin-fill aquifer unit (UBFAU) zone IDs in Pine and Wah Wah Valleys are 31, 35, 41, and 48 in the GBCAAS v. 3.0 model. These zones, however, occur across the entire GBCAAS model domain (see Figure A4-8). To address this, zone 48 was subdivided into 481, 4811, 4812, and 4813 (Figure A4-9). Zone 481, 4811, and 4812 were based on a gradation assumption from the valley margins to valley centers. UBFAU thicknesses of 0'-500', 500'-1000', and > 1000' were assumed as the basis to construct the subdivision. Zone 4813 defined a subdivision in southern Wah Wah Valley. Zone 35 was subdivided into zones 351 and 352, and Zone 41 was subdivided into zones 411, 4111, and 4112, in a manner similar to zone 48. The lower carbonate aquifer unit (LCAU) zone 51 was subdivided into three zones: 511, 5111, and 5112 (see Figure A4-10). Zones for LBFAU, NCCU, UCAU, USCU, and VU were not changed.

A4.8.1.4 LAYER ELEVATION ADJUSTMENT

Although the top of the groundwater system is unconfined, GBCAAS designates model layers as confined for numerical stability and efficiency (Brooks and others, 2014, p. 19). Simulating layer 1 as confined is a reasonable assumption if the simulated saturated thickness approximates the specified saturated thickness (Reilly and Harbaugh, 2004, p. 15). As such, development of the GBCAAS models incorporated a process to adjust the model top elevation and layer thicknesses such that the model top elevation approximated the simulated heads and the bottom of layer 1 was lower than the simulated heads. The thickness of layers 2 through 6 was also adjusted to maintain a minimum thickness of 10 feet (Figure 4-2; Brooks, 2017). A similar process was implemented during calibration of GBCAAS-PV. As calibration proceeded, layer elevation adjustments were repeated as needed.

A4.8.2 PARAMETER VALUES IN CALIBRATED MODEL

Model parameters from GBCAAS v.3.0 in the GBCAAS-PV domain were maintained but renamed so that they could be adjusted independently of the parent model. This was necessary because some property zones extend across multiple valleys in the GBCAAS v. 3.0 model domain. With the exceptions of hydraulic

conductivity parameters and recharge parameters that crossed the parent/child LGR model boundary, the parent model was unchanged, except for parameter LCAU4191hkp (see section A4.8.1.2). The child model for HA273 (see Stolp *et. al.* 2017) was also unchanged.

Subdivision of zones occurred primarily with HGU zones. Parameters associated with subdivided zones adopted a "c" at the end of each parameter name, indicating a child model parameter. In some cases, "p" was used to represent separated parameters in the parent model.

The final model has 218 adjustable parameters; this is a slight increase from GBCAAS v. 3.0 (208 parameters) because of the shared parameters that crossed the parent/child boundary and sub-divided parameter zones.

Ten parameters were estimated using UCODE parameter optimization in the final calibration and include UBFAU and LCAU parameters (Table A5). Following parameter estimation, final model calibration included manual adjustments to parameters LCAU516HKc, LCAU5241hk, and LCAU6181hk. A minor adjustment was made to LCAU516HKc and its final value is within the estimated 95% confidence interval. Manual adjustments to LCAU5241hk and LCAU6181hk were made that are outside the 95% confidence interval range. However, the values are within the "reasonable value" range presented in Brooks (2017, Table 4) and represent a small adjustment from the original GBCAAS v. 3.0 parameters. The final GBCAAS-PV parameter values are compared with GBCAAS v. 3.0 parameter values in Table A6 and Figure A4-11. The UBFAU zones in Pine Valley and Wah Wah Valley that contain the pumping test wells listed in Table A2 include 4811, 4812, 4813, and 4111 (see Figure A4-12). The final calibrated hydraulic conductivities of these zones are 2.2, 1.14, 0.5, and 4.5 ft/day, respectively. These values are generally consistent with pumping test results. By comparison, the final calibrated hydraulic conductivity GBCAAS v. 3.0 was 0.229 ft/day, which was less than all pumping test results (see Table A2).

In the final model, in-place recharge was reduced approximately 7% (IP_FACTOR = 0.9337) and run-off recharge was increased by approximately 177% (RO_FACTOR = 2.768). Table A7 compares in-place and runoff recharge components for GBCAAS-PV and GBCAAS v. 3.0. The final estimate of fraction of runoff that becomes recharge is 11% and 14% for Pine Valley and Wah Wah Valley, respectively. These estimates are generally consistent with estimates of 10% for HAs not highly irrigated with surface water (Masbruch *et al.* 2011, p. 86). The recharge rate in recharge zone 2831 between Wah Wah Valley and the Milford Area was not adjusted as the in-place recharge estimated in GBCAAS v. 3.0 was negligible.

TABLE A5. FINAL MODEL PARAMETERS ESTIMATED WITH UCODE

Estimated Parameter Using UCODE Optimization	Upper 95% Confidence Interval	Final Estimate	Lower 95% Confidence Interval	Final Calibrated Value
	(ft^3/day)	(ft^3/day)	(ft^3/day)	(ft^3/day)
UBFAU4111H	5	4.5	4.04	4.5
UBFAU461HK	58.4	16.4	4.59	16.4
UBFAU4812H	1.26	1.14	1.03	1.14
LCAU425hkc	0.215	0.103	0.0496	0.103
LCAU511HKc	0.00279	0.00265	0.00251	0.00265
LCAU516HKc	0.153	0.143	0.133	0.15
LCAU518hkc	26	19.1	14	19.1
LCAU5211hk	0.598	0.527	0.464	0.527
1LCAU5241hk	84.8	69.2	56.4	34
LCAU6181hk	0.0562	0.0516	0.0473	0.044

TABLE A6. FINAL MODEL PARAMETERS AND COMPARISON TO GBCAAS V. 3.0

Pine Valley Child Model Parameter Name	Calibrated Value	UCODE Group Name	GBCAAS v.3.0 Parameter Name	GBCAAS v.3.0 Parameter Value	Units
rch254c	1.16	recharge_c	rch254	1.16	-
rch2541c	0.35	recharge_c	rch2541	0.35	-
rch2542c	***0.581***	recharge_c	rch2541	0.35	-
rch255c	0.471	recharge_c	rch255	0.471	-
rch2551c	***0.767***	recharge_c	rch255	0.471	-
rch256wwrc	1	recharge_c	Undefined	-	-
rch2821c	1.21	recharge_c	rch2821	1.21	-
rch283c	1.07	recharge_c	rch283	1.07	-
rch2831c	1.07	recharge_c	rch283	1.07	-
rch287c	1.85	recharge_c	rch287	1.85	-
rch999c	0.0989	recharge_c	rch999	0.0989	-
rch9999c	0.01	recharge_c	rch9999	0.01	-
UBFAU31HKc	8.03	hk_c	UBFAU31HK	8.03	ft/d
UBFAU311HKc	***8***	hk_c	UBFAU31HK	8.03	ft/d
UBFAU34HKc	1	hk_c	UBFAU34HK	1	ft/d
UBFAU35HKc	38.8	hk_c	UBFAU35HK	38.8	ft/d
UBFAU351HKc	***36***	hk_c	UBFAU35HK	38.8	ft/d
UBFAU352HKc	***36***	hk_c	UBFAU35HK	38.8	ft/d
UBFAU353HKc	38.8	hk_c	UBFAU35HK	38.8	ft/d
UBFAU36HKc	14.7	hk_c	UBFAU36HK	14.7	ft/d
UBFAU41HKc	2.03	hk_c	UBFAU41HK	2.03	ft/d
UBFAU411HKc	***7.59***	hk_c	UBFAU41HK	2.03	ft/d
UBFAU4111HKc	***4.5***	hk_c	UBFAU41HK	2.03	ft/d
UBFAU4112HKc	***7.59***	hk_c	UBFAU41HK	2.03	ft/d

Pine Valley Child Model Parameter Name	Calibrated Value	UCODE Group Name	GBCAAS v.3.0 Parameter Name	GBCAAS v.3.0 Parameter Value	Units
UBFAU431HKc	***45***	hk_c	UBFAU35HK	38.8	ft/d
UBFAU45HKc	22.5	hk_c	UBFAU45HK	22.5	ft/d
UBFAU46HKc	17.1	hk_c	UBFAU46HK	17.1	ft/d
UBFAU461HKc	***16.4***	hk_c	UBFAU46HK	17.1	ft/d
UBFAU48HKc	0.229	hk_c	UBFAU48HK	0.229	ft/d
UBFAU481HKc	***1.73***	hk_c	UBFAU48HK	0.229	ft/d
UBFAU4811HKc	***2.2***	hk_c	UBFAU48HK	0.229	ft/d
UBFAU4812HKc	***1.14***	hk_c	UBFAU48HK	0.229	ft/d
UBFAU4813HKc	***0.5***	hk_c	UBFAU48HK	0.229	ft/d
LBFAU1_hKc	0.0419	hk_c	LBFAU1_hK	0.0419	ft/d
LBFAU4_hKc	0.3	hk_c	LBFAU4_hK	0.3	ft/d
LBFAU5_hkc	0.229	hk_c	LBFAU5_hk	0.229	ft/d
VU1_hkc	0.474	hk_c	VU1_hk	0.474	ft/d
VU2_hkc	***0.0202***	hk_c	VU2_hk	0.00337	ft/d
UCAU11hkc	***0.0222***	hk_c	UCAU11hk	0.0419	ft/d
UCAU2_hkc	2.05	hk_c	UCAU2_hk	2.05	ft/d
USCU13HKc	0.00128	hk_c	USCU13HK	0.00128	ft/d
LCAU4111HKc	***0.0023***	hk_c	LCAU43_HK	0.00762	ft/d
LCAU417hkc	0.0503	hk_c	LCAU417hk	0.0503	ft/d
LCAU4191hkp	***5***	hk	LCAU42_hk	1.24	ft/d
LCAU42_hkc	1.24	hk_c	LCAU42_hk	1.24	ft/d
LCAU424hkc	0.012	hk_c	LCAU424hk	0.012	ft/d
LCAU425hkc	***0.103***	hk_c	LCAU42_hk	1.24	ft/d
LCAU511HKc	***0.00265***	hk_c	LCAU511HK	0.0023	ft/d
LCAU5111HKc	***0.00339***	hk_c	LCAU511HK	0.0023	ft/d
LCAU5112HKc	***0.0067***	hk_c	LCAU511HK	0.0023	ft/d
LCAU5151hkc	***0.00685***	hk_c	LCAU511HK	0.0023	ft/d
LCAU516HKc	***0.15***	hk_c	LCAU516HK	0.121	ft/d
LCAU518hkc	***19.1***	hk_c	LCAU524hk	20.3	ft/d
LCAU5181hkc	***3.4***	hk_c	LCAU524hk	20.3	ft/d
LCAU52_hkc	0.0663	hk_c	LCAU52_hk	0.0663	ft/d
LCAU5211hkc	***0.527***	hk_c	LCAU521hk	0.681	ft/d
LCAU5241hkc	***34***	hk_c	LCAU524hk	20.3	ft/d
LCAU53_HKc	2.48	hk_c	LCAU53_HK	2.48	ft/d
LCAU610hkc	8.35	hk_c	LCAU610hk	8.35	ft/d
LCAU618hkc	***0.0285***	hk_c	LCAU618hk	0.017	ft/d
LCAU6181hkc	***0.044***	hk_c	LCAU618hk	0.017	ft/d
LCAU71_HKc	0.0609	hk_c	LCAU71_HK	0.0609	ft/d
NCCU13hkc	0.5	hk_c	NCCU13hk	0.5	ft/d
NCCU17hkc	***0.0138***	hk_c	NCCU17hk	0.00846	ft/d
NCCU2_hkc	0.0483	hk_c	NCCU2_hk	0.0483	ft/d
NCCU23hkc	0.00534	hk_c	NCCU23hk	0.00534	ft/d
NCCU24hkc	0.00317	hk_c	NCCU24hk	0.00317	ft/d
NCCU36hkc	***0.00613***	hk_c	NCCU36hk	0.0109	ft/d
bfau_vnc	10.7	vk_c	bfau_vn	10.7	-

Pine Valley Child Model Parameter Name	Calibrated Value	UCODE Group Name	GBCAAS v.3.0 Parameter Name	GBCAAS v.3.0 Parameter Value	Units
playa_vnc	***100***	vk_c	playa_vn	66.1	-
rock_vnc	1	vk_c	rock_vn	1	-
SpecStorc	0.00000012	storage_c	SpecStor	0.00000012	-
sy_rockc	0.00994	storage_c	sy_rock	0.00994	-
sy_fillc	0.074	storage_c	sy_fill	0.074	-
sy3c	0.03	storage_c	sy3	0.03	-
et_berylc	1.42	et_c	et_beryl	1.42	-
EVT_parowanc	2.1	et_c	EVT_parowan	2.1	-
EVT1c	2.03	et_c	EVT2	2.03	-
EVT2c	2.03	et_c	EVT2	2.03	-
IP_FACTOR	***0.934***	recharge_c	Undefined	1	-
RO_FACTOR	***2.77***	recharge_c	Undefined	1	-

Note: ***Parameters*** and ***values*** in bold italics indicates parameter modified in the GBCAAS-PV calibration.

TABLE A7. FINAL IN-PLACE AND RUNOFF RECHARGE COMPONENTS

	In-Place (%)	Runoff (%)
GBCAAS v. 3.0		
Pine Valley	94	6
Wah Wah Valley	92	8
GBCAAS-PV		
Pine Valley	89	11
Wah Wah Valley	86	14

A4.9 MODEL EVALUATION

The GBCAAS-PV model calibration was evaluated to assess the accuracy of simulated results by evaluating the model fit to observations of water levels and discharge. As described below, the model provides a reasonable representation of the groundwater system in the model focus area.

Three observation types were used in the GBCAAS-PV model calibration. The model was fit to 92 water-level observations, two spring flow observations, and eight estimated ETg discharge rates. Observations within the child model domain were evaluated using weighted and unweighted residuals. Unweighted residuals have the same dimensions as the observations. Unweighted residuals, however, can be misleading because observations may be measured with different accuracy. For example, two unweighted residuals that are of equal value may not indicate an equally satisfactory model fit (Stolp *et al.* 2017). Weighted residuals are dimensionless and reflect model fit in the context of the expected accuracy of the observations (Hill and Tiedeman, 2007, p. 35). Being dimensionless, they have the benefit of being able to aggregate estimation errors based on different observation types into a single combined error score (SSWR: Sum of Squares Weighted Residual). This is required for automated model calibration.

A4.9.1 WATER-LEVEL OBSERVATIONS

Figure A4-13 illustrates the calibrated unweighted water-level residuals in GBCASS-PV, including simulated versus observed heads (Figure A4-13A) and a comparison of calibration statistics to GBCAAS v. 3.0 (Figure A4-13B). Suspected perched water-level observations ("Possibly perched" and "Pine Valley/Wah Wah Valley Perched") were not included in the calibration statistics. The calibrated unweighted head residuals statistics indicate a general improvement from GBCAAS v. 3.0. The RMSE/Range for both GBCAAS v. 3.0 (5.5%) and the GBCAAS (4.4%), is less than 10%, which is a general standard for an acceptable model fit using unweighted head residuals (Rumbaugh and Rumbaugh 2017). The unweighted water-level residuals do not indicate a spatial bias (see Figure A4-14).

Weighted water-level residuals are expected to be random and normally distributed (Hill and Tiedeman, 2007, p. 109). A histogram of weighted water-level residuals is illustrated in Figure A4-15A. Evaluation using a chi-square method (Intactprolink 2021), where the count per histogram bar interval is evaluated, suggests normally distributed residuals. A more detailed Shapiro-Wilk test (Zaiontz 2021) shows the weighted residuals are unlikely to be normally distributed. Graphs of weighted residuals and simulated values of water levels (see Figure A4-15B), however, indicate little model bias (i.e., the residuals vary randomly about zero). The weighted water-level residuals do not indicate a spatial bias (see Figure A4-16). Fine-tuning of the model using manual calibration methods focused primarily on Pine Valley and Wah Wah Valley. The non-normality of residuals in the child model may be the result of this focused effort in the area where the largest pumping impacts will be seen.

The square root of the sum of square weighted residuals divided by the number of observations (see Figure A4-15C) is called the standard error of the regression (Hill and Tiedeman, 2007, p. 95) and provides a measure of model fit relative to the weighting that can be compared for different types of observations (Brooks 2017). The standard error of the regression (7.72) for water levels in wells in the model focus area multiplied by the average standard deviation of observations in wells (10.3 ft) indicates that the model has an overall fit to water levels in wells of 79.5 ft (Hill and Tiedeman, 2007, p. 96). Using the simulated equivalents of water-level observations, 88 percent are within 79.5 ft (one standard deviation of the error) of the observation. Fifty-one percent are within 25 ft. Unweighted water-level residuals organized by HAs are provided graphically in Figure A4-17.

A4.9.2 DISCHARGE OBSERVATIONS

Calibration included matching groundwater discharge to springs and ETg. The fit of simulated to observed discharge in the model focus area is generally good. Figure A4-18A and Figure A4-18B illustrates simulated ETg discharge and spring discharge compared to estimated observed (or conceptual) discharge. The total discharge in the model focus area is 96% of the discharge simulated in GBCAAS v. 3.0 and 87% of the conceptual, or estimated, ETg discharge observation (Figure A4-18C). The total discharge at Wah Wah Springs and Clay Spring is 100% and 102% of the estimated discharge observation, respectively.

Discharge at zone et37snake3 (see Figure A4-5) represents the largest error in simulated discharge. Zone et37snake3 occurs primarily in the parent model just outside the child model domain. The estimated error suggests additional parent model calibration near zone et37snake3 would benefit the overall model fit.

Modifications in the parent model in this region, however, did not have a significant effect on the predicted effects of PVWS Project pumping and additional calibration outside the model focus area was therefore beyond the scope of this analysis.

A4.9.3 INTERBASIN FLOWS

Figure A4-19 graphically compares simulated interbasin flows in GBCAAS-PV to simulated and 95% confidence intervals of the simulated values from GBCAAS v. 3.0 (Brooks 2017, Table 9). Table A8 lists the simulated results of interbasin flows and is organized into two groups: A) Simulated Groundwater Divide Approximates the HA Boundary and B) No Simulated Groundwater Divide at HA Boundary.

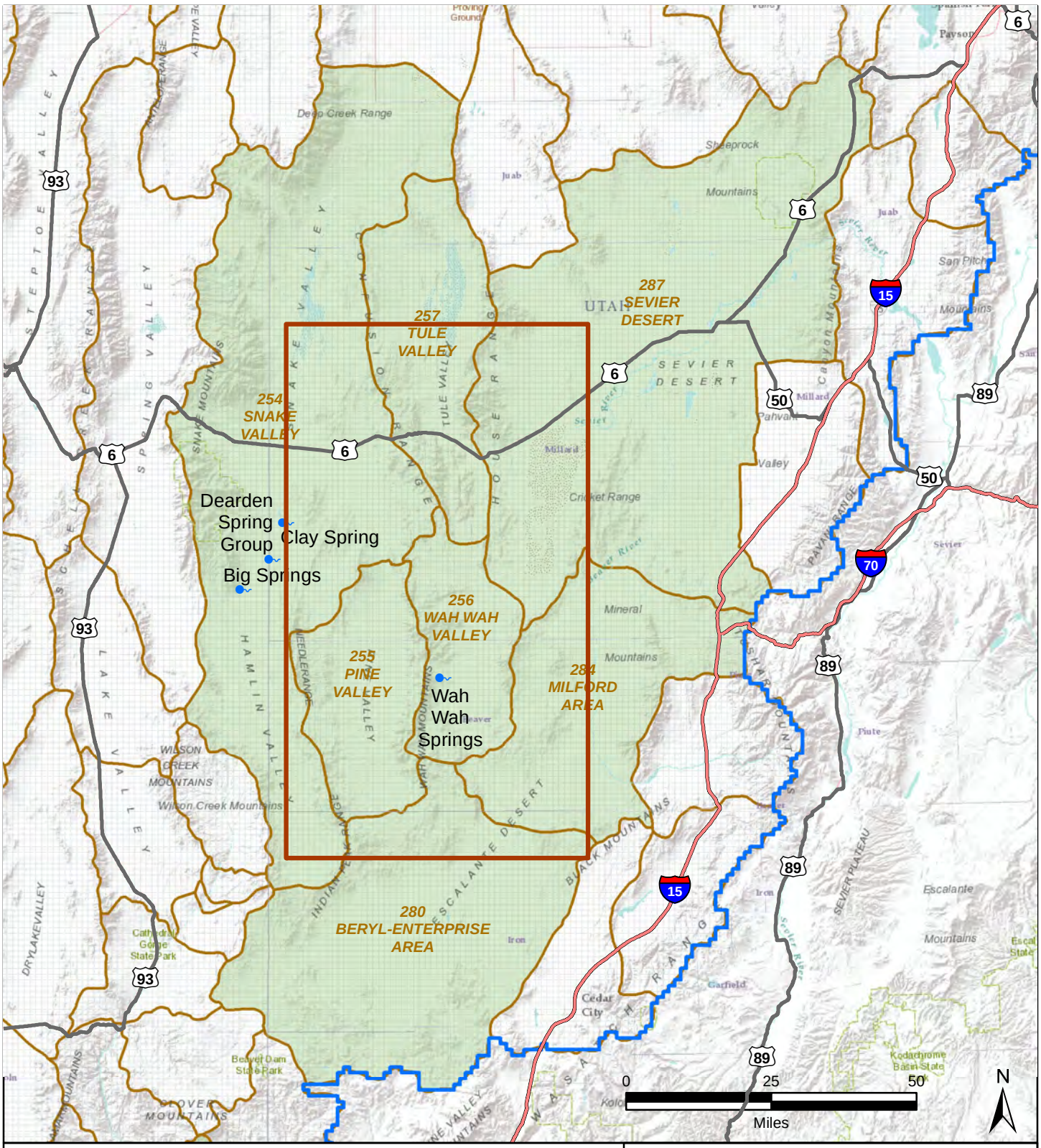
An HA boundary with a small, simulated flow indicates the simulated groundwater divide closely aligns with the HA boundary (Table A8, Group A). A small change in interbasin flow at these boundaries between GBCAAS-PV and GBCAAS v. 3.0 is the result of a minor difference in the location of the simulated groundwater divide relative to the HA boundary. These differences are considered insignificant.

An HA boundary with a large, simulated flow (Table A8, Group B) indicates a groundwater flow path (i.e., no groundwater divide). The primary difference in interbasin flows simulated in GBCAAS-PV are the result of increased recharge in Pine Valley and Wah Wah Valley. The effect is increased flow northward, towards Sevier Desert and Tule Valley. As illustrated in Figure A4-19, simulated interbasin flows fall within the 95% confidence intervals of the simulated values from GBCAAS v. 3.0.

TABLE A8. COMPARISON OF SIMULATED INTERBASIN FLOWS

Hydrographic Area Boundary	GBCAAS-PV (AFY)	GBCAAS v. 3.0 (AFY)
Group A) Simulated Groundwater Divide Approximates the HA Boundary		
Pine to Beryl	800	500
Pine to Snake	1,100	-500 [1]
Beryl to Wah Wah	500	400
Milford to Wah Wah	700	700
Group B) No Groundwater Divide at HA Boundary		
Pine to Wah Wah	15,900	11,000
Wah Wah to Sevier	9,800	6,800
Wah Wah to Tule	11,900	8,500
Sevier to Tule	19,700	18,000
Milford to Sevier	17,400	17,000

[1] Negative rate indicates opposite flow direction (i.e., Snake to Pine).



Legend

- Regional Spring
- Interstates
- US Route
- Study Area
- Hydrographic Area
- Focused Model Area
- GBCAAS Model Boundary
- GBCAAS Model Grid

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-1

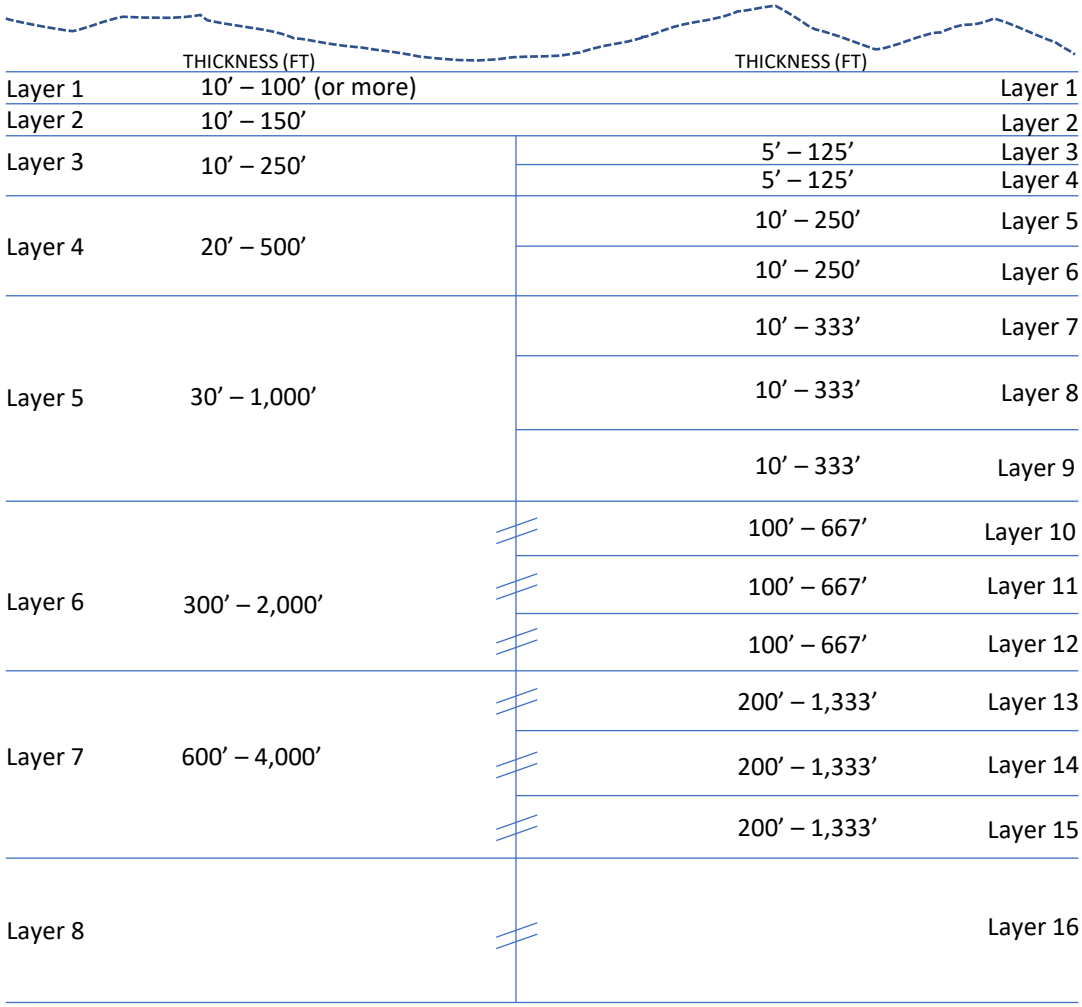
PROJECT STUDY AREA AND CHILD MODEL DOMAIN

DATE: FEB 16, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Appx\Fig4_01_ModelFocusArea.mxd



PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

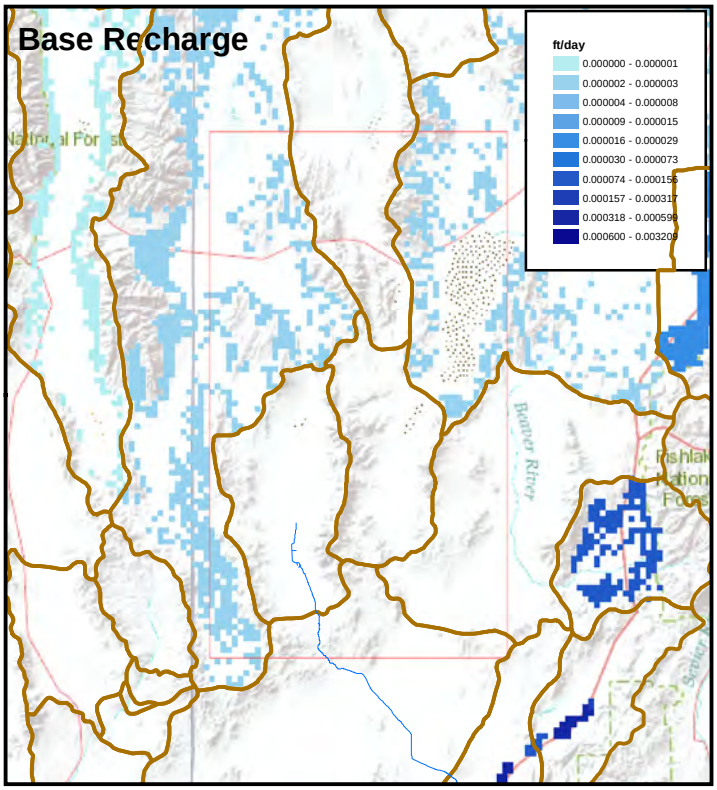
FIGURE A4-2

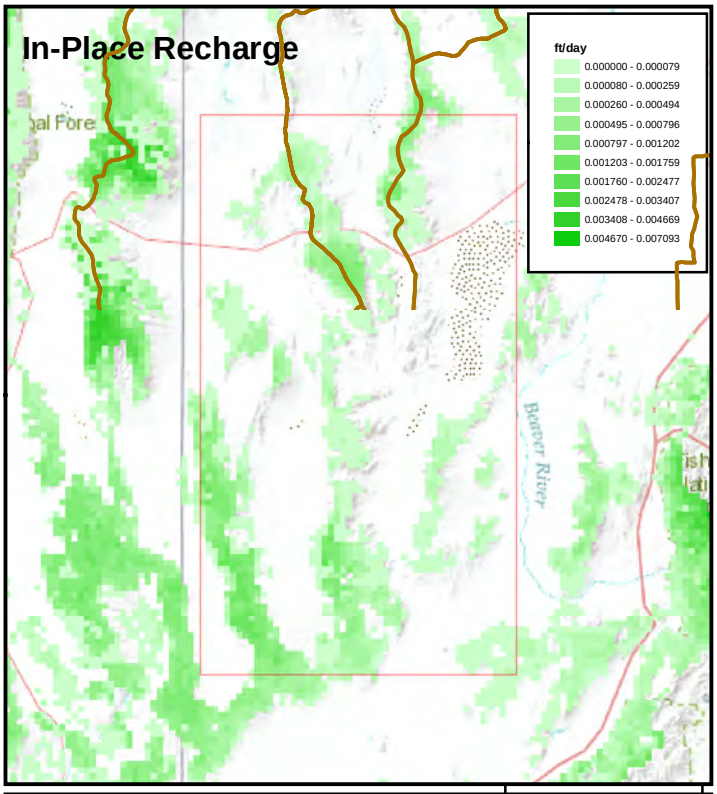
PARENT AND CHILD MODEL LAYERS AND THICKNESS

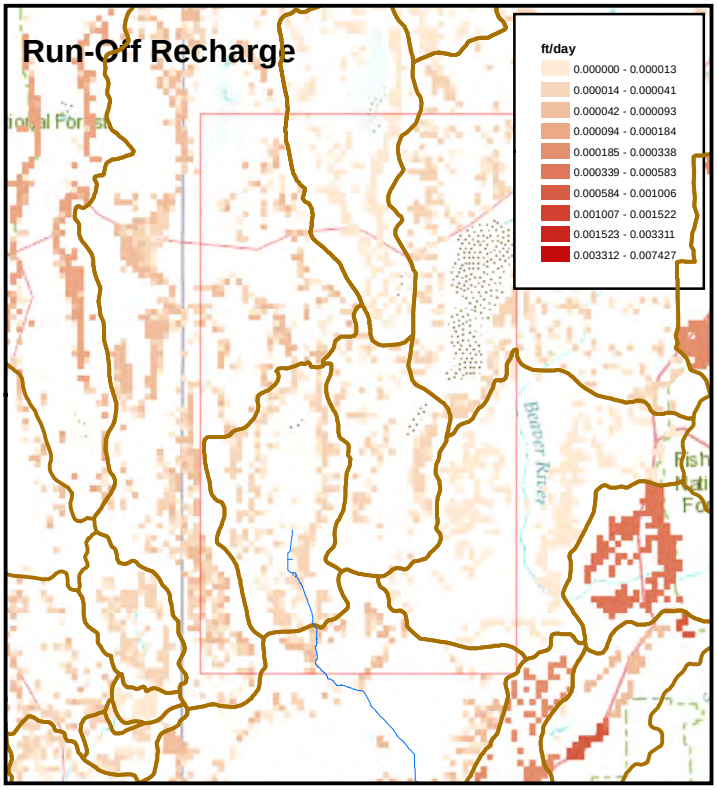
DATE: FEB 24, 2021
BY: WW
FOR: PT

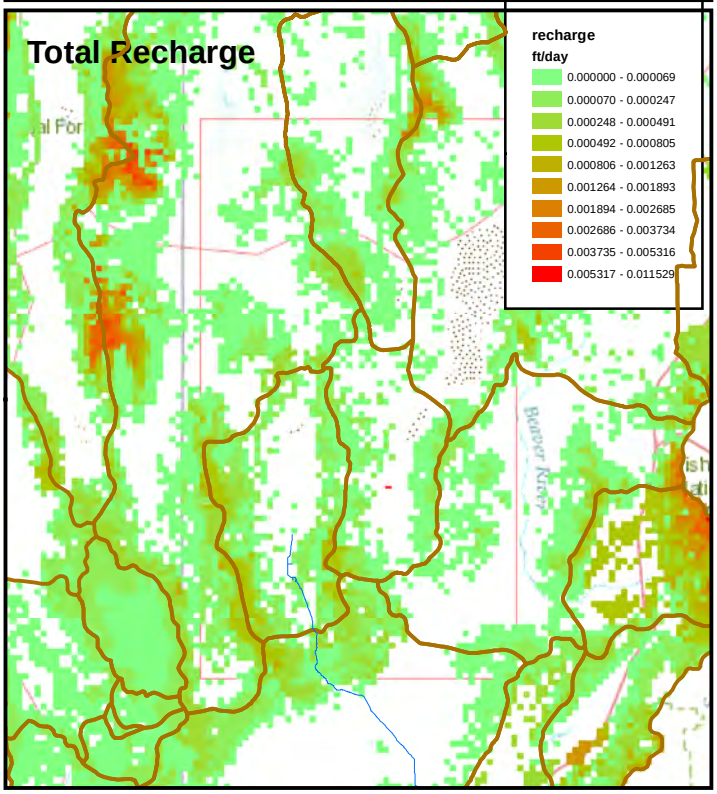
FORMATION ENVIRONMENTAL

"S:\GIS\a5\Transcon_PineValley\pltGRIA\Appx\Fig4_02_ModelLayers.pptx"









Legend

- Project Pipeline Alignment
- Hydrographic Area

PINE VALLEY WATER SUPPLY PROJECT

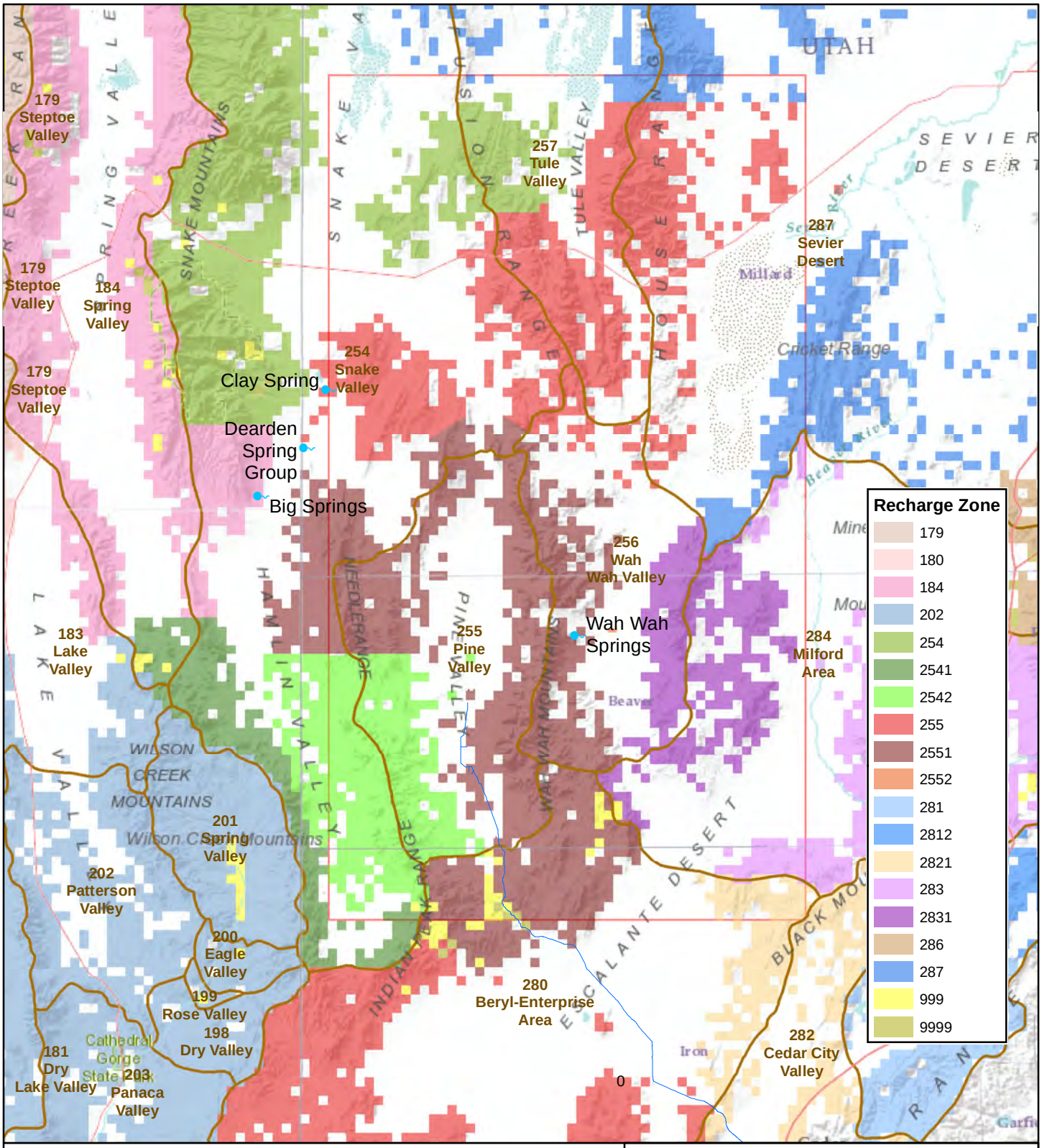
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-3

RECHARGE COMPONENTS SIMULATED IN GBCAAS V. 3.0

DATE: FEB 20, 2021	FORMATION ENVIRONMENTAL
BY: WLW	FOR: PHT

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Appx\Fig4_03_RechargeComponents.mxd



Legend

- Regional Spring
- Project Pipeline Alignment
- Hydrographic Area

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-4

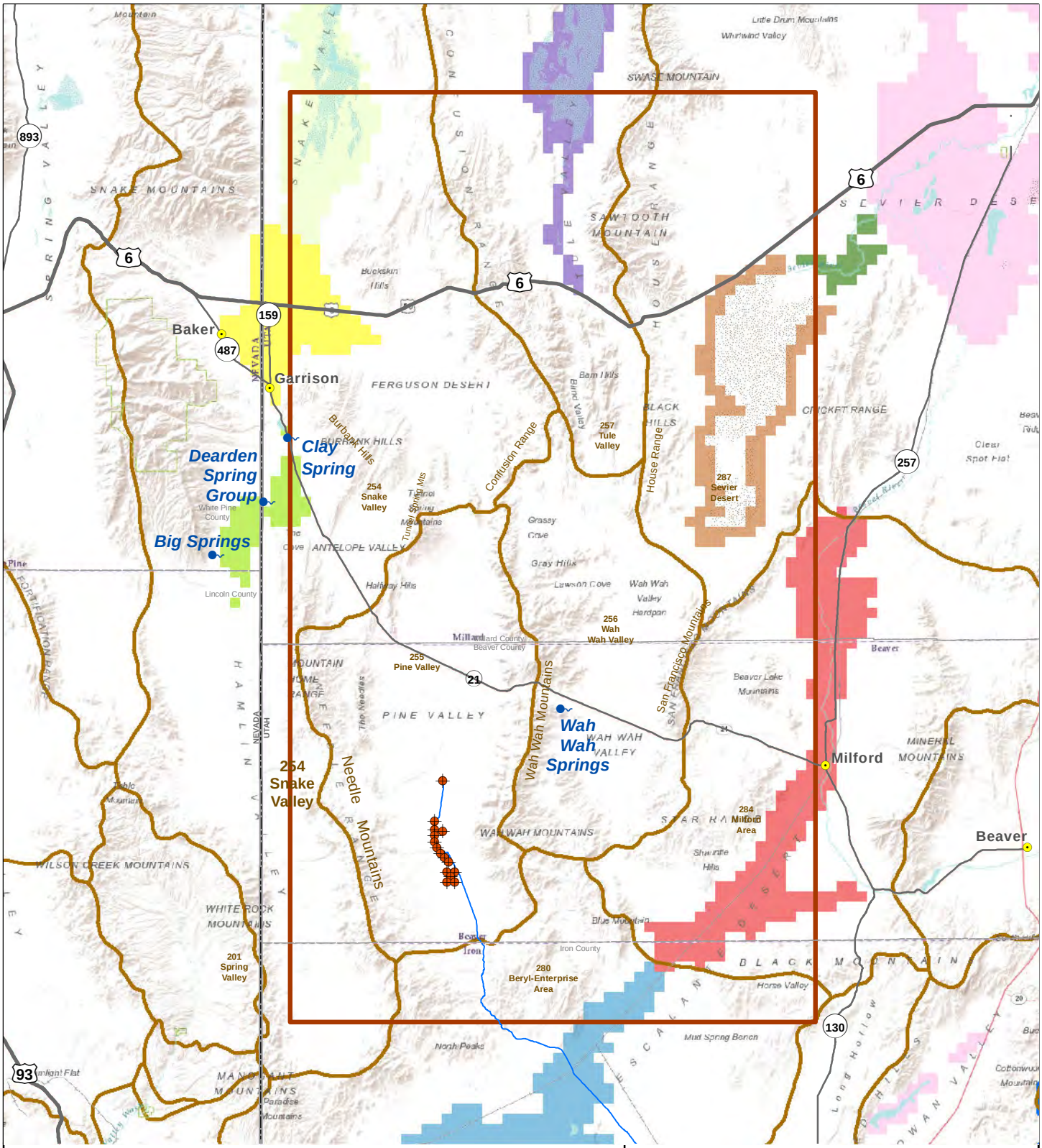
RECHARGE ZONES SIMULATED IN GBCAAS V. 3.0 AND GBCAAS-PV

DATE: FEB 20, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Appx\Fig4_04_RechargeZones.mxd



Legend

- Regional Spring
- PVWS Project Well
- US Route
- State Route
- Project Pipeline Alignment
- Hydrographic Area

ET Zones

- Beryl Enterprise (et39beryl)
- Milford (et39milf)
- Tule (et37tule)
- Snake (et37Snake2)
- Snake (et37Snake3)
- Snake (et37snake4)
- Sevier (et39sevier2)
- Sevier (et39sevier3)
- Other discharge areas

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-5

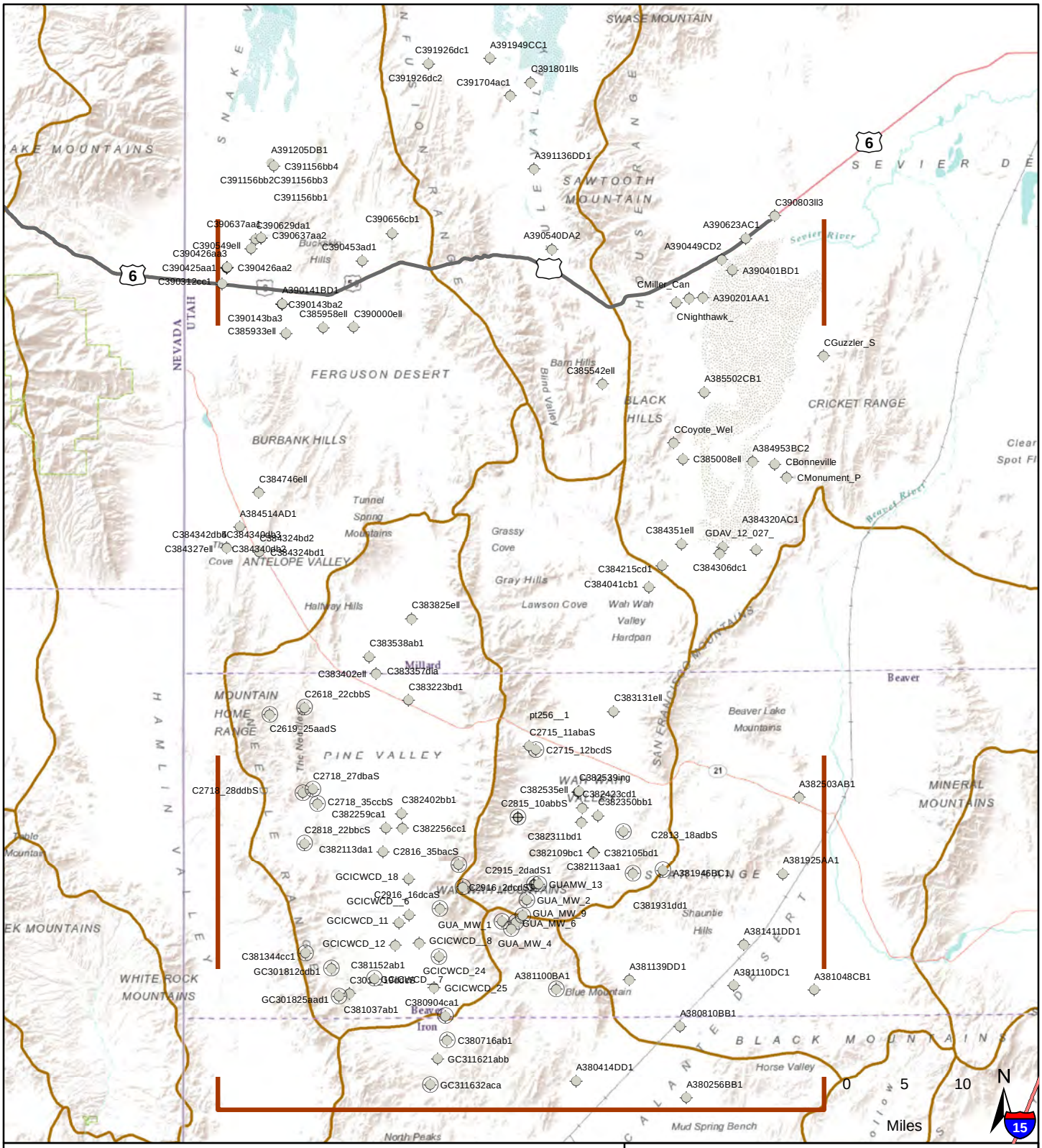
ET DISCHARGE AND SPRINGS IN FOCUSED MODEL AREA

DATE: FEB 19, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRI\AppxFig4_05_ETSprings.mxd



Legend

- Interstates
- US Route
- Hydrographic Area
- Focused Model Area
- Water-Level Observation
- Assumed Perched Water-Level (not used in non-linear regression statistics)

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-6

WATER LEVEL OBSERVATIONS IN GBCAAS-PV

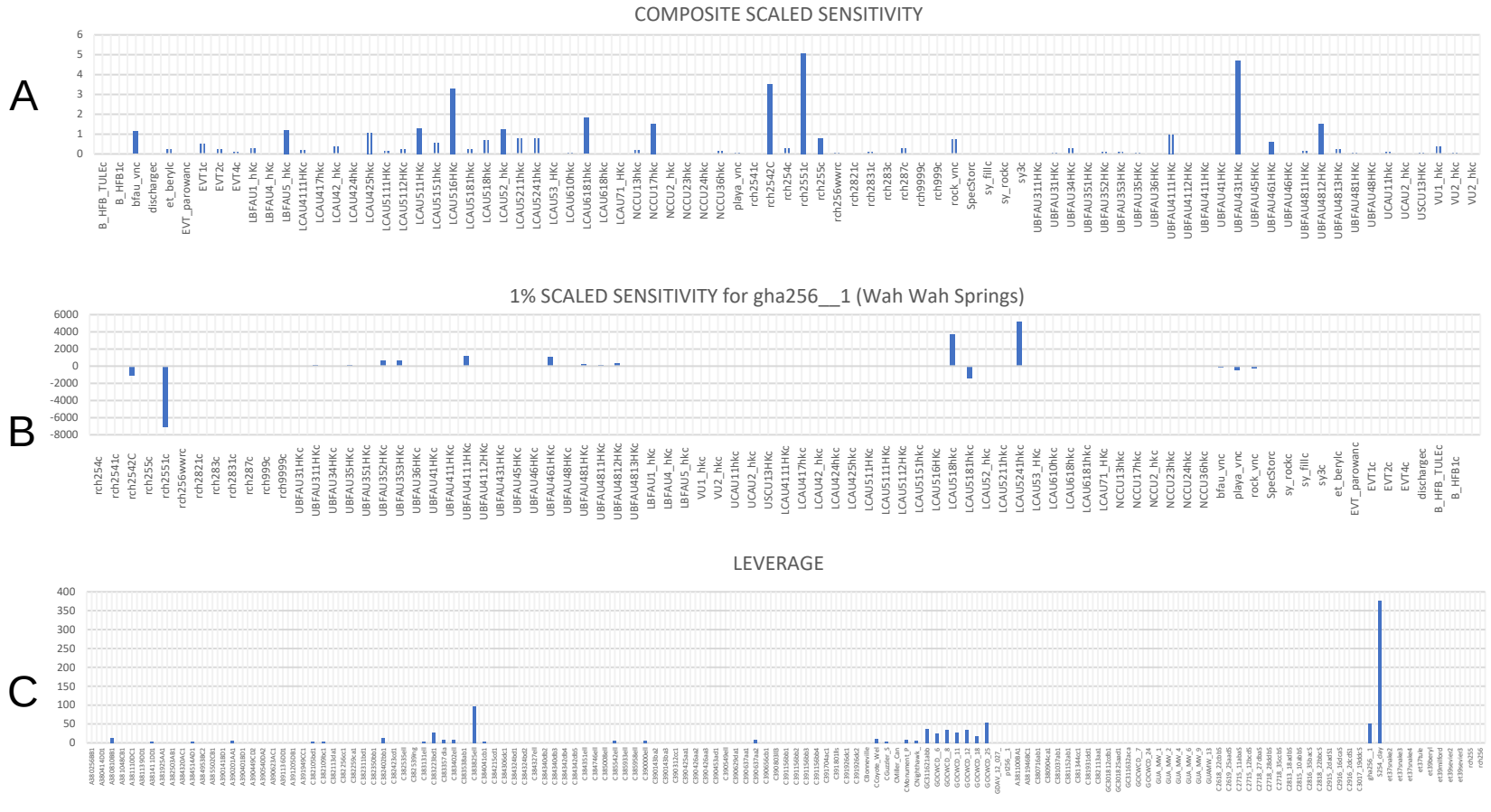
DATE: MAY 22, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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PINE VALLEY WATER SUPPLY PROJECT

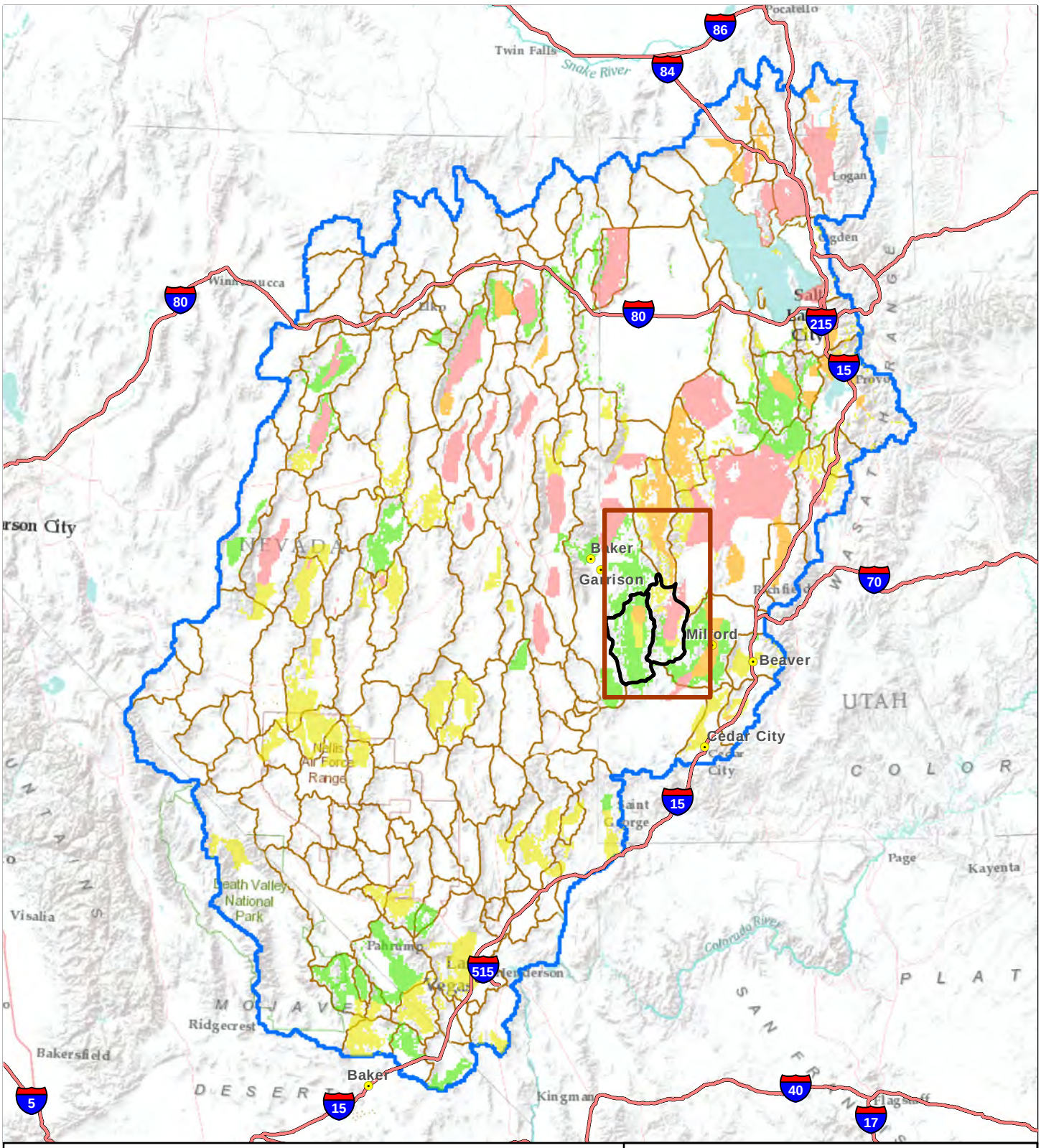
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-7

COMPOSITE AND 1% SCALED SENSITIVITIES AND LEVERAGE STATISTIC

DATE: JUNE 15, 2021	FORMATION ENVIRONMENTAL
BY:PHT	FOR: MT

"S:\GIS\A5\TRANSCON_PINEVALLEY\PLT\GRIA\APPX\FIG4_07_SENSITIVITY.PPTX"



Legend

- Interstates
- Hydrographic Area
- Focused Model Area
- GBCAAS Model Boundary

UBFAU Zones

- 31
- 35
- 41
- 48

0 25 50 Miles

N

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-8

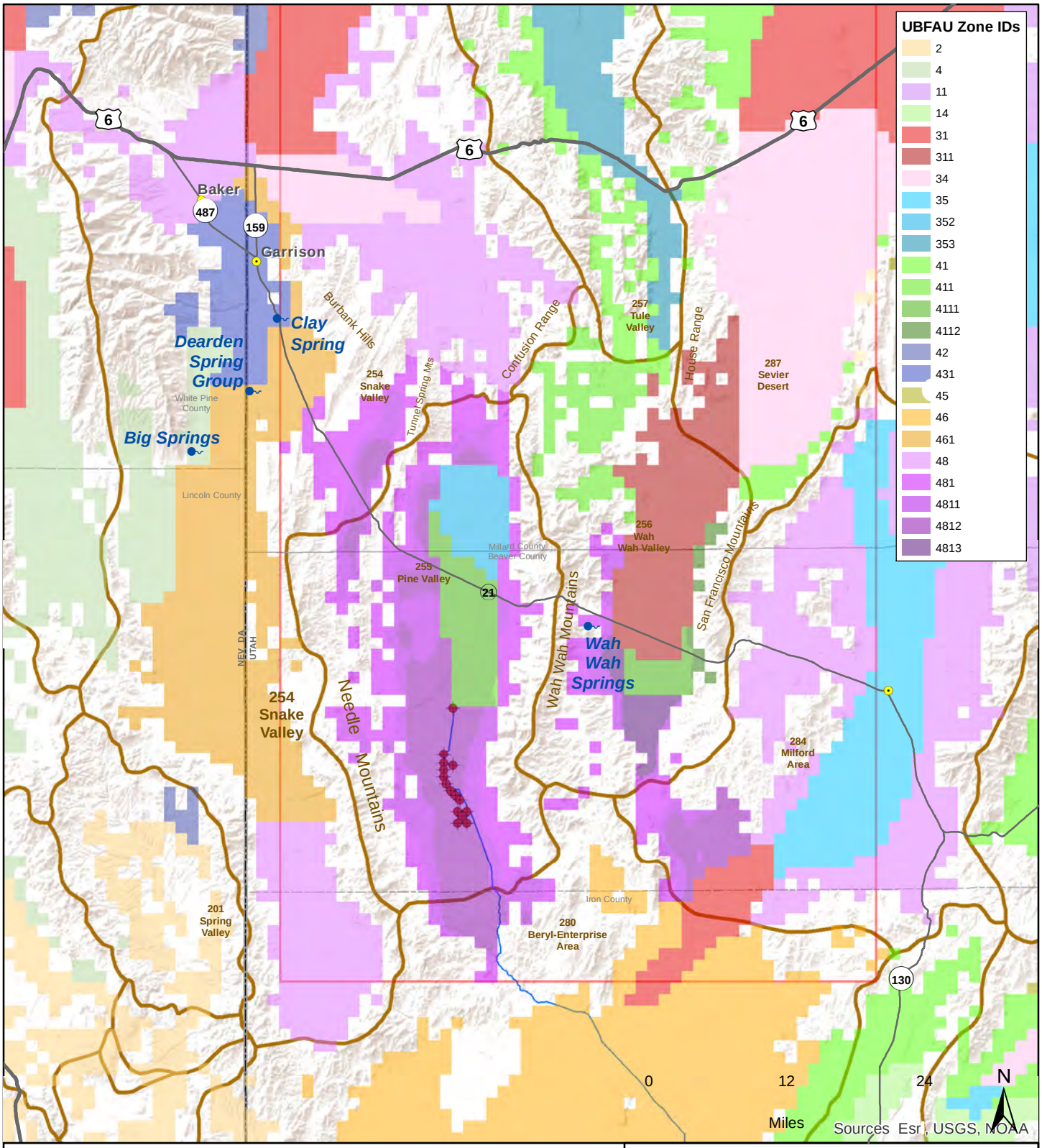
GBCAAS V. 3.0 UBFAU ZONES IN PINE VALLEY AND WAH WAH VALLEY

DATE: FEB 20, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Appx\Fig4_08_UBFAU_GBCAAS.mxd



Legend

- PVWS Project Well
- Regional Spring
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

from Brooks (2017)

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-9

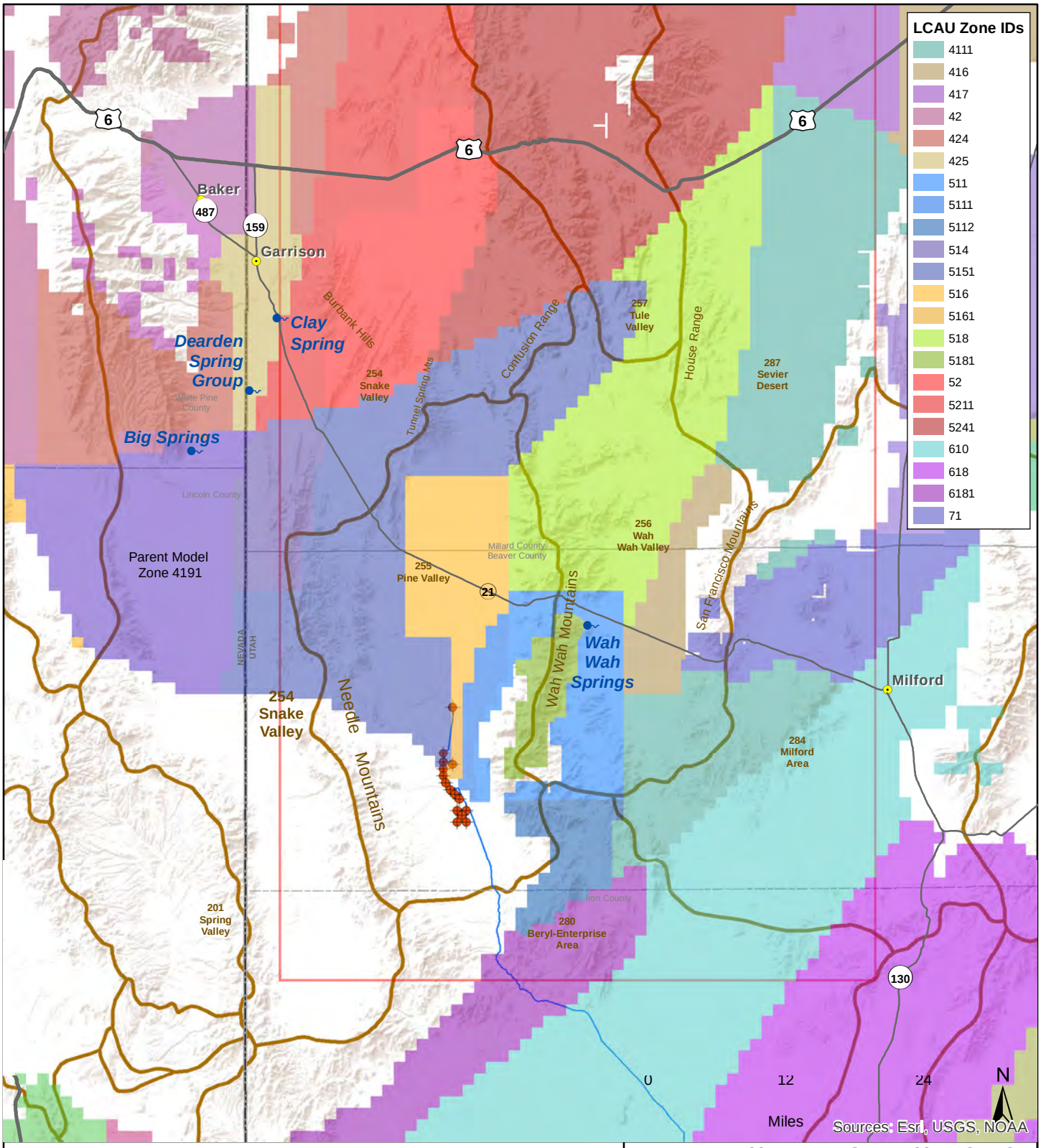
GBCAAS-PV
UBFAU ZONES

DATE: FEB 20, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Appx\Fig4_09_UBFAU_Zones.mxd



Legend

- PVWS Project Well
- Regional Spring
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

from Brooks (2017)

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-10

GBCAAS-PV LCAU ZONES

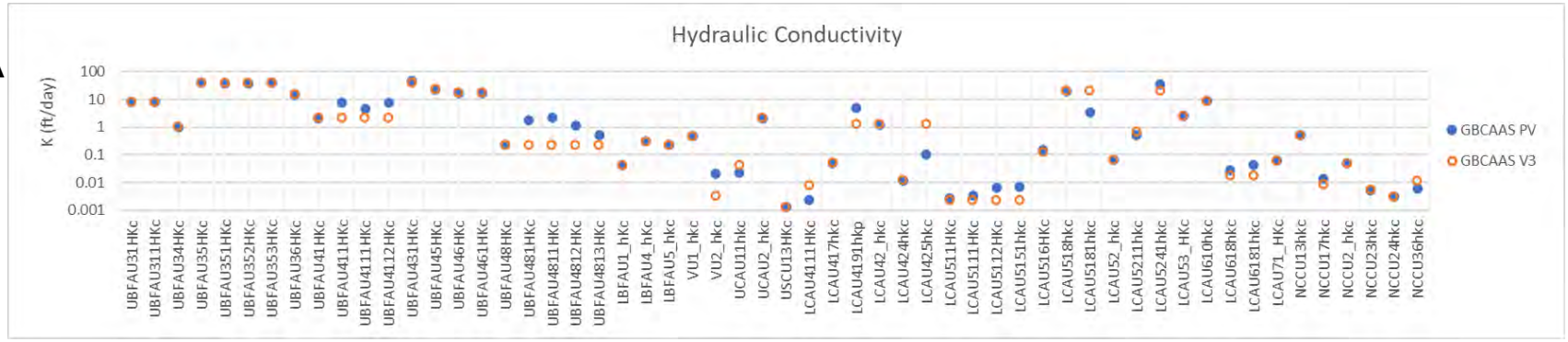
DATE: MAY 22, 2021

BY: CRL | FOR: PHT

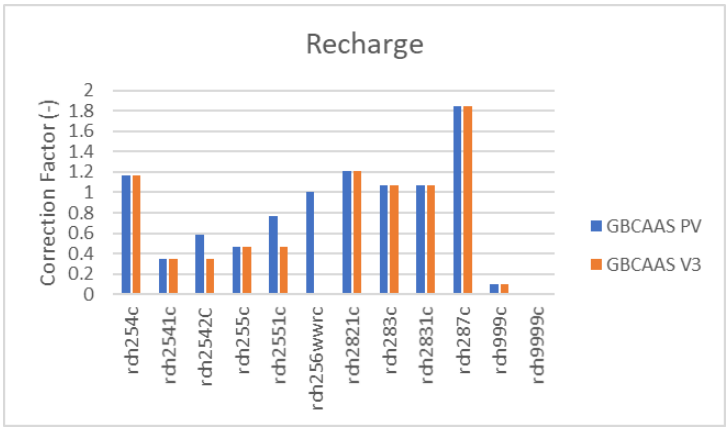
FORMATION ENVIRONMENTAL

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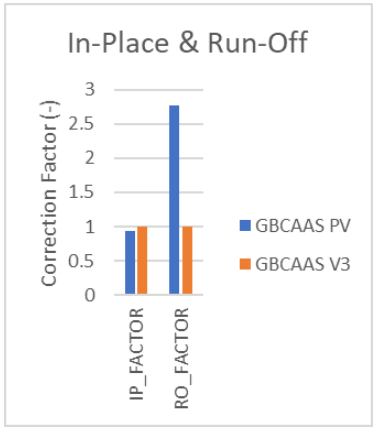
A



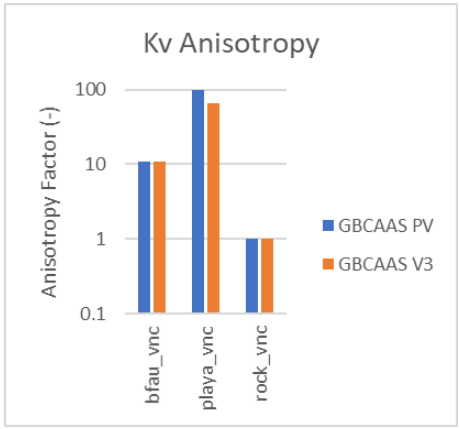
B



C



D



PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-11

FINAL MODEL PARAMETERS AND COMPARISON TO GBCAAS V. 3.0

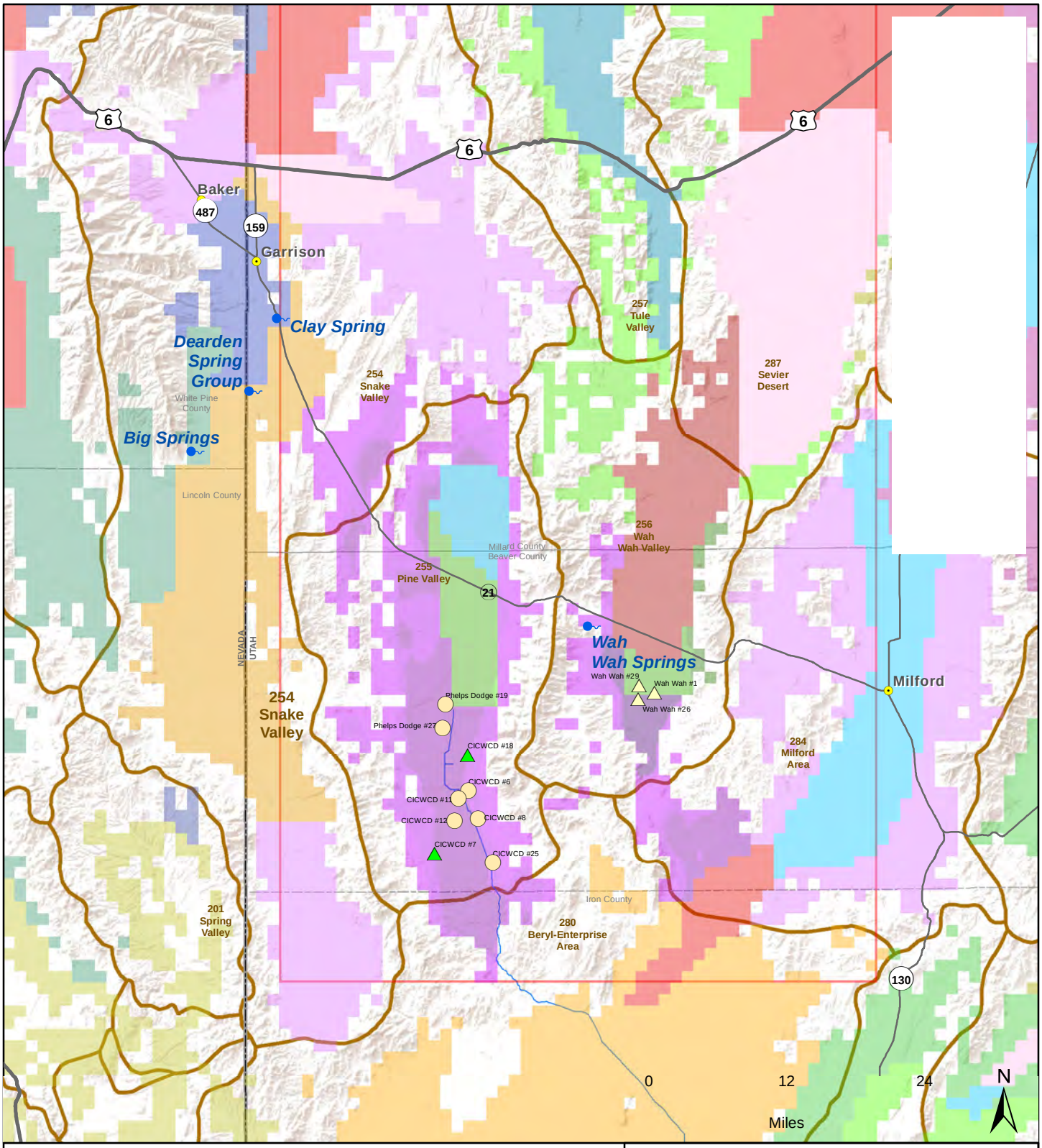
DATE: FEB 24, 2021

BY: CRL

FOR: PHT

FORMATION ENVIRONMENTAL

"S:\GIS\AS\TRANSCON_PINEVALLEY\PLT\GRI\AAPPX\FIG4_11_PARAMCOMPARE.PPTX"



Legend

- Regional Spring
- Hydrographic Area
- Project Pipeline Alignment
- US Route
- State Route

Pumping Test Locations

- basin-fill
- basin-fill / bedrock
- bedrock

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-12

PUMPING TEST LOCATIONS IN THE PINE AND WAH WAH VALLEY HAs

DATE: FEB 20, 2021

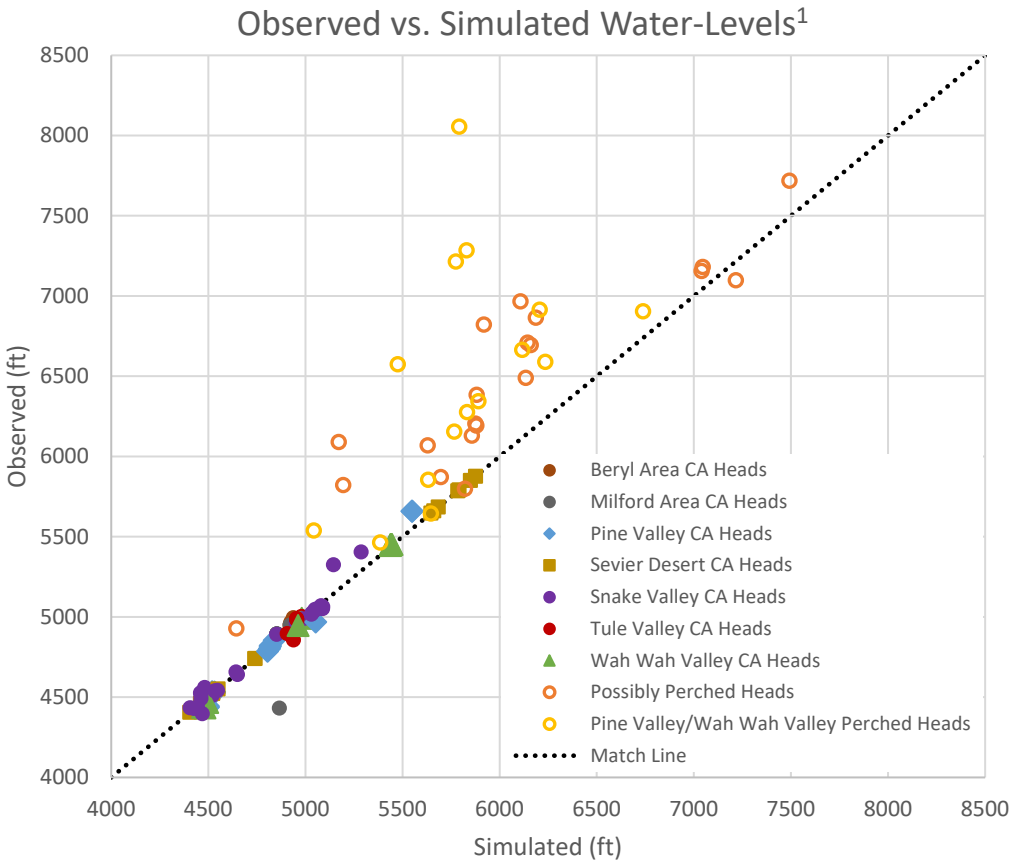
BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Appx\Fig4_12_UBF_PTest.mxd

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A



B

	GBCAAS v. 3.0[2]	GBCAAS-PV
Mean Error	1.64	2.33
Mean Absolute Error	38.08	37.24
Sum of Squared Residuals	408982.11	392028.94
Root Mean Square Error (RMSE)	69.37	65.28
Minimum Residual	-441.01	-435.99
Maximum Residual	262.42	179.66
Range of Observed Heads	1262.82	1477.56
RMSE / Range	5.5%	4.4%
Number of Observations	85	92

Notes:

[1] Referenced to the North American Vertical Datum of 1988 (NAVD 88).

[2] GBCAAS v. 3.0 head residuals in child model domain.

PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-13

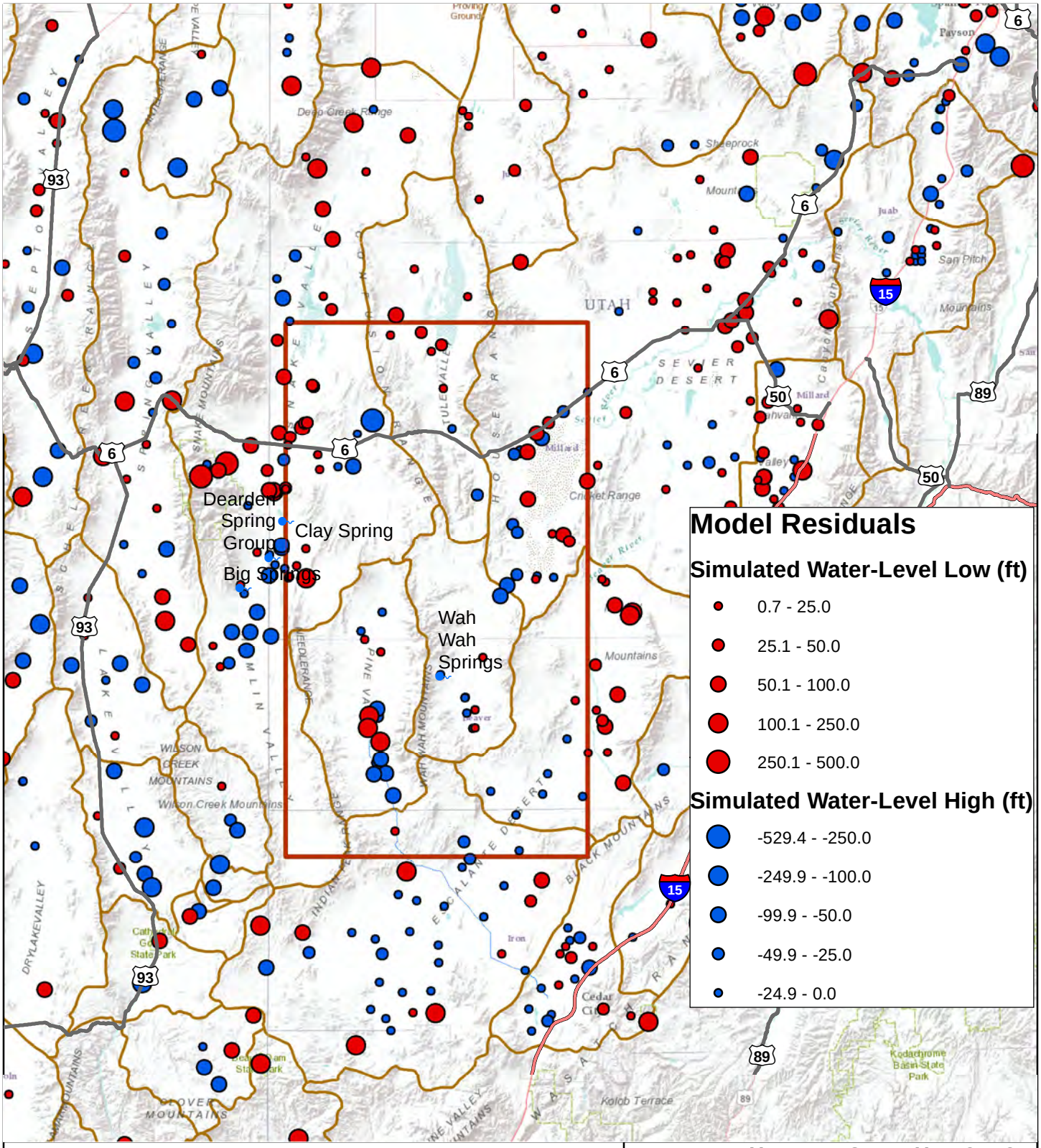
UNWEIGHTED WATER-LEVEL RESIDUALS IN GBCAAS-PV

DATE: JUNE 14, 2021

BY: PHT | FOR: MT

FORMATION ENVIRONMENTAL

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Appx\Fig4_13_UnweightedHeads.pptx



Legend

- Interstates
- US Route
- Hydrographic Area
- Focused Model Area

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

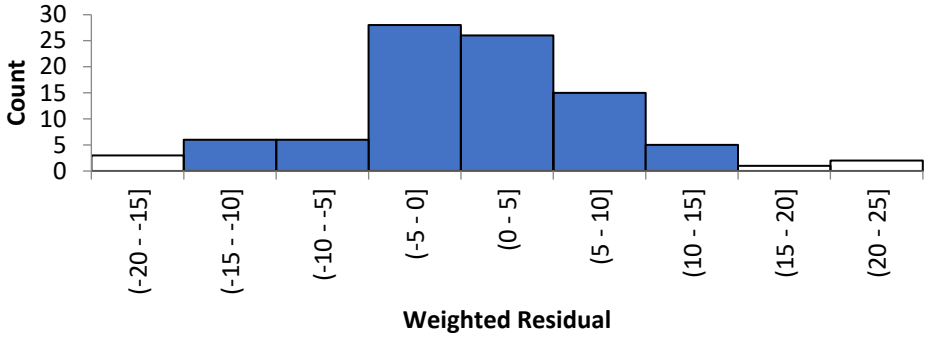
FIGURE A4-14

MAP OF UNWEIGHTED WATER-LEVEL RESIDUALS

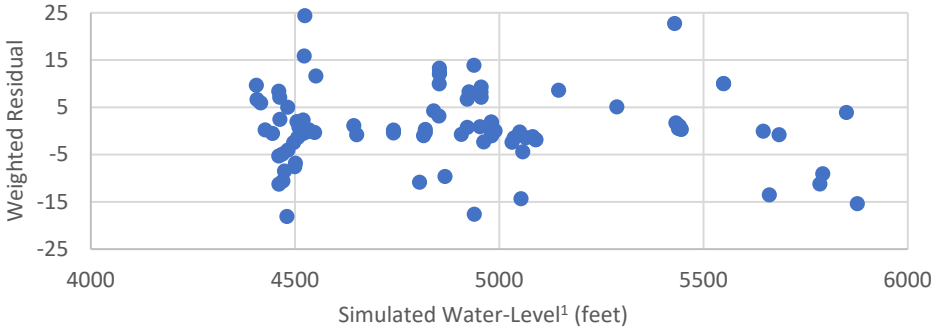
DATE: JUN 15, 2021	FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT

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A



B



C

	GBCAAS-PV
Mean Error	0.81
Mean Absolute Error	5.34
Sum of Square Weighted Residuals (SSWR)	5589.4
Minimum Residual	-18.11
Maximum Residual	24.36
Number of Observations (Nobs)	92
Standard Error of Regression (SSWR/Nobs)$^{1/2}$	7.72
Average standard deviation of observation error	10.3
Overall fit (10.9*7.7)	79.5 ft

Notes:

[1] Referenced to the North American Vertical Datum of 1988 (NAVD 88).

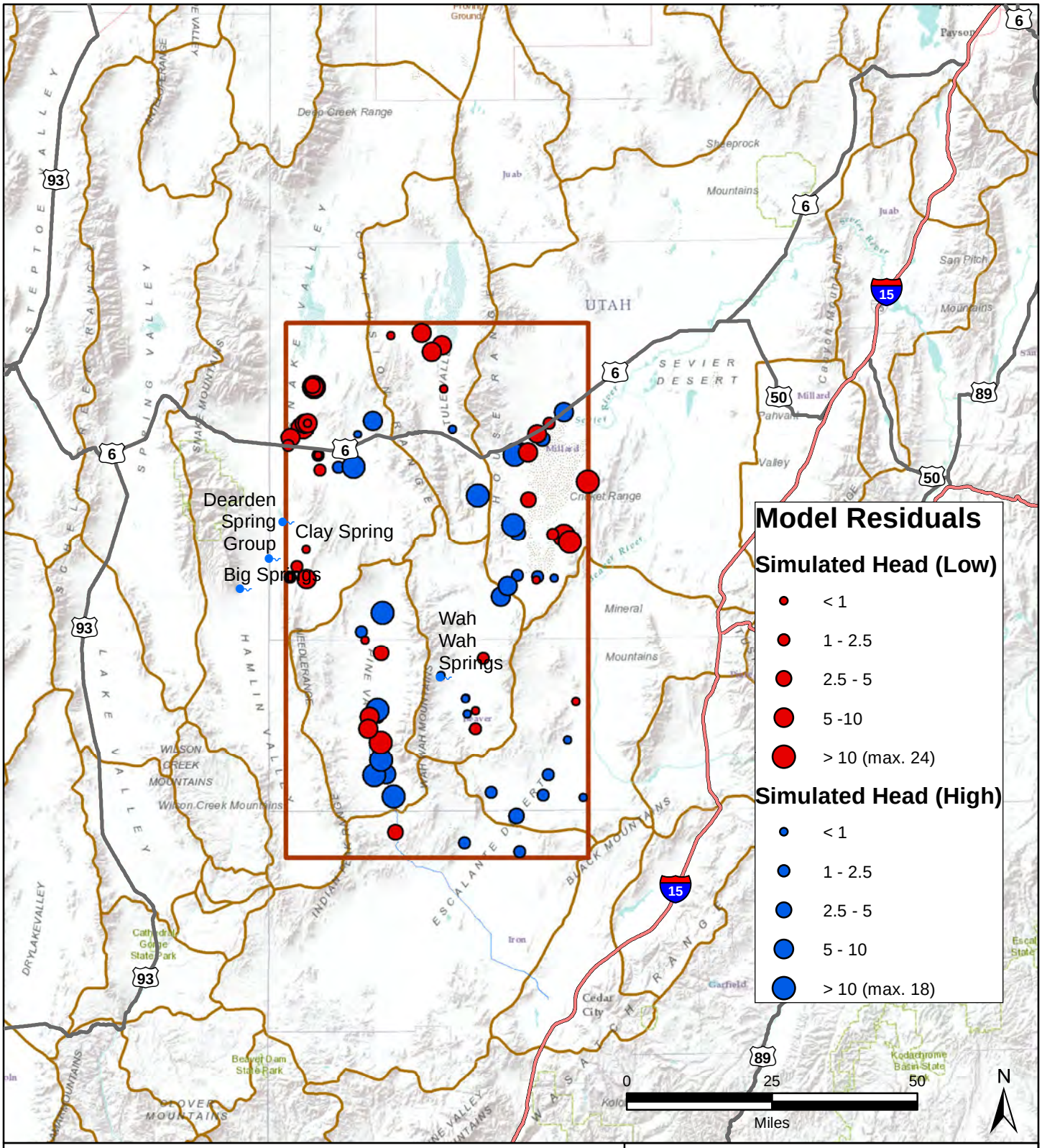
PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-15

WEIGHTED WATER-LEVEL RESIDUAL STATISTICS

DATE: JUNE 4, 2021
BY: PHT | FOR: MT

FORMATION ENVIRONMENTAL



Legend

- Interstates
- US Route
- Hydrographic Area
- Focused Model Area

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-16

MAP OF WEIGHTED WATER-LEVEL RESIDUALS

DATE: JUN 15, 2021	FORMATION ENVIRONMENTAL
BY: CRL	FOR: PHT

S:\GIS\a5\Transcon_PineValley\plt\GRIA\Appx\Fig4_16_MapWeightedHeads.mxd

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PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-17

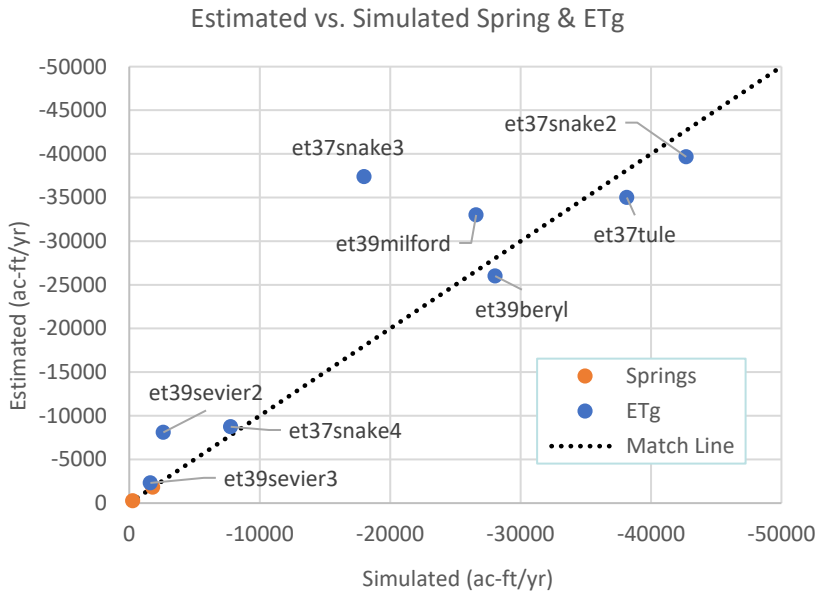
WEIGHTED AND UNWEIGHTED WATER-LEVEL RESIDUALS BY HYDROGRAPHIC AREA

DATE: JUNE 14, 2021	FORMATION ENVIRONMENTAL
BY: PHT	FOR: MT

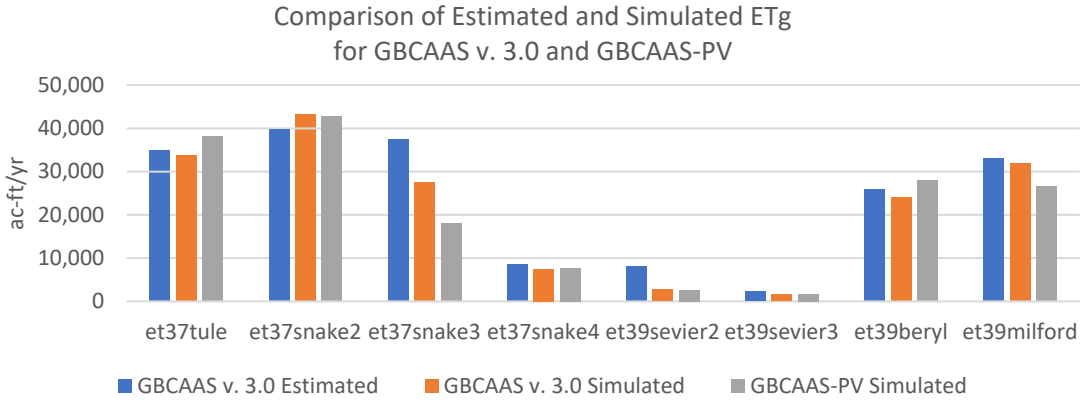
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A



B



C

	GBCAAS v. 3.0 Estimated Discharge (ac-ft/yr)	GBCAAS v. 3.0 Simulated Discharge (ac-ft/yr)	GBCAAS-PV Simulated Discharge (ac-ft/yr)
Total Discharge	190,200	172,500	165,494
Percent of GBCAAS v.3.0 Estimated		91%	87%
Percent of GBCAAS v.3.0 Simulated			96%

PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-18

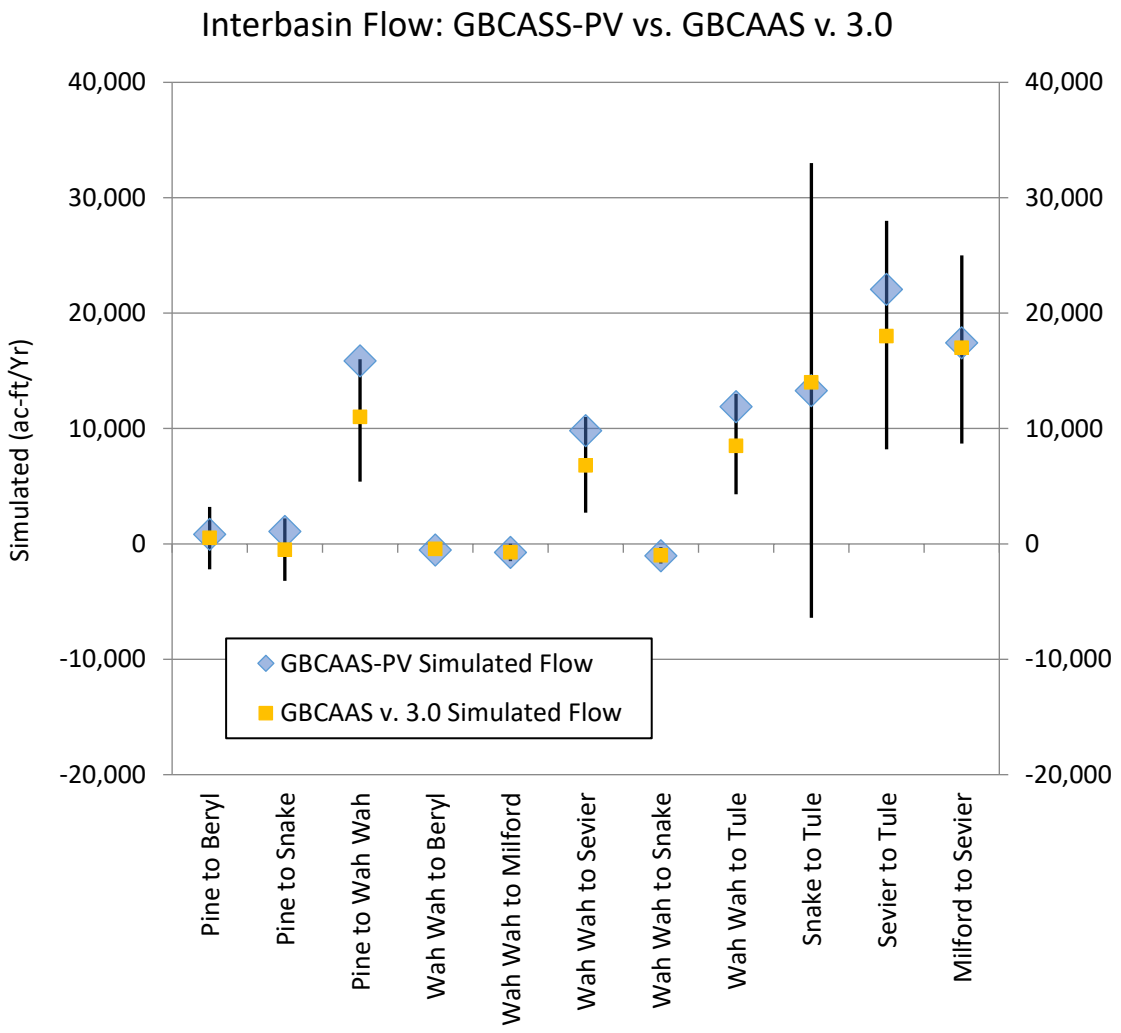
SIMULATED DISCHARGE IN GBCAAS-PV

DATE: FEB 24, 2021
BY: PHT
FOR: MT

FORMATION ENVIRONMENTAL

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Note:

Negative rate indicates opposite flow direction

Upper limit GBCAAS v. 3.0 (Brooks 2019, Table 9)

Lower limit GBCAAS v. 3.0 (Brooks 2019, Table 9)

PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A4-19

SIMULATED INTERBASIN FLOW In GBCAAS-PV

DATE: FEB 24, 2021

BY: PHT | FOR: MT

FORMATION ENVIRONMENTAL

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A5 MODEL PREDICTIONS

A5.1 PVWS PROJECT PUMPING

CICWCD proposes to install and operate a wellfield with 15 production wells in the Pine Valley HA to extract up to 15,000 AFY of groundwater. Under the Proposed Action, a production wellfield is proposed to be constructed in the southern portion of Pine Valley (Figure A1-2). Under the ANWS Alternative, nine production wells would be shifted farther to the north in Pine Valley (Figure A1-3). Each well is assumed to pump groundwater at an annualized average rate of approximately 1,000 AFY from the basin-fill alluvial aquifer from depths up to 1,500 feet bgs. Pumping for the Proposed Action and the ANWS Alternative terminates after 50 years, which is equal to the initial right-of-way grant plus one 20-year extension. Operation beyond this period is speculative, and CICWCD would need to submit a new right-of-way application and conduct an additional environmental review under NEPA in order to continue or resume pumping. Otherwise, the project would be decommissioned and any disturbed areas restored.

Because the proposed PVWS Project wellfield is located remote from the groundwater discharge areas associated with this groundwater flow system, the hydrogeologic effects induced by pumping for the Project would persist for a long period of time. For this reason, the modeling simulations include a 450-year recovery period after pumping ceases. This period covers the time needed for the lateral extent of drawdown to spread to its maximum extent (150 to 200 years), and for long-term recovery trends of interbasin flow, storage depletion, spring flow depletion and ETg depletion to be adequately assessed.

The prediction model assumes that water levels are at or near steady-state conditions when the well field is activated. This is a reasonable assumption since groundwater levels in Pine Valley are relatively stable. Thus, predicted drawdowns estimate the impacts to the GBCAAS system due to the PVWS Project pumping. Prediction models runs utilized the capabilities of MODFLOW LGR, which iteratively couples the parent model and child model, thereby balancing heads and fluxes across the shared boundaries. These dynamic boundary conditions allow PVWS Project impacts to also be evaluated in the parent model domain, outside the child model boundary and throughout the entire Study Area.

A5.1.1 MODEL STRESS PERIODS

The prediction models use four conceptual stress periods, including 1) a steady-state pre-project stress period, 2) a pre-project, long-term equilibrium stress period (LTEQ; 1,000 years), 3) a pumping stress period, and 4) a recovery stress period. Conceptual stress periods 1 and 2 were used for model calibration. Conceptual stress period 3 and 4 were used to simulate PVWS Project pumping and recovery following the pumping period. Twenty-one stress periods were used in MODFLOW-LGR. The additional stress periods did not reflect stress changes but allowed some flexibility in model design.

Normally initial heads would be defined from the calibrated model and the first two stress periods would not be needed. However, an issue with the version of MODFLOW LGR developed by the USGS for GBCAAS v. 3.0 did not permit a restart from a prior model. As a work-around, the steady-state and LTEQ stress periods were simulated for each model prediction. After confirmation of the existence of the issue with

USGS staff, further investigation into the cause of the problem was not considered in the scope of this analysis and not pursued.

One-year time steps were used for PVWS Project pumping. This assumption is consistent with the transient portion of the GBCAAS v. 3.0 model.

A5.1.2 RECHARGE

Recharge was constant during the entire model run. See Sections A4.4.1 and A4.8 for a description of recharge.

A5.1.3 WELLS

The MODFLOW MNW2 (multi-node well) (Konikow *et al.* 2009) package was used to simulate the production wells. All wells were set to pump 1,000 AFY for a total of 15,000 AFY for PVWS Project alternative pumping scenarios. All wells were assumed to be 6-inch diameter wells, fully screened and completed to a depth of 1,500 feet from the ground surface. The 6-inch diameter assumption is consistent with the CICWCD's current test wells. However, the production wells will likely be at least 14-inch diameter. Thus, simulated near-well drawdown is conservatively estimated with a smaller diameter assumption because a smaller diameter well would induce a steeper cone of depression near the well.

The MNW2 takes as input the desired withdrawal rate, and the option to limit that withdrawal rate if the head at the well drops below a specified value. To simulate drawdowns that might more realistically occur during actual well operation (Masbruch 2019), the following pumping rules were used to simulate withdrawals from the PVWS wells: (1) Extraction would be constrained such that the drawdown in any PVWS pumping well would not fall below 10% (150 feet) of the bottom of the well; and (2) If this threshold is reached, pumping would stop until drawdown has recovered to 20% (300 feet) from the bottom of the well. For all prediction scenarios, the 15,000 AFY pumping rate was sustained without reaching this limitation in any of the pumping wells.

A5.1.4 STORAGE PARAMETERS

Transient calibration of GBCAAS v. 3.0 was limited to Parowan Valley and storage parameters outside Parowan Valley are considered uncalibrated (Brooks 2017). The GBCAAS-PV model was calibrated to steady-state conditions. Therefore, simulated storage properties in Pine Valley and Wah Wah Valley are not considered calibrated. Consistent with GBCAAS v. 3.0 in areas outside Parowan Valley, the values of specific yield of 0.074 for basin fill and 0.01 for rock, and the value of specific storage for all units of 1.2×10^{-7} (see Brooks et al. 2017, Table 2-9) were assumed in prediction simulations. These values are consistent with the calibrated parameters in the transient numerical model of the Death Valley regional groundwater flow system (Faunt *et al.* 2010, Table F-13). Sweetkind *et al.* (2011, p. 16) indicate that the units in the Death Valley regional groundwater system can be used to represent the GBCAAS study area (Brooks 2017).

A5.1.5 PROPOSED ACTION AND ANWS ALTERNATIVE RESULTS

Refer to section 4.2 of the GRIA for a detailed description of simulation results for the Proposed Action and ANWS Alternatives. GRIA figures illustrating prediction results for the Proposed Action include:

- Figure 4-1. Simulated Drawdown and Recovery for Proposed Action
- Figure 4-3. Proposed Action and ANWS Alternative Effects on Inter-Basin Flows
- Figure 4-4. Proposed Action and ANWS Alternative Effects on Discharge
- Figure 4-5. Changes in Interbasin Flow Under Proposed Action
- Figure 4-6. Estimated Changes in Interstate Groundwater Flows
- Figure 4-8. Existing Wells in the Predicted Drawdown Areas (>15ft) for Proposed Action
- Figure 4-10. Regional and Local Springs in Predicted Drawdown Areas (>1ft) for Proposed Action
- Figure 4-11. Spring Flow Depletion Effects of Pumping for Proposed Action
- Figure 4-14. ETg Discharge Effects of Pumping for Proposed Action.

GRIA figures illustrating prediction results for the ANWS Alternative include:

- Figure 4-2. Simulated Drawdown and Recovery for ANWS Alternative
- Figure 4-3. Proposed Action and ANWS Alternative Effects on Inter-Basin Flows
- Figure 4-4. Proposed Action and ANWS Alternative Effects on Discharge
- Figure 4-6. Estimated Changes in Interstate Groundwater Flows
- Figure 4-7. Changes in Interbasin Flow Under ANWS Alternative
- Figure 4-9. Existing Wells in the Predicted Drawdown Areas (>15ft) for ANWS Alternative
- Figure 4-12. Regional and Local Springs in Predicted Drawdown Areas (>1ft) for ANWS Alternative
- Figure 4-13. Spring Flow Depletion Effects of Pumping for ANWS Alternative
- Figure 4-15. ETg Discharge Effects of Pumping for ANWS Alternative.

A5.2 STARTUP PUMPING

As discussed in Section 3 of the GRIA, the southern portion of the Pine Valley HA is underlain at depth by volcanic bedrock. Gravity data and geologic mapping suggests the presence of several caldera complexes in the volcanic basement rocks beneath the valley alluvial basin fill. Historical groundwater levels recorded in wells in this area show a relatively steep gradient across parts of Pine Valley, suggesting the possible presence of a flow-impeding structure in this area (GRIA Figure 3-14). The presence of such a structure, and its effect if present, cannot be assessed based on the existing data, and is best verified by monitoring during significant aquifer stresses, such as will be imposed by the proposed pumping for the PVWS Project. The effect of a flow impedance or barrier north of all or part the proposed wellfield would be to increase drawdown to the south above that predicted by the GBCAAS-PV model, potentially increasing impacts to the Beryl-Enterprise Area HA.

To avoid or minimize drawdown impacts to the south beyond those predicted by the GBCAAS-PV model, an adaptive management program will be implemented as discussed in section A1.3 of this appendix and Sections 2 and 6 of the GRIA Report. As part of this program, six startup production wells (see GRIA Figure 2-3 and Figure A1-3) will be constructed and pumped for a period of at least three months. This is the minimum amount of time judged to be needed to detect boundary effects in the southern portion of Pine Valley; however, CICWCD may continue pumping the first six wells for up to two years to gather additional data prior to making a decision whether to complete the remaining wells at their northern alternative locations. Four wellfield monitoring wells (one existing well and three new wells) will be used to monitor the drawdown response in the aquifer during this initial wellfield operation period.

The drawdown response to startup pumping at the wellfield monitoring wells was simulated using the GBCAAS-PV model. Simulation of the startup wells was consistent with methods described in section A4.4.2. However, stress periods were revised to a monthly schedule. Based on the revised calibration and assumed storage properties, simulated drawdowns at the four proposed monitoring wells range approximately 5 ft to 15 ft after a 3-month period (0.25 years) and 10 ft to 24 ft after a one-year period (see Figure A5-1).

A5.3 CUMULATIVE EFFECTS ANALYSIS

Section 4.3 of the GRIA describes the potential cumulative effects of the proposed PVWS Project and other historical, ongoing, and reasonably foreseeable groundwater extraction in nearby HAs in the Study Area. The rationale for the amount of groundwater pumping included in the cumulative effects analysis is described below for the Sevier Desert, Snake Valley, and Beryl-Enterprise Area HAs. Pumping locations for these additional areas is illustrated in Figure A5-2.

Cumulative pumping was simulated using the GBCAAS-PV model for PVWS Project pumping in the Pine Valley HA (see section A5.1) and the southern Sevier Desert HA. To simulate cumulative pumping in the Snake Valley HA and the Beryl Enterprise Area HA, a recently updated version of the GBCAAS v. 3.0 model with refinements focused on Snake Valley (Masbruch 2019) was utilized. Masbruch (2019) evaluated the long-term effects of pumping in Snake Valley and, as such, this model was assumed to represent the most refined modeling tool available to evaluate the effects of cumulative pumping in that area.

Pumping drawdown from multiple sources was considered additive, and drawdown predicted by these models at any point was summed to produce the cumulative drawdown analysis. These analyses were conducted using a 50-year pumping period (30 years in the case of the Crystal Peak Minerals Project in Sevier Desert) and a 200-year recovery period to match the 50-year pumping period evaluated for the Project. Given the potential long-term effects of agricultural pumping in Snake Valley, longer-term simulation was considered speculative. Similarly, simulation of longer-term pumping in the northern Beryl-Enterprise Area HA would be speculative and would be inconsistent with the retirement of six of the associated water rights prior to this time. Pumping for the Crystal Peak Minerals Project is simulated consistent with the right-of-way grant for that project, which is 30 years.

A5.3.1 SEVIER DESERT

The Crystal Peak Minerals (CPM) Sevier Playa Potash Project (CPM Project) was simulated in the GBCAAS-PV model using pumping assumptions consistent with Whetstone and ENValue (2019, Figure 1, Appendix A, and pg 65), including:

- 1,500 AFY combined total pumping rate;
- 4 wells (pumping at a rate of 44,722.8 cubic feet per day per well);
- Well depths to approximately 1,500 feet.

The simulation consisted of 30 years of pumping and 200 years of recovery. Results are discussed in Section 4.3 of the GRIA.

A5.3.2 SNAKE VALLEY

To estimate current groundwater pumping in the Snake Valley HA, the analysis performed by Southern Nevada Water Authority (see GRIA section 3.9.5) was updated using the following approach:

- Areas under agricultural land use were identified from satellite imagery and actual ET (ETa) distribution maps developed for 2004 through 2015 and extrapolated to the present time based on historical land use trends.
- The average ETa on agricultural land was estimated for the period of 2004-2015.
- The average ETa rate was adjusted using an average precipitation rate of 6 in/yr to reflect irrigation demand.
- For crop areas where only groundwater irrigation is assumed to occur (based on place-of-use data from Nevada DWR and Utah DWR) the area of the irrigated cropland was multiplied by the long-term adjusted average ETa rate for irrigated land in the valley.
- For crop areas where both surface water and groundwater were used conjunctively (based on place-of-use data from Nevada DWR and Utah DWR), the area of irrigated cropland was multiplied by the long-term average ETa rate and a factor of 0.5 to reflect the intermittent use of supplemental water.

Based on this analysis approach, the total estimated groundwater pumping for agricultural irrigation under current conditions is estimated to be 28,655 AFY. The actual amount of pumping may vary from year to year based on climatic conditions and actual cropping patterns.

Masbruch (2019) performed a study to assess long-term groundwater level effects if all available groundwater rights in the Utah and Nevada portions of Snake Valley HA were to be exercised. The study considered potential pumping associated with all approved, perfected, certified, permitted, and vested (Allocated and Unallocated) groundwater rights in Snake Valley HA, which were determined to comprise about 55,272 AFY as of February 2018.

Available online water-right data for Snake Valley from Utah DWR (accessed 7/27/2020) and Nevada DWR (accessed 9/14/2020) were updated; the total water rights falling into the above categories were approximately 53,383 AFY. The small difference was the result of new permitted applications and cancelled (or terminated) applications since 2018. Approximately 41,927 AFY of this total comprised perfected or certificated water rights. It is important to note that current pumping represents about 68 percent of these water rights, and it appears unlikely they will ever be fully exercised. The rate at which irrigated acreage has been added in the basin has decreased significantly since 2000 (BLM 2012). Thus, in the absence of projections that would indicate planned or anticipated agricultural expansion in the Snake Valley HA, it is assumed that groundwater demand will remain relatively constant at current levels.

Masbrauch (2019) used the parent model of GBCAAS v. 3.0 (Brooks 2017) and converted the model to run with MODFLOW-2005. The MODFLOW-2005 Well Package for Masbruch's Scenario B provided the basis for the pumping locations, well-screen interval assumptions, and relative pumping rates assumed for this cumulative effects analysis (see Masbruch 2019, pg. 29). The rates specified in the Scenario B Well file was scaled by the factor 28,655/55,272 (current pumping/total water rights) to approximate the distribution of groundwater pumping for current conditions.

For this analysis, it was assumed that 2020 extraction rates are held constant throughout the 50-year simulation period, but it is possible that future extraction rates will change to adapt to information from future studies regarding the long-term sustainability of groundwater supplies in the region. Thus, although groundwater pumping in the surrounding HAs is expected to persist for longer than 50 years, simulation of a specific extraction rate beyond this time frame was considered speculative.

The assumed long-term pumping rate does not account for the net effect of groundwater recharge from the deep percolation of applied irrigation and assumes that all historically cultivated agricultural parcels will be irrigated every year. Total simulation time includes 50 years of pumping and 200 years of recovery. Results are discussed in Section 4.3 of the GRIA.

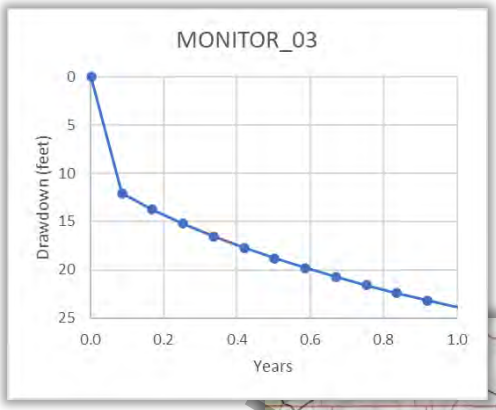
A5.3.3 BERYL-ENTERPRISE AREA

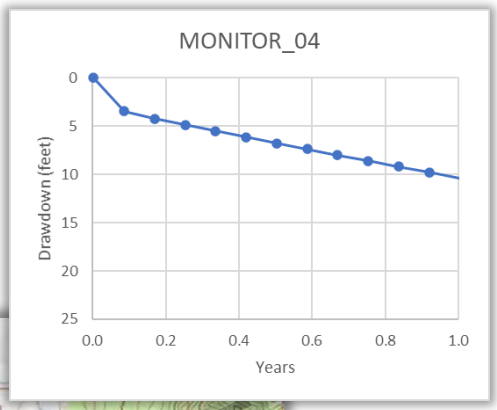
Published hydrographs for wells in the Beryl-Enterprise Area HA from USGS National Water Information System (NWIS) show that groundwater levels south of the APE of the Proposed Action and ANWS Alternative, have been declining since the 1940s. Drawdown induced by the Proposed Action after 50 years of pumping may add about a foot to the drawdown at the northern fringe of this cone of depression, about 6 miles south of the Pine Valley HA, but the two cones of depression do not intersect significantly.

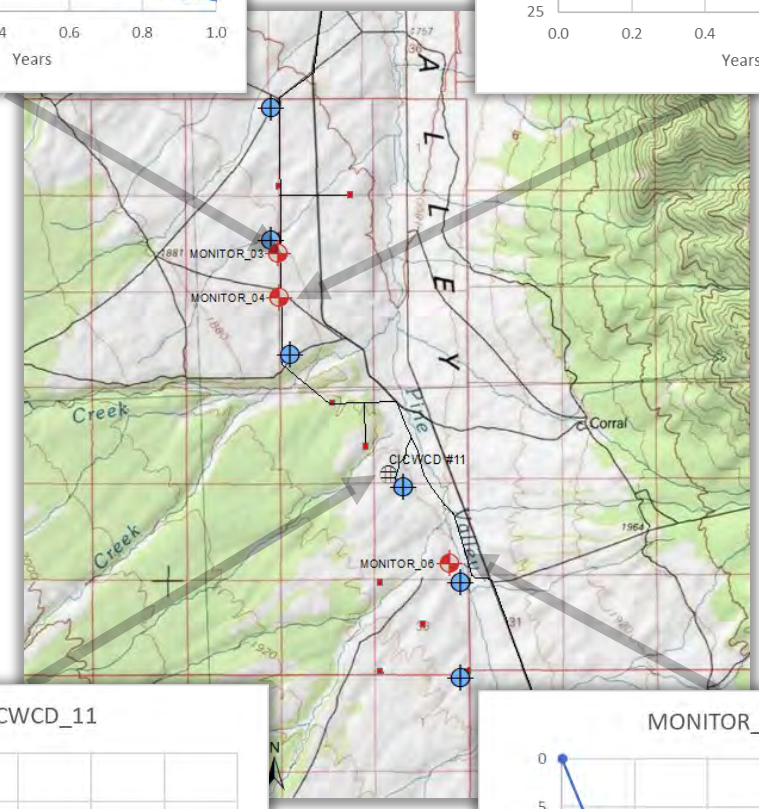
To estimate current groundwater pumping in the Beryl-Enterprise Area HA, perfected underground PODs from Utah DWR (accessed 7/27/2020) that are located within the APE for the Proposed Action or ANWS Alternative (see GRIA Figure 3-1) were selected and assumed to be pumping at their maximum permitted rates as a conservative assumption. The MODFLOW-2005 Well Package (Harbaugh, 2005) was used to simulate groundwater withdrawals. Data required for the Well Package are the withdrawal rates and model cell(s). Assignment of withdrawal rates to model cells followed the procedures in Masbruch (2019, pg. 29).

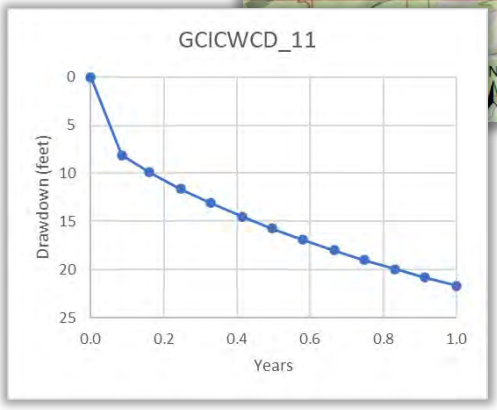
The total volume of the perfected water rights within the APE for the Proposed Action or ANWS Alternative is 1,396 AFY. Ten of these water rights are scheduled to be retired under the GMP. For consistency with the simulation of groundwater extraction in the Snake Valley HA, pumping was simulated for a period of 50 years; six water rights will retire prior to the end of the simulation period. Attachment 2 lists the Beryl-Enterprise Area PODs simulated in the cumulative analysis and GWMP retirement date, if applicable.

The assumed long-term pumping rate does not account for the net effect of groundwater recharge from the deep percolation of applied irrigation. Total simulation time includes 50 years of pumping and 200 years of recovery. Results are discussed in Section 4.3 of the GRIA.











Legend

- Proposed startup monitoring well
- CICWCD startup monitoring well (existing)
- Startup pumping well
- Hydrographic Area
- Project Alignment
- CICWCD well parcel

PINE VALLEY WATER SUPPLY PROJECT
GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A5-1

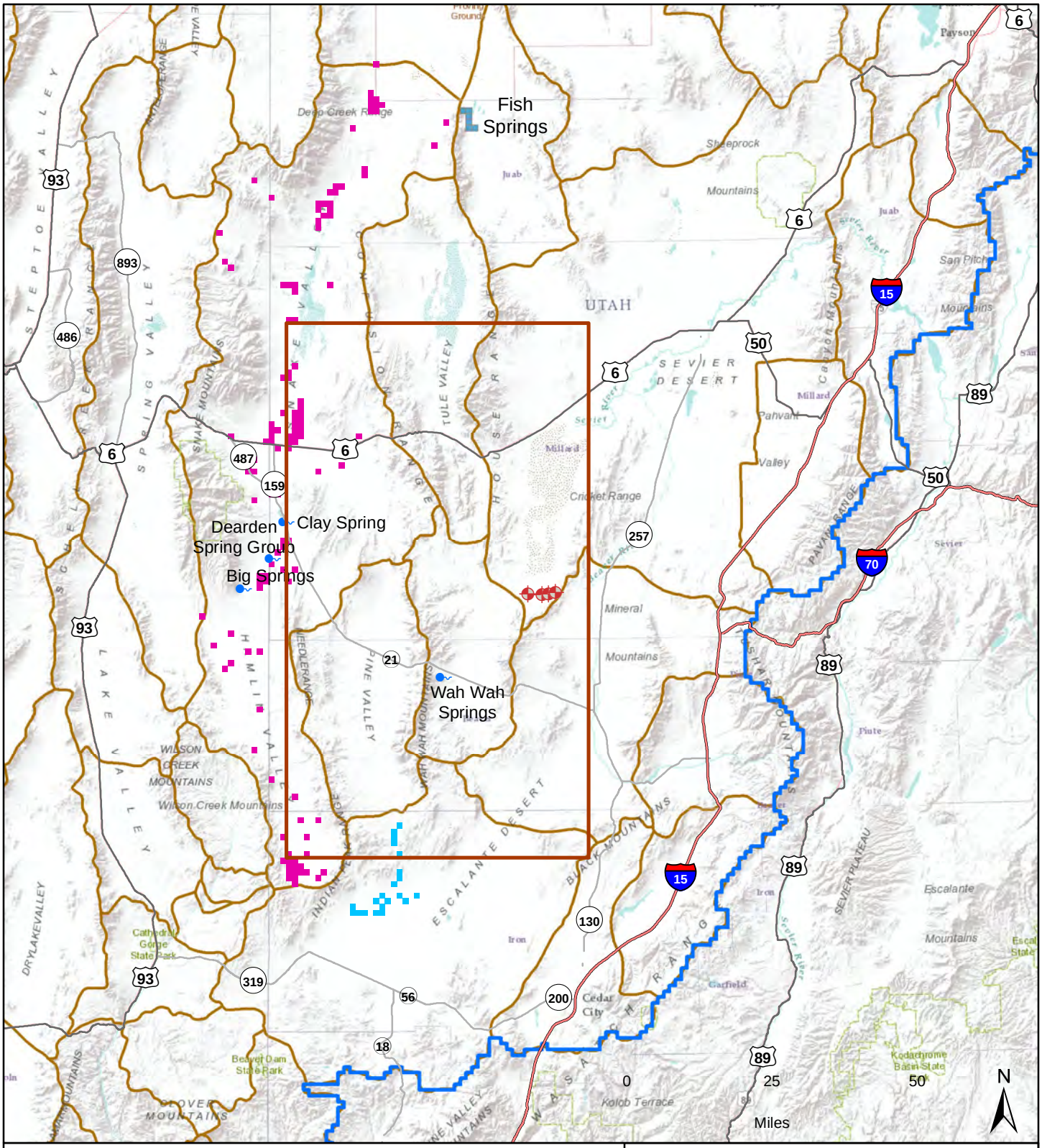
SIMULATED DRAWDOWN AT PROPOSED WELLFIELD MONITORING WELLS

DATE: MAY 22, 2021

BY: PHT | FOR: MT

FORMATION ENVIRONMENTAL

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Legend

- Interstates
- US Route
- State Route
- Hydrographic Area
- Focused Model Area
- GBCAAS Model Boundary
- CPM Project Wells
- Regional Spring
- Snake Valley Wells
- Beryl-Enterprise Area Wells

PINE VALLEY WATER SUPPLY PROJECT

GROUNDWATER RESOURCES IMPACT ASSESSMENT

FIGURE A5-2

ADDITIONAL PUMPING WELLS IN CUMULATIVE EFFECTS ANALYSIS

DATE: FEB 20, 2021

BY: CRL | FOR: PHT

FORMATION ENVIRONMENTAL

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A6 SUMMARY

This appendix documents the development of the GBCAAS-PV model. The GBCAAS-PV model was developed to support the assessment of groundwater resources-related impacts that could result from implementation of the PVWS Project. Discussion of analyses supporting groundwater resources-related impacts are described in the GRIA Report, including pumping effects associated with the Proposed Action and the ANWS Alternative, the development of monitoring strategies, the development of measures that could minimize or avoid Project impacts, and development of mitigation measures when potentially significant impacts cannot be completely avoided.

The selected model used for these analyses is a locally refined version of GBCAAS v. 3.0 (Brooks 2017). GBCAAS v. 3.0 was developed with MODFLOW-LGR, which supports local grid refinement within a larger regional model. The local grid refinement approach allows the simulation of the large regional groundwater system with added details of recharge, discharge, and aquifer properties within the Project study area. MODFLOW-LGR allows one or more, higher resolution, local grids (child models) within the coarser grid (parent model) by iteratively coupling separate MODFLOW-2005 models, thereby balancing heads and fluxes across the shared boundaries. The focus of the GBCAAS-PV child model is around Pine Valley and Wah Wah Valley. The extent of the child model was chosen to incorporate drawdown from Project pumping and key discharge areas potentially influenced by Project effects, including Wah Wah Springs, and groundwater discharge areas around Sevier Lake and in Tule Valley.

Multiple refinements were incorporated in the GPCAAS-PV model, including a finer grid spacing, revised estimates of aquifer properties, and revised groundwater budgets for the Pine Valley and Wah Wah Valley HAs. The revised groundwater budgets included updated recharge estimates in Pine Valley and Wah Wah Valley of 17,700 AFY and 5,160 AFY, respectively. The model was calibrated to reasonable base conditions, particularly in Pine Valley and Wah Wah Valley, so changes to groundwater level, flow, storage, spring discharge and ETg area discharge in the carbonate and alluvial aquifer system in response to proposed water supply pumping in Pine Valley by the PVWS Project could be more accurately evaluated. Evaluation of the GBCAAS-PV model performance indicates it provides a reasonable representation of the groundwater system.

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ATTACHMENT A1 – WELL DATA, WATER-LEVEL OBSERVATIONS, AND UNCERTAINTY IN THE GBCAAS-PV MODEL

OBSNAM	GWSI	HA #	Source	Period of record used for observation	Accuracy of altitude	Estimated water-level gradient	Variance caused by water-level error	Variance caused by location error	Variance caused by altitude error	Variance caused by discretization	Variance caused by depth of well	Decluster Weight[6]	Variance used in model files	Well Depth	NAVD88 Well Elevation	NADV88 Water Level
					feet	%	feet^2	feet^2	feet^2	feet^2	feet^2		feet^2	feet	feet	feet
GC301812cdb1	381236113485601	255	Gardener[1]	7/23/2014	20	5.47%						1.150	885		7194.3	7155.3
GC311621abb	NA	280	Gardener[1]	2/10/2004	10	0.40%	1				1	1.150		300	6053.93	5873.93
GC311632aca	NA	280	Gardener[1]	7/8/2008	10	1.93%	1				1	1.150		217	5983.87	5798.87
GCICWCD__6	NA	255	Gardener[1]	11/7/2016	10	0.40%	1				1	1.150		1000	6092.08	5578.08
GCICWCD__8	NA	255	Gardener[1]	11/2/2016	10	0.40%	1				1	1.150		1000	6204.04	5736.04
GCICWCD_11	NA	255	Gardener[1]	11/11/2016	10	0.40%	1				1	1.150		1000	6084.02	5680.02
GCICWCD_12	NA	255	Gardener[1]	1/24/2017	10	0.40%	1				1	1.150		1000	6224.05	5716.05
GCICWCD_18	NA	255	Gardener[1]	11/2/2016	10	0.40%	1				1	1.150		880	5988.07	5569.07
GCICWCD_24	NA	255	Gardener[1]	2/9/2017	10	8.64%	1				1	1.150		0	6431.06	6821.06
GCICWCD_25	NA	255	Gardener[1]	10/29/2016	10	0.40%	1				1	1.150		1000	6294	5782
GDAV_12_027_	NA	287	Gardener[1]	5/20/2013	10	0.53%	1				1	1.150		380	4545.93	4497.93
GUA_MW_1	NA	280	Gardener[1]	10/6/2012	10	5.25%	1				1	1.150		145	7004.24	6966.24
GUA_MW_2	NA	256	Gardener[1]	10/4/2012	10	5.57%	1				1	1.150		170	6654.06	6489.06
GUA_MW_4	NA	280	Gardener[1]	10/5/2012	10	3.99%	1				1	1.150		255	6849.2	6709.2
GUA_MW_6	NA	280	Gardener[1]	8/8/2013	10	3.54%	1				1	1.150		300	6904.16	6864.16
GUA_MW_9	NA	256	Gardener[1]	8/8/2013	10	5.87%	1				1	1.150		61	6724.12	6694.12
A380256BB1	380256113150401	280	GBCAAS v.1.0[2]	1940 to 1959	3		0.51					1.150			5130.58	5069.94
A380414DD1	380414113253501	280	GBCAAS v.1.0[2]	1940 to 1959	20							1.150	196		5201.65	5063.35
A380810BB1	380810113153601	284	GBCAAS v.1.0[2]	1940 to 1959	0.1	0.43%	0.25					1.150			5074.56	5046.76
A381048CB1	381048113024601	284	GBCAAS v.1.0[2]	1940 to 1959	0		1.70					1.150			5132.52	5047.11
A381100BA1	381100113272501	280	GBCAAS v.1.0[2]	1960 to 1995	10		0.67					1.150			5913.89	5871.39
A381110DC1	381110113102701	284	GBCAAS v.1.0[2]	1960 to 1995	5		11.00					1.150			5038.53	5025.53
A381139DD1	381139113202601	284	GBCAAS v.1.0[2]	1940 to 1959	0.1		0.35					1.150			5223.68	5051.68
A381411DD1	381411113092701	284	GBCAAS v.1.0[2]	1940 to 1959	5		0.46					1.150			5098.5	5016.66
A381925AA1	381925113054001	284	GBCAAS v.1.0[2]	1940 to 1959	0		10.00					1.150			5026.44	4989.41
A381946BC1	381946113170801	256	GBCAAS v.1.0[2]	1960 to 1995	20		2.60					1.150		490	6173.91	6089.91
A382503AB1	382503113040301	284	GBCAAS v.1.0[2]	1940 to 1959	20		16.00					1.150	184		5238.56	4964.56
A384320AC1	384320113075501	287	GBCAAS v.1.0[2]	1960 to 1995	20		1.20					1.150			4654.1	4511.71
A384514AD1	384514113573601	254	GBCAAS v.1.0[2]	1960 to 1995	10		1.40					1.150			5573.81	5448.14
A384953BC2	384953113081101	287	GBCAAS v.1.0[2]	1960 to 1995	20		5.40					1.150			4533.91	4529.67
A385502CB1	385502113124901	287	GBCAAS v.1.0[2]	1960 to 1995	3		18.00					1.150			4618.74	4560.03
A390141BD1	390141113532901	254	GBCAAS v.1.0[2]	1960 to 1995	10		0.93					0.478			5019.7	4982.73
A390201AA1	390201113125101	287	GBCAAS v.1.0[2]	1960 to 1995	10		5.80					1.150			4528.63	4514.93
A390401BD1	390401113100001	287	GBCAAS v.1.0[2]	1960 to 1995	20		76.00					1.150			4553.61	4396.37
A390449CD2	390449113110001	287	GBCAAS v.1.0[2]	1960 to 1995	5		5.10					1.150			4528.12	4525.9
A390540DA2	390540113272301	257	GBCAAS v.1.0[2]	1960 to 1995	20	0.18%	0.20				1.10	1.150		620	4523.73	4438.53
A390623AC1	390623113084101	287	GBCAAS v.1.0[2]	1960 to 1995	20	0.44%	0.13				1.06	1.150		150	4547.35	4491.33
A391136DD1	391136113290401	257	GBCAAS v.1.0[2]	1960 to 1995	20	0.36%	0.22				1.06	1.150		197	4533.74	4429.44
A391205DB1	391205113543401	254	GBCAAS v.1.0[2]	1960 to 1995	20	0.92%	0.27				1.05	1.150		97	4975.1	4890.93
A391949CC1	391949113332001	257	GBCAAS v.1.0[2]	1960 to 1995	5	0.53%	0.17				1.05	1.150		400	4482.4	4433.44
C2618_22cbbS	383153113512301	255	Gardener[1]	11/1/1973	10		1					1.150	359		6574.17	6574.17
C2619_25aadS	383122113544401	255	Gardener[1]		20		1					1.150			6914.33	6914.33
C2715_11abaS	382901113295101	256	Gardener[1]	1/1/1935	20	4.42%	1				1	0.575		0	5643.84	5643.84
C2715_12bcdS	382843113291401	256	Gardener[1]	10/12/1972	20	4.79%	1				1	1.150		0	5463.79	5463.79
C2718_27dbaS	382550113504001	255	Gardener[1]	11/15/2012 to 12/5/2012	10	6.60%	1				1	1.150		2.9	6339.02	6344.02
C2718_28ddbS	382534113513401	255	Gardener[1]		10	5.93%	1	0	37	1022	1	1.150	923	0	6664.05	6664.05
C2718_35ccbS	382445113501401	255	Gardener[1]	11/15/2012 to 12/5/2012	10	5.20%	1	0	37	784	1	1.150	715	2.5	6278.97	6276.33

OBSNAM	GWSI	HA #	Source	Period of record used for observation	Accuracy of altitude	Estimated water-level gradient	Variance caused by water-level error	Variance caused by location error	Variance caused by altitude error	Variance caused by discretization	Variance caused by depth of well	Decluster Weight[6]	Variance used in model files	Well Depth	NAVD88 Well Elevation	NADV88 Water Level
					feet	%	feet^2	feet^2	feet^2	feet^2	feet^2		feet^2	feet	feet	feet
C2813_18adbS	382238113205301	256	Gardener[1]	8/31/1963	20	6.92%	1	0	148	1391	1	1.150	1340	0	5533.8	5538.8
C2815_10abbS	382344113305901	256	Gardener[1]	10/11/1972	20	3.65%	1	0	148	386	1	1.150	466	0	5853.97	5853.97
C2816_35bacS	382016113364001	255	Gardener[1]	11/14/2012	20	8.85%	1	0	148	2274	1	1.150	2108	0	7214.55	7214.55
C2818_22bbcS	382151113512301	255	Gardener[1]		20	4.64%	1	0	148	625	1	1.150	674	0	6589.04	6589.04
C2915_2dadS1	381848113292701	256	Gardener[1]	9/1/1963	20	4.89%	1	0	148	693	1	1.150	733	0	6154.01	6154.01
GUAMW_13	NA	256	Gardener[1]	8/8/2013	10	4.86%	1	0	37	686	1	1.150	630	220	6084	6069
C2916_16dcaS	381700113383001	255	Gardener[1]		20	11.40%	1	0	148	3775	1	1.150	3413	0	7284.41	7284.41
C2916_2dcdS1	381835113361701	255	Gardener[1]	10/11/1972	20	3.38%	1	0	148	332	1	1.150	419	0	8054.52	8054.52
C3017_19ddcS	381045113470701	255	Gardener[1]	5/9/1965	20	7.96%	1	0	148	1840	1	1.150	1730	0	6904.21	6904.21
C380716ab1	380716113374901	280	Gardener[1]	9/5/2012	10	2.46%	11.28125	0	37	176	1	1.150	196	150	6138.96	6129.96
C380904ca1	380904113380101	280	Gardener[1]	9/5/2012	1	2.39%	1	0	0	166	1	1.150	146	170	6233.96	6191.96
C381037ab1	381037113474001	255	Gardener[1]	9/6/2012	20	3.45%	1	0	148	345	1	1.150	430	286	7197.25	7180.25
GC301825aad1	381033113480701	255	Gardener[1]	9/6/2012	1	3.12%	1	0	0	283	1	1.150	248	0	7102.28	7097.28
C381152ab1	381152113442801	255	Gardener[1]	11/22/1995	10	7.21%	1	0	37	1509	1	1.150	1346	385	6554.14	6204.14
GCICWCD__7	NA	255	Gardener[1]	2/2/2017	10	7.18%	1	0	37	1495	1	1.150	1334	1000	6604.15	6384.15
C381344cc1	381344113512301	255	Gardener[1]	9/1/2012	20	5.80%	1	0	148	977	1	1.150	980	430	7809.48	7717.48
C381931dd1	381931113200201	256	Gardener[1]	9/4/2012	20	3.75%	0.3127795	0	148	407	1	1.150	484	194	5848.85	5821.85
C382105bd1	382105113234801	256	NWIS[5]	Sept 2012	20	0.40%	2	0	148	5	1	1.150	135	1104	5388.79	4641.34
C382109bc1	382109113232101	256	NWIS[5]	Dec 2015	20	0.40%	2	0	148	5	1	1.150	135	1155	5408.79	4656.7
C382113aa1	382113113240401	256	NWIS[5]	Dec 2015	20	0.40%	2	0	148	5	1	1.150	135	1205	5403.79	4928.31
C382113da1	382113113435401	255	Snake Valley Model[3]	9/6/2012	20	4.00%	0.4381005	0	148	464	1	1.150	534	2006	5778.96	5404.41
C382256cc1	382256113420501	255	NWIS[5]	2012 to 2013	5	4.00%	0.00045	0	9	464	1	1.150	413	1120	5660.92	5051.66
C382259ca1	382259113433701	255	Snake Valley Model[3]	9/6/2012	10	4.00%	0.1984623	0	37	464	1	1.150	437	970	5686.92	5325.05
C382311bd1	382311113244901	256	NWIS[5]	2012 to 2013	20	0.40%	115.56903	0	148	5	1	1.150	234	970	5323.76	4542.38
C382350bb1	382350113231901	256	Snake Valley Model[3]	9/4/2012	40	0.40%	1.0277048	0	591	5	1	1.150	520	1475	5198.74	4539.23
C382402bb1	382402113421101	255	NWIS[5]	2012 to 2013	5	1.00%	0.3781476	0	9	29	1	1.150	35	1460	5588.89	4968.72
C382423cd1	382423113243601	256	NWIS[5]	2012 to 2013	20	0.40%	27.981633	0	148	5	1	1.150	158	1480	5213.74	4532.75
C382535ell	382535113251101	256	Snake Valley Model[3]	9/5/2012	20	0.40%	0.1191357	0	148	5	1	0.977	157	1399	5093.74	4529.66
C382539ing	382539113250601	256	Snake Valley Model[3]	9/5/2012	20	0.40%	0.150497	0	148	5	1	0.977	157	987	5088.74	4530.02
C383131ell	383131113214301	256	Snake Valley Model[3]	9/7/2012	10	0.40%	0.4423884	0	37	5	1	1.150	37	1135	4763.74	4533.94
C383223bd1	383226113412401	255	NWIS[5]	July 1960	5	0.20%	2	0	9	1	1	1.150	12	394	5208.88	4853.88
C383357dia	383402113440601	255	Snake Valley Model[3]	9/6/2012	10	0.20%	0.0423223	0	37	1	1	0.575	68	882	5251.88	4816.4
C383402ell	383402113440601	255	Snake Valley Model[3]	9/6/2012	10	0.20%	0.0423223	0	37	1	1	0.575	68	882	5251.88	4821.73
C383538ab1	383538113450801	255	NWIS[5]	July 1933	20	0.20%	2	0	148	1	1	1.150	132	628	5268.88	4802.88
C383825ell	383303113343201	255	Snake Valley Model[3]	9/6/2012	10	0.20%	1	#N/A	#N/A	1	1	1.150	3	340	5088.85	4787.08
C384041cb1	384042113181601	256	NWIS[5]	2008 to 2014	10	1.43%	0.0226787	0	37	59	1	1.150	85	294	4648.75	4438.32
C384215cd1	384215113165701	287	NWIS[5]	1981 to 2014	10	0.83%	0.1808559	0	37	20	1	1.150	51	201	4622.77	4445.29
C384306dc1	384306113112601	287	NWIS[5]	1997 to 2014	10	0.83%	2.7585952	0	37	20	1	1.150	53	532	4598.93	4515.42
C384324bd1	384324113554401	254	Snake Valley Model[3]	—	10	1.14%	0.2592	0	37	38	1	0.632	120	160	5753.9	5658.6
C384324bd2	384324113554402	254	Snake Valley Model[3]	—	10	1.16%	0.125	0	37	39	1	0.632	122	398	5753.9	5659.48
C384327ell	384327113591401	254	Snake Valley Model[3]	—	0.1	2.16%	0.0590305	0	0	135	1	1.150	119	370	5704.44	5451.99
C384340db2	384340113585701	254	Snake Valley Model[3]	—	0.1	1.32%	0.0184333	0	0	50	1	0.373	138	455	5664.94	5450.97
C384340db3	384340113585702	254	Snake Valley Model[3]	—	0.1	2.12%	0.0040333	0	0	131	1	0.373	353	539	5664.94	5451.1
C384342db4	384342113585401	254	Snake Valley Model[3]	—	0.1	2.07%	0.1058	0	0	124	1	0.373	336	740	5659.34	5451.16
C384342db5	384342113585402	254	Snake Valley Model[3]	—	0.1	1.92%	0.0592	0	0	107	1	0.373	291	1159	5659.34	5451.19
C384351ell	384351113150501	287	Snake Valley Model[3]	—	1	2.30%	4.7096699	0	0	154	1	1.150	139	145	4558.8	4467.46
C384746ell	384746113554701	254	Snake Valley Model[3]	—	20	1.29%	0.101137	0	148	48	1	1.150	171	472	5793.89	5445.19

OBSNAM	GWSI	HA #	Source	Period of record used for observation	Accuracy of altitude	Estimated water-level gradient	Variance caused by water-level error	Variance caused by location error	Variance caused by altitude error	Variance caused by discretization	Variance caused by depth of well	Decluster Weight[6]	Variance used in model files	Well Depth	NAVD88 Well Elevation	NADV88 Water Level
					feet	%	feet^2	feet^2	feet^2	feet^2	feet^2		feet^2	feet	feet	feet
C385008ell	385008113145301	287	Snake Valley Model[3]	9/7/2012	20	0.77%	0.3954614	0	148	17	1	1.150	145	560	4635.8	4433.58
C385542ell	385542113223601	257	Snake Valley Model[3]	—	5	0.17%	0.0101156	0	9	1	1	1.150	10	493	4782.87	4437.72
C385933ell	385933113530801	254	Snake Valley Model[3]	—	10	0.47%	1	0	37	7	1	1.150	40	166	5045.68	4992.07
C385958ell	385958113493401	254	Snake Valley Model[3]	—	10	0.48%	1	0	37	7	1	1.150	40	205	5055.7	4947.3
C390000ell	390000113463701	254	Snake Valley Model[3]	—	5	0.72%	0.21125	0	9	15	1	1.150	22	316	5074.73	4856.21
C390143ba2	390143113533002	254	Snake Valley Model[3]	—	0.1	0.88%	0.2557	0	0	23	1	0.421	57	1285	5020.08	4973.64
C390143ba3	390143113533003	254	Snake Valley Model[3]	—	0.1	0.60%	1.7880333	0	0	10	1	0.478	28	570	5019.62	4975.05
C390312cc1	390312113591701	254	Snake Valley Model[3]	—	20	0.40%	6.9992002	0	148	5	1	1.150	140	68	5031.84	5002.92
C390425aa1	390425113585201	254	Snake Valley Model[3]	—	0.1	0.47%	0.07605	0	0	6	1	0.460	16	65	5010.33	4984.06
C390426aa2	390426113585201	254	Snake Valley Model[3]	—	0.1	0.37%	0.045	0	0	4	1	0.402	12	138	5009.7	4984.31
C390426aa3	390426113585202	254	Snake Valley Model[3]	—	0.1	0.37%	0.5202	0	0	4	1	0.402	13	317	5009.73	4989.89
C390453ad1	390453113454701	254	Snake Valley Model[3]	—	20	1.94%	0.00245	0	148	109	1	1.150	224	735	5493.81	4895.83
C390549ell	390549113562901	254	Snake Valley Model[3]	—	5	0.35%	5.8318127	0	9	4	1	1.150	17	375	4988.75	4995.44
C390629da1	390629113560301	254	Snake Valley Model[3]	—	0.5	0.69%	13.093106	0	0	14	1	1.150	25	97	5042.2	4966.99
C390637aa1	390637113553201	254	Snake Valley Model[3]	—	50	0.55%	0.80645	0	924	9	1	0.575	1625	263	5126	4950.35
C390637aa2	390637113553102	254	Snake Valley Model[3]	—	0.5	0.55%	0.13005	0	0	9	1	0.575	17	735	5124.54	4949.33
C390656cb1	390656113425101	254	Snake Valley Model[3]	—	20	1.71%	0.17405	0	148	85	1	1.150	203	1643	5853.93	4431.19
C390803ll3	390803113054801	287	Snake Valley Model[3]	—	5	0.23%	0.0211633	0	9	2	1	1.150	10	507	4658.61	4447.37
C391156bb1	391156113541901	254	Snake Valley Model[3]	—	0.1	0.23%	0.0961333	0	0	2	1	0.288	9	190	5000.8	4893.52
C391156bb2	391156113541902	254	Snake Valley Model[3]	—	0.1	0.35%	0.0905333	0	0	4	1	0.288	16	320	5000.9	4893.7
C391156bb3	391156113541903	254	Snake Valley Model[3]	—	0.1	0.27%	0.0446333	0	0	2	1	0.288	11	390	5000.9	4893.82
C391156bb4	391156113541904	254	Snake Valley Model[3]	—	0.1	0.23%	0.4356333	0	0	2	1	0.288	10	553	5000.47	4893.7
C391704ac1	391704113312001	257	Snake Valley Model[3]	—	5	0.07%	0.0650118	0	9	0	1	1.150	9	197	4458.63	4434.02
C391801lls	391801113292201	257	Snake Valley Model[3]	—	5	0.24%	0.2346766	0	9	2	1	1.150	11	42	4436.61	4437.01
C391926dc1	391926113391801	257	Snake Valley Model[3]	—	0.1	1.21%	595.8152	0	0	42	1	0.575	1111	669	5266.32	4725.75
C391926dc2	391926113391802	257	Snake Valley Model[3]	—	0.1	1.21%	628.35125	0	0	42	1	0.575	1168	738	5266.32	4746.59
CBonneville	NA	287	Gardener[1]	5/22/2013	2	0.84%	2	0.01	1.48	20	1.07	1.150	22	315	4772.99	4595.99
CCoyote_Wel	NA	287	Gardener[1]	9/17/2012	2	0.30%	2	0.00	1.48	3	1.11	1.150	6	765	4784.82	4434.82
CGuzzler_S	NA	287	CH2M[4]	May 2013	2	0.42%	2	0	1	5	1	1.150	8		4967.85	4595.1
CMiller_Can	NA	287	CH2M[4]	May 2013	2	0.89%	2	0	1	23	1	1.150	24		4699.66	4434.07
CMonument_P	NA	287	Gardener[1]	9/17/2012	2	0.70%	2	0.00	1.48	14	1.17	1.150	16	1215	4892.04	4598.04
CNighthawk_	NA	287	CH2M[4]	Sept 2012	2	0.34%	2	0	1	3	1	1.150	7		4804.69	4431
pt256__1	382901113295101	256	Gardener[1]		20	4.42%	1	0	148	567	1	0.575	1247	0	5643.84	5643.84

[1] Gardner et al. (2020)
[2] GBCAAS v.1.0 (Brooks et al. 2014)
[3] Snake Valley model (Masbruch et al. 2014)
[4] CH2M (Stephen Hill, written commun., Oct 2, 2014; Gardener et al. 2020)
[5] NWIS (https://waterdata.usgs.gov/nwis/gw) Accessed 5/4/2020
[6] GSLIB DECLUS (Deutsch and Journel, 1998)

Data Imported from Brooks et al. (2014), Table A2-1
Data from Gardner et al. (2020)
Coordinates interpolated from GBCAAS V3 HOBS file
NWIS

Calculation
Variance caused by well depth assumed 1 sq-ft
Gradient calculation based on LTEQ heads
Unknown water level variance set to 1.0
Unknown altitude accuracy set to 10.0

[Abbreviations: GWSI, U.S. Geological Survey Groundwater Site Inventory; HA, hydrographic area; #, number; —, not applicable]

ATTACHMENT A2 – BERYL-ENTERPRISE AREA, UNDERGROUND, PERFECTED POINTS OF DIVERSION (PODS) USED IN CUMULATIVE ANALYSIS SIMULATIONS

WRNUM	CHEXNUM	TYPE	SUMMARY_ST	STATUS	PRIORITY	USES	CFS	ACFT	LOCATION	WIN	OWNER	SOURCE	GWMP Retire Date
71-2873		Underground	P	APPLWU(	1963020	DS	0	3.53	N2280 E1020 SW 33 32S 16W SL	0	N ROBERT AND SUSAN BLAKE REVOCABLE LIVING TRU	Underground Water Well	2030-10-31
71-5123		Underground	P	APPLCER	1956122	I	0	2.5	S893 W1316 NE 30 33S 16W SL	431435	TAMMY BELL ENCE	Underground Water Well	2030-10-31
71-1707		Underground	P	APPLNPR	1951043	S	0	9.38	S50 E50 W4 20 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	2050-10-31
71-4024		Underground	P	APPLCER	1951052	I	0	0.73	S893 W1316 NE 30 33S 16W SL	431435	MICHAEL AND CHESA L. ALEXIS	Underground Water Well	2050-10-31
71-4607		Underground	P	APPLCER	1954101	DI	0	1	S174 E377 NW 02 31S 15W SL	19221	RUSSELL AND WENDY ALBRECHT	Underground Water Well	2050-10-31
71-774		Underground	P	APPLWU(	1949122	I	0	371.6	S920 W1045 NE 30 33S 16W SL	431435	ENZ MANAGEMENT LC	Underground Water Well	2060-10-31
71-1167		Underground	P	APPLCER	1946081	IS	0	1.856	N1472 W2598 E4 27 32S 16W SL	3560	N ROBERT AND SUSAN BLAKE REVOCABLE LIVING TRU	Underground Water Well	2070-10-31
71-3159		Underground	P	APPLWU(	1947030	I	0	21	S30 W2680 NE 23 33S 16W SL	0	SOUTHWEST EMPIRE CORPORATION	Underground Water Well	2070-10-31
71-3930		Underground	P	APPLCER	1945101	I	0	2	S893 W1316 NE 30 33S 16W SL	431435	ENZ MANAGEMENT 3 LC	Underground Water Well	2090-10-31
71-4931		Underground	P	APPLCER	1945101	I	0	2	S893 W1316 NE 30 33S 16W SL	431435	ENZ MANAGEMENT 3 LC	Underground Water Well	2090-10-31
71-10		Underground	P	UGWC	191505	I	0	3.04	N860 E500 S4 29 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-1083		Underground	P	DILCERT	1908	S	0.015	4.144	N2091 W1371 SE 19 30S 14W SL	433457	USA BUREAU OF LAND MANAGEMENT	Underground Water Well	
71-135		Underground	P	UGWC	1917	S	0	1.68	N145 E245 SW 07 33S 15W SL	0	HOWARD W. BECKY C. JONES	Underground Water Well	
71-135		Underground	P	UGWC	1917	S	0	1.68	N2546 W90 S4 08 33S 15W SL	0	HOWARD W. BECKY C. JONES	Underground Water Well	
71-136		Underground	P	UGWCWU	1918	S	0	2.268	N1055 E200 SW 17 33S 16W SL	0	TAMMY BELL ENCE	Underground Water Well	
71-245		Underground	P	UGWC	1918	DS	0	2.214	N255 E220 SW 10 33S 16W SL	32597	LHK FARMS LLC	Underground Water Well	
71-251		Underground	P	UGWC	192312	S	0	1.68	N54 W456 E4 25 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-251		Underground	P	UGWC	192312	S	0	1.68	N35 W415 E4 25 33S 17W SL	0	UNITED STATES OF AMERICA	Underground Water Well	
71-253		Underground	P	UGWC	1916	DS	0	6.89	N280 E140 S4 13 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-255		Underground	P	UGWC	1915	DS	0	1.85	N2375 E880 S4 28 32S 16W SL	0	N ROBERT AND SUSAN BLAKE REVOCABLE LIVING TRU	Underground Water Well	
71-267		Underground	P	APPLWU(	1942040	S	0	8.092	N350 W670 S4 07 33S 16W SL	0	MATHEW AND MARILYN WOOD	Underground Water Well	
71-271		Underground	P	DILCERT	1895	IS	0	28	S1112 E168 N4 21 31S 16W SL	32390	MATHEW WOOD	Spring and Underground Water Wells (2)	
71-271		Underground	P	DILCERT	1895	IS	0	28	S78 E2034 W4 10 31S 16W SL	32354	MATHEW WOOD	Spring and Underground Water Wells (2)	
71-3172		Underground	P	APPLCER	1942040	D	0	0.72	S1112 E167 N4 21 31S 16W SL	32390	MATTHEW AND MARILYN WOOD	Underground Water Well	
71-324		Underground	P	UGWCWU	1925	DIS	0	12.486	N1315 W422 SE 24 33S 17W SL	0	TAMMY BELL ENCE	Underground Water Well	
71-3386		Underground	P	UGWC	1918	I	0	0.5	N270 E220 SW 10 33S 16W SL	32597	GOLDEN CALIFORNIA PACKING INC.	Underground Water Well	
71-3608		Underground	P	UGWC	1918	S	0	0.5	N270 E220 SW 10 33S 16W SL	32597	DAVID L. AND NATALIE STOUT	Underground Water Well	
71-3742		Underground	P	APPLCER	1945013	OS	0	4.42	N837 W31 SE 21 33S 17W SL	435393	USA BUREAU OF LAND MANAGEMENT	Underground Water Well	
71-3815		Underground	P	APPLCER	1942021	I	0	1	S893 W1316 NE 30 33S 16W SL	431435	MOENAVE LLC	Underground Water Well	
71-4368		Underground	P	UGWC	192312	I	0	13.2	N54 W456 E4 25 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-4368		Underground	P	UGWC	192312	I	0	13.2	N35 W415 E4 25 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-4370		Underground	P	APPLCER	1944060	I	0	388	N390 W380 E4 25 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-4697		Underground	P	APPLCER	1941111	DS	0	0.534	N2335 W106 S4 03 32S 16W SL	0	SHEILA R. JONES AND LAWRENCE S. JONES JR.	Underground Water Well	
71-4822		Underground	P	UGWCCE	1927050	O	0	2	S686 E1386 W4 21 31S 16W SL	27644	K.S.P. INVESTMENT LLC	Underground Water Well	
71-4969		Underground	P	APPLCER	1944011	I	0	1	S893 W1316 NE 30 33S 16W SL	431435	TAMMY BELL ENCE	Underground Water Well	
71-4970		Underground	P	APPLCER	1944090	I	0	1	S893 W1316 NE 30 33S 16W SL	431435	TAMMY BELL ENCE	Underground Water Well	
71-4971		Underground	P	APPLCER	1945030	I	0	1	S893 W1316 NE 30 33S 16W SL	431435	GREGORY ALDRED	Underground Water Well	
71-5082		Underground	P	APPLCER	1944041	I	0	6	S893 W1316 NE 30 33S 16W SL	431435	TAMMY BELL ENCE	Underground Water Well	
71-5122		Underground	P	UGWCCE	192403	I	0	12	S893 W1316 NE 30 33S 16W SL	431435	TAMMY BELL ENCE	Underground Water Well	
71-5201		Underground	P	UGWC	191505	DS	0	2.83	N860 E500 S4 29 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-5205		Underground	P	UGWC	192312	DS	0	1.57	N54 W456 E4 25 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-5205		Underground	P	UGWC	192312	DS	0	1.57	N35 W415 E4 25 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-5206		Underground	P	APPLCER	1944060	D	0	0.45	N390 W380 E4 25 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-5207		Underground	P	UGWC	191506	D	0	0.45	N335 E1085 S4 26 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-5208		Underground	P	UGWC	1918	DS	0	0.786	S194 E318 N4 34 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-5335		Underground	P	UGWCCE	1915	S	0	0.34	N2092 E877 SW 32 32S 16W SL	437445	LHK FARMS LLC	Underground Water Well	
71-5371		Underground	P	UGWC	1918	S	0	1	N270 E220 SW 10 33S 16W SL	32597	PINTO PROPERTIES LLC	Underground Water Well	
71-5407		Underground	P	UGWC	1918	I	0	0.58	N270 E220 SW 10 33S 16W SL	32597	N ROBERT AND SUSAN BLAKE REVOCABLE LIVING TRU	Underground Water Well	
71-728		Underground	P	UGWC	1915	S	0	13.3	N325 W220 S4 29 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-729		Underground	P	UGWC	191506	IS	0	5.44	N335 E1085 S4 26 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-744		Underground	P	UGWC	1918	I	0	0.52	S194 E318 N4 34 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-775		Underground	P	APPLCER	1944060	S	0	2.8	N390 W380 E4 25 33S 17W SL	0	ESCALANTE FARMS COMPANY	Underground Water Well	
71-1014		Underground	P	APPLCER	1944121	I	0	80	S73 W167 N4 23 33S 16W SL	435158	ALMA LAMONT WOOD AND CINDY WOOD	Underground Water Well	
71-1366		Underground	P	APPLCER	1944121	I	0	240	S73 W167 N4 23 33S 16W SL	435158	ALMA LAMONT WOOD AND CINDY WOOD	Underground Water Well	
71-205		Underground	P	UGWCCE	1932	I	0	76.32	S73 W167 N4 23 33S 16W SL	435158	ALMA LAMONT WOOD AND CINDY WOOD	Underground Water Well	
71-4511		Underground	P	UGWCCE	1900	DIS	0	1	S1273 W524 NE 32 31S 16W SL	29562	DENNIS L. CHAMBERS	Underground Water Well	
71-4979		Underground	P	APPLCER	1944041	I	0	1	S893 W1316 NE 30 33S 16W SL	431435	TAMMY BELL ENCE	Underground Water Well	
71-5270		Underground	P	UGWCCE	1929	I	0	1	S893 W1316 NE 30 33S 16W SL	431435	TAMMY BELL ENCE	Underground Water Well	
71-5271		Underground	P	APPLCER	1941111	I	0	0.466	N2335 W106 S4 03 32S 16W SL	0	SHEILA R. JONES AND LAWRENCE S. JONES JR.	Underground Water Well	

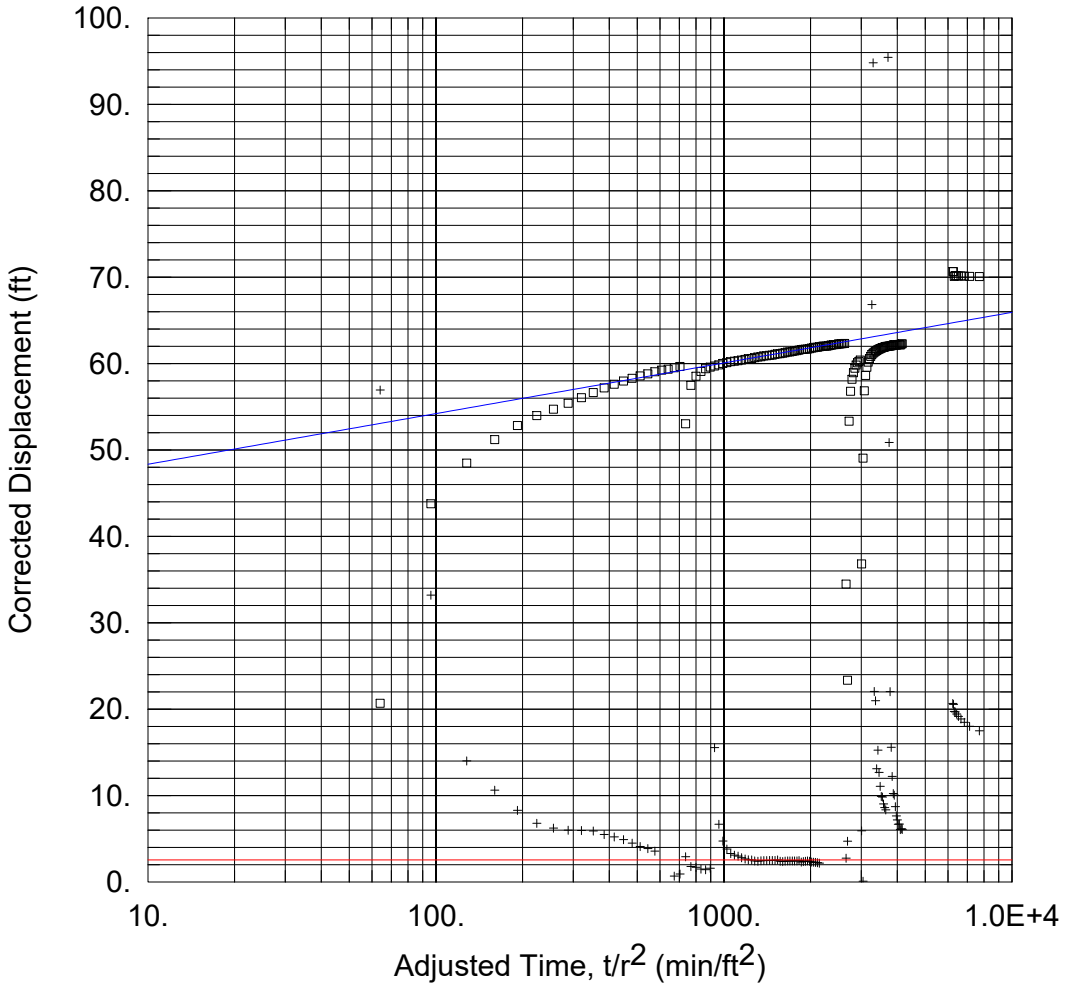
POINT OF DIVERSION INFORMATION

Date accessed: 7/27/20

Source: https://opendata.gis.utah.gov/search?groupIds=4de5aefb5f6540348da4c633bd57cced&source=utah%20division%20of%20water%20rights

Meta data: https://www.arcgis.com/sharing/rest/content/items/5d530e62e6ca42528dd13e0a453a3b73/info/metadata/metadata.xml?format=default&output=html

APPENDIX B– AQUIFER TEST ANALYSES



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell6_CJ.aqt
Date: 06/20/19 Time: 14:40:08

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #6

AQUIFER DATA

Saturated Thickness: 400. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #6	0	0

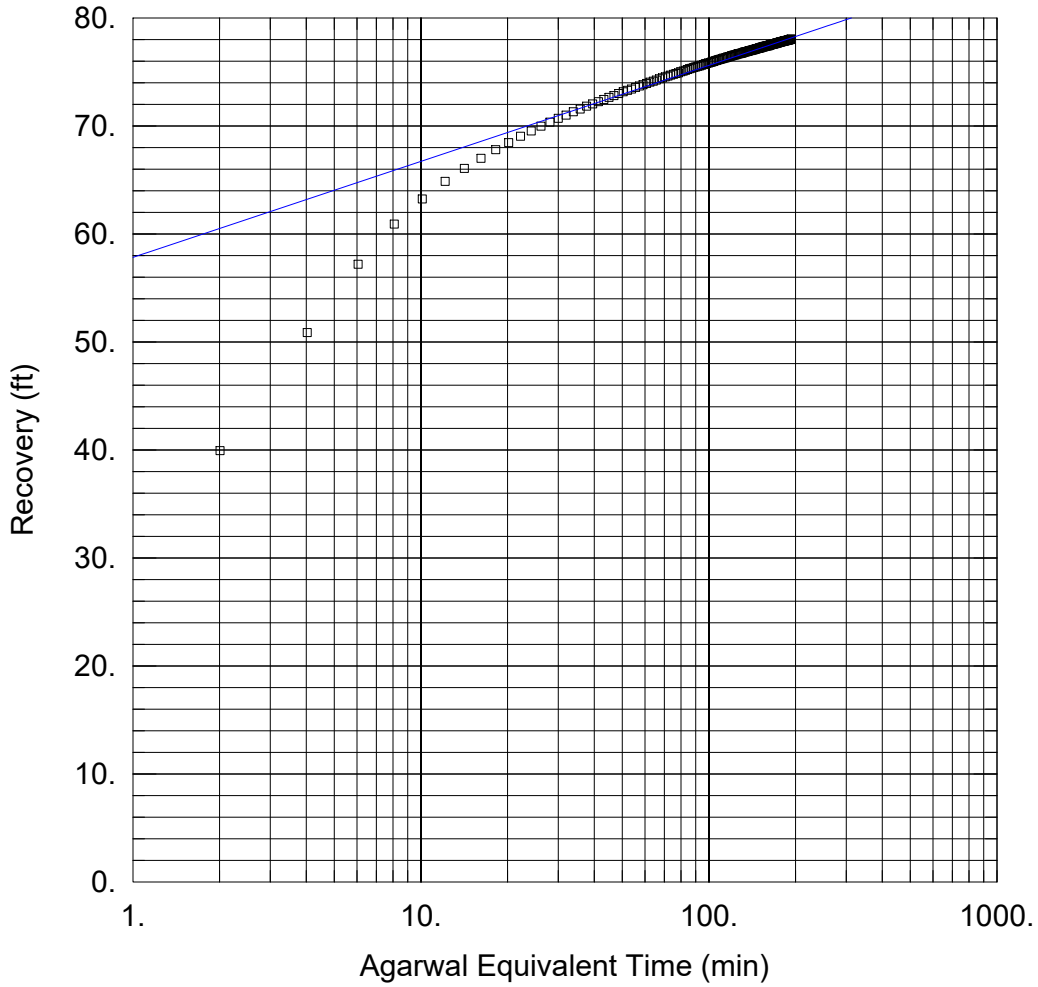
Observation Wells

Well Name	X (ft)	Y (ft)
▫ CICWCD #6	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 1011.3 ft^2/day S = 8.869E-8



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell6_RecovCJa.aqt
Date: 06/20/19 Time: 10:57:10

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #6

AQUIFER DATA

Saturated Thickness: 400. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #6	0	0

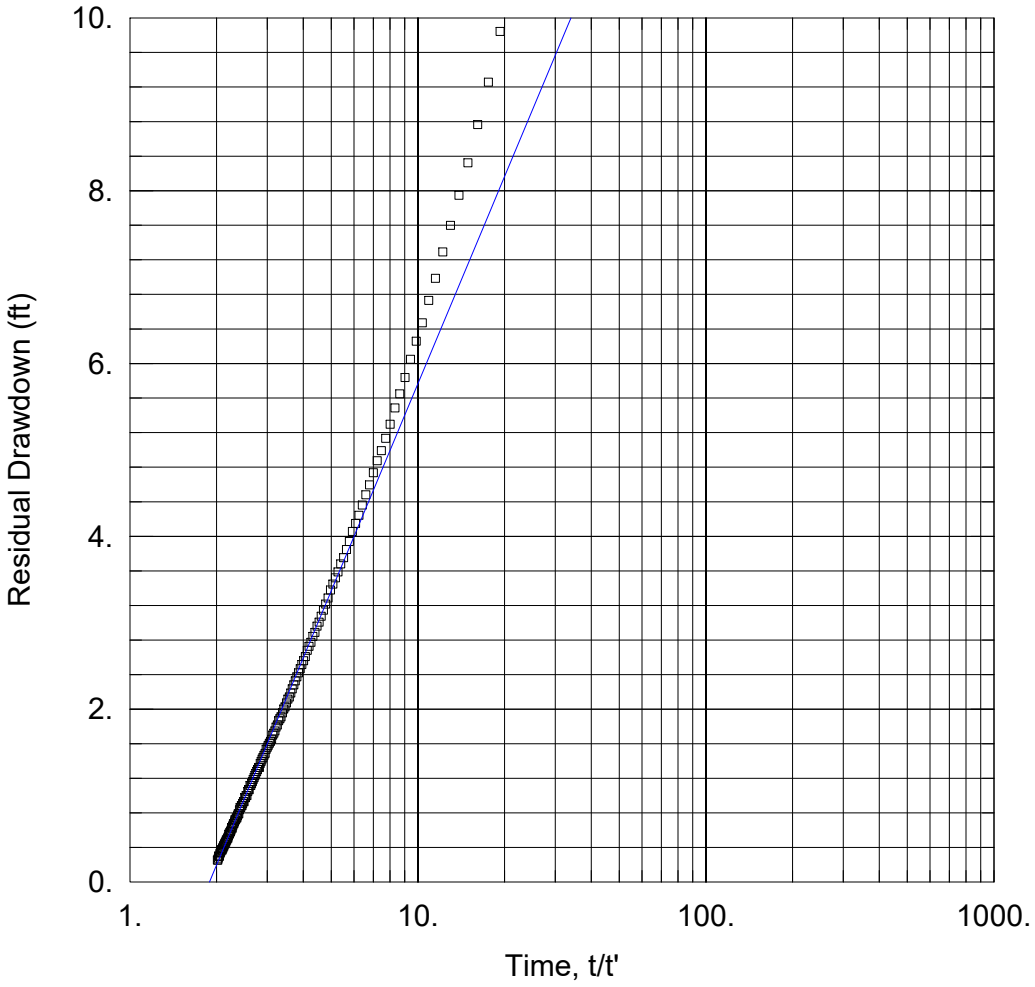
Observation Wells

Well Name	X (ft)	Y (ft)
▫ CICWCD #6	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 666.8 ft^2/day S = 5.178E-6



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell6_RecovTh.aqt
Date: 06/20/19 Time: 09:36:35

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #6

AQUIFER DATA

Saturated Thickness: 400. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #6	0	0

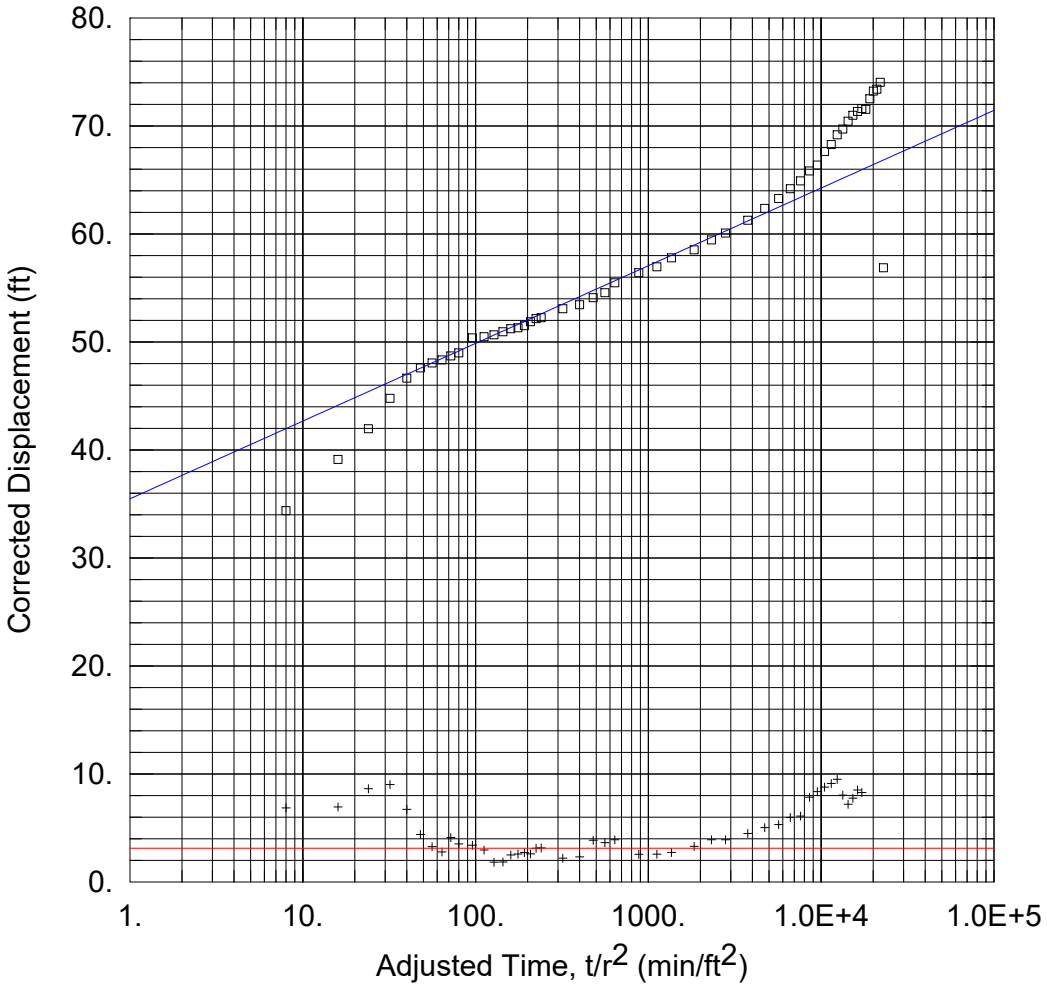
Observation Wells

Well Name	X (ft)	Y (ft)
CICWCD #6	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 743.8 ft^2/day S/S' = 1.89



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell7_CJ.aqt
Date: 06/20/19 Time: 14:41:06

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #7

AQUIFER DATA

Saturated Thickness: 750. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #7	0	0

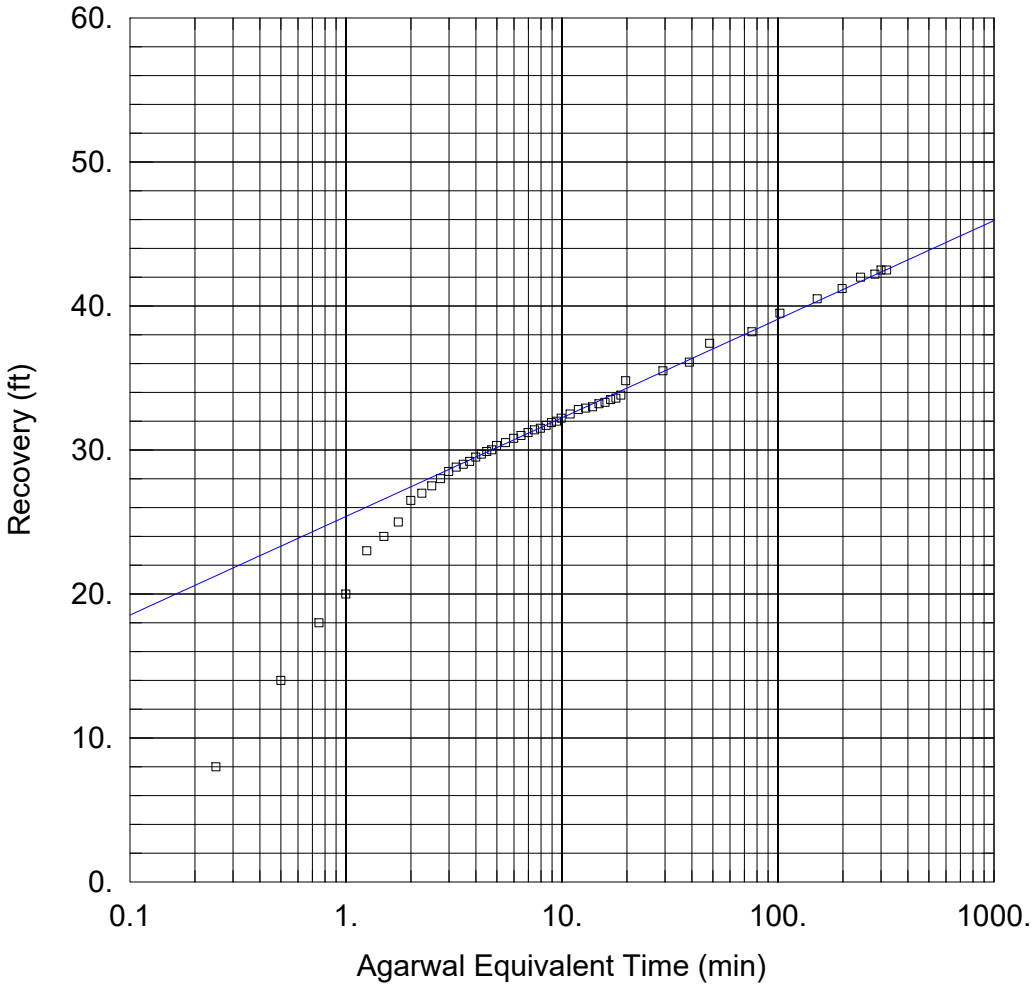
Observation Wells

Well Name	X (ft)	Y (ft)
CICWCD #7	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 970.9 ft^2/day S = 1.772E-5



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell7_RecovCJa.aqt
Date: 06/20/19 Time: 11:22:44

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #7

AQUIFER DATA

Saturated Thickness: 750. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #7	0	0

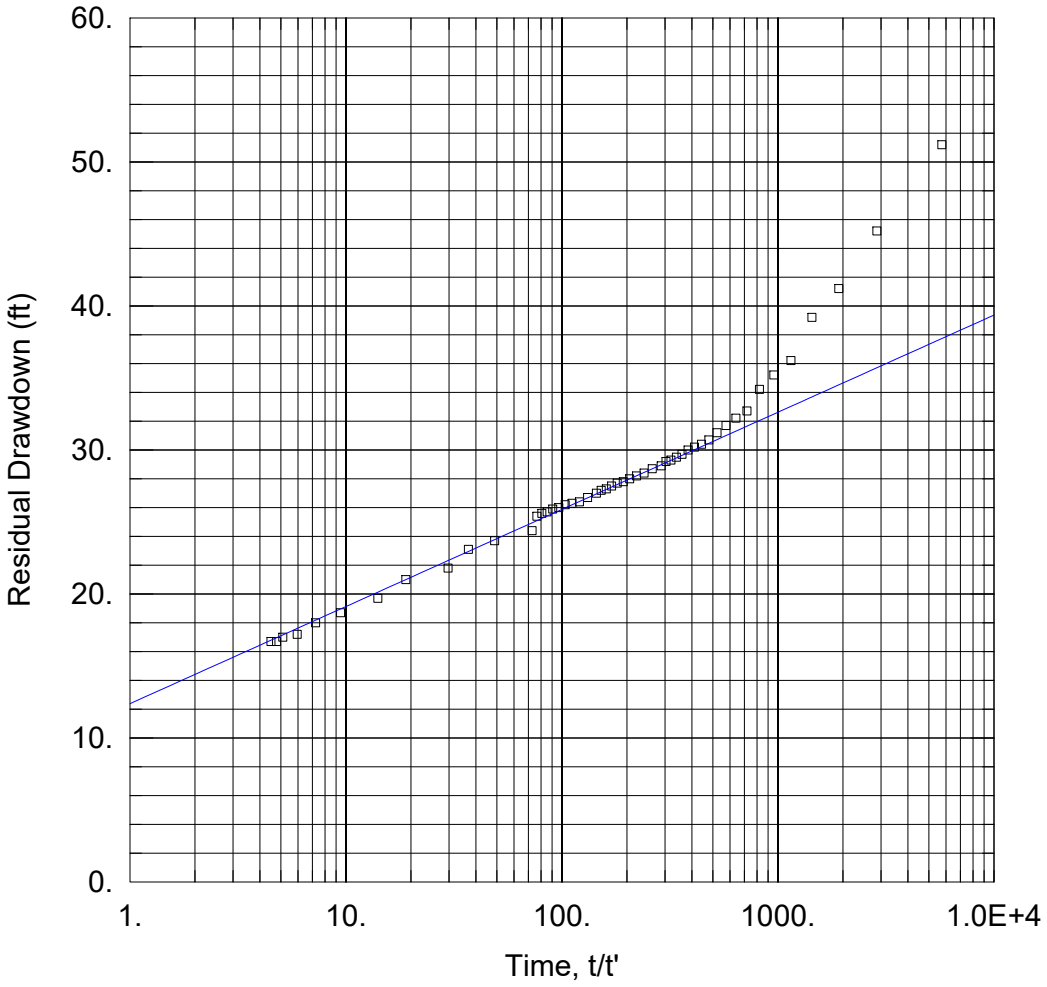
Observation Wells

Well Name	X (ft)	Y (ft)
CICWCD #7	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 1019.8 ft^2/day S = 0.005011



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell7_RecovTh.aqt
Date: 06/20/19 Time: 09:59:44

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #7

AQUIFER DATA

Saturated Thickness: 750. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #7	0	0

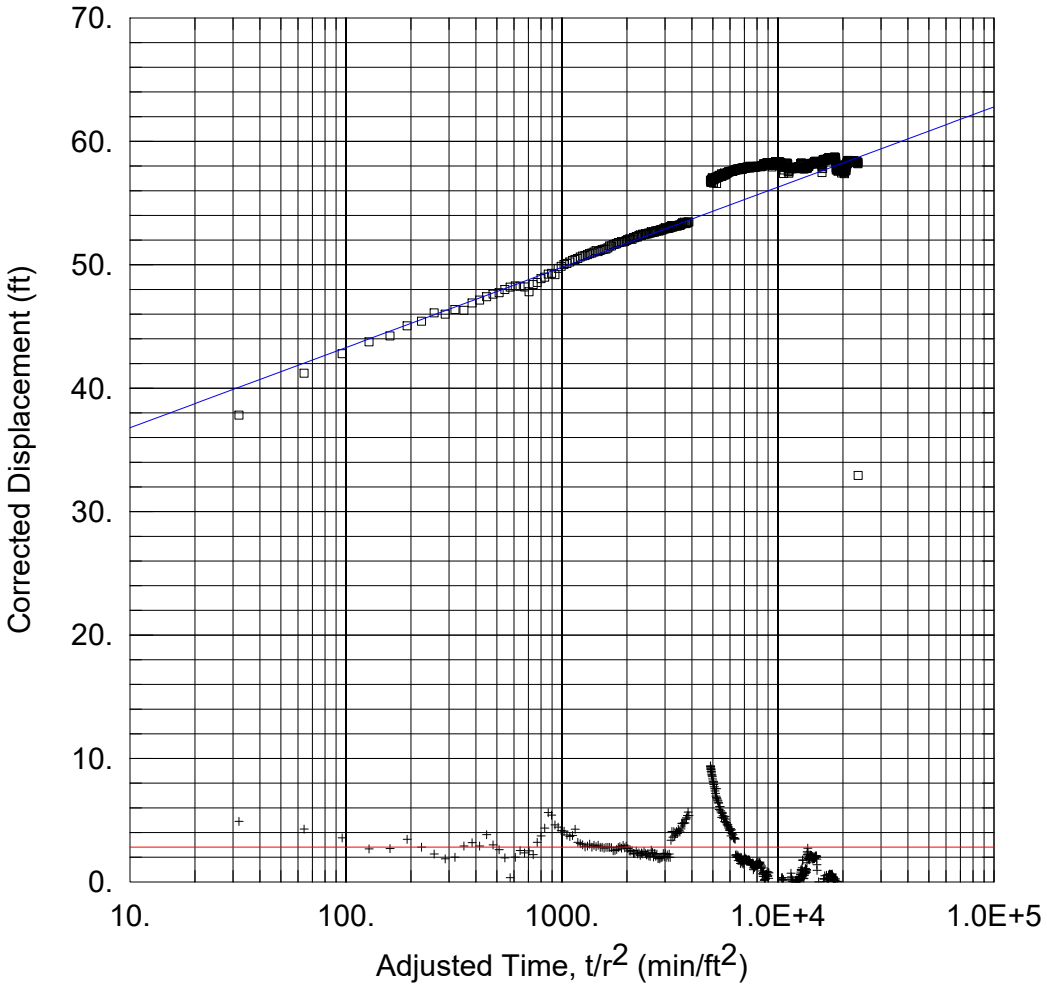
Observation Wells

Well Name	X (ft)	Y (ft)
CICWCD #7	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 1035.5 ft^2/day S/S' = 0.01463



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell8_CJ.aqt
Date: 06/20/19 Time: 14:42:49

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #8

AQUIFER DATA

Saturated Thickness: 450. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #8	0	0

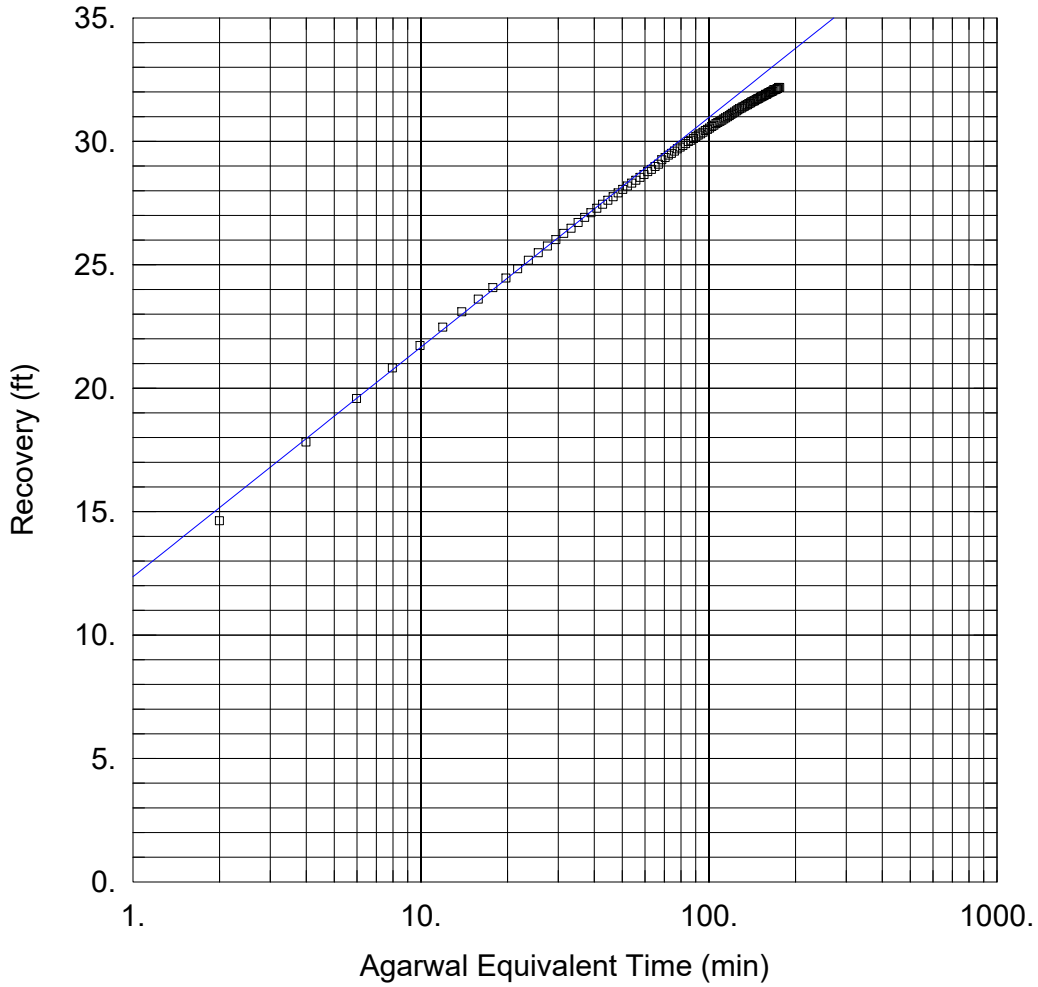
Observation Wells

Well Name	X (ft)	Y (ft)
▫ CICWCD #8	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 911.8 ft^2/day S = 3.099E-5



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell8_RecovCJa.aqt
Date: 06/20/19 Time: 11:25:58

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #8

AQUIFER DATA

Saturated Thickness: 450. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #8	0	0

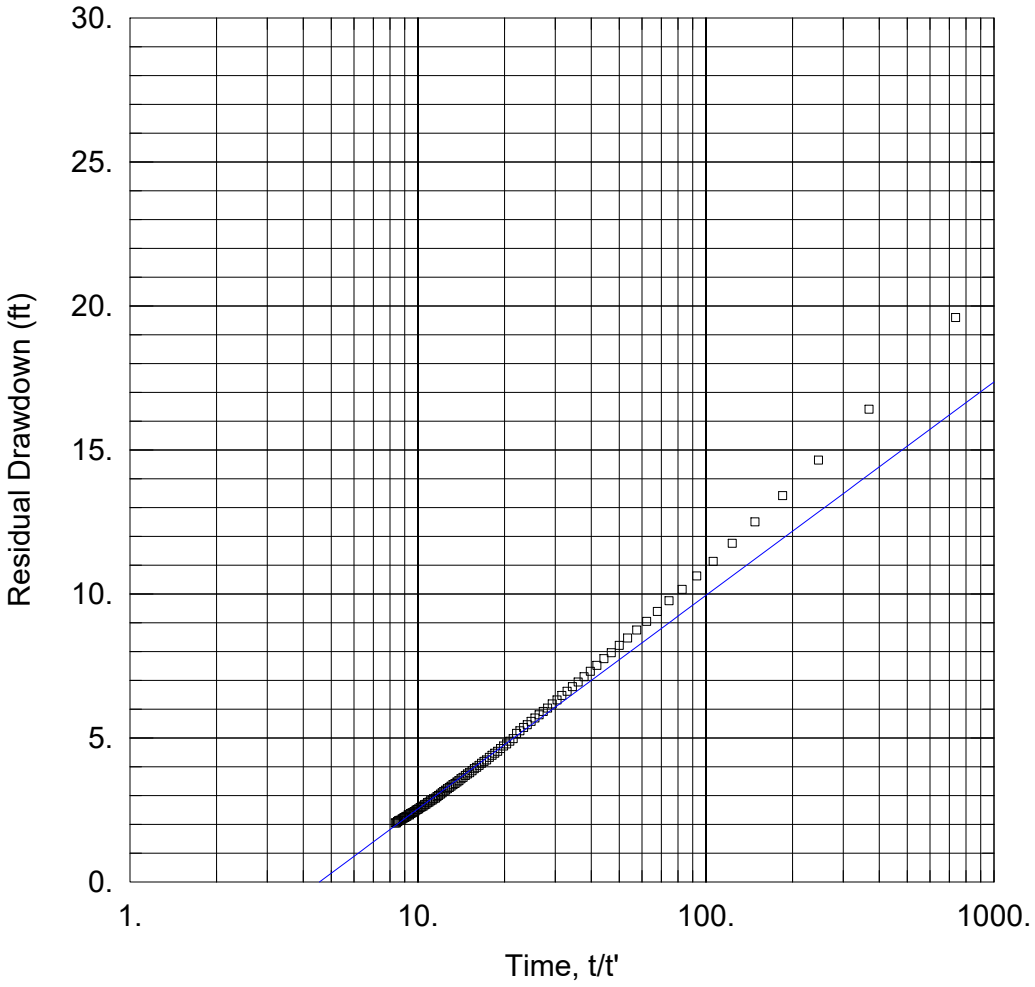
Observation Wells

Well Name	X (ft)	Y (ft)
▫ CICWCD #8	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 637. ft^2/day S = 0.7458



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell8_RecovTh.aqt
Date: 06/20/19 Time: 10:19:45

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #8

AQUIFER DATA

Saturated Thickness: 450. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #8	0	0

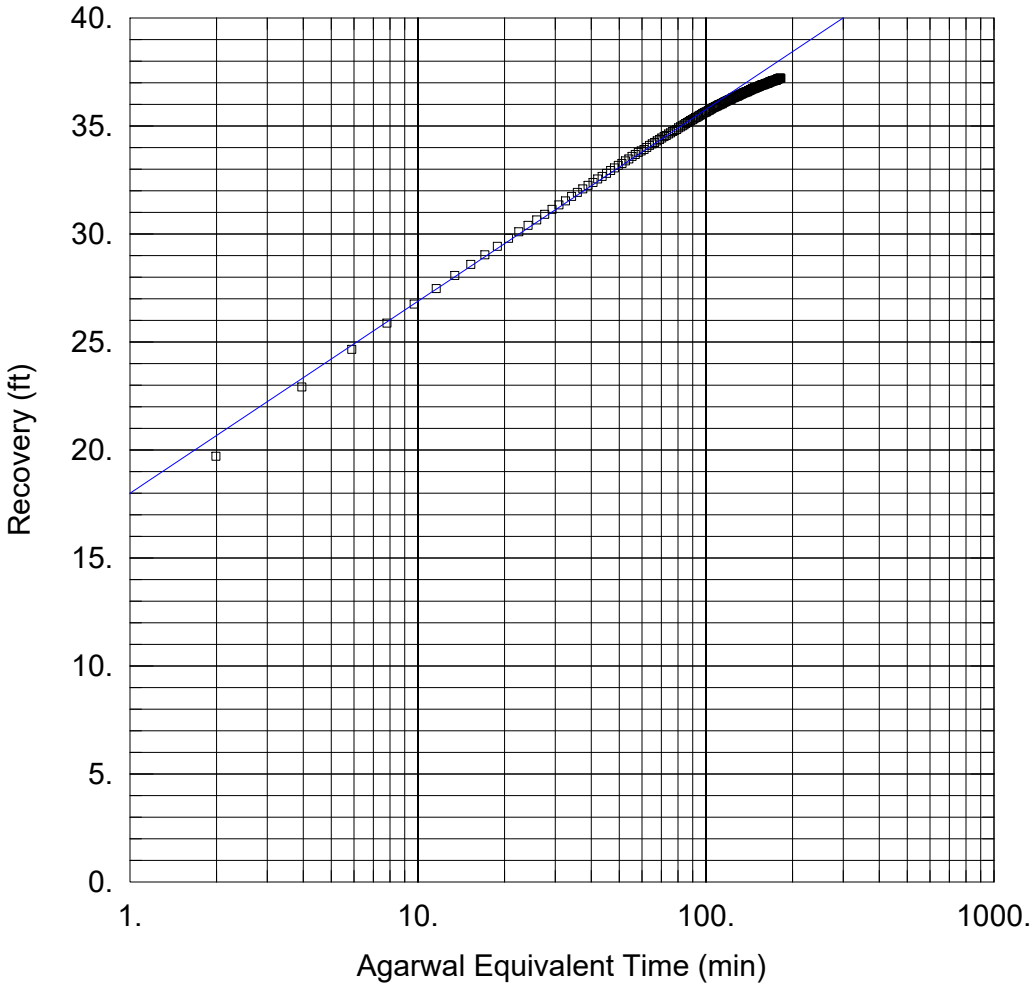
Observation Wells

Well Name	X (ft)	Y (ft)
□ CICWCD #8	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 799.6 ft^2/day S/S' = 4.552



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell8_StepRecovCJa.aqt
Date: 06/20/19 Time: 12:09:44

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #8

AQUIFER DATA

Saturated Thickness: 450. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #8	0	0

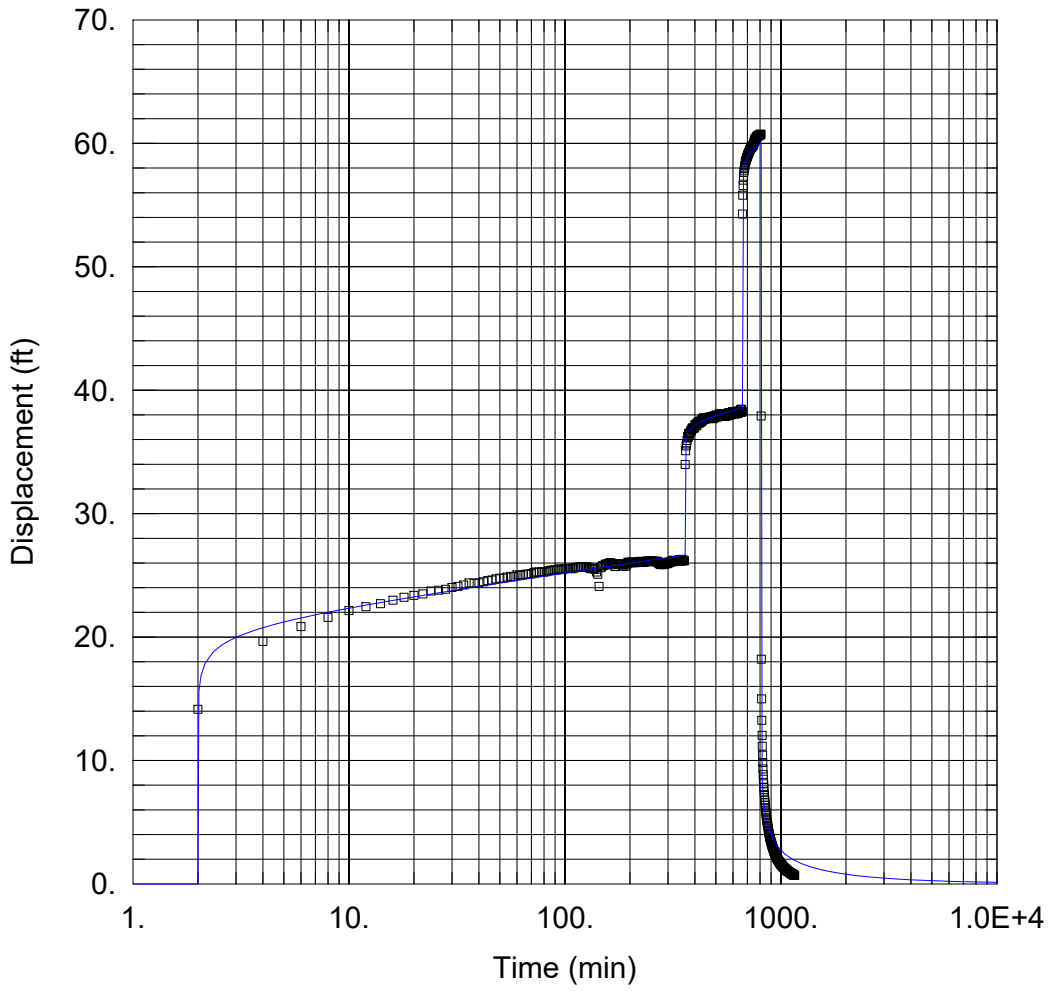
Observation Wells

Well Name	X (ft)	Y (ft)
▫ CICWCD #8	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 666.8 ft^2/day S = 0.1573



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell8_StepTheis.aqt
Date: 06/20/19 Time: 10:31:03

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #8

AQUIFER DATA

Saturated Thickness: 450. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #8	0	0

Observation Wells

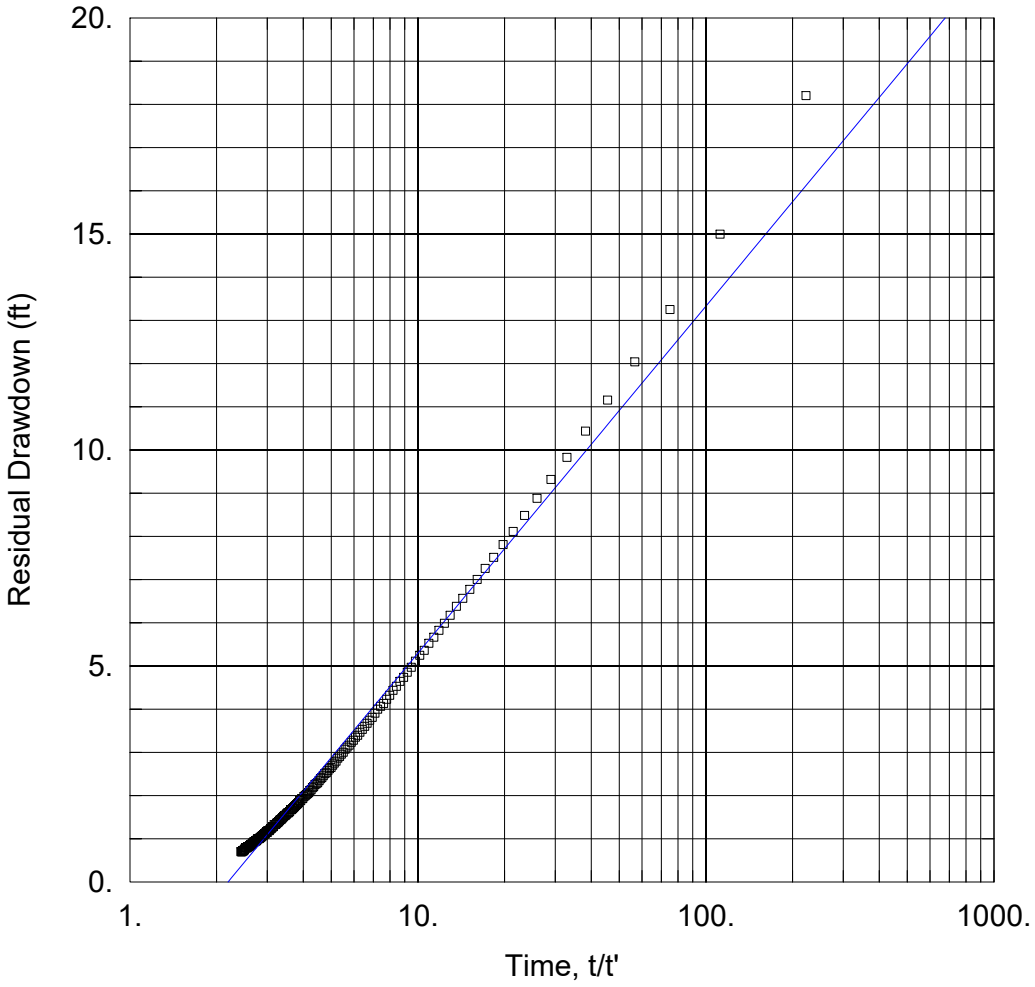
Well Name	X (ft)	Y (ft)
CICWCD #8	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Step Test)

T = 1200.8 ft^2/day
S = 0.0002654
Sw = 1.55
C = 0.0075 min^2/ft^5
P = 2.451

Step Test Model: Jacob-Rorabaugh
$s(t) = 0.Q + 0.0075Q^{2.451}$
Time (t) = 1. min Rate (Q) in cu. ft/min
W.E. = 0.% (Q from last step)



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell8_StepTheisRecov.aqt
Date: 06/20/19 Time: 12:06:33

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #8

AQUIFER DATA

Saturated Thickness: 450. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #8	0	0

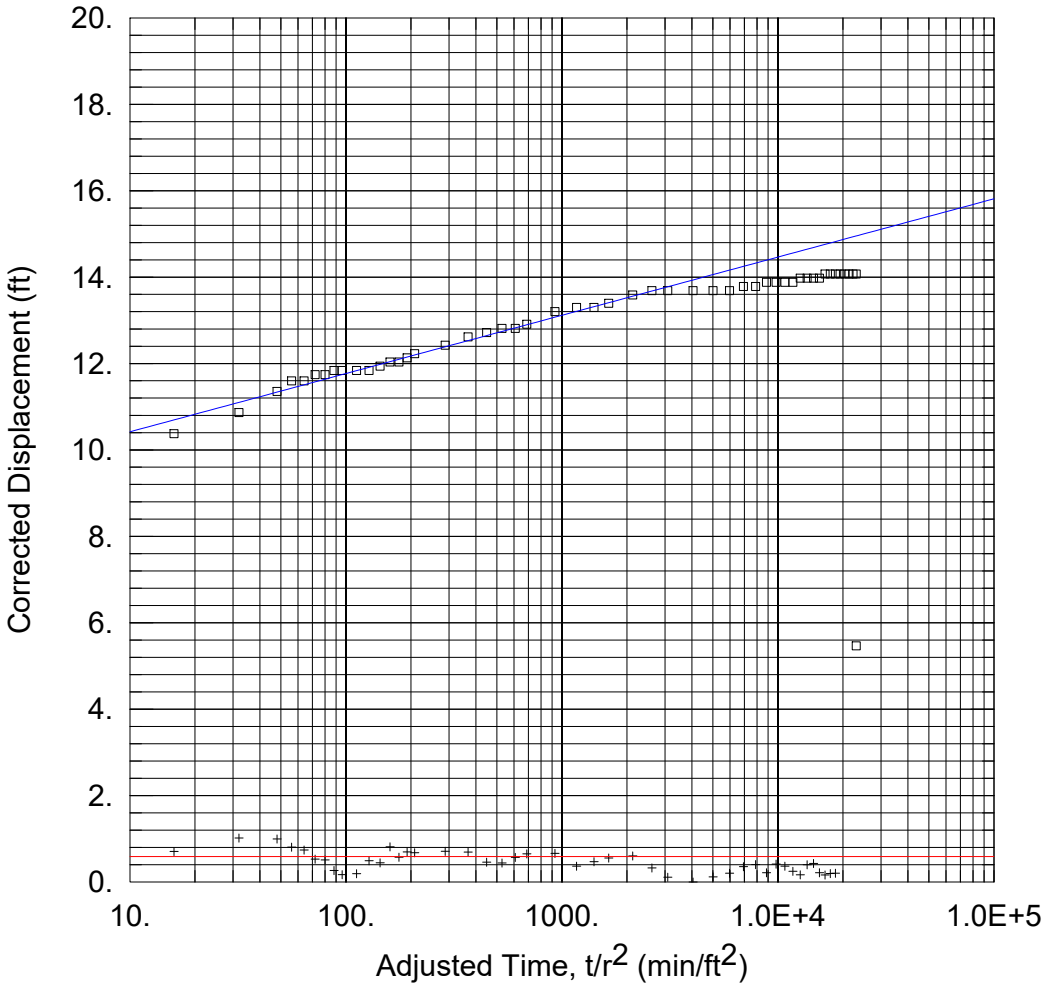
Observation Wells

Well Name	X (ft)	Y (ft)
CICWCD #8	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 737.9 ft^2/day S/S' = 2.192



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell12_CJ.aqt
Date: 06/20/19 Time: 14:45:28

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #12

AQUIFER DATA

Saturated Thickness: 450. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #12	0	0

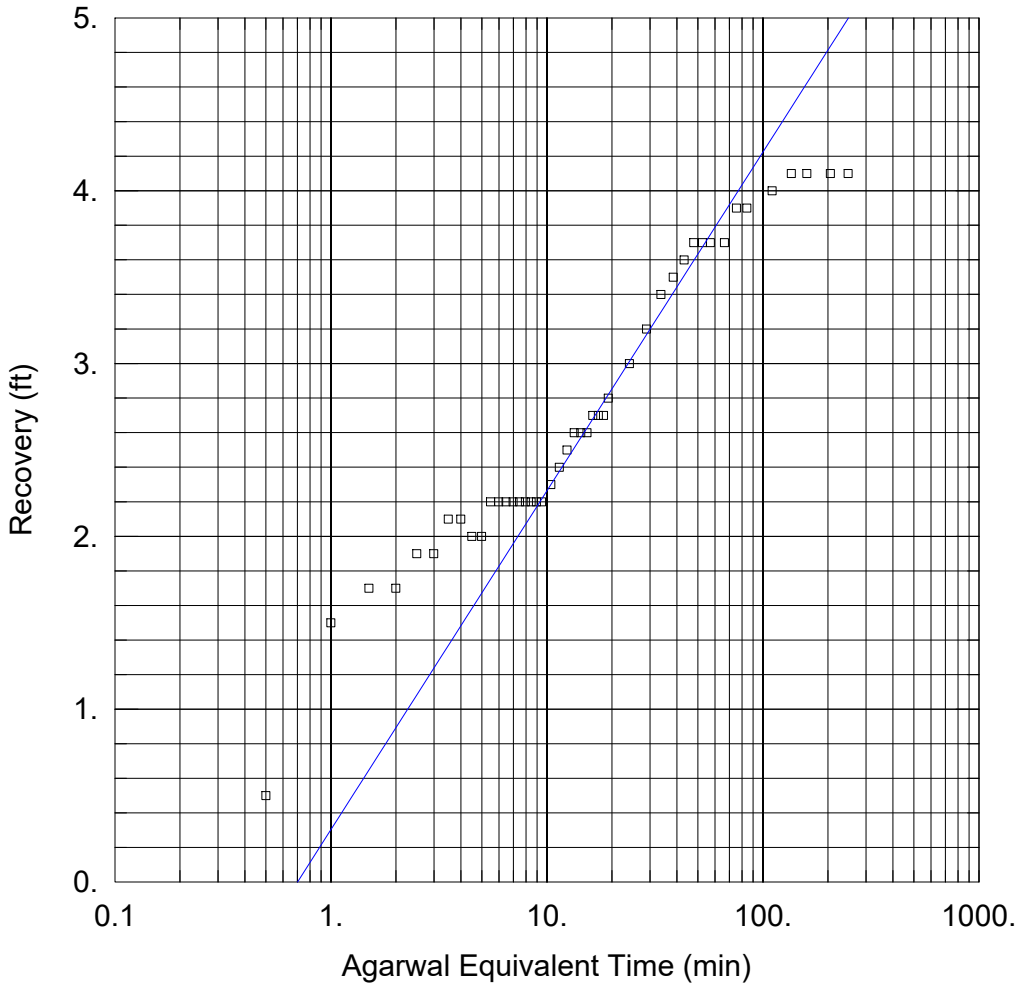
Observation Wells

Well Name	X (ft)	Y (ft)
▫ CICWCD #12	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 4395.6 ft^2/day S = 1.279E-6



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell12_RecovCJa.aqt
Date: 06/20/19 Time: 11:20:31

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #12

AQUIFER DATA

Saturated Thickness: 450. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #12	0	0

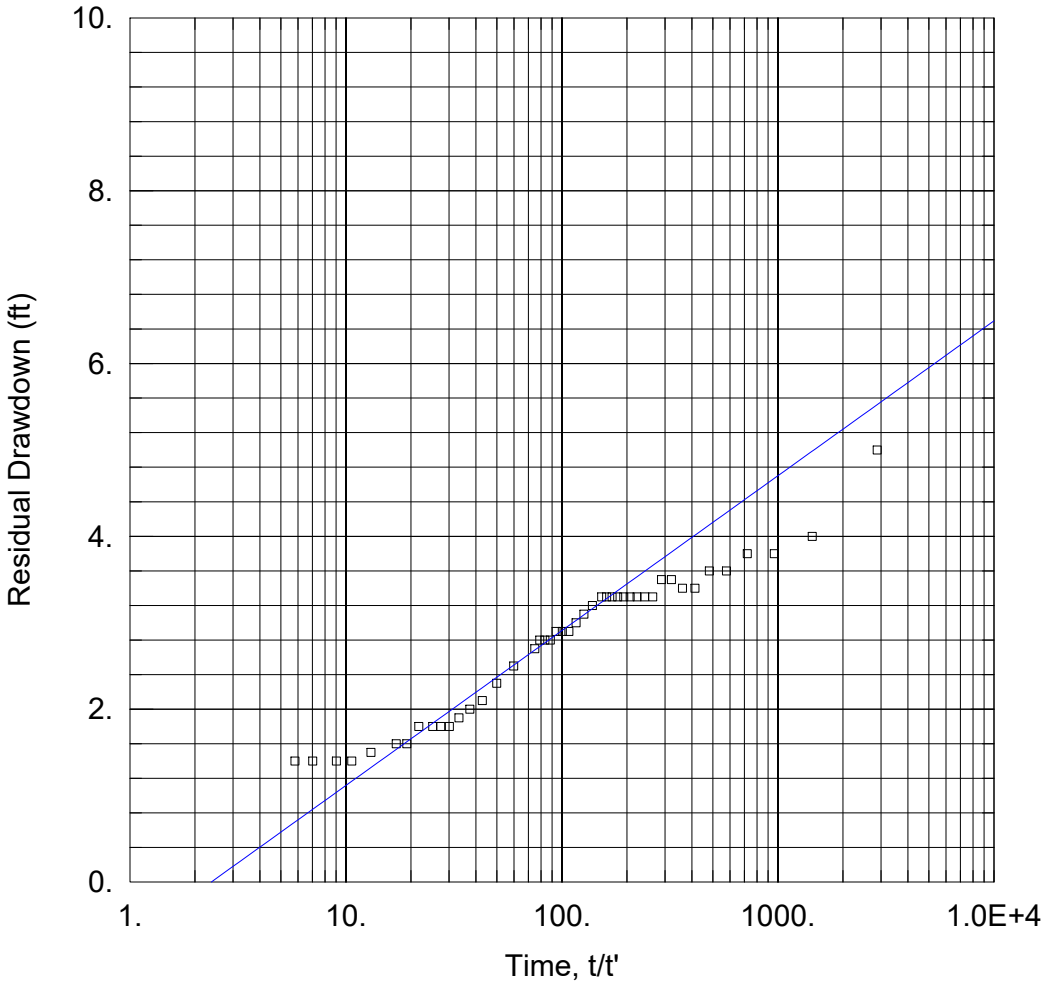
Observation Wells

Well Name	X (ft)	Y (ft)
□ CICWCD #12	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 3022.7 ft^2/day S = 52.89



WELL TEST ANALYSIS

Data Set: S:\...\PineValleyWell12_RecovTh.aqt
Date: 06/20/19 Time: 10:36:04

PROJECT INFORMATION

Company: Formation Environmental
Location: Pine Valley
Test Well: CICWCD #12

AQUIFER DATA

Saturated Thickness: 450. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CICWCD #12	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
CICWCD #12	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 3306.5 ft^2/day S/S' = 2.385

APPENDIX C– POINTS OF DIVERSION FROM UTAH WATER RIGHTS DATABASE

PROPOSED ACTION
SPRING PODs

POINT OF DIVERSION INFORMATION

Utah POD data accessed:	7/27/20
Source:	https://opendata.gis.utah.gov/search?groupIds=4de5aefb5f6540348da4c633bd57cced&source=utah%20division%20of%20water%20rights
Meta data:	https://www.arcgis.com/sharing/rest/content/items/5d530e62e6ca42528dd13e0a453a3b73/info/metadata/metadata.xml?format=default&output=html
Nevada POD data accessed	9/14/2020
Source:	https://hub.arcgis.com/datasets/NDWR::ndwr-water-right-permits?layer=0
Meta data:	https://hub.arcgis.com/datasets/NDWR::ndwr-water-right-permits

MODEL INFORMATION

Model ID	PV19, 99a
Pumping scenario	Proposed
Drawdown threshold	1 ft, layer 1 drawdown
Reference map	GRIA Figure 4-8

Fields joined to POD database	**PRELIMINARY MODEL RESULTS (PODS INTERSECTED WITH SIMULATED DRAWDOWN >1FT)**
DateText	Nevada Only. The prior_dt field is provided in text format as a reference for dates <1/1/1900, which are translated to negative numbers.
DD010	Model simulated drawdown (feet) after 10 years project pumping
DD020	Model simulated drawdown (feet) after 20 years project pumping
DD030	Model simulated drawdown (feet) after 30 years project pumping
DD040	Model simulated drawdown (feet) after 40 years project pumping
DD050	Model simulated drawdown (feet) after 50 years project pumping
DD_r010	Model simulated drawdown (feet) after 50 years project pumping and 10 years recovery with pumping off
DD_r050	Model simulated drawdown (feet) after 50 years project pumping and 50 years recovery with pumping off
DD_r100	Model simulated drawdown (feet) after 50 years project pumping and 100 years recovery with pumping off
DD_r200	Model simulated drawdown (feet) after 50 years project pumping and 200 years recovery with pumping off
Hyperlink (Utah wells only)	POD records that have "WIN" > 0, a well log is available. A URL was created to provide access to the well log, if available. (The URL can also be obtained from "Utah Well Logs" (Utah DWR data source link provided above)

DEFAULT FILTERS APPLIED TO UTAH PODS WORKSHEET: Wells_UT_DD_merge

TYPE	Spring
SUMMARY_ST	P = Perfected: proof filed, right certificated

DEFAULT FILTERS APPLIED TO NEVADA PODS WORKSHEET: Wells_NV_DD_merge

source	SPR	SPRING
app_status	CER	CERTIFICATE (active)
	RES	RESERVED (active)
	VST	VESTED RIGHT (active)

PROPOSED ACTION
UTAH SPRING PODs

WRNUM	CHEXNUM	TYPE	SUMMARY_ST	STATUS	PRIORITY	USES	CFS	ACFT	LOCATION	WIN	OWNER	SOURCE	DD010	DD020	DD030	DD040	DD050	DD_r010	DD_r050	DD_r100	DD_r200
19-284		Spring	P	DIL	1856	S	0.011	0	S4077 E462 NW 02 31S 20W SL	0	COMMERCIAL SECURITY BANK	Unnamed Spring									1.85
19-285		Spring	P	DIL	1856	S	0.011	0	S4077 E924 NW 02 31S 20W SL	0	COMMERCIAL SECURITY BANK	Unnamed Spring									1.85
19-4		Spring	P	APPLCERT	19110731	S	0.02	0	S2390 E2175 NW 28 32S 18W SL	0	ESCALANTE FARMS COMPANY	Bannion Spring								1.31	2.66
14-84		Spring	P	DIL	19030312	OS	0.001	0	N740 E3677 SW 08 24S 17W SL	0	RICHFIELD DISTRICT USA BUREAU OF LAND MANAGEMENT	Tunnel Spring								2.45	4.64
14-122		Spring	P	APPLCERT	20081215	S	0	1.73	N771 W275 E4 32 28S 18W SL	0	STATE OF UTAH SCHOOL AND INSTITUTIONAL TRUST LANDS	Unnamed Spring		1.46	4.70	9.78	16.32	23.71	41.61	42.34	34.23
14-123		Spring	P	APPLCERT	20081215	S	0	1.73	S732 W389 E4 32 28S 18W SL	0	STATE OF UTAH SCHOOL AND INSTITUTIONAL TRUST LANDS	Unnamed Spring		1.51	4.85	10.05	16.73	24.24	42.18	42.69	34.41
14-87		Spring	P	DILCERT	19990426	S	0.045	0	N8 E1708 SW 35 30S 18W SL	0	ESCALANTE FARMS COMPANY	Little Pinto and Big Pinto Springs				1.44	2.82	4.72	14.38	22.80	25.68
14-87		Spring	P	DILCERT	19990426	S	0.045	0	S2483 W1481 NE 02 31S 18W SL	0	ESCALANTE FARMS COMPANY	Little Pinto and Big Pinto Springs				1.24	2.47	4.20	13.30	21.66	24.82
14-91		Spring	P	APPLCERT	19910712	O	0.002	0	N1786 W2284 SE 14 27S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Lopers Spring							2.07	5.00	8.28
19-33		Spring	P	DIL	1856	S	0.011	0	N1140 E690 S4 15 32S 18W SL	0	ESCALANTE FARMS COMPANY	Upper Spanish George Spring Area							1.21	3.02	4.85
19-426		Spring	P	APPLCERT	20000211	S	0	1.28	S503 E245 NW 36 29S 20W SL	0	GARTH AND SHARYL CARTER FAMILY TRUST	Rip Gut Springs No.`s 1, 2 & 2A								1.31	2.07
19-268		Spring	P	DIL	1856	S	0.011	0	S530 W1320 N4 30 32S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Unnamed Spring									1.23
19-426		Spring	P	APPLCERT	20000211	S	0	1.28	S520 E289 NW 36 29S 20W SL	0	GARTH AND SHARYL CARTER FAMILY TRUST	Rip Gut Springs No.`s 1, 2 & 2A								1.31	2.07
19-334		Spring	P	APPLWUC	19841211	S	0.045	4.76	S530 W700 N4 30 32S 19W SL	0	L B FARM CATTLE LP	Unnamed Spring									1.23
19-335		Spring	P	APPLCERT	19930305	OS	0.022	2.8	S376 W980 N4 30 32S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Adit Spring									1.23
19-337		Spring	P	APPLCERT	19860701	DIS	0.047	2.854	S503 E244 NW 36 29S 20W SL	0	GARTH K AND SHARYL L CARTER FAMILY TRUST	Rip Gut Spring Number 2								1.31	2.07
19-426		Spring	P	APPLCERT	20000211	S	0	1.28	S363 E309 NW 36 29S 20W SL	0	GARTH AND SHARYL CARTER FAMILY TRUST	Rip Gut Springs No.`s 1, 2 & 2A								1.31	2.07
19-347		Spring	P	APPLCERT	19901119	D	0	0.45	N502 W767 S4 32 32S 18W SL	0	IRA DOROTHY M. ADKINS	Pinion Spring									1.55
19-348		Spring	P	APPLCERT	19910712	OS	0.001	0	N2661 E226 S4 14 28S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Stanley Seep				1.13	2.24	3.80	11.53	16.99	17.48
19-5		Spring	P	APPLCERT	19100524	S	0.024	0	S2390 E2175 NW 28 32S 18W SL	0	ESCALANTE FARMS COMPANY	Bannion Spring								1.31	2.66
19-57		Spring	P	APPLCERT	19110731	S	0.003	0	S2390 E2175 NW 28 32S 18W SL	0	S. W. COMPANY HALL	Bannion Spring								1.31	2.66
19-63		Spring	P	DILCERT	1856	S	0	8.4	S503 E245 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A								1.31	2.07
19-63		Spring	P	DILCERT	1856	S	0	8.4	S520 E289 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A								1.31	2.07
19-63		Spring	P	DILCERT	1856	S	0	8.4	S363 E309 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A								1.31	2.07
19-64		Spring	P	DILCERT	1856	S	0	8.4	S503 E245 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A								1.31	2.07
19-64		Spring	P	DILCERT	1856	S	0	8.4	S520 E289 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A								1.31	2.07
19-64		Spring	P	DILCERT	1856	S	0	8.4	S363 E309 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A								1.31	2.07
19-66		Spring	P	APPLCERT	19100524	S	0.003	0	S2390 E2175 NW 28 32S 18W SL	0	S. W. COMPANY HALL	Bannion Spring								1.31	2.66
19-67		Spring	P	APPLCERT	19190125	I	0.089	0	N650 E2050 W4 28 32S 18W SL	0	S. W. COMPANY HALL	Bannion Spring Stream								1.49	2.94
19-9		Spring	P	APPLCERT	19190125	I	0.089	0	N650 E2050 W4 28 32S 18W SL	0	ESCALANTE FARMS COMPANY	Bannion Spring Stream								1.49	2.94
19-373		Spring	P	APPLCERT	20000211	D	0	0.45	S378 E316 NW 36 29S 20W SL	0	GARTH AND SHARYL CARTER FAMILY TRUST	Rip Gut Spring 2A								1.31	2.07
19-110		Spring	P	DILCERT	1856	OS	0	16.8	S426 W77 E4 35 28S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Ryan Spring				2.11	4.03	6.58	17.22	22.35	20.72
18-21		Spring	P	APPLCERT	19121122	S	0.002	0	N1200 W2500 SE 08 28S 19W SL	0	E. W. CLAY	Cowboy Spring							2.61	4.53	5.45
19-163		Spring	P	DIL	1856	S	0.011	0	N150 W630 E4 11 32S 20W SL	0	USA BUREAU OF LAND MANAGEMENT	White Rock Spring									1.31
19-164		Spring	P	DIL	1856	S	0.011	0	S1200 W1630 NE 14 32S 20W SL	0	USA BUREAU OF LAND MANAGEMENT	Fence Line Spring									1.31
19-165		Spring	P	DIL	1856	DS	0.011	0	S250 E2000 W4 24 32S 20W SL	0	USA BUREAU OF LAND MANAGEMENT	Middle Rice Spring									1.09
19-166		Spring	P	DIL	1856	DS	0.011	0	S100 W2200 NE 23 32S 20W SL	0	USA BUREAU OF LAND MANAGEMENT	Upper Rice Spring									1.18
19-167		Spring	P	DIL	1856	S	0.011	0	N1160 W90 S4 07 32S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Butcher Spring West									1.55
19-168		Spring	P	DIL	1856	DS	0.011	0	N1130 W500 SE 24 32S 20W SL	0	USA BUREAU OF LAND MANAGEMENT	Lower Rice Spring									1.23
19-169		Spring	P	DIL	1856	S	0.011	0	S60 E1070 W4 31 32S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Unnamed Spring									1.07
19-170		Spring	P	DIL	1856	S	0.011	0	S1540 W1180 NE 31 32S 19W SL	0	CEDAR CITY DISTRICT USA BUREAU OF LAND MANAGEMENT	Pine Creek Spring									1.30
19-171		Spring	P	DIL	1856	S	0.011	0	S680 W630 E4 31 32S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Lower Pine Creek Spring									1.19
19-172		Spring	P	DIL	1856	S	0.011	0	N870 E1570 W4 06 33S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Upper Pine Creek Spring									1.07
19-174		Spring	P	DIL	1856	DS	0.011	0	S1680 W470 N4 04 33S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Forces Spring									1.21
19-387		Spring	P	APPLCERT	20031205	D	0	0.45	S1366 W93 N4 05 33S 18W SL	0	BENJAMIN R. GARCIA	Unnamed Spring									1.55
19-18		Spring	P	APPLCERT	19540625	OS	0.011	0	S1075 E750 N4 10 31S 18W SL	0	USA BUREAU OF LAND MANAGEMENT	Pipeline Spring					1.02	1.78	6.25	11.20	14.06
19-180		Spring	P	DILCERT	1856	O	0.011	1.05	N290 W890 S4 09 27S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Cougar Spring								2.37	4.31
19-181		Spring	P	DILCERT	1856	O	0.011	1.05	N323 W227 SE 27 27S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	North Sulphur Spring							3.44	7.34	10.46
19-20		Spring	P	APPLCERT	19590422	DS	0.002	0	S1504 W2561 E4 07 32S 19W SL	0	BUREAU OF LAND MANAGEMENT	Butcher Spring									1.55
19-232		Spring	P	DILCERT	1856	OS	0	16.8	S367 E12 W4 24 30S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Atchinson Creek Springs								2.06	3.27
19-232		Spring	P	DILCERT	1856	OS	0	16.8	N721 E1287 W4 24 30S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Atchinson Creek Springs							1.86	3.40	4.71
19-24		Spring	P	UGWC	1856	DS	0.018	0	S545 W1370 N4 30 32S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	State Line Spring Stream									1.23
19-25		Spring	P	APPLCERT	19050227	S	0.04	0	N450 W500 SE 07 29S 18W SL	0	SAGE VALLEY HOLDINGS LLC	Green Canyon Seeps Spring #1			2.39	5.49	9.89	15.28	32.76	36.94	31.22
19-26		Spring	P	APPLCERT	19050227	S	0.018	0	N717 E450 SW 20 29S 18W SL	0	SAGE VALLEY HOLDINGS LLC	Side Hill Spring				2.51	4.93	8.22	23.15	31.31	29.10
19-265		Spring	P	DIL	1856	S	0.011	0	S970 E30 NW 30 32S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Unnamed Spring									1.23
19-266		Spring	P	DIL	1856	S	0.011	0	S1130 E30 NW 30 32S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Unnamed Spring									1.23
14-41		Spring	P	DILCERT	19030312	S	0.06	0	N1216 E3194 SW 16 29S 16W SL	0	CEDAR CITY DISTRICT USA BUREAU OF LAND MANAGEMENT	Water Hollow Spring	2.06	9.14	18.49	28.48	38.41	45.60	42.57	31.92	22.16
14-116		Spring	P	APPLCERT	20040517	D	0	1.5	S2027 E577 W4 32 28S 18W SL	0	SAGE VALLEY HOLDINGS LLC	Pine Valley Bench Spring		1.11	3.77	8.13	13.90	20.58	38.28	40.03	32.80
69-105		Spring	P	APPLCERT	20081021	S	0.015	1.73	S1181 E688 N4 32 29S 14W SL	0	UTAH SCHOOL AND INSTITUTIONAL TRUST LANDS	Bumblebee Spring							2.82	5.42	7.82
71-1788		Spring	P	DILCERT	1916	S	0	1.73	N173 W1743 SE 09 33S 18W SL	0	USA BUREAU OF LAND MANAGEMENT	Tillie Creek Spring									1.50
71-2269		Spring	P	DILCERT	1860	S	0.004	0	N375 W430 E4 09 30S 15W SL	0	USA BUREAU OF LAND MANAGEMENT	Seep Spring				1.83	3.33	5.26	13.47	19.24	20.64
71-2272		Spring	P	DILCERT	1860	S	0.022	0	S249 E1189 W4 12 31S 15W SL	0	USA BUREAU OF LAND MANAGEMENT	Prout Doutson Spring						1.04	3.75	6.32	7.21
71-2400		Spring	P	DILCERT	1860	S	0.011	0	N402 W744 S4 21 30S 15W SL	0	USA BUREAU OF LAND MANAGEMENT	Jockey Spring				1.91	3.50	5.58	14.81	21.85	23.77
71-264		Spring	P	DIL	1880	S	0.56	0	N304 W876 SE 03 32S 16W SL	0	MATTHEW AND MARILYN WOOD	Polliwog Spring				1.34	3.02	5.38	16.92	23.80	24.06
71-271		Spring	P	DILCERT	1895	IS	0	28	S328 E1784 W4 10 31S 16W SL	0	MATHEW WOOD	Spring and Underground Water Wells (2)			2.46	5.63	10.07	15.52	33.85	40.85	38.03
71-2858		Spring	P	DILCERT	1860	S	0	1.26	N173 W1743 SE 09 33S 18W SL	0	USA BUREAU OF LAND MANAGEMENT	Tillie Creek Spring									1.50
71-4923		Spring	P	APPLCERT	20050427	S	0	1.73	S1502 W597 N4 02 26S 12W SL	0	STATE OF UTAH SCHOOL INSTITUTIONAL TRUST LANDS ADMI	Hidden Spring									1.09
71-4942		Spring	P	DILCERT	1888	D	0	0.25	N1126 W541 SE 19 32S 17W SL	0	C. DARWIN AND REVOE D. HULET LIVING TRUST	North Trough Spring							4.61	9.00	10.96
71-623		Spring	P	DIL	1888	DS	0.011	0	N109 E709 W4 03 32S 16W SL	0	MATTHEW AND MARILYN WOOD	Mont`s Spring				1.67	3.61	6.32	19.15	26.53	26.52

PROPOSED ACTION
NEVADA SPRING PODs

	site_name	app	cert	app_status	mou	permit_info	basin	county	source	duty_balance	div_balance	prior_dt	pod_twn	pod_rng	pod_sec	pod_q	pod_qq	poly_id	DateText	DD010	DD020	DD030	DD040	DD050	DD_r010	DD_r050	DD_r100	DD_r200
196	N02 E71 29D 1	R04555		RES	OTH	http://water.nv.gov/permitinformation.aspx?app=R04555	196	LI	SPR	0	0.006	1926-04-17	02N	71E	29	SE	SE		19260417									1.04
196	N04 E71 06ADCB1	V02120		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02120	196	LI	SPR	0	0.025	1900-01-01	04N	70E	01	NE	NE		19000101								1.10	1.81
196	N04 E71 06ADDC1	V02119		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02119	196	LI	SPR	0	0.025	1900-01-01	04N	70E	01	SE	NE		19000101								1.10	1.92
196	N04 E71 06CBCA1	V02123		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02123	196	LI	SPR	0	0.025	1900-01-01	04N	71E	06	SW	NW		19000101									1.17
196	N04 E71 06DAAD1	V02124		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02124	196	LI	SPR	0	0.025	1900-01-01	04N	71E	06	SE			19000101								1.10	1.92
196	N04 E71 08AAAD1	V02122		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02122	196	LI	SPR	0	0.025	1900-01-01	04N	70E	12	NE	NE		19000101								1.19	2.05
196	N04 E71 18DCCC1	V02112		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02112	196	LI	SPR	0	0.025	1900-01-01	04N	70E	18	NE	SW		19000101									1.68
196	N04 E71 29ABBD1	V02113		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02113	201	LI	SPR	0	0.025	1900-01-01	04N	70E	25	NE	NE		19000101									1.55
196	N04 E71 30DB 1	V02115		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02115	196	LI	SPR	0	0.025	1900-01-01	04N	71E	30	SE	NW		19000101									1.48
196	N05 E70 25DBAB1	V11457		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V11457	196	LI	SPR	0	0.025	##########	05N	70E	25	SE			18900101									1.27
196	N05 E70 25DCDA1	V11455		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V11455	196	LI	SPR	0	0.025	##########	05N	70E	25	SE			18900101									1.27
196	N05 E70 36DACB1	V11448		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V11448	196	LI	SPR	0	0.05	##########	05N	70E	36	SE	NW NE		18900101									1.49
196	N30 W20 02 1	V02205		VST	IRR	http://water.nv.gov/permitinformation.aspx?app=V02205	196	LI	SPR	19.5	0	1900-01-01	04N	70E	12	NE	SW NE	14763	19000101								1.19	2.05
201	N02 E71 29BDAB1	V04410		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V04410	201	LI	SPR	0	0.006	1926-04-17	02N	71E	29	NE	SW		19260417									1.04
201	N03 E70 01DBAC1	R04417		RES	OTH	http://water.nv.gov/permitinformation.aspx?app=R04417	201	LI	SPR	0	0.004	1926-04-17	03N	70E	01	SE	NW		19260417									1.01
201	N03 E71 05AAAC1	R04419		RES	OTH	http://water.nv.gov/permitinformation.aspx?app=R04419	201	LI	SPR	0	0.004	1926-04-17	03N	71E	05	NE	NE		19260417									1.84
201	N03 E71 29BDCD1	R04425		RES	OTH	http://water.nv.gov/permitinformation.aspx?app=R04425	201	LI	SPR	0	0.004	1926-04-17	03N	71E	29	NW	SE		19260417									1.09
201	N03 E71 31ABAB1	R04426		RES	OTH	http://water.nv.gov/permitinformation.aspx?app=R04426	201	LI	SPR	0	0.004	1926-04-17	03N	71E	31	NE	NW		19260417									1.09
201	N04 E70 24ADDB1	V02111		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02111	201	LI	SPR	0	0.025	1900-01-01	04N	70E	24	NE	SE		19000101									1.14
201	N04 E71 18DB 1	R04439		RES	OTH	http://water.nv.gov/permitinformation.aspx?app=R04439	201	LI	SPR	0	0.004	1926-04-17	04N	71E	18	SE	NE		19260417									1.68
201	N04 E71 18DDCB1	R04441		RES	OTH	http://water.nv.gov/permitinformation.aspx?app=R04441	201	LI	SPR	0	0.004	1926-04-17	04N	71E	18	SE	SE		19260417									1.68
201	N04 E71 29BAA 1	R04440		RES	OTH	http://water.nv.gov/permitinformation.aspx?app=R04440	201	LI	SPR	0	0.004	1926-04-17	04N	71E	29	NW	NE		19260417									1.55
201	N04 E71 29BB 1	V02114		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02114	201	LI	SPR	0	0.025	1900-01-01	04N	70E	25	NE			19000101									1.55
201	N04 E71 31CDBA1	R04443		RES	OTH	http://water.nv.gov/permitinformation.aspx?app=R04443	201	LI	SPR	0	0.004	1926-04-17	04N	71E	32	SE	SW		19260417									1.03

PROPOSED ACTION
UNDERGROUND (WELL) PODs

POINT OF DIVERSION INFORMATION

Utah POD data accessed:	7/27/20
Source:	https://opendata.gis.utah.gov/search?groupIds=4de5aefb5f6540348da4c633bd57cced&source=utah%20division%20of%20water%20rights
Meta data:	https://www.arcgis.com/sharing/rest/content/items/5d530e62e6ca42528dd13e0a453a3b73/info/metadata/metadata.xml?format=default&output=html
Nevada POD data accessed	9/14/2020
Source:	https://hub.arcgis.com/datasets/NDWR::ndwr-water-right-permits?layer=0
Meta data:	https://hub.arcgis.com/datasets/NDWR::ndwr-water-right-permits

MODEL INFORMATION

Model ID	PV19, 99a
Pumping scenario	Proposed Action
Drawdown threshold	15 ft drawdown
Reference map	GRIA Figure 4-6

PRELIMINARY MODEL RESULTS (PODS INTERSECTED WITH SIMULATED DRAWDOWN >1FT)

Fields joined to POD database	
DateText	Nevada Only. The prior_dt field is provided in text format as a reference for dates <1/1/1900, which are translated to negative numbers.
DD010	Model simulated drawdown (feet) after 10 years project pumping
DD020	Model simulated drawdown (feet) after 20 years project pumping
DD030	Model simulated drawdown (feet) after 30 years project pumping
DD040	Model simulated drawdown (feet) after 40 years project pumping
DD050	Model simulated drawdown (feet) after 50 years project pumping
DD_r010	Model simulated drawdown (feet) after 50 years project pumping and 10 years recovery with pumping off
DD_r050	Model simulated drawdown (feet) after 50 years project pumping and 50 years recovery with pumping off
DD_r100	Model simulated drawdown (feet) after 50 years project pumping and 100 years recovery with pumping off
DD_r200	Model simulated drawdown (feet) after 50 years project pumping and 200 years recovery with pumping off
Hyperlink (Utah only)	POD records that have "WIN" > 0, a well log is available. A URL was created to provide access to the well log, if available. (The URL can also be obtained from "Utah Well Logs" (Utah DWR data source link provided above)

DEFAULT FILTERS APPLIED TO UTAH PODS WORKSHEET: Wells_UT_DD_merge

TYPE	Underground
SUMMARY_ST	P = Perfected: proof filed, right certificated

DEFAULT FILTERS APPLIED TO NEVADA PODS WORKSHEET: Wells_NV_DD_merge

not applicable

PROPOSED ACTION
UTAH UNDERGROUND (WELL) PODs

WRNUM	CHEXNUM	TYPE	SUMMARY_ST	STATUS	PRIORITY	USES	CFS	ACFT	LOCATION	WIN	OWNER	SOURCE	DD010	DD020	DD030	DD040	DD050	Hyperlink
14-121		Underground	P	APPLCERT	20071206	D	0	0.25	N127 E201 W4 03 30S 18W SL	436082	LARY M. CARTER	Underground Water Well				15.91	23.35	https://waterrights.utah.gov/wellinfo/welldrilling/wlbrowse.asp?WIN=436082
14-28		Underground	P	APPLCERT	19440522	O	0.094	0	S218 W930 E4 10 30S 18W SL	0	TINTIC STANDARD MINING COMPANY	Underground Water Well				17.49	25.32	
14-47		Underground	P	UGWC	1930	S	0.002	0	S1130 W1493 NE 23 29S 16W SL	0	NELLIE R. EYRE	Underground Drain				18.75	24.57	
14-108		Underground	P	APPLCERT	19940607	I	0	0.25	N2013 E1625 SW 15 30S 17W SL	10968	S-CAPE LODGE LLC	Underground Water Well		40.43	68.25	94.74	119.47	https://waterrights.utah.gov/wellinfo/welldrilling/wlbrowse.asp?WIN=10968
14-109		Underground	P	APPLCERT	20001207	O	0	0.25	N2013 E1625 SW 15 30S 17W SL	10968	S-CAPE LODGE LLC	Underground Water Well		40.43	68.25	94.74	119.47	https://waterrights.utah.gov/wellinfo/welldrilling/wlbrowse.asp?WIN=10968
14-114		Underground	P	APPLCERT	20000110	DIS	0	1.73	N2012 E1625 SW 15 30S 17W SL	0	S-CAPE LODGE LLC	Underground Water Well		40.43	68.25	94.74	119.47	

ANWS ALTERNATIVE
SPRING PODs

POINT OF DIVERSION INFORMATION

Utah POD data accessed:	7/27/20
Source:	https://opendata.gis.utah.gov/search?groupIds=4de5aefb5f6540348da4c633bd57cced&source=utah%20division%20of%20water%20rights
Meta data:	https://www.arcgis.com/sharing/rest/content/items/5d530e62e6ca42528dd13e0a453a3b73/info/metadata/metadata.xml?format=default&output=html
Nevada POD data accessed	9/14/2020
Source:	https://hub.arcgis.com/datasets/NDWR::ndwr-water-right-permits?layer=0
Meta data:	https://hub.arcgis.com/datasets/NDWR::ndwr-water-right-permits

MODEL INFORMATION

Model ID	PV19, 99b
Pumping scenario	ANWS Alternative
Drawdown threshold	1 ft, layer 1 drawdown
Reference map	GRIA Figure 4-10

Fields joined to POD database	**PRELIMINARY MODEL RESULTS (PODS INTERSECTED WITH SIMULATED DRAWDOWN >1FT)**
DateText	Nevada Only. The prior_dt field is provided in text format as a reference for dates <1/1/1900, which are translated to negative numbers.
DD010	Model simulated drawdown (feet) after 10 years project pumping
DD020	Model simulated drawdown (feet) after 20 years project pumping
DD030	Model simulated drawdown (feet) after 30 years project pumping
DD040	Model simulated drawdown (feet) after 40 years project pumping
DD050	Model simulated drawdown (feet) after 50 years project pumping
DD_r010	Model simulated drawdown (feet) after 50 years project pumping and 10 years recovery with pumping off
DD_r050	Model simulated drawdown (feet) after 50 years project pumping and 50 years recovery with pumping off
DD_r100	Model simulated drawdown (feet) after 50 years project pumping and 100 years recovery with pumping off
DD_r200	Model simulated drawdown (feet) after 50 years project pumping and 200 years recovery with pumping off
Hyperlink (Utah wells only)	POD records that have "WIN" > 0, a well log is available. A URL was created to provide access to the well log, if available. (The URL can also be obtained from "Utah Well Logs" (Utah DWR data source link provided above)

DEFAULT FILTERS APPLIED TO UTAH PODS WORKSHEET: Wells_UT_DD_merge

TYPE	Spring
SUMMARY_ST	P = Perfected: proof filed, right certificated

DEFAULT FILTERS APPLIED TO NEVADA PODS WORKSHEET: Wells_NV_DD_merge

source	SPR	SPRING
app_status	RES	RESERVED (active)
	VST	VESTED RIGHT (active)

ANWS ALTERNATIVE
UTAH SPRING PODs

WRNUM	CHEXNUM	TYPE	SUMMARY_ST	STATUS	PRIORITY	USES	CFS	ACFT	LOCATION	WIN	OWNER	SOURCE	DD010	DD020	DD030	DD040	DD050	DD_r010	DD_r050	DD_r100	DD_r200
19-284		Spring	P	DIL	1856	S	0.011	0	S4077 E462 NW 02 31S 20W SL	0	COMMERCIAL SECURITY BANK	Unnamed Spring									1.01
19-285		Spring	P	DIL	1856	S	0.011	0	S4077 E924 NW 02 31S 20W SL	0	COMMERCIAL SECURITY BANK	Unnamed Spring									1.01
19-4		Spring	P	APPLCERT	19110731	S	0.02	0	S2390 E2175 NW 28 32S 18W SL	0	ESCALANTE FARMS COMPANY	Bannion Spring									1.25
14-84		Spring	P	DIL	19030312	OS	0.001	0	N740 E3677 SW 08 24S 17W SL	0	RICHFIELD DISTRICT USA BUREAU OF LAND MANAGEMENT	Tunnel Spring						1.61	5.07	8.26	9.84
14-122		Spring	P	APPLCERT	20081215	S	0	1.73	N771 W275 E4 32 28S 18W SL	0	STATE OF UTAH SCHOOL AND INSTITUTIONAL TRUST LANDS	Unnamed Spring			2.67	5.66	9.60	14.20	27.18	30.16	26.54
14-123		Spring	P	APPLCERT	20081215	S	0	1.73	S732 W389 E4 32 28S 18W SL	0	STATE OF UTAH SCHOOL AND INSTITUTIONAL TRUST LANDS	Unnamed Spring			2.73	5.77	9.79	14.44	27.45	30.33	26.62
14-87		Spring	P	DILCERT	19990426	S	0.045	0	N8 E1708 SW 35 30S 18W SL	0	ESCALANTE FARMS COMPANY	Little Pinto and Big Pinto Springs					1.19	2.01	6.39	10.77	13.27
14-87		Spring	P	DILCERT	19990426	S	0.045	0	S2483 W1481 NE 02 31S 18W SL	0	ESCALANTE FARMS COMPANY	Little Pinto and Big Pinto Springs					1.04	1.78	5.88	10.13	12.66
14-91		Spring	P	APPLCERT	19910712	O	0.002	0	N1786 W2284 SE 14 27S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Lopers Spring							2.83	6.05	9.22
19-33		Spring	P	DIL	1856	S	0.011	0	N1140 E690 S4 15 32S 18W SL	0	ESCALANTE FARMS COMPANY	Upper Spanish George Spring Area								1.35	2.32
19-426		Spring	P	APPLCERT	20000211	S	0	1.28	S503 E245 NW 36 29S 20W SL	0	GARTH AND SHARYL CARTER FAMILY TRUST	Rip Gut Springs No.`s 1, 2 & 2A									1.35
19-426		Spring	P	APPLCERT	20000211	S	0	1.28	S520 E289 NW 36 29S 20W SL	0	GARTH AND SHARYL CARTER FAMILY TRUST	Rip Gut Springs No.`s 1, 2 & 2A									1.35
19-337		Spring	P	APPLCERT	19860701	DIS	0.047	2.854	S503 E244 NW 36 29S 20W SL	0	GARTH K AND SHARYL L CARTER FAMILY TRUST	Rip Gut Spring Number 2									1.35
19-426		Spring	P	APPLCERT	20000211	S	0	1.28	S363 E309 NW 36 29S 20W SL	0	GARTH AND SHARYL CARTER FAMILY TRUST	Rip Gut Springs No.`s 1, 2 & 2A									1.35
19-348		Spring	P	APPLCERT	19910712	OS	0.001	0	N2661 E226 S4 14 28S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Stanley Seep					1.54	2.62	8.19	12.78	14.12
19-5		Spring	P	APPLCERT	19100524	S	0.024	0	S2390 E2175 NW 28 32S 18W SL	0	ESCALANTE FARMS COMPANY	Bannion Spring									1.25
19-57		Spring	P	APPLCERT	19110731	S	0.003	0	S2390 E2175 NW 28 32S 18W SL	0	S. W. COMPANY HALL	Bannion Spring									1.25
19-63		Spring	P	DILCERT	1856	S	0	8.4	S503 E245 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A									1.35
19-63		Spring	P	DILCERT	1856	S	0	8.4	S520 E289 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A									1.35
19-63		Spring	P	DILCERT	1856	S	0	8.4	S363 E309 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A									1.35
19-64		Spring	P	DILCERT	1856	S	0	8.4	S503 E245 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A									1.35
19-64		Spring	P	DILCERT	1856	S	0	8.4	S520 E289 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A									1.35
19-64		Spring	P	DILCERT	1856	S	0	8.4	S363 E309 NW 36 29S 20W SL	0	SAGE VALLEY HOLDINGS LLC	Rip Gut Springs #1, #2, and #2A									1.35
19-66		Spring	P	APPLCERT	19100524	S	0.003	0	S2390 E2175 NW 28 32S 18W SL	0	S. W. COMPANY HALL	Bannion Spring									1.25
19-67		Spring	P	APPLCERT	19190125	I	0.089	0	N650 E2050 W4 28 32S 18W SL	0	S. W. COMPANY HALL	Bannion Spring Stream									1.38
19-9		Spring	P	APPLCERT	19190125	I	0.089	0	N650 E2050 W4 28 32S 18W SL	0	ESCALANTE FARMS COMPANY	Bannion Spring Stream									1.38
19-373		Spring	P	APPLCERT	20000211	D	0	0.45	S378 E316 NW 36 29S 20W SL	0	GARTH AND SHARYL CARTER FAMILY TRUST	Rip Gut Spring 2A									1.35
19-110		Spring	P	DILCERT	1856	OS	0	16.8	S426 W77 E4 35 28S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Ryan Spring				1.24	2.40	3.97	11.11	15.60	15.76
18-21		Spring	P	APPLCERT	19121122	S	0.002	0	N1200 W2500 SE 08 28S 19W SL	0	E. W. CLAY	Cowboy Spring							1.85	3.37	4.33
19-18		Spring	P	APPLCERT	19540625	OS	0.011	0	S1075 E750 N4 10 31S 18W SL	0	USA BUREAU OF LAND MANAGEMENT	Pipeline Spring							2.77	5.22	7.09
19-180		Spring	P	DILCERT	1856	O	0.011	1.05	N290 W890 S4 09 27S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Cougar Spring							1.11	2.73	4.68
19-181		Spring	P	DILCERT	1856	O	0.011	1.05	N323 W227 SE 27 27S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	North Sulphur Spring							3.23	6.79	9.81
19-232		Spring	P	DILCERT	1856	OS	0	16.8	S367 E12 W4 24 30S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Atchinson Creek Springs								1.07	1.80
19-232		Spring	P	DILCERT	1856	OS	0	16.8	N721 E1287 W4 24 30S 19W SL	0	USA BUREAU OF LAND MANAGEMENT	Atchinson Creek Springs								1.78	2.65
19-25		Spring	P	APPLCERT	19050227	S	0.04	0	N450 W500 SE 07 29S 18W SL	0	SAGE VALLEY HOLDINGS LLC	Green Canyon Seeps Spring #1			1.27	2.97	5.45	8.58	20.02	24.73	22.95
19-26		Spring	P	APPLCERT	19050227	S	0.018	0	N717 E450 SW 20 29S 18W SL	0	SAGE VALLEY HOLDINGS LLC	Side Hill Spring				1.24	2.48	4.22	12.89	19.12	19.69
14-41		Spring	P	DILCERT	19030312	S	0.06	0	N1216 E3194 SW 16 29S 16W SL	0	CEDAR CITY DISTRICT USA BUREAU OF LAND MANAGEMENT	Water Hollow Spring	1.02	4.41	8.83	13.59	18.40	21.99	22.16	18.48	14.26
14-116		Spring	P	APPLCERT	20040517	D	0	1.5	S2027 E577 W4 32 28S 18W SL	0	SAGE VALLEY HOLDINGS LLC	Pine Valley Bench Spring			2.13	4.67	8.12	12.24	24.80	28.29	25.27
69-105		Spring	P	APPLCERT	20081021	S	0.015	1.73	S1181 E688 N4 32 29S 14W SL	0	UTAH SCHOOL AND INSTITUTIONAL TRUST LANDS	Bumblebee Spring							1.39	2.74	4.17
71-2269		Spring	P	DILCERT	1860	S	0.004	0	N375 W430 E4 09 30S 15W SL	0	USA BUREAU OF LAND MANAGEMENT	Seep Spring					1.54	2.42	6.26	9.31	10.72
71-2272		Spring	P	DILCERT	1860	S	0.022	0	S249 E1189 W4 12 31S 15W SL	0	USA BUREAU OF LAND MANAGEMENT	Prout Doutson Spring							1.64	2.86	3.52
71-2400		Spring	P	DILCERT	1860	S	0.011	0	N402 W744 S4 21 30S 15W SL	0	USA BUREAU OF LAND MANAGEMENT	Jockey Spring					1.59	2.52	6.70	10.24	11.98
71-264		Spring	P	DIL	1880	S	0.56	0	N304 W876 SE 03 32S 16W SL	0	MATTHEW AND MARILYN WOOD	Polliwog Spring					1.24	2.19	7.28	10.76	11.84
71-4923		Spring	P	APPLCERT	20050427	S	0	1.73	S1502 W597 N4 02 26S 12W SL	0	STATE OF UTAH SCHOOL INSTITUTIONAL TRUST LANDS ADMIN	Hidden Spring							1.47	1.94	2.02
71-4942		Spring	P	DILCERT	1888	D	0	0.25	N1126 W541 SE 19 32S 17W SL	0	C. DARWIN AND REVOE D. HULET LIVING TRUST	North Trough Spring							2.00	4.06	5.32
71-623		Spring	P	DIL	1888	DS	0.011	0	N109 E709 W4 03 32S 16W SL	0	MATTHEW AND MARILYN WOOD	Mont`s Spring					1.51	2.62	8.27	12.03	13.10
71-271		Spring	P	DILCERT	1895	IS	0	28	S328 E1784 W4 10 31S 16W SL	0	MATHEW WOOD	Spring and Underground Water Wells (2)	1.07	2.44	4.34	6.68	14.83	18.88	19.22		

ANWS ALTERNATIVE
NEVADA SPRING PODs

site_name	app	cert	app_status	mou	permit_info	basin	county	source	duty_balance	div_balance	prior_dt	pod_twn	pod_rng	pod_sec	pod_q	pod_qq	poly_id	DateText	DD010	DD020	DD030	DD040	DD050	DD_r010	DD_r050	DD_r100	DD_r200
196 N04 E71 06ADCB1	V02120		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02120	196	LI	SPR	0	0.025	1900-01-01	04N	70E	01	NE	NE		19000101									1.17
196 N04 E71 06ADDC1	V02119		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02119	196	LI	SPR	0	0.025	1900-01-01	04N	70E	01	SE	NE		19000101									1.21
196 N04 E71 06DAAD1	V02124		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02124	196	LI	SPR	0	0.025	1900-01-01	04N	71E	06	SE			19000101									1.21
196 N04 E71 08AAAD1	V02122		VST	STK	http://water.nv.gov/permitinformation.aspx?app=V02122	196	LI	SPR	0	0.025	1900-01-01	04N	70E	12	NE	NE		19000101									1.29
196 N30 W20 02 1	V02205		VST	IRR	http://water.nv.gov/permitinformation.aspx?app=V02205	196	LI	SPR	19.5	0	1900-01-01	04N	70E	12	NE	NE	14763	19000101									1.29
201 N03 E71 05AAAC1	R04419		RES	OTH	http://water.nv.gov/permitinformation.aspx?app=R04419	201	LI	SPR	0	0.004	1926-04-17	03N	71E	05	NE	NE		19260417									1.02

ANWS ALTERNATIVE
UNDERGROUND (WELL) PODs

POINT OF DIVERSION INFORMATION

Utah POD data accessed:	7/27/20
Source:	https://opendata.gis.utah.gov/search?groupIds=4de5aefb5f6540348da4c633bd57cced&source=utah%20division%20of%20water%20rights
Meta data:	https://www.arcgis.com/sharing/rest/content/items/5d530e62e6ca42528dd13e0a453a3b73/info/metadata/metadata.xml?format=default&output=html
Nevada POD data accessed	9/14/2020
Source:	https://hub.arcgis.com/datasets/NDWR::ndwr-water-right-permits?layer=0
Meta data:	https://hub.arcgis.com/datasets/NDWR::ndwr-water-right-permits

MODEL INFORMATION

Model ID	PV19, 99b
Pumping scenario	ANWS Alternative
Drawdown threshold	15 ft drawdown
Reference map	GRIA Figure 4-7

Fields joined to POD database	**PRELIMINARY MODEL RESULTS (PODS INTERSECTED WITH SIMULATED DRAWDOWN >=15FT)**
DateText	Nevada Only. The prior_dt field is provided in text format as a reference for dates <1/1/1900, which are translated to negative numbers.
DD010	Model simulated drawdown (feet) after 10 years project pumping
DD020	Model simulated drawdown (feet) after 20 years project pumping
DD030	Model simulated drawdown (feet) after 30 years project pumping
DD040	Model simulated drawdown (feet) after 40 years project pumping
DD050	Model simulated drawdown (feet) after 50 years project pumping
DD_r010	Model simulated drawdown (feet) after 50 years project pumping and 10 years recovery with pumping off
DD_r050	Model simulated drawdown (feet) after 50 years project pumping and 50 years recovery with pumping off
DD_r100	Model simulated drawdown (feet) after 50 years project pumping and 100 years recovery with pumping off
DD_r200	Model simulated drawdown (feet) after 50 years project pumping and 200 years recovery with pumping off
Hyperlink (Utah only)	POD records that have "WIN" > 0, a well log is available. A URL was created to provide access to the well log, if available. (The URL can also be obtained from "Utah Well Logs" (Utah DWR data source link provided above)

DEFAULT FILTERS APPLIED TO UTAH PODS WORKSHEET: Wells_UT_DD_merge

TYPE	Underground
SUMMARY_ST	P = Perfected: proof filed, right certificated

DEFAULT FILTERS APPLIED TO NEVADA PODS WORKSHEET: Wells_NV_DD_merge

not applicable

ANWS ALTERNATIVE
UTAH UNDERGROUND (WELL) PODs

WRNUM	CHEXNUM	TYPE	SUMMARY_ST	STATUS	PRIORITY	USES	CFS	ACFT	LOCATION	WIN	OWNER	SOURCE	DD010	DD020	DD030	DD040	DD050	Hyperlink
14-89		Underground	P	UGWCCERT	192910	S	0.033	0	S2028 W3089 NE 18 25S 16W SL	433610	USA BUREAU OF LAND MANAGEMENT	Underground Water Well				15.09	20.54	https://waterrights.utah.gov/wellinfo/welldrilling/wlbrowse.asp?WIN=433610
14-27		Underground	P	APPLCERT	19440408	S	0.016	0	N1516 W972 SE 17 26S 17W SL	0	USA BUREAU OF LAND MANAGEMENT	Underground Water Well				18.66	24.68	
14-42		Underground	P	UGWC	192910	S	0.041	0	N606 E2145 W4 18 25S 16W SL	0	CARTER CATTLE FAMILY PARTNERSHIP LP	Underground Water Well				15.09	20.54	
14-43		Underground	P	UGWC	193102	S	0.033	0	S660 W330 NE 08 26S 16W SL	0	THOMAS BEARDEN	Underground Water Well				17.62	23.46	
14-44		Underground	P	UGWC	19331114	DIS	0.022	0	N2152 W2270 SE 33 25S 17W SL	21108	USA FOREST SERVICE	Underground Water Well				15.27	20.72	https://waterrights.utah.gov/wellinfo/welldrilling/wlbrowse.asp?WIN=21108
14-45		Underground	P	UGWC	19281130	S	0.045	0	N200 E2440 W4 18 25S 16W SL	0	THOMAS D. DEARDEN	Underground Water Well				15.09	20.54	
14-108		Underground	P	APPLCERT	19940607	I	0	0.25	N2013 E1625 SW 15 30S 17W SL	10968	S-CAPE LODGE LLC	Underground Water Well		16.18	27.94	39.29	50.06	https://waterrights.utah.gov/wellinfo/welldrilling/wlbrowse.asp?WIN=10968
14-109		Underground	P	APPLCERT	20001207	O	0	0.25	N2013 E1625 SW 15 30S 17W SL	10968	S-CAPE LODGE LLC	Underground Water Well		16.18	27.94	39.29	50.06	https://waterrights.utah.gov/wellinfo/welldrilling/wlbrowse.asp?WIN=10968
14-114		Underground	P	APPLCERT	20000110	DIS	0	1.73	N2012 E1625 SW 15 30S 17W SL	0	S-CAPE LODGE LLC	Underground Water Well		16.18	27.94	39.29	50.06	
71-2820		Underground	P	APPLNPR	19581030	DS	0	0	N1315 W105 S4 05 26S 16W SL	0	LEORNAL GARDNER	Underground Water Well				17.08	22.84	