Big Valley Groundwater Sustainability Plan

Public Review Draft
October 2021

No. 5-004 Big Valley Groundwater Basin

Prepared by:

Big Valley Groundwater Sustainability Plan

Public Review Draft October 28, 2021

Prepared by:

Lassen County
Groundwater Sustainability Agency

Modoc County
Groundwater Sustainability Agency

Board Members

Lassen County:

Aaron Albaugh (District 4), Chair
Chris Gallagher (District 1), Vice-Chair
Gary Bridges (District 2)
Jeff Hemphill (District 3)
Tom Hammond (District 5)

Modoc County:

Ned Coe (District I), Chair
Geri Byrne (District V), Vice-Chair
Kathie Rhoads (District III)
Elizabeth Cavasso (District IV)
Vacant (District II)

County Staff

Department of Planning and Building Services
Maurice Anderson, Director
Gaylon Norwood, Assistant Director
Nancy McAllister, Associate Planner
Brooke Suarez, Fiscal Officer
Dana Hopkins, Administrative Assistant

Office of Administration
Tiffany Martinez, Assistant County Administrative Officer

Big Valley Groundwater Basin Advisory Committee

Aaron Albaugh, Board Representative, Vice-Chair
Gary Bridges, Alt. Board Representative
Kevin Mitchell, Public Representative
Duane Conner, Public Representative

Geri Byrne, Board Representative, Chair
Ned Coe, Alt. Board Representative
Jimmy Nunn, Public Representative
John Ohm, Public Representative

Technical Team

Laura K. Snell, University of California Cooperative Extension, Modoc County
David F. Lile, University of California Cooperative Extension, Lassen County
Claire K. Bjork, University of California Cooperative Extension, Modoc County
David Fairman, GEI Consultants
Rodney Fricke, GEI Consultants
Chris Petersen, GEI Consultants

Other Acknowledgements

Stacey Hafen, Executive Director North Cal-Neva Resource Conservation and Development Council
Jason Housel, Lassen County Information Technology

The Basin Setting (Chapters 4-6) was developed under the direction of Professional Geologists:

{STAMP}

David Fairman
Professional Geologist 9025

{STAMP}

Rodney Fricke
Professional Geologist 4089

Cover photo credits: Pivot: Laura Snell; Deer in Alfalfa: Kim Steed Photography

<< Insert GSA Resolutions Adopting the Plan Here >>

Table of Contents

List of Figures

List of Tables

List of Appendices

Acronyms and Abbreviations

ACWA	Ash Creek Wildlife Area
AF	acre-feet
AFY	acre-feet per year
AgMAR	Agriculture Managed Aquifer Recharge
ASR	Aquifer Storage and Recovery
Basin	Big Valley Groundwater Basin
Basin Plan	Water Quality Control Plan
bgs	below ground surface
BIA	U.S. Bureau of Indian Affairs
Big Valley	Big Valley Groundwater Basin
BLM	U.S. Bureau of Land Management
BMO	Basin Management Objective
BMP	Best Management Practices
BVGB	Big Valley Groundwater Basin
BVAC	Big Valley Groundwater Basin Advisory Committee
BVWUA	Big Valley Water Users Association
C&E	communication and engagement
CAL FIRE	California Department of Forestry and Fire Protection
CASGEM	California Statewide Groundwater Elevation Monitoring
CDEC	California Data Exchange Center
CDFA	California Dept of Food and Agriculture
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CFCC	California Financing Coordinating Committee
CGPS	continuous global positioning system
CIMIS	California Irrigation Management Information System
CRP	conservation reserve program
CWA	Clean Water Act
CWC	California Water Code

DDW	State Water Resources Control Board's Division of Drinking Water
District	Lassen-Modoc County Flood Control and Water Conservation District
DMS	Data Management System
DOI	Department of the Interior
DTW	depth to water
DWR	California Department of Water Resources
EC	electrical conductivity
EQIP	Environmental Quality Incentives Program
ET	evapotranspiration
ETo	reference evapotranspiration
°F	degrees Fahrenheit
Forest Service	U.S. Forest Service
ft bgs	feet below ground surface
ft/d	foot or feet per day
ft/yr	foot or feet per year
GAMA	Groundwater Ambient Monitoring and Assessment Program
GAMA GIS	GAMA Groundwater Information System
GDE	groundwater dependent ecosystem
General Order	Statewide ASR General Order
GIS	geographic information system
GP	General Plan
gpm	gallons per minute
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	hydrogeologic conceptual model
HSG	Hydrologic Soils Group
IC	institutional controls
ILRP	Irrigated Lands Regulatory Program
IM	Interim Milestone
in/hr	inches per hour
InSAR	Interferometric Synthetic Aperture Radar, a technology used to detect subsidence

IRWMP	Upper Pit Integrated Regional Water Management Plan
IWFM	Integrated Water Flow Model
LCGMP	Lassen County Groundwater Management Plan
LCWD #1	Lassen County Waterworks District #1
LNAPL	Light non-aqueous phase liquid (found in petroleum hydrocarbons)
LUST	Leaking underground storage tank
M	million
MCL	Maximum Contaminant Level
Mn	manganese
MOMeasurable Objective	
MOU	Memorandum of Understanding
msl	mean sea level
MT Minimum Threshold	
MTBE	Methyl tert-butyl ether
NCCAG	Natural Communities Commonly Associated with Groundwater
North Cal-Neva	North Cal-Neva Resource Conservation and Development Council
NCWA	Northern California Water Association
NECWA	Northeastern California Water Association
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NR	Natural Resources
NRCS	Natural Resources Conservation Service
NSP	Nonpoint Source Program
OS	Open Space
OWTS	Onsite Water Treatment System
PFAS	per/polyfluoroalkyl substances
PG&E	Pacific Gas and Electric
Plan	Groundwater Sustainability Plan
Reclamation	United States Bureau of Reclamation
RWMG	Regional Water Management Group

RWQCB	Regional Water Quality Control Board
RWQCB-R5	Regional Water Quality Control Board Region 5
Regulations	GSP Regulations, California Code of Regulations Title 23, Division 2, Chapter 1.5
SAGBI	Soil Agricultural Groundwater Banking Index
SB	Senate Bill
SC	specific conductance
SGMA	Sustainable Groundwater Management Act of 2014
SMC	Sustainable Management Criteria
SRI	Sacramento River Index of water year types
SSURGO	Soil Survey Geographic Database
State Water Board	California State Water Resources Control Board
SVE	Surprise Valley Electric
SVWQC	Sacramento Valley Water Quality Coalition
SWEEP	State Water Efficiency and Enhancement Program
SY	specific yield
TBA	tert-Butyl alcohol
TDS	total dissolved solids
TMDL	Total Maximum Daily Load Program
TNC	The Nature Conservancy
UCCE	University of California Cooperative Extension
U.S.	United States
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	United States Geologic Survey
UST	Underground Storage Tank
WAA	Water Availability Analysis
WCR	well completion report
WDR	Waste Discharge Requirement
WRP	wetland reserve project
WY	Water Year (October 1 – September 30)

Executive Summary

ES.1. Introduction & Plan Area (Chapters 1 – 3)

The Big Valley Groundwater Basin (BVGB, Basin, or Big Valley) lies on the border of Modoc and Lassen counties in one of the most remote and untouched areas of California. The sparsely populated Big Valley has a rich biodiversity of wildlife and native species who live, feed and raise young on the irrigated lands throughout the Basin. The snow-fed high desert streams entering the Basin have seasonal hydrographs with natural periods of reduced flows or complete cessation of flows late in the summer season. The Pit River is the largest stream and is so named because of the practice, employed by the Achumawi and other Native American bands that are now part of the Pit River Tribe, of digging pits in the river channel when it went dry to expose water and trap game that came to water at the river. Farming and ranching in Big Valley date back to the late 19th and early 20th centuries, when families immigrated to Big Valley and made use of the existing water resources. A large amount of the land in the Basin is still owned and farmed by the families who homesteaded here.

Historically, agriculture was complemented by a robust timber industry as a key component of the economy for Big Valley, which supported four lumber mills. Due to regulations and policies imposed by state and federal governments, the timber industry has been diminished over time and subsequently caused a great economic hardship to the Big Valley communities. Stakeholders realize that the Sustainable Groundwater Management Act of 2014 (SGMA) will unfortunately cause a similar decline to agriculture. The change in land management has transformed once thriving communities in the Basin to “disadvantaged” and “severely disadvantaged” communities. Viable agriculture is of paramount importance to the residents of Big Valley because it supports the local economy and unique character of the community. As required by SGMA, stakeholders have developed a sustainability goal:

> The sustainability goal for the Big Valley Groundwater Basin is to maintain a locally governed, economically feasible, sustainable groundwater basin and surrounding watershed for existing and future legal beneficial uses with a concentration on agriculture. Sustainable management will be conducted in context with the unique culture of the basin, character of the community, quality of life of the Big Valley residents, and the vested right of agricultural pursuits through the continued use of groundwater and surface water.

Lassen and Modoc counties are fulfilling their unfunded, mandated roles as Groundwater Sustainability Agencies (GSAs) to develop this Groundwater Sustainability Plan (GSP) after exhausting its administrative challenges to the California Department of Water Resources’ (DWR’s) determination that Big Valley qualifies as a medium-priority basin. Both counties are disadvantaged, have declining populations, and have no ability to cover the costs of GSP development and implementation.

The Basin, shown on **Figure ES-1**, encompasses an area of about 144 square miles (92,057 acres), with Modoc County representing 28 percent and Lassen County comprising 72 percent of the Basin by area. The Basin includes the towns of Adin and Lookout in Modoc County and the towns of Bieber and

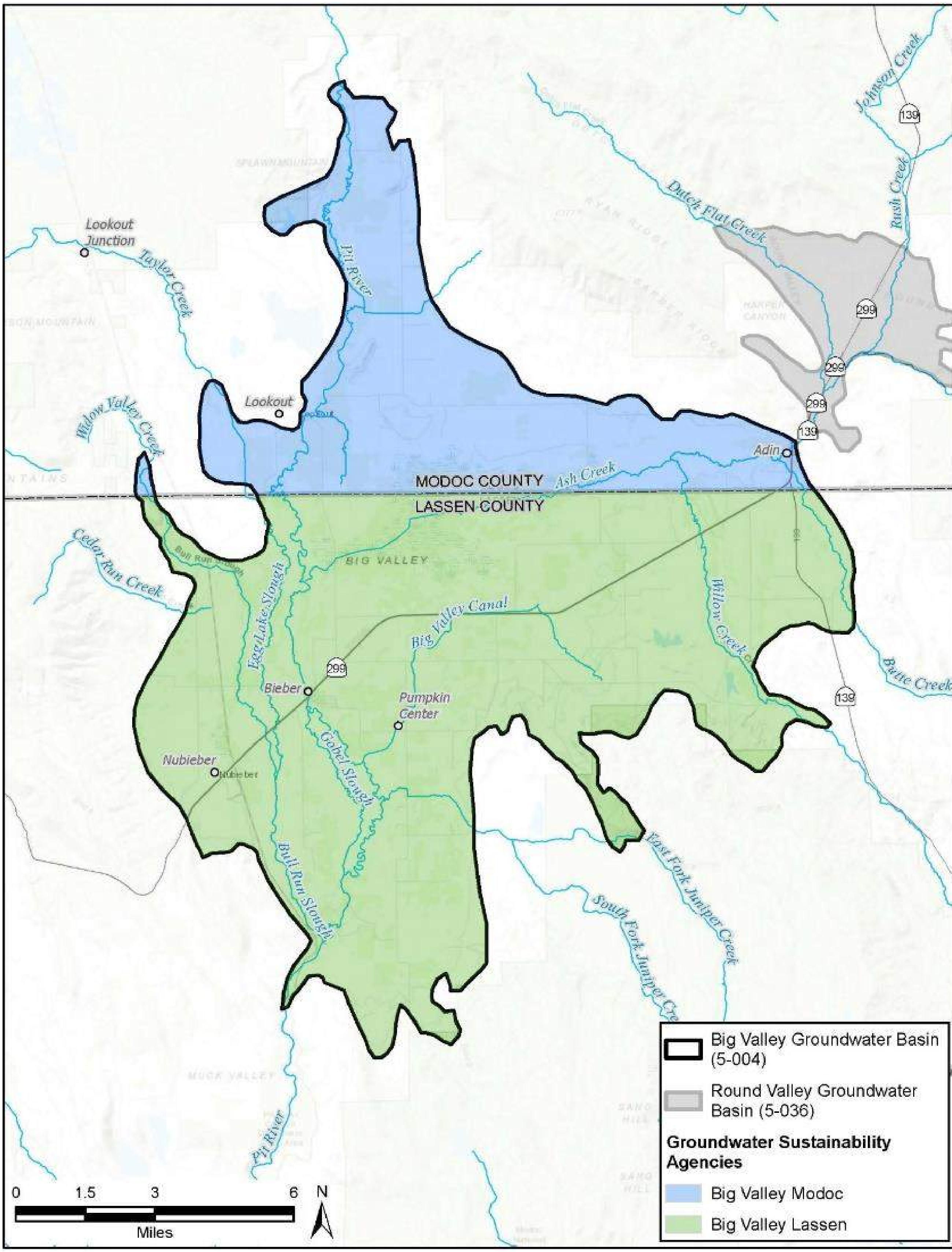


Figure ES-1 Groundwater Sustainability Agencies in Big Valley Groundwater Basin.
Source: DWR 2018d

Nubieber in Lassen County. The Ash Creek State Wildlife Area straddles both counties occupying 22.5 square miles in the center of the Basin in the marshy/swampy areas along Ash Creek. Land use in the BVGB is detailed in **Table ES-1**.

Table ES-1 2016 Land Use Summary by Water Use Sector

Water Use Sector	Acres	Percent of Total
Community[a]	250	<1%
Industrial	196	<1%
Agricultural	22,246	24%
State Wildlife Area[b]	14,583	16%
Managed Recharge	-	0%
Native Vegetation and Rural Domestic[c]	54,782	60%
Total	**92,057**	**100%**

Notes:
[a] Includes the use in the communities of Bieber, Nubieber and Adin
[b] Made up of a combination of wetlands and non-irrigated upland areas
[c] Includes the large areas of land in the Valley which have domestic wells interspersed
Source: See Chapter 6 – Water Budget for explanation of approach

ES.2. Basin Setting (Chapters 4 – 6)

Hydrogeologic Setting

The topography of BVGB is relatively flat in the central area with increasing elevations along the perimeter, particularly in the eastern portions where Willow and Ash Creeks enter the Basin. This low relief in the Basin results in a meandering river morphology and widespread flooding during large storm events. The Basin is underlain by a thick sequence of sediment derived from the surrounding mountains of volcanic rocks and is interbedded with lava flows and water-lain tuffs. The volcanic material is variable in composition and is Miocene to Holocene age (23 million to several hundred years ago). The compositions of the lava flows are primarily basalt[1] and basaltic andesite[2], while pyroclastic[3] ash deposits are rhyolitic[4] composition. In general, the Basin boundary drawn by DWR was intended to define the contact between the valley alluvial deposits and the surrounding mountains of volcanic rocks. During development of this GSP, the Basin boundary has been found to be grossly inaccurate in many areas and is not clearly isolated from areas outside the valley floor. The mountains outside of the groundwater Basin capture and accumulate precipitation, which produces runoff that flows into BVGB. Moreover, DWR (1963) stated that these mountains serve as "upland recharge areas" and provide subsurface recharge to BVGB *via* fractures in the rock and water bearing formations that underlie the volcanics.

---

[1] Basalt is an extrusive (volcanic) rock with relatively low silica content and high iron and magnesium content.
[2] Andesite is an extrusive rock with intermediate silica content and intermediate iron and magnesium content.
[3] Pyroclastic rocks are formed during volcanic eruptions, typically not from lava flows, but from material (clasts) ejected from the eruption such as ash, blocks, or "bombs."
[4] Rhyolitic rocks are extrusive with relatively high silica content and low iron and magnesium. Rhyolites are the volcanic equivalent of granite.

The Bieber Formation (TQb), formed in the Pliocene-Pleistocene age (5.3 million to 12 thousand years ago) and shown in **Figure ES-2**, is the main formation of aquifer material defined within the BVGB, and DWR (1963) estimates that it ranges in thickness from a thin veneer to over 1,000 feet. The formation was deposited in a lacustrine (lake) environment and is comprised of unconsolidated to semi-consolidated layers of interbedded clay, silt, sand, gravel, and diatomite. The coarse-grained deposits (gravel and sand) are aquifer material[5] and are part of the Big Valley principal aquifer. The "physical bottom" has not been clearly encountered or defined but may extend 4,000 to 7,000 feet or deeper. The "practical bottom" of the aquifer is 1,200 feet because that depth encompasses the known production wells and water quality may be poorer below that depth. As required by SGMA, 1,200 feet is used as the "definable bottom" for this GSP. A single principal aquifer is used for this GSP because distinct, widespread confining beds have not been identified in the subsurface.

The Natural Resources Conservation Service (NRCS) Hydrologic Soils Group (HSG) classifications provide an indication of soil infiltration potential and ability to transmit water under saturated conditions based on hydraulic conductivities of shallow, surficial soils. Characterizing these soils is important because water must first penetrate the shallow subsurface to provide any chance of groundwater recharge. According to the HSG dataset, the Basin is composed of only soils with "slow" or "very slow" infiltration rates. While the soils are not highly permeable, some research has found that water can penetrate through these soils, indicating that managed aquifer recharge projects such as on-farm recharge may be viable.

Groundwater Conditions

Historic groundwater elevations are available from a total of 22 wells in Big Valley that are part of the CASGEM[6] monitoring network, six located in Modoc County and 16 in Lassen County**.** In addition to these 22 wells, five well clusters were constructed in late 2019 and early 2020 to support the GSP. Groundwater level hydrographs from the historic wells show that most areas of the Basin have remained stable, and a few areas have seen some decline averaging 0.53 feet per year of groundwater level decline in the last 38 years.[7]

To determine the annual and seasonal change in groundwater storage, groundwater elevation surfaces[8] were developed for spring and fall for each year between 1983 and 2018. **Figure ES-3** shows this information graphically, along with the annual precipitation. This graph shows that groundwater storage generally declines during dry years and stays stable or increases during normal or wet years. During the period from 1983 to 2000, groundwater levels dipped in the late 1980s and early 1990s, then recovered during the wet period of the late 1990s. After 2000, while most wells are still stable, a few wells have

[5] Meaning the sediments contain porous material with recoverable water.
[6] California Statewide Groundwater Elevation Monitoring Program
[7] Average slope of the trend lines in Appendix 5A.
[8] Groundwater elevation surfaces are developed from the known groundwater elevations at wells throughout the Basin and then estimating/interpolating elevations at intermediate locations *via* a mathematical method known as kriging. The kriging elevation surface is based on a grid covering the entire basin that has interpolated groundwater elevation values for each node of the grid.

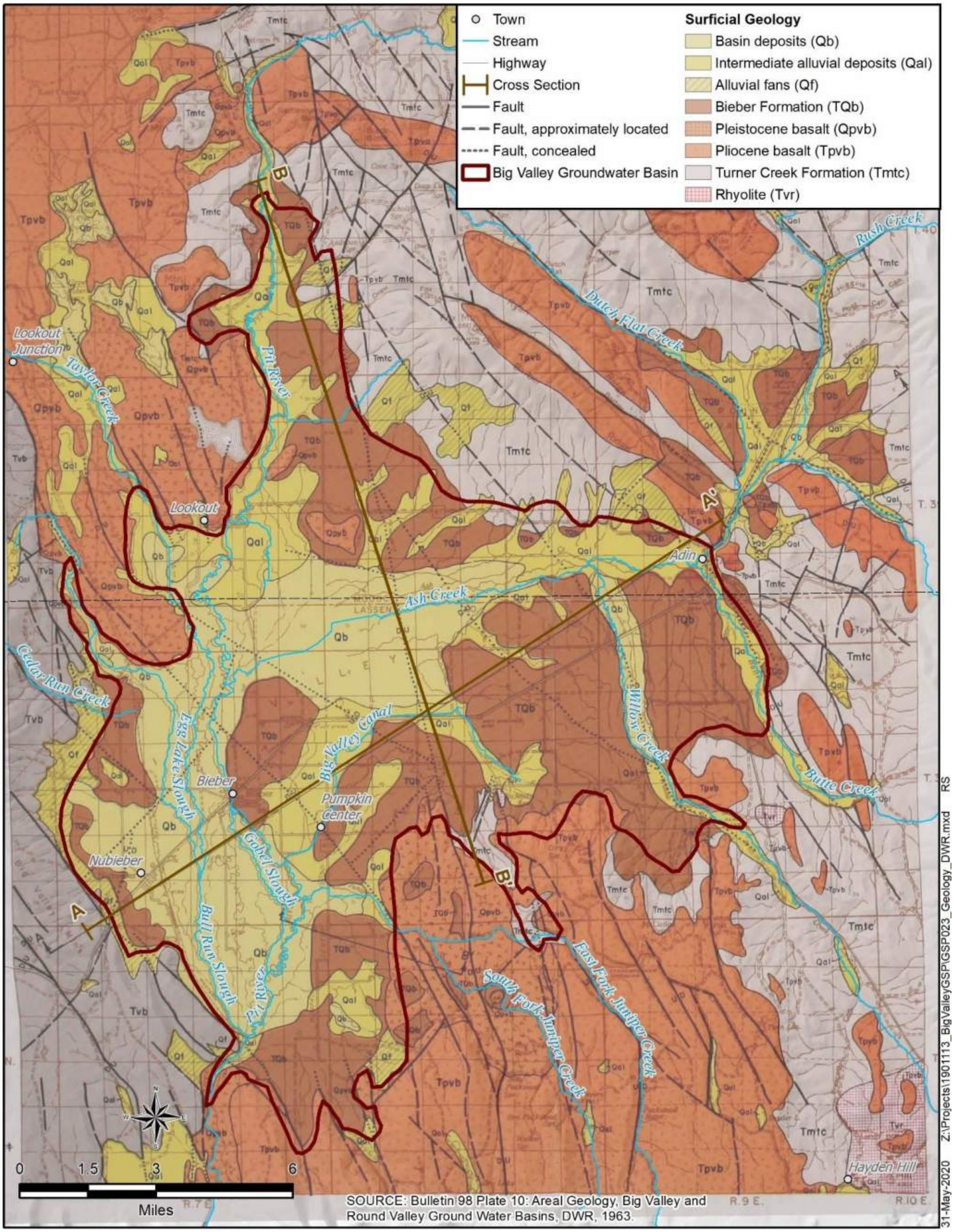


Figure ES-2 DWR 1963 Local Geologic Map.

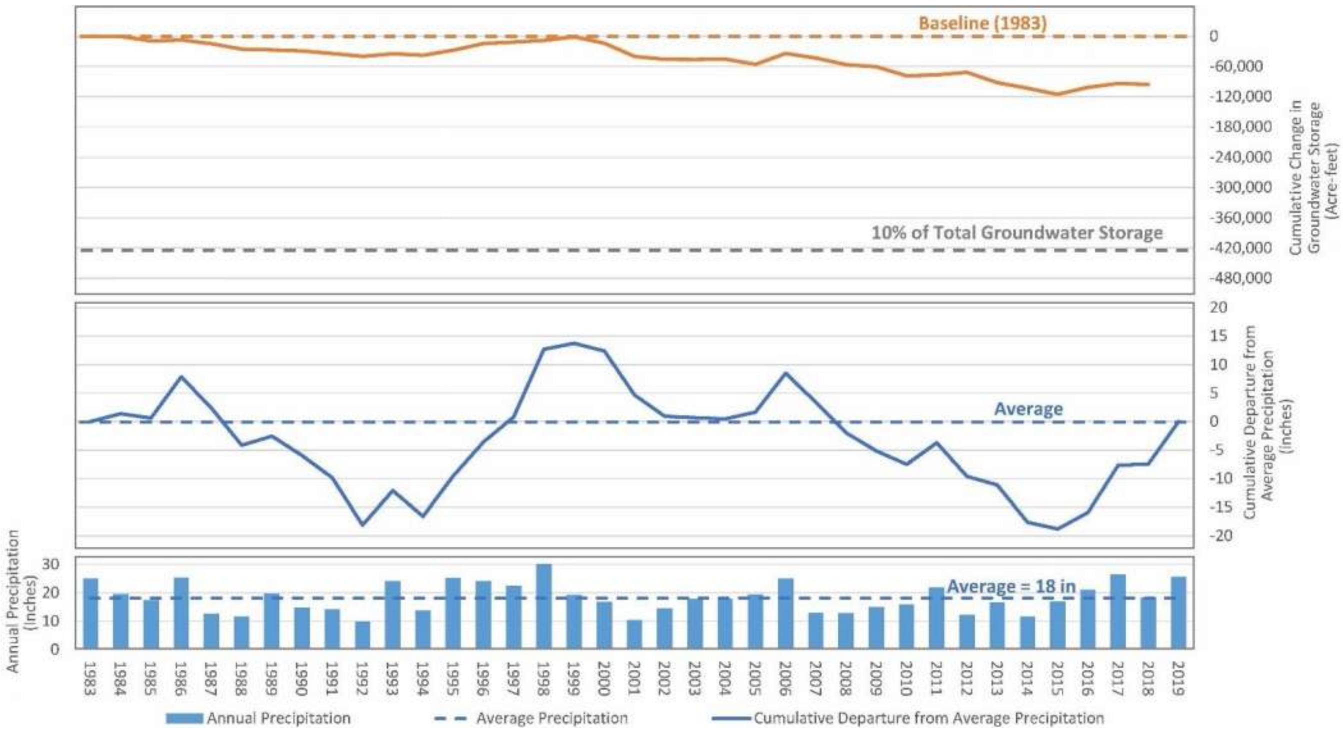


Figure ES-3 Cumulative Change in Groundwater Storage and Precipitation

generally declined, resulting in a reduction in overall groundwater storage. The amount of decline represents a cumulative reduction in storage of less than 2 percent of groundwater storage.[9]

Groundwater in the BVGB is generally of good- to excellent-quality (DWR 1963, United States Bureau of Reclamation [Reclamation] 1979). An analysis of available historic water quality indicates that some naturally occurring constituents associated with volcanic formations and thermal waters are slightly elevated. These elevated concentrations are extremely isolated and primarily not above thresholds that are a risk to human health nor does the water quality affect beneficial uses. There are no contamination plumes or cleanup sites that are likely to affect groundwater quality for beneficial use.

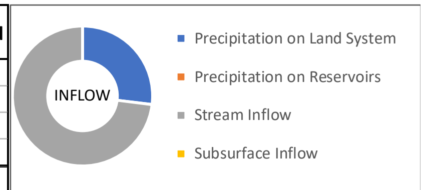
Water Budget

A historic water budget was developed for the 1983-2018 timeframe, shown in **Figure ES-4.** From this water budget analysis, a rough estimate for the sustainable yield is about 39,300 acre-feet per year (AFY) and a rough estimate of average annual overdraft is 5,000 AFY.

[9] Based on assessment in Section 5.2, indicating storage has been reduced by about 96,000 AF since 1983 and using a total storage of about 5.2 million AF (92,057 acre basin area * 1,200 feet to definable bottom * 5% specific yield)

TOTAL BASIN WATER BUDGET | **Acre-Feet**

item	Flow Type	Origin/ Destination	Component	Estimated
(1)	Inflow	Into Basin	Precipitation on Land System	136,800
(14)	Inflow	Into Basin	Precipitation on Reservoirs	500
(13)	Inflow	Into Basin	Stream Inflow	371,100
(27)	Inflow	Into Basin	Subsurface Inflow	1
(32)	Inflow	*(1)+(14)+(13)+(27)*	*Total Inflow*	*508,400*
(5)	Outflow	Out of Basin	Evapotranspiration	154,000
(24)	Outflow	Out of Basin	Stream Evaporation	400
(23)	Outflow	Out of Basin	Reservoir Evaporation	700
(19)	Outflow	Out of Basin	Conveyance Evaporation	-
(18)	Outflow	Out of Basin	Stream Outflow	358,500
(29)	Outflow	Out of Basin	Subsurface Outflow	-
(33)	Outflow	*(5)+(24)+(23)+(19)+(18)+(29)*	*Total Outflow*	*513,600*
(34)	Storage Change	(32)-(33)	Change in Total System Storage	(5,000)



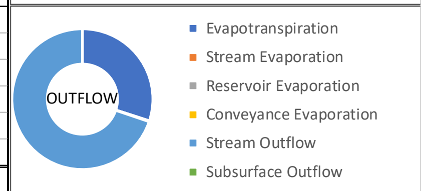


Figure ES-4 Average Total Basin Water Budget 1984-2018

ES.3. Sustainable Management (Chapters 7 – 9)

Sustainable Management Criteria

Sustainable Management Criteria (SMC) define the conditions that constitute sustainable groundwater management. The following is a description of the SMC for each of the six sustainability indicators:

- **Groundwater Levels:** Do not allow groundwater levels to decline to a level where the energy cost to lift groundwater exceeds the economic value of the water for agriculture. The minimum threshold for each well in the monitoring network was determined to be the depth at which groundwater pumping becomes uneconomical for agricultural use.
- **Groundwater Storage:** Groundwater levels are used as a proxy for this sustainability indicator because change in storage is directly correlated to changes in groundwater levels.
- **Seawater Intrusion:** This sustainability indicator does not apply to Big Valley.
- **Water Quality:** Due to the existence of excellent water quality in the Basin, a significant amount of existing water quality monitoring, generally low-impact land uses, and a robust effort to conduct conservation efforts by agricultural and domestic users, per §354.26(d), SMCs were not established for water quality because undesirable results are not present and not likely to occur. At the five-year update of this GSP, data from various existing programs will be assessed to determine if degradation trends are occurring in the principal aquifer.
- **Land Subsidence:** Based on evaluation of subsidence data from a continuous GPS station and Interferometric Synthetic Aperture Radar (InSAR) provided by DWR, no significant subsidence has occurred. Therefore, per §354.26(d), SMCs were not established for subsidence because undesirable results are not present and not likely to occur. At the five-year update of this GSP, subsidence data will be assessed for any trends that can be correlated with groundwater pumping.
- **Interconnected Surface Water:** Data for this sustainability indicator is limited. Currently there is no evidence to suggest that undesirable results have occurred or are likely to occur. At the five-year update, future data will be evaluated.

Monitoring Network

Monitoring networks are developed to promote the collection of data of sufficient quality, frequency, and distribution to characterize groundwater and related surface-water conditions in the Basin and to evaluate changing conditions that occur as the Plan is implemented. The GSAs developed monitoring networks for the parameters listed below. **Figure ES-5** shows the water level monitoring networks.

- Groundwater levels
- Groundwater storage *via* groundwater levels as proxy
- Shallow groundwater for interconnection of groundwater and surface water
- Groundwater quality
- Land subsidence
- Streamflow and climate
- Land use

Projects and Management Actions

Through an extensive planning and public outreach process, the GSAs have identified an array of projects and management measures that may be implemented to meet sustainability objectives in the BVGB. Some of the projects can be implemented immediately while others will take significantly more time for necessary planning and environmental review, navigation of regulatory processes, and implementation. The various projects and estimated timeline can be found in **Table ES-2**.

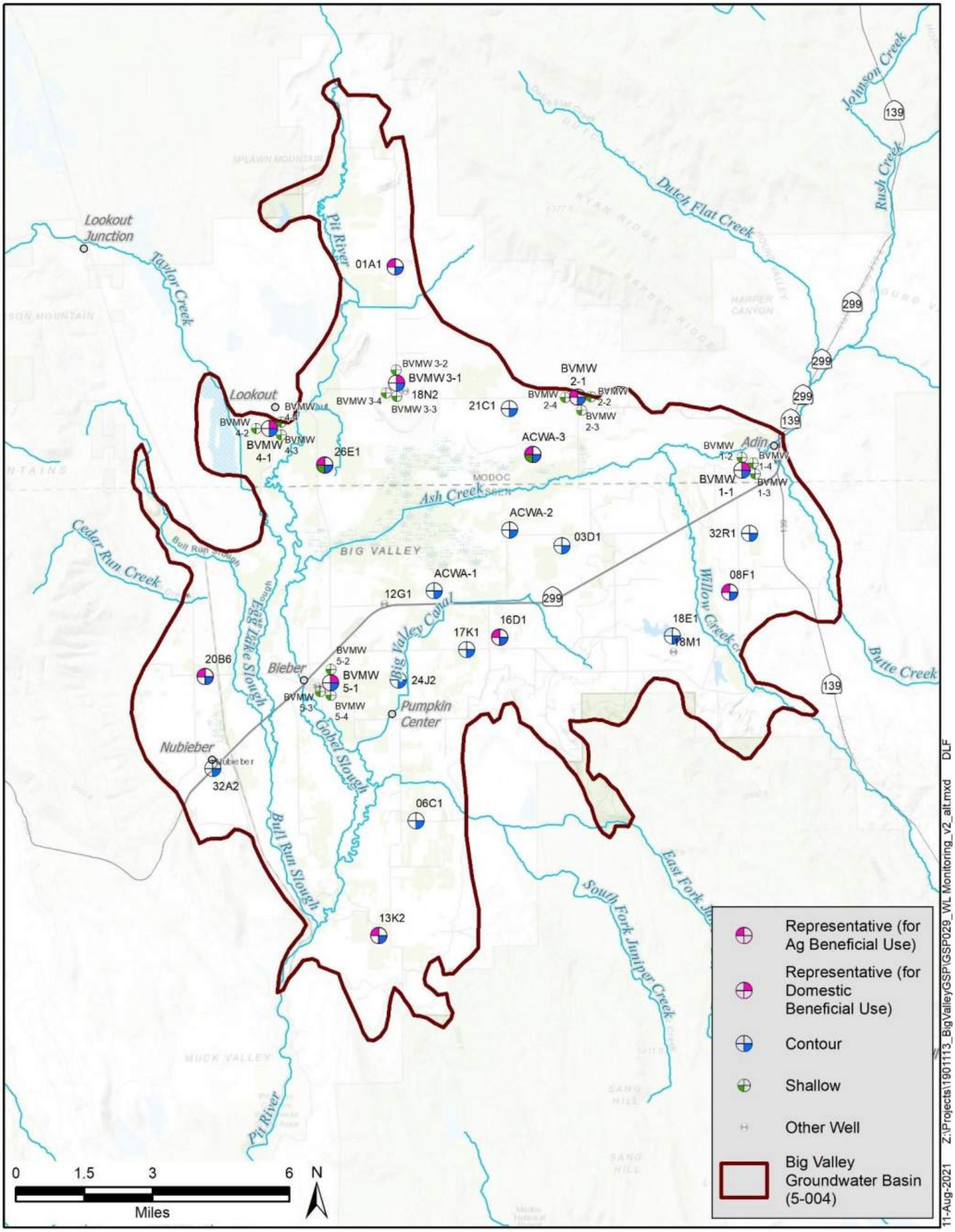


Figure ES-5 Groundwater Level Monitoring Networks

Table ES-2 Projects and Potential Implementation Timeline

No.	Category	Description	Estimated Time for Potential Implementation (years)		
			0-2	2-8	>8
1	9.1 Recharge Projects	AgMAR	X	X	X
2		Drainage and Basin Recharge	X	X	X
3		Ag Injection Wells			X
4	9.2 Research and Data Development	Stream Gages	X		
5		Refined Water Budget	X	X	
6		Agro-Climate Station	X		
7		Voluntary Installation of Well Meters	X	X	
8		Adaptive Management	X	X	X
9		Mapping and Land Use	X	X	
10	9.3 Increased Storage Capacity	Expanding Existing Reservoirs		X	
11		Allen Camp Dam			X
12	9.4 Improved Hydrologic Function	Forest Thinning and Management	X	X	X
13		Juniper Removal	X	X	X
14		Stream and Meadow Restoration	X	X	X
15	9.5 Water Conservation	Irrigation Efficiency	X	X	
16		Landscaping and Domestic Water Conservation	X	X	
17		Conservation Projects	X	X	
18	9.6 Education and Outreach	Public Communication	X		
19		Information and Data Sharing	X	X	
20		Fostering Relationships	X		
21		Compiling Efforts	X	X	
22		Educational Workshops	X		

Note: AgMAR = Agricultural Managed Aquifer Recharge

ES.4. Plan Implementation (Chapters 10 – 11)

The GSP lays out a roadmap for addressing the activities needed for GSP implementation. Implementing this GSP requires the following activities:

- **GSA Administration and Public Outreach:** The fundamental activities that will need to be performed by the GSAs are public outreach and coordination of GSP activities. Public outreach will entail updates at County Board of Supervisors' meetings and/or public outreach meetings. At a minimum the GSAs will receive and respond to public input on the Plan and inform the public about progress implementing the Plan as required by §354.10(d)(4) of the Regulations. Coordination activities would include ensuring monitoring is performed, annual reports to DWR, five-year GSP updates, and coordinating projects and management actions.

- **Monitoring and Data Management:** Data collection and management will be required for both annual reporting and five-year updates. Monitoring data that will be collected and stored in the data management system (DMS) for reporting will include water levels, precipitation, evapotranspiration, streamflow, water quality, land use, and subsidence.

- **Annual Reporting:** According to §356.2 of the Regulations, the Big Valley GSAs are required to provide an annual report to DWR by April 1 of each year following the adoption of the GSP. The first annual report will be provided to DWR, with assistance by GEI, by April 1, 2022 and will include data for the prior Water Year (WY), which will be WY 2021 (October 1, 2020 to September 30, 2021), despite DWR's definition of a WY being inconsistent with what works for Big Valley[10]. The Annual Report will establish the current conditions of groundwater within the BVGB, the status of the GSP implementation, and the trend towards maintaining sustainability.
- **Plan Evaluation (Five-Year Update)**: Updates and amendments to the GSP can be performed at any time, but at a minimum the GSAs must submit an update and evaluation of the plan every 5 years (§356.4). While much of the content of the GSP will likely remain unchanged for these five-year updates, the Regulations require that most chapters of the plan be updated and supplemented with any new information obtained in the preceding 5 years.

Cost of Implementation

Cost is a fundamental concern to the GSAs and stakeholders in the BVGB, as the Basin is disadvantaged and there is no revenue generated in the counties to fund the state-mandated requirements of SGMA. Therefore, the GSAs will rely on outside funding to implement this unfunded mandated Plan.

[10] The water year defined by DWR runs from October 1-September 30 to accommodate for the unique Mediterranean and annual grass growing season in much of the state. It does not fit well in the mountainous and great basin areas of the state like Big Valley that are primarily perennial native vegetation and cropping systems which do not follow the same growing cycle. In the annual system, plants start growing around the end of October, but in the perennial system, plants are still growing from the prior water year and October and soon go dormant for winter. This also mirrors the way that water is used in these areas as well. The end of irrigation season extends into October in the perennial system making water measurements sometimes difficult and not truly marking the end of the irrigation season. (Snell 2021)

1. Introduction § 354.2-4

1.1 Introduction

The Big Valley Groundwater Basin (BVGB, Basin, or Big Valley) is located in one of the most remote and untouched areas of California. The sparsely populated Big Valley has a rich biodiversity of wildlife and native species who feed, live, and raise young primarily on the irrigated lands throughout the Basin. The Basin has multiple streams which enter from the North, East, and West. The Pit River is the only surface-water outflow and exits at the southern tip of the Basin. The streams that enter the Basin are some of the most remote, least improved, and most pristine surface waters in all of California. The snow-fed high desert streams entering the Basin have seasonal hydrographs with natural periods of reduced flows or complete cessation of flows late in the summer season. The Pit River is the largest stream and is so named because of the practice, employed by the Achumawi and other Native American bands that are now part of the Pit River Tribe, of digging pits in the river channel when it went dry to expose water and trap game that came to water at the river. In addition to the Pit River, the Basin is also fed by Ash Creek year-round, along with Willow Creek and many seasonal streams and springs.

Farming and ranching in Big Valley date back to the late 19th and early 20th centuries when families immigrated to Big Valley and made use of the existing water resources. A large amount of the land in the Basin is still owned and farmed by the families that homesteaded here. The surnames on the tombstones at any of the three cemeteries are the same names that can be overheard during a visit to the Bieber Market or the Adin Supply store, local institutions and gathering places for the residents of this tight-knit community. These stores are remaining evidence of a much more vibrant time in Big Valley.

Following World War II, with the advent and widespread use of vertical turbine pumps, farmers and ranchers began using groundwater to irrigate the land, supplementing their surface-water supplies to make a living in Big Valley. The local driller, Conner's Well Drilling, has drilled the majority of wells in Big Valley and the third-generation driller, Duane Conner has been on the advisory committee during the development of this Groundwater Sustainability Plan (GSP or Plan) (Conner 2020-2021).

Historically, agriculture was complemented by a robust timber industry, a key component of the economy for Big Valley, which supported four lumber mills. Due to regulations and policies imposed by state and federal government, the timber industry has been diminished over time which has caused a great economic hardship to the Big Valley communities. Stakeholders realize that the Sustainable Groundwater Management Act of 2014 (SGMA) will unfortunately cause a similar decline to agriculture. The loss of jobs due to the closure of all four lumber mills and the reduction of timber yield tax, which had provided financial support to the small rural schools and roads, is evident in the many vacant buildings which once had thriving businesses. In addition to the loss of jobs, the reduced student enrollment in local schools has caused an economic hardship to the school district, which struggles to remain viable. The change in land management has transformed once thriving communities in the Basin to "disadvantaged" and "severely disadvantaged" communities as defined by multiple state agencies, including the Department of Water Resources (DWR). The addition of SGMA will increase the severity of the disadvantaged and severely disadvantaged status in the Basin due to increased regulatory costs and potential actions that must be taken to comply with SGMA and is likely to intensify rural decline in this area. With the increased cost of this unfunded mandate for monitoring, annual reports and GSP updates, land values will likely decline and lower the property tax base.

The two counties that overlie the BVGB are fulfilling their unfunded mandated role as the Groundwater Sustainability Agencies (GSAs) since there are no other viable entities that can serve as GSAs. Both counties have severe financial struggles as their populations and tax base are continually declining. The counties not only lack the tax revenue generated out of Big Valley to implement SGMA, but they have no buffer from revenue generated county-wide to cover such costs. As such, the GSAs are depending almost solely on outside funding sources for development and implementation of this Plan.

With the demise of the timber industry, agriculture has been the only viable industry remaining to support residents living and working in the Basin, with many of the families who ranch and farm today having cultivated the land for over a century. These families are fighting to maintain the viability and productivity of their land so that their children and grandchildren can continue to pursue the rural lifestyle that their forebearers established.

The ranchers and farmers have developed strategies to enhance the land with not only farming and ranching in mind, but also partnerships with state and federal agencies as well as local non-governmental agencies (NGOs). The purpose of these partnerships is to maintain and improve the condition of privately-owned land for the enhancement of plant and animal populations while addressing invasive plant and pest concerns.

The Ash Creek Wildlife Area (ACWA) is an example of a local rancher who provided land for conservation efforts with an understanding that managed lands promote wildlife enhancement for the enjoyment of all. The California Department of Fish and Wildlife (CDFW) has largely left the property unmanaged. (Albaugh 2021, Conner 2021) While the ACWA does offer some refuge, most species graze and rear their young on the private lands around the Basin which are actively being cultivated because those lands offer better forage and protection from predators. Below is an account from the former landowner of how the ACWA property has fared since being sold to the government.

> The government bought the ranch as a refuge for birds and wildlife. When I was running cattle on that ranch it was alive with waterfowl. They fed around and amongst the cattle. It was a natural refuge. The cattle kept the feed down so the birds didn’t have to worry about predators, and they could feed on the new growth grass. After the government got their hands on it all the fences were removed, at taxpayer expense. In the years since, the meadows have turned into a jungle -- old dead feed and tules. The birds are gone, moved to other ranches where they get protection from skunks and coyotes and other predators that work on waterfowl and wildlife. Under the management of the U.S. Fish and Wildlife the value of the land has been completely destroyed. All those acres of wonderful grass and the irrigation system that for generations have produced food for the people of this country now *produce nothing*. (Stadtler 2007)

Recently the CDFW has attempted to manage the property by constructing a 65-acre wetland using their water rights from the Big Valley Canal. In conjunction with the project and to more efficiently move adjudicated water to users (including ACWA) down-canal, the CDFW constructed a ¾-mile pipeline to replace an unlined portion of the canal. The pipeline has purportedly increased flows down-canal of the pipeline from 4cfs to 8cfs. The abandoned portion of unlined canal travels through a private land-owner's property. Although CDFW asserts that there are no documented water rights holders on the abandoned canal, it has dried that portion of the land-owner's property and reduced groundwater recharge there. However, the constructed wetlands likely provide more recharge on the ACWA property than the abandoned canal provided on private property.[11] (CDFW 2021)

Such projects which advance state priorities over private landowners exacerbate the negative sentiments from local stakeholders toward state government and make them extremely wary of unintended consequences of government programs. This distrust, coupled with the burden imposed on locals through regulations such as SGMA, are some of the fundamental reasons why residents of this area generally consider themselves distinct from the rest of the state. Furthermore, local political leaders have pointed out that the state is behind on tax payments to the disadvantaged counties. (Albaugh 2021)

The BVGB differs physically from California's other groundwater basins because the climate sees extreme cold. On average, there are fewer warm-temperature days, making the growing season considerably shorter than in other parts of the state. Ground elevations in the Basin range from about 4,100 to over 5,000 feet, and along with its northerly latitude in the state, this creates conditions where snow can fall in any month of the year. According to the Farmer's Almanac, the average growing season for the Big Valley Basin is about 101 days. The typical crops for the Big Valley Basin are low-land-use-intensity and low-value crops such as native pasture, grass hay, alfalfa hay, and rangeland.

The vast majority of the farmed land utilizes low-impact farming, employing no-till methods to grow nitrogen-fixing crops which require little to no fertilizer or pesticide application. While this climate and range of viable crops is a challenge to farmers and ranchers, it helps maintain the pristine nature of surface water and groundwater. As an example of how local landowners have been good stewards of their water resources, they have participated in the Natural Resources Conservation Service's (NRCS's) Environmental Quality Incentives Program (EQIP), drilling wells away from streams to encourage watering of cattle outside of riparian corridors. Now these additional wells have increased the inventory of wells in the Basin, one of the criteria used by DWR to categorize Big Valley as medium priority and subject to the SGMA unfunded mandate of developing a GSP. (Albaugh 2020-2021)

The GSAs are also aware of the impact of poor water stewardship, such as illegal water uses (e.g. unlicensed marijuana growers). These operations may utilize groundwater, are known to have illegal diversions of surface water and have a negative impact on water quality. However, the counties have not received the state and federal support needed to identify, eliminate, and prosecute these operations.

The Big Valley Basin has a population of 1,046 residents and a projected slow growth of 1,086 by 2030. (DWR 2021a). The largest town (unincorporated community) within the Basin is Adin, California, which had a population of 272 residents according to the 2010 Census (USCB 2021). Located in Modoc

[11] This paragraph is based on information provided by CDFW and hasn't been verified.

County, Adin had a 2.43 percent decline in population from 2017 to 2018. Both Modoc and Lassen are experiencing a decline in population county-wide (USCB 2021).

As detailed in this GSP, there are three major beneficial uses of groundwater: agriculture, community/domestic, and environmental. However, the importance of agriculture to Big Valley cannot be overstated, as it is the economic base upon which community/domestic users rely and provides the habitat for many species important to healthy wildlife and biodiversity. Both groundwater and surface water are important to maintaining this ecosystem. There are efforts being made to diversify the economic base of the community. While economic diversity of Big Valley is not the purview of this GSP, it is acknowledged that at present and for the foreseeable future, the Big Valley communities rely almost solely on farming and ranching to support their residents. The financial and regulatory impact of implementing SGMA will negatively affect this disadvantaged community. Therefore, minimizing the GSP's impact to agriculture while complying with SGMA and working to enhance water supply in Big Valley is the thrust of this GSP.

1.2 Sustainability Goal

The GSAs are developing this GSP to comply with SGMA's unfunded mandates, maintain local control and preclude intervention by the State Water Resources Control Board (State Water Board), and prove that the Basin is sustainable and should be ranked as low priority. Satisfying the requirements of SGMA generally requires four activities:

1. Formation of at least one GSA to fully cover the basin (Multiple GSAs are acceptable and Big Valley has two GSAs.)
2. Development of this GSP that fully covers the basin
3. Implementation of this GSP and management to achieve quantifiable objectives
4. Regular reporting to DWR

Two GSAs were established in the Basin: County of Modoc GSA and County of Lassen GSA, each covering the portion of the Basin in their respective jurisdictions. This document is a single GSP, developed jointly by both GSAs for the entire Basin. This GSP describes the BVGB, develops quantifiable management criteria that accounts for the interests of the Basin's legal beneficial groundwater uses and users, and identifies projects and management actions to ensure and maintain sustainability.

The Lassen and Modoc GSAs developed a Memorandum of Understanding (MOU) which details the coordination between the two GSAs. The MOU states that the Big Valley Advisory Committee (BVAC) is to be established to provide local input and direction on the development of a GSP. The counties solicited applicants to be members of the BVAC through public noticing protocols. Big Valley landowners and residents submitted applications to the County Boards of Supervisors, who then appointed the members of the BVAC. The BVAC is comprised of one county board member from each county, one alternate board member from each county, and two public applicants from each county. The BVAC and county staff have dedicated countless hours to reviewing the data and content of the GSP, largely uncompensated. After careful consideration of the available data and community input from the BVAC and interested parties, the GSAs have developed the following sustainability goal:

> The sustainability goal for the Big Valley Groundwater Basin is to maintain a locally governed, economically feasible, sustainable groundwater basin and surrounding watershed for existing and future legal beneficial uses with a concentration on agriculture. Sustainable management will be conducted in context with the unique culture of the basin, character of the community, quality of life of the Big Valley residents, and the vested right of agricultural pursuits through the continued use of groundwater and surface water.

The BVGB sustainability goal will be culminated through DWR's better understanding of the surface-water and groundwater conditions over time and the implementation of projects and management actions described in this GSP. Several areas of identified data gaps have been established and, while an estimated future water budget has been completed, its accuracy is uncertain since many assumptions had to be made due to the lack of available data. The monitoring network established under this Plan includes new and existing monitoring wells, inflow/outflow measurement of surface water, groundwater quality, and land subsidence.

The implementation of projects such as winter recharge studies currently in progress will help establish the feasibility of immediate actions the GSAs can take to improve Basin conditions. A detailed off-season water availability analysis has not been conducted on the Upper Pit River watershed and this has been identified as a data gap within the Basin. The GSAs are working to locate funds to conduct an off-season and storage-capacity water accounting which will provide the amount of available surface water for potential winter recharge in the Basin. Additional research will be conducted on the available use of non-active surface-water rights for storage. An additional stream gage is being installed where the Pit River enters the Basin and will provide a more accurate accounting of the amount of surface water entering the Big Valley Basin from the Pit River. While better accounting is needed, it should be noted that SGMA and this GSP will not affect existing water rights in the Basin.

The understanding that has been further engrained by the GSAs is that with proper management, coordination and support from federal and state landowner partners, the Big Valley Basin, which is not currently at risk of overdraft, will remain sustainable for the benefit of all interested parties. The BVGB should be re-ranked as low priority.

1.3 Background of Basin Prioritization

The Big Valley GSAs are being forced to develop this GSP after exhausting their challenges to the California Department of Water Resources' (DWR's) determination that Big Valley qualifies as a medium-priority basin. DWR first prioritized the state's basins in 2014, at which time Big Valley was the lowest-ranked medium-priority basin that had to develop a GSP. In 2019, DWR changed their prioritization process and criteria and issued draft and final prioritizations. In the end, Big Valley is still the lowest-ranked medium-priority basin.

From the draft to final re-prioritization, the Big Valley GSAs recognize the scoring revisions made by DWR for Component 8.b, "Other Information Deemed Relevant by the Department." However, the

GSAs continue to firmly believe that the all-or-nothing scoring for Component 7.a, regarding documented declining groundwater levels, is inconsistent with the premise of SGMA: that prioritization levels recognize different levels of impact and conditions across the basins of the state. DWR's adherence to treating all declines the same, assigning a fixed 7.5 points for any amount of documented groundwater level decline, renders meaningless the degrees of groundwater decline and penalizes those basins experiencing minor levels of decline, including Big Valley which has only experienced approximately 0.53 feet per year of groundwater level decline on average in the last 38 years.

Additionally, the GSAs recognize the adjustments made to Component 7.d regarding overall total water quality degradation. Noting that degradation implies a lowering from human-caused conditions, the Big Valley GSAs urge DWR to further refine the groundwater quality scoring process for Secondary Maximum Contamination Levels (MCLs) – which are not tied to public health concerns, but rather aesthetic issues such as taste and odor. Secondary MCLs which are due to naturally occurring minerals should not be factored into the scoring process. In the BVGB, the water quality conditions reflect the natural baseline and are not indicative of human-caused degradation and cannot be substantially improved through better groundwater management.

The inaccurate Basin boundary was drawn with a 63-year old regional scale map (CGS 1958), and subsequent geologic maps with more precision and detail are available. Additionally, the "upland" areas outside the Basin boundary are postulated to be recharge areas interconnected to the Basin, which is contrary to DWR's definition of a lateral basin boundary as being, "…features that significantly impede groundwater flow" (DWR 2016c). The GSAs submitted a request to DWR for basin boundary modification to integrate planning at the watershed level and leverage a wider array of multi-benefit water management options and strategies within the Basin and larger watershed. DWR's denial of the boundary modification request greatly hampers jurisdictional opportunities to protect groundwater recharge areas in higher elevations. The final boundary significantly curtails management options to increase supply through upland recharge, requiring that groundwater levels be addressed primarily through demand restrictions. *See* **Appendix 1A** for communications with DWR regarding Basin prioritization ranking and boundary modification. Due to information that has come to light during this process, the Basin boundary has been shown to be inaccurate. The GSAs will submit a Basin boundary modification.

Development of this GSP by the GSAs, in partnership with the BVAC and members of the community, does not constitute agreement with DWR's classification as a medium-priority basin – nor does it preclude the possibility of other actions by the GSAs or by individuals within the Basin seeking regulatory relief.

1.3.1 Timeline

In September 2014, the state of California enacted SGMA. This law requires medium- and high-priority groundwater basins in California to take actions to ensure they are managed sustainably. DWR is tasked with prioritizing all 515 defined groundwater basins in the state as high-, medium-, low- and very-low- priority. Prioritization establishes which basins need to go through the process of developing a GSP. When SGMA was passed, basins had already been prioritized under the California Statewide

Groundwater Elevation Monitoring (CASGEM) program, and that existing ranking process was used as the initial priority baseline for SGMA.

DWR was required to develop its rankings for SGMA based on the first seven criteria listed in **Table 1-1**. For the final SGMA scoring process, groundwater basins with a score of 14 or greater (up to a score of 21) were ranked as medium-priority basins (DWR 2019). Big Valley scored 13.5 and DWR chose to arbitrarily round the score up to put it in the medium-priority category as the lowest ranked Basin in the state required to develop a GSP. Lassen County reviewed the 2014 ranking process and criteria that were used and found erroneous data. The County made a request to DWR for the raw data that was used, which were eventually provided, and verified the error that would have put the BVGB into the low priority category. However, because the comment period for these rankings had already expired in 2014 (prior to the passage of SGMA), DWR would not revise their ranking. County staff were misled because when the rankings were first publicized, SGMA had not yet existed, and County staff were told that being ranked as a medium priority basin was insignificant and would actually be a benefit to the counties.

Table 1-1 Big Valley Groundwater Basin Prioritization

Criteria	2014	2018	2019	Comments
2010 Population	1	1	1	
Population Growth	0	0	0	
Public Supply Wells	1	1	1	
Total # of Wells	1.5	2	2	Existing information inaccurate and includes all types of wells, including newly constructed stockwatering wells under EQIP
Irrigated Acreage	4	3	3	
Groundwater Reliance	3	3.5	3.5	
Impacts	3	3	2	Declining water levels, water quality
Other Information	0	7	2	Streamflow, habitat, and "other information determined to be relevant"
Total Score	**13.5**	**20.5**	**14.5**	**Medium priority each year**

Source: DWR 2019

Once SGMA was passed and the onerous repercussions of being ranked as medium priority were better understood (and the counties identified erroneous data), DWR did not offer any recourse, simply saying the Big Valley Basin would remain ranked as medium priority and that the basins would soon be re-prioritized anyway.

In 2016, Lassen County submitted a request for a basin boundary modification as allowed under SGMA. The request was to extend the boundaries of the BVGB to the boundary of the watershed. The purpose of the proposed modification was to enhance management by including the volcanic areas surrounding the valley sediments, including federally managed timberlands and rangelands, that have an impact on groundwater recharge. The modification was proposed on a scientific basis but was denied by DWR because the request, "…did not include sufficient detail and/or required components necessary and evidence was not provided to substantiate the connection [of volcanic rock] to the porous permeable alluvial basin, nor were conditions presented that could potentially support radial groundwater flow as observed in alluvial basins." DWR therefore justifies denial based on inadequate scientific evidence, yet as stated above they used inaccurate, unscientific information to rank the Basin as medium priority in the first place.

In 2018, DWR released an updated draft basin prioritization based on the eight components shown in **Table 1-1** using slightly different data and methodology than previously used. For this prioritization, Big Valley's score increased from 13.5 to 20.5, primarily because of an addition of 5 ranking points awarded under the category of "other information determined to be relevant" by DWR. DWR's justification for the five points was poorly substantiated as "Headwaters for Pit River/Central Valley Project – Lake Shasta." Lassen and Modoc counties sent a joint comment letter questioning DWR's justification and inconsistent assessment of these five points as well as their methodology for awarding the same number of points for water level and water quality impacts to basins throughout the state regardless of the severity of the impacts.

In 2019, DWR released their final prioritization with the BVGB score reduced to 14.5, but still ranked as medium priority and subject to the development of a GSP. DWR's documentation of the 2019 prioritization can be viewed on their website (DWR 2019).

Meanwhile, throughout this time, Lassen and Modoc counties began moving forward to comply with SGMA unfunded mandates through a public process that established them as the GSAs in 2017. The establishing resolutions forming the GSAs adopted findings that it was in the public interest of both counties to maintain local control by declaring themselves the GSA for the respective portion of the Basin. The Water Resources Control Board would become the regulating agency if the counties did not agree to be the GSAs since there were no other local agencies in a position or qualified to assume GSA responsibility. The counties obtained state grant funding to develop the GSP in 2018 and began the GSP development process and associated public outreach in 2019.

1.4 Description of Big Valley Groundwater Basin

The BVGB is identified by DWR in Bulletin 118 as Basin No. 5-004 (DWR, 2016a). The inaccurate Basin boundary was drawn by DWR using a 1:250,000 scale geologic map produced by the California Geological Survey (CGS 1958) along the boundary between formations labeled as volcanic and those labeled as alluvial. The Basin boundary was not drawn with as much precision as subsequent geologic maps, and because of this the "uplands" areas outside the Basin boundary are postulated to be recharge areas interconnected to the Basin. The 63-year old map being used to define the Basin boundary is inadequate and contrary to DWR's definition of a lateral basin boundary as being "features that significantly impede groundwater flow" (DWR 2016c).

The Basin is one of many small, isolated basins in the northeastern region of California, an area with widespread volcanic formations, many of which produce large quantities of groundwater and are not included within the defined groundwater basin due to their classification as “volcanic” rather than “alluvial.”

The boundary between Lassen and Modoc counties runs west-east across the Basin. Each county formed a GSA for its respective portion of the Basin and the counties are working together to manage the Basin under a single GSP. The Basin, shown on **Figure 1-1**, encompasses an area of about 144 square miles with Modoc County comprising 40 square miles (28%) on the north and Lassen County comprising 104 square miles (72%) on the south. The Basin includes the towns of Adin and Lookout in Modoc County and the towns of Bieber and Nubieber in Lassen County. The ACWA is located along the boundary of both counties, occupying 22.5 square miles in the center of the Basin encompassing the marshy/swampy areas along Ash Creek.

The BVGB, as drawn by DWR, is isolated and does not share a boundary with another groundwater basin. However, Ash Creek flows into Big Valley from the Round Valley Groundwater Basin at the town of Adin. Despite the half-mile gap of alluvium which may provide subsurface flow between the two basins, DWR doesn’t consider them interconnected due to the way the basin boundary was defined.

The surface expression of the Basin boundary is defined as the contact of the valley sedimentary deposits with the surrounding volcanic rocks. The sediments in the Basin are comprised of mostly Plio-Pleistocene alluvial deposits and Quaternary lake deposits eroded from the volcanic highlands and some volcanic layers interbedded within the alluvial and lake deposits. The Basin is surrounded by Tertiary- and Miocene-age volcanic rocks of andesitic, basaltic, and pyroclastic composition. These volcanic deposits may be underlain by alluvial deposits in these upland areas. The boundary between the BVGB and the surrounding volcanic rocks generally correlates with change in topography along the margin of the valley.

Throughout the development of this GSP, the inaccuracies of the Basin boundary have become clear and revisions to the boundary are needed. The hydrogeology of Big Valley is complex and requiring an all-or-nothing (inside or outside Basin Boundary), one-size-fits-all approach to the Basin under SGMA does not sit well with stakeholders and will be difficult to implement by the GSAs.

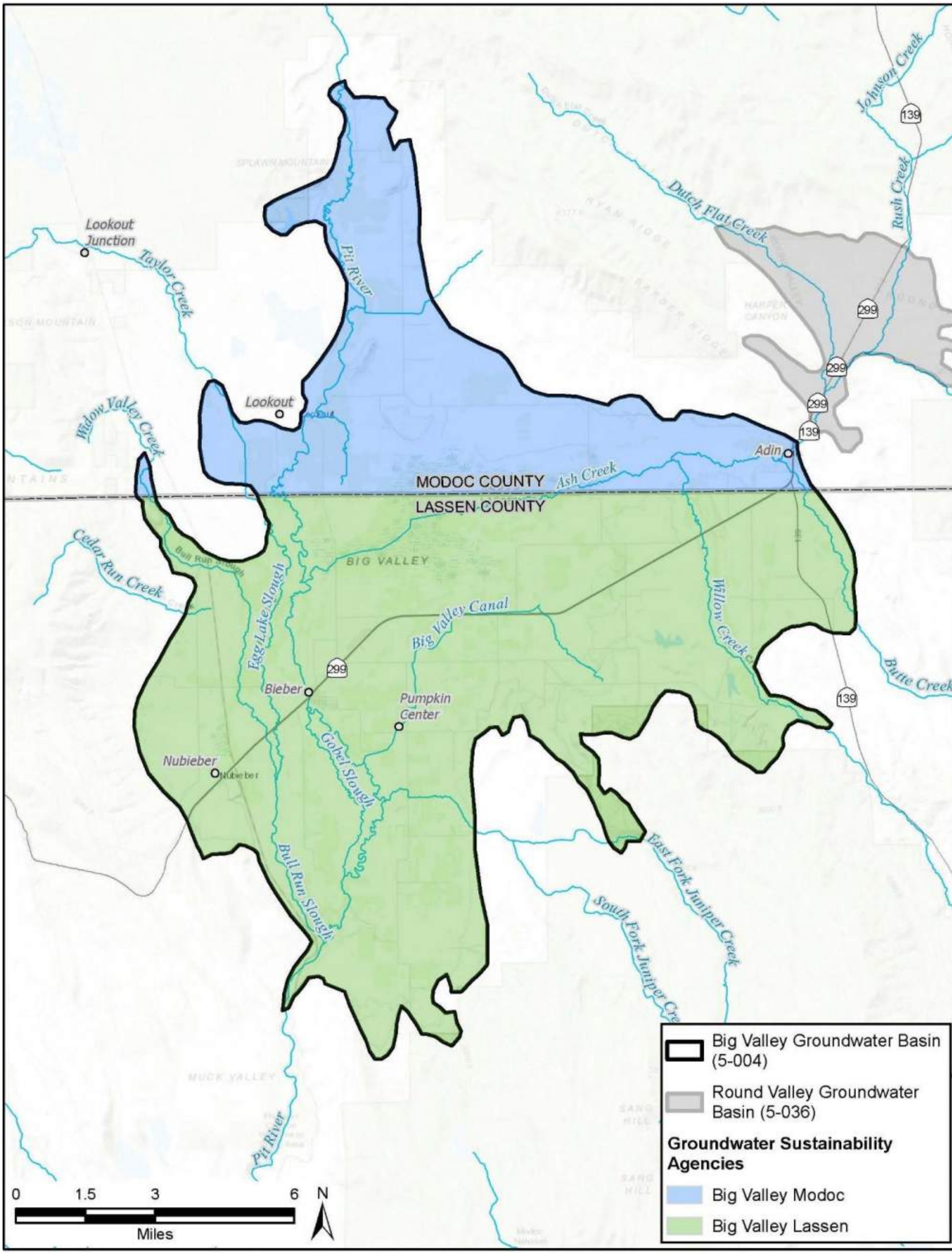


Figure 1-1 Big Valley Groundwater Basin, Surrounding Basins and GSAs
Source: DWR 2018d

2. Agency Information § 354.6

The two Big Valley GSAs were established for the entire BVGB to jointly develop, adopt, and implement a single mandated GSP for the BVGB pursuant to SGMA and other applicable provisions of law.

2.1 Agency Names and Mailing Addresses

The following contact information is provided for each GSA pursuant to California Water Code (CWC) §10723.8.

Modoc County
204 S. Court Street
Alturas, CA 96101
(530) 233-6201
tiffanymartinez@co.modoc.ca.us

Lassen County
Department of Planning and Building Services
707 Nevada Street, Suite 5
Susanville, CA 96130
(530) 251-8269
landuse@co.lassen.ca.us

2.2 Agency Organization and Management Structure

The two GSAs, Lassen and Modoc counties, were established in 2017 as required by the unfunded SGMA-mandated legislation. **Appendix 2A** contains the resolutions forming the two agencies. Each GSA is governed by a five-member Board of Supervisors. In 2019, the two GSAs established the BVAC through an MOU, included as **Appendix 2B**. The membership of the BVAC is comprised of:

- one member of the Lassen County Board of Supervisors selected by said Board.
- one alternate member of the Lassen County Board of Supervisors selected by said Board.
- one member of the Modoc County Board of Supervisors selected by said Board.
- one alternate member of the Modoc County Board of Supervisors selected by said Board.
- two public members selected by the Lassen County Board of Supervisors. Said members must either reside or own property within the Lassen County portion of the BVGB.
- two public members selected by the Modoc County Board of Supervisors. Said members must either reside or own property within the Modoc County portion of the BVGB.

The decisions made by the BVAC are not binding, but the committee serves the important role of providing formalized, local stakeholder input and guidance to the GSA governing bodies, GSA staff and consultants in developing and implementing the GSP.

2.3 Contact Information for Plan Manager

The plan manager is from Lassen County and can be contacted at:

Gaylon Norwood
Assistant Director
Lassen County Department of Planning and Building Services
707 Nevada Street, Suite 5
Susanville, CA 96130
(530) 251-8269
gnorwood@co.lassen.ca.us

2.4 Authority of Agencies

The GSAs were formed in accordance with the requirements of CWC §10723 et seq. Both GSAs are local public agencies organized as general law counties under the State Constitution and have land-use responsibility for their respective portions of the Basin. The resolutions of formation for the GSAs are included in **Appendix 2B**.

2.4.1 Memorandum of Understanding

In addition to the MOU establishing the BVAC, the two GSAs may enter into an agreement to jointly implement the GSP for the Basin. However, this agreement is not a SGMA requirement.

3. Plan Area § 354.8

3.1 Area of the Plan

This GSP covers the BVGB, which is located within Modoc and Lassen counties and is about 144 square miles (92,057 acres). The Basin is a broad, flat plain extending about 13 miles north to south and 15 miles east to west and consists of depressed fault blocks surrounded by tilted fault-block ridges. The BVGB is designated as basin number 5-004 by the DWR and was most recently described in the 2003 update of Bulletin 118 (DWR 2003):

> The basin is bounded to the north and south by Pleistocene and Pliocene basalt and Tertiary pyroclastic rocks of the Turner Creek Formation, to the west by Tertiary rocks of the Big Valley Mountain volcanic series and to the east by the Turner Creek Formation.
>
> The Pit River enters the Basin from the north and exits at the southernmost tip of the valley through a narrow canyon gorge. Ash Creek flows into the valley from Round Valley and disperses into Big Swamp. Near its confluence with the Pit River, Ash Creek reforms as a tributary at the western edge of Big Swamp. Annual precipitation ranges from 13 to 17 inches.

Communities in the Basin are Nubieber, Bieber, Lookout, and Adin which are categorized as census-designated places. Highway 299 is the most significant east-to-west highway in the Basin, with Highway 139 at the eastern border of the Basin. **Figure 3-1** shows the extent of the GSP area (the BVGB), as well as the significant water bodies, communities, and highways.

Lassen and Modoc counties were established as the exclusive GSAs for their respective portions of the Basin in 2017. **Figure 3-1** shows the two GSAs within the Basin. Round Valley Basin (5-036) is a very low-priority basin to the northeast; DWR does not consider it to be connected to Big Valley Basin, but there is a half-mile-wide gap of alluvium between the basins. The ACWA occupies 22.5 square miles (14,400 acres) in the center of Big Valley.

No other GSAs are associated with the Basin, nor are there any areas of the Basin that are adjudicated or covered by an alternative to a GSP. **Landowners have the right to extract and use groundwater beneath their property.**

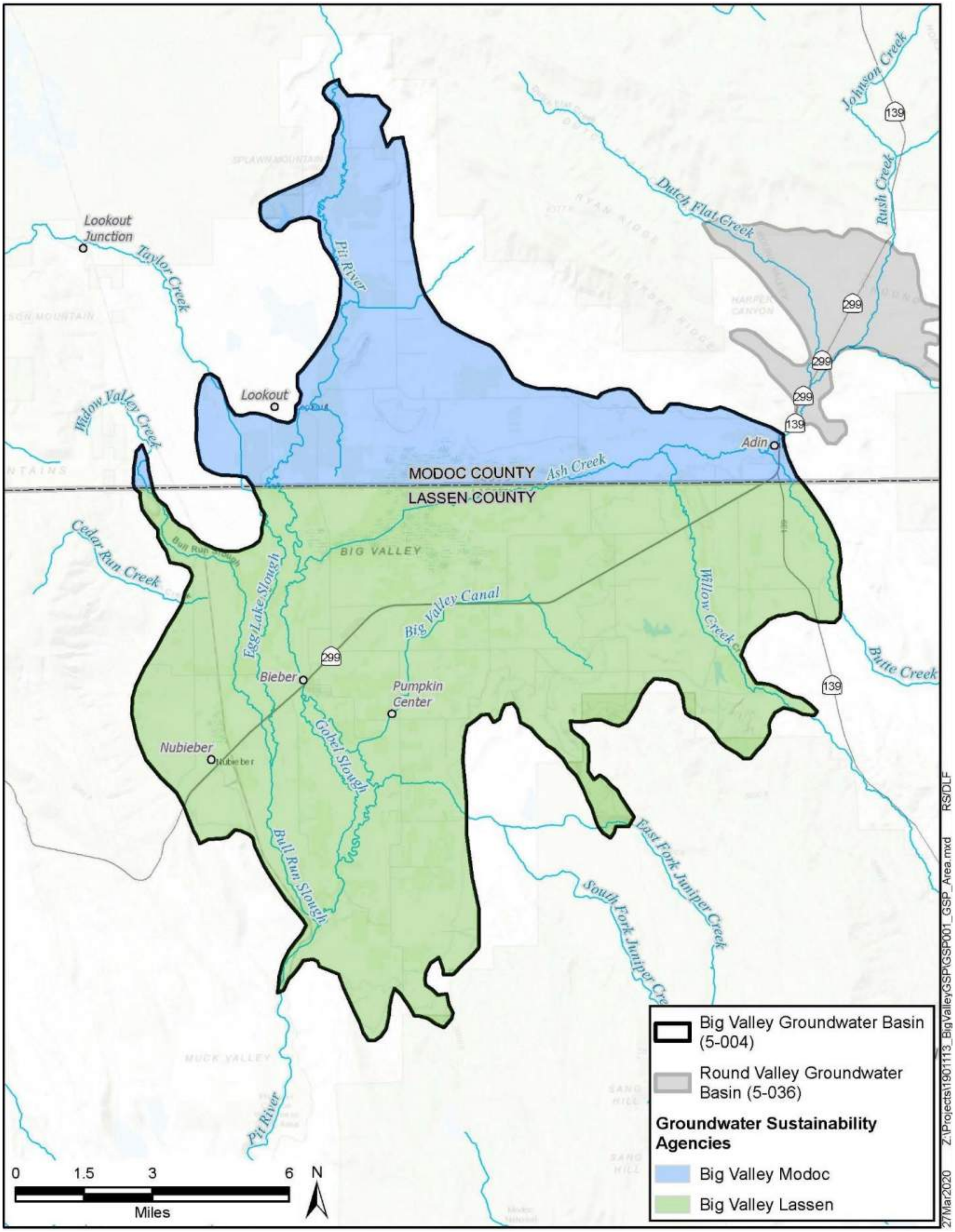


Figure 3-1 Area Covered by the GSP

Source: DWR 2018d

3.2 Jurisdictional Areas

In addition to the GSAs, other entities have water management authority or planning responsibilities in the Basin, as discussed below. A map of the jurisdictional areas within the Basin is shown on **Figure 3-2**.

3.2.1 Superior Courts

SGMA does not alter existing water rights. Therefore, water use in the Basin exists within the confines of state water law and existing water rights. These rights are ultimately governed by court decisions. In Big Valley, two decrees govern much of the surface-water rights allocations: Decree 3670 (1947) for Ash Creek and Decree 6395 (1959) for the Pit River. Any changes to these and any other judgments relevant to Big Valley would have to go through the Superior Court of Modoc County.

3.2.2 Federal Jurisdictions

The U.S. Bureau of Land Management (BLM) and the U.S. Forest Service (USFS or Forest Service) have jurisdiction over land within the Basin including portions of the Modoc National Forest, shown on **Figure 3-2**. Information on their Land and Resource Management Plan is described in Section 3.8. The Forest Service Ranger Station in Adin is a non-community public water supplier with a groundwater well, identified as Water System No. CA2500547 (SWRCB 2021).

3.2.3 Tribal Jurisdictions

The U.S. Bureau of Indian Affairs (BIA) Land Area Representations database identifies one tribal property in the BVGB (BIA 2020a). Lookout Rancheria, shown on **Figure 3-2**, is associated with the Pit River Tribe. There are other "public domain allotments" or lands held in trust for the exclusive use of individual tribal members within the Basin not shown (BIA 2020b).

3.2.4 State Jurisdictions

The CDFW has jurisdiction over the ACWA, as shown on **Figure 3-2**.

3.2.5 County Jurisdictions

The County of Modoc and the County of Lassen have jurisdiction over the land within the Basin in their respective counties as shown on **Figure 3-1** and **Figure 3-2**. Information on their respective General Plans is provided in Section 3.7 – Land Use Plans. Within the Basin, Modoc County includes the census-designated community of Adin and part of the community of Lookout. Lassen County contains the census-designated communities of Bieber and Nubieber.

3.2.6 Agencies with Water Management Responsibilities

Upper Pit Integrated Regional Water Management Plan

Big Valley lies within the area of the Upper Pit Integrated Regional Water Management Plan (IRWMP), which was developed by the Regional Water Management Group (RWMG). The IRWMP is managed by the North Cal-Neva Resource Conservation and Development Council (North Cal-Neva), a member of the RWMG along with 27 other stakeholders. Other stakeholders include community organizations,

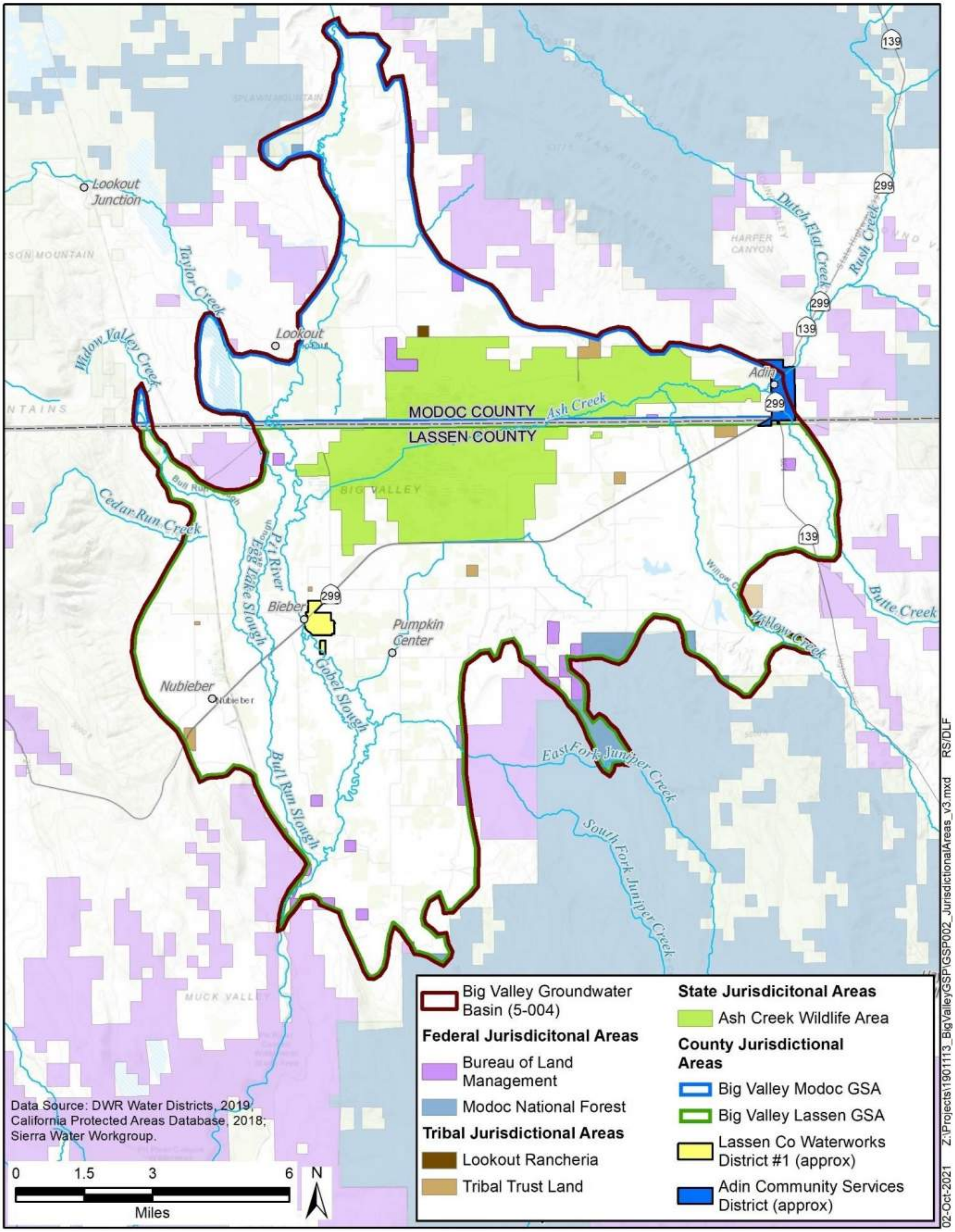


Figure 3-2 Jurisdictional Areas

environmental stewards, water purveyors, numerous local, county, state and federal agencies, industry, the University of California, and the Pit River Tribe. The IRWMP addresses a 3-million-acre watershed across four counties in northeastern California. **Figure 3-3** shows the Upper Pit IRWMP boundary and the BVGB's location in the center of the IRWMP area. **Figure 3-3** also shows the complete watershed that flows into the BVGB and the local watershed area. At 92,057 acres, the BVGB comprises about 3 percent of the IRWMP area at its center.

The IRWMP was established under the Integrated Regional Water Management Act (Senate Bill [SB]1672) which was passed in 2002 to foster local management of water supplies to improve reliability, quantity and quality, and to enhance environmental stewardship. Several propositions were subsequently passed by voters to provide funding grants for planning and implementation. Beginning in early 2011, an IRWMP was developed for the Upper Pit River area and was adopted in late 2013. During 2017 and 2018, the IRWMP was revised according to 2016 guidelines.

Lassen-Modoc County Flood Control and Water Conservation District

The Lassen-Modoc County Flood Control and Water Conservation District (District) was established in 1959 by the California Legislature and was activated in 1960 by the Lassen County Board of Supervisors (LAFCo 2018). The entirety of the Lassen and Modoc counties portions of the Basin is covered by the District, extending from the common boundary northward beyond Canby and Alturas, as shown on **Figure 3-3**. In 1965, the District established Zone 2 in a nearly 1000-square mile area encompassing and surrounding Big Valley. In 1994, the District designated boundaries for management Zone 2A for, "…groundwater management including the exploration of the feasibility of replenishing, augmenting and preventing interference with or depletion of the subterranean supply of waters used or useful or of common benefit to the lands within the zone" (LAFCo 2018). These zones are shown on **Figure 3-4**.

Watermasters

Two entities measure water diversions for reporting to the State Water Resources Control Board (SWRCB). These include the Big Valley Water Users Association (BVWUA) and the Modoc County Watermaster. The boundaries of these two entities are shown on **Figure 3-4**. Numerous private parties also measure and report their water diversions.

Lassen County Waterworks District #1

Lassen County Waterworks District #1 (LCWD #1) was established in 1932 originally for the purpose of fire protection. Homes started being added to the system in the 1940s. Eventually all residential and commercial properties became part of the system, with most properties leaving their private wells unused. LCWD #1 now provides both water and sewer services to the customers within its boundary shown on **Figure 3-2**. (Hutchinson 2021)

Adin Community Services District

Adin Community Services District provides wastewater services to the town of Adin. The district boundary is shown on **Figure 3-2**.

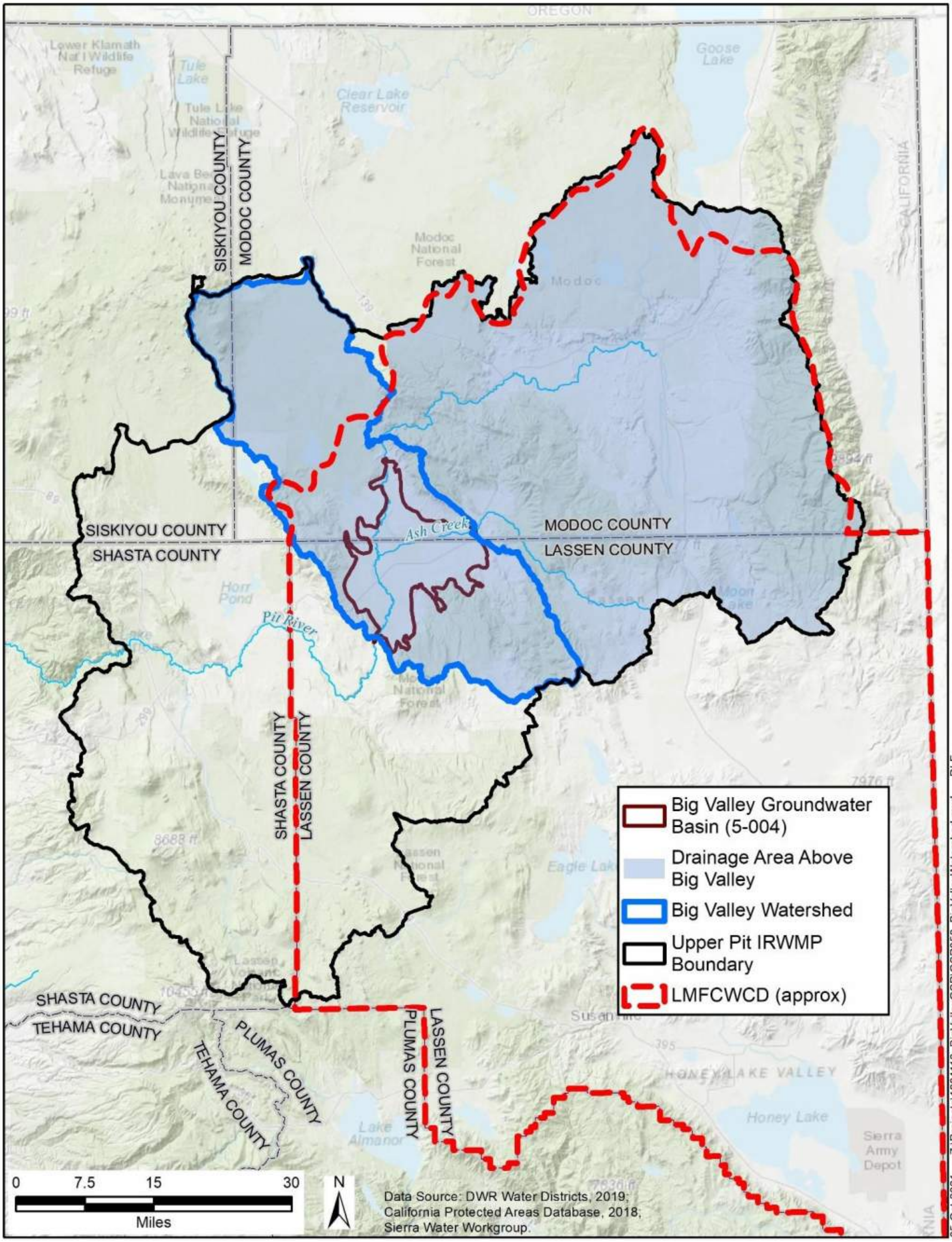


Figure 3-3 Upper Pit IRWMP, Watershed, and LMFCWCD Boundaries

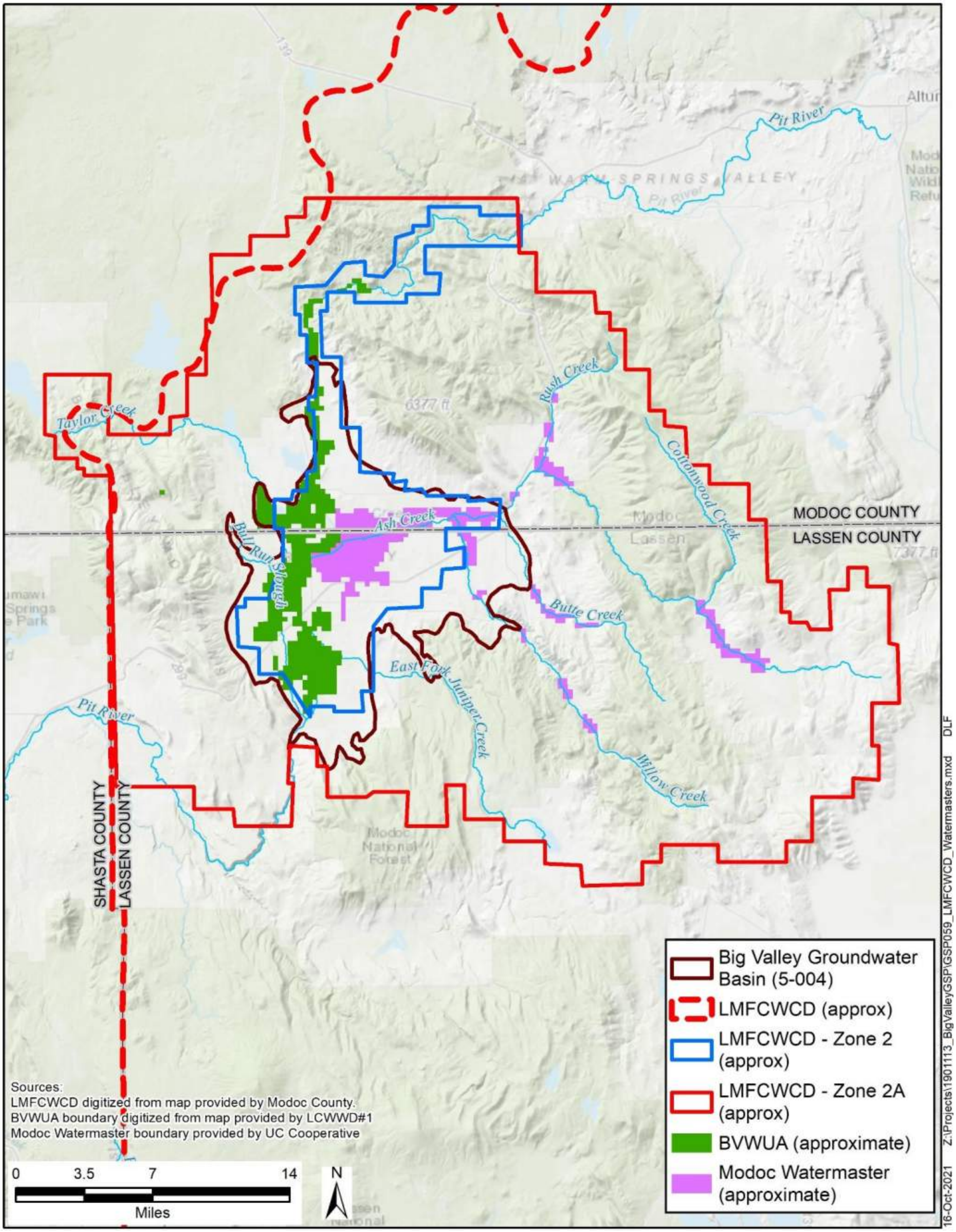


Figure 3-4 LMFCWCD Zones and Watermaster Service Areas

3.3 Land and Water Use

This section describes land use in the BVGB, water use sectors, and water source types using the best available data. The most recent, best available data for distinguishing surface-water and groundwater uses comes from DWR land-use datasets. This data is developed by DWR "…to serve as a basis for calculating current and projected water uses" (DWR 2021d). Surveys performed prior to 2014 were developed by DWR using some aerial imagery with field verification. These previous surveys also included DWR's estimate of water source.

Since 2014, DWR has developed more sophisticated methods of performing the surveys with a higher reliance on remote sensing information. These more recent surveys do not make available the water source. **Table 3-1** is a listing of the years for which surveys are available.

Table 3-1 Available DWR Land Use Surveys

Year	Modoc County	Lassen County	Water Source Included
1997	Yes	Yes	Yes
2011	Yes	No	Yes
2013	No	Yes	Yes
2014	Yes	Yes	No
2016	Yes	Yes	No[a]

Note:
[a] DWR provided the GSAs a hybrid dataset with the 2011 and 2013 water sources superimposed onto the 2016 land use
Source: DWR 2020d

Land use in the BVGB is organized into the water use sectors listed in **Table 3-2**. These sectors differ from DWR's water use sectors identified in Article 2 of the GSP regulations because DWR's sectors don't adequately describe the uses in Big Valley. **Figure 3-5** shows the 2016 distribution of land uses and **Table 3-2** summarizes the acreages of each. Several data sources were used to designate land uses as described below, including information provided by DWR through a remote sensing process developed by Land IQ (DWR 2016d). Other data sources are described below.

- **Community** This is non-agricultural, non-industrial water use in the census-designated places of Bieber, Nubieber, and Adin, although some of these areas may also have some minor industrial uses. These community areas were delineated using the areas designated as "urban" by DWR (2016d). DWR's data included the areas north and northeast of Bieber (area of the former mill and medical center) as "urban." For this GSP, those areas were re-categorized from urban to industrial, as that is more descriptive of the actual land use. In addition, parcels that make up the core of Nubieber were included as community.
- **Industrial** There is limited industrial use in the Basin. The DWR well log inventory shows 6 industrial wells, all located at the inactive mill in Bieber. The areas north and northeast of Bieber, including the former mill and the medical center, have been categorized as industrial. In addition, the parcels associated with railroad operations in Nubieber were added. There is some

industrial use associated with agriculture, but that is included under the agricultural water use sector.

- **Agricultural** Agricultural use is spread across the Basin and was delineated using DWR's (2016g) land-use data.[12]
- **State Wildlife Area** The area delineated in **Figure 3-5** is the boundary of the ACWA, located within the center of the Basin. The area includes some wetlands created by the seasonal flow of 6 streams and year-round flow from Ash Creek. The area also has upland ecosystems.
- **Managed Recharge** Flood irrigation of some fields and natural flooding of lowland areas provides recharge to the Basin even though it is not of a formalized nature that would put it into this managed recharge category. Some of the future projects and management actions in this GSP include managed recharge.
- **Native Vegetation** Native vegetation is widespread throughout the Basin. Many of the areas under this category also have domestic users. Native vegetation and domestic land uses are categorized together because it is not possible to distinguish between the two with readily available data.
- **Domestic** This sector includes water use for domestic purposes, for users that aren't located in a community service district. Domestic use generally occurs in conjunction with agricultural and native vegetation and is best represented on the map categorized with native vegetation, as most of the agricultural area is delineated by each field and does not include residences.

Table 3-2 2016 Land Use Summary by Water Use Sector

Water Use Sector	Acres	Percent of Total
Community[a]	250	<1%
Industrial	196	<1%
Agricultural	22,246	24%
State Wildlife Area[b]	14,583	16%
Managed Recharge	-	0%
Native Vegetation and Rural Domestic[c]	54,782	60%
Total	**92,057**	**100%**

Notes:
[a] Includes the use in the communities of Bieber, Nubieber and Adin
[b] Made up of a combination of wetlands and non-irrigated upland areas
[c] Includes the large areas of land in the Valley which have domestic wells interspersed
Source: Modified from DWR 2020d

Many of the lands within the Basin are enrolled in the Conservation Reserve Program (CRP) and Wetlands Reserve Program (WRP). The CRP is a land conservation program administered by the Farm Service Agency (FSA). In exchange for a yearly rental payment, farmers enrolled in the program agree to promote plant species that will improve environmental health and quality. Contracts for land enrolled

[12] This dataset has been identified as being inaccurate and has been included as a data gap.

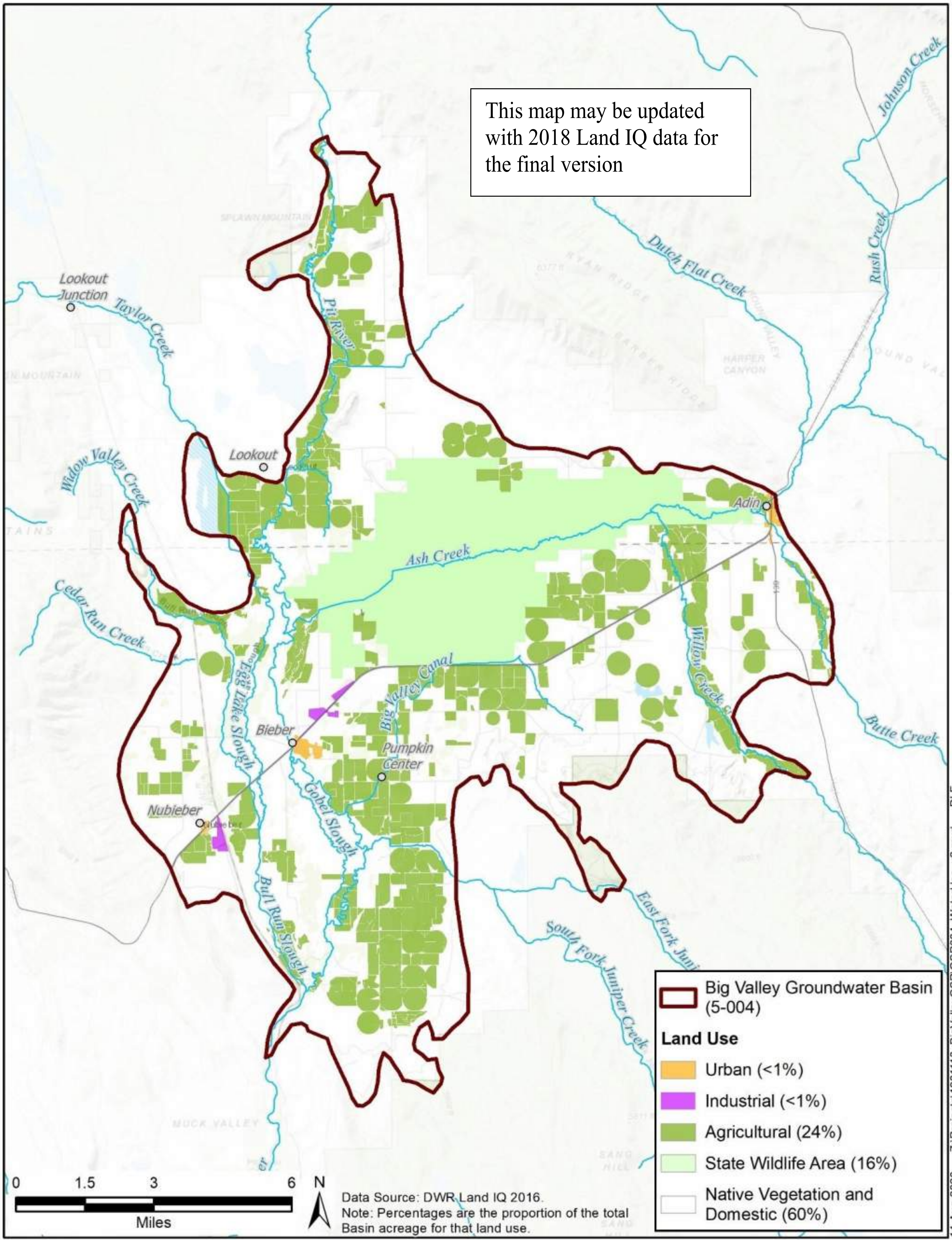


Figure 3-5 Land Use by Water Use Sector

in the CRP vary in length. The WRP is a similar program for wetlands and was available for enrollment until February 7, 2014. Land enrolled in the program before the end date continues to be enrolled until the termination of the contract.

In addition to the uses described above, the Big Valley GSAs are aware of illegal land-use activity within the Basin (i.e., unlicensed marijuana cultivation), which is likely having a negative impact on surface-water quality and quantity within the Basin and watershed. This illegal activity is occurring both within the alluvial portion of the Basin and the upstream watershed and may utilize groundwater and/or illegal diversions of surface water for cultivation. Lassen and Modoc counties have limited staff to monitor and enforce this situation on private land. However, in the last two growing seasons Lassen County Code Enforcement have identified and abated seven large-scale commercial marijuana grows within the Basin as public nuisances, and the Lassen County Sherriff has eradicated at least two under penal code. Some enforcement action is also within the purview of state and federal agencies. These agencies. These agencies include the Bureau of Cannabis Control, CDFW, State Water Board, USFS, and BLM. The GSAs are not aware that these state and federal agencies have taken aggressive enforcement action against this illegal activity and according to county staff, the problem is getting noticeably worse over time. The timing and volume of water used for illegal marijuana cultivation and extent of the potential contamination cannot be quantified at this time.

3.3.1 Water Source Types

The Basin has two water source types: groundwater and surface water. Recycled water[13] and desalinated water are not formally utilized in the Basin, nor is stormwater used as a formal, measured supplemental water supply at the time of the development of this GSP. Informal reuse of irrigation water occurs with capture and reuse of tail water by farmers and ranchers. Storm water is stored in reservoirs for future use as a water source. **Figure 3-6** and shows an approximate distribution of water sources to lands throughout the Basin. Chapter 6 – Water Budget provides details on how the sources were mapped for this figure.

There are three public water suppliers (as designated by the State Water Board) in the Basin which use groundwater: LCWD #1 in Bieber, the Forest Service Ranger Station in Adin, and the California Department of Forestry and Fire Protection (CAL FIRE) conservation camp west of the BVGB. The conservation camp is located outside the Basin boundary, but their supply well is inside the Basin and the water is pumped to the camp. Many domestic users have groundwater wells, but there are some surface-water rights from Ash Creek and the Pit River that are designated for domestic use. The ACWA is fundamentally supported by surface water, but the CDFW does have three wells that are utilized in the fall for ecological enhancement.

---

[13] Recycled water generally refers to treated urban wastewater that is used more than once before it passes back into the water cycle. (WateReuse Association, 2020)

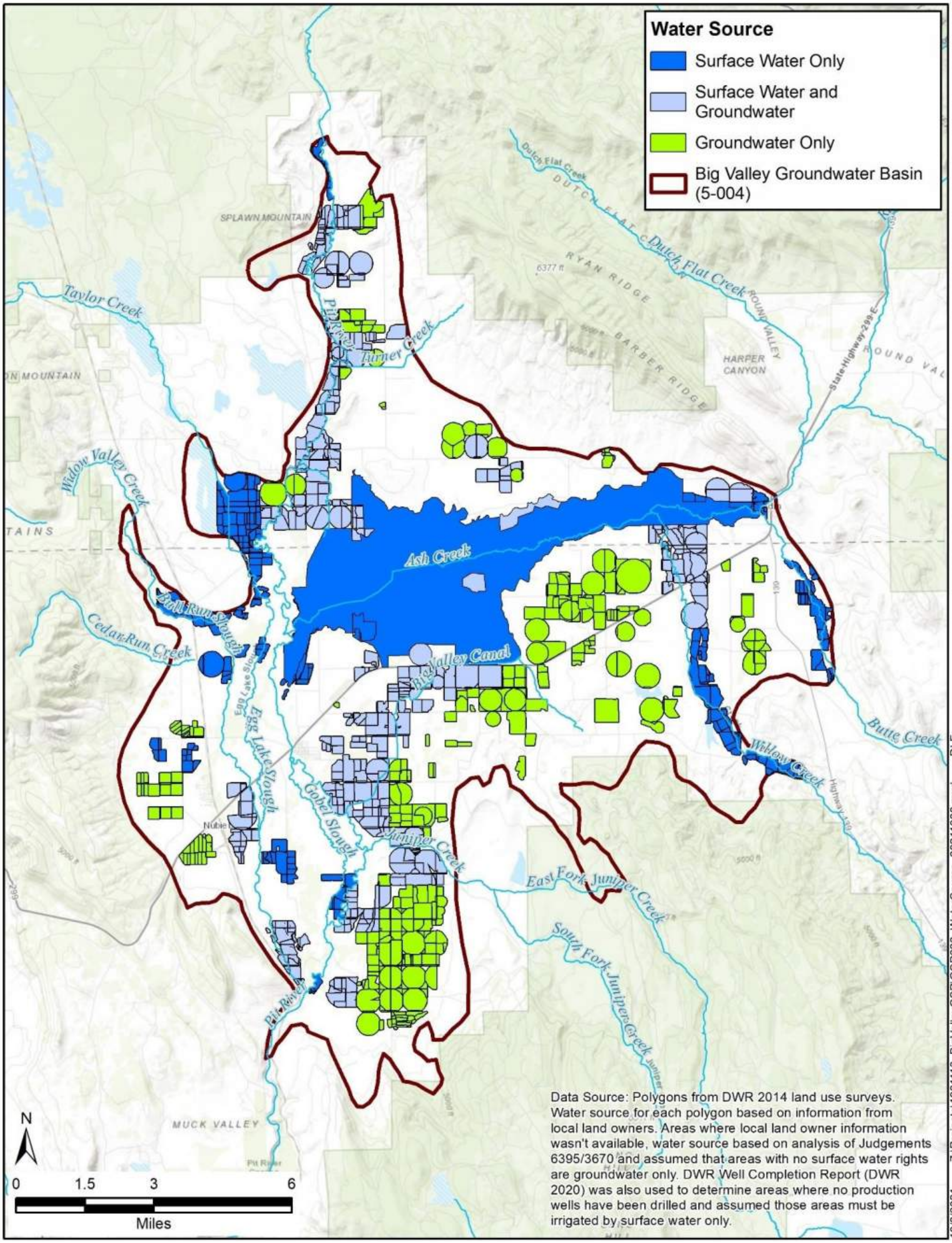


Figure 3-6 Water Sources

3.4 Inventory and Density of Wells

3.4.1 Well Inventory

The best available information about the number, distribution and types of wells in Big Valley comes from well completion reports (WCRs) maintained by DWR.[14] The most recent catalog of WCRs was provided through their website (DWR, 2018c) as a statewide map layer. This data includes an inventory and statistics about the number of wells in each section under three categories: domestic, production, or public supply.[15] **Table 3-3** shows the unverified number of wells in the BVGB for each county from this data. Many wells may be inactive or abandoned and this data gap will need to be filled over time. Once this data gap is filled, Basin priority could be affected.

Table 3-3 Well Inventory in the BVGB

WCR 2018 DWR Map Layer			DWR 2015 and 2017 WCR Inventory		
Type of Well [a]	**Lassen County Total Wells**	**Modoc County Total Wells**	**Proposed Use of Well [b]**	**Lassen County Total Wells**	**Modoc County Total Wells**
Domestic	136	81	Domestic	142	79
Production	177	76	Irrigation	157	65
			Stock	11	5
			Industrial	6	0
Public Supply	5	1	Public	5	1
Subtotal =476	**318**	**158**	**Subtotal = 471**	**321**	**150**
			Monitor	55	0
			Test	25	29
			Other	7	2
			Unknown	27	7
Total =476	**318**	**158**	**Total = 623**	**435**	**188**

Source:
[a] DWR 2018 Statewide Well Completion Report Map Layer; downloaded April 2019
[b] DWR Well Completion Report Inventories from DWR data provided to the counties in 2015 and 2017

Lassen and Modoc counties had requested and received WCRs for their areas from DWR during 2015 and 2017, respectively. An inventory of the wells was included by DWR. This data source had additional well categories included as shown in **Table 3-3**, which are more closely tied to the categories identified by the well drillers when each WCR is submitted and provides additional information about the use of the wells.

The correlation between the 2018 WCR map layer categories and the categories in the 2015 and 2017 WCR inventory provided to the counties is indicated in **Table 3-3** by the grey shading. The table shows similar totals from the two datasets for the number of domestic, production, and public supply wells. It is unkn

[14] All water-well drillers with a C57 drilling license in California are required to submit a well completion report to DWR whenever a well is drilled, modified, or destroyed.
[15] A section is defined through the public land survey system as a 1 mile by 1 mile square of land.

own why these two datasets don’t match exactly, but both datasets are provided to represent the data available for this GSP. As stated earlier, verification of the data in this table needs to occur. This table shows that more than 600 wells have been drilled, of which 476 are of a type that could involve extraction (e.g., domestic, production, or public supply).[16] It is unknown how many wells are actively used, as some portion of them are likely abandoned. Abandoned wells no longer in use should be formally destroyed in accordance with state well standards. The 2015 and 2017 inventory of WCRs showed six well destructions, all on the Lassen County side of the Basin. It should be noted that some of the recent wells in the Basin were drilled in cooperation with the EQUIP program to provide stock watering outside the riparian area to improve surface-water quality.

3.4.2 Well Density

Figure 3-7, **Figure 3-8**, and **Figure 3-9** show the density of wells in the Basin per square mile for domestic, production, and public supply, respectively, based on the 2018 WCR DWR map layer. These maps provide an approximation of extraction-well distributions and give a general sense of where groundwater use occurs.

Figure 3-7 shows that domestic wells are in 74 of the 180 sections (including partial sections) that comprise the BVGB. The density varies from 0 to 18 wells per square mile with a median value of two wells per section and an average of three wells per section. The highest densities of domestic wells are located near Adin, Bieber and Lookout. There are also sections east of Lookout and south of Adin which have high densities. In addition, 22 wells are present in the four sections around the town of Nubieber. Virtually all the domestic wells in Bieber are no longer used since the community water system was developed (Hutchinson 2020-2021).

Figure 3-8 shows that production wells (primarily for irrigation) are located in 93 of the 180 sections with a maximum density of nine wells per section (median: 2 wells per section, average: nearly 3 wells per section). The highest densities of production wells are located between the towns of Bieber and Adin, to the southeast of Bieber, and one section northeast of Lookout.

Figure 3-9 shows that public supply wells have been drilled in four sections. It should be noted that the designation as a public supply well that is depicted on the map is from the designation provided in the WCR by the driller when the well was drilled. The State Water Board identifies three public water suppliers in the BVGB: LCWD #1 which is a community system with two wells serve Bieber; the Forest Service station in Adin which maintains a well for non-community supply to its employees and visitors; and the CAL FIRE conservation camp west of the Basin. These public suppliers account for three of the six public wells with WCRs. The other three are either inactive or aren’t designated by the State Water Board as public supply. The CAL FIRE conservation camp well does not show up as a public supply well in the WCR inventory, but its location is shown on **Figure 3-9**.

[16] It should be noted that the majority of the stock watering wells were drilled in the 2009 to 2014 timeframe as part of the EQIP program to move watering of stock away from stream channels and that this increase in the inventory of wells in the Basin was used by DWR to put Big Valley into the medium prioritization category.

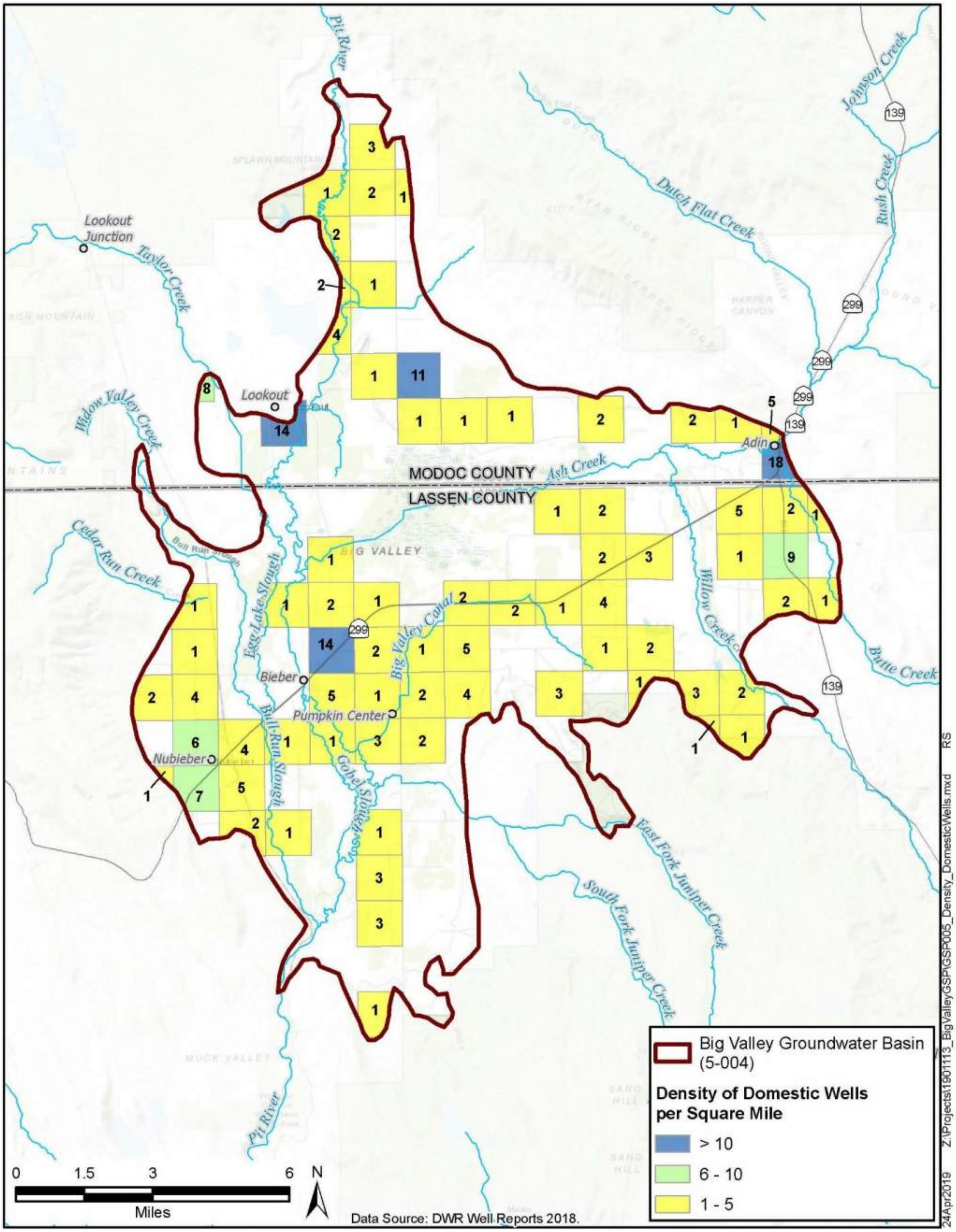


Figure 3-7 Density of Domestic Wells

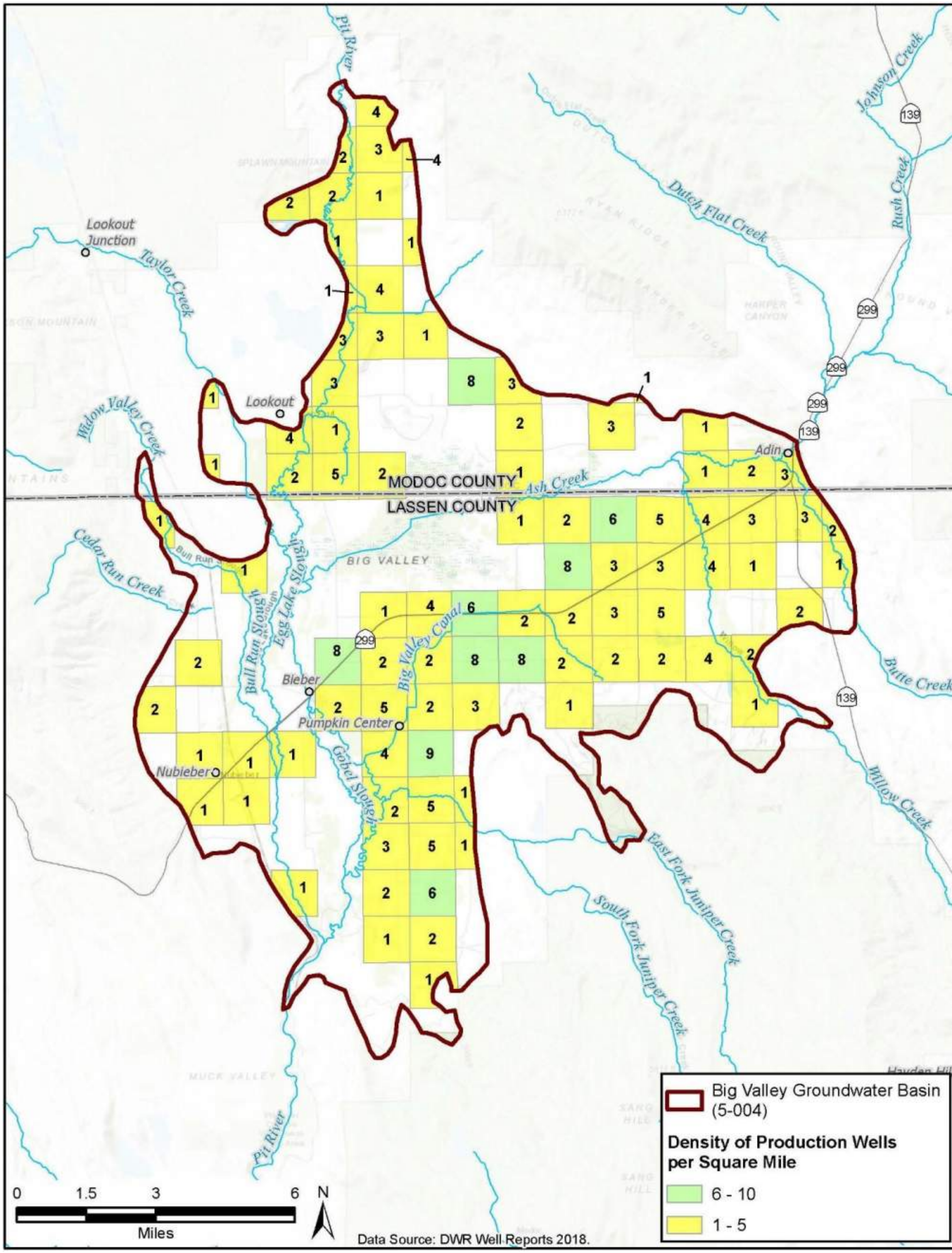


Figure 3-8 Density of Production Wells

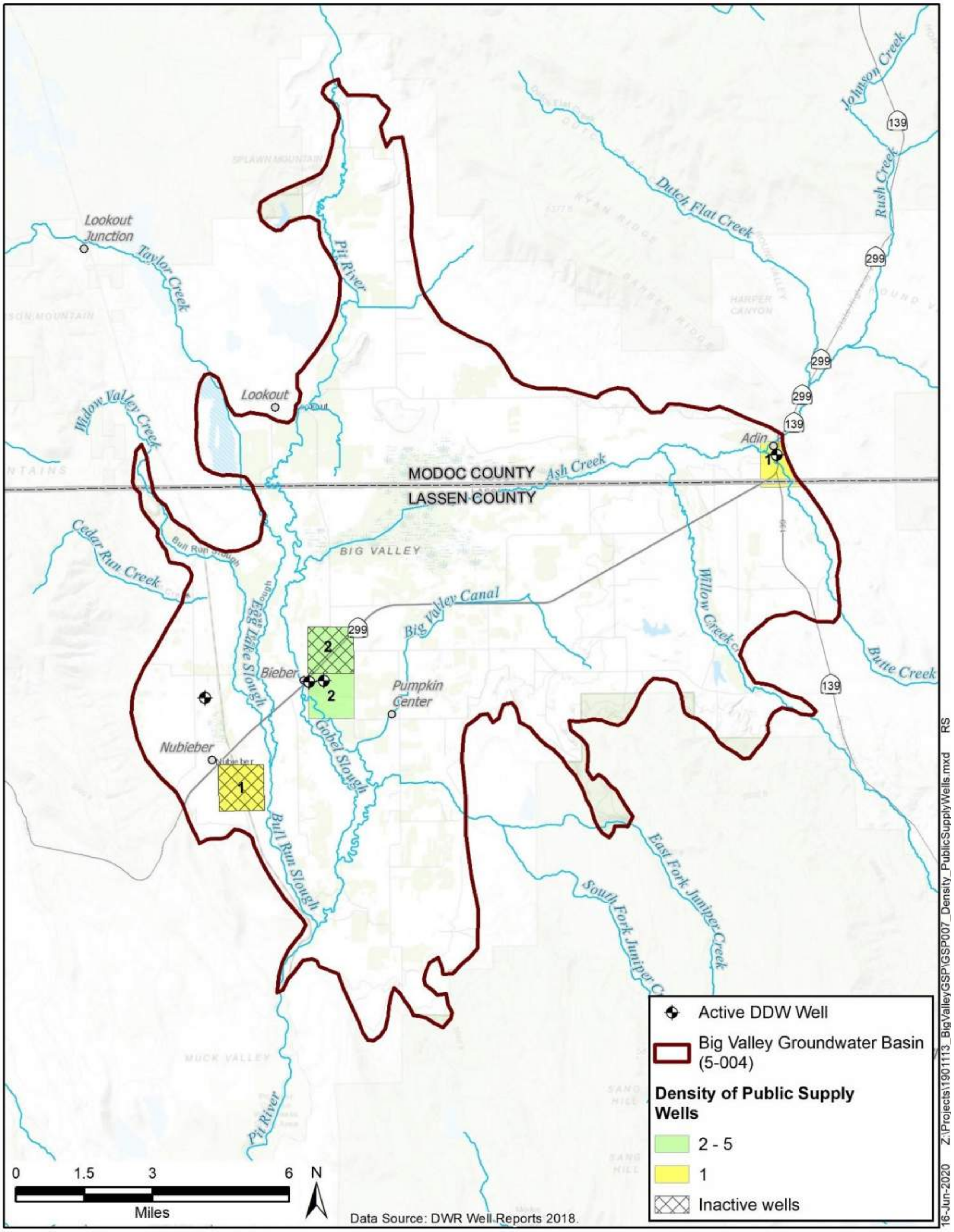


Figure 3-9 Density of Public Supply Wells

3.5 Existing Monitoring, Management and Regulatory Programs

3.5.1 Monitoring Programs

This section describes the existing monitoring programs for data used in this GSP and describes sources that can be used for the GSP monitoring networks.

3.5.1.1 Groundwater Monitoring

Levels

Lassen and Modoc counties are the monitoring entities for the CASGEM program. Each county has an approved CASGEM monitoring plan which provides for water level measurements twice a year (spring and fall) at 21 wells. The monitoring is performed by staff from DWR on behalf of the counties. All but one of the wells have depth information, and depths range from 73 to 800 feet below ground surface [ft bgs] (median: 270 ft bgs, mean: 335 ft bgs). **Figure 3-10** shows the locations of the 21 CASGEM wells and one additional well which has historic data, but measurements were discontinued in the 1990s.

Lassen and Modoc counties drilled five monitoring well clusters between 2019 and 2020. Each cluster consists of three shallow wells and one deep well. The locations of these clusters and the depth of the deep well at each site is shown on **Figure 3-10**.

Quality

Water quality is regulated and monitored under a myriad of programs. **Table 3-4** describes the programs relevant to Big Valley. The State Water Board makes groundwater data from many of these programs available on their Groundwater Ambient Monitoring and Assessment (GAMA) Groundwater Information System (GAMA GIS) website (State Water Board 2019). **Table 3-5** lists and describes the groundwater programs from which historic data is available on GAMA GIS. The locations of wells with historic water quality data from GAMA GIS are shown on **Figure 3-11.**

Along with the many programs that monitor surface-water quality, the following are currently in place to monitor groundwater quality on an ongoing basis:

- Public Drinking Water Systems (State Water Board's Division of Drinking Water [DDW])
- Monitoring associated with Underground Storage Tanks (USTs) and Waste Discharge Requirement

The BVGB contains three active public water suppliers regulated by the DDW: Lassen County Water District #1 in Bieber, the Forest Service station in Adin, and the CAL FIRE conservation camp west of the Basin. Water quality monitoring at wells regulated by the DDW can be used for ongoing monitoring in the Basin, and their locations are shown on **Figure 3-11**. At each of five newly-constructed monitoring well clusters, the deep well at each site was sampled for water quality after construction. The locations of the well cluster sites are shown on **Figure 3-11**.

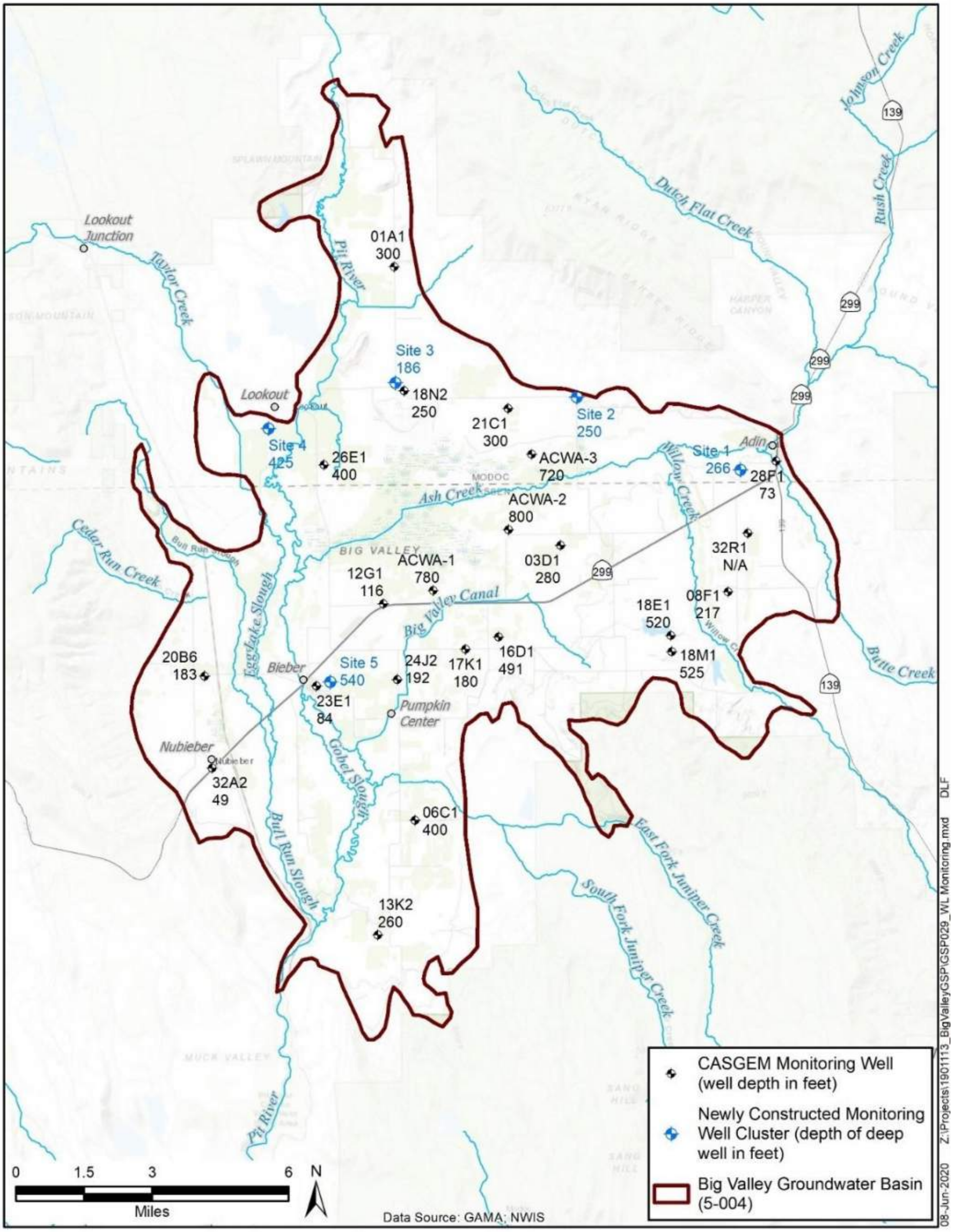


Figure 3-10 Water Level Monitoring Network

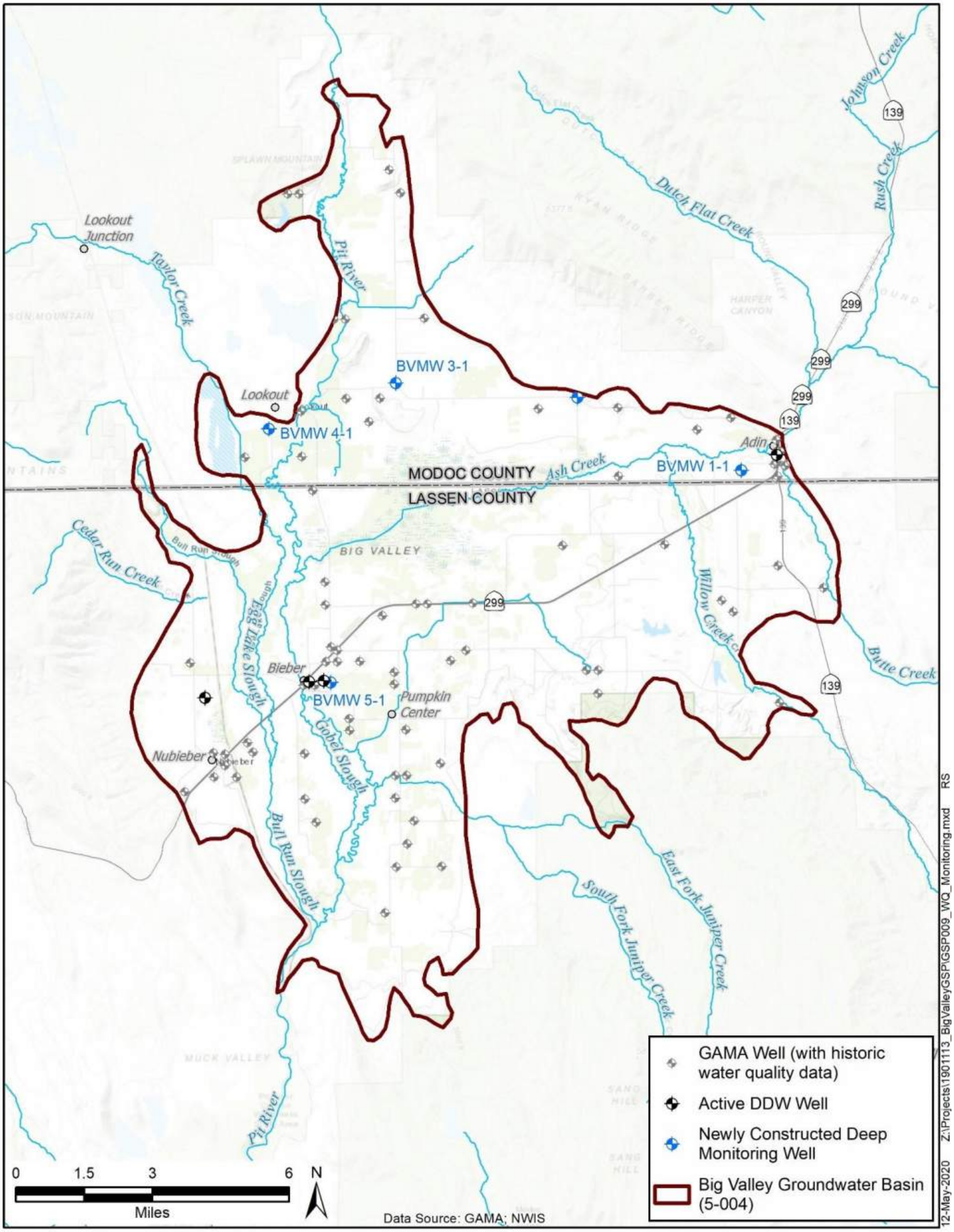


Figure 3-11 Water Quality Monitoring

Table 3-4 Water Quality Monitoring Programs

Program	Description
Irrigated Lands Regulatory Program (ILRP)	Initiated in 2003 to prevent agricultural runoff from impairing surface-waters; in 2012 groundwater regulations were added to the program. To comply with the ILRP, Big Valley growers were forced to join the Northeastern California Water Association (NECWA), which is a sub-watershed coalition of the Northern California Water Association. Growers pay increasing fees to NECWA for monitoring and compliance with the ILRP even though Big Valley farmers grow low intensity crops that generally don't require nitrogen application or cause water quality degradation.
Waste Discharge Requirements (WDR) Program	Also known as the Non-Chapter 15 Permitting, Surveillance and Enforcement Program, this is a mandated program issuing WDRs to regulate the discharge of municipal, industrial, commercial, and other wastes to the land that will, or has the potential to, affect groundwater.
Central Valley Salinity Coalition (CVSC)	Represents the stakeholder groups working with the State Water Board in the CV-SALTS collaborative basin planning process.
RWQCB Basin Plan	Adopted by the Regional Water Board and approved by the State Water Board and the Office of Administrative Law. The U.S. Environmental Protection Agency approves the water quality standards contained in the Basin Plan, as required by the Clean Water Act (CWA).
Public Drinking Water Regulations	Effective July 1, 2018, various sections of California Code of Regulations, Title 27 were revised. Revisions to Title 27 were necessary in order to reorganize, update and incorporate new parameters for administering the Unified Program and accomplishing the objectives of coordination, consolidation and consistency in the protection of human health, safety, and the environment.
Total Maximum Daily Load Program (TMDL) Program	TMDLs are established at the level necessary to implement the applicable water quality standards.
Local Agency Management Programs	These programs regulate Onsite Water Treatment Systems (OWTSs); the programs are designed to "correct and prevent system failures due to poor siting and design and excessive OWTS densities" (RWQCB 2021).
Underground Storage Tank Site Cleanup Program (UST)	The purpose of the UST Program is to protect the public health and safety and the environment from releases of petroleum and other hazardous substances from USTs.
National Pollutant Discharge Elimination System (NPDES)	The NPDES permit program, created in 1972 by the CWA, helps address water pollution by regulating point sources that discharge pollutants to waters of the U.S. The permit provides two levels of control: technology-based limits and water quality-based limits (if technology-based limits are not sufficient to provide protection of the water body).
Nonpoint Source Program (NSP)	NSP focuses and expands the state's efforts over the next 13 years to prevent and control nonpoint source pollution. Its long-term goal is to implement management measures by the year 2013 to ensure the protection and restoration of the state's water quality, existing and potential beneficial uses, critical coastal areas, and pristine areas. The state's nonpoint source program addresses both surface and ground water quality.
Other	Water quality samples are required when a property is sold and when a foster child is placed.

Table 3-5 Datasets Available from State Water Board's GAMA Groundwater Information System

Name	Source
DDW	Division of Drinking Water, State Water Board
DPR	Department of Pesticide Regulation
DWR	California Department of Water Resources
GAMA_USGS	Groundwater Ambient Monitoring and Assessment Program performed by USGS
USGS_NWIS	USGS National Water Information System
WB_CLEANUP	Water Board Cleanup
WB_ILRP	Water Board Irrigated Lands Regulatory Program
Source: GAMA GIS available at https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/	

The Basin has five active groundwater cleanup sites in various stages of assessment and remediation, all located in the town of Bieber. These sites are not appropriate for ongoing monitoring for the GSP because they monitor only the shallow aquifer and represent a localized condition that may not be representative of the overall quality of groundwater resources in the Basin. One of the open sites is the Bieber Class II Solid Waste Municipal Landfill which has ongoing water quality monitoring. The Lookout Transfer Station also has ongoing water quality monitoring but is located outside the boundaries of the BVGB.

Growers in Big Valley are required to participate in the ILRP, which imposes a fee per acre, through the Sacramento Valley Water Quality Coalition (SVWQC). The SVWQC Monitoring and Reporting Plan does not include any wells within the BVGB. Basin residents have expressed concerns with regulatory programs that involve costs, especially ongoing costs, particularly for a disadvantaged community. The Goose Lake Basin, which has similar land use and land-use practices, has been exempted from the ILRP.

3.5.1.2 Surface-water Monitoring

Streamflow

Streamflow gages have historically been constructed and monitored within the BVGB, but active, maintained streamflow gages for streams in BVGB are limited. For the Pit River, the closest active gage that monitors stage and streamflow is located at Canby, 20 miles upstream of Big Valley. Flow on Ash Creek was measured at a gage in Adin from 1981 to 1999 and was reactivated in Fall 2019 to provide stream stage data at 15-minute intervals. There is a gage where the Pit River exits the Basin in the south at the diversion for the Muck Valley Hydro Power Plant. Stream gages are shown on **Figure 3-12**.

Diversions

Two watermasters, described below, measure diversions in the BVGB. Those surface-water rights holders who divert more than 10 AFY whose rights are not measured by a watermaster must measure and report their diversions to the State Water Board.

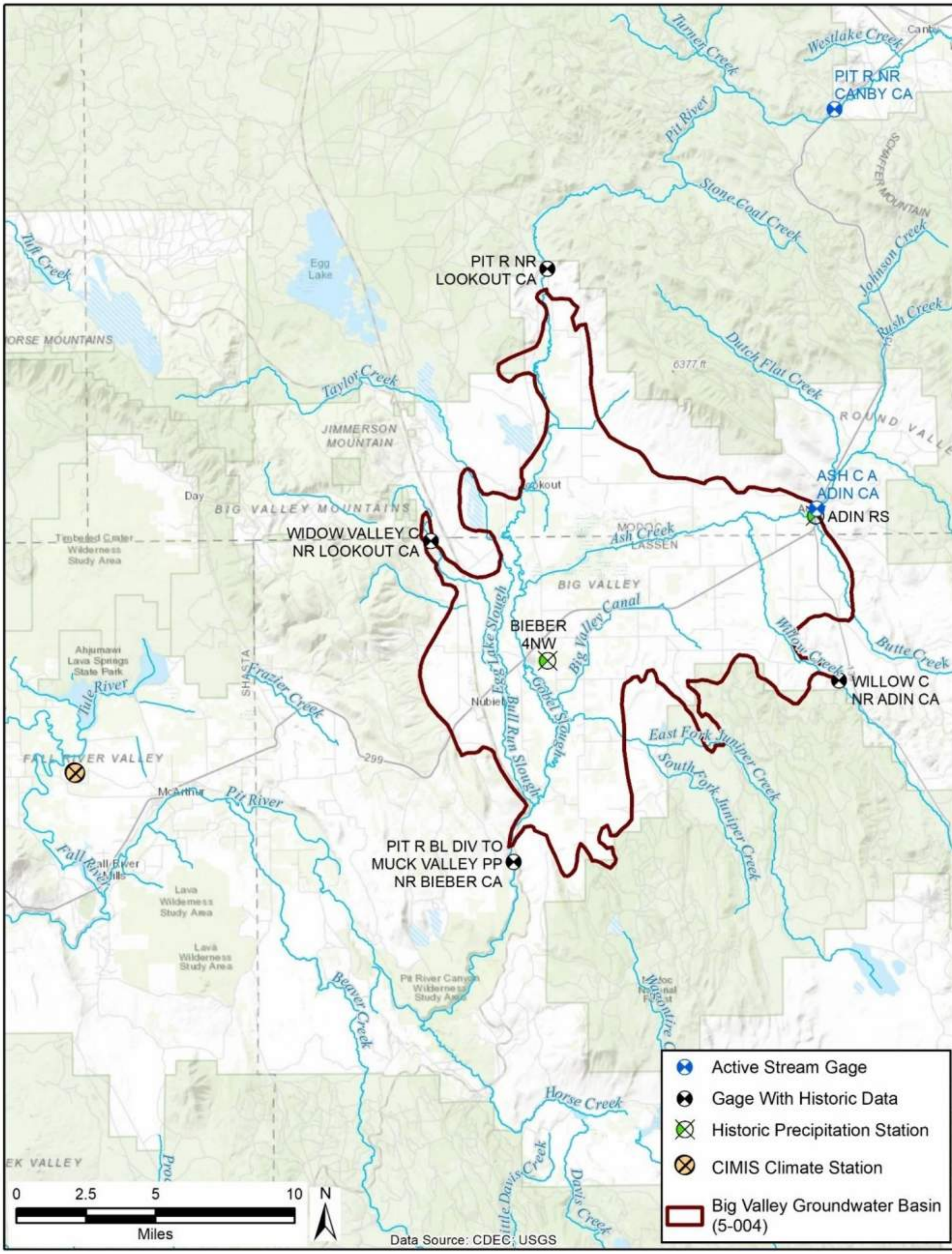


Figure 3-12 Historical Surface-water and Climate Monitoring Network

Diversions from the Pit River are detailed in water rights Decree #6395. In 2006, the BVWUA petitioned the Modoc Superior Court who granted permission to separate from the costly state watermaster service. A private watermaster service is now contracted by the BVWUA to administer/distribute allocated 2nd priority rights in conjunction with state watermaster guidelines during the irrigation season (April 1 through September 30) each year as a neutral 3rd party. The watermaster service measures diversions every two weeks and reports the data to each water rights holder. At the end of the irrigation season, the watermaster sends each member a yearly use report. The water rights holder is responsible to submit their reports to the State Water Board. Currently there are five Pit River water rights holders that do not participate in the BVWUA watermaster service. (Hutchinson 2021)

Ash Creek water rights are governed by Decree 3670 and Willow Creek by Decree 1237. Ash Creek and Willow Creek are within the Ash Creek Watermaster Service Area (WMSA). The WMSA also includes Butte and Rush Creeks and is under the jurisdiction of the Modoc County Watermaster. The Watermaster files the annual reports to DWR and Modoc County Superior Court. (Modoc County Watermaster 2021)

3.5.1.3 Climate Monitoring

The National Oceanic and Atmospheric Administration (NOAA) has two stations located in the Basin: Bieber 4 NW and Adin RS. Neither station is active, thus they only provide historic data. Annual precipitation at the Bieber station is shown for 1985 to 1995 in **Table 3-6**.

Table 3-6 Annual Precipitation at Bieber from 1985 to 1995

Water Year	Precipitation at Station ID: BBR (inches)
1985	14.1
1986	25.4
1987	11.6
1988	10.9
1989	20.2
1990	16.1
1991	16.5
1992	10.4
1993	28.2
1994	16.3
1995	31.8
Minimum	10.4
Maximum	31.8
Average	18.3

Source: DWR 2021b

The closest California Irrigation Management Information System (CIMIS) station, number 43, is in McArthur, CA, and measures several climatic factors that allow a calculation of daily reference evapotranspiration for the area. This station is approximately 10 miles southwest of the western boundary of the Basin. **Table 3-7** provides a summary of average monthly rainfall, temperature and refe**Error! Reference source not found.** shows annual rainfall for 1984 through 2018. The bar graph along the bottom shows annual precipitation, and the line graph on top shows the cumulative departure from average. The cumulative departure graph indicates when there are dry periods (downward slope of the line), wet periods (upward slope of the line), and average periods (flat slope of the line). Each time the line graph crosses the dashed line indicates that an average set of years has occurred. A set of average years has occurred between 1983-1997, 1997 to 2010, and 2010 to 2019. The locations of all climate monitoring stations are shown on **Figure 3-12**. Climate monitoring is a data gap that could be filled with a CIMIS station located in the Basin.

Table 3-7 Monthly Climate Data from CIMIS Station in McArthur (1984-2018)

Month	Average Rainfall (inches)	Average ET_o (inches)	Average Daily Temperature (°F)
October	1.4	3.02	49.5
November	2.3	1.21	38.2
December	2.9	0.75	32.1
January	2.5	0.89	32.5
February	2.6	1.57	36.8
March	2.4	3.01	42.4
April	1.8	4.39	48.2
May	1.6	5.93	55.1
June	0.7	7.24	62.8
July	0.2	8.17	69.1
August	0.2	7.18	66.1
September	0.4	5.02	59.5
Monthly Average	1.6	4.03	49.4
Average Water Year	18.8	48.3	49.4

Source: DWR 2020c

3.5.1.4 Subsidence Monitoring

Subsidence monitoring is available in the BVGB at a single continuous global positioning satellite station (P347) on the south side of Adin. P347 began operation in September 2007 and provides daily readings. The five monitoring well clusters constructed in 2019-2020 were surveyed and a benchmark established at each site. These sites can be reoccupied in the future to determine changes in ground elevation at those points if needed. The surveyor’s report is included as **Appendix 3A**.

In addition, DWR has provided data processed from InSAR collected by the European Space Agency. The InSAR data currently available provides vertical displacement information between January 2015 and September 2019. InSAR is a promising, cost-effective technique, and DWR will likely provide additional data and information going forward.

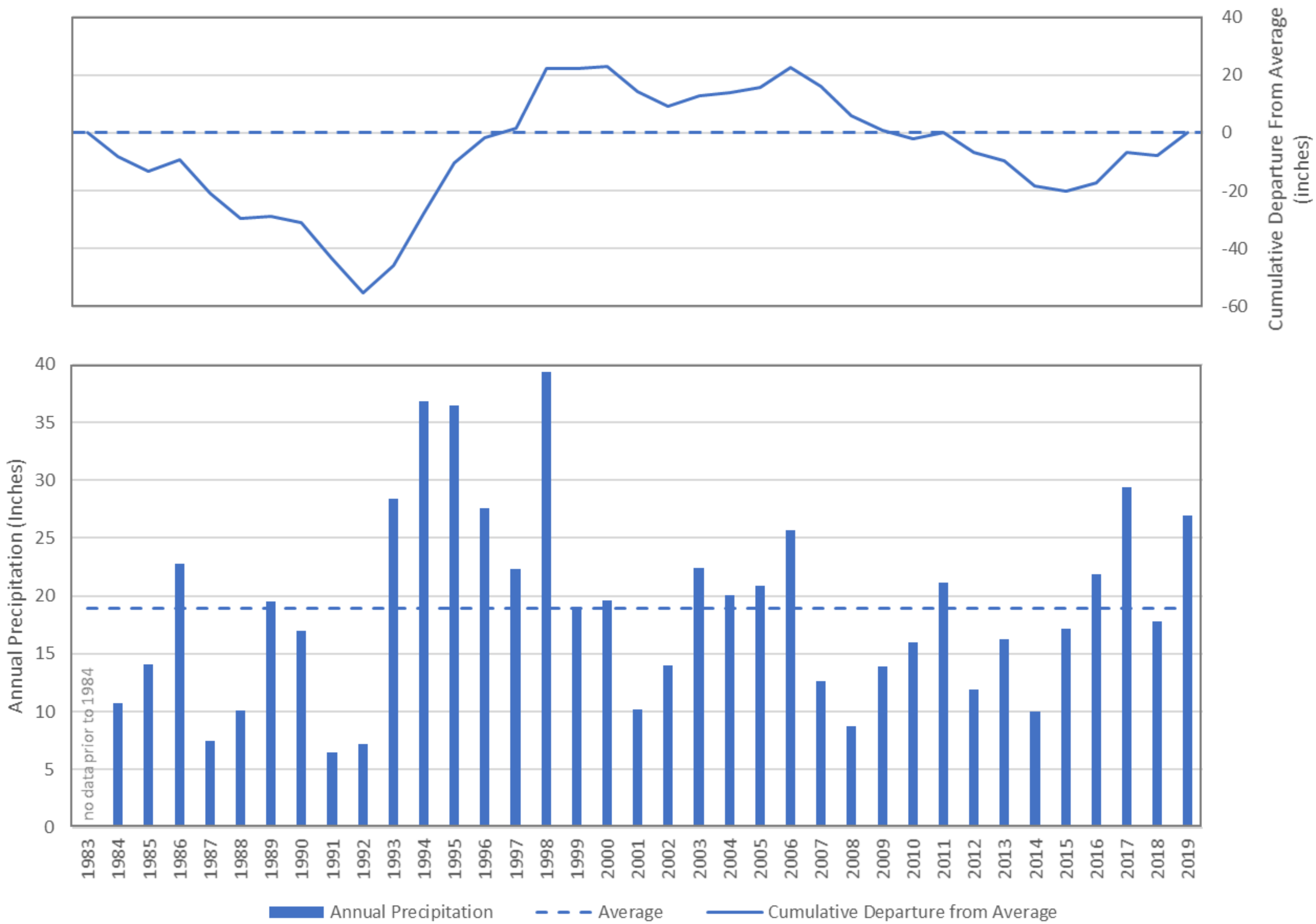


Figure 3-13 Annual Precipitation at the McArthur CIMIS Station

3.5.2 Water Management Plans

Two water management plans exist that cover the BVGB: the Lassen County Groundwater Management Plan (LCGMP) and the Upper Pit River IRWMP.

Lassen County Groundwater Management Plan

The LCGMP was completed in 2007 and covers all groundwater basins in Lassen County, including the Lassen County portion of the BVGB. The goal of the LCGMP is to, "…maintain or enhance groundwater quantity and quality, thereby providing a sustainable, high-quality supply for agricultural, environmental and urban use…" (Brown and Caldwell 2007). The LCGMP achieves this through the implementation of Basin Management Objectives[17] (BMOs), which establish key wells for monitoring groundwater levels and define "action levels," which, when exceeded, activate stakeholder engagement to determine actions to remedy the exceedance. Action levels are similar to minimum thresholds in SGMA. A BMO ordinance was passed by Lassen County in 2011 and codified in Chapter 17.02.

Upper Pit River Watershed IRWMP

The Upper Pit IRWMP was adopted by the RWMG in 2013. Twenty-five regional entities were involved in the plan development, which included water user groups, federal, state and county agencies, tribal groups, and conservation groups. The management of the IRWMP has now transferred to North Cal-Neva who has been working to update the IRWMP. The goal of the IRWMP is to:

> …maintain or improve water quality within the watershed; maintain availability of water for irrigation demands and ecological needs (both ground and surface water); sustain/improve aquatic, riparian and wetland communities; sustain and improve upland vegetation and wildlife communities; control & prevent the spread of invasive noxious weeds; strengthen community watershed stewardship; reduce river and stream channel erosion and restore channel morphology; support community sustainability by strengthening natural-resource-based economies; support and encourage better coordination of data, collection, sharing and reporting in the watershed; improve domestic drinking water supply efficiency/reliability; address the water-related needs of disadvantaged communities; conserve energy, address the effects of climate variability and reduce greenhouse gas emissions. (NECWA 2017)

The Upper Pit IRWMP contains the entire Watershed above Burney and extends past Alturas to the northeast (see **Figure 3-3**) and includes the entire BVGB. This GSP has been identified as a "Project" in the IRWMP.

3.5.3 Groundwater Regulatory Programs

The Basin is located within the jurisdiction of the Regional Water Quality Control Board (RWQCB) Region 5 (R5) and subject to a Basin Plan, which is required by the CWC (§13240) and supported by the federal Clean Water Act. The Basin Plan for the Sacramento River Basin and the San Joaquin River

[17] Codified as Chapter 17.02 of Lassen County Code.

Basin was first adopted by the RWQCB-R5 in 1975. The current version of the Basin Plan was adopted in 2018. The Porter-Cologne Water Quality Control Act requires that basin plans address beneficial uses, water quality objectives, and a program of implementation for achieving water quality objectives. Water Quality Objectives for both groundwater (drinking water and irrigation) and surface water are provided in Chapter 3 of the Basin Plan (State Water Board, 2020c).

Lassen County Water Well Ordinance

Lassen County adopted a water well ordinance in 1988 to provide for the construction, repair, modification, and destruction of wells in such a manner that the groundwater of Lassen County aquifers will not be contaminated or polluted. The ordinance ensures that water obtained from wells will be suitable for beneficial use and will not jeopardize the health, safety, or welfare of the people of Lassen County. The ordinance includes requirements for permits, fees, appeals, standards and specifications, inspection, log of the well (lithology and casing), abandonment, stop work, enforcement, and violations and well disinfection. Lassen County Environmental Health Department is responsible for the code enforcement related to wells.

In 1999, Lassen County adopted an ordinance requiring a permit for export of groundwater outside the county (Lassen County Code 17.01).

Modoc County Water Well Requirements

Modoc County Environmental Health Department established its requirements for the permitting of work on water wells in 1990, based on the requirements of the CWC (§13750.5). The fee structure was last revised in 2018. Modoc County also has an ordinance prohibiting the extraction of groundwater for use outside of the groundwater basin from which it was extracted (Title 20 Chapter 20.04).

California DWR Well Standards

DWR is responsible for setting the minimum standards for the construction, alteration, and destruction of wells in California to protect groundwater quality, as allowed by CWC §13700 to §13806. DWR began this effort in 1949 and has published several versions of standards in Bulletin 74, and are working on an update that has yet to be released. Current requirements are provided in Bulletin 74-81, Water Well Standards: state of California and in Bulletin 74-90 (Supplement) (DWR 2021c). Cities, counties, and water agencies have regulatory authority over wells and can adopt local well ordinances that meet or exceed the state standards. Lassen and Modoc Counties are the well permitting agencies for their respective portions of the Basin.

Title 22 Drinking Water Program

The DDW was established in 2014 when the regulatory responsibilities were transferred from the California Department of Public Health. DDW regulates public water systems that provide, "…water for human consumption through pipes or other constructed conveyances that have 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year," as defined by the Health and Safety Code (§116275(h)). DDW further defines public water systems as:

- Community: Serves at least 15 service connections used by year-round residents or regularly serves 25-year-round residents. LCWD #1 is a community system that provides groundwater in Bieber.
- Non-Transient Non-Community: Serves at least the same 25 non-residential individuals during 6 months of the year. The State Water Board classifies the Adin Ranger Station and the Intermountain Conservation Camp as systems in this category which serve groundwater.
- Transient Non-Community: Regularly serves at least 25 non-residential individuals (transient) during 60 or more days per year. There is no system of this category in the BVGB.

Private domestic wells, industrial wells, and irrigation wells are not regulated by the DDW.

The State Water Board-DDW enforces the monitoring requirements established in Title 22 of the California Code of Regulations for public water system wells and all the data collected must be reported to the DDW. Title 22 designates the regulatory limits (e.g., MCLs) for various constituents, including naturally occurring inorganic chemicals and metals and general characteristics and sets limits for man-made contaminants, including volatile and non-volatile organic compounds, pesticides, herbicides, disinfection byproducts, and other parameters.

3.5.4 Incorporation Into GSP

Information in these and other various and numerous programs have been incorporated into this GSP and used during the preparation of Sustainability Management Criteria (minimum thresholds, measurable objectives, interim milestones) and have been considered during development of Projects and Management Actions.

3.5.5 Limits to Operational Flexibility

While some of the existing management programs and ordinances may have the potential to affect operational flexibility, they are not likely to be a factor in the Basin. For example, runoff and stormwater quality is of high quality and would not constrain recharge options. Similarly, groundwater export limitations by Lassen County and Modoc County would be considered for any decisions in the Basin.

3.6 Conjunctive Use Programs

Formally established conjunctive use programs are not currently operating within the Basin.

3.7 Land Use Plans

The following sections provide a general description of the land-use plans and how implementation may affect groundwater. Section 3.2 – Jurisdictional Areas, describes the jurisdictional areas within the BVGB and many of these entities have developed land-use plans for their respective jurisdictions. This includes the general plans (GPs) for Modoc County and Lassen County and the Modoc National Forest Land and Resource Management Plan.

3.7.1 Modoc County General Plan

The 1988 Modoc County GP was developed to meet a state requirement and to serve as the "constitution" for the community development and use of land. The GP discusses the mandatory elements of a GP, including land use, housing, circulation (transportation), conservation and open space, noise and safety, as well as economic development and an action program in the county. The GP was intended to serve as a guide for growth and change in Modoc County. Under the Conservation Element, Modoc County recognizes the importance of "use-capacity" for groundwater, among other issues, and the minimization of "adverse resource-use," such as "groundwater mining." The Water Resources section advocates the "wise and prudent" management of groundwater resources to support a sustainable economy as well as maintaining adequate supplies for domestic wells for rural subdivisions. Groundwater quality was recognized as good to excellent within the county's basins.

Policy items from the Modoc GP related to groundwater include:

- Cooperate with responsible agencies and organizations to solve water quality problems
- Work with the agricultural community to resolve any groundwater overdraft problems
- Require adequate domestic water supply for all rural subdivisions

The action program included several general statements for water, including:

- Initiate a cooperative effort among state and local agencies and special districts to explore appropriate actions necessary to resolve long-term water supply and quality problems in the counties
- Require as a part of the review of any subdivision approval a demonstration to the satisfaction of the county that the following conditions exist for every lot in the proposed development:
  - An adequate domestic water supply
  - Suitable soil depth, slope, and surface acreage capable of supporting an approved sewage disposal system

In 2018, a GP amendment was adopted to update the housing element section.

3.7.2 Lassen County General Plan

The Lassen County GP 2000 was adopted in 1999 by the Lassen County Board of Supervisors (Resolution 99-060) to address the requirements of California Government Code Section 65300 et seq and related provisions of California law pertaining to GPs. The GP reflects the concerns and efforts of the County to efficiently and equitably address a wide range of development issues which confront residents, property owners, and business operators. Many of these issues also challenge organizations and agencies concerned with the management of land and resources and the provisions of community services within Lassen County.

The goals of the GP are to:

- Protect the rural character and culture of Lassen County life
- Maintain economic viability for existing industries such as agriculture, timber, and mining
- Promote new compatible industries to provide a broader economic base
- Create livable communities through carefully planned development which efficiently utilize natural resources and provide amenities for residents
- Maintain and enhance natural wildlife communities and recreational opportunities
- Sustain the beauty and open space around use in this effort

The GP addresses the mandatory elements (land use, circulation, housing, conservation, open space, noise, and safety) *via* several GP documents and alternate element titles. The 1999 GP elements include land use, natural resources (conservation), agriculture, wildlife, open space, circulation, and safety. Separate documents were produced for housing, noise, and energy. The land-use element designates the proposed general distribution and intensity of uses of the land, serves as the central framework for the entire GP, and correlates all land-use issues into a set of coherent development policies. The GP land-use map from 1999, shown on **Figure 3-14,** shows Intensive Agriculture as the dominant land use within the Big Valley area, along with scattered population (small) centers. Otherwise, Extensive Agriculture is the dominant land use.

Groundwater is addressed in several elements, including agriculture, land use, and natural resources. The GP identified the BVGB as a 'major ground water basin' due to the operation of wells at over 100 gallons per minute [gpm]. Moreover, the GP expressed concern about water transfers and their impact on local water needs and environmental impacts due to the possibility of water marketeers either pumping groundwater from the BVGB into the Pit River and selling it to downstream water districts or municipalities or using groundwater to augment summer flow through the Delta. The GP recognized that safe yield is dependent on recharge and that overdraft pumping would increase operating costs due to a greater pumping lift. The GP also recognized that overdraft pumping could result in subsidence and water quality degradation. In addition, the GP referred to 1980s legislation that authorized the formation of water districts in Lassen County to manage and regulate the use of groundwater resources and to the 1959 Lassen-Modoc County Flood Control and Water Conservation District, as discussed above. The SGMA process established the requirements for a GSP in the BVGB and creation of the two GSAs. The land-use element identified several issues related to groundwater, including public services where 62 percent of rural, unincorporated housing units relied on individual (domestic) wells for their water.

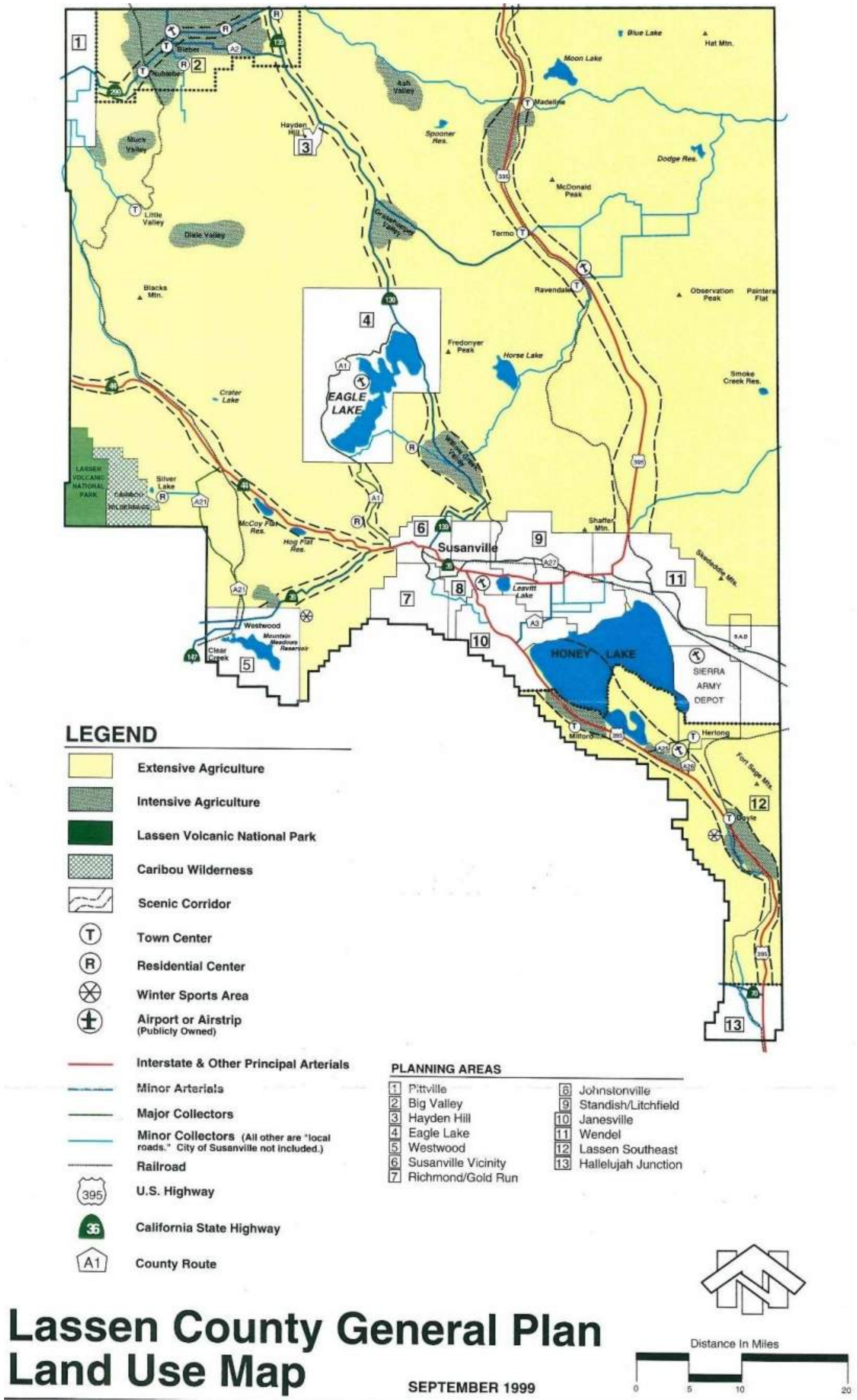


Figure 3-14 Lassen County General Plan Land Use Map

Another issue included open space and the managed production of resources, which includes areas for recharge of groundwater, among others. The GP referred to the 1972 Open Space Plan, which required that residential sewage disposal systems would not contaminate groundwater supplies. The agriculture element identified an issue with incompatible land uses where agricultural pumping lowers the groundwater level and impacts the use of domestic wells. The wildlife element recognized that changes in groundwater storage could impact wet meadow ecosystems and threaten fish and wildlife species. Groundwater is included in polices under the water resources section of the Natural Resources (NR) and Open Space (OS) Elements, as listed below:

- NR15 POLICY: Lassen County advocates the cooperation of state and federal agencies, including the State Water Board and its regional boards, in considering programs and actions to protect the quality of ground water and surface-water resources.
- NR17 POLICY: Lassen County supports measures to protect and ensure the integrity of water supplies and is opposed to proposals for the exportation of ground water and surface waters from ground water basins and aquifers located in Lassen County (in whole or part) to areas outside those basins.
    - Implementation Measure:

      NR-H: Lassen County will maintain ground water ordinances and other forms of regulatory authority to protect the integrity of water supplies in the county and regulate the exportation of water from ground water basins and aquifers in the county to areas outside those basins.
- NR19 POLICY: Lassen County supports control of water resources at the local level, including the formation of local ground water management districts to appropriately manage and protect the long-term viability of ground water resources in the interest of county residents and the county's resources.
- OS27 POLICY: Lassen County recognizes that its surface and ground water resources are especially valuable resources which deserve and need appropriate measures to protect their quality and quantity.
- OS28 POLICY: Lassen County shall, in conjunction with the Water Quality Control Board, adopt specific resource policies and development restrictions to protect specified water resources (e.g., Eagle Lake, Honey Lake, special recharge areas, etc.) and to support the protection of those resources from development or other damage which may diminish or destroy their resource value.
    - Implementation Measure:

      OS-N: When warranted, Lassen County shall consider special restrictions to development in and around recharge areas of domestic water sources and other special water resource areas to prevent or reduce possible adverse impacts to the quality or quantity of water resources.

3.7.3 Modoc National Forest Land and Resource Management Plan

Modoc National Forest lies in the mountain areas surrounding Big Valley to the south and northeast. A small portion of the National Forest extends into the Basin boundary in the south as shown in **Figure 3-2**

. The U.S. Forest Service developed their Land and Resource Management Plan in 1991 to, "…guide natural resource management activities and establish management standards and guidelines." Regarding water resources, the Modoc National Forest Land and Resource Management Plan seeks to "maintain and improve the quality of surface water" through the implementation of Best Management Practices (BMPs) among other goals. The plan is available on the Modoc National Forest website (USFS 1991).

3.7.4 GSP Implementation Effects on Existing Land Use

The implementation of this GSP is not expected to affect existing designation of land use.

3.7.5 GSP Implementation Effects on Water Supply

The implementation of this GSP is not expected to influence water supply. Prior to the development of this GSP, the counties had established several policies and ordinances for the management of water and land use in the BVGB. This GSP will incorporate the previous work and will establish sustainable management criteria to continue the successful use of the groundwater resources during the SGMA implementation period and beyond.

3.7.6 Well Permitting

Lassen and Modoc counties both require a permit to install a well. The Lassen County Municipal Code (§7.28.030) states that, "…no person, firm, corporation, governmental agency or any other legal entity shall, within the unincorporated area of Lassen County, construct, repair, modify or destroy any well unless a written permit has first been obtained from the health officer of the county." Further, Modoc County Code (§13.12.020) states that, "…No person shall dig, bore, drill, deepen, modify, repair or destroy a water well … without first applying for and receiving a permit…"

3.7.7 Land Use Plans Outside of the Basin

Areas inside and outside the Basin are subject to the Lassen and Modoc County General Plans or the Modoc National Forest Land Resource and Management Plan. Other land-use plans by organizations such as the BLM also exist in the watershed.

3.8 Management Areas

SGMA allows for the Basin to be delineated into management areas which:

> "…may be defined by natural or jurisdictional boundaries, and may be based on differences in water use sector, water source type, geology, or aquifer characteristics. Management areas may have different minimum thresholds and measurable objectives than the basin at large and may be monitored to a different level. However, GSAs in the basin must provide descriptions of why those differences are appropriate for the management area, relative to the rest of the basin." (DWR 2017)

It should be noted that minimum thresholds and measurable objectives can vary throughout the Basin even without established management areas. The GSAs have not defined management areas within the BVGB.

3.9 Additional GSP Elements, if Applicable

The plan elements from CWC Section 10727.4 require GSPs to address numerous components listed in **Table 3-8**. The table lists the agency or department with whom the GSA will coordinate or where it is addressed in the GSP.

Table 3-8 Plan Elements from CWC Section 10727.4

Element of Section 10727.4	Approach
(a) Control of saline water intrusion	Not applicable
(b) Wellhead protection areas and recharge areas	To be coordinated with county environmental health departments
(c) Migration of contaminated groundwater	Coordinated with RWQCB
(d) A well abandonment and well destruction program	To be coordinated with county environmental health departments
(e) Replenishment of groundwater extractions	Chapter 9, Projects and Management Actions
(f) Activities implementing, opportunities for and removing impediments to, conjunctive use or underground storage	Chapter 9, Projects and Management Actions
(g) Well construction policies	To be coordinated with county environmental health departments
(h) Measures addressing groundwater contamination cleanup, groundwater recharge, in-lieu use, diversions to storage, conservation, water recycling, conveyance, and extraction projects	Coordinated with RWQCB and in Chapter 9, Projects and Management Actions
(i) Efficient water management practices, as defined in Section 10902, for the delivery of water and water conservation methods to improve the efficiency of water use	To be coordinated with county farm advisors
(j) Efforts to develop relationships with state and federal regulatory agencies	Chapter 8, Plan Implementation
(k) Processes to review land-use plans and efforts to coordinate with land-use planning agencies to assess activities that potentially create risks to groundwater quality or quantity	To be coordinated with appropriate county departments.
(l) Impacts on groundwater-dependent ecosystems	Chapter 5, Groundwater Conditions

4. Hydrogeologic Conceptual Model §354.14

A hydrogeologic conceptual model (HCM) is a description of the physical characteristics of a groundwater basin related to the hydrology and geology, which defines the principal aquifer based on the best available information. The HCM provides the context for the water budget (Chapter 6), sustainable management criteria (Chapter 7), and monitoring network (Chapter 8).

This chapter presents the HCM for the BVGB and was developed by GEI Consultants Inc. (GEI) for the Lassen and Modoc GSAs. The content of this HCM is defined by the regulations of SGMA – Chapter 1.5, Article 5, Subarticle 2: 354.14.

Groundwater characteristics and dynamics in the Basin are variable. Located in a sparsely-populated area, the amount of existing data and literature to support this HCM is limited, with the most thorough studies being conducted prior to the 1980s. This HCM provides some limited new data and analyses that further the understanding. With that said, there are many data gaps in the HCM that have been identified in this chapter. The HCM presents best available information and expert opinion to form the basis for descriptions of elements of this GSP: basin boundary, confining conditions, definable bottom, nature of flows near or across faults, soil permeability, and recharge potential. Significant uncertainty exists in this HCM, and stakeholders have expressed concern about the possible regulatory repercussions associated with making decisions using incomplete and/or uncertain information, particularly as the relevance of the information changes under evolving regulatory frameworks.

Recommendations and options for prioritizing and addressing the data gaps are part of this document. The stakeholders in the disadvantaged communities of the BVGB have limited financial means to address data gaps, so the data gaps presented at the end of this chapter are contingent on outside funding.

4.1 Basin Setting

BVGB is located in Lassen and Modoc counties in northeastern California, 50 miles north-northwest of Susanville and 70 miles east-northeast of Redding (road distances are greater). Most of BVGB is in Lassen County (72%) with the remainder in Modoc County. At its widest points, the BVGB is approximately 21 miles long (north-south) in the vicinity of the Pit River and 15 miles wide (east-west) south of ACWA. The Basin has an irregular shape totaling about 144 square miles or 92,057 acres. (DWR 2004) The topography of BVGB is relatively flat within the central area with increasing elevations along the perimeter, particularly in the eastern portions where Willow and Ash Creeks enter the Basin. Ground surface elevations range from about 4,100 feet above mean sea level (msl) near the south end of BVGB to over 4,500 feet msl at the eastern edge of the Basin. In the north-central portion of the Basin, two buttes protrude from the valley (Pilot Butte and Roberts Butte). The Pit River enters the BVGB at an elevation of 4,150 feet msl and leaves the Basin at 4,100 feet msl over the course of about 30 river miles, giving the Pit River a gradient of less than 2 feet per mile. By contrast, the Pit River above and below Big Valley has a gradient over 50 feet per mile. This low gradient in the Basin results in a meandering river morphology and widespread flooding during large storm events. Ash Creek enters the Basin at Adin at an elevation of 4,200 feet msl, eventually joining the Pit River when flows are sufficient to make it past Big Swamp. **Figure 4-1** shows the ground topography for the BVGB.

Portions of eight topographic maps (7.5-minute) cover the BVGB area and are named as follows (north-south, west-east):

Donica Mountain	Halls Canyon	
Lookout	Big Swamp	Adin
Bieber	Hog Valley	Letterbox Hill

4.2 Regional Geology and Structure

The regional geology is depicted on the Alturas Sheet (CGS 1958), a 1:250,000 scale map with an excerpt shown on **Figure 4-2**. The BVGB is in the central area of the Modoc Plateau geomorphic province. According to the California Geological Survey (CGS 2002), the Modoc Plateau is, "…a volcanic table land" broken into blocks by north-south faults. The Basin is underlain by a thick sequence of lava flows and tuffs. The volcanic material is variable in composition as described below, is Miocene to Holocene age,[18] and erupted into sediment-filled basins between the block-faulted mountain ranges (Norris and Webb 1990).

According to MacDonald (1966), the Modoc Plateau is transitional between two geomorphic provinces: block faulting of the Basin and Range to the east and volcanism of the Cascade Range to the west. This transition can be observed on **Figure 4-2** with the numerous faults trending north-northwest surrounding Big Valley and the most recent center of volcanism (indicated by the numerous cinders [asterisks] centered around Medicine Lake, with several eruptions about 1000 years before present) about 30 miles northwest of Big Valley. Moreover, the historic volcanism and tectonics occurred concurrently, which disrupted the drainage from the province and resulted in the formation of numerous lakes, including an ancestral lake in Big Valley. Volcanic material was deposited as lava flows, ignimbrites (hot ash flows), subaerial and water-laid layers of ash (cooler), and mudflows combined with sedimentary material, although thick sections of rock can be either entirely sedimentary or volcanic. The composition of the lava flows is primarily basalt[19] and basaltic andesite[20], while pyroclastic[21] ash deposits are rhyolitic[22] composition.

[18] Miocene is 23 million to 5.3 million years ago; Holocene is 12,000 years ago to present.
[19] Basalt is an extrusive (volcanic) rock with relatively low silica content and high iron and magnesium content.
[20] Andesite is an extrusive rock with intermediate silica content and intermediate iron and magnesium content.
[21] Pyroclastic means formed from volcanic eruptions, typically not from lava flows, but from material (clasts) ejected from the eruption such as ash, blocks, or "bombs."
[22] Rhyolitic rocks are extrusive with relatively high silica content and low iron and magnesium. Rhyolites are the volcanic equivalent of granite.

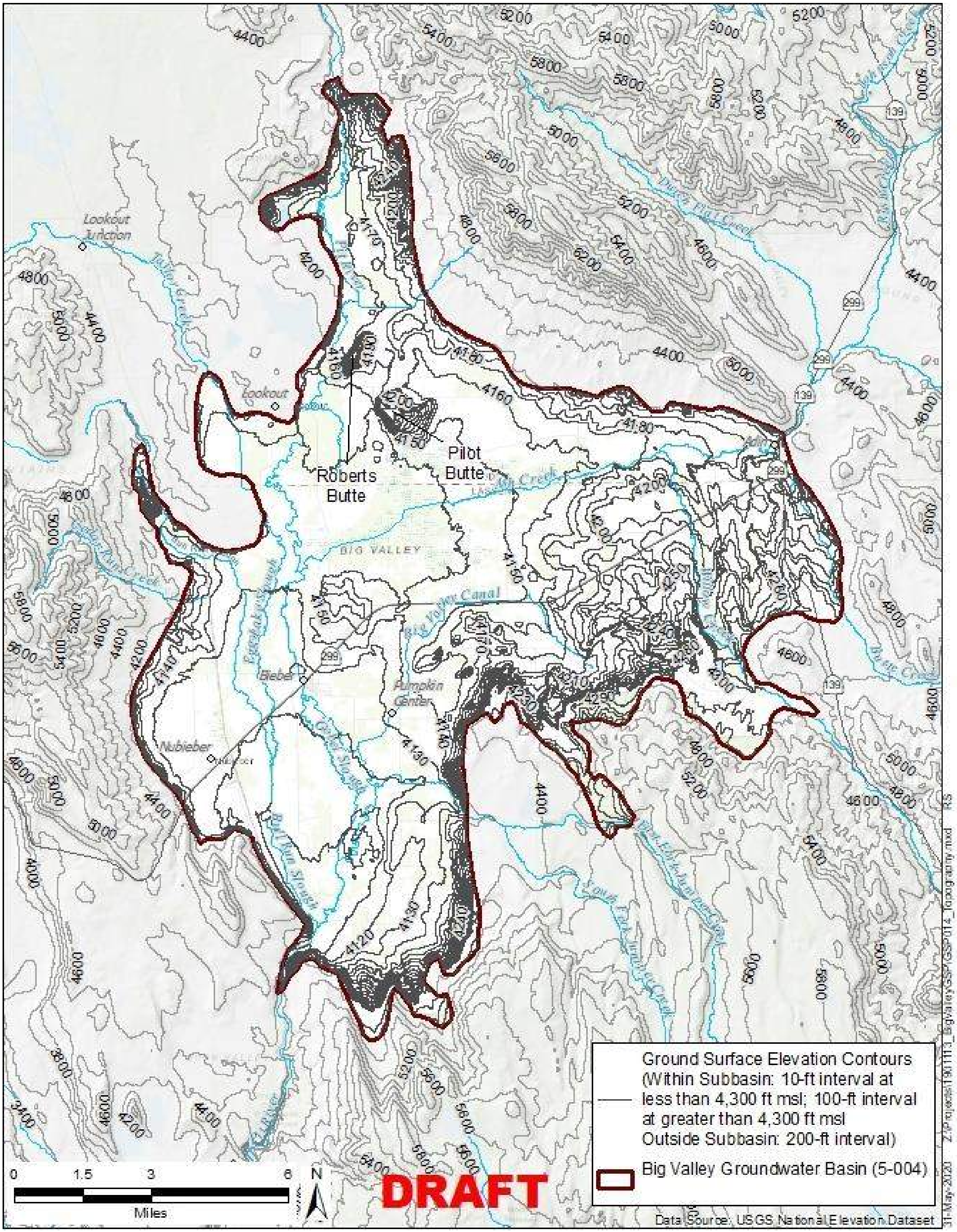
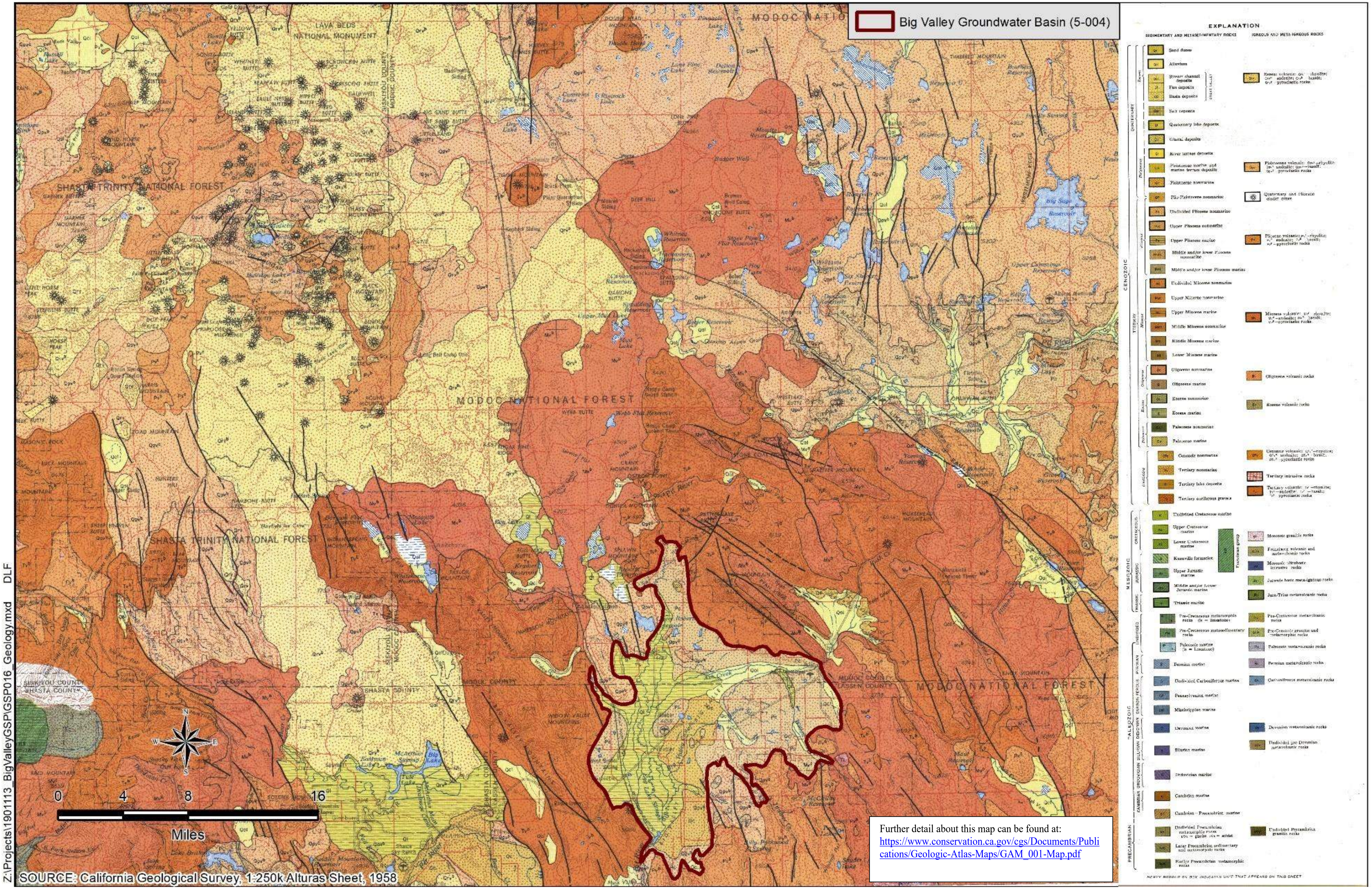


Figure 4-1 Topography

Source: USGS 2016



Z:\Projects\1901113_BigValleyGSP\GSP016_Geology.mxd DLF

Figure 4-2 Regional Geologic Map

4.2.1 Lateral Basin Boundaries

The CGS (1958) geology map (**Figure 4-2**) was used by DWR to draw the BVGB boundary. That 63-year-old map has proven to be inaccurate in many places, and more recent, more accurate geologic maps are available (DWR 1963, GeothermEx 1975). The lateral boundaries of BVGB are described by DWR (2004) as, "…bounded to the north and south by Pleistocene and Pliocene basalt and Tertiary pyroclastic rocks of the Turner Creek Formation, to the west by Tertiary rocks of the Big Valley Mountain volcanic series, and to the east by the Turner Creek Formation." In general, the boundary drawn by DWR was intended to define the contact between the valley alluvial deposits and the surrounding volcanic rocks. Because this boundary was drawn using a regional-scale map from 1958 that was drawn with the surface expression of geologic units, a basin boundary modification at a future date would be more precise and would include the aquifer materials which extend outside of the current boundary. This future modification could include consideration of the "upland recharge areas" described by DWR (1963).

Additionally, the Basin boundary is inaccurate in the southeastern portion of the Basin where two fingers extend into the uplands area. The narrower of the two fingers extends too far into the upland elevations and intersects with East Fork Juniper Creek which doesn't drain into the finger, as shown in **Figure 4-1**. East Fork Juniper Creek naturally flows to the west and is confluent with the Pit River south of Pumpkin Center. A more thorough mapping of the elevations and geologic contacts in the upper area of East Fork Juniper Creek would help to refine the boundary between alluvium and upland volcanics as some areas are clearly not underlain by alluvial deposits.

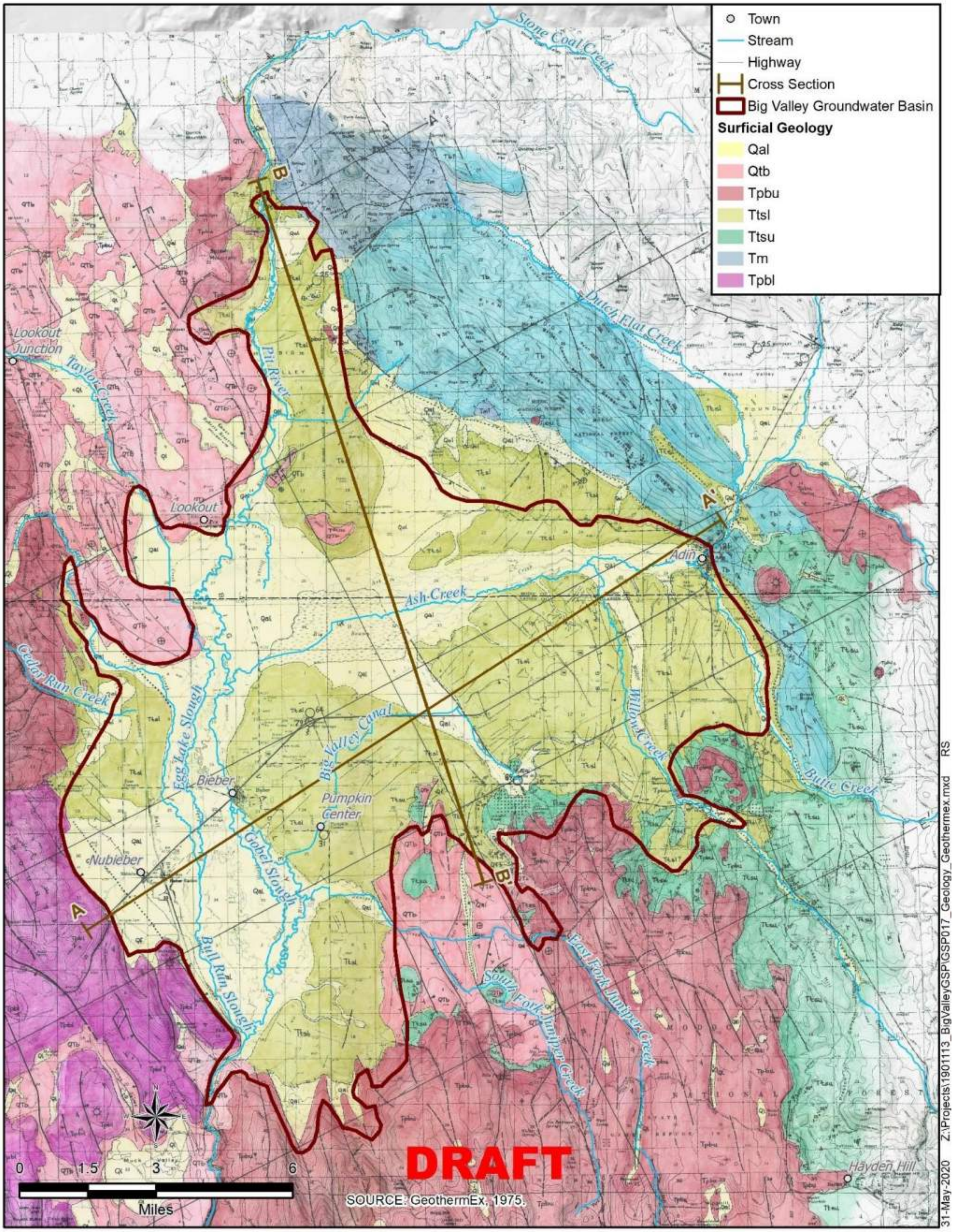
In the northeastern portion of the Basin, the boundary curves around the base of the Barber Ridge and Fox Mountain. The CGS contact between the alluvium and volcanics here is well below the change in slope of the mountain range. More recent mapping (GeothermEx 1975) extends alluvium 1.5 miles further upslope as shown on **Figure 4-3**. This 1975 mapping also shows other locations along the current basin boundary that should be modified, including the aforementioned narrow finger at East Fork Juniper Creek.

4.3 Local Geology

Several geologic maps were available at a more detailed scale than the CGS (1958) map. Two of them had accompanying studies that more thoroughly described the geology. Although relatively old studies, they both provide useful information. However, they differ slightly on some details, particularly the surface geology. Further refinement of their contacts may be necessary. The two maps are shown on **Figure 4-3** and **Figure 4-4**.

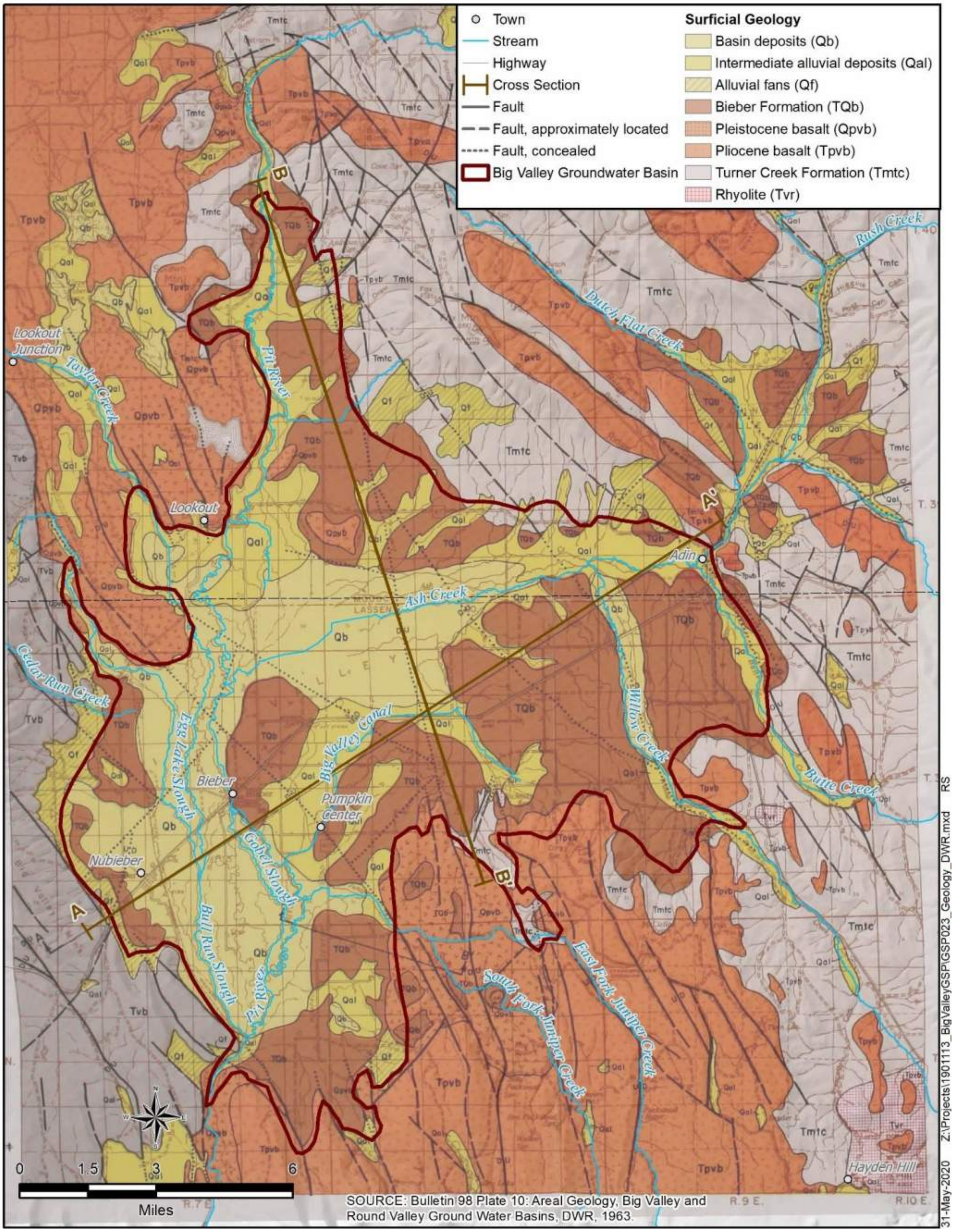
The two different reports were written for different purposes, with DWR (1963) being developed as a general investigation of the potential groundwater resources, and GeothermEx (1975) as a specific investigation of potential hydrothermal groundwater resources. All reviewed sources agree that the BVGB is surrounded by mountain blocks of volcanic rocks of somewhat variable composition, but primarily basalt. Although these mountains are outside of the groundwater basin, they may be underlain by alluvial formations. The mountains capture and accumulate precipitation, which produces runoff that flows into BVGB. Moreover, DWR (1963) stated that these mountains serve as "upland recharge areas"

1202



1203 **Figure 4-3 GeothermEx 1975 Local Geologic Map**

1204



1205 **Figure 4-4 DWR 1963 Local Geologic Map** and provide subsurface recharge to the BVGB. These recharge areas suggested by DWR are shown in red shading on **Figure 4-5** and correlate with Pliocene to Pleistocene[23] basalts (Tpbv and Qpbv). These units are mapped by DWR (1963) outside the Basin to the northwest and southeast, as well as along the crests of Barber and Ryan Ridges to the northeast of Big Valley.[24] GeothermEx (1975) generally concurs with this mapping, except for the areas along Barber and Ryan Ridges, which they map as a much older unit (Miocene), corroborated by a radiometric age date measured at 13.8 million years. This distinction is important because an older unit is more likely to underlie the Basin sediments and is less likely to be hydraulically connected to the BVGB. At the northwestern end of Barber Ridge, GeothermEx mapped the oldest unit in the BVGB area (Tm) of andesitic composition. This unit contains the site of the Shaw Pit quarry.

4.4 Principal Aquifer

4.4.1 Formation Names

The Pliocene-Pleistocene[23] age Bieber Formation (TQb) is the main formation of aquifer material defined within BVGB, and DWR (1963) estimates that it ranges in thickness from a thin veneer to over 1,000 feet. It meets the ground surface around the perimeter of the Basin, especially on the southeast side (DWR 1963). The formation was deposited in a lacustrine (lake) environment and is comprised of unconsolidated to semi-consolidated layers of interbedded clay, silt, sand, gravel, and diatomite[25]. Layers of black sand and white sand (pumiceous) were identified as highly permeable but discontinuous and mostly thin. GeothermEx (1975) did not embrace the DWR name and identified this formation as an assemblage of tuffaceous, diatomaceous lacustrine, and fluvial sediments (Ttsu, Ttsl). Both investigations identified the formation in the same overall location based on a comparison of the two geologic maps, but the GeothermEx map provides more detail and resolution than the DWR map. For the purposes of the GSP, the name Bieber Formation will be used.

Recent Holocene[26] deposits (labeled with Q) were mapped within the center of the Basin and along drainage courses from the upland areas and are identified by DWR (1963) as alluvial fans (Qf), intermediate alluvium (Qal) and Basin deposits (Qb). The composition of these unconsolidated deposits varies from irregular layers of gravel, sand and silt with clay to poorly sorted silt and sand with minor clay and gravel (Qal) to interbedded silt, clay and "organic muck" (Qb). The latter two deposits occur in poorly drained, low-lying areas where alkali[27] could accumulate. The thickness of these sediments is estimated to be less than 150 feet. GeothermEx (1975) identified these deposits as older valley fill (Qol), lake and swamp deposits (Ql), fan deposits (Qf) and undifferentiated alluvium (Qal). All these recent deposits are aquifer material[28] and are part of the Big Valley principal aquifer. There is discrepancy

[23] 5.3 million years to 12 thousand years ago.

[24] The GSAs specifically requested a basin boundary modification to include these upland recharge areas within the Basin boundary. The request was denied by DWR as not being sufficiently substantiated. (*See* **Appendix 1A**)

[25] Diatomite is a fine-grained sedimentary rock made primarily of silica, and is formed from the deposition of diatoms, which are microscopic creatures with shells made from silica.

[26] Recent geologic period from 12 thousand years old to present.

[27] Alkali means relatively high in alkali and alkali earth metals (primarily sodium, potassium, calcium, and magnesium) and generally results in a high pH (greater than 7 or 8).

[28] Meaning they contain porous material with recoverable water.

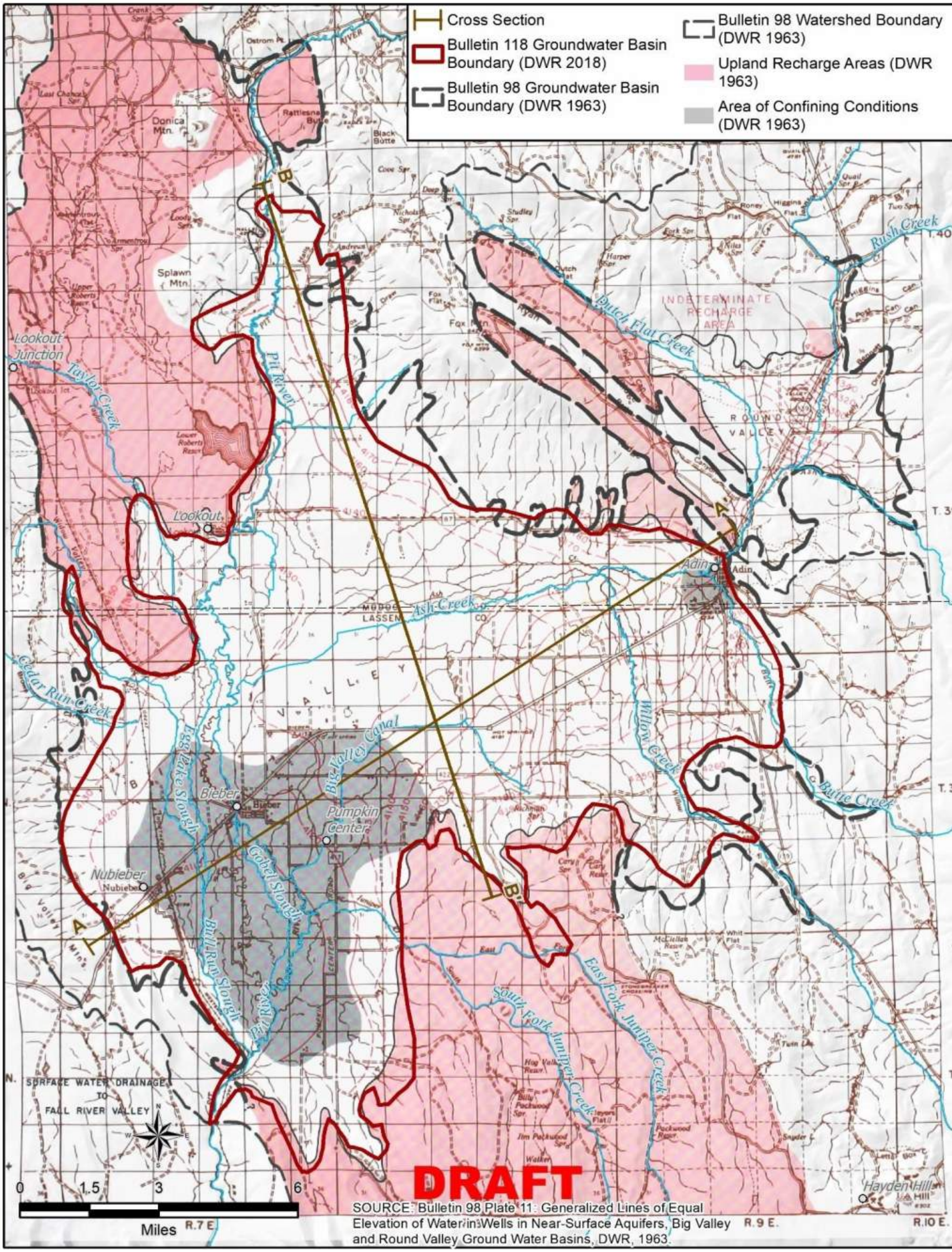


Figure 4-5 DWR 1963 Upland Recharge Areas and Areas of Confining Conditions

between the two maps in the northeastern portion of the Basin, where GeothermEx extends the alluvial sediments much further upslope toward Barber Ridge and Fox Mountain as discussed in Section 4.3 – Local Geology.

The principal aquifer consists of the Bieber Formation (TQb and recent deposits (Qal, Qg, Qb)). While DWR (1963) delineates an "area of confining conditions" in the southwest area of the Basin on **Figure 4-5**, the data to support the confinement and the definition of a broad-scale, well-defined aquitard[29] is not currently available.

As described herein, aquifer conditions vary greatly throughout the Basin. However, clearly defined, widespread distinct aquifer units have not been identified, and with the data currently available all the water bearing units in the Basin are defined as a single principal aquifer for this GSP.

4.4.2 Geologic Profiles

Figure 4-6 and **Figure 4-7** show cross-sections across Big Valley. The locations of the cross-sections are shown on **Figure 4-3**, **Figure 4-4** and **Figure 4-5**. The locations of these sections were drawn to be similar to those drawn by DWR (1963) and GeothermEx (1975) and characterize the aquifers in two directions (southwest-northeast and northwest-southeast). The sections show the lithology of numerous wells across the Basin. Very little geological correlation could be made across each section which is likely to be related to the concurrent block faulting and volcanic and alluvial depositional input from various highland areas flowing radially into Big Valley. These complex structural and depositional variables result in great stratigraphic variation over short distances. The pertinent information from cross-sections presented by DWR (1963) and GeothermEx (1975) are shown on the sections.

4.4.3 Definable Bottom

The SGMA and DWR GSP regulations do not provide clear guidance for what constitutes a "definable bottom" of a basin. However, DWR (2016a) Bulletin 118 Interim Update describe the "physical bottom" as where the porous sediments contact the underlying bedrock and the "effective bottom" as the depth below which water could be unusable because it is brackish or saline.

The "physical bottom" of BVGB is difficult to define because few borings have been drilled deeper than 1200feet and the compositions of the alluvial and bedrock formations are similar (derived from active volcanism), with contacts that are gradational. Also, some of the lavas most likely flowed into Big Valley forming lava lenses that are now interlayered with permeable aquifer sediments. Moreover, the base of the aquifer system is likely variable across BVGB due to the concurrent volcanism and horst/graben faulting of the bedrock.

The deepest lithologic information in the Basin is derived from two test borings by DWR to depths of 1843 and 1231 feet and from two geothermal test wells near Bieber to depths of 2125 and 7000 feet. The 7000-foot well is east of Bieber, but only has lithologic descriptions to a depth of 4100 feet, including descriptions of aquifer-type materials (sands) throughout. The other three deep lithologies give similar indication of aquifer material to their total depth.

[29] Layer of low permeability that prevents significant flow, except at very slow rates.

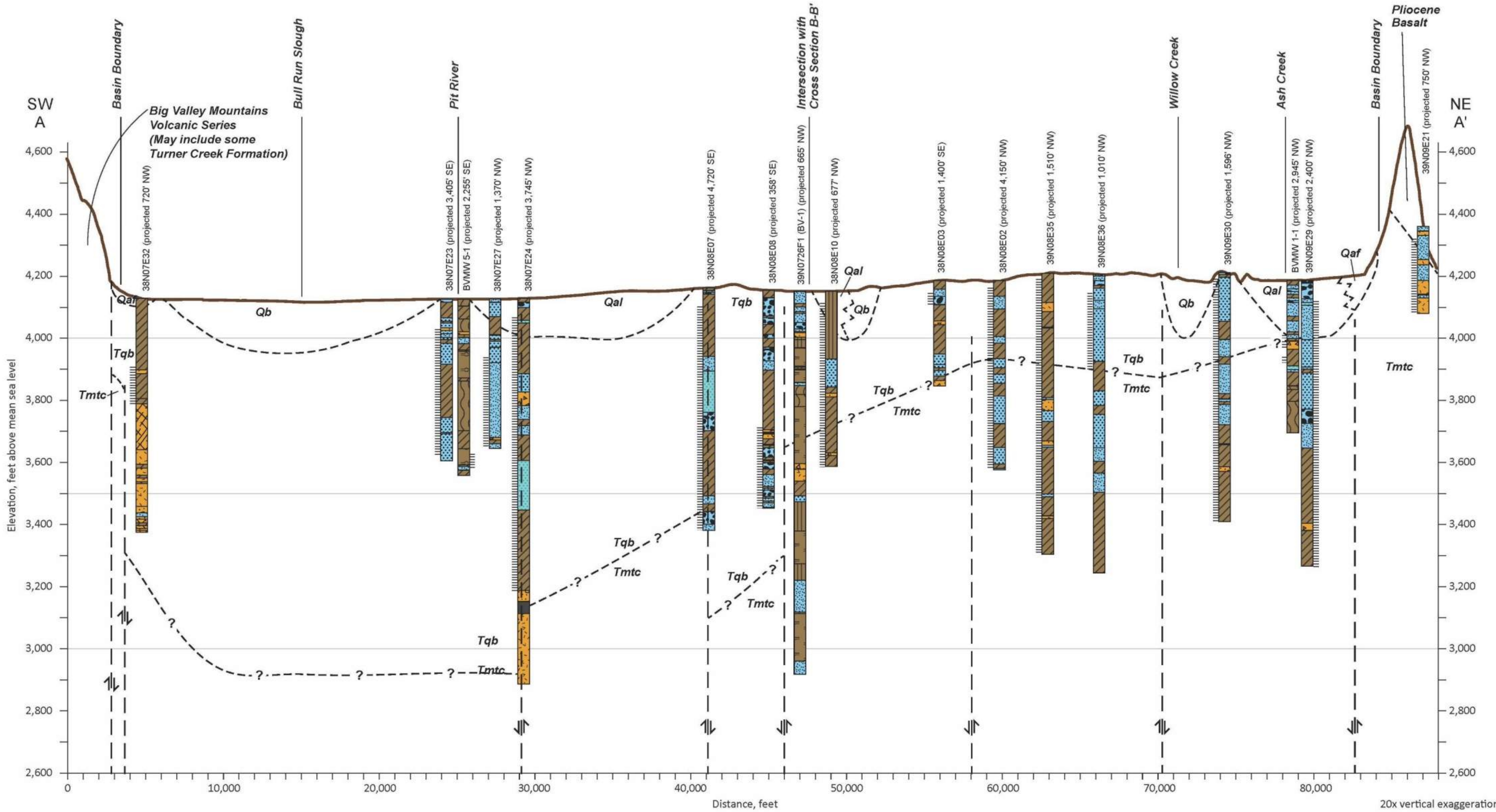
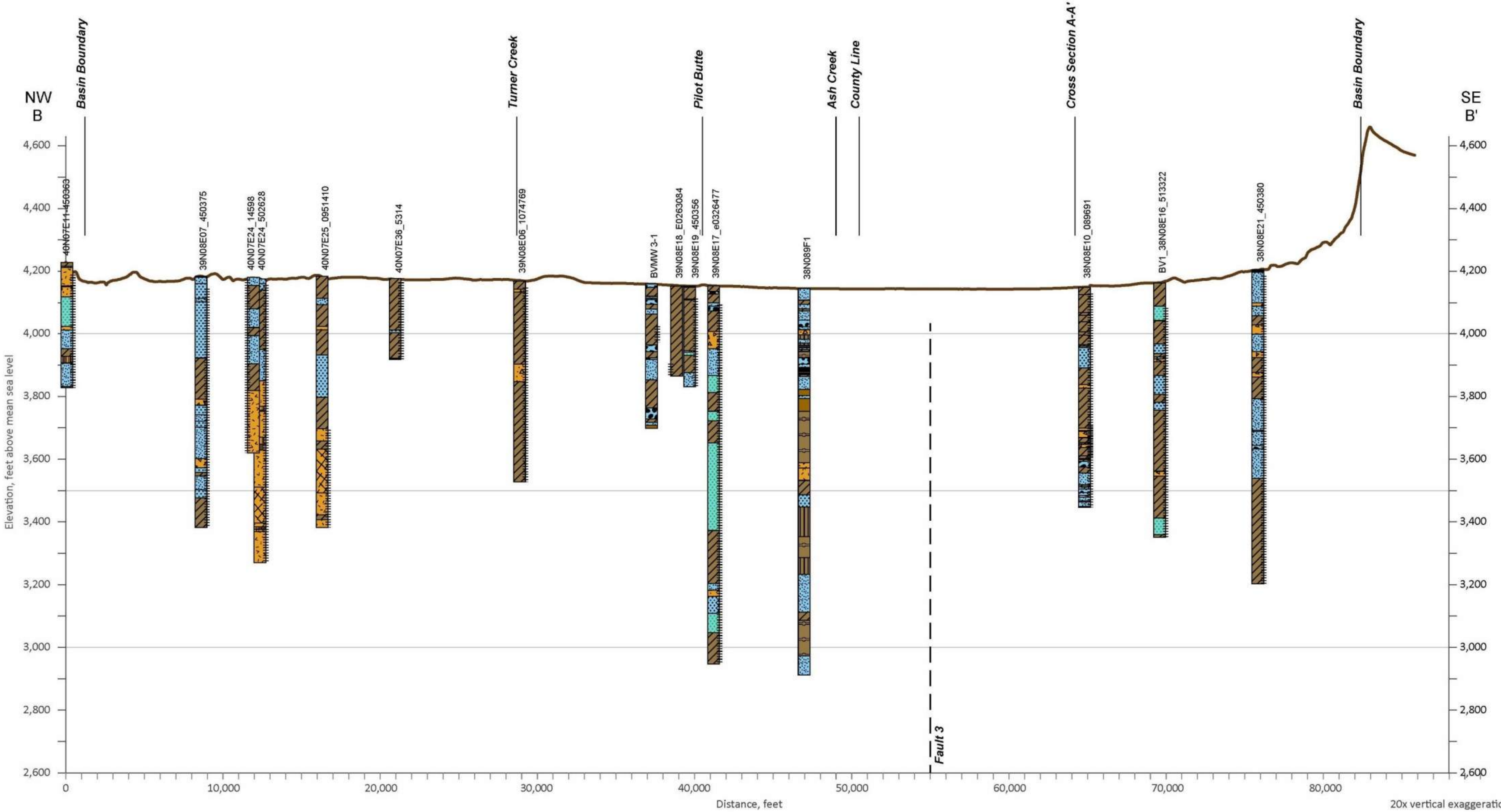


Figure 4-6 Geologic Cross Section A-A'

Note: Key to lithologic symbologies is in development and will be included in future draft(s)



1274

1275 **Figure 4-7 Geologic Cross Section B-B'**

1276 Note: Key to lithologic symbologies is in development and will be included in future draft(s)

The two geothermal wells also had temperature logs and some water quality. Water temperatures increased to over 100°F at depths of about 2000 to 3000 feet. One of them located near the Bieber School had water quality samples collected from the 1665- to 2000-foot interval and indicated water quality higher in total dissolved solids (632 milligrams per liter) than is present in shallower portions of the Basin.

The information from these two wells indicated that temperature and water quality concerns increase with depth, but a clear delineation of where water becomes unusable cannot be determined with the data available. With limited scientific evidence to clearly define a physical or effective bottom of the aquifer, an approach to define a practical bottom is being used to satisfy the GSP Regulations which require the aquifer bottom to be defined (§ 354.14(a)(1)), as described below.

The approach for defining the practical bottom is to ensure that all known water wells are included within the aquifer. DWR's well log inventory shows that over 600 wells have been installed in the BVGB. Although DWR's well log inventory does not completely and precisely assess the total number or status of the wells (e.g. abandoned), it is the only readily-available data. The well inventory has been identified as a data gap within this GSP. Wells in this inventory with known depths are summarized in **Table 4-1**. The only borings drilled deeper than 1,200 feet are the two DWR test borings and two geothermal wells discussed previously.

Table 4-1 Well Depths in DWR Inventory

Depth Interval (ft bgs)	Deepest Well per Section[a]		Count of All Wells
< 200	10%		41%
200 – 400	16%	43%	25%
400 – 600	27%		17%
600 – 800	28%	42%	12%
800 – 1000	14%		4%
1000 – 1200	4%		1%
> 1200[b]	1%		< 1%

Notes:
[a] Section is a 1 mile by 1 mile square. There are 134 sections in the BVGB
[b] Test borings: BV-1 and BV-2 were drilled deeper than 1200 feet

For this GSP, the "practical bottom" of the aquifer is set at 1200 feet but may extend to 4,100 or deeper. This delineation of 1200 feet is consistent with DWR's approach, established over 50 years ago, which declared a practical bottom of 1000 feet. A depth of 1200 feet encompasses the levels where groundwater can be accessed and monitored for beneficial use but does not preclude drilling and pumping from greater depths.

4.4.4 Structural Properties with Potential to Restrict Groundwater Flow

Faults can sometimes affect flow, but sufficient evidence has not been gathered and analyzed to determine whether any of the faults in Big Valley restrict or facilitate flow. The mountains around BVGB are heavily faulted, with older basalt units more faulted than younger basalt units.

Most of the faults trend to the north/northwest with some perpendicular faulting oriented northeasterly. **Figure 4-8** is an excerpt of the regional fault map by the California Geological Survey (2010). Faults on the western side of BVGB are shown to be Quaternary in age, while faults on the eastern side are pre-Quaternary (older than 2.6 million years). Note that numerous faults to the west of BVGB were identified as late Quaternary to Holocene-age faults (displacement during the last 700,000 years or within the last 12 thousand years, respectively).

Some of the faults extend across the Basin, concealed beneath the alluvial materials. Two hot springs are located in the Basin near these faults. DWR (1963) acknowledged the potential restriction of groundwater flow by faults but did not provide specific information. However, such fault impacts on groundwater flow cannot be determined with certainty at this time with the available groundwater level data, given the limited number and the wide spacing of wells, and the absence of a pumping test to verify restricting conditions.

4.4.5 Physical Properties and Hydraulic Characteristics

The physical properties of a groundwater system are typically defined by the hydraulic conductivity,[30] transmissivity,[31] and storativity[32] of the aquifer. The preferred method of defining hydraulic characteristics is a pumping test with pumping rates and water levels monitored (either in the pumping well or preferably a nearby monitoring well) throughout the test. Such pumping tests were performed after the construction of five sets of monitoring wells (MWs) in late 2019 and early 2020.

The tests were performed by pumping each 2.5-inch-diameter MW for 1 hour at a rate of 8 gpm while measuring water level drawdown in the pumping well. A well efficiency[33] of 70 percent was assumed, and the length of the well screen was used as a proxy for the aquifer thickness (b). **Table 4-2** shows the results of the Theis[34] solution that best matched the drawdown curve at each well. Storativity (S) ranged from highly confined ($3.0x10^{-6}$ at BVMW 3-1) to unconfined ($1.5x10^{-1}$ at BVMW 4-1). Hydraulic

[30] Hydraulic conductivity (K) is defined as the volume of water that will move in a unit of time under a unit hydraulic gradient through a unit area. It is a measure of how easily water moves through a material and is usually given in gallons per day per square foot (gpd/ft^2) or feet per day (ft/day).

[31] Transmissivity (T) is the product of K and aquifer thickness (b) and is a measure of how easily water moves through a thickness of aquifer. It is usually expressed in units of gallons per day per foot of aquifer (gpd/ft) or square feet per day (ft^2/day).

[32] Storativity (S, also called storage coefficient) is defined as the volume of water that an aquifer releases from or takes into storage per unit surface area per unit change in groundwater elevation. High values of S are indicative of unconfined or water table aquifers, while low values indicate confined (pressurized) aquifers. S does not have units.

[33] A pumping well will experience more groundwater level drawdown than a nearby non-pumping well due to inefficiency in the movement of groundwater from the aquifer into the well. The predicted drawdown divided by the actual drawdown is well efficiency.

[34] Theis is a mathematical solution to estimate K, T, and S and is based on pumping rate and the resultant rate of groundwater level drawdown (Theis, 1935).

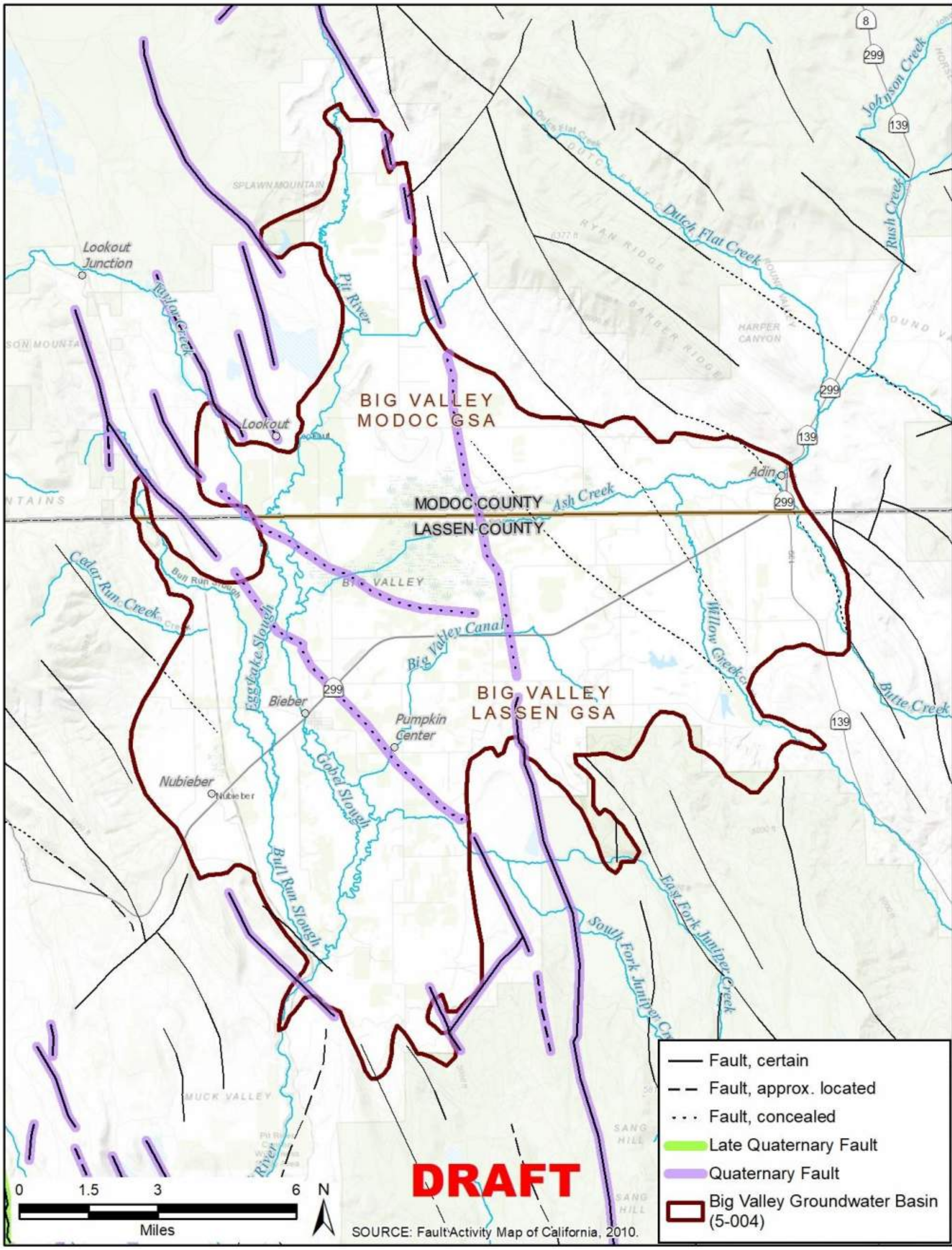


Figure 4-8 Local Faults

Table 4-2 Aquifer Test Results

Parameter	Units	BVMW 1-1	BVMW 2-1	BVMW 3-1	BVMW 4-1	BVMW 5-1
Well depth	ft	265.5	250.5	185.5	425	540
Thickness[a] (b)	ft	50	40	50	30	50
Flow (Q)	gpm	8	8	8	8	8
Drawdown after 1 hour	ft	4.3	16.0	27.5	2.0	3.0
Transmissivity (T)	gpd/ft	3000	750	700	4200	4500
Storativity (S)	unitless	$1.5x10^{-3}$	$1.0 x10^{-3}$	$3.0x10^{-6}$	$1.0 x10^{-1}$	$2.0 x10^{-3}$
Hydraulic Conductivity (K)	ft/d	8	3	2	19	12

[a] Assumed to be the length of the screen interval

Source: GEI 2021

conductivity (K) ranged from 2 feet per day (ft/d) to 19 ft/d, which is consistent with silty sand and clean, fine sand. The K values may range higher since pumping tests in larger wells with larger pumps for longer periods of time tend to give higher T and K values. The results of these five pumping tests are documented further in **Appendix 4A**. More thorough assessment of Basin aquifer characteristics is needed and is identified as a data gap.

Specific yield (SY) is another important aquifer characteristic, as it defines the fraction of the aquifer that contains recoverable water and therefore governs the volume of groundwater stored in the Basin. Reclamation (1979) discussed the SY in Big Valley and postulated that it varies with depth, at 7 percent for the first 100 ft bgs, 6 percent for the 100 to 200 ft bgs and 5 percent from 200 to 1000 ft bgs. However, Reclamation doesn't give any supporting evidence for these percentages. SY in the Sacramento Valley has been estimated to vary between 5 to 10 percent (DWR 1978). Since Big Valley aquifer materials were primarily deposited in a lacustrine environment (as opposed to Sacramento Valley which has a higher percentage of riverine deposits), Big Valley's SY is likely on the lower end at 5 percent. This conservative percentage will be used for all depth intervals in this GSP.

4.5 Soils

Information on soils within the BVGB were obtained from the Soil Survey Geographic Database (SSURGO) of the NRCS. The SSURGO data includes two categories of information relevant to the GSP: taxonomic soil orders and hydrologic soil groups. Taxonomic data include general characteristics of a soil and the processes of formation, while hydrologic data relate to the soil's ability to transmit water under saturated conditions and is an important consideration for hydrology, runoff, and groundwater recharge. The following section describes the soils of BVGB.

4.5.1 Taxonomic Soil Orders

Of the 12 established taxonomic soil orders, three were found within the BVGB, as listed below, and their distributions are presented in **Figure 4-9**. Descriptions below were taken from the Illustrated Guide to Soil Taxonomy (NRCS, 2015):

- Alfisol – Naturally fertile soils with high base saturation and a clay-enriched subsoil horizon. Alfisols develop from a wide range of parent materials and occur under broad environmental conditions, ranging from tropical to boreal. The movement of clay and other weathering products from the upper layers of the soil and their subsequent accumulation in the subsoil are important processes. The soil-forming processes are in relative balance. As a result, nutrient bases (such as calcium, magnesium, and potassium) are supplied to the soil through weathering, and the leaching process is not sufficiently intense to remove them from the soil before plants can use and recycle them.
- Mollisol – Very dark-colored, naturally very fertile soils of grasslands. Mollisols develop predominantly from grasslands in temperate regions at mid-latitudes and result from deep inputs of organic matter and nutrients from decaying roots, especially the short, mid, and tall grasses common to prairie and steppe areas. Mollisols have high contents of base nutrients throughout their profile due to mostly non-acid parent materials in environments (subhumid to semiarid) where the soil was not subject to intense leaching of nutrients.
- Vertisol – Very clayey soils that shrink and crack when dry and expand when wet. Vertisols are dominated by clay minerals (smectites) and tend to be very sticky and plastic when wet and very firm and hard when dry. Vertisols are commonly very dark in color and distinct soil horizons are often difficult to discern due to the deep mixing (churning) that results from the shrink-swell cycles. Vertisols form over a variety of parent materials, most of which are neutral or calcareous, over a wide range of climatic environments, but all Vertisols require seasonal drying.

Mollisols are the most prominent soil order within the BVGB occupying nearly 78 percent of the total area. Vertisols occupy over 16 percent and are found mostly on the southwestern side of BVGB within the floodplain of the Pit River. Small patches of Vertisols are scattered in the remainder of the Basin. Alfisols occupy over 5 percent of the Basin and are found mostly on the west side of the Basin and along Hot Spring Slough in the south-central portion of the Basin.

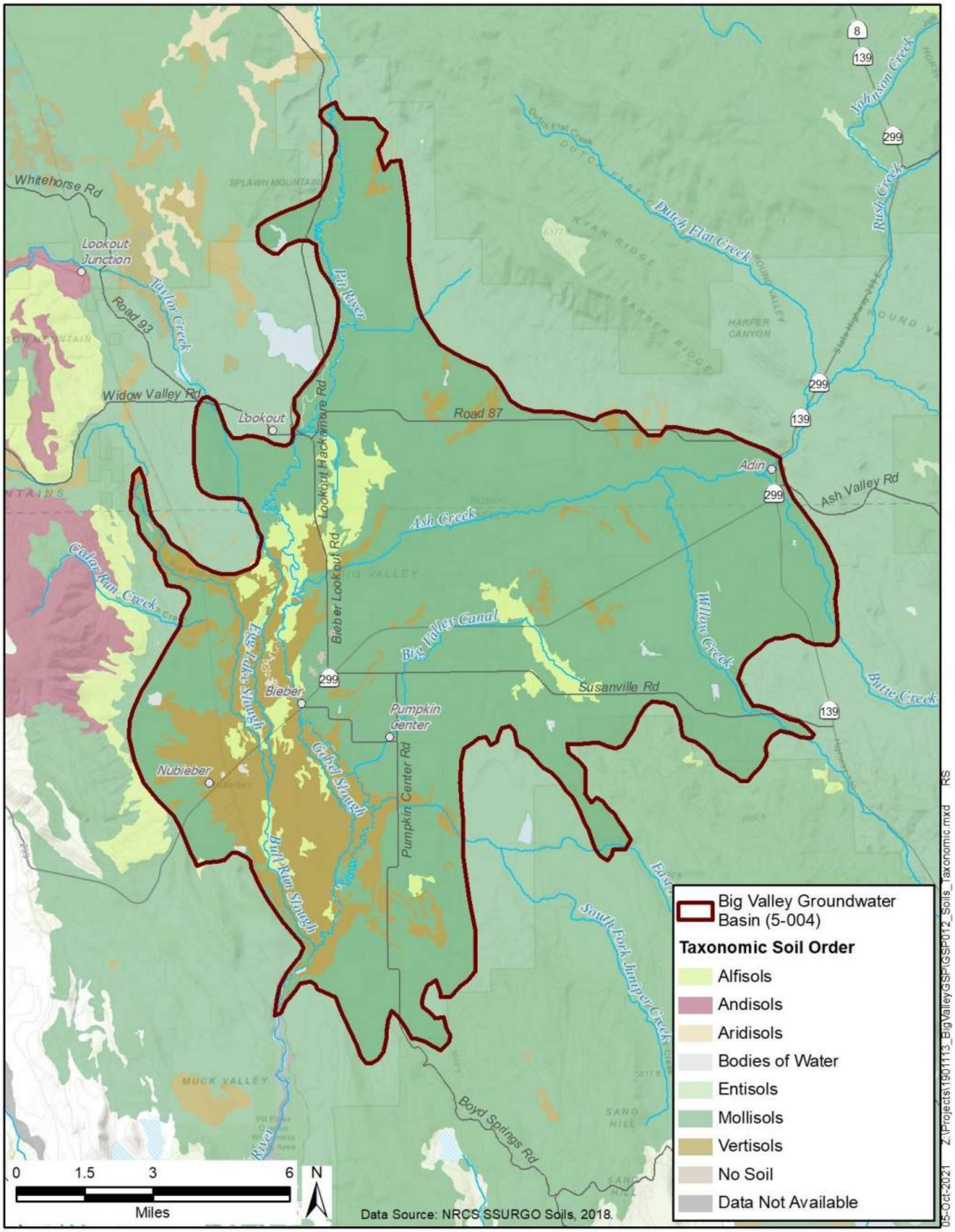


Figure 4-9 Taxonomic Soils Classifications

4.5.2 Hydrologic Soil Groups

The NRCS Hydrologic Soils Group (HSG) classifications provide an indication of soil infiltration potential and ability to transmit water under saturated conditions, based on hydraulic conductivities of shallow, surficial soils. **Figure 4-10** shows the distribution of the hydrologic soil groups, where higher conductivities (greater infiltration) are labeled as Group A and lowest conductivities (lower infiltration) as Group D. As defined by the NRCS (2012), the four HSGs are:

- Hydrologic Group A – "Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10% clay and more than 90% sand or gravel and have gravel or sand textures." Group A soils have the highest conductivity values (greater than 5.67 inches per hour [in/hr]) and therefore a high infiltration rate.

  Hydrologic Group B – "Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission is unimpeded. Group B soils typically have between 10 and 20% clay and 50 to 90% sand and have loamy sand or sandy loam textures." Group B soils have a wide range of conductivity values (1.42 in/hr to 5.67 in/hr), and a moderate infiltration rate.

- Hydrologic Group C – "Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 and 40% clay and less than 50% sand and have loam, silt loam, sandy clay loam, clay loam and silty clay loam textures." Group C soils have a relatively low range of conductivity values (0.14 to 1.42 in/hr), and a slow infiltration rate.

- Hydrologic Group D – "Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40% clay, less than 50% sand and have clayey textures. In some areas, [Group D soils] also have high shrink-swell potential." Group D soils have conductivity values less than 0.14 in/hr, a very slow infiltration rate.

A dual hydrologic group (C/D) is assigned to an area to characterize runoff potential under drained and undrained conditions, where the first letter represents drained conditions, and the second letter applies to undrained conditions.

According to this HSG dataset, BVGB does not show high infiltration rates (Group A) and only a tiny area (<0.1%) of Group B soil (moderate infiltration) are present, located on the western edge of the Basin at the top of Bull Run Slough near Kramer Reservoir. The remainder of the Basin is shown with hydrologic soils Groups C and D, slow to very slow infiltration rates (Group C at 30% and Group D at 58% of Basin area). Most of the ACWA is underlain by the dual hydrologic group C/D (11% of Basin area) and due to the wetland nature of this area contains primarily undrained soils corresponding to the very slow infiltration rates.

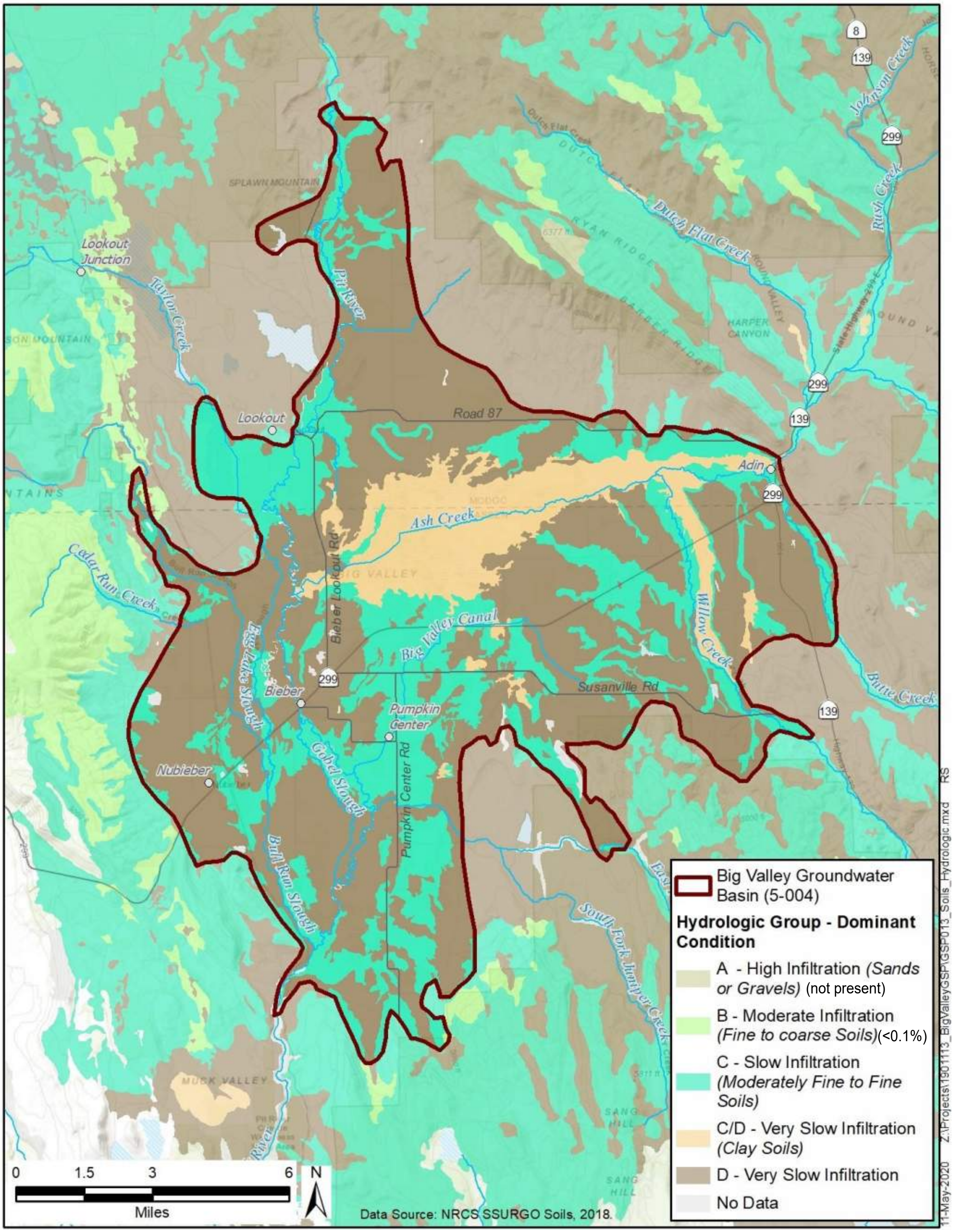


Figure 4-10 Hydrologic Soils Group Classifications

It should be noted that the NRCS develops these maps using a variety of information including remote sensing and some limited field data collection and does not always capture variations that may occur on a small scale. Historical experience from landowners and additional field data could identify areas of better infiltration. These soils groups do not necessarily preclude vertical movement of water and, while recharge may be slower than desired, recharge is still possible. Additionally, Group C and D soils may have slow infiltration rates due to shallow hardpan, and groundwater recharge could potentially be enhanced if this hardpan can be disrupted. Soil permeability has been identified as a data gap, particularly at the small scale.

4.5.3 Soil Agricultural Groundwater Banking Index

The University of California at Davis has established the Soil Agricultural Groundwater Banking Index (SAGBI) using data within the SSURGO database, which gives a rating of suitability of the soils for groundwater recharge. This index expands on the HSG to include topography, chemical limitations, and soil surface condition. This effort has resulted in a mapping tool that illustrates six SAGBI classes (excellent-very poor) and has been completed for much of the state. This mapping tool is only available for the Modoc County portion of BVGB as shown on **Figure 4-11**, and the index varies mostly between moderately poor to very poor. Small areas of moderately good are present along the Pit River as it enters BVGB and to the west of Adin. It should be noted that the SAGBI is a large-scale, planning level tool and does not preclude local site conditions that are good for groundwater recharge.

4.6 Beneficial Uses of Principal Aquifer

Primary beneficial uses of groundwater in the BVGB include agricultural, environmental, municipal and domestic uses. A description of each is provided below.

Agricultural

Agricultural users get their supply from surface-water diversions, groundwater, or a combination of the two. **Figure 3-6** from the previous chapter illustrates DWR’s estimate of the primary source being used around the Basin. The primary crops are grain and hay crops (primarily alfalfa) with some wild rice. Agricultural use provides numerous environmental benefits and the majority of wildlife habitat in the Basin. (Albaugh 2021)

Industrial

Industrial groundwater use is limited in the BVGB. According to DWR well logs, six industrial wells have been drilled, all of them near Bieber at Big Valley Lumber, which is not currently in operation. **Figure 3-5** shows some areas of industrial use, but more use is likely present throughout the Basin as agricultural users have some associated industrial needs.

Environmental

Environmental uses for wetland and riparian botanical and wildlife habitat occur within the ACWA in the center of the Basin, near the overflow channels adjacent to the Pit River in the southern portion of the Basin, and along the riparian corridors of some of the minor streams that flow into Big Valley. Additionally, private lands throughout the Basin provide for environmental uses, including those enrolled in the CRP and WRP programs discussed in Section 3.3.

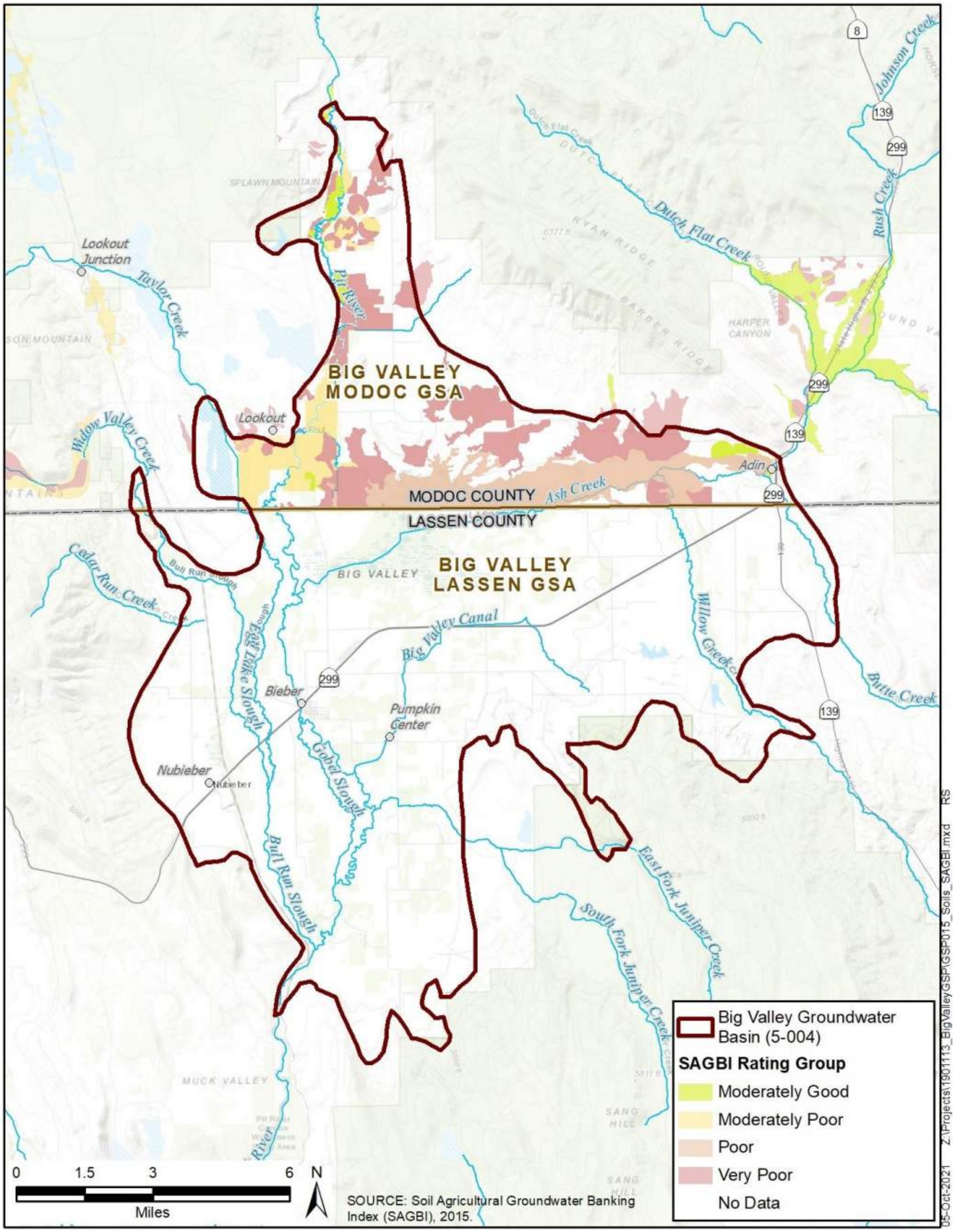


Figure 4-11 SAGBI Classifications

Municipal

The State Water Board recognizes three public water systems that use groundwater under the purview of the DDW: LCWD #1 which serves the community of Bieber, the Forest Service Station in Adin (a non-community, non-transient system), and the CAL FIRE conservation camp west of the Basin whose well is located within the Basin boundary.

Domestic

Domestic users include residents who use their own wells for household purposes. The BVGB has a population of about 1,046. With the 312 Bieber residents receiving water from municipal supply, the majority of the remaining 734 residents are domestic users.

4.7 General Water Quality

Previous reports have characterized the water quality as excellent (DWR 1963, Reclamation 1979). The central area of the Basin, where naturally occurring hot springs influence the chemistry, has elevated levels of sulfate, fluoride, boron, and arsenic (Reclamation 1979). These localized areas with higher mineral content occur near the major faults that traverse the valley.

Figure 4-12 shows a Piper Diagram for water samples that were collected in late 2019 and early 2020, and characterizes the relative concentrations of the major cations (Ca, Mg, Na, K) and anions (SO_4, Cl, HCO_3). The dominant cations are derived from the minerals in the aquifer and range from sodium-rich to mixed with higher amounts of calcium and magnesium, which increases the water hardness. The major anion is strongly bicarbonate, which is derived from carbon dioxide in the atmosphere and soil zone and indicates that the water is generally young in geologic terms.

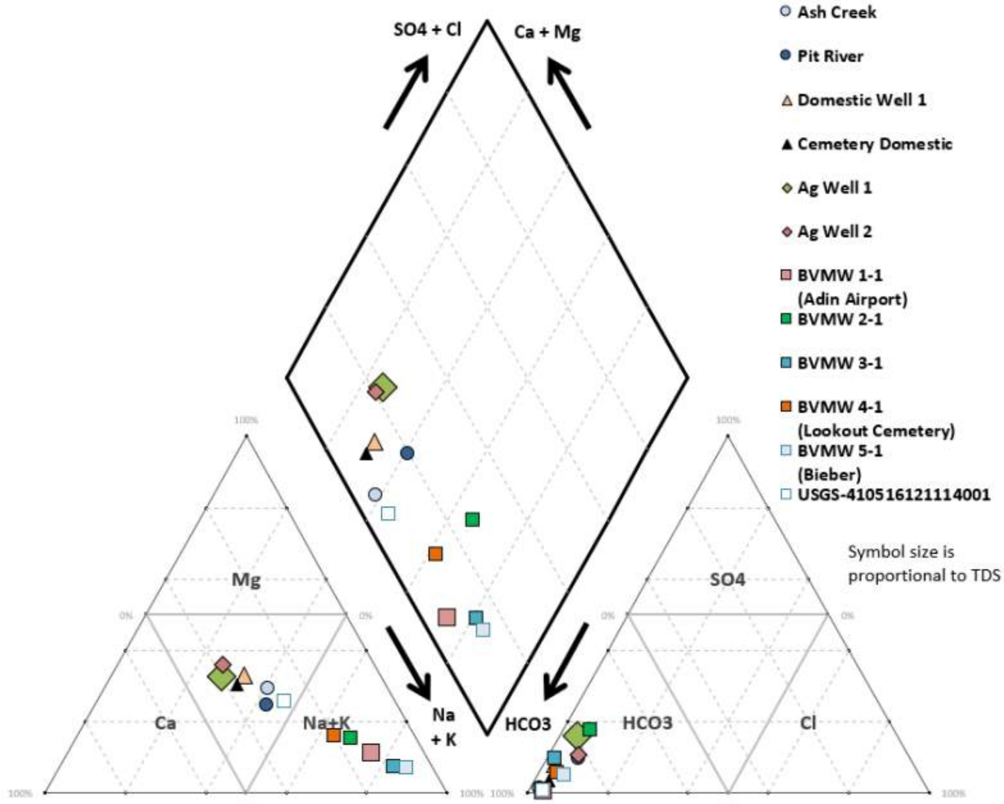


Figure 4-12 Piper Diagram showing major cations and anions

Some areas in the Basin have elevated levels of iron, manganese, and/or arsenic, all of which are naturally occurring in volcanic terrains such as Big Valley. The nature and distribution of these constituents will be discussed further in Chapter 5 – Groundwater Conditions.

4.8 Groundwater Recharge and Discharge Areas

4.8.1 Recharge

Groundwater recharge in BVGB likely occurs *via* several mechanisms discussed below.

Underflow from adjacent upland areas and other areas outside the Basin

The upland areas consist of fractured basalt flows where the precipitation infiltrates vertically through joints and fractures until it reaches underlying aquifer material and then travels horizontally into the Basin. DWR has postulated that the areas shown in pink on **Figure 4-13** provide recharge in such a way. However, other areas adjacent to the Basin could provide some recharge in a similar fashion. In addition, underflow enters the Basin where the Pit River and Ash Creek enter the Basin. A Basin boundary modification is needed to encompass other important recharge areas outside the currently defined Basin boundary.

Infiltration of precipitation on the valley floor

Some direct infiltration of rain and snow on the valley floor occurs. However, because the aquifer materials in the Basin are largely lacustrine and much of the soils have slow infiltration rates, a high proportion of the precipitation likely runs off or is evapotranspirated. **Figure 4-13** shows the areas from the NRCS datasets that may have a slightly higher infiltration rate (HSG B and HSG C) than the other areas and therefore potentially more recharge.

Rivers and streams that flow through the Basin

Streams that flow through the Basin lose water to the aquifer, particularly where they enter the Basin. Aquifer materials are typically coarser on the fringes of the Basin where the stream gradient begins to flatten. In general, recharge likely occurs in the eastern portions of the Basin along Ash Creek, Butte Creek, and Willow Creek and then flows westerly through the subsurface. As Ash Creek flows to the center of the Basin and Big Swamp, the water slows and spreads out into a large marsh. The CDFW has recently enhanced this slowing and spreading of water through “pond and plug” projects which bring the water up out of the previously incised channel. Other pond and plug projects have been successfully implemented in the region. Even though the soils and aquifer materials in this portion of the Basin have slow infiltration rates, recharge is likely to occur from Big Swamp because of the long period of time that the shallow soils remain wet and saturated. Support from the public has been received at outreach meetings to conduct more pond and plug projects within and near the Basin.

Deep percolation of irrigation water

Depending on the irrigation method, particularly flood irrigation, deep percolation of irrigation water into the aquifer occurs. Flood irrigation is an active practice in the Basin and provides valuable recharge.

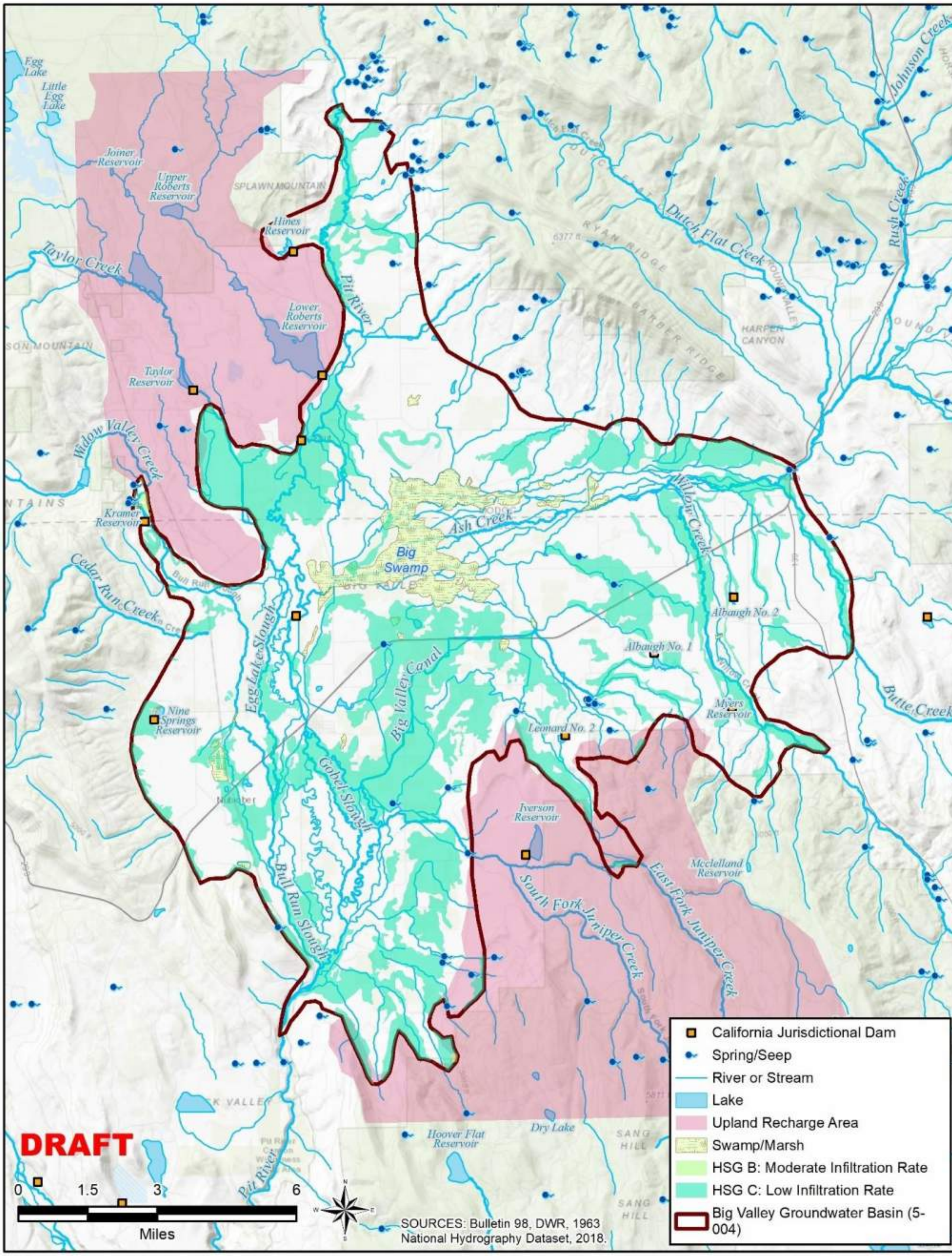


Figure 4-13 Recharge, Discharge and Major Surface-water Bodies

4.8.2 Discharge

Historically, flow out of the groundwater aquifer (and out of the Basin) most likely occurred at the southern portion of the Basin where the aquifer discharged to the Pit River. DWR (1963) indicates that artesian[35] conditions occurred in this southwestern area. The gaining river[36] then transported the water out of the Basin. However, based on currently documented water levels, this area is no longer artesian and likely hasn't been a gaining stream for decades. There are numerous springs throughout the Basin shown on **Figure 4-13** where groundwater is discharged, including several hot springs in the center of the Basin. Evapotranspiration may also be a significant discharge mechanism.

4.9 Surface-Water Bodies

Figure 4-14 shows the numerous small streams that enter the Basin and flow towards the center where they connect with the two major streams: Pit River and Ash Creek. The figure also shows the many small ponds and several reservoirs that are in and around the perimeter of the Basin. The dams that are within the jurisdiction of the DWR Division of Safety of Dams are shown. While many of these impoundments are located outside of Basin boundaries, they represent supplies that hydrologically flow to/through the Basin. The reservoirs provide options for the timing of release of those waters, rather than importing supplies from sources external to the Basin.

4.10 Imported Water Supplies

BVGB users do not import surface water into the Basin because all surface water used in the Basin originates in the watershed of the Pit River or the watershed of a local BVGB stream.

4.11 Data Gaps in the Hydrogeologic Conceptual Model

As discussed in the introduction, hydrogeology has inherent uncertainties due to sparse data and in the case of Big Valley, a limited number of detailed studies on the groundwater resources in the Basin. Identified below are some of the uncertainties associated with the hydrogeology in the Basin. In some instances, this uncertainty can be reduced while other uncertainties will remain. The filling of the data gaps below is contingent on the needs that arise as the GSP is developed and implemented and the level of available outside funding.

Basin Boundary

The current, inaccurate Basin boundary was drawn by DWR with a regional scale map (CGS 1958) and was not drawn with as much precision as subsequent geologic maps. Additionally, the "uplands" areas outside the Basin boundary are postulated to be recharge areas interconnected to the Basin, which is contrary to DWR's definition of a lateral Basin boundary as being "…features that significantly impede groundwater flow" (DWR 2016c). Further refinement of the Basin boundary is desired and necessary, particularly in the areas of "upland recharge" mapped by DWR, the fingers in the southeastern portion of the Basin, and in the northeastern portion of the Basin below Barber Ridge and Fox Mountain.

---

[35] Artesian aquifers are under pressure and wells screened in them flow at the surface.
[36] Gaining rivers are where groundwater flows toward the river and contributes to surface-water flow.

Confining Conditions

Confining conditions probably exist throughout much of the Basin. Often, the confinement is simply a result of depth and the fact that horizontal hydraulic conductivities are 10 times (or more) greater than vertical conductivities. However, in the southwest portion of the Basin, DWR (1963) documented an area of confined groundwater conditions. It is unknown whether that confinement is due to a single, coherent aquitard or is just a result of depth. In addition, aquifer characteristics in the various areas of the Basin are not thoroughly understood as discussed in Section 4.4.5, and an assessment is needed on how aquifer characteristics vary throughout the Basin in shallow and deep portions of the aquifer.

Definable Bottom

This HCM has used the "practical" depth of 1,200 feet as the definable bottom. If stakeholders seek to develop groundwater deeper than this depth, newly constructed wells will demonstrate that the "physical bottom" and the base of fresh water ("effective bottom") extend deeper.

Faults as Barriers to Flow

It is unknown if the faults which traverse the Basin are barriers to flow. Groundwater contours indicate that there is east-to-west flow, but this flow is uncertain due to a mapped fault between the two areas. This uncertainty could be reduced by conducting a pumping test with observation well(s) on the other side of the fault.

Soil Permeability

The NRCS mapping of soils indicates primarily low- to very-low-permeability soils throughout the Basin. However, there is some variation of permeabilities indicated by the maps, which are drawn at a large scale with limited field verification. Further field investigation of soils and permeability tests could help identify more permeable areas where groundwater recharge could be enhanced.

Recharge

The recharge sources below have been identified, but the rate and amount of recharge is unknown. In the water budget (*see* Chapter 6 – Water Budget), the amount of recharge is roughly estimated. Below are the data gaps related to recharge.

- Effect of Ash Creek on recharge (including Big Swamp)
- Effect of Pit River on recharge (including overflow channels)
- Effect of smaller streams on recharge (including Willow Creek)
- Amount of recharge from direct precipitation
- Amount of recharge from deep percolation of applied water
- Amount of recharge from upland recharge areas
- Amount of recharge from seepage of ditches, canals and reservoirs

5. Groundwater Conditions §354.16

This chapter presents available information on groundwater conditions for the BVGB developed by GEI for the Lassen County and Modoc County GSAs. This chapter provides some of the information needed for the development of the monitoring network and the sustainable management criteria of this GSP. The content of this chapter is defined by the regulations of SGMA (Chapter 1.5, Article 5, Subarticle 2: 354.16). GEI Professional Geologists provided the content of this chapter and will affix their professional stamps (as required by the regulations) certifying that it was developed under their supervision once the chapter is finalized into the GSP.

5.1 Groundwater Elevations

Historic groundwater elevations are available from a total of 22 wells in Big Valley, six located in Modoc County and 16 in Lassen County as shown on **Figure 5-1** and listed in **Table 5-1**. Twenty of the wells are part of Lassen and Modoc counties' monitoring network, which was approved by the counties in 2011, in compliance with the CASGEM program. DWR staff measure water levels in these wells twice annually (spring and fall) on behalf of the counties. Some measurements from wells are missing, which is typically a result of access issues to the wells site, or occasionally a well owner who has removed their well from the monitoring program. These wells may or may not be used as part of the GSP monitoring network, which will be addressed in Chapter 8 – Monitoring Networks.

The first water level measurements in the BVGB began in the late 1950s at two wells near Bieber (17K1) and Nubieber (32A2). Regular monitoring of these two wells began in the mid-1960s and monitoring began in most of the other wells during the late 1970s or early 1980s. Three wells located on the ACWA were added to the CASGEM networks in 2016. Of the 22 historically monitored wells, one well (12G1) has not been monitored since 1992 and one well (06C1) has no measurements since 2015. Construction details are not available for one well (32R1) and could benefit from a 'downhole' video inspection of the well casing to determine the depth interval associated with the water levels.

In addition to these 22 wells, five well clusters were constructed in late 2019 and early 2020 to support the GSP. Their locations are also shown on **Figure 5-1**. Each cluster consists of a deep well (200-500 feet) and three shallow wells (60-100 feet). These wells were drilled to explore the geology, with the deep well giving water level information for the main portion of the aquifer at that location. The three shallow wells are screened shallow to determine the direction and magnitude of flow in the shallow subsurface and potentially to give an indication if groundwater interacts with surface water and possibly the location of groundwater recharge. Limited water level information is available from these five clusters.

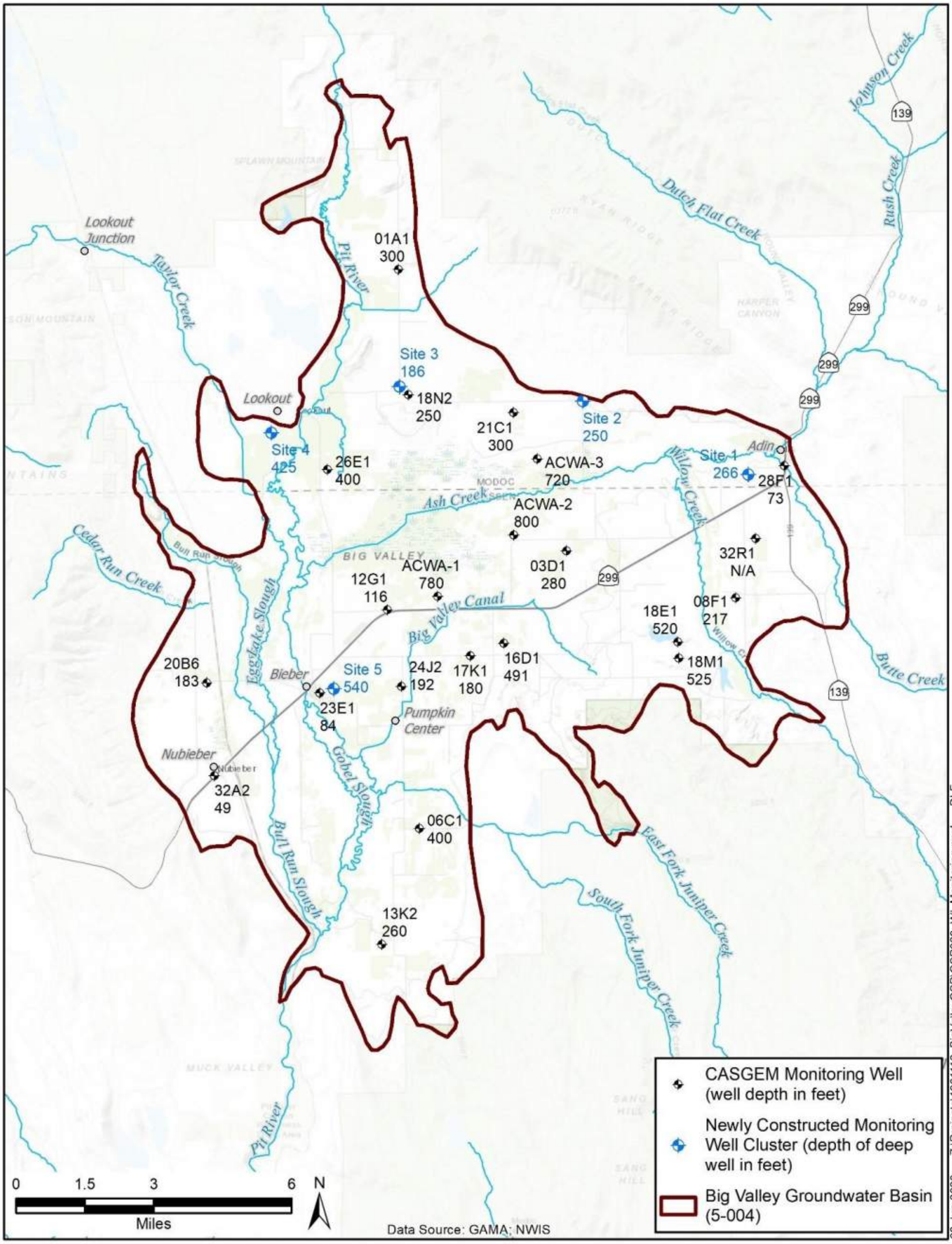


Figure 5-1 Water Level Monitoring

Table 5-1 Historic Water Level Monitoring Wells

Well Name	State Well Number	CASGEM ID	County	Well Use	Well Depth (feet bgs)	Ground Elevation (feet msl)	Reference Point Elevation (feet msl)	Period of Record Start Year	Period of Record End Year	Number of Measure-ments	Minimum Groundwater Elevation (feet msl)	Maximum Groundwater Elevation (feet msl)
18E1	38N09E18E001M	411356N1209900W001	Lassen	Irrigation	520	4248.40	4249.50	1981	2019	73	4198.20	4234.10
23E1	38N07E23E001M	411207N1211395W001	Lassen	Residential	84	4123.40	4123.40	1979	2020	81	4070.40	4109.10
260	39N07E26E001M	411911N1211354W001	Modoc	Irrigation	400	4133.40	4135.00	1979	2020	79	4088.90	4131.30
01A1	39N07E01A001M	412539N1211050W001	Modoc	Stockwatering	300	4183.40	4184.40	1979	2020	81	4035.40	4163.90
03D1	38N08E03D001M	411647N1210358W001	Lassen	Irrigation	280	4163.40	4163.40	1982	2020	71	4076.60	4148.60
06C1	37N08E06C001M	410777N1210986W001	Lassen	Irrigation	400	4133.40	4133.90	1982	2016	69	4066.20	4126.80
08F1	38N09E08F001M	411493N1209656W001	Lassen	Other	217	4253.40	4255.40	1979	2020	83	4167.90	4229.50
12G1	38N07E12G001M	411467N1211110W001	Lassen	Residential	116	4143.38	4144.38	1979	1993	28	4130.98	4138.68
13K2	37N07E13K002M	410413N1211147W001	Lassen	Irrigation	260	4127.40	4127.90	1982	2018	70	4061.90	4109.70
16D1	38N08E16D001M	411359N1210625W001	Lassen	Irrigation	491	4171.40	4171.60	1982	2020	74	4078.73	4162.40
17K1	38N08E17K001M	411320N1210766W001	Lassen	Residential	180	4153.30	4154.30	1957	2020	146	4115.08	4150.00
18M1	38N09E18M001M	411305N1209896W001	Lassen	Irrigation	525	4288.40	4288.90	1981	2020	74	4192.30	4232.70
18N2	39N08E18N002M	412144N1211013W001	Modoc	Residential	250	4163.40	4164.40	1979	2020	80	4136.60	4160.20
20B6	38N07E20B006M	411242N1211866W001	Lassen	Residential	183	4126.30	4127.30	1979	2019	80	4076.94	4116.60
21C1	39N08E21C001M	412086N1210574W001	Modoc	Irrigation	300	4161.40	4161.70	1979	2020	79	4082.10	4148.50
24J2	38N07E24J002M	411228N1211054W001	Lassen	Irrigation	192	4138.40	4139.40	1979	2019	77	4056.70	4137.70
28F1	39N09E28F001M	411907N1209447W001	Modoc	Residential	73	4206.60	4207.10	1982	2020	76	4194.57	4202.10
32A2	38N07E32A002M	410950N1211839W001	Lassen	Other	49	4118.80	4119.50	1959	2020	133	4106.70	4118.80
32R1	39N09E32R001M	411649N1209569W001	Lassen	Irrigation	unknown	4243.40	4243.60	1981	2020	64	4161.20	4205.50
ACWA-1	38N08E07A001M	411508N1210900W001	Lassen	Irrigation	780	4142.00	4142.75	2016	2020	8	4039.15	4126.35
ACWA-2	39N08E33P002M	411699N1210579W001	Lassen	Irrigation	800	4153.00	4153.20	2016	2020	8	4126.40	4139.35
ACWA-3	39N08E28A001M	411938N1210478W001	Modoc	Irrigation	720	4159.00	4159.83	2016	2020	7	4136.23	4150.58

Notes:
bgs = below ground surface
msl = above mean sea level
source: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer

5.1.1 Groundwater Level Trends

Figure 5-2 and **Figure 5-3** show hydrographs for the two wells with the longest monitoring records along with background colors representing the Water Year (WY) type: wet, below normal, above normal, dry, and critical dry. These WY types are developed from the Sacramento River Index (SRI), which is calculated from annual runoff of the Sacramento River Watershed, of which the Pit River is a tributary. The SRI (no units) has varied between 3.1 and 15.3 (average: 8.1) over its 115-year history (1906-2020) and is divided into the five WY categories. For 1983 to 2018, the average SRI is 7.9.

Figure 5-2 Hydrograph of Well 17K1

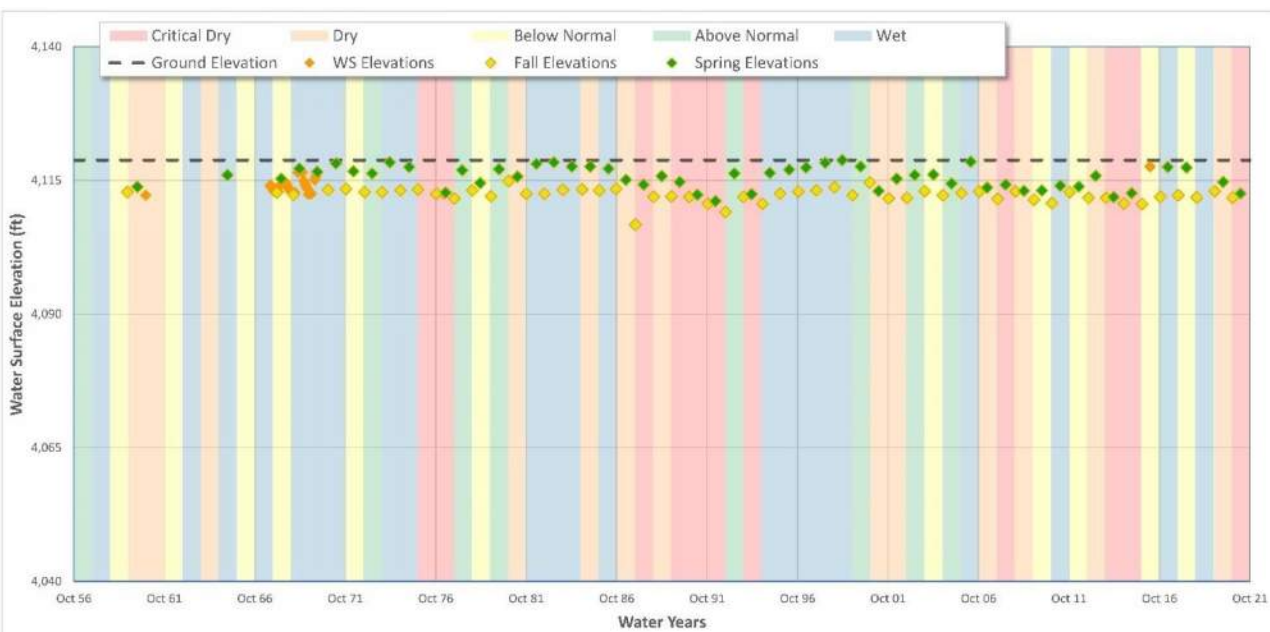


Figure 5-3 Hydrograph of Well 32A2

The water level record for these two wells illustrates that some areas of the Basin have experienced little to no change in water levels, while other areas have fluctuated and declined during the last 20 years. Declines during the drought period of the late 1980s and early 1990s were offset by recovery during the wet period of the late 1990s. Water levels in some wells have declined during the sustained dry period that has occurred since 2000. Hydrographs for all 22 wells are presented in **Appendix 5A**. On each of these hydrographs, an orange trend line is shown, which is determined from a line of best fit for the spring water level measurements between WY 1979 and 2021. The average water level change during that period, in feet per year, is also shown. Sixteen wells show relatively stable (less than -1.0 foot per year [ft/yr] of decline) or rising water levels, and six wells show declining water from -1.0 ft/yr to -3.1 ft/yr. The locations of these water level changes are shown graphically on **Figure 5-4**, with the stable or rising water levels shown in green, and areas with declines more than -1.0 ft/yr in orange.

5.1.2 Vertical Groundwater Gradients

Vertical hydraulic gradients are apparent when groundwater levels in wells screened deep in the aquifer differ from water levels measured shallow in the aquifer at the same general location. Significant vertical gradients can indicate that the deep portion of the aquifer is separate from the shallow (e.g., by a very low permeability clay layer) and/or that pumping in one of the aquifers has occurred and the vertical flow between the aquifers is in progress of stabilizing. Chapter 4 – Hydrogeologic Conceptual Model defines a single principal aquifer in the BVGB. However, vertical gradients likely exist, and the five recently constructed well clusters will have data to describe these gradients once sufficient water level data are available from those wells. The locations of the clusters are shown on **Figure 5-1**.

5.1.3 Groundwater Contours

Spring and fall 2018 water level measurements from the 21 active CASGEM wells were used to illustrate current groundwater conditions. The 2018 data was used to illustrate current conditions because there were several wells without data for 2019 or 2020. **Figure 5-5** and **Figure 5-6** show the 2018 seasonal high and seasonal low groundwater elevation contours, respectively, which were interpolated from the locations of the 21 active wells. Each contour line shows equal groundwater elevation. Groundwater flows from higher elevations to lower elevations, perpendicular to the contour lines. The direction of flow is emphasized on the figures in certain areas with arrows. In general, groundwater is highest in the east, where Ash, Willow and Butte Creeks enter the Basin. The general flow of water is to the west and south. The contours do indicate, however, northerly flow from the lower reaches of Ash Creek. In the southern portions of the BVGB, groundwater flows toward the east.

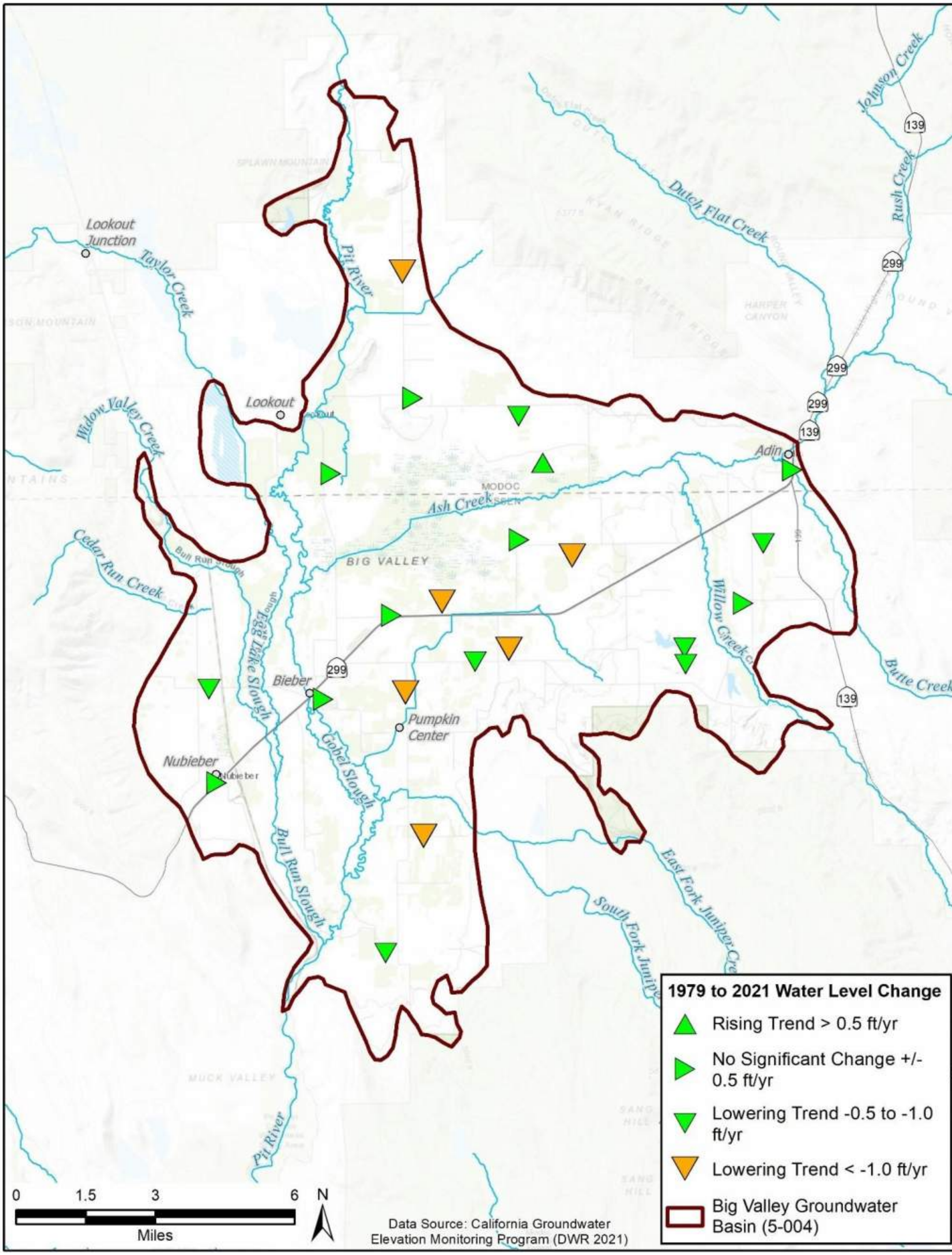


Figure 5-4 Average Water Level Change Since 2000 Using Spring Measurements

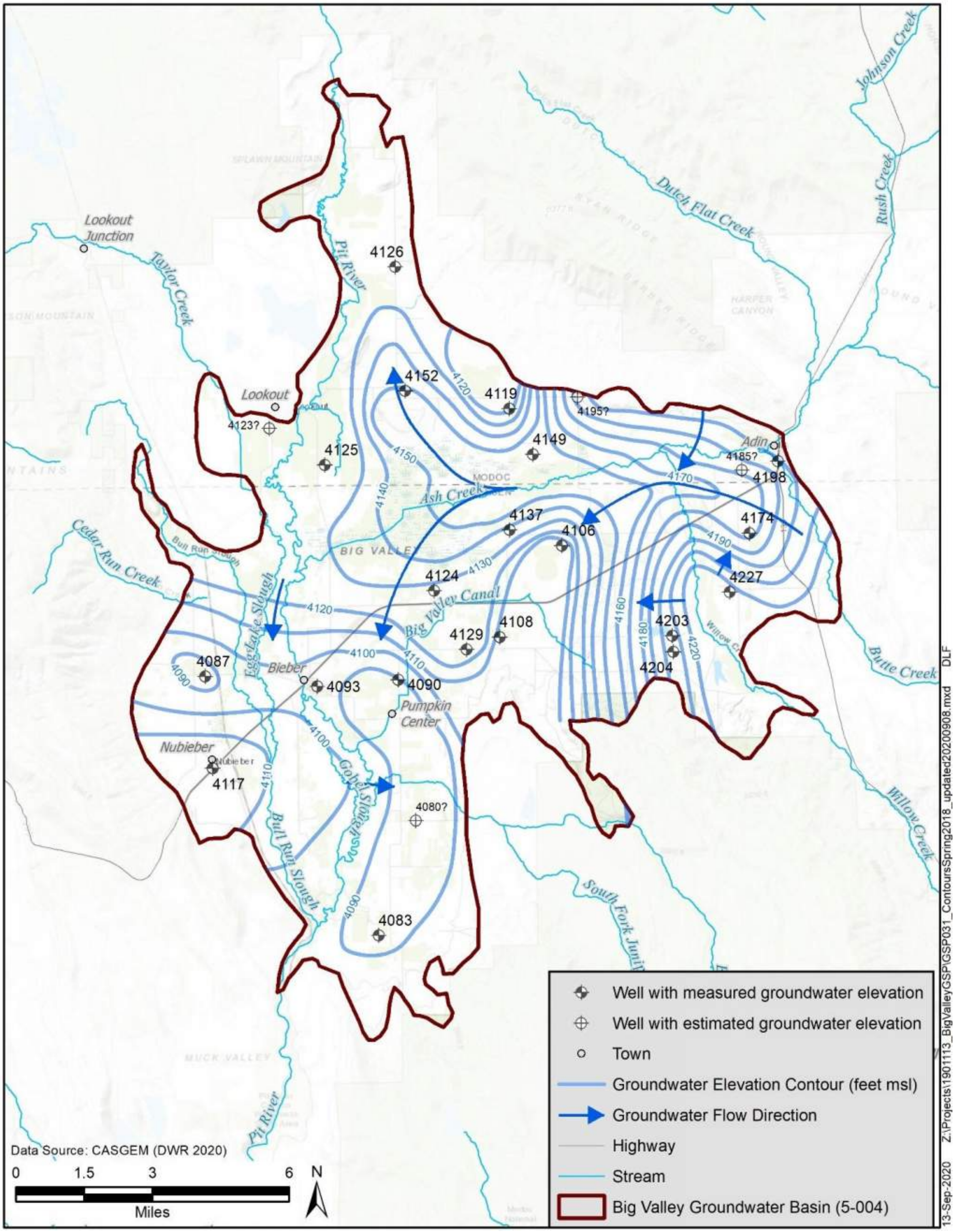


Figure 5-5 Groundwater Elevation Contours and Flow Direction Spring 2018

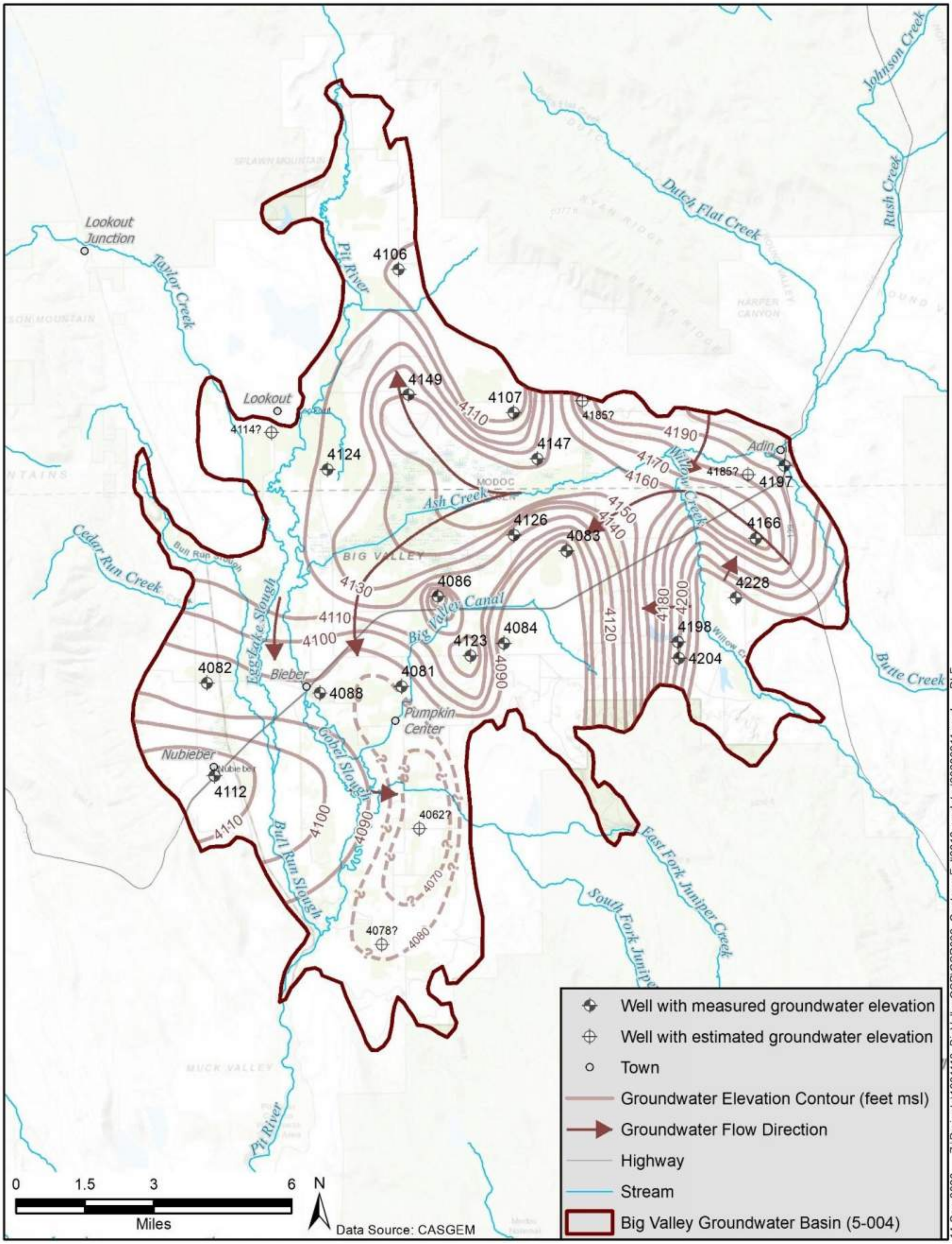


Figure 5-6 Groundwater Elevation Contours and Flow Direction Fall 2018

5.2 Change in Storage

To determine the annual and seasonal change in groundwater storage, groundwater elevation contoured surfaces[37] were developed for spring and fall for each year between 1983 and 2018. These surfaces are included in **Appendix 5B**. The amount of groundwater in storage for each set of contours was calculated using software which can subtract the groundwater elevation surface from the ground elevation surface (using a digital elevation model) at each grid cell (pixel) and calculate the average depth to water (DTW) for the entire Basin. This average DTW was then subtracted from the practical bottom of the Basin (1,200 feet), multiplied by the area of the Basin, and multiplied by 5 percent, which is used as the specific yield[38].

Table 5-2 shows, from 1983 to 2018, the total groundwater in storage for each year and the cumulative change in storage. The highest SRI occurred in 1983 and the fourth lowest SRI occurred in 2015. Moreover, this 36-year period also include five of the lowest ten SRIs and five of the highest ten SRIs, which demonstrates the high degree of variability in climatic conditions.

Figure 5-7 shows this information graphically, along with the annual precipitation from the McArthur station. This graph shows that groundwater storage generally declines during dry years and stays stable or increases during normal or wet years. During the early portion of the 36-year period, groundwater levels dipped, then recovered to 1983 conditions by 1999 due to six consecutive years of above-average precipitation. Since 2000, groundwater storage has generally declined by about 96,000 acre-feet (AF) (using spring measurements) which is a slight increase from the historic low of about 116,000 AF in spring 2015.

Annual groundwater use is not shown on **Figure 5-7** as required by SGMA regulations. Groundwater use will be addressed in Chapter 6 – Water Budget.

5.3 Seawater Intrusion

The BVGB is not located near the ocean, and therefore seawater intrusion is not applicable to this GSP.

5.4 Groundwater Quality Conditions

As noted in Chapter 4, previous reports have characterized the water quality in the BVGB as excellent (DWR 1963, Reclamation 1979). Groundwater is generally suitable for all beneficial uses and only localized contamination plumes have been identified in the BVGB. This section presents an analysis of recent groundwater quality conditions and the distribution of known groundwater contamination sites in compliance with GSP Regulation §354.16(d).

---

[37] Groundwater elevation surfaces are developed using a kriging mathematically method and the known groundwater elevations at wells throughout the Basin. Kriging predicts (interpolates) what groundwater levels are between known points. The kriging surface consists of a grid (pixels) covering the entire basin that has interpolated groundwater elevation values for each node of the grid.

[38] The fraction of the aquifer material that contains recoverable water. Specific yield is described in more detail in Chapter 4 – Hydrologic Conceptual Model.

Table 5-2 Change in Storage 1983-2018

Year	Average Spring Depth to Water[1] (feet)	Spring Storage[2] (Acre-feet)	Spring Cumulative Change in Storage[3] (Acre-feet)
1983	29.3	5,390,192	-
1984	29.4	5,389,508	(684)
1985	31.4	5,380,526	(9,666)
1986	31.0	5,382,539	(7,653)
1987	32.6	5,375,135	(15,057)
1988	34.9	5,364,459	(25,733)
1989	35.2	5,363,150	(27,042)
1990	35.6	5,360,976	(29,216)
1991	36.8	5,355,677	(34,515)
1992	38.0	5,350,297	(39,895)
1993	36.9	5,355,293	(34,899)
1994	37.5	5,352,221	(37,971)
1995	35.3	5,362,737	(27,456)
1996	32.4	5,375,861	(14,332)
1997	31.8	5,378,600	(11,592)
1998	31.1	5,382,014	(8,179)
1999	29.5	5,389,070	(1,122)
2000	32.3	5,376,287	(13,905)
2001	38.0	5,350,015	(40,177)
2002	39.3	5,344,357	(45,835)
2003	39.4	5,343,881	(46,311)
2004	39.2	5,344,515	(45,677)
2005	41.5	5,334,164	(56,028)
2006	36.7	5,356,175	(34,017)
2007	38.8	5,346,641	(43,551)
2008	41.6	5,333,712	(56,480)
2009	42.5	5,329,337	(60,856)
2010	46.4	5,311,440	(78,752)
2011	45.9	5,313,710	(76,482)
2012	44.9	5,318,299	(71,893)
2013	49.3	5,298,013	(92,179)
2014	51.7	5,287,059	(103,133)
2015	54.4	5,274,644	(115,548)
2016	51.3	5,288,702	(101,490)
2017	49.7	5,296,127	(94,066)
2018	50.1	5,294,464	(95,728)

Note: Parentheses indicate negative numbers

[1] From water surface elevation contours - Appendix 5A

[2] Calculated from average depth to water, area of basin, 1,200 foot aquifer bottom, and specific yield of 5%

[3] This is the total change in storage since the baseline, defined as Spring 1983.

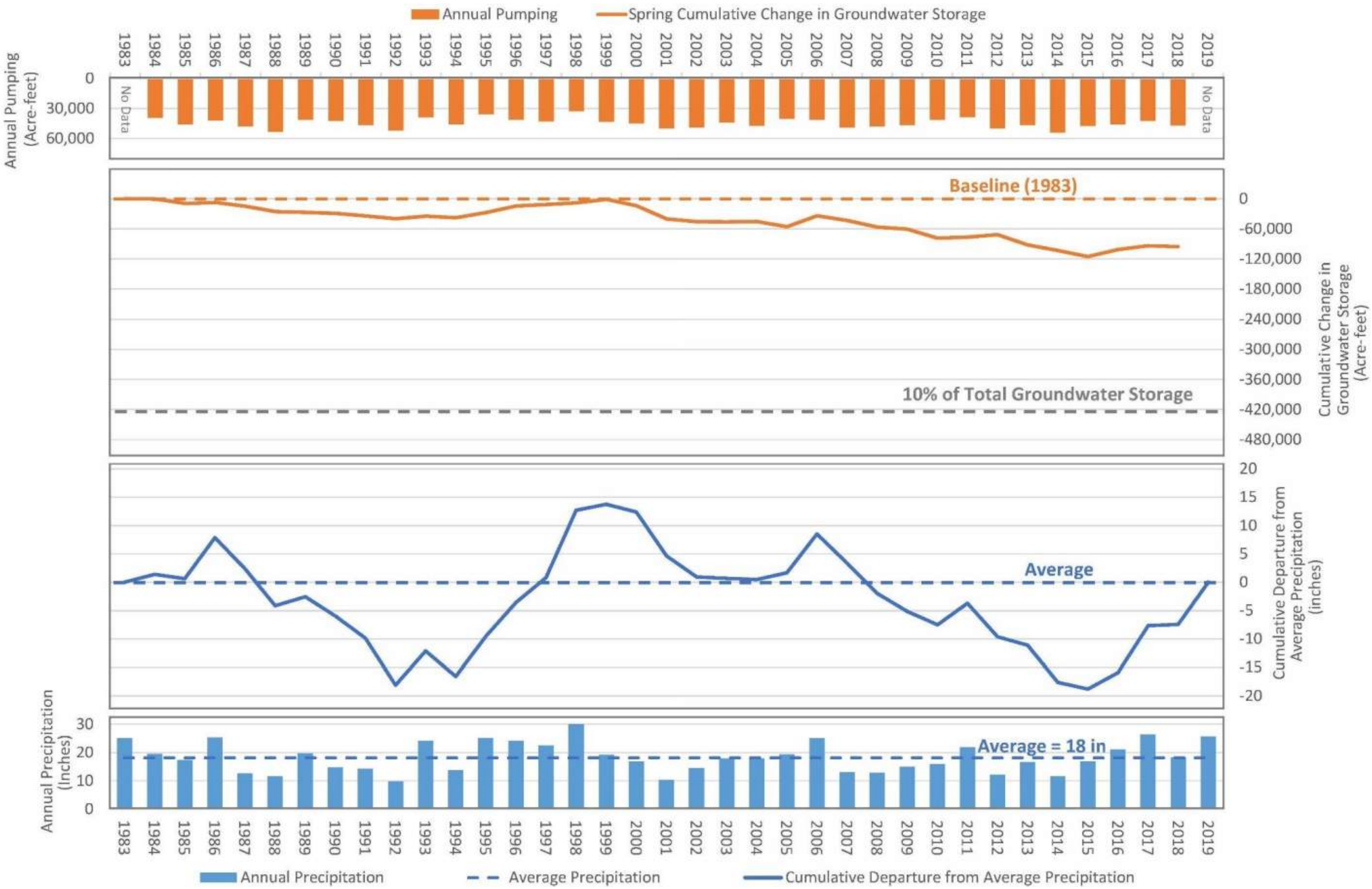


Figure 5-7 **Precipitation, Pumping and Change in Groundwater Storage**

5.4.1 Naturally Occurring Constituents

The concentration of naturally occurring constituents varies throughout the BVGB. Previous reports have noted the potential elevated concentrations of arsenic, boron, fluoride, iron, manganese, and sulfate. (DWR 1963, Reclamation 1979) All of these constituents are naturally occurring and, in these historic reports, they indicate that most of these constituents are associated with localized thermal waters found near hot springs in the center of the Basin.

More recent conditions were analyzed using a statistical approach on available data from the GAMA Groundwater Information System [GAMA GIS] (State Water Board 2020a). The GAMA GIS data provides the most comprehensive, readily available water quality dataset and contains results from numerous programs, including:

- Division of Drinking Water (public supply systems)
- Department of Pesticide Regulation
- Department of Water Resources (historic ambient monitoring)
- Environmental Monitoring Wells (regulated facilities and cleanup sites)
- U.S. Geological Survey (USGS) GAMA program
- USGS National Water Information System data

Water quality results in these datasets go back to the 1950s. Because conditions can change as groundwater is used over time, data prior to the WY 1983 were eliminated from the statistical analysis of the data. WY 1983 was chosen because the bulk of the historic water level wells (**Figure 5-1**) came online by 1983. Data from the Environmental Monitoring Wells programs were also eliminated since water quality issues associated with these regulated sites are typically highly localized, often are associated with isolated, perched groundwater, and are already regulated. The nature and location of groundwater contamination sites are discussed in Section 5.4.2. – Groundwater Contamination Sites and Plumes.

Table 5-3 shows the statistical evaluation of the filtered GAMA water quality data along with the water quality results obtained from the five well clusters constructed to support the GSP. The constituents selected to assess the suitability in the Basin are based on thresholds for different beneficial uses. For domestic and municipal uses, the inorganic constituents that are regulated under state drinking water standards are shown. Boron and sodium are also shown because elevated concentrations can affect the suitability of the water for agricultural uses. The suitability threshold concentration for each constituent is shown, using either the MCL or agricultural threshold, whichever was lower. Iron and manganese were evaluated for both drinking water and agricultural thresholds. It is assumed that water suitable for domestic, municipal, and agricultural purposes would also be suitable for environmental and industrial beneficial uses.

Table 5-3 Water Quality Statistics

Constituent Name	Suitability Threshold Concentration	Suitability Threshold Type	Total # of Meas	min	max	# Meas Above Threshold	% of Meas Above Threshold	# Wells With Meas	# Wells with Average Above Threshold	% of Wells with Average Above Threshold	# Wells with Most Recent Meas Above Threshold	% of Wells with Most Recent Meas Above Threshold	Comment
Aluminum	200	DW1	41	0	552	2	5%	18	1	6%	0	0%	Low concern due to only two threshold exceedances and zero recent measurements above MCL
Antimony	6	DW1	45	0	36	1	2%	20	1	5%	0	0%	Low concern due to only one threshold exceedance and zero recent measurements above MCL
Arsenic	10	DW1	53	0	12	4	8%	23	3	13%	3	13%	
Barium	1000	DW1	49	0	600	0	0%	23	0	0%	0	0%	
Beryllium	4	DW1	48	0	1	0	0%	23	0	0%	0	0%	
Cadmium	5	DW1	49	0	1	0	0%	23	0	0%	0	0%	
Chromium (Total)	50	DW1	36	0	20	0	0%	13	0	0%	0	0%	
Chromium (Hexavalent)	10	DW1*	13	0.05	3.29	0	0%	13	0	0%	0	0%	
Copper	1300	DW1	34	0	190	0	0%	21	0	0%	0	0%	
Fluoride	2000	DW1	42	0	500	0	0%	16	0	0%	0	0%	
Lead	15	DW1	28	0	6.2	0	0%	16	0	0%	0	0%	
Mercury	2	DW1	44	0	1	0	0%	19	0	0%	0	0%	
Nickel	100	DW1	46	0	10	0	0%	20	0	0%	0	0%	
Nitrate (as N)	10000	DW1	151	0	4610	0	0%	24	0	0%	0	0%	
Nitrite	1000	DW1	62	0	930	0	0%	20	0	0%	0	0%	
Nitrate + Nitrite (as N)	10000	DW1	2	40	2250	0	0%	2	0	0%	0	0%	
Selenium	50	DW1	49	0	5	0	0%	23	0	0%	0	0%	
Thallium	2	DW1	46	0	1	0	0%	20	0	0%	0	0%	
Chloride	250000	DW2	66	1400	79000	0	0%	43	0	0%	0	0%	
Iron	300	DW2	50	0	11900	26	52%	21	8	38%	9	43%	Low human health concern due to being a secondary MCL for aesthetics
Iron	5000	AG	50	0	11900	2	4%	21	2	10%	2	10%	
Manganese	50	DW2	45	0	807	28	62%	21	12	57%	11	52%	Low human health concern due to being a secondary MCL for aesthetics
Manganese	200	AG	45	0	807	22	49%	21	7	33%	7	33%	
Silver	100	DW2	36	0	20	0	0%	19	0	0%	0	0%	
Specific Conductance	900	DW2	66	125	1220	3	5%	42	1	2%	1	2%	
Sulfate	250000	DW2	60	500	1143000	1	2%	40	0	0%	0	0%	Low concern due to only one threshold exceedance and zero recent measurements above MCL
Total Dissolved Solids (TDS)	500000	DW2	57	131000	492000	0	0%	39	0	0%	0	0%	
Zinc	5000	DW2	34	0	500	0	0%	20	0	0%	0	0%	
Boron	700	AG	40	0	100	0	0%	34	0	0%	0	0%	
Sodium	69000	AG	33	11600	69000	0	0%	21	0	0%	0	0%	

Sources:

GAMA Groundwater Information System, accessed June 5, 2020 (SWRCB 2020)

University of California Cooperative Extension Farm Advisor (UCCE 2020)

Notes:

GAMA data was filtered to remove all measurements before Oct 1, 1982 and all GeoTracker cleanup sites

Constituents listed are all inorganic naturally occurring elements and compounds that have a SWRCB drinking water maximum contaminant limit (MCL), plus Boron, which has a threshold for agricultural use.

All measurements in micrograms per liter, except specific conductance which is measured in microsiemens per centimeter.

Green indicates less than 1%

Yellow indicates between 1% and 10%

Red indicates greater than 10%

Threshold Types:

DW1: Primary drinking water MCL

DW2: Secondary drinking water MCL (for aesthetics such as taste, color, and odor)

AG: Agricultural threshold based on guidelines by the Food and Agricultural Organization of the United Nations (Ayers and Westcot 1985)

* Hexavalent chromium was regulated under a primary drinking water MCL until the MCL was invalidated in 2017. The SWRCB is working to re-establish the MCL.

The subset of water quality data was analyzed to determine which constituents to investigate further. **Table 5-3** shows that most constituents have not had concentrations measured above their corresponding threshold since 1983 and were not investigated further. Sulfate, aluminum, and antimony only had one or two detections above their threshold, and none of these values were recent so these constituents were not investigated further. Arsenic (As), iron (Fe), manganese (Mn), specific conductance (SC), and total dissolved solids (TDS) were investigated further. All these constituents are naturally occurring.

Arsenic, Iron and Manganese

As, Fe, and Mn show elevated concentrations in over 10 percent of the wells. Although iron and manganese are regulated under secondary drinking water standards (for aesthetics such as color, taste, and odor) but are not of concern for human health as drinking water, these constituents were still chosen for further investigation because they also have multiple detections above the agricultural suitability threshold (Ayers and Westcot 1985). **Figure 5-8** through **Figure 5-10** show the trends over time. Wells with single measurements are shown as dots, where wells that had multiple measurements are shown as lines. These figures indicate that the number of wells with highly elevated concentrations of arsenic and manganese concentrations may have decreased over the last 40 years of groundwater use. Iron concentrations are generally below the agricultural suitability threshold (Ayers and Westcot, 1985), with two recent elevated measurements from the monitoring wells constructed in support of the GSP.

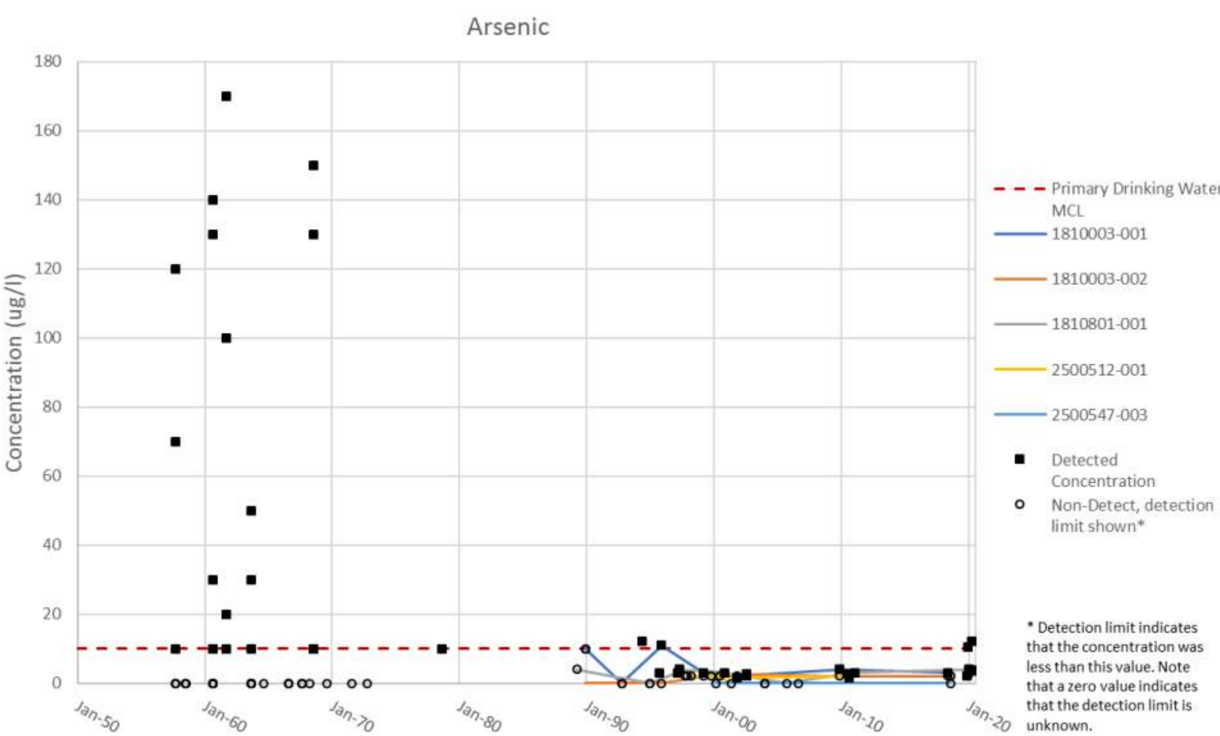


Figure 5-8 Arsenic Trends

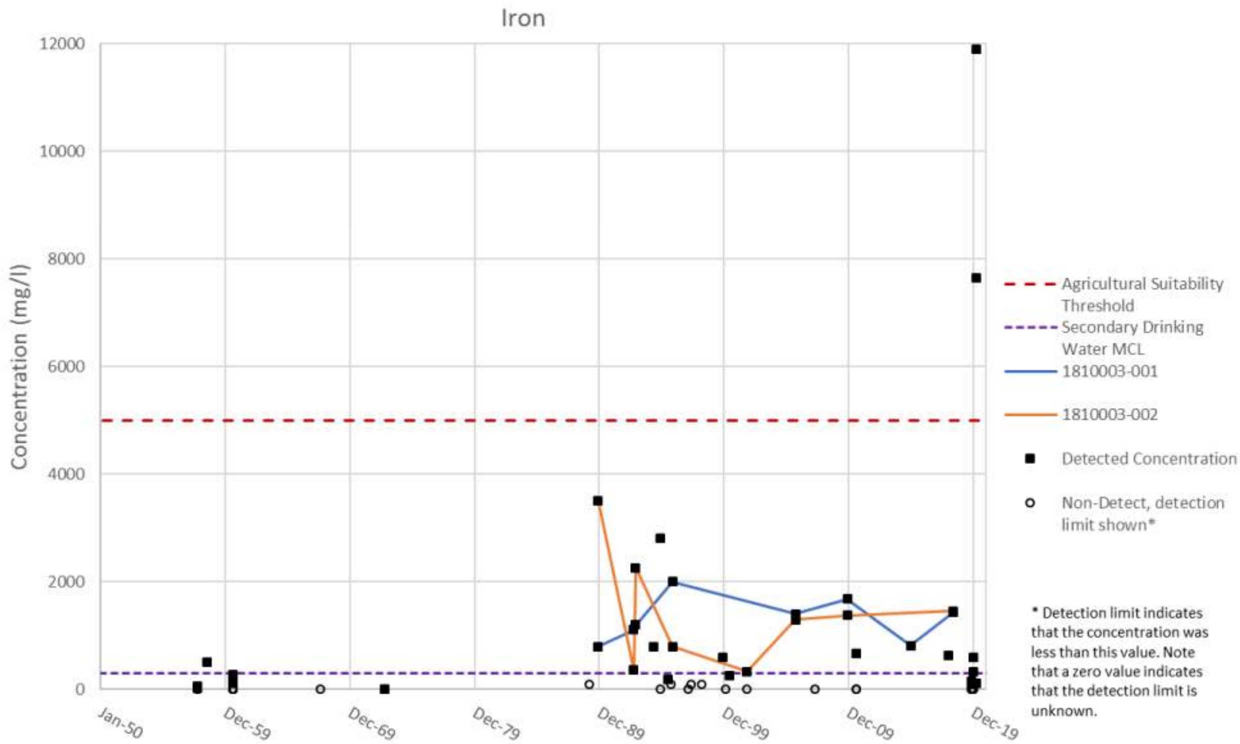


Figure 5-9 Iron Trends

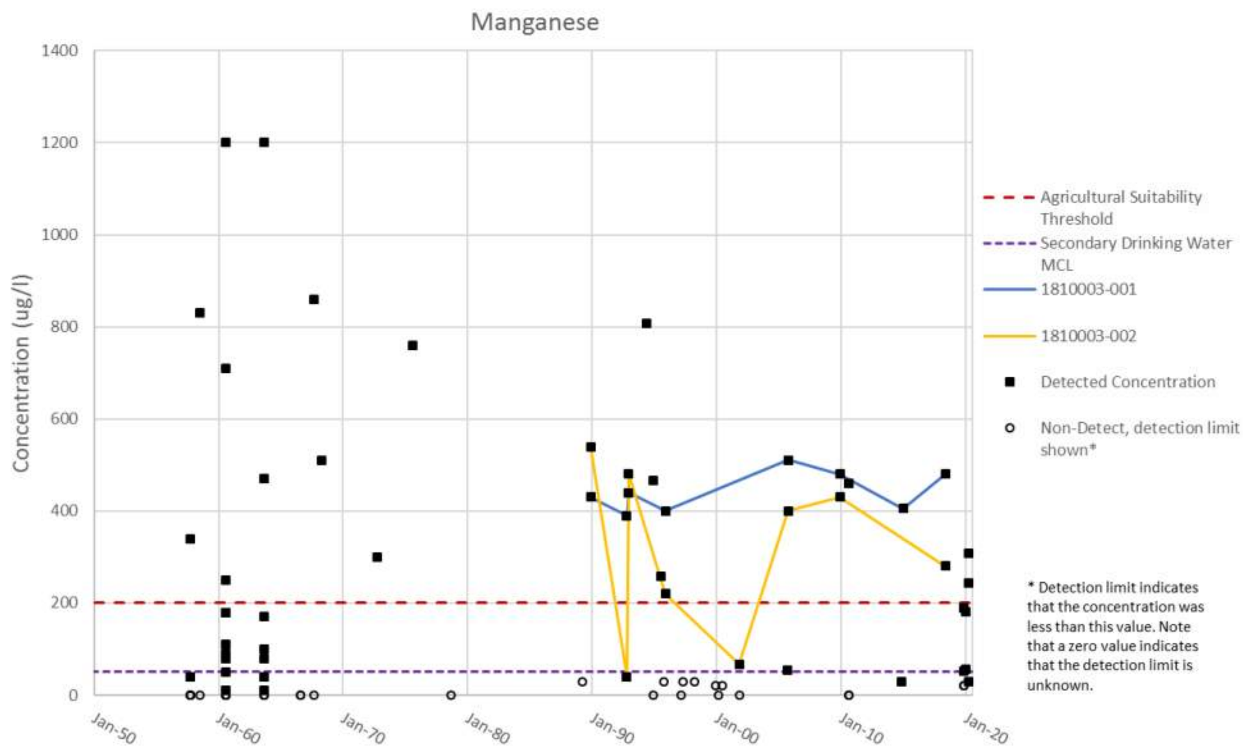


Figure 5-10 Manganese Trends

Specific Conductance and Total Dissolved Solids

SC is a measure of the water's ability to conduct electricity. TDS is a measure of the total amount of dissolved materials (e.g., salts) in water. SC and TDS are related to one another (higher TDS results in higher SC) and SC is often used as a proxy for TDS. Although there was only one recent measurement over the MCL for SC, both SC and TDS were investigated further because they are important indicators of general water quality conditions.

Figure 5-11 and **Figure 5-12** show the trends over time. Wells with single measurements are shown as dots, where wells that had multiple measurements are shown as lines. These figures indicate that the number of wells with highly elevated concentrations of SC and TDS may have decreased over the last 40 years. **Figure 5-13** and **Figure 5-14** show the distribution of elevated levels of SC and TDS around the Basin.

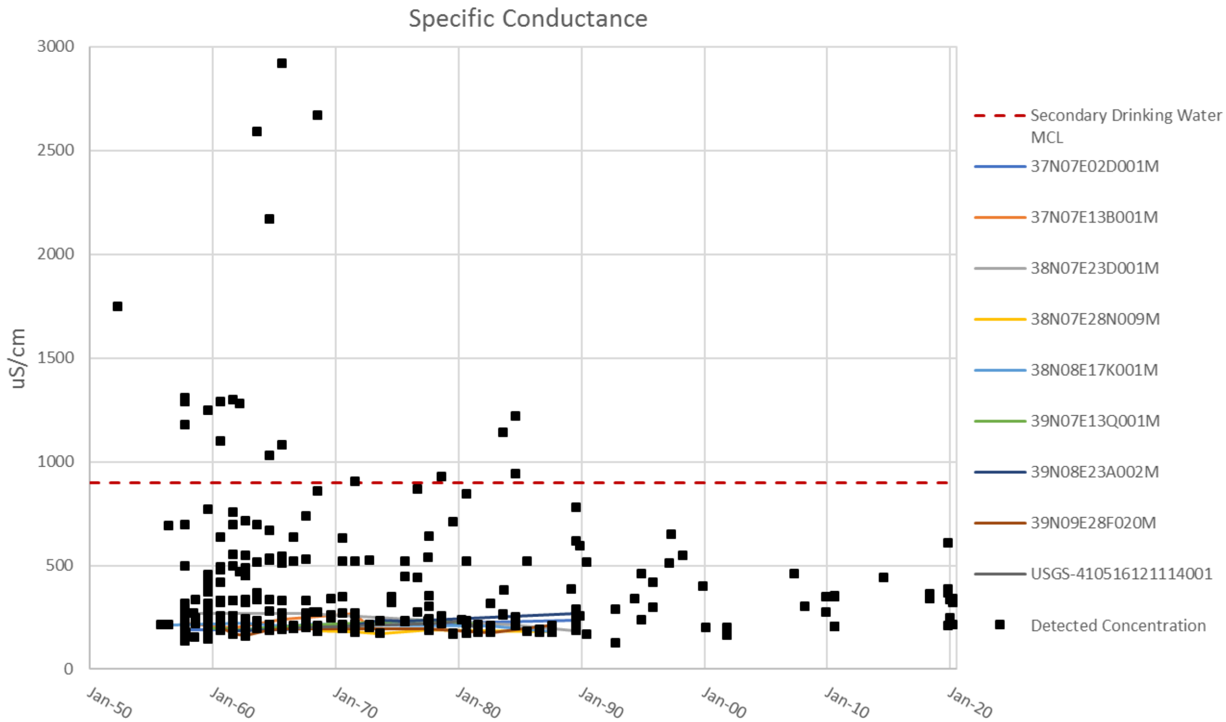


Figure 5-11 Specific Conductance Trends

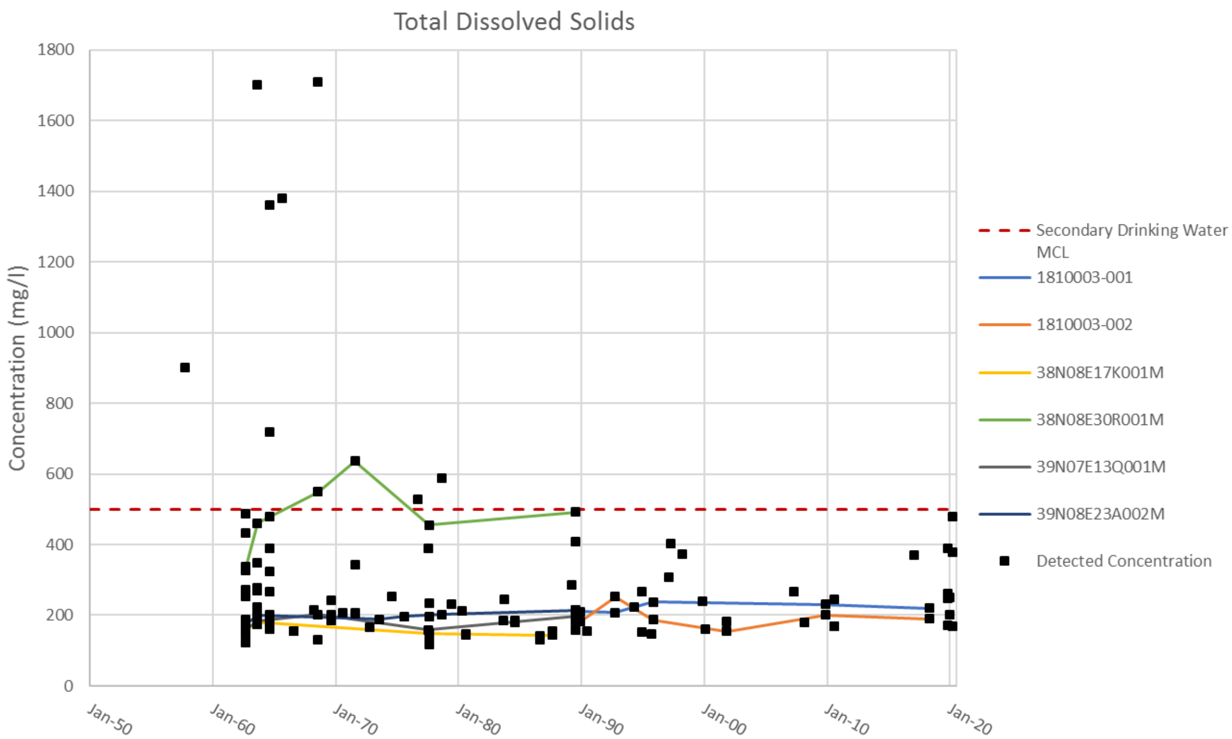


Figure 5-12 TDS Trends

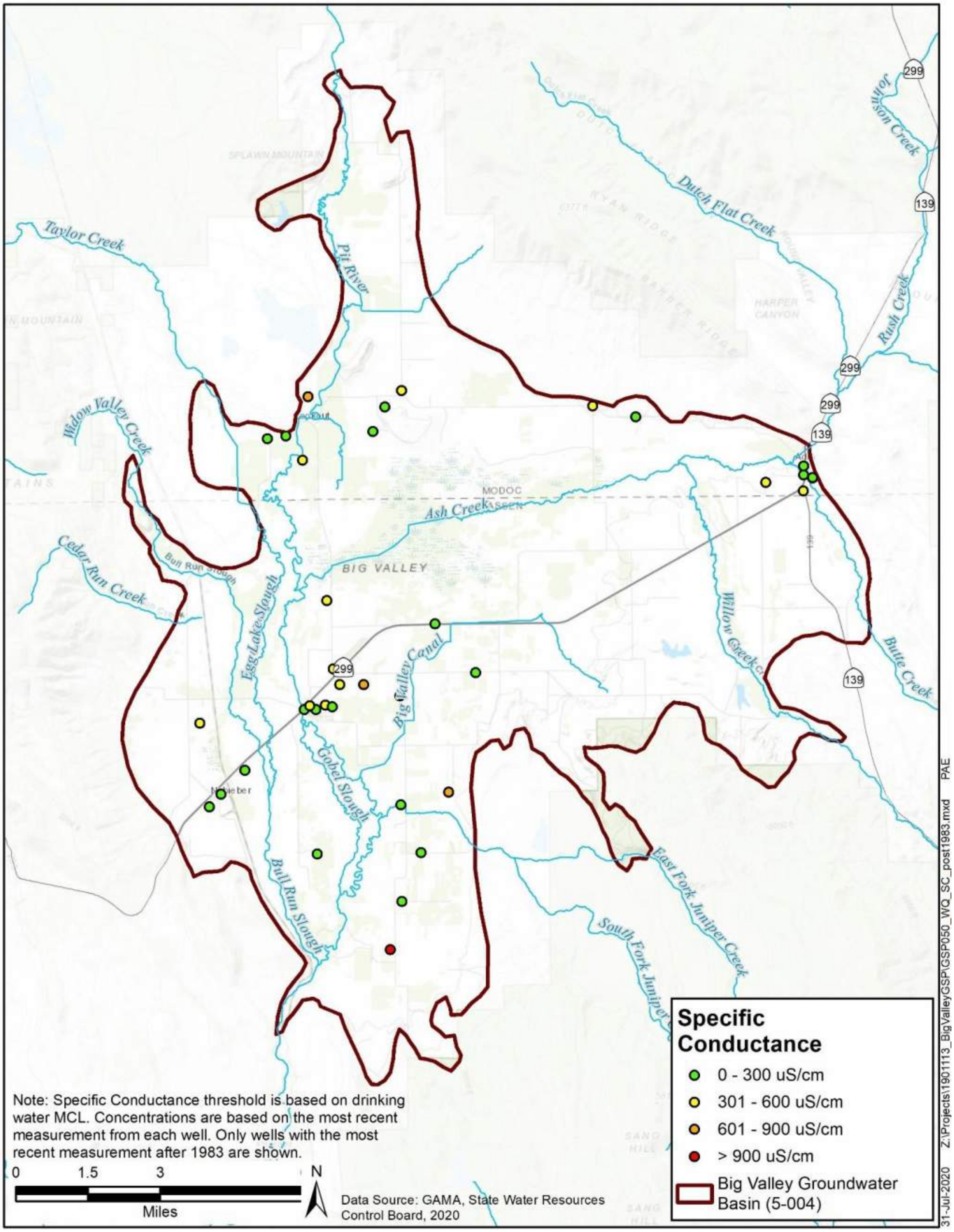


Figure 5-13 Distribution of Elevated Specific Conductance

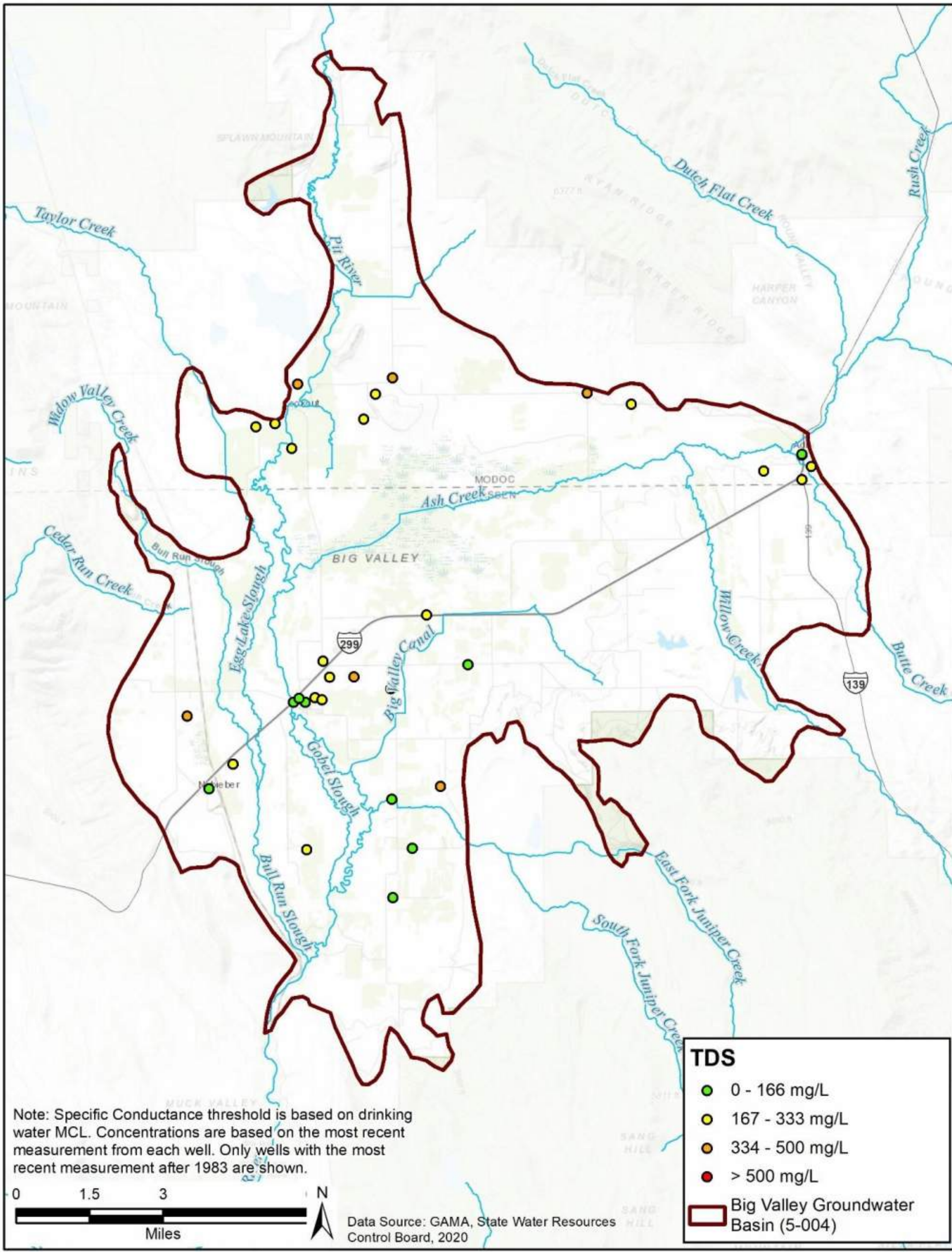


Figure 5-14 Distribution of Elevated TDS Concentrations

5.4.2 Groundwater Contamination Sites and Plumes

To determine the location of potential groundwater contamination sites and plumes, the State Water Board's GeoTracker website was consulted. GeoTracker catalogs known groundwater contamination sites and waste disposal sites (State Water Board 2020b). A search of GeoTracker identified ten sites where groundwater could potentially be contaminated. These sites are in the vicinity of Bieber and Nubieber as listed in **Table 5-4** and shown on **Figure 5-15**. The sites include leaking underground storage tanks (LUSTs), cleanup program sites, and a land disposal site. Half of the sites are open and subject to ongoing regulatory requirements. The contaminants are listed in **Table 5-4**, which also gives a summary of the case history.

Most of the contaminants originated at LUST sites are leaking petroleum hydrocarbons, which are light non-aqueous phase liquids (LNAPLs). LNAPLs are less dense than water and their solubility is quite low, meaning that if they reach groundwater, they float on top and generally do not migrate into the deeper portions of the aquifer. Moreover, many of the constituents can be degraded by naturally occurring bacteria in soil and groundwater so the hydrocarbons do not migrate far from the LUST sites. However, MTBE,[39] TBA,[40] and fuel oxygenates are more soluble in water. Two LUST sites and the landfill site are subject to long-term monitoring while a fourth site is ready for case closure.

The Bieber Landfill is subject to ongoing semi-annual monitoring of groundwater levels and groundwater quality at four shallow wells. This monitoring is required by the RWQCB (Order No. R5-2007-0175) after the formal closure of the landfill in the early 2000s. Trace concentrations of several organic constituents[41] have been detected at MW-1, the closest downgradient well to the site, but rarely at the other three wells. Higher concentrations of inorganic constituents (e.g., TDS, SC, others) are also present at MW-1. During 2019, the landfill was also required to analyze groundwater samples from MW-1, MW-2, and MW-4 for per/polyfluoroalkyl substances (PFAS), which are an emerging group of contaminants that are being studied for their effect on human health and may be subject to very low regulatory criteria (parts per trillion). Fifteen of 28 PFASs were detected at MW-1, and nine of 28 PFASs were detected at MW-4 (none at MW-2). The State Water Board/RWQCB evaluation of these data is still pending.

[39] Methyl tert-butyl ether (MTBE) is a fuel additive that was used starting in 1979 and was banned in California after 2002. MTBE is sparingly soluble in water and has a primary MCL of 13 ug/l for human health and a secondary MCL of 5 ug/l for aesthetics.
[40] tert-Butyl alcohol (TBA) is also a fuel additive and is used to produce MTBE. TBA does not have a drinking water MCL in California.
[41] 1,1-dichoroethane, 1,4-dichlorobenzene, cis-1,2-dichloroethylene, benzene, chlorobenzene, MTBE, 2,4,5-trichlorophenoxyacetic acid

Table 5-4 Known Potential Groundwater Contamination Sites in the BVGB

GeoTracker ID	Latitude	Longitude	Case Type	Status	Last Regulatory Acitivity	Case Begin Date	Potential Contaminants of Concern	Site Summary
T10000003882	41.12050	-121.14605	LUST Cleanup Site	Open - Assessment & Interim Remedial Action	04/16/20	10/17/11	Benzene, Diesel, Ethylbenzene, Total Petroleum Hydrocarbons (TPH), Xylene	The case was opened following an unauthorized release from an UST(s). Tank removal and further site assessment, including installation of 8 monitoring wells, led to remedial actions. Periodic groundwater monitoring started in October 2013 and has been ongoing though March 2020.
T0603593601	41.13230	-121.13070	LUST Cleanup Site	Open - Remediation	07/29/20	03/22/00	Gasoline	Active gas station with groundwater impacts. Full-scale remediation *via* groundwater extraction and treatment began in September 2013 and was shut down in April 2017 because it was determined that it was no longer an effective remedy to treat soil and groundwater. At the time of system shutdown, the influent MTBE concentration was 5,650 micrograms per liter which exceeds the Low-Threat Closure Policy criteria. Additionally, high levels of TPHg and sheen/free product are present. A soil vapor extraction system operated for a limited time in 2016/2017 but was not effective. In April 2018, it was determined that active remediation is not a cost-effective path to closure given low permeability of site soils. Staff suggested incorporating institutional controls (IC) and risk-based cleanup objectives instead of active remediation of soil and groundwater. The IC approach was dependent on the submittal of several documents related to soil management, deed restriction, risk modeling and annual groundwater sampling. This information has not been provided, and the RWQCB sent an Order for this information.
T0603500006	41.12241	-121.14128	LUST Cleanup Site	Completed - Case Closed	01/04/00	06/28/99	Diesel	A 2000-gallon UST was removed, and limited contaminated soil was present in the excavation. Petroleum hydrocarbons were not found in the uppermost groundwater. These findings led to the closure of the case.
L10005078943	41.12941	-121.14169	Land Disposal Site	Open - Closed facility with Monitoring*	06/26/20	06/30/08	Higher levels of Inorganic constituents, organic chemicals (synthetic), per/polyfluoroalkyl substances	Disposal activities at Bieber Landfill occurred from the early 1950s until 1994. The landfill was closed during the early 2000s. While active, the site received residential, commercial, and industrial non-hazardous solid waste. Formerly an unlined burn dump, the site was converted to cut-and-cover landfill operation in 1974. Landfill refuse is estimated to occupy less than 13 acres of the 20-acre site. Wastes are estimated to be approximately 10-15 feet thick. The Class III landfill was closed in accordance with Title 27 of the California Code of Regulations. A transfer station was established at the site for the transportation of waste to another landfill. Groundwater levels and quality are monitored twice per year at 4 wells.
T0603500003	41.12124	-121.14061	LUST Cleanup Site	Completed - Case Closed	09/13/94	07/31/91	Heating Oil / Fuel Oil	A 1000-gallon UST was removed, and contaminated soil was present beneath the tank, which led to installation of nine soil borings and three monitoring wells. Contaminated soil was removed but an adjacent building limited the extent of the excavation so contaminated soil remains under the building. Hydrocarbons were initially found in 1 well but not in subsequent sampling. The RWQCB concurred with a request to close the investigation.
T10000003101	41.13151	-121.13658	Cleanup Program Site	Open - Assessment & Interim Remedial Action	07/22/20	04/03/07	Benzene, Toluene, Xylene, MTBE / TBA / Other Fuel Oxygenates, Gasoline, Other Petroleum	A diesel leak was found in association with an industrial chipper. Corrective action included excavation of diesel-impacted soil, removing contaminated water and groundwater monitoring. Results of soil and groundwater sampling indicate low concentrations of TPHg and BTEX and that there is no offsite migration. Staff have determined that the case is ready for closure, pending decommissioning of the site monitoring wells.
SL0603581829	41.09251	-121.17904	Cleanup Program Site	Completed - Case Closed	09/01/05	01/08/05	Petroleum - Diesel fuels, Petroleum - Other	Contaminated soil excavated and transported to Forward Landfill for disposal. Contaminated groundwater (7,000 gallons) extracted with vacuum truck for disposal.
T0603500002	41.12188	-121.13546	LUST Cleanup Site	Completed - Case Closed	07/17/06	10/20/86	Gasoline / diesel	Three USTs were removed, and contaminated soil was present beneath the tank, which led to installation of nine monitoring wells and three remediation wells. Natural attenuation of the hydrocarbon impact was acceptable to the RWQCB due to the limited, well-defined extent of the impact and the limited and declining impact to groundwater. The RWQCB concurred with a request to close the site.
T0603500004	41.12134	-121.13547	LUST Cleanup Site	Completed - Case Closed	03/12/99	06/12/97	Diesel	A 5000-gallon UST was removed and very low levels of petroluem hydrocarbons were detected in the soil, which was allowed to be spread onsite and the case was closed.
T10000002713	41.11993	-121.14271	Cleanup Program Site	Open - Site Assessment	12/30/16	03/10/10	Other Petroleum	The site is an old bulk plant which was built in the 1930s and handled gasoline and diesel. During a routine inspection in March 2010, evidence of petroleum spills were identified at the loading dock area. A follow-up inspection was conducted in April 2010. The ASTs and loading dock were removed but additional contamination was noted under the removed structures. Furthermore, a shallow excavation contained standing water with a sheen. Due to the potential impacts to shallow groundwater, the Regional Water Board became the lead agency in December 2010. Additional information was requested in December 2016. A response is not evident.

*This terminology indicates that the landfill is closed (no new material being disposed), but the site is open with regard to ongoing groundwater monitoring.

Source: GeoTracker (State Water Board 2020b)

MTBE = Methyl tert-butyl ether; TBA = tert-Butyl alcohol

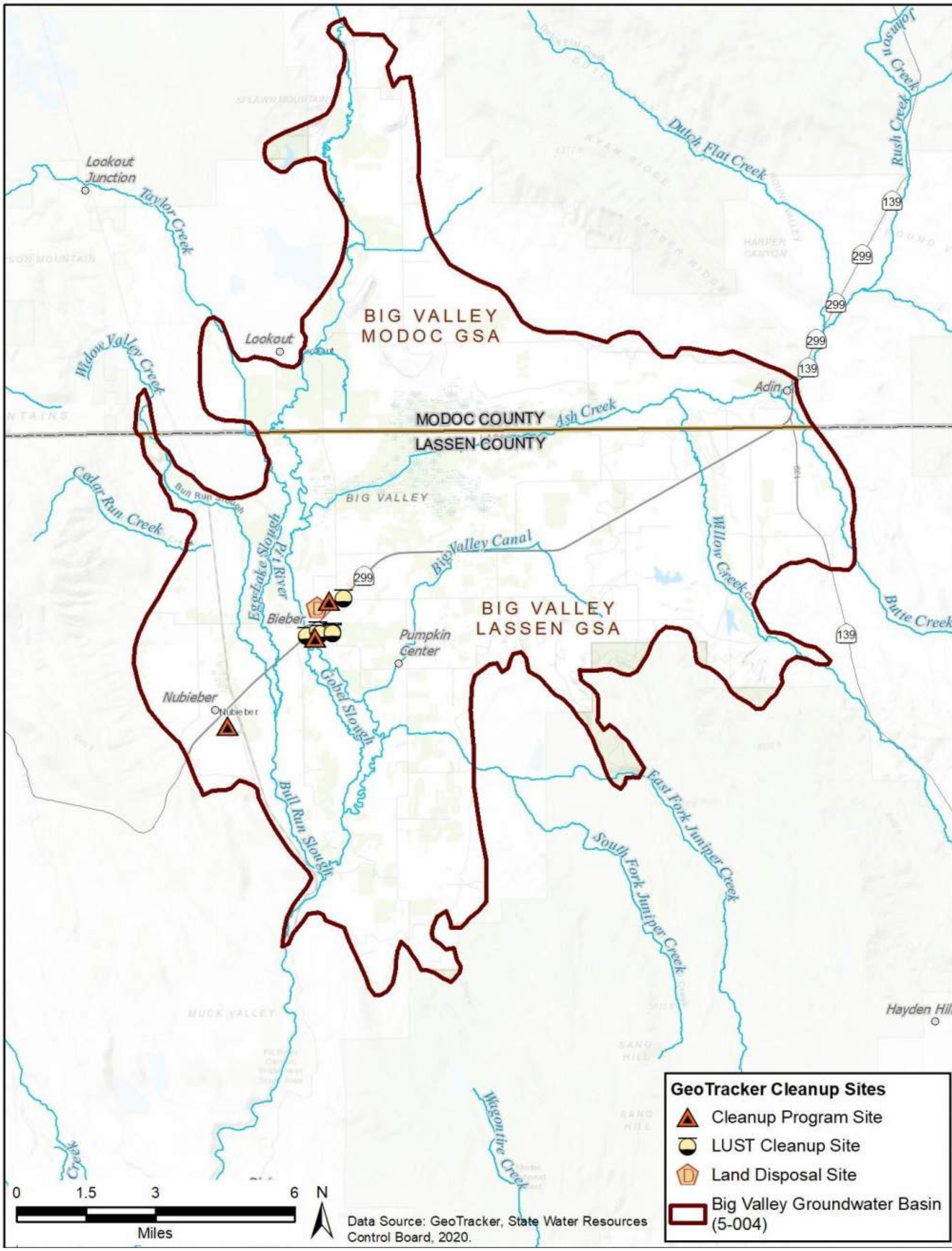


Figure 5-15 Location of Known Potential Groundwater Contamination Sites

5.5 Subsidence

Vertical displacement of the land surface (subsidence) is comprised of two components: 1) elastic displacement which fluctuates according to various cycles (daily, seasonally, and annually) due to temporary changes in hydrostatic pressure (e.g., atmospheric pressure and changes in groundwater levels) and 2) inelastic displacement or permanent subsidence which can occur from a variety of natural and human-caused phenomena. Lowering of groundwater levels can cause prolonged and/or extreme decrease in the hydrostatic pressure of the aquifer. This decrease in pressure can allow the aquifer to compress, primarily within fine-grained beds (clays). Inelastic subsidence cannot be restored after the hydrostatic pressure increases. Other causes of inelastic subsidence include natural geologic processes (e.g., faulting) and the oxidation of organic rich (peat) soils as well as human activities such as mining and grading of land surfaces.

Subsidence can be measured by a variety of methods, including:

- Regular measurements of any vertical space between the ground surface and the concrete pad surrounding a well. If space is present and increasing over time, subsidence may be occurring at that location. If a space is not present, subsidence may not be occurring, or the well is not deep enough to show that subsidence is occurring because the well and ground are subsiding together.
- Terrestrial (ground-based) surveys of paved roads and benchmarks.
- Global Positioning Survey (GPS) of benchmarks. GPS uses a constellation of satellites to measure the 3-dimensional position of a benchmark. The longer the time that the GPS is left to collect measurements, the higher the precision. Big Valley has one continuously operating GPS (CGPS) station near Adin.
- Monitoring of specially constructed “extensometer” wells. There are no extensometers in the BVGB.
- Use of InSAR, which is microwave-based satellite technology that has been used to evaluate ground surface elevation and deformation since the early 1990s. InSAR can document changes in ground elevation between successive passes of the satellite. Between 2015 and 2019, InSAR was used to evaluate subsidence throughout California, including Big Valley.

Subsidence was recognized as an important consideration in the 2007 LCGMP (Brown and Caldwell 2007) but was not identified as an issue for Big Valley specifically. The analysis in the LCGMP was based on indirect observations (groundwater levels) and anecdotal information. This section presents additional data that has become available since the development of the LCGMP.

5.5.1 Continuous GPS Station P347

A CGPS station (P347) was installed at the CalTrans yard near Adin in September 2007. The station is part of the Plate Boundary Observatory, which is measuring 3-dimensional changes in the Earth surface due to the movement of tectonic plates (e.g., Pacific and North American plates).

Figure 5-16 is a plot of the vertical displacement at P347 and shows a slight decline (0.6 inch) over the first 11 years of operation, based on the annual mean values (large black open circles). Daily values (blue dots) show substantial variation, as much as an inch, but more typically only 0.1 inch on average. This scattering of daily values around the annual mean provides an indication of the elastic nature of the displacement. The overall decline of 0.6 inch is an indication of inelastic displacement has occurred over an 11-year period, which equates to a rate of -0.05 inch per year at this location near Adin.

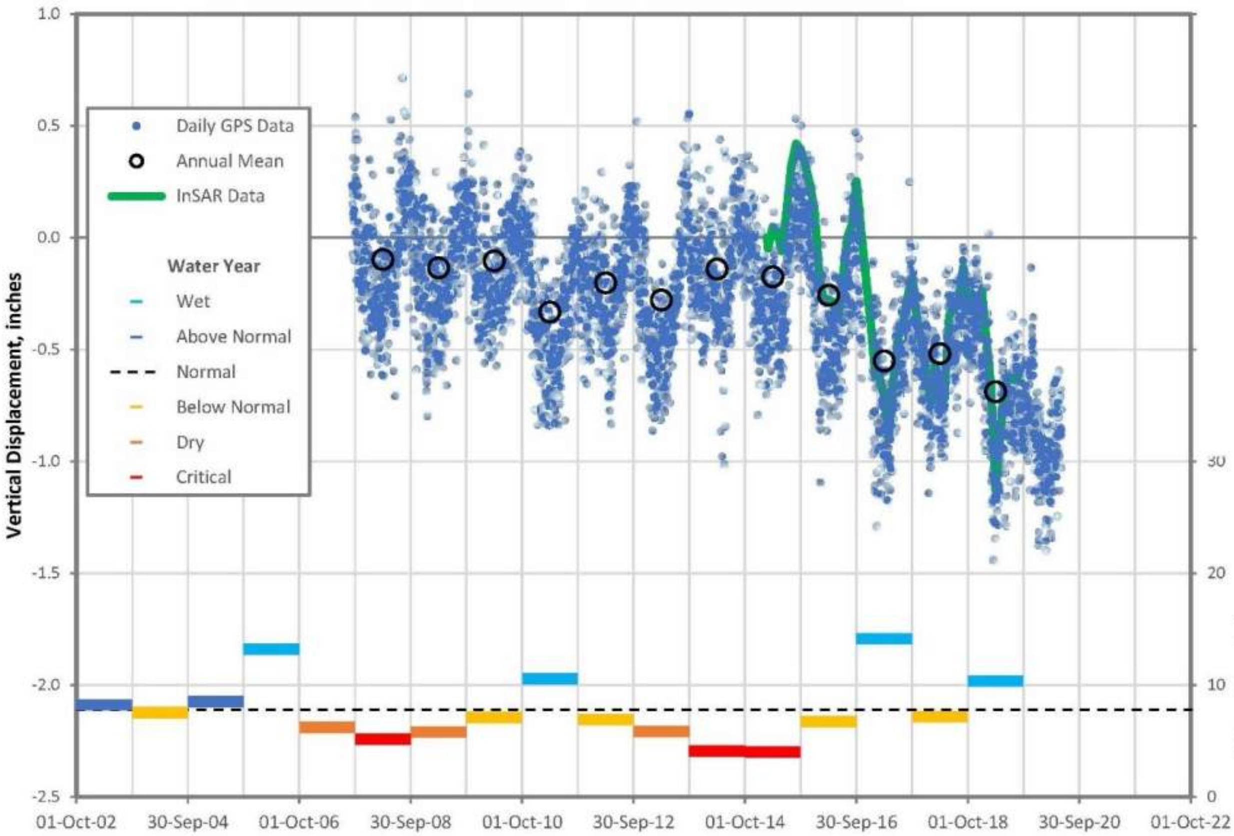


Figure 5-16 Vertical Displacement at CGPS P347

5.5.2 Interferometric Synthetic Aperture Radar

Figure 5-17 is a map of InSAR data made available by DWR for the 4.3-year period between June 2015 and September 2019. The majority of Big Valley was addressed by this InSAR survey, although the survey excludes some areas (shown in white on **Figure 5-17**), including much of the Big Swamp (ACWA), areas along the Pit River near Lookout, and areas south of Bieber. The accuracy of this type of InSAR data in California has been calculated at 18mm (0.7 inches) at a 95% confidence level (Towill 2021). Most of the survey shows downward displacement between 0 and -1 inch throughout Big Valley. This small displacement is close to the level of accuracy of the data, but if true is likely due to natural geologic activities due to its widespread nature.

Two localized areas of subsidence exceeding -1.5 inches are apparent from this data, one in the east-central portion of the Basin north of Highway 299 and one in the southern portion of the Basin between the Pit River and Bull Run Slough. Maximum downward displacement in the Basin is -3.3 inches, over the 4.3-year period. Some of the downward displacement in the Basin may be due to laser leveling of fields, particularly for production of wild rice.

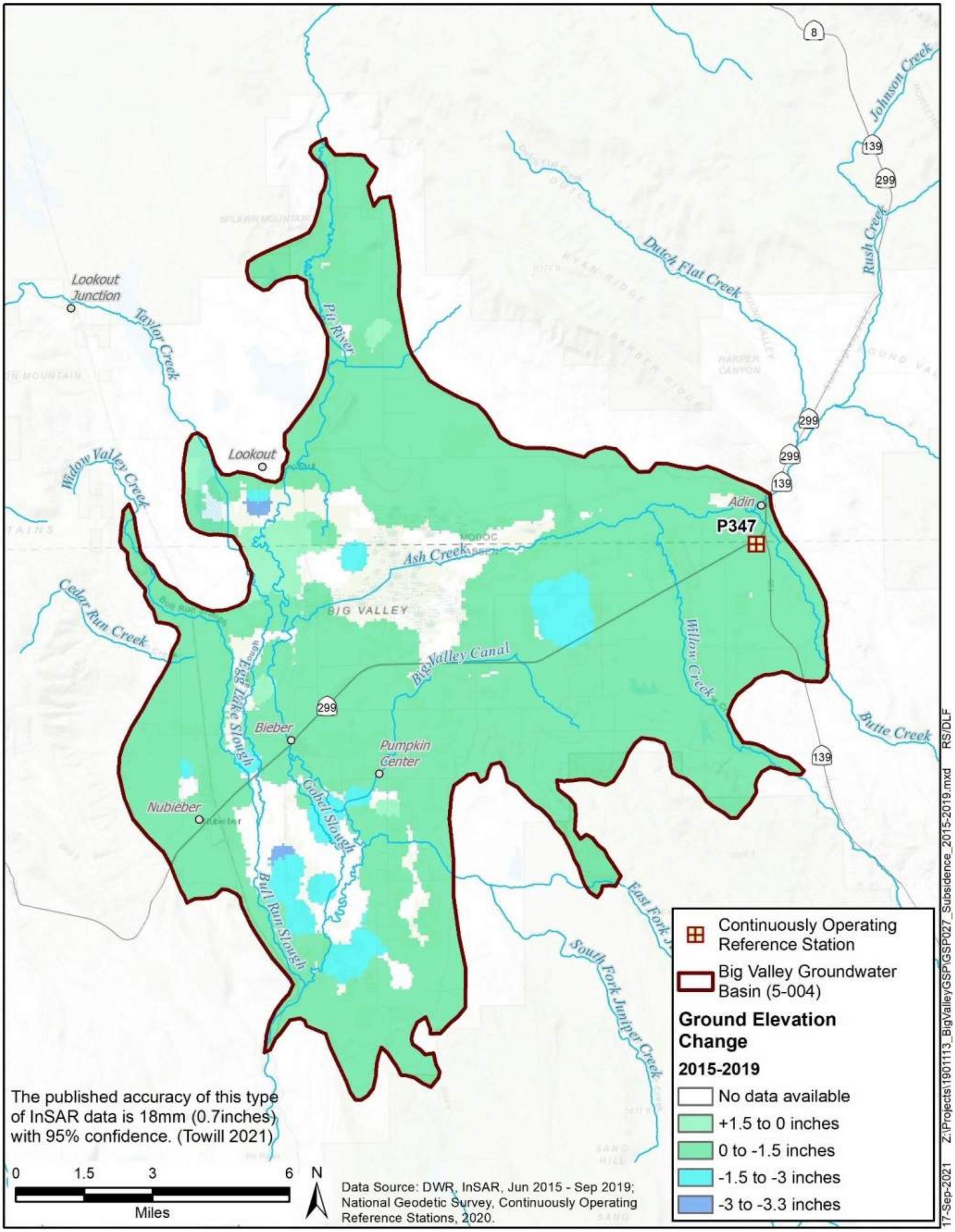


Figure 5-17 InSAR Change in Ground Elevation 2015 to 2019

5.6 Interconnected Surface Water

Interconnected surface water refers to surface water that is "hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted" (DWR 2016c). For the principal aquifer to be interconnected to surface-water streams, groundwater levels need to be near ground surface. As a first determination of where surface water *may* be interconnected, **Figure 5-18** shows the major[42] streams in the Basin which have groundwater levels near ground surface, with a depth to water of less than 15 feet based on spring 2015 groundwater contours. These areas *may* have the potential to be interconnected with surface water.

Interconnected streams can be gaining (groundwater flowing toward the stream) or losing (groundwater flowing away from the stream). Preliminary data from the shallow monitoring well clusters[43] give an indication the direction of shallow groundwater flow adjacent to streams in two locations in the Basin as shown by the black arrows on **Figure 5-18**.

Section §354.16(f) of the regulations require an estimate of the "quantity and timing of depletions of [interconnected surface water] systems, utilizing…best available information." The existence and quantity cannot be determined with any reasonable level of accuracy using empirical data, so the best available information is presented in Chapter 6 – Water Budget. The timing of depletions also cannot be determined with existing data.

5.7 Groundwater-Dependent Ecosystems

SGMA requires GSPs to identify groundwater-dependent ecosystems (GDEs) but does not explicitly state the requirements that warrant a GDE designation. SGMA defines a GDE as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (DWR 2016c). GDEs are considered a beneficial use of groundwater.

The most comprehensive and readily accessible data to identify GDEs is referred to as the NCCAG[44] dataset. Upon inspection of the data,[45] many inaccuracies were noted. The abstract of the dataset documentation reads:

> The Natural Communities dataset is a compilation of 48 publicly available State and federal agency datasets that map vegetation, wetlands, springs, and seeps in California. A working group comprised of DWR, the California Department of Fish and Wildlife (CDFW), and The Nature Conservancy (TNC) reviewed the compiled dataset and conducted a screening process to exclude vegetation and wetland types less likely to be associated with

[42] Named streams from the National Hydrography Dataset [NHD] (USGS 2020a)

[43] The clusters are sets of three wells drilled in close proximity to each other for the purpose of determining shallow groundwater flow direction and gradient. At the time of writing this draft chapter, 2 clusters have enough data to determine flow direction; one cluster near Adin and one cluster near Lookout. **Appendix 5C** contains data collected at the two clusters and their flow directions.

[44] Natural communities commonly associated with groundwater

[45] By local landowners and local experts familiar with the Basin and its ecological communities.

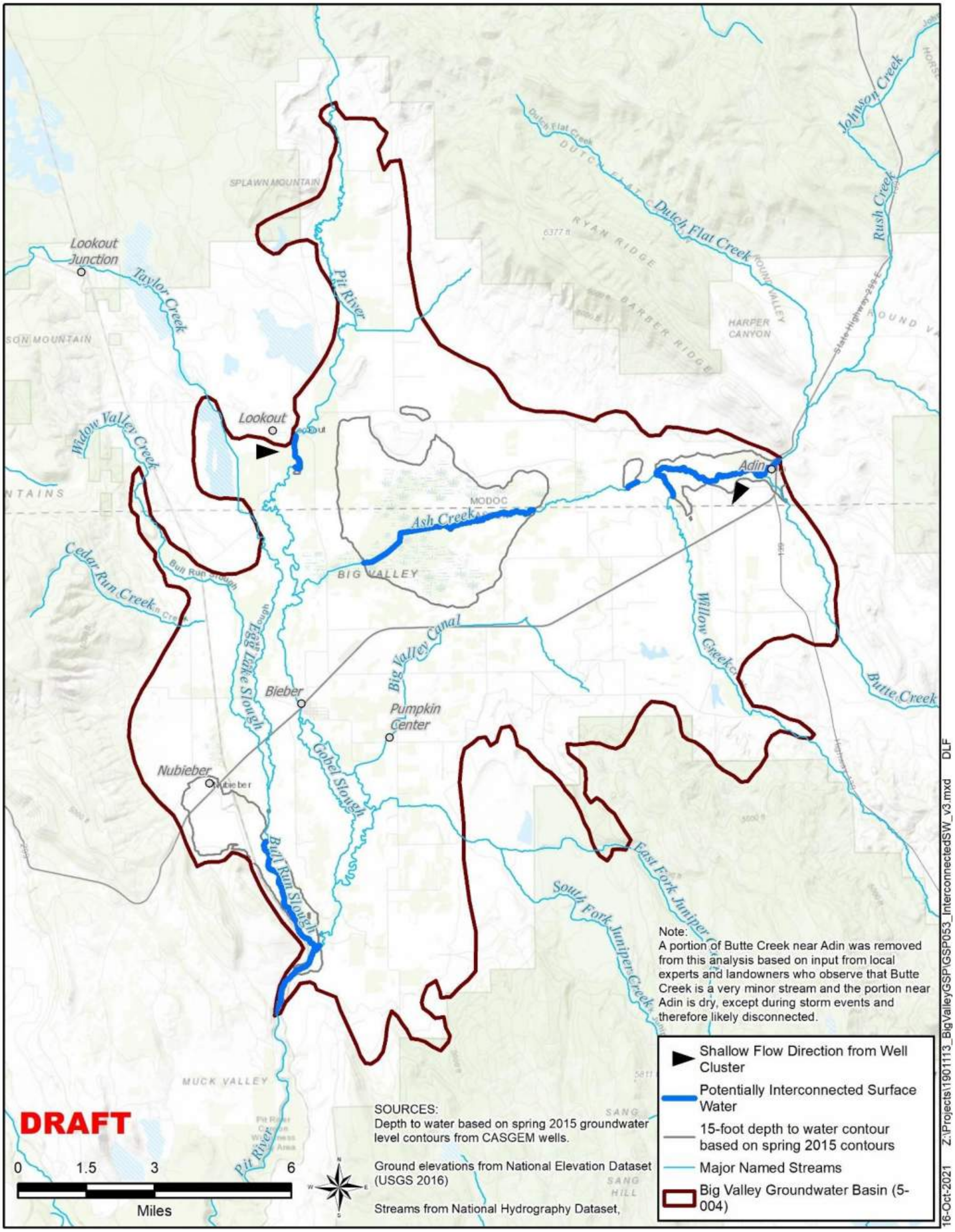


Figure 5-18 Potentially Interconnected Surface Water

> groundwater and retain types commonly associated with groundwater, based on criteria described in Klausmeyer et al. (2018).
>
> Two habitat classes are included in the Natural Communities dataset: (1) wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions; and (2) vegetation types commonly associated with the sub-surface presence of groundwater (phreatophytes).
>
> The data included in the Natural Communities dataset do not represent DWRs determination of a GDE. However, the Natural Communities dataset can be used by GSAs as a starting point when approaching the task of identifying GDEs within a groundwater basin. (DWR 2018a)

The NCCAG geospatial data (DWR 2018a) is separated into two categories: wetlands and vegetation, respectively.

The Wetlands area is subdivided into two primary habitats present in Big Valley: palustrine[46] and riverine.[47] Palustrine is the dominant habitat at 96 percent of the total wetland area, while riverine is present at four percent and occurs along river courses. Sixteen springs account for a very small area. Most of the springs are in Lassen County (13), although numerous springs are located outside the BVGB boundary.

The Vegetation area is subdivided into two primary habitats, based on the plant species. Wet Meadows was the largest primary habitat at 59 percent of the vegetation area, but there was no dominant species. Willow was the second largest habitat at 41 percent of the vegetation area.

For the NCCAG areas to be designated as actual GDEs, the groundwater level needs to be close enough to the ground surface that it would support the vegetation. For determining potential GDEs, fall 2015[48] depth to water is used, because mid-summer months are the critical limiting factor for plant communities. Furthermore, if groundwater moisture isn't available later in the summer, then the groundwater dependent communities don't have an advantage over communities that are typically not associated with groundwater, such as sagebrush, juniper, and bunchgrass (Lile 2021).

The depth to water that could potentially be accessed by GDEs depends on the rooting depth of the vegetation. An assessment of native plants in the BVGB found that maximum rooting depths of species present is 10 feet as shown in **Table 5-5**. Access to groundwater by plant roots extends above the water table because the groundwater is drawn upward to fill soil pores, and this zone is known as the capillary fringe. The thickness of the capillary fringe extends upward several feet, depending on the soil type.

[46] Palustrine are freshwater wetlands, such as marshes, swamps and bogs, not associated with flowing water (Cowardin et al. 2013).
[47] Riverine are freshwater wetlands located in or near a flowing stream (Cowardin et al. 2013).
[48] 2015 is used because it is the baseline for SGMA.

Table 5-5 Big Valley Common Plant Species Rooting Depths

Species	Rooting Depth
Carex spp.	Up to 5 feet
Alfalfa	9 feet
Aspen	10 feet and less
Willow	2-10 feet
Elderberry	10 feet and less
Saltgrass	2 feet
Sources: CNPS 2020, TNC 2020, Snell 2020	

As a conservative estimate, a capillary fringe of 10 feet is used. In order for plants to access the water and thrive, not just barely touch, there needs to be significant overlap (of, say 5 feet) between the rooting depth and the capillary fringe (Lile 2021). Furthermore, while roots may extend to a deep level, documentation of maximum depth to water for some of the deep-rooting species in **Table 5-5** to thrive is on the order of 2-3 meters (6-9 feet) (Pezeshki and Shields 2006, Springer et. al. 1999). Therefore, as a conservative estimate for the purposes of delineating GDEs, only those areas in the NCCAG datasets that are in areas with fall 2015 groundwater less than 15 feet are classified as potential GDEs.

Figure 5-19 shows the area with potential GDEs, which is a preliminary assessment and needs to be ground-truthed. Moreover, the data are inaccurate in many places.

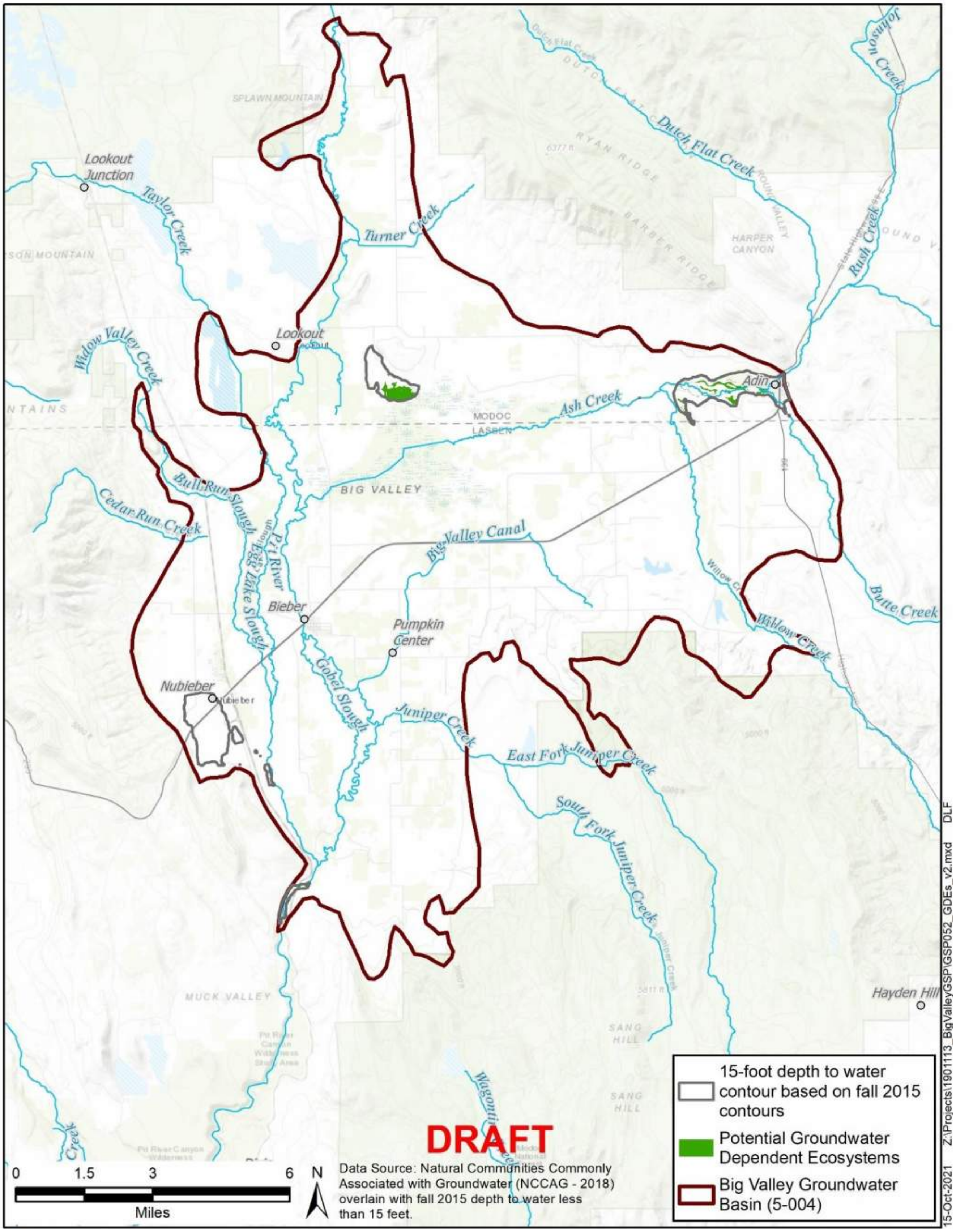


Figure 5-19 Potential Groundwater-Dependent Ecosystems

6. Water Budget § 354.18

The hydrologic cycle describes how water is moved on the earth among the oceans, atmosphere, land, surface-water bodies, and groundwater bodies. **Figure 6-1** is a depiction of the hydrologic cycle.

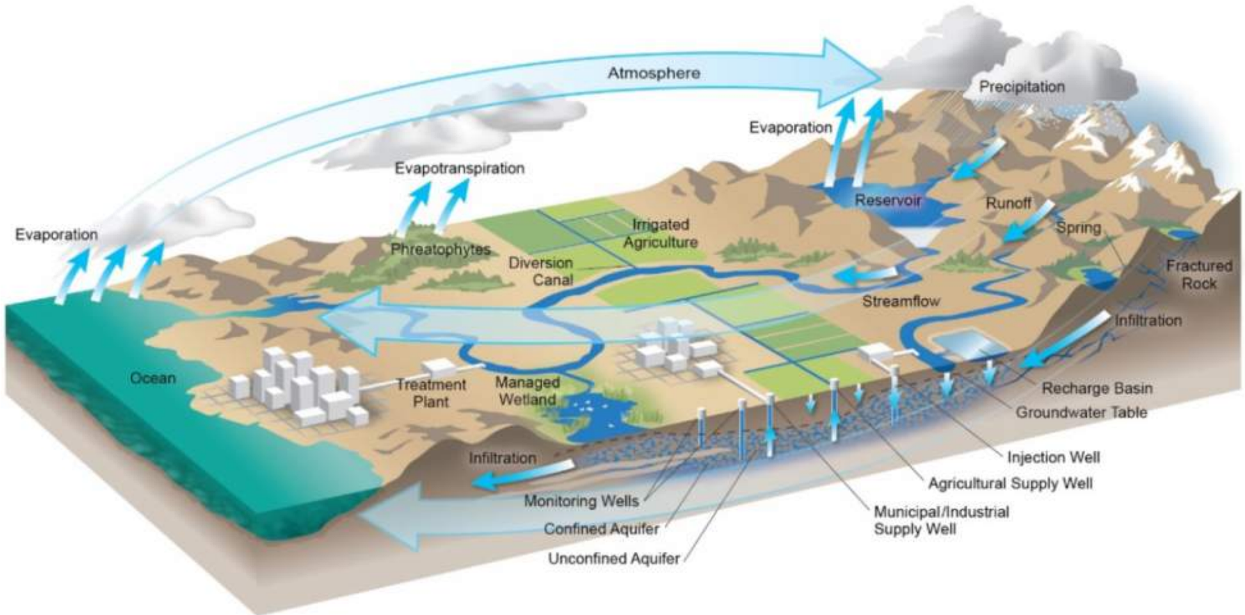


Figure 6-1 Hydrologic Cycle

A water budget accounts for the movement of water among the four major systems in Big Valley: atmospheric, land surface, surface water, and groundwater. The BVGB consists of the latter three systems (land surface, surface water, and groundwater) as shown by the black outline on **Figure 6-2**. This figure shows the exchange between the systems and identifies the specific components of the water budget. The systems and the flow arrows are color coded. Inflows to the BVGB are shown with blue arrows, and outflows from the BVGB are shown with orange arrows. Flows between the systems are shown with green arrows, and flows within a system are shown in purple. The land system, surface-water system, and groundwater system are green, blue, and brown respectively.

Like a checking account, a water budget helps the GSA and stakeholders better understand the deposits and withdrawals and identify what conditions result in positive and negative balances. It should be noted that the development of a water budget is required by the GSP regulations, but the regulations don’t require actions based directly on the water budget. Actions are only required based on outcomes related to the six sustainability indicators: groundwater levels, groundwater storage, water quality, subsidence, seawater intrusion, and surface-water depletions. Therefore, a water budget should be viewed as a tool to develop a common understanding of the Basin and a basis for making decisions to achieve sustainability and avoid undesirable results with the sustainability indicators.

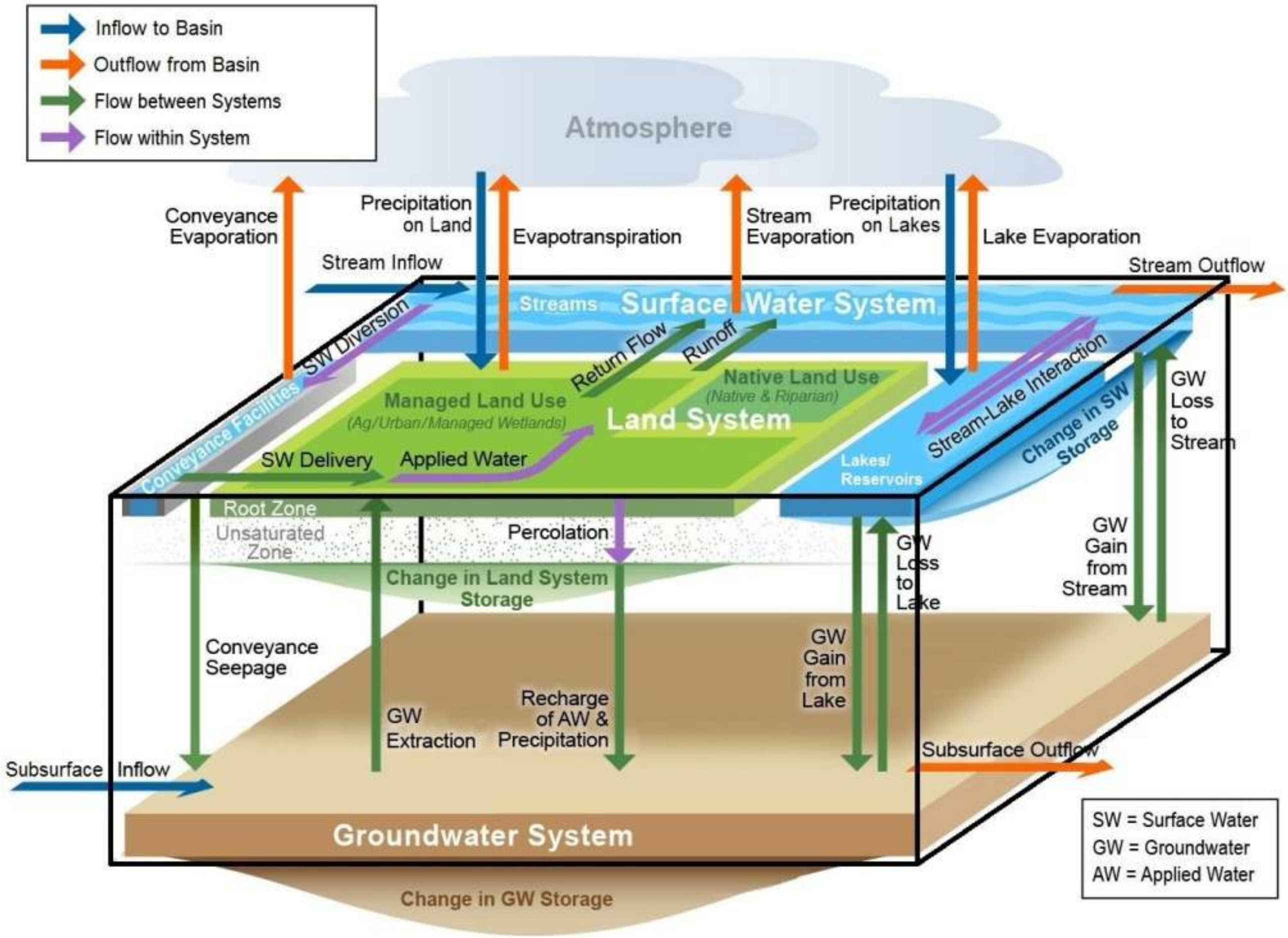


Figure 6-2 Water Budget Components and Systems

6.1 Water Budget Data Sources

Each component shown in **Figure 6-2** was estimated using readily available-data and assembled into a budget spreadsheet. Many groundwater basins in California utilize a numerical groundwater model, such as MODFLOW[49] or IWFM,[50] to calculate the water budget. These models require a specialized hydrogeologist to run them, and the methodology by which the water budget is calculated is not readily apparent to the lay person. For the BVGB, a non-modeling (spreadsheet) approach was used so that future iterations of the water budget could be performed by a wider range of hydrology professionals (potentially reducing future GSP implementation costs) and so that the calculations of the specific components could be understood by a broader range of people.

In concept, each component is quantified precisely and accurately, and the resultant budget is balanced. In practice, most of the components can only be roughly estimated and in many cases not at all. Therefore, much of the work to balance the water budget is adjusting some of the unknown or roughly-

[49] Modular Finite-Difference Groundwater Flow model, developed by USGS.
[50] Integrated Water Flow Model, developed by DWR.

estimated parameters within acceptable ranges until the budget is balanced and all components are deemed reasonable.

As such, the water budget calculations presented herein are not unique, and the precision of the component estimates are within an order of magnitude. Estimation of nearly all components involves assumptions and, with more Basin-specific data, the accuracy and precision of many of the components are improved. Additional and improved data will result in a budget that more closely reflects the Basin conditions and allows the GSAs to make more informed decisions to sustainably maintain groundwater resources. **Appendix 6A** show the components of the water budget, their data source(s), assumptions, and relative level of precision.

Major data sources include the PRISM[51] model (NACSE 2020) for precipitation, CIMIS (DWR 2020c) for evapotranspiration data, the National Water Information System (USGS 2020b) for surface-water flows, and DWR land-use surveys (DWR 2020d).

6.2 Historical Water Budget

The historic water budget presented in this section covers 1984 to 2018. This period was chosen because it represents an average set of climatic conditions. **Figure 6-3** shows the annual precipitation and year type for the period. The criteria for year types were critical dry below 70 percent of average precipitation, dry between 70 and 85 percent of average precipitation, normal between 85 and 115 percent of average precipitation and wet years greater than 115 percent of average precipitation.

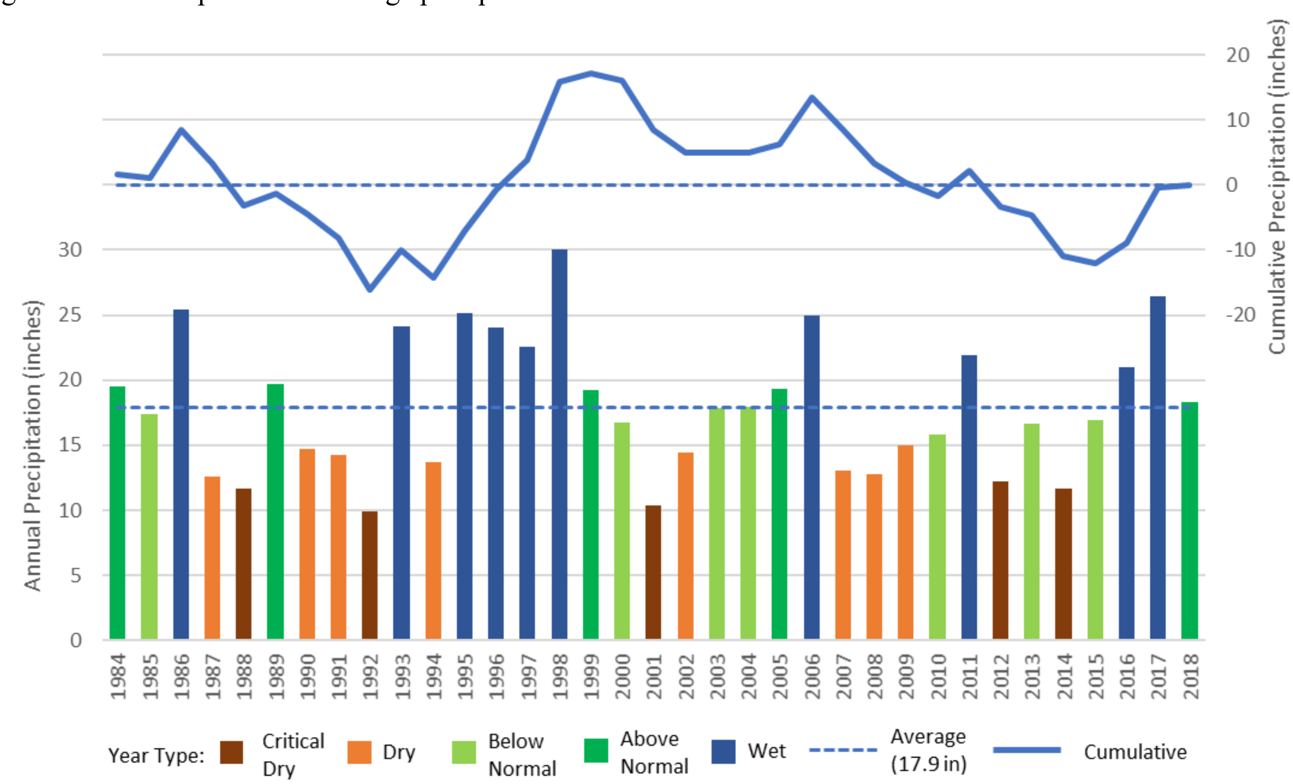


Figure 6-3 Annual and Cumulative Precipitation and Water Year Types 1984 to 2018

---

[51] PRISM stands for Parameter-elevation Regression on Independent Slopes Model and is provided by the Northwest Alliance for Computational Science and Engineering from Oregon State University. This model provides location-specific, historical precipitation values on monthly and annual time scales. Precipitation was evaluated at Bieber.

The budget was developed using this precipitation and other climate data (evapotranspiration) along with stream flow to estimate the inflows (credits) and outflows (debits) to the total BVGB. The budget was balanced by assuming that the land and surface-water systems remain nearly in balance from year to year and allowing the groundwater system to vary. **Figure 6-4** shows the average annual values for the overall water budget. The detailed water budget for each year is included in **Appendix 6B**. **Appendix 6C** shows graphically how the water budget varies over time.

TOTAL BASIN WATER BUDGET				Acre-Feet
item	Flow Type	Origin/ Destination	Component	Estimated
(1)	Inflow	Into Basin	Precipitation on Land System	136,800
(14)	Inflow	Into Basin	Precipitation on Reservoirs	500
(13)	Inflow	Into Basin	Stream Inflow	371,100
(27)	Inflow	Into Basin	Subsurface Inflow	1
(32)	Inflow	*(1)+(14)+(13)+(27)*	*Total Inflow*	*508,400*
(5)	Outflow	Out of Basin	Evapotranspiration	154,000
(24)	Outflow	Out of Basin	Stream Evaporation	400
(23)	Outflow	Out of Basin	Reservoir Evaporation	700
(19)	Outflow	Out of Basin	Conveyance Evaporation	-
(18)	Outflow	Out of Basin	Stream Outflow	358,500
(29)	Outflow	Out of Basin	Subsurface Outflow	-
(33)	Outflow	*(5)+(24)+(23)+(19)+(18)+(29)*	*Total Outflow*	*513,600*
(34)	Storage Change	(32)-(33)	Change in Total System Storage	(5,000)

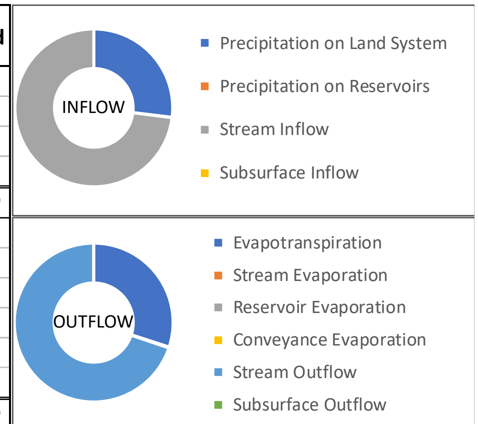


Figure 6-4 Average Total Basin Water Budget 1984-2018 (Historic)[52]

The evapotranspiration value was calculated using land-use data (crop and wetland acreages) from DWR for 2014, and land use was assumed to be constant throughout the water budget period.

Using the evapotranspiration for irrigated lands, the amount of irrigation from surface water and groundwater was determined using 85 percent irrigation efficiency (NRCS 2020) and a respective 35 to 65 percent split between surface water and groundwater. This surface-water – groundwater split was determined from input received from local landowners, an assessment of surface-water rights (areas without surface-water rights were assumed to use 100% groundwater), well drilling records (areas without wells drilled were assumed to use 100% surface water), and an assessment of aerial imagery to see if water source could be determined. For the evapotranspiration associated with the ACWA, the ecosystem largely relies on surface water and very shallow subsurface[53] water. This surface-water delivery[54] was enhanced by implementation of a "pond and plug" project in 2012 to keep the water table higher and broader throughout ACWA. The ACWA also has three wells that extract groundwater from the deeper aquifers which is applied in portions of the habitat during dry months (fall). These areas with groundwater use are indicated by the light blue areas within ACWA. Based on the limited area and time groundwater is used to support the habitat, 98 percent of the evapotranspiration for ACWA is estimated to come from surface water and two percent from groundwater. **Figure 3-6** shows the lands with applied water and their water source based on this assessment.

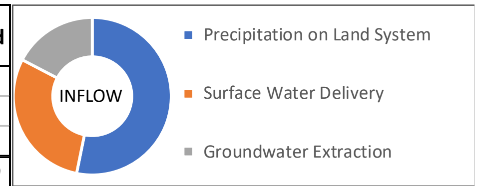
[52] To re-emphasize, these are rough estimates and better and more accurate data are needed.
[53] Within about the top 10 feet that plant roots can access.
[54] For the purposes of the water budget, water from Ash Creek is considered "delivered" to the wetland areas.

Stakeholders have noted that despite the efforts to improve estimates of water source and some input from local residents, **Figure 3-6** still contains significant inaccuracies and further refinement of this dataset is needed.

The average annual water budgets for the three systems (land, surface water, and groundwater) are shown on **Figure 6-5**, **Figure 6-6,** and **Figure 6-7**. The detailed water budget for each year is included in **Appendix 6B**. **Appendix 6C** shows graphically how the system water budgets vary over time.

LAND SYSTEM — Acre-Feet

item	Flow Type	Origin/ Destination	Component	Estimated
(1)	Inflow	Into Basin	Precipitation on Land System	136,800
(2)	Inflow	Between Systems	Surface Water Delivery	75,800
(3)	Inflow	Between Systems	Groundwater Extraction	44,600
(4)	Inflow	*(1)+(2)+(3)*	*Total Inflow*	*257,000*
(5)	Outflow	Out of Basin	Evapotranspiration	154,000
(6)	Outflow	Between Systems	Runoff	83,400
(7)	Outflow	Between Systems	Return Flow	5,000
(8)	Outflow	Between Systems	Recharge of Applied Water	13,100
(9)	Outflow	Between Systems	Recharge of Precipitation	1,600
(10)	Outflow	Between Systems	Managed Aquifer Recharge	-
(11)	Outflow	*(5)+(6)+(7)+(8)+(9)+(10)*	*Total Outflow*	*257,000*
(12)	Storage Change	(4)-(11)	Change in Land System Storage	-



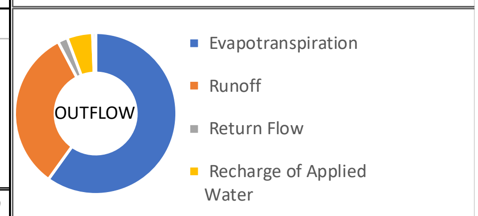
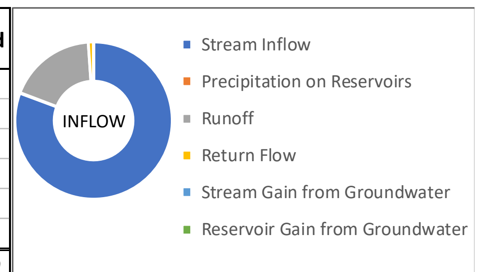


Figure 6-5 Average Land System Water Budget 1984-2018 (Historic)

SURFACE WATER SYSTEM — Acre-Feet

item	Flow Type	Origin/ Destination	Component	Estimated
(13)	Inflow	Into Basin	Stream Inflow	371,100
(14)	Inflow	Into Basin	Precipitation on Reservoirs	500
(6)	Inflow	Between Systems	Runoff	83,400
(7)	Inflow	Between Systems	Return Flow	5,000
(15)	Inflow	Between Systems	Stream Gain from Groundwater	-
(16)	Inflow	Between Systems	Reservoir Gain from Groundwater	-
(17)	Inflow	*(13)+(14)+(6)+(7)+(15)+(16)*	*Total Inflow*	*460,000*
(18)	Outflow	Out of Basin	Stream Outflow	358,500
(19)	Outflow	Out of Basin	Conveyance Evaporation	50
(20)	Outflow	Between Systems	Conveyance Seepage	30
(2)	Outflow	Between Systems	Surface Water Delivery	75,800
(21)	Outflow	Between Systems	Stream Loss to Groundwater	24,000
(22)	Outflow	Between Systems	Reservoir Loss to Groundwater	600
(23)	Outflow	Out of Basin	Reservoir Evaporation	700
(24)	Outflow	Out of Basin	Stream Evaporation	400
(25)	Outflow	*(18)+(19)+(20)+(2)+(21)+(22)+(23)+(24)*	*Total Outflow*	*460,000*
(26)	Storage Change	(17)-(25)	Change in Surface Water Storage	-



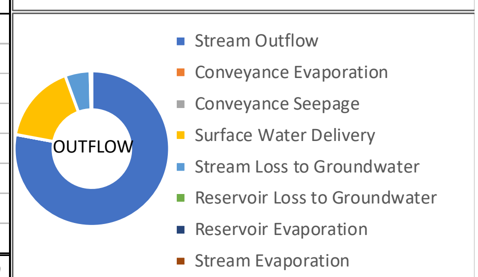
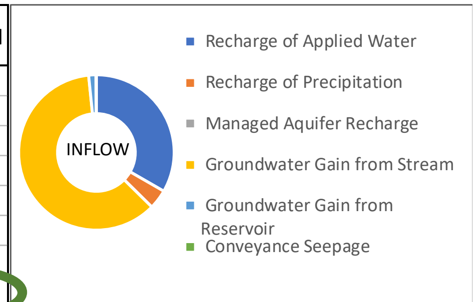


Figure 6-6 Average Surface-Water System Water Budget 1984-2018 (Historic)

GROUNDWATER SYSTEM				Acre-Feet
item	Flow Type	Origin/ Destination	Component	Estimated
(8)	Inflow	Between Systems	Recharge of Applied Water	13,100
(9)	Inflow	Between Systems	Recharge of Precipitation	1,600
(10)	Inflow	Between Systems	Managed Aquifer Recharge	-
(21)	Inflow	Between Systems	Groundwater Gain from Stream	24,000
(22)	Inflow	Between Systems	Groundwater Gain from Reservoir	600
(20)	Inflow	Between Systems	Conveyance Seepage	30
(27)	Inflow	Into Basin	Subsurface Inflow	1
(28)	Inflow	*(8)+(9)+(10)+(21)+(22)+(20)+(27)*	*Total Inflow*	*39,300*
(3)	Outflow	Between Systems	Groundwater Extraction	44,600
(15)	Outflow	Between Systems	Groundwater Loss to Stream	-
(16)	Outflow	Between Systems	Groundwater Loss to Reservoir	-
(29)	Outflow	Out of Basin	Subsurface Outflow	-
(30)	Outflow	*(3)+(15)+(16)+(29)*	*Total Outflow*	*44,600*
(31)	Storage Change	**(28)-(30)**	Change in Groundwater Storage	(5,000)



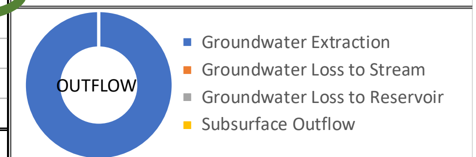


Figure 6-7 Average Groundwater System Water Budget 1984 to 2018 (Historic)

With the land system and surface-water system assumed to be in balance, the groundwater system varies and reflects the change in water stored in the Basin. This change in storage is shown in **Figure 6-8** and is analogous to the change in storage presented in Chapter 5 – Groundwater Conditions, which used groundwater contours to calculate the change. These two approaches show similar trends, but the magnitude of the changes differs slightly, with the groundwater contours showing a maximum cumulative overdraft (2015) of about 116,000 AF and the water budget indicating about 183,000 AF. This difference may indicate that the water budget overdraft may be slightly overestimated or that the average specific yield of the Basin is higher.

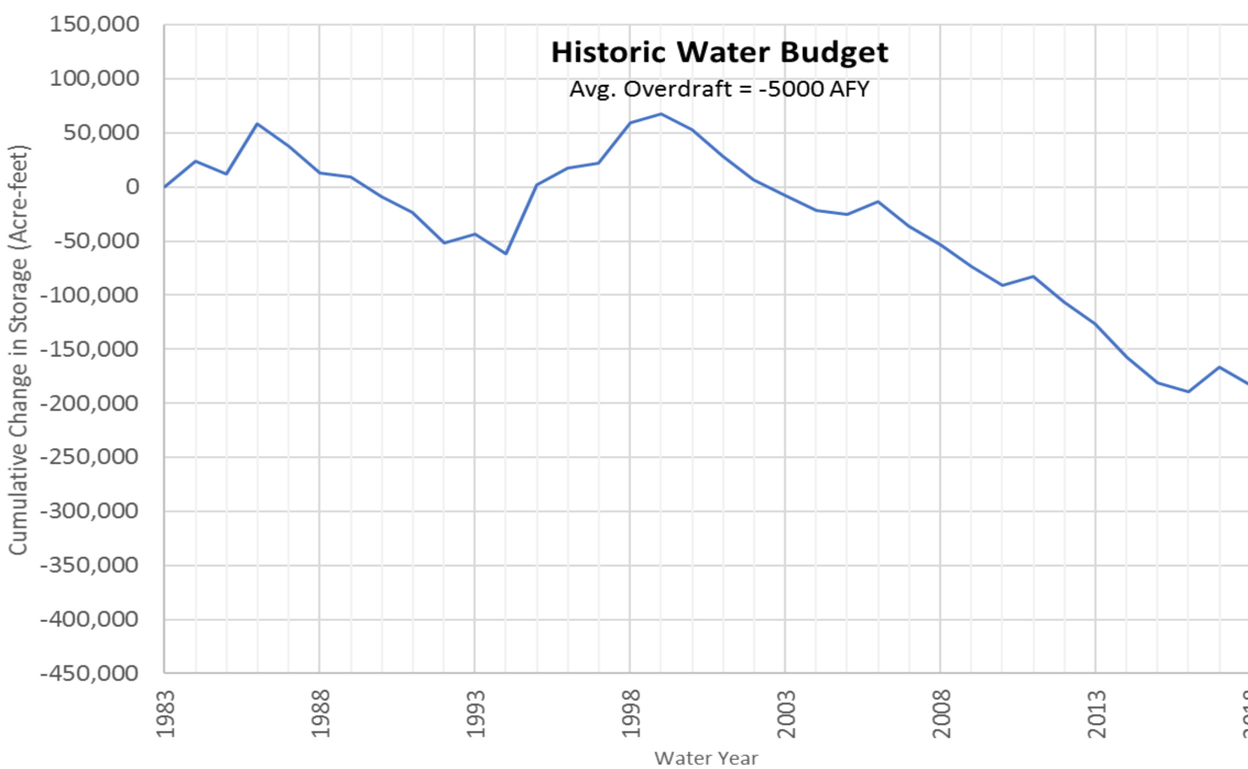


Figure 6-8 Cumulative Groundwater Change in Storage 1984 to 2018 (Historic)

The GSP regulations require an estimate of the sustainable yield[55] for the Basin (§354.18(b)(7)). This requirement is interpreted as the average annual inflow to the groundwater system, which for the 34-year period of the historic water budget is approximately 39,300 AF, as indicated on item 28 of **Figure 6-7** (circled in green) for the groundwater system. The estimate of annual average groundwater use is approximately 44,600 AFY.

The regulations also require a quantification of overdraft[56] (§354.18(b)(5)). For the water budget period of 1984 to 2018, overdraft is estimated at approximately 5,000 AFY, shown as the average annual groundwater system change in storage, circled in red on **Figure 6-7** (item 31).

6.3 Current Water Budget

The current water budget is demonstrated by estimating future water budget holding current conditions, land use and water use. The projection described in section 6.4.1 below holds these values constant and therefore represents both the current and projected.

6.4 Projected Water Budget

As required by the GSP Regulations, the projected water budget is developed using at least 50 years of historic climate data (precipitation, evapotranspiration, and streamflow) along with estimates of future land and water use. The climate data from 1962 to 2011 was used as an estimate of future climate baseline conditions.

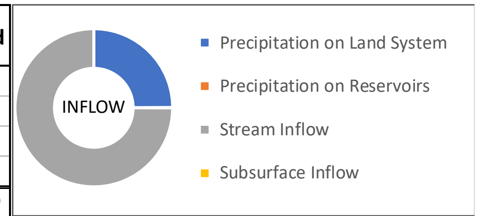
6.4.1 Projection Baseline

The baseline projected water budget uses the most recent estimates of population and land use and keeps them constant. **Figure 6-9** shows the average annual future water budget. Long-term overdraft is projected to be about 2,000 AFY, which is less than the overdraft for the historic water budget because it uses a longer, wetter time-period for its projections. **Figure 6-10** shows the projected cumulative change in groundwater storage.

[55] The state defines sustainable yield as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result." (CWC §10721(w))

[56] DWR defines overdraft as "the condition of a groundwater basin or Subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions." (DWR 2016b)

item	Flow Type	Origin/ Destination	Component	Estimated
	TOTAL BASIN WATER BUDGET			**Acre-Feet**
(1)	Inflow	Into Basin	Precipitation on Land System	143,200
(14)	Inflow	Into Basin	Precipitation on Reservoirs	500
(13)	Inflow	Into Basin	Stream Inflow	430,200
(27)	Inflow	Into Basin	Subsurface Inflow	1
(32)	Inflow	*(1)+(14)+(13)+(27)*	*Total Inflow*	*574,000*
(5)	Outflow	Out of Basin	Evapotranspiration	156,900
(24)	Outflow	Out of Basin	Stream Evaporation	400
(23)	Outflow	Out of Basin	Reservoir Evaporation	700
(19)	Outflow	Out of Basin	Conveyance Evaporation	50
(18)	Outflow	Out of Basin	Stream Outflow	418,000
(29)	Outflow	Out of Basin	Subsurface Outflow	-
(33)	Outflow	*(5)+(24)+(23)+(19)+(18)+(29)*	*Total Outflow*	*576,000*
(34)	Storage Change	(32)-(33)	Change in Total System Storage	(2,000)



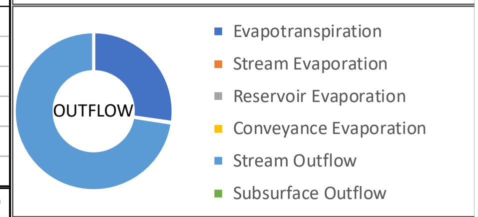


Figure 6-9 Average Projected Total Basin Water Budget 2019-2068 (Future Baseline)

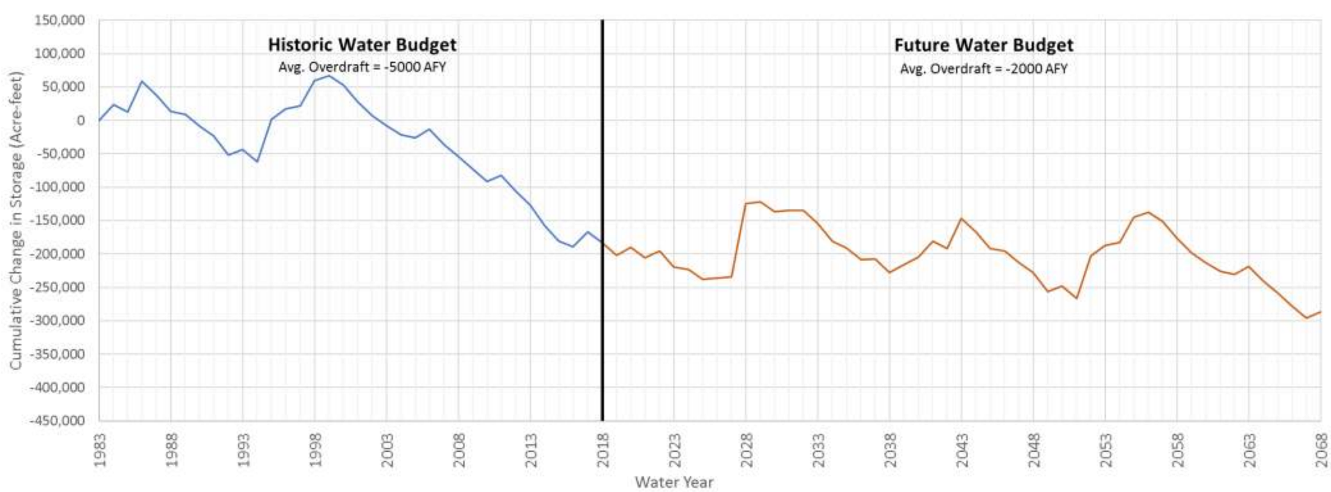
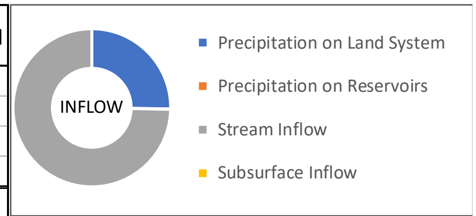


Figure 6-10 Cumulative Groundwater Change in Storage 1984 to 2068 (Future Baseline)

6.4.2 Projection with Climate Change

The SGMA regulations require an analysis of future conditions based on a potential change in climate. DWR provides location-specific change factors for precipitation, evapotranspiration, and streamflow based on climate change models. While there is variability in the climate change models, if the models are correct, they indicate that the future climate in Big Valley will be wetter and warmer, resulting in more precipitation and more of that precipitation falling in the form of rain rather than snow. The change factors were applied to the baseline water budget and are shown in **Figure 6-11** and **Figure 6-12**. Land use was assumed to be constant, with conditions the same as DWR's 2014 land-use survey. Future conditions with climate change projections indicate that the Basin may be nearly in balance, with overdraft of only about 1000 AFY.

item	Flow Type	Origin/ Destination	Component	Estimated
	TOTAL BASIN WATER BUDGET			**Acre-Feet**
(1)	Inflow	Into Basin	Precipitation on Land System	152,200
(14)	Inflow	Into Basin	Precipitation on Reservoirs	600
(13)	Inflow	Into Basin	Stream Inflow	450,400
(27)	Inflow	Into Basin	Subsurface Inflow	-
(32)	Inflow	*(1)+(14)+(13)+(27)*	*Total Inflow*	*603,000*
(5)	Outflow	Out of Basin	Evapotranspiration	165,800
(24)	Outflow	Out of Basin	Stream Evaporation	400
(23)	Outflow	Out of Basin	Reservoir Evaporation	800
(19)	Outflow	Out of Basin	Conveyance Evaporation	-
(18)	Outflow	Out of Basin	Stream Outflow	436,700
(29)	Outflow	Out of Basin	Subsurface Outflow	-
(33)	Outflow	*(5)+(24)+(23)+(19)+(18)+(29)*	*Total Outflow*	*604,000*
(34)	Storage Change	(32)-(33)	Change in Total System Storage	(1,000)



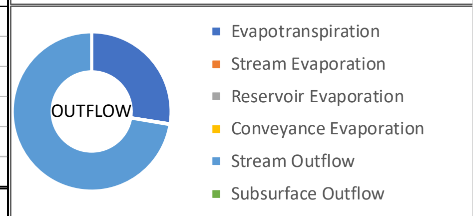


Figure 6-11 Average Projected Total Basin Water Budget 2019-2068 (Future with Climate Change)

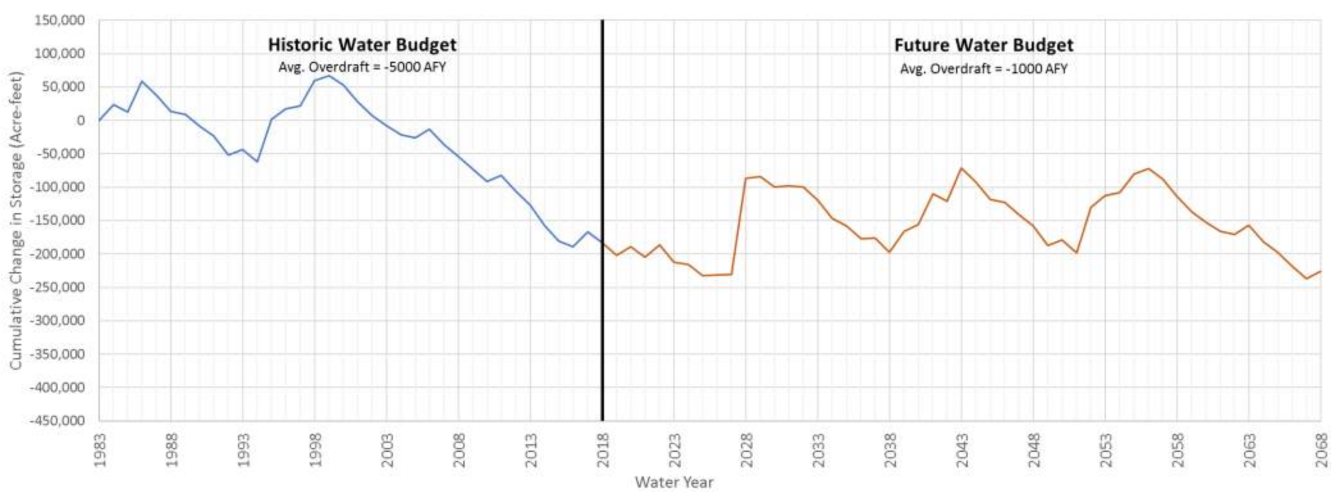


Figure 6-12 Cumulative Groundwater Change in Storage 1984 to 2068 (Future with Climate Change)

7. Sustainable Management Criteria § 354.20

This chapter describes criteria and conditions that constitute sustainable groundwater management for the BVGB, also known as Sustainable Management Criteria (or SMC). Below are descriptions of key terms used in the GSP Regulations and described in this chapter:

- **Sustainability goal:** This is a qualitative, narrative description of the GSP's objective and desired conditions for the BVGB and how these conditions will be achieved. The Regulations require that the goal should, "culminate in the absence of undesirable results within 20 years" (§ 354.22).
- **Undesirable result:** This is a description of the condition(s) that constitute "significant and unreasonable" effects (results) for each of the 6 sustainability indicators:
    - Chronic lowering of *groundwater levels*
    - Reduction in *groundwater storage*
    - *Seawater intrusion* – Not applicable to BVGB
    - Degraded *water quality*
    - Land *subsidence*
    - Depletion of *interconnected surface water*
- **Minimum threshold (MT):** Numeric values that define when conditions have become undesirable ("significant and unreasonable"). Minimum thresholds are established for representative monitoring sites. Undesirable results are defined by minimum threshold exceedance(s) and define when the Basin conditions are unsustainable (i.e., out of compliance with SGMA).
- **Measurable objective (MO):** Numeric values that reflect the desired groundwater conditions at a particular monitoring site. MOs must be set for the same monitoring sites as the MTs and are not subject to enforcement.
- **Interim milestones (IMs):** Numeric values for every 5 years between the GSP adoption and sustainability (20 years, 2042) that indicate how the Basin will reach the MO (if levels are below the MO). IMs are optional criteria and not subject to enforcement.

Figure 7-1 shows the relationship of the MT, MO, and IMs. In addition to these regulatory requirements, some GSAs in other basins have developed "action levels," applicable when levels are above the MT but below the MO, for each well to indicate where and when to focus projects and management actions. This GSP also has action levels that are described in this chapter.

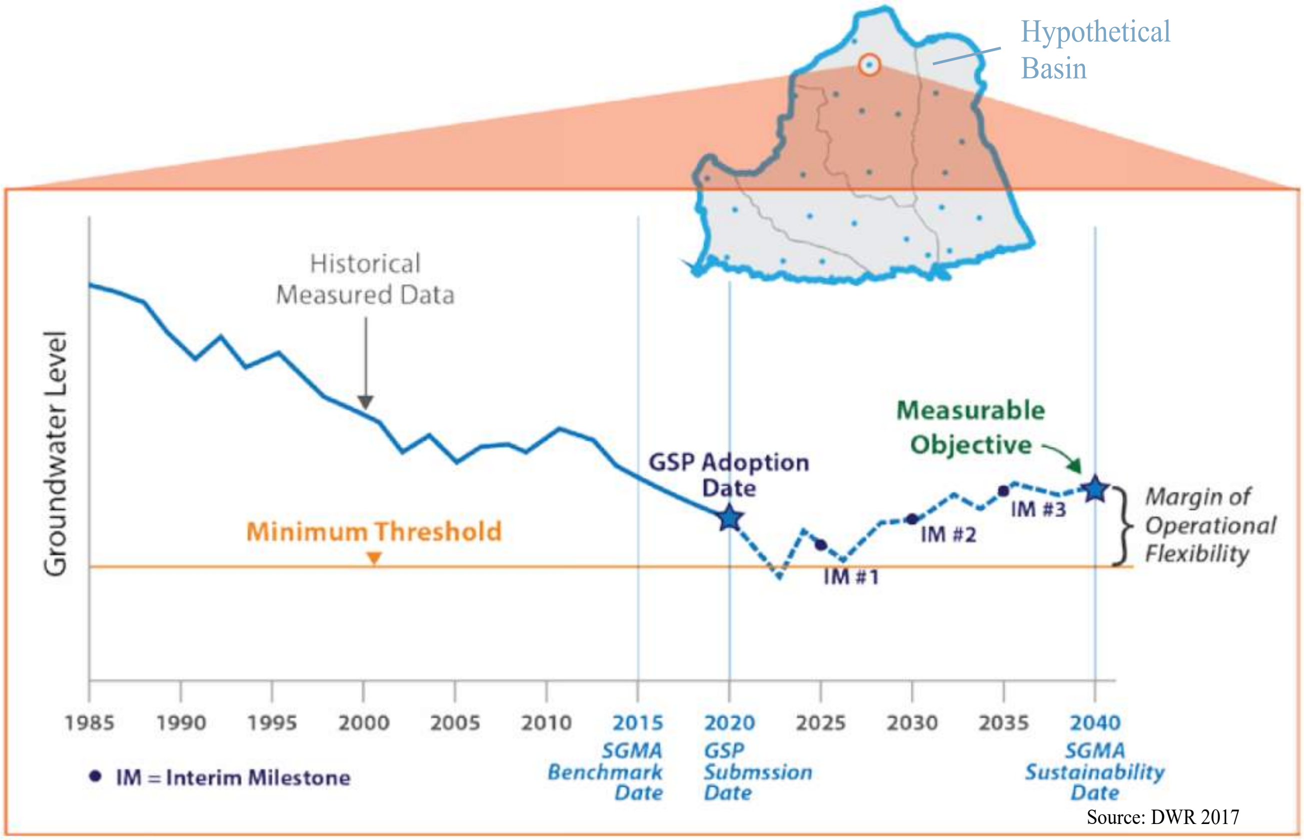


Figure 7-1 Relationship among the MTs, MOs, and IMs for a hypothetical basin

7.1 Process for Establishing SMCs

The SMCs detailed in this chapter were developed by the GSAs through consultation with the BVAC. The sustainability goal was developed by an ad hoc committee and presented to the larger BVAC, GSA staff, and the public for review and comment. The BVAC also formed ad hoc committees for each sustainability indicator and evaluated the data and information presented in Chapters 1-6. In consultation with GSA staff, each committee determined whether significant and unreasonable effects for each sustainability indicator have occurred historically and the likelihood of significant and unreasonable effects occurring in the future. The sections below reflect the guidance given to the GSAs and consultants by the ad hoc committees.

7.2 Sustainability Goal

The sustainability goal was presented in Chapter 1 and is reiterated here:

> The sustainability goal for the Big Valley Groundwater Basin is to maintain a locally governed, economically feasible, sustainable groundwater basin and surrounding watershed for existing and future legal beneficial uses with a concentration on agriculture. Sustainable management will be conducted in context with the unique culture of the basin, character of the community, quality of life of the Big Valley residents, and the vested right of agricultural pursuits through the continued use of groundwater and surface water.

7.3 Undesirable Results

Undesirable results must be described for each Sustainability Indicator. To comply with §354.26 of the Regulations, the narrative for each applicable indicator includes:

- *Description* of the "significant and unreasonable" conditions that are undesirable
- Potential *causes* of the undesirable results
- *Criteria* used to define when and where the effects are undesirable
- Potential *effects* on the beneficial uses and users of groundwater, on land uses, and on property interests

Sustainability indicators that have not experienced undesirable results and are unlikely to do so in the future describe the justification for non-applicability of that Sustainability Indicator.

7.3.1 Groundwater Levels

For this section, it is necessary to understand that it is natural (and expected) that groundwater levels will rise and fall during a particular year and over the course of many years. Chapters 4 through 6 describe the nature of groundwater levels throughout the Basin and how levels have changed over time. These chapters conclude that many areas of the Basin have seen no significant change. Other areas saw a lowering of levels in the late 1980s and early 1990s, recovery during the wet period of the late 1990s and lowering water levels since 2000. Groundwater usage has only seen minor increases since 2000, therefore the declines are more related to climatic conditions than to a lack of stewardship of the resource. As illustrated in **Figure 5-4**, water levels in 12 wells have shown stable (less than one foot of change) or rising water levels. Nine wells have shown declining trends, with only three of those wells declining by more than two feet per year.

This context is given both to set the stage for discussion of undesirable results and to illustrate that water levels overall have not declined significantly. This re-emphasizes the point raised in Section 1.3 that the GSAs believe the Basin should be ranked as low priority. As mentioned previously, the GSAs also believe its ranking of medium priority is due in large part to the DWR's scoring of all basins with water level declines with a fixed number of points rather than considering the severity of declines. Big Valley has seen only minor declines in comparison to the widespread decline of hundreds of feet experienced elsewhere in the state. The Basin has demonstrated that it can recover during wet climatic cycles (e.g., late 1990s) as shown in **Figure 5-7**. There have not been widespread reports of issues or concerns regarding groundwater levels from the residents of the Basin (whether agricultural producers or domestic users or others). The GSAs contend that Big Valley's medium priority ranking is based on unscientific concerns raised by DWR based on isolated wells that experienced limited decline during a below-average climatic cycle.

Therefore, undesirable results have not occurred in the past and the measurable objective established in this section is set at the fall 2015 groundwater level for each well in the monitoring network (*see* Chapter 8 – Monitoring Networks). Fall 2015 is the most recent measurement prior to the adoption of this GSP and is generally the lowest groundwater level throughout the period of record. Since these levels are economically feasible for agricultural uses, this level is a reasonable proxy for the desired conditions.

Description

This section describes undesirable results for groundwater levels by defining significant and unreasonable impacts on beneficial uses. As described in Section 1.1 and emphasized in the Sustainability Goal, agricultural production is of paramount importance due to its economic, cultural, and environmental benefits. For agricultural pursuits to be viable, growers need a large margin of operational flexibility (*refer to* **Figure 7-1**) so that crops can be irrigated even during dry years. Accordingly, and consistent with the goal, 140 feet below the 2015 groundwater level was established as the minimum threshold.

Consistent with the Sustainability Goal, significant and unreasonable lowering of groundwater levels is defined as the level where the energy cost to lift groundwater exceeds the economic value of the water for agriculture.[57] Through discussions in BVAC ad hoc committee meetings among committee members, a local well driller (Conner 2021) and the Lassen County Farm Advisor (Lile 2021), the MT was determined to be the depth at which groundwater pumping becomes economically unfeasible for agricultural use.

The increase in horsepower required to pump from a well approaching the MT would result in an increased cost of $15 per acre foot of water using Surprise Valley Electric (SVE) rates and $30 per acre foot using Pacific Gas and Electric (PG&E) rates (Conner 2021). Calculated on a per-ton basis, the increased cost of water level decline to the MT translates to about $6.50 per ton using SVE power and $13 per ton with PG&E (*see* **Appendix 7A**).

Total operating costs for a typical grass hay farm in the intermountain area are estimated to be $119 per ton. Total cash costs, not counting land and depreciation are estimated at $138 per ton of hay produced (Orloff et al 2016). Considering hay prices have been in the $200 per ton range (U.S. Department of Agriculture [USDA], Agricultural Marketing Service), the potential increase in required pumping power reduces return over cost by 10 to 20 percent.

To produce grain hay, pumping costs are less because less water is required. Because the relative value of grain hay, approximately $120 per ton, is also much less, the overall impact to economic returns is equal if not greater. Thus, the agricultural production economic threshold for well levels is determined to be the MT.

Figure 7-2 shows an assessment of the depths of wells throughout the Basin based on DWR well logs.[58] While this dataset has inaccuracies, it gives a sense of the impact of lowering water levels on the different well types and indicates that lowering of water levels throughout the Basin to the MT could result in a significant percentage of wells going dry. Many of the shallower wells are likely the oldest wells in the Basin and may be unused or abandoned.

Figure 7-3 shows that domestic well density is not evenly distributed throughout the Basin and that representative wells are located near the areas of highest domestic well density.

It is also acknowledged that utilizing the margin of operational flexibility by agriculture could have impacts on users of surface water if it is determined to be interconnected. This potentially includes

[57] The Lassen County General Plan identifies this.
[58] This is an inaccurate dataset, but the best well data available to the GSAs.

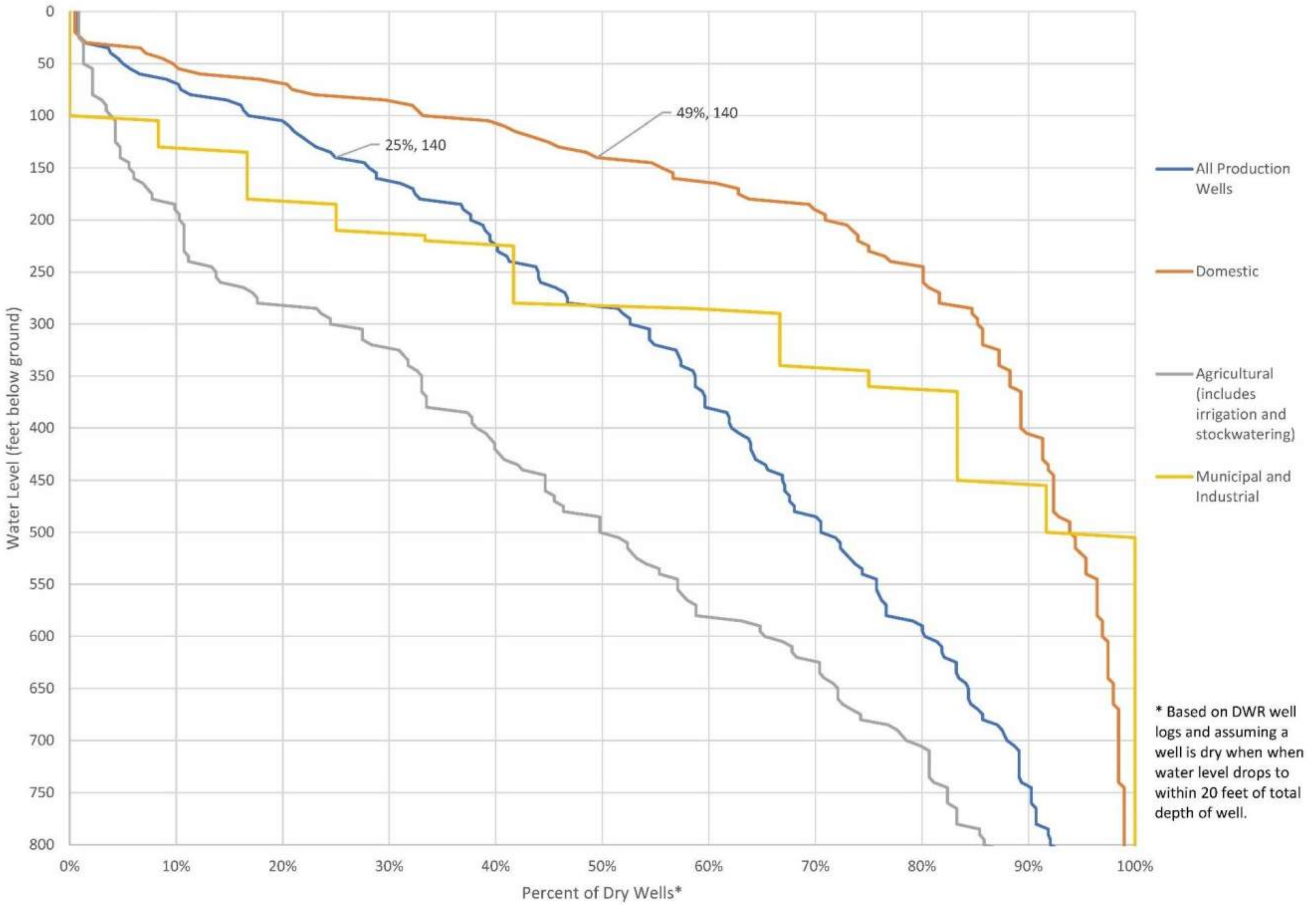


Figure 7-2 Analysis of Wells That Could Potentially Go Dry at Different Depths

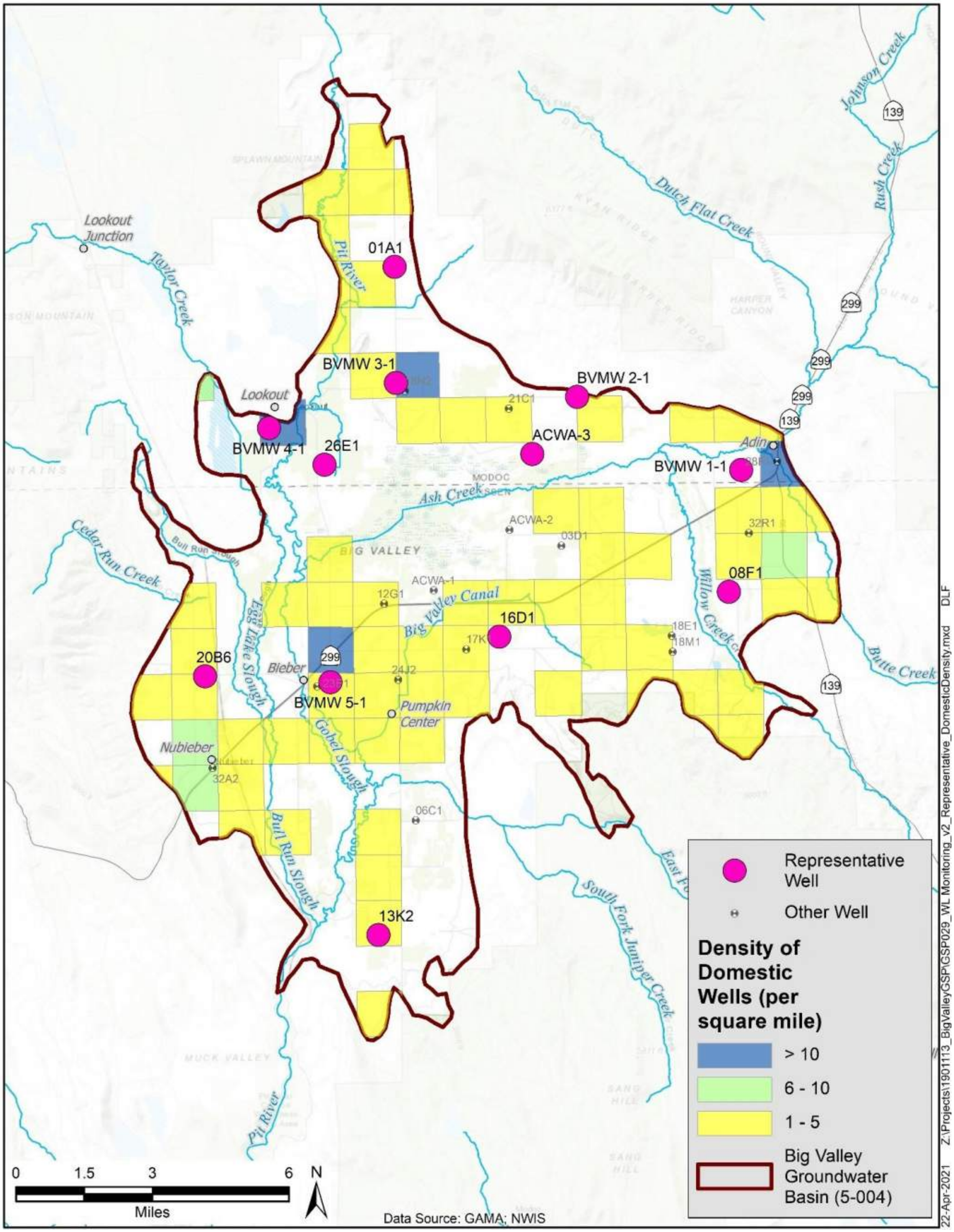


Figure 7-3 Domestic Well Density and Representative Groundwater Level Wells

groundwater-dependent ecosystems and surface-water rights holders. Discussion of this effect is discussed in Section 7.3.6 – Interconnected Surface Water, below.

Causes

Long-term sustainability of groundwater is achieved when pumping and recharge are measured and balanced over multiple wet and dry cycles. When the groundwater pumping exceeds recharge, groundwater levels may decline. Similarly, when recharge exceeds pumping, groundwater levels may rise. Lower-than-average precipitation and snowpack over the last 20 years has resulted in declining groundwater levels in some parts of the Basin. A similar period of declining water levels occurred in the late 1980s through the middle of the 1990s. In the late 1990s, several years in a row of above-average precipitation caused groundwater levels to fully recover. Future wet periods, enhanced recharge, increased storage, and addressing data gaps will likely cause groundwater levels to experience a similar recovery and maintain balance within the Basin.

Criteria

The undesirable result criterion for the groundwater level sustainability indicator occurs when the groundwater level in one-third of the representative monitoring wells drop below their minimum threshold for 5 consecutive years.

In addition to the above definition of undesirable result, it is recognized that although groundwater levels naturally fluctuate, some actions may be justified even before levels fall below the minimum threshold at a particular representative well. Thus, the GSAs are defining an "action level" to identify areas within the Basin where management actions and projects are needed (*see* Chapter 9 – Projects and Management Actions). The definition of the term "Action Level" is also at the discretion of the GSAs. "Action Levels" and the associated protocol are defined as follows:

"Action Level": When monitoring within the established monitoring network identifies the following groundwater level trends, targeted projects or management actions may be considered, at the discretion of the GSAs, when any of the following occur:

- 1/3 of the representative monitoring wells in the Basin decline below the measurable objective (i.e., the fall 2015 baseline levels) for five consecutive years
- Water levels at a 1/3 of the representative wells decline three times the average historic decline that well experienced between 2000 and 2018 as shown in **Appendix 5A**
- Water levels at 1/3 of the representative wells decline more than five feet in one year

Effects

As discussed above, if groundwater levels were to fall below the minimum threshold, pumping costs would render agricultural pursuits in the affected areas unviable. Without agriculture, the unique culture, character of the community, and quality of life for Big Valley residents would be drastically changed. Reductions in agriculture would also affect wildlife who use irrigated lands as habitat, breeding grounds, and feeding grounds.

Low water levels could cause wells to go dry, requiring deepening, redrilling, or developing a new water source. However, the long-term costs of agriculture becoming unviable causing reduced property values and tax revenue outweigh the short-term costs of investing in deeper wells or alternative water supplies. The potential effect would be offset by a shallow well mitigation program, which would apply to wells that have gone dry because water levels have fallen below the measurable objective. Substandard (e.g., hand-dug) wells would not qualify for mitigation. Mitigation would rely on a “good neighbor” practice already demonstrated in the Basin and would leverage any state or federal funding that may be secured. For example, the USDA Rural Development has offered low-interest loans to drill new or replace existing wells. Additionally, prior to the first five-year update, a program will be developed (*see* Chapter 9 – Projects and Management Actions) to cover a portion of the cost if new residential wells must be drilled because groundwater levels drop below the measurable objective. Any such program would apply to legally-established wells and would be dependent on state and federal funding. Criteria will likely include well depth, screen interval, age of the well, and other factors.

7.3.2 Groundwater Storage

The discussion and analysis regarding groundwater levels is directly related to groundwater storage. The groundwater levels for the fall 2015 measurement for each of the wells in the monitoring network (*see* Chapter 8 – Monitoring Network) is established as the measurable objective for groundwater storage (identical to the groundwater level measurable objective). The measurable objective is established at this level for storage using the same reasons discussed in Section 7.3.1 – Groundwater Levels. In summary, through public outreach, coordination with the BVAC and analysis of available data, the GSAs have determined that groundwater storage has not reached significant and unreasonable levels historically. Like the groundwater levels minimum threshold, the minimum threshold for groundwater storage is the same as for groundwater levels. The minimum threshold is set at this level for the same reasons discussed in Section 7.3.1 – Groundwater Levels.

Chapter 5 contains estimates of groundwater storage from 1983 to 2018 using groundwater contours from each year and an assumption that the definable bottom of the groundwater basin is 1,200 feet bgs. During this period, storage has fluctuated between a high of about 5,390,000 AF in fall 1983 (and 1999) to a low of 5,214,000 AF in fall 2015.

Description

Like groundwater levels, significant and unreasonable reduction in groundwater storage is defined as a level at which the energy cost to lift the groundwater exceeds the economic value of the water for agriculture or when a significant number of domestic wells are affected.

Justification of Groundwater Elevations as a Proxy

Again, the use of groundwater elevations as a substitute metric for groundwater storage is appropriate because change in storage is directly correlated to changes in groundwater elevation.

Causes

Long-term sustainability of groundwater is achieved when pumping and recharge are measured and balanced over multiple wet and dry cycles. When the groundwater pumping exceeds recharge, groundwater levels may decline. Similarly, when recharge exceeds pumping, groundwater levels may rise. Lower-than-average precipitation and snowpack over the last 20 years have resulted in declining groundwater levels in some parts of the Basin. A similar period of declining water levels occurred in the late 1980s through the middle of the 1990s. In the late 1990s, several years in a row of above-average precipitation caused groundwater levels to fully recover. Future wet periods, enhanced recharge, increased storage, and addressing data gaps will likely cause groundwater storage to experience a similar recovery and maintain balance within the Basin.

Criteria

As said, the measurable objective and the minimum threshold for groundwater levels and groundwater storage are the same. The monitoring network described in Chapter 8 – Monitoring Networks is also the same for both groundwater levels and storage. As such, the GSAs will use the voluntary and discretionary “Action Level” protocol described in the groundwater level section as a technique to improve management of groundwater when groundwater storage is below the measurable objective but above the minimum threshold.

Effects

Please *refer to* the “Effects” discussion in the groundwater levels section of this chapter, as the content in both sections is the same.

7.3.3 Seawater Intrusion

§354.26(d) of the GSP Regulations states that “An agency that is able to demonstrate that Undesirable Results related to one or more sustainability indicators are not present and are not likely to occur in a basin shall not be required to establish criteria for undesirable results related to those sustainability indicators.”

The BVGB is not located near an ocean and ground surface elevations are over 4000 feet above msl. Seawater intrusion is not present and is not likely to occur. Therefore, SMCs are not required for seawater intrusion as per §354.26(d) cited above.

7.3.4 Water Quality

As described in Chapter 5 – Groundwater Conditions, the groundwater quality conditions in the Basin are oveall excellent (DWR 1963, Reclamation 1979). After a review of the best available data on water quality in the Basin, it was concluded that all the constituents which were elevated above suitable thresholds are naturally occurring. There has been no identifiable increase in the level of concentrations over time, and several constituents have indications of improvement in recent decades compared to concentrations in the 1950s and 1960s (e.g., Arsenic and Manganese **Figures 5-8** and **5-10**).

While the water quality is considered excellent in the Basin, water quality is an important issue to both agricultural and domestic users within the Basin and they are working in coordination to retain the existence of excellent water quality. The multitude of programs which regulate water quality is listed in Section 3.5.

In addition, Big Valley residents are voluntarily participating and coordinating in activities that will ensure continued excellent quality water in the Basin. Over the last 15 years, landowners have drilled stock watering wells as part of the EQIP program to protect water quality in streams. In 2018, the Upper Pit River Watershed IRWMP 2017 Update was completed. This document conducted a thorough analysis of the entire Pit River Watershed and found no water quality issues within the BVGB.

Agricultural users are also proactively managing water quality *via* partnerships with agencies such as the NRCS to implement on-site programs which are designed to improve water quality as detailed in Chapter 9 – Projects and Management Actions. As described in Section 1.1 – Introduction, agricultural users primarily grow low-impact crops with no-till methods and little application of fertilizer or pesticides. Domestic water users are also assisting in maintaining good water quality within the Basin through community action. Through the civic process, Big Valley residents were engaged in the development of the Modoc and Lassen County ordinances to deter unlicensed outdoor marijuana growers and the unpermitted use of pesticides and rodenticides which may make their way into the groundwater and surface water. The domestic water users are also actively seeking to assist in code enforcement and reduce the amount of harmful debris within the Big Valley communities that may cause water quality issues. Public outreach through the offices of Public Health, Environmental Health, and the Regional Recycling Group Recycle Used Oil and Filter Campaign will assist in maintaining excellent water quality. These outreach efforts are further discussed in Chapter 9 – Projects and Management Actions.

Due to the existence of excellent water quality in the Basin, significant amount of existing water quality monitoring, generally low impact land uses, and a robust effort to conduct conservation efforts by agricultural and domestic users, per §354.26(d), SMCs were not established for water quality because Undesirable Results are not present and not likely to occur. At the five-year updates of this GSP, data from various existing programs, including the RWQCB sites, public supply wells (regulated by the Division of Drinking Water), and electrical conductivity transducers installed by the GSAs at three wells (BVMW 1-2, 4-1 and 5-1) will be assessed to determine if degradation trends are occurring in the principal aquifer. In addition, water quality impacts resulting from projects and management actions will be evaluated during their planning and implementation. At the five-year update, SMCs will be considered only if the trends indicate that undesirable results are likely to occur in the subsequent 5 years.

7.3.5 Land Subsidence

As detailed in Section 5.5, little-to-no measurable subsidence is occurring in the Basin. Furthermore, causes of micro-subsidence identified by the InSAR data presented in Section 5.5 are likely due to either agricultural land leveling operations or natural geologic activity. The specific identified areas of subsidence are considered acceptable and necessary agricultural operations to promote efficient irrigation. Similar situations may occur throughout the Basin and will be investigated if identified through InSAR. As detailed in Chapter 5, very minor areas of land subsidence have been observed in the Basin by the Continuous Global Positioning System site near Adin (CGPS P347, -0.6 inch over 11 years) and by the InSAR data provided by DWR (maximum of -3.3 inches over 4 years). The cause of these downward displacements has not been determined conclusively, but due to the widespread nature is likely natural and unavoidable due to the movement of Tectonic plates.

Given the lack of significant subsidence and the fact that some subsidence is acceptable to stakeholders in the absence of impacts on infrastructure (roadways, railroads, conveyance canals, and wells among others), no undesirable results have occurred and none are likely to occur. Therefore, per §354.26(d), SMCs were not established for subsidence. At the five-year updates of this GSP, data from GPS P347 and InSAR data provided by DWR will be assessed for notable subsidence trends that can be correlated with groundwater pumping. SMCs and undesirable results for subsidence will be established at the five-year update only if trends indicate significant and unreasonable subsidence is likely to occur in the subsequent 5 years.

7.3.6 Interconnected Surface Water

The rivers and streams of the Basin are an important and vital resource for all interested parties. The agricultural industry has an extensive history of surface-water use in the Basin and has operated for over a century. Many of the surface-water rights on farms and ranches are pre-1914 water rights. All surface water flowing in the Basin during irrigation season is fully allocated. For all interested parties, there is need for better tracking of surface-water allocations.

Section 5.6 presents the available information related to interconnected surface water. It is nearly impossible to quantify surface-water depletion impact based on flow alone, even in an area where there is good data, such as pumping quantity, deep aquifer groundwater elevation, precipitation, and surface flow. Many of these criteria are current data gaps in the Basin, particularly the variation in precipitation and flow across the Basin. Uncertainty in the amount of surface water entering the Basin and the unpredictability of weather patterns has already been established and will continue to be a barrier. Pumping data in the Basin is also a data gap as there is no current monitoring system which annually measures the amount of water pumped. The connection between upland recharge areas and the unique volcanic geologic features surrounding the Basin are mostly unknown and make understanding the connectivity of surface and groundwater very difficult, if not impossible.

Furthermore, the number of wells located next to streams and the river in the Basin are not quantified. While Chapter 5 – Groundwater Conditions details the streams in Big Valley which *may* be interconnected by a "…continuous saturated zone to the underlying aquifer and the overlying surface water…" (DWR 2016c), there is currently no evidence to support interconnected surface water. Therefore, there is a lack of evidence for interconnection of streams. **Figure 5-18** overlays the general direction(s) of groundwater flow around the Basin in relation to the major streams. Also shown is the general direction of flow determined from the newly constructed well clusters near Adin and Lookout. The remaining clusters were constructed later and do not yet have a sufficient period of data to determine flow directions with certainty. The newly constructed monitoring wells will continue to gather data on whether there is any evidence of interconnected surface water.

Chapter 4 – Hydrogeological Conceptual Model identified data gaps related to the effect of Ash Creek, Pit River, and smaller streams on recharge. These data gaps may partially be filled once adequate data from the five monitoring well clusters are collected. Scientific research related to groundwater and surface water will improve over time. As this science is made available, the GSAs will work to locate funding for improved data depending on available staffing and financial resources.

SMCs were not established for interconnected surface water because there is insufficient evidence to determine that Undesirable Results are present or likely to occur. At the five-year updates of this GSP, data from newly established well clusters, new and historic stream gages, and the monitoring network detailed in Chapter 9 – Projects and Management Actions will be assessed to determine if undesirable trends are occurring in the principal aquifer. At the five-year update, SMCs will be considered only if the trends indicate that undesirable results are likely to occur in the subsequent 5 years.

7.4 Management Areas

Management areas are not being established for this GSP.

8. Monitoring Networks § 354.34

8.1 Monitoring Objectives

This chapter describes the monitoring networks necessary to implement the BVGB GSP. The monitoring objectives under this GSP are twofold:

- to characterize groundwater and related conditions to evaluate the Basin's short-term, seasonal, and long-term trends related to the six sustainability indicators, and
- to provide the information necessary for annual reports, including water levels and updates to the water budget.[59]

The sections below describe the different types of monitoring required to meet the above objectives, including groundwater levels, groundwater quality, subsidence, streamflow, climate, and land use. Each type of monitoring relies on existing programs not governed by the GSAs and therefore the monitoring networks described in this chapter are subject to change if the outside agencies modify or discontinue their monitoring. The monitoring networks will generally be adjusted to the availability of data collected and provided by the outside agencies.

8.2 Monitoring Network

8.2.1 Groundwater Levels

Monitoring of groundwater levels is necessary to meet several needs based on the above stated objectives of the monitoring networks, including:

- Representative monitoring for groundwater levels
- The groundwater contours required for annual reports
- Shallow groundwater monitoring to help define potential interconnection of groundwater aquifers with surface-water bodies

Table 8-1 lists existing wells that have been used for groundwater monitoring and includes the newly-constructed, dedicated monitoring wells. The table indicates which wells are used for each of the three groundwater level monitoring networks. A more detailed table with elements required under §352.4(c) is included in **Appendix 8A**. Further details for each well and water level hydrographs are included in **Appendix 5A**. **Appendix 8B** contains the As-Built Drawings for the dedicated monitoring wells, also required by §352.4(c). The locations of the wells are shown on **Figure 8-1**.

[59] Water levels are needed to generate hydrographs, contours, and an estimate of change in storage as required for the annual report. Also required for the annual reports are estimates of groundwater pumping, surface-water use, and total water use which can be estimated from the water budget.

Table 8-1 Big Valley Groundwater Basin Water Level Monitoring Network

Well Name	Well Use	Well Depth (feet bgs)	Screen[1] Interval (feet bgs)	Representative Well[2]	Depth to Water (feet bgs): Measurable Objective[3]	Depth to Water (feet bgs): Minimum Threshold[4]	Groundwater Elevation (feet msl): Measurable Objective[3]	Groundwater Elevation (feet msl): Minimum Threshold[4]	Contour Well	Shallow Well	Monitoring Frequency
01A1	Stockwatering	300	40 - 300	X	148	288	4035	3895	X		biannual
03D1	Irrigation	280	50 - 280						X		biannual
06C1	Irrigation	400	20 - 400						X		biannual
08F1	Other	217	26 - 217	X	32	172	4222	4082	X		biannual
12G1	Residential	116	--								biannual
13K2	Irrigation	260	20 - 260	X	66	206	4062	3922	X		biannual
16D1	Irrigation	491	100 - 491	X	93	233	4079	3939	X		biannual
17K1	Residential	180	30 - 180						X		biannual
18E1	Irrigation	520	21 - 520						X		biannual
18M1	Irrigation	525	40 - 525								biannual
18N2	Residential	250	40 - 250								biannual
20B6	Residential	183	41 - 183	X	41	181	4085	3945	X		biannual
21C1	Irrigation	300	30 - 300						X		biannual
22G1	Residential	260	115 - 260								biannual
23E1	Residential	84	28 - 84								biannual
24J2	Irrigation	192	1 - 192						X		biannual
26E1	Irrigation	400	20 - 400	X	20	160	4114	3974	X	X	biannual
28F1	Residential	73	--								biannual
32A2	Other	49	--						X		biannual
32R1	Irrigation	--	--						X		biannual
ACWA-1	Irrigation	780	60 - 780						X		biannual
ACWA-2	Irrigation	800	50 - 800						X		biannual
ACWA-3	Irrigation	720	60 - 720	X	23	163	4136	3996	X	X	biannual
BVMW 1-1	Observation	265	175 - 265	X	53	193	4162	4022	X		continuous[5]
BVMW 1-2	Observation	52	32 - 52							X	continuous[5]
BVMW 1-3	Observation	50	30 - 50							X	continuous[5]
BVMW 1-4	Observation	49	29 - 49							X	continuous[5]
BVMW 2-1	Observation	250	210 - 250	X	22	162	4194	4054	X		continuous[5]
BVMW 2-2	Observation	70	50 - 70							X	continuous[5]
BVMW 2-3	Observation	70	50 - 70							X	continuous[5]
BVMW 2-4	Observation	60	40 - 60							X	continuous[5]
BVMW 3-1	Observation	185	135 - 185	X	18	158	4146	4006	X		continuous[5]
BVMW 3-2	Observation	40	25 - 40							X	continuous[5]
BVMW 3-3	Observation	50	25 - 50							X	continuous[5]
BVMW 3-4	Observation	50	25 - 50							X	continuous[5]
BVMW 4-1	Observation	425	385 - 415	X	65	205	4088	3948	X		continuous[5]
BVMW 4-2	Observation	74	54 - 74							X	continuous[5]
BVMW 4-3	Observation	80	60 - 80							X	continuous[5]
BVMW 4-4	Observation	93	73 - 93							X	continuous[5]
BVMW 5-1	Observation	540	485 - 535	X	47	187	4082	3942	X		continuous[5]
BVMW 5-2	Observation	115	65 - 115							X	continuous[5]
BVMW 5-3	Observation	85	65 - 85							X	continuous[5]
BVMW 5-4	Observation	90	70 - 90							X	continuous[5]

Notes:

-- = information not available
feet bgs = feet below ground surface (depth to water)
feet msl = feet above mean sea level (groundwater elevation NAVD88)
water year = October 1 to September 30

[1] For the purposes of this GSP, the terms "screen" or "perforation" encompases any interval that allows water to enter the well from the aquifer, including casing perforations, well screens, or open hole.
[2] Respresentative wells for Water Levels and Groundwater Storage
[3] Measurable objective is set at the Fall 2015 water level or at the lowest water level measured for wells that don't have a Fall 2015 measurement
[4] Minimum threshold is set at 140 feet below the measurable objective
[5] Continuous measurements are currently available due to the water level transducers installed in the wells. Less frequent monitoring may be appropriate in the future once the period of record of these wells is longer and interconnection of surface and groundwater is better understood.

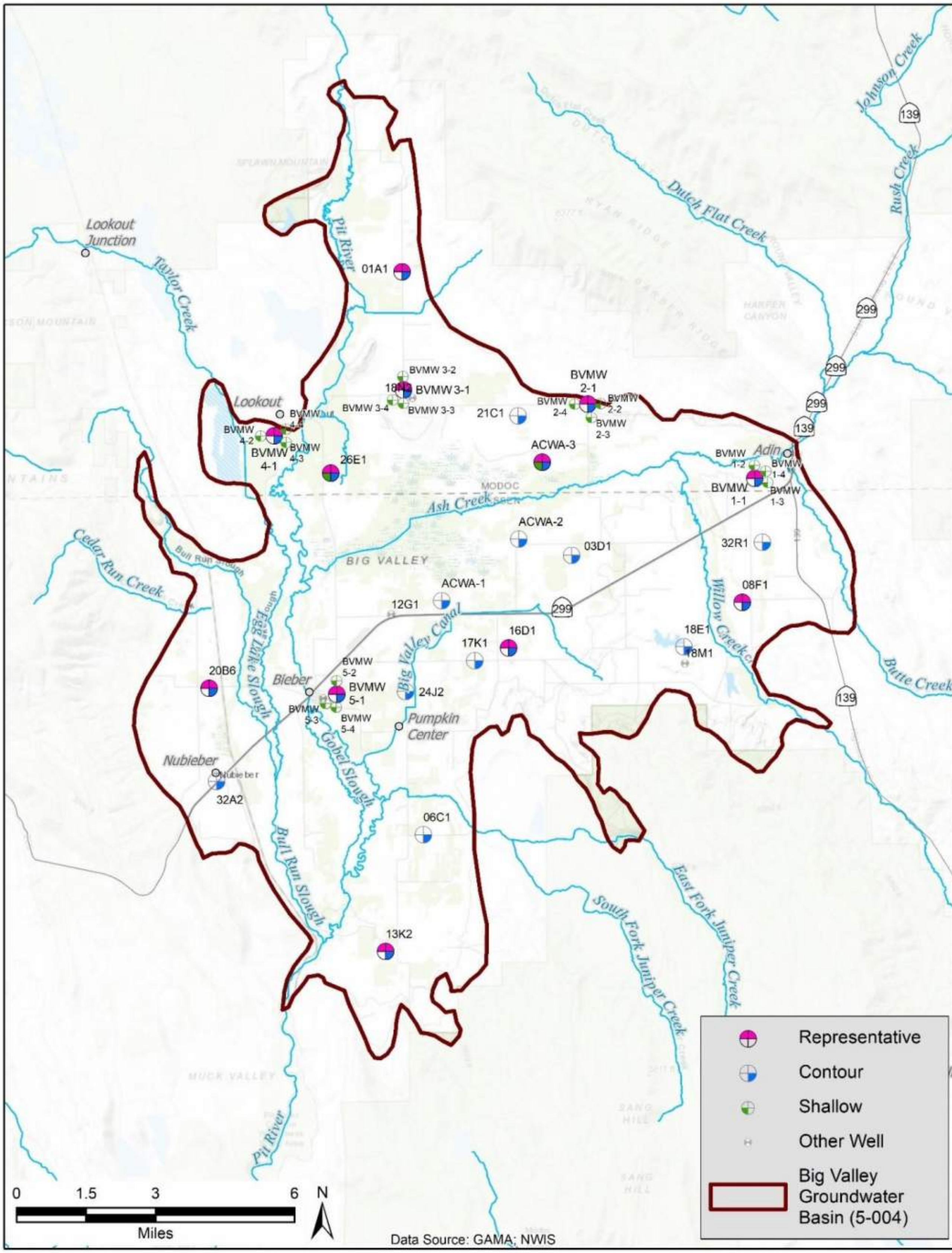


Figure 8-1 Water Level Monitoring Networks

GSP Regulation §352.4 states that monitoring sites that do not conform to DWR BMPs, "…shall be identified and the nature of the divergence from [BMPs] described." DWR's BMP (DWR 2016e) states that wells should be dedicated to groundwater monitoring. In addition, §354.34 indicates that wells in the monitoring network should have "depth-discrete[60] perforated intervals." Many of the historic wells listed in **Table 8-1** diverge from these standards and the explanation of their suitability for monitoring is described below.

Previous groundwater level monitoring in the Basin has relied on existing domestic and irrigation wells that often have pumps in them used for irrigation, stock watering, or domestic uses. The intent of groundwater level monitoring is to capture static (non-pumping) water levels. However, historic monitoring is performed before and after the irrigation season: March or April for spring measurements and October for fall measurements.[61] Since these measurements are taken at a time when large-scale groundwater use is typically not active, using production wells is acceptable in the absence of dedicated monitoring wells. DWR staff who monitor the wells will indicate if the well (or a nearby well) is pumping in order to be considered when assessing water level measurements.

In addition to the well use considerations, most of the historic wells do not have depth-discrete screen intervals,[62] as the typical well construction practice in the Basin has been to use long (100 feet up to 800 feet) screens, perforations, or open hole below about 30 to 40 feet of blank well casing. This construction practice is designed to maximize well yield. The use of such long-screen wells is acceptable for monitoring in Big Valley because multiple principal aquifers have not been defined in the Basin and therefore these long intervals do not cross defined principal aquifers. Since most wells are constructed with this practice, water levels in these long-screen wells should be indicative of the aquifer as a whole and less likely to be affected by perched water or isolated portions of the aquifer that may not be interconnected over large areas.

8.2.1.1 Representative Groundwater Levels and Storage Monitoring Network

The representative monitoring network includes all wells that have been assigned sustainable management criteria (minimum thresholds and measurable objectives). DWR does not give strict guidance on the number or density of wells appropriate for representative monitoring. DWR's BMP document cites sources that recommend well densities ranging from 0.2 to 10 wells per 100 square miles (DWR 2016e). Through consultation with the BVAC, 12 wells were selected for representative monitoring of the Basin (which has an area of about 144 square miles), a density of 8.3 wells per 100 square miles.

Extensive discussion and consideration were performed by the GSAs and local stakeholders to determine an appropriate water level monitoring network. Based on the comprehensive review of the wells, the network was selected based on:

[60] "Depth-discrete" means that the screens, perforations, or open hole is relatively short (typically less than about 20 feet).

[61] Local stakeholders have advocated for future measurements to occur in mid-March and late-October to ensure they are taken before and after the irrigation season.

[62] Screens in this context includes perforated casing, well screens, or open hole, all of which allow water to flow into the well.

- Spatial distribution throughout the Basin to represent agricultural pumping areas
- Areas with a high density of domestic wells
- An existing monitoring record (where available) to track long-term trends
- Access for long-term future monitoring
- Well depth (greater than the MT)
- Wells dedicated to monitoring where available

Table 8-1 shows the MOs and MTs for the 12 representative wells. As stated in Chapter 7 – Sustainable Management Criteria, MOs are set at the fall 2015 water level. MTs are shown in **Table 8-1** to protect agricultural beneficial use.

8.2.1.2 Groundwater Contour Monitoring Network.

The GSP Regulations (§356.2) require that annual reports include groundwater contours for the previous year (spring and fall) as well as an estimate of change in groundwater storage. Historic groundwater storage changes were estimated in Chapter 5 – Groundwater Conditions, using groundwater contours contained in **Appendix 5B**. Therefore, for annual reports to be comparable to historic conditions, the wells used for groundwater contouring should be the same, or nearly the same, as those used for the historic contours. Five wells that were used in the historic contours are not included in the groundwater contour monitoring network (18M1, 18N2, 22G1, 23E1 and 28F1), because they were either replaced by a new dedicated monitoring well or there was another well close by that makes the measurement unnecessary. **Table 8-1** lists the groundwater contour monitoring network and **Figure 8-1** shows their locations.

8.2.1.3 Shallow Groundwater Monitoring Network

Chapter 5 – Groundwater Conditions discusses interconnected surface water and describes the major streams in the BVGB. As described in Chapter 7 – Sustainable Management Criteria, there is currently no conclusive evidence for interconnection of streams with the groundwater aquifer and all summer flows are 100 percent allocated based on existing surface-water rights. Therefore, measurable objectives, minimum thresholds, and a representative monitoring network for interconnected surface water have not been established. Monitoring will be assessed at the five-year update. Through consultation with the BVAC, a shallow monitoring network has been established that includes the shallow wells from each of the five monitoring well clusters. These clusters were designed to measure the magnitude and direction of shallow groundwater flow and are equipped with water level transducers that collect continuous (15-minute interval) water level measurements so that potential correlations with streamflow gages can be assessed. Well 26E1 was also added to the shallow network due to its position between the two major streams (Pit River and Ash Creek), its shallow screen depth (20 feet bgs), and its lack of a pump. Well number ACWA-3 was also selected for the shallow network due to its location on the ACWA within the northern portion of the Ash Creek wetlands associated with Big Swamp and the possible groundwater-dependent ecosystems shown in **Figure 5-19**. **Table 8-1** lists the shallow groundwater monitoring network, and **Figure 8-1** shows the well locations.

8.2.1.4 Monitoring Protocols and Data Reporting Standards

Currently, DWR measures groundwater levels at 21 wells in Big Valley. The expectation of the GSAs is that DWR will also monitor levels at the dedicated monitoring wells and download the transducer data from these wells. Transducer data will be corrected for barometric fluctuations using data from two barometric probes installed at two of the clusters. Water level data will be made available on the state's SGMA Data Viewer website for use by the GSAs in their annual reports and GSP updates. DWR's water level monitoring protocols are documented in their Monitoring Protocols, Standards and Sites BMP (DWR 2016b). Portions of the BMP relevant to water levels are included in **Appendix 8C**.

8.2.1.5 Data Gaps in the Water Level Monitoring Network

Data gaps are identified in this section using guidelines in SGMA Regulations and BMP published by DWR on monitoring networks (DWR, 2016e). **Table 8-2** summarizes the suggested attributes of a groundwater-level monitoring network from the BMP in comparison to the current network and identifies data gaps. No data gaps exist except the area near well 06C1, shown on **Figure 8-1**.

8.2.2 Groundwater Quality

Chapter 5 describes overall water quality conditions as excellent, and the few constituents that are infrequently elevated in Big Valley are all naturally-occurring. Therefore, measurable objectives, minimum thresholds and a representative monitoring network have not been established. Monitoring will be assessed at the five-year update. To make such an assessment, the GSAs will rely on existing programs, described in Chapter 7. Focus will be on the water quality reported for wells regulated by the State Water Board's DDW. DDW wells are shown on **Figure 8-2** and are in Bieber and Adin, with one well in the western portion of the Basin. In addition to data from DDW, the GSAs have installed three transducers to measure electrical conductivity (EC) at wells BVMW 1-1, 4-1, and 5-1, shown on **Figure 8-2**. These transducers increase the distribution of the monitoring network around the Basin and with increased frequency of measurement will allow the GSAs to better understand temporal trends that may not be apparent from infrequent DDW measurements. The EC transducers may be able to put anomalous[63] measurements from DDW into better context. **Table 8-3** lists the groundwater quality monitoring sites and their details.

[63] Anomalous measurements are those that are out of the norm or deviate from what would be expected. The source of the deviation from the norm should be noted and if errors are identified, the measurement(s) removed from the dataset based on professional judgment. At a minimum, anomalous measurements are marked as questionable, and the potential source(s) of the deviation documented.

2491 **Table 8-2 Summary of Best Management Practices, Groundwater Level Monitoring Well Network and Data Gaps**

Best Management Practice (DWR, 2016d)	Current Monitoring Network	Data Gap
Groundwater level data will be collected from each principal aquifer in the Basin.	12 representative wells	None. There is a single principal aquifer and therefore all wells monitor the aquifer.
Groundwater level data must be sufficient to produce seasonal maps of groundwater elevations throughout the Basin that clearly identify changes in groundwater flow direction and gradient (Spatial Density).	22 contour wells	21 of the 22 proposed contour wells are currently monitored. Well 06C1 was monitored up until WY 2016. This well fills an important spatial area in the southern part of the Basin. To fill the data gap, the well could be re-activated, a new willing well owner found, or a dedicated monitoring well constructed in the area.
Groundwater levels will be collected during the middle of October and March for comparative reporting purposes, although more frequent monitoring may be required (Frequency).	All proposed monitoring network wells, except 06C1, are measured biannually, with the dedicated monitoring wells collecting continuous (15-minute) measurements	None. Current DWR monitoring occurs in March or April and in October for seasonal high (spring) and low (fall) respectively.
Data must be sufficient for mapping groundwater depressions, recharge areas, and along margins of basins where groundwater flow is known to enter or leave a basin.	Groundwater depressions are present in the east-central part of the Basin near 03D1 and in the southern portion of the Basin near Well 06D1 and Well 13K2	03D1 defines the east-central depression. To ensure adequate definition of the southern depression, well 06C1 could be re-activated, a new, willing well owner found, or a dedicated monitoring well constructed in the area.
Well density must be adequate to determine changes in storage.	22 contour wells	Filling of data gap near 06C1.
Data must be able to demonstrate the interconnectivity between shallow groundwater and surface-water bodies, where appropriate.	17 shallow wells, including 5 clusters of 3 shallow wells each	None.
Data must be able to map the effects of management actions, i.e., managed aquifer recharge.	22 contour wells and 17 shallow wells	None. Once projects and management actions are defined, monitoring specific to those projects and management actions will be identified.
Data must be able to demonstrate conditions near Basin boundaries; agencies may consider coordinating monitoring efforts with adjacent basins to provide consistent data across Basin boundaries. Agencies may consider characterization and continued impacts of internal hydraulic boundary conditions, such as faults, disconformities, or other internal boundary types.	22 contour wells and 17 shallow wells	None. There are no direct boundaries with adjacent Basins. Inflow/outflow from Basin addressed above.
Data must be able to characterize conditions and monitor adverse impacts to beneficial uses and users identified within the Basin.	12 representative wells	None

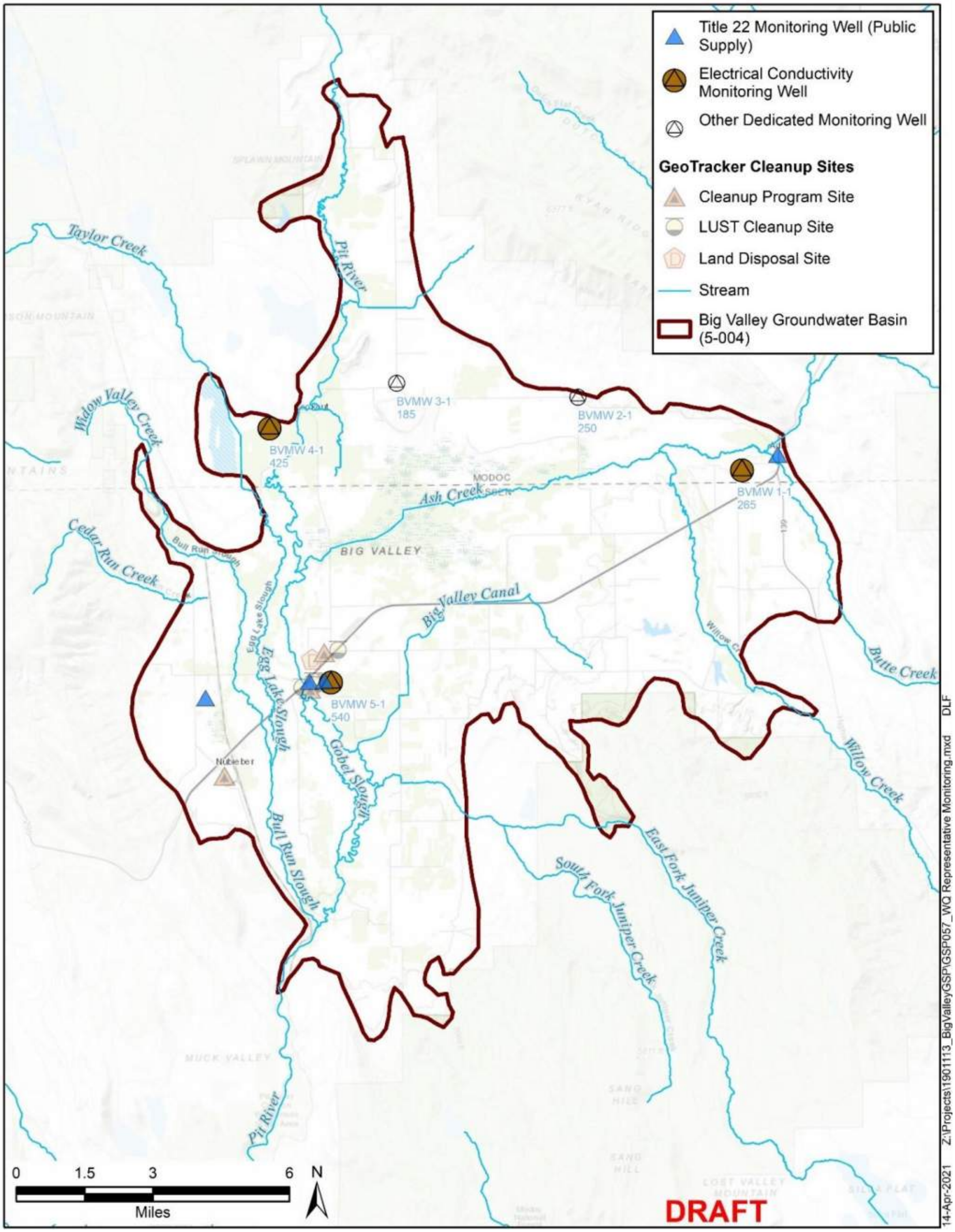


Figure 8-2 Water Quality Monitoring Network

Table 8-3 Big Valley Groundwater Basin Water Quality Monitoring Network

Well Name	SWRCB Public Source Code	DWR Site Code	Well Use	Well Depth (feet bgs)	Open Hole	Screen[1] Interval (feet bgs)	Constituents
Bieber Town Well 1	1810003-001		Public Supply	200	yes	62 - 200	Title 22
Bieber Town Well 2	1810003-002		Public Supply	240	no	60 - 240	Title 22
Adin Ranger Station Well 3	2500547-003		Public Supply	--	--	--	Title 22
Intermountain Conservation Camp Well 1	1810801-001		Public Supply	--	--	--	Title 22
BVMW 1-1		411880N1209599W001	Observation	265	no	175 - 265	Electrical conductivity
BVMW 3-1		412029N1211587W001	Observation	185	no	135 - 185	Electrical conductivity
BVMW 5-1		411219N1211339W001	Observation	540	no	485 - 535	Electrical conductivity

Notes:
-- = information not available
feet bgs = feet below ground surface (depth to water)
[1] For the purposes of this GSP, the terms "screen" or "perforation" encompases any interval that allows water to enter the well from the aquifer, including casing perforations, well screens, or open hole.

8.2.2.1 Monitoring Protocols and Data Reporting Standards

While DWR provides guidance on protocols and standards for water quality in their BMP (DWR 2016f), these don't generally apply to the Big Valley water quality monitoring network. For the DDW wells, monitoring protocols used by the parties responsible for collecting and analyzing samples will be relied upon. DDW and other data regulated by the State Water Board is made available on their GAMA GIS website. At the five-year update, the GSAs will obtain and analyze the available data. The measurements for EC transducers are made in situ with no samples collected or analyzed in a laboratory.

8.2.2.2 Data Gaps in the Water Quality Monitoring Network

Table 8-4 summarizes the recommendations for groundwater quality monitoring from DWR's BMPs, the current network, and data gaps. There are no data gaps in the water quality monitoring network.

8.2.3 Land Subsidence

As described in Chapter 5 - Groundwater Conditions and Chapter 7 – Sustainable Management Criteria, no significant land subsidence has occurred in the BVGB, and no significant subsidence is likely to occur. Therefore, MOs, MTs and a representative monitoring network have not been established. This assessment was made based on a CGPS station near Adin (P347) and InSAR data provided by DWR. Future assessment of subsidence at the five-year GSP update will rely on data provided by NOAA, who operates Well P347, and updated InSAR data provided by DWR. The data will be assessed to determine if significant subsidence is occurring and the source of that subsidence.

2515 **Table 8-4 Summary of Groundwater Quality Monitoring, Best Management Practices and Data Gaps**

Best Management Practices (DWR, 2016a)	Current Network	Data Gap
Monitor groundwater quality data from each principal aquifer in the Basin that is currently, or may be in the future, impacted by degraded water quality. The spatial distribution must be adequate to map or supplement mapping of known contaminants. Monitoring should occur based upon professional opinion, but generally correlate to the seasonal high and low groundwater level, or more frequent as appropriate.	4 public supply wells and 3 monitoring wells with EC transducers.	None. Most known contaminants are located in Bieber and Nubieber. Monitoring at wells in Bieber and in BVMW 5-1 have not shown contaminants, but monitoring there would indicate if they become present.
Collect groundwater quality data from each principal aquifer in the Basin that is currently, or may be in the future, impacted by degraded water quality. Agencies should use existing water quality monitoring data to the greatest degree possible. For example, these could include ILRP, GAMA, existing RWQCB monitoring and remediation programs and drinking water source assessment programs.	4 public supply wells and 3 monitoring wells with EC transducers.	None.
Define the three-dimensional extent of any existing degraded water quality impact.	No degraded water quality impacts are present.	None.
Data should be sufficient for mapping movement of degraded water quality.	No degraded water quality impacts are present.	None.
Data should be sufficient to assess groundwater quality impacts to beneficial uses and users.	No degraded water quality impacts are present.	None.
Data should be adequate to evaluate whether management activities are contributing to water quality degradation.	None. Projects and management activities that are implemented will assess potential water quality impacts.	None.

8.2.3.1 Monitoring Protocols and Data Reporting Standards

Since the monitoring network relies on NOAA and DWR-provided data, the monitoring protocols and reporting standards for those organizations apply.

8.2.3.2 Data Gaps in the Subsidence Monitoring Network

Since InSAR data is contiguous across the Basin, there are no spatial data gaps. If subsidence is indicated by future InSAR datasets, there may be a need to field verify those areas to determine if field leveling has occurred or there is another reason or cause for the subsidence. Additional field validation could potentially be made by re-surveying monuments in the Basin, including those installed at the new monitoring wells.

8.2.4 Monitoring to Support Water Budget

8.2.4.1 Streamflow and Climate

Streamflow and climate data are needed to update the water budget. Current monitoring sites are shown on **Figure 8-3**. Modoc County has been working to improve water budget estimates and is proposing to add a stream gage on the Pit River just north of the BVGB, shown on **Figure 8-3**, which will be maintained by the state. Data gaps for smaller streams, such as inflow from Roberts Reservoir, Taylor Creek and Juniper Creek are proposed to be filled by investigating SB-88 stream diversion records submitted to the State Water Board.

8.2.4.2 Land Use

Land use data is needed for updates to the water budget. Since 2014, DWR has provided land-use mapping using remote sensing processed by DWR's LandIQ mapping resource. DWR has provided these datasets for 2014, 2016, and 2018.[64] The GSAs will rely on DWR continuing to provide this land- use data to generate annual updates to the water budget. The most recent land-use data available will be used to generate the evapotranspiration estimates. Current research is being performed to develop the relationship between evapotranspiration (ET) and applied water. This research indicates that crops in this area are typically irrigated less than indicated by the assumptions made by multiplying ETo by crop coefficients.

[64] Landowners in the Basin have pointed out that these datasets are inaccurate, but they represent the best available information.

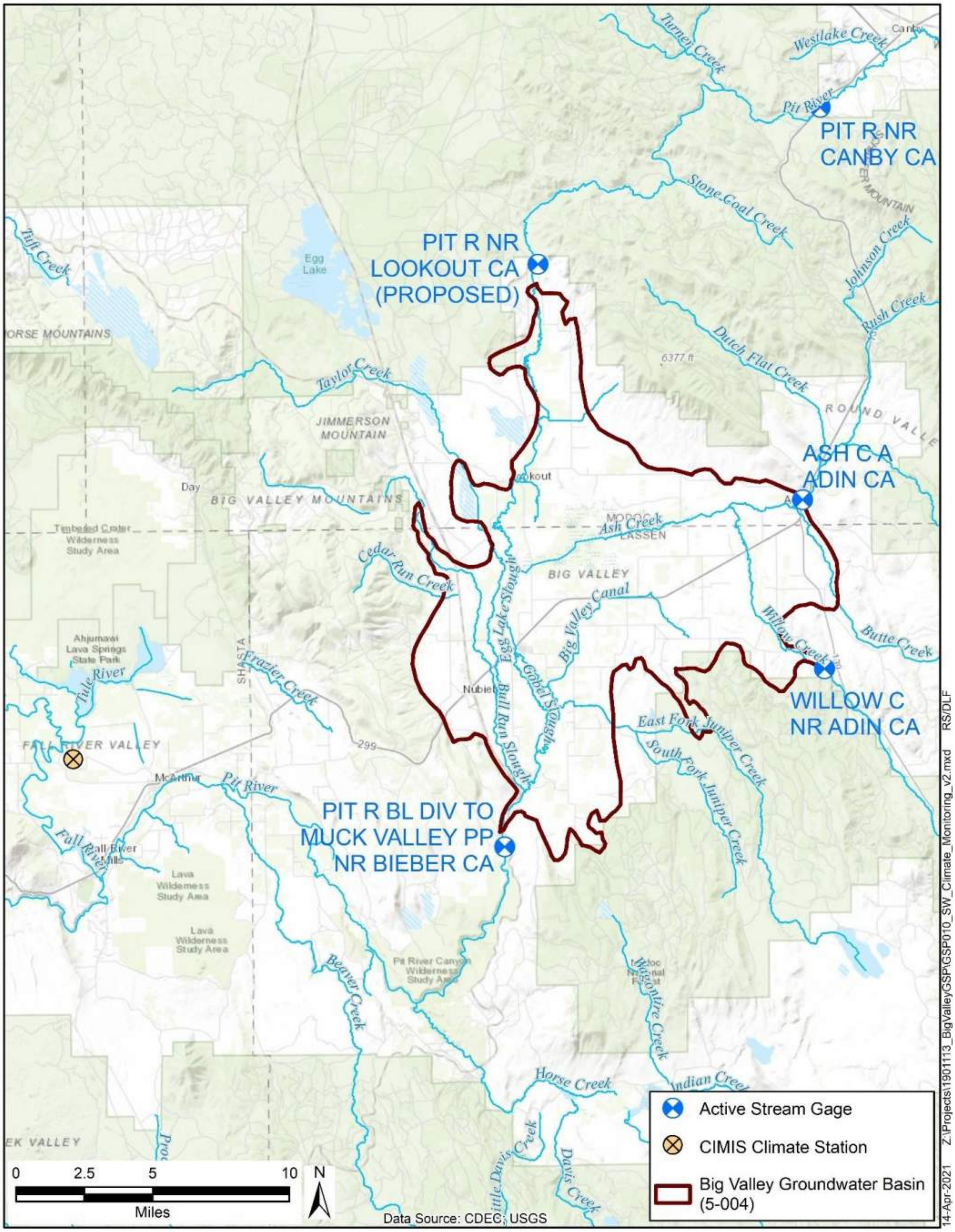


Figure 8-3 Proposed Surface-Water and Climate Monitoring Network

9. Projects and Management Actions §354.44

Through an extensive planning and public outreach process, the GSAs have identified an array of projects and management measures that may be implemented to meet sustainability objectives in the BVGB. Additionally, numerous state and federal programs are available in the Basin to help meet the sustainability goals. Some of the projects can be implemented immediately, while others will take significantly more time for necessary planning and environmental review, navigation of regulatory processes, and implementation. The Big Valley Basin is relatively small, and while recharge does occur within the Basin itself, significant recharge comes from the extensive uplands surrounding the Basin. Projects will be located within the greater Big Valley watershed boundary shown in **Figure 9-1**.

Although the Big Valley area is extremely rural and economically disadvantaged, and resource capacity is limited, there are several local, state, and federal agencies that can assist in project development.

Project implementation will also be impacted by funding acquisition. **Table 9-1** lists current state and local funding sources that can be targeted to support project planning and implementation.

With a proactive approach to identify projects for increased recharge and conservation in the Big Valley Basin and surrounding watershed, it is envisioned that the GSAs will be successful in remaining a sustainable groundwater basin. With the possible exception of a large surface-water storage project such as Allen Camp Dam, the projects and management measures describe in this chapter are expected to work in combination and should be considered as a whole rather than dependent on any single strategy. Should sustainability not be realized, additional projects and management actions will be considered and developed as appropriate. A timeline for projects can be found in **Table 9-2**. The Regulations require details about each project to satisfy CWC§354.44. Most of those details can be found in **Table 9-3**. One of the items not included in **Table 9-3** is a description of the legal authority required for each project per CWC§354.44(b)(7). The GSAs have the legal authority to coordinate and/or implement each of the projects described based on their authority under SGMA and state law. Some of these projects include aspects that will be implemented on private and public land. In those cases, permission and authority to implement the project will be obtained from the landowner.

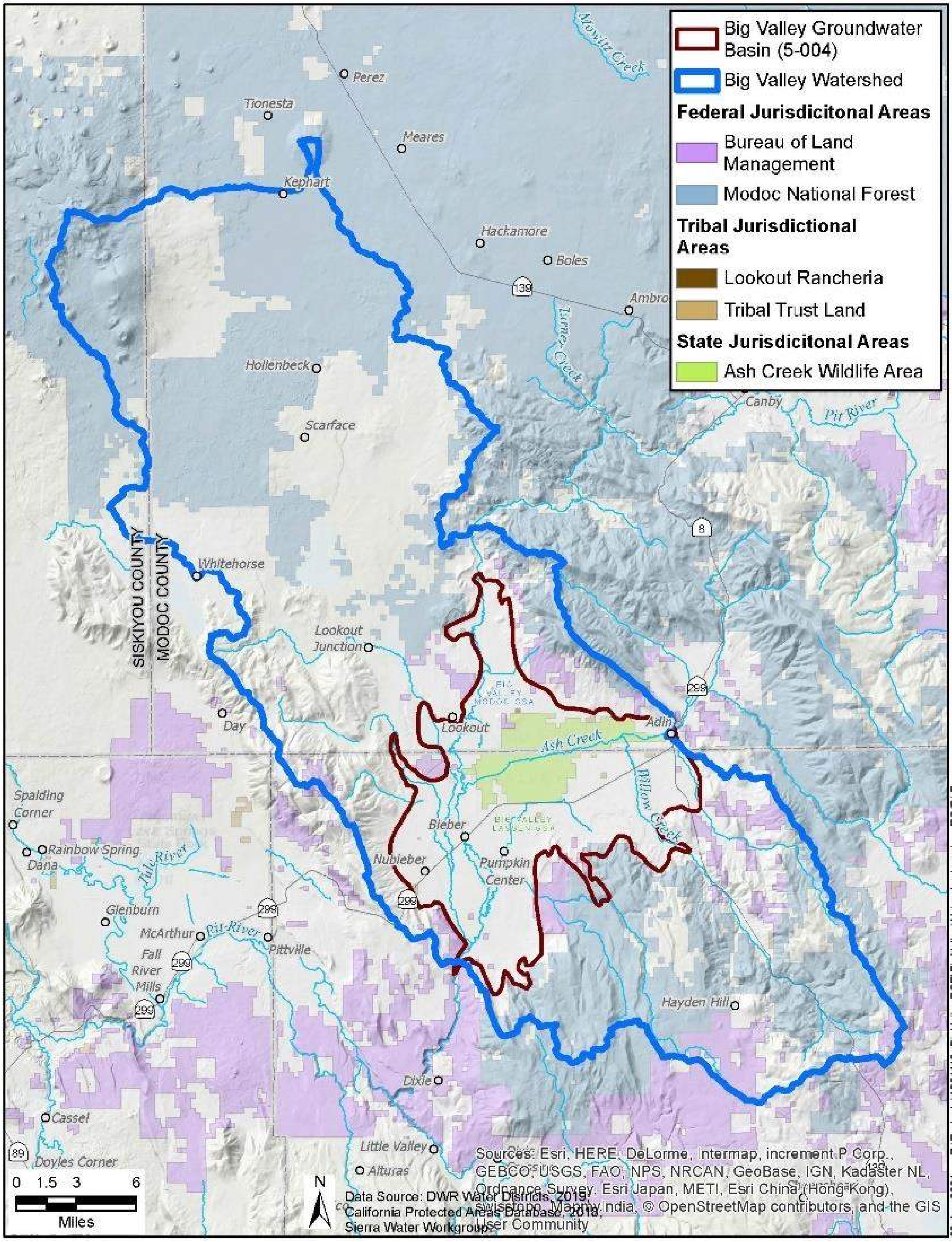


Figure 9-1 Big Valley Watershed Boundary

Table 9-1 Available Funding Supporting Water Conservation

Funding Program Title	Managing Agency	Description of Funding
Wetlands Reserve Program, Crop Reserve Program, Environmental Quality Improvement Program	NRCS (website)	Cost-share funding for wide array of soil, water, and wildlife conservation practices. Funding priorities developed locally.
Conservation Innovation Grants	NRCS (website)	Supports development of new tools, approaches, practices, and technologies to further conservation on private lands.
Partners for Fish and Wildlife Program	US Fish and Wildlife Service (website)	Private land meadow, forest, or rangeland restoration, conservation easement.
State Water Efficiency and Enhancement Program (SWEEP)	California Dept of Food and Agriculture (CDFA) (website)	Supports implementation of water-saving irrigation systems.
Healthy Soils Program	CDFA (website)	Supporting management and conservation practices for enhancing soil health (which includes water holding capacity).
Farmer/Rancher and/or Professional + Producer grants	Western Sustainable Agriculture Research and Education (website)	Farmer-driven innovations in agricultural sustainability including profitability, stewardship, and quality of life.
Alternative Manure Management Program (AMMP) (link)	CDFA (website)	Financial assistance for non-digester manure management.
Sustainable Groundwater Management	DWR (website)	Planning and implementation grants supporting sustainable groundwater management with preference toward disadvantaged communities and economically distressed areas.
State Forest Health Program	CAL FIRE (website)	Improve forest health throughout California.
USDA for household well deepening	USDA Rural Development (website)	No interest loan up to $11K to improve existing domestic wells.

Table 9-2 Projects and Potential Implementation Timeline

No.	Category	Description	Estimated Time for Potential Implementation (years)		
			0-2	2-8	>8
1	9.1 Recharge Projects	AgMAR	X	X	X
2		Drainage and Basin Recharge	X	X	X
3		Ag Injection Wells			X
4	9.2 Research and Data Development	Stream Gages	X		
5		Refined Water Budget	X	X	
6		Agri-Climate Station	X		
7		Voluntary Installation of Well Meters	X	X	
8		Adaptive Management	X	X	X
9		Mapping and Land Use	X	X	
10	9.3 Increased Storage Capacity	Expanding Existing Reservoirs		X	
11		Allen Camp Dam			X
12	9.4 Improved Hydrologic Function	Forest Thinning and Management	X	X	X
13		Juniper Removal	X	X	X
14		Stream and Meadow Restoration	X	X	X
15	9.5 Water Conservation	Irrigation Efficiency	X	X	
16		Landscaping and Domestic Water Conservation	X	X	
17		Conservation Projects	X	X	
18	9.6 Education and Outreach	Public Communication	X		
19		Information and Data Sharing	X	X	
20		Fostering Relationships	X		
21		Compiling Efforts	X	X	
22		Educational Workshops	X		

Note: AgMAR = Agricultural Managed Aquifer Recharge

Table 9-3 Required Elements for Projects and Management Actions

Project	Brief description	Circumstances under which the project will be implemented	Public notification process	Permitting and regulatory process	Benefits	Schedule	Estimated cost
9.1 Basin Recharge Projects	Agricultural Managed Aquifer Recharge is the practice of using excess surface water (when available) and applying it to agricultural fields to intentionally recharge groundwater aquifers	AgMAR will be performed during winter months during high surface flows. The nature, frequency and timing of these flows will be evaluated through a Water Availability Analysis (WAA).	Notification of available water and success of this projects will be communicated at public GSA meetings. Agreements will be made between the GSAs and interested producers.	Following development of the WAA, an AgMAR permit for surface-water diversions can be solicited from the State Water Board. Currently this permitting process can take 6-18+ months and cause significant economic burden to the applicant. An organized application for Basin-wide winter diversions by the GSAs could lessen some of the regulatory burden since they qualify for a streamlined process but a waiver of fees for extremely disadvantaged communities working to improve groundwater recharge may also be needed.	Irrigating every 5-7 days for roughly 10 weeks in the winter/spring would benefit 2-5 AF of water per acre. Previous research has quantified that over 90% of water is recharged to deep aquifers or available in the soil profile with AgMAR. The limitation to this project is available winter for recharge but a project goal of 1,000 acres per year could provide roughly 10,000 AF of water per year benefit.	Water budget planning and permitting will take 6-18 months and possibly more depending on the case load at the department of water resources. After an off-season water budget is completed, permitting can be distributed to the GSAs for winter recharge location selection. AgMAR could start being used at productive scale by 2024 if all processes go smoothly.	The cost to develop the WAA is still being developed but may be covered under existing grants from DWR. The cost of submitting a streamlined permit will also be developed, including fees.
9.2 Research and Data Development	Stream gages are scientific instruments used to collect streamflow and water quality data to decrease scientific uncertainty in order to inform water management decisions. Agri-Climate/CIMIS stations are helpful in monitoring for climatic factors such as temperature, humidity, wind speed, etc., and overall help refine estimates of ET in the Basin. Refining the water budget for the Basin will improve the accuracy with which management decisions are made because many of the assumptions used to generate the water budget stem from data gaps that need to be addressed, or other efforts to collect and analyze data submitted through other regulatory programs.	In addition to the continued use of existing stream gages which monitor many of the seasonal streams that contribute inflow to the Big Valley Basin, stream gages may be installed if locations and need are determined. Presently, Modoc County is working to install an additional stream gage where the Pit River enters the Basin. Data from Agri-Climate/CIMIS stations may be utilized in order to make water management decisions with regard for climatic factors such as wind, rain etc. Adaptive management will be employed throughout the implementation process to allow for management decisions to reflect the best available data as more information comes available. Employing adaptive management strategies will also expand our capacity to conduct research and data development. Refining the water budget will be done as more data becomes available through the combination of the data development projects described previously.	All research and data development progress will be shared at public GSA meetings. Data collected from gaging stations will be publicly available.	We will continue to work with DWR to ensure compliance with any relevant laws and to obtain any necessary permits related to stream gage installation and maintenance, as well as for other projects that fall under adaptive management strategies and the water budget.	Decreasing data gaps would decrease reliance on assumptions to govern groundwater management decisions. As more data becomes available, more accurate estimates of evapotranspiration would allow for more precise water budgeting estimates.	Gaging stations will be installed where necessary early in the planning process to decrease uncertainty related to streamflow. They will be monitored throughout. Adaptive management strategies are anticipated to be employed throughout the GSP development and implementation phases. Refining the water budget is important early on in order to create a GSP that best reflects existing conditions in the Basin and which may be referenced in the future to perform adaptive management.	Funding is available for the development of new gaging stations. Maintenance costs may vary, but one estimate projects the annual maintenance cost for a single gage to be around $15,000. Funding for projects related to adaptive management and refining the water budget will be acquired as necessary. Presently, there is funding to maintain or install flow meters on private wells. More funding is likely available for similar projects, such as refining mapping and land-use designations within the Basin.

Project	Brief description	Circumstances under which the project will be implemented	Public notification process	Permitting and regulatory process	Benefits	Schedule	Estimated cost
9.3 Increased Surface-water Storage Capacity	Surface water storage may be used to reduce reliance on groundwater by providing an alternative water source. Presently, Roberts Reservoir and several others, including the Inverson, Silva and BLM reservoirs, mitigate potential overdraft. As water levels in streams and other water courses diminish during the dry months, existing diversions may not adequately meet the needs of users. Expanding the capacity of these reservoirs and possibly constructing new reservoirs such as the Allen Camp Project would allow additional water from snowmelt and storm events to be stored. This would help circumvent reliance on groundwater and would provide reliable supplies of surface water for users.	Projects intended to increase surface-water storage will be implemented when it is economically advisable to do so and when they may help mitigate Basin overdraft.	Pursuant to environmental review, these projects will have opportunities for public comment and project documents will be made publicly available whenever appropriate. Both National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) compliance mandate opportunities for public comment.	Permitting for surface-water storage projects will be subject to NEPA and CEQA depending on whether the project sites are located on federal or state land respectively.	Increasing the capacity to store surface water by capturing runoff could reduce reliance on groundwater during summer months. Further, increasing surface-water storage would improve water security during dry years.	The timeframe for largescale infrastructure projects would likely be upwards of 8 years, as the regulatory and environmental review processes generally require extensive coordination between agencies and stakeholders for planning and compliance.	Large infrastructure projects can be quite expensive. $1 in May 1981 had the same buying power as $2.97 in April 2021. A ballpark estimate of the capital costs for the Allen Camp Project in its entirety would amount to approximately $344,041,830, with the dam and reservoir component amounting to an additional $174,487,500. These figures assume funding may be available from the federal government in the form of loans under the Small Reclamation Projects Act of 1956. The cost associated with expanding existing reservoirs depends on the method employed. Sediment removal typically costs between "$8,000 and $32,000 per acre foot," (Lund 2014) and would be done infrequently. Increasing dam height typically costs between "1,700 to $2,700 per acre foot" (Lund 2014).
9.4 Improved Hydrologic Function and Upland Recharge	Upland forest recharge enhancement occurs in conjunction with vegetation management and forest fuels reduction by increasing snow-water content and reducing dense forest canopy and associated evapotranspiration.	Upland forest recharge will be enhanced by implementation of forest health and fuels reduction projects within the Big Valley watershed. Such projects are ongoing and in varying stages of planning and implantation. Support from GSAs and local, state, and federal partners will increase implementation rate and scope. Water availability and recharge enhancement will be realized along with fire/fuels and wildlife habitat benefits.	On federally-managed lands, public notification of projects will be conducted under NEPA by the Modoc National Forest or Applegate BLM. State funded projects will follow CEQA public notification process. Opportunities on private land be communicated by GSAs, Pit Resource Conservation District, and other state and local entities.	Projects permitting will vary by land ownership. On federal lands: NEPA and applicable federal land policies. On private lands: state forestry rules are applicable and programs such as CAL FIRE's Forest Health Program will help clarify and streamline permitting processes.	Snow-water content has been shown to increase by 33% to 44% from a dense conifer canopy to an open area. Surface runoff has also been shown to respond to treatments. Recharge figures are difficult to quantify, but even a modest increase in recharge over 10% of the potential upland recharge area could result several thousand AF of water.	The initial upland forest recharge project "Wagontire Project" is scheduled for implementation in 2022 and is expected completion in a 2- to 4-year window.	Project costs vary by site, but an estimated average is from $500 to $650 per acre.
9.5 Water Conservation Projects	Water conservation and water use efficiency projects would primarily be adopted by growers and homeowners on their private property. Infrastructure improvements, while requiring capital outlay, are not subject to permitting or public environmental review.	Project implementation will be voluntary with cost-share incentives. Projects will be implemented on a site-by-site basis and designed for overall production and economic efficiency, along with water use savings.	Notification of opportunity to participate will be through local agricultural organizations, extension outreach meetings, and by sponsoring agencies. Broad public notification of individual projects is not required.	Projects in this category such as upgrading irrigation infrastructure, irrigation management techniques, home landscaping, etc. are generally not subject to permitting requirements.	Some practices have been shown to result in efficiency increases in the range of 10% at the field scale. Multiplied over a number of farms, water use savings could be significant.	Irrigation infrastructure and water-use efficiency incentives are ongoing. UC Cooperative Extension has submitted a grant proposal to SWEEP to initiate an outreach education program in 2022.	Costs vary widely. New irrigation infrastructure on a field scale can exceed $100,000. Soil moisture meters for irrigation scheduling can be in the $100s to $1,000s of dollars per farm. Landscaping and homeowner water efficiency projects in the $100s to $1000s per home.
9.6 Education and Outreach	Education and outreach efforts can drive beneficial changes in patterns of use and protect water resources. Existing efforts employed by the GSAs include outreach about funding opportunities that support water conservation methods, coordinating information sharing efforts, and facilitating informational meetings with stakeholder groups.	As an essential part of sustainability, outreach and education will be conducted throughout the development of the GSP, with many opportunities for public engagement.	Public information is available through the Big Valley GSP communication portal, accessible at bigvalleygsp.org. Informational brochures will be distributed to interested parties to make information about the GSP more accessible.	Public engagement is important to the regulatory process of SGMA and other acts that the GSP may be subject to. However, education and outreach are an incredibly important part of meeting the sustainability goals of this GSP, especially as it relates to equity and inclusion.	Public involvement in the GSP development is crucial in attaining sustainability. Research (OECD 2015) has shown that here are many social, economic, and environmental benefits to education and outreach efforts in water management. These benefits can vary widely, but generally include increased levels of social cohesion, equity and conflict avoidance, improved water use efficiency, and improved water quality.	Ongoing efforts to engage the public in outreach and education programs related to groundwater management are essential as part of the Groundwater Sustainability Plan. The anticipated timeline for outreach and education efforts is indefinite, but it is especially important throughout the planning and implementation process of the GSP.	Costs may vary depending on program type.

9.1 Basin Recharge Projects

Enhancing recharge to get more of the available water into the aquifer is one of the key means to attaining sustainability. Priority is given to the immediate Big Valley watershed, but additional recharge projects will be considered for surrounding upland and upstream areas of the Pit River watershed. A more detailed watershed map is provided in Chapter 3 – Plan Area. For off-season diversion recharge projects to be widely available in the Big Valley Basin, an off-season water availability study must be completed for the Pit River watershed up-river of Big Valley. This would allow growers to be able to obtain a permit for winter flow diversion. This study would include a survey of potential water rights held for off-season use, storage, and hydroelectric power. *See* footnote link for a more detailed description of what is needed in this process.[65]

Once this survey is completed and approved by a licensed engineer, permits to divert for available surface water can be solicited from DWR. Currently this permitting process can take 6 to 18+ months and cause significant economic burden to the applicant. An organized application for Basin-wide winter diversions by the GSAs could lessen some of the regulatory burden since they qualify for a streamlined process but a waiver of fees for extremely disadvantaged communities working to improve groundwater recharge is needed. *See* footnote link for a more detailed description of what is needed in this process.[66]

Along with permitting costs, there are also costs to the irrigator in electricity and labor costs to apply water.

9.1.1 Agriculture Managed Aquifer Recharge

One approach to Basin recharge currently being considered is AgMAR, which is the intentional recharge of groundwater aquifers by spreading water over agricultural fields at times when excess surface water (Kocis & Dahlke, 2017, Dahlke et al. 2018). With significant surface-water irrigation and diversions already present in Big Valley, AgMAR is a viable option in the Basin. Much of the current research on AgMAR has been completed on relatively well-drained soils that are not present in Big Valley. Research on Big Valley soils with slow to very-slow infiltration rates appears to be initially promising. While recharge of groundwater may be slower in the Basin, it could still be a feasible means for deep water recharge and filling the shallow aquifer and root zone. AgMAR can be utilized for both, increasing recharge and decreasing water application of groundwater during the growing season due to a saturated soil profile. A conservative estimate suggests that 25,000 acres in Big Valley of agricultural and native vegetation lands are accessible to surface water and available for AgMAR. Priority will be given to low infiltration over very-low infiltration soils for recharge and areas addressing more critical groundwater levels.

Among the perennial crops, alfalfa is considered a promising candidate for AgMAR for several reasons, and significant initial research has been completed throughout California on its feasibility (Dahlke et al. 2018). Eighty to eighty-five percent of the alfalfa in California is irrigated by flood irrigation, which in

[65] https://www.waterboards.ca.gov/waterrights/water_issues/programs/applications/groundwater_recharge/docs/streamlined_waa_guidance.pdf

[66] https://www.waterboards.ca.gov/waterrights/water_issues/programs/applications/groundwater_recharge/streamlined_permits.html

turn could allow for areas where surface water can be utilized for groundwater recharge (Dahlke et. al. 2018). Alfalfa is widely grown in Big Valley and flood irrigation is common. Alfalfa is a nitrogen-fixing plant that seldom receives nitrogen fertilizer, which reduces the risk of leaching excess nitrate to groundwater, one of the main concerns of AgMAR (Putnam and Lin 2016; Walley et al. 1996). Dahlke, H.E., Et. al. 2018 found that winter recharge had no discernible effect on alfalfa yield (first and second cutting) and led to increased crop water availability in the deep soil profile, offsetting potential irrigation deficits during the growing season.

Research currently being completed in Big Valley on the feasibility of AgMAR on perennial grass pasture and hay fields looks promising. Although soils in Big Valley have lower infiltration rates, winter recharge rates of 0.2 - 0.5 AF per acre per irrigation between March and April have shown no damage to crops. Soil infiltration rates show 2 to 3.5 inches of infiltration over a 24-hour period to be feasible. Irrigating every 7 to 10 days for six irrigations in the winter/spring would benefit 1 to 2 AF of water per acre into groundwater storage. This is the first AgMAR research completed on grass, which is a dominant perennial crop in Big Valley. Given that some forms of applied nitrogen, particularly nitrate, have a propensity for leaching, which has presented a challenge in other parts of the state, there has been some concern over nitrogen application and AgMAR. This can easily be addressed with BMPs of applying nitrogen outside of the winter recharge window. This work could also be easily applied to AgMAR feasibility on adjacent rangeland, conservation reserve project (CRP), or NRCS WRP land.

9.1.2 Drainage or Basin Recharge

Using the same principles as used in AgMAR, excess surface water can be diverted into irrigation drainages or canals and recharge basins to percolate into the groundwater table and replenish upper levels of the aquifer. This water is then available to be extracted at a later date for beneficial use. The volume of water recharged is limited by the availability and access to surface water, infiltration rates of the soils, losses to evaporation, and available infrastructure.

The total number of feet or miles of irrigation canals or ditches needs to be determined, along with the availability of current water storage basins (reservoirs) for recharge. Additional basins may need to be created for the sole purpose of groundwater recharge. Producers wanting to participate in this program would notify the GSA and report diverted water for the purpose of drainage or Basin recharge. The development of a water availability study and permitting as described on in **Table 9-3** also applies to this project. Unlined drainages, canals, and basins could recharge up to 90 percent of diverted surface water to the aquifer.

9.1.3 Aquifer Storage and Recovery and Injection Wells

Aquifer storage and recovery (ASR) is the use of a new or existing well to inject and store water underground during wet periods and then extract by the same or other nearly wells to meet demand during dry periods. Increased aquifer storage provides some of the same benefits as new surface storage but can be phased in over time and can be less expensive. From an operations perspective, increased aquifer storage is a practical option since it involves the use of new or existing groundwater wells retrofitted for injection. ASR projects require a permit from the RWQCB, and the permitting method is usually the Statewide ASR General Order (General Order)[67] adopted by the State Water Board in 2012.

The General Order requires that the water being injected into aquifer storage meet drinking water standards, so in the case of Big Valley, this will require filtration and chlorination of surface water prior to injection into aquifer storage.

Because pre-treatment of the water source for injection and operation and maintenance of ASR wells is relatively expensive, ASR is typically used when surface spreading *via* basins or flooded fields is not feasible. ASR may be favored in areas of the Basin constrained by land area limitations, unfavorable surface soils, or shallow confining layers at or near the ground surface preventing deep percolation of applied water.

In Big Valley, the most likely scenarios in which ASR would be implemented are when under the following conditions:

- Flood MAR projects are not able to stabilize groundwater levels in some location due to the presence of impermeable soils at or near the surface, or
- As mitigation to reverse declining groundwater levels near public or domestic supply wells.

ASR would be implemented in phases if the conditions above warrant it. ASR would only be feasible with outside funding assistance through either state or federal grant programs to both cover the capital expenses and assist with the monitoring required for compliance with the ASR General Order. Under these conditions, ASR will be developed in phases as summarized below:

- Phase 1 – Assessment of wells and hydrogeology culminating in a technical report to accompany a notice of intent to inject provided to the RWQCB. This phase will identify locations and monitoring during ASR pilot testing.
- Phase 2 – ASR pilot testing following receipt of a Notice of Applicability from the RWQCB. Pilot testing may include a single well test or may involve multiple wells throughout the Basin based on the finding and recommendations in the technical report developed in Phase 1.
- Phase 3 – Implementation including retrofit of existing wells, construction of new wells, and operation of these facilities to stabilize or increase aquifer storage.

More information about ASR is available from the U.S. Environmental Protection Agency.[68]

9.2 Research and Data Development

Data gaps are mentioned and detailed throughout the GSP chapters. Continuing to fill these gaps, participate in research, and collect data to support the GSP is necessary to support sustainability using the best science available.

---

[67] https://www.waterboards.ca.gov/water_issues/programs/asr/
[68] https://www.epa.gov/uic/aquifer-recharge-and-aquifer-storage-and-recovery

9.2.1 Additional Stream Gages and Flow Measurement

Several seasonal streams contribute inflow to the Big Valley Basin (**Figure 9-2**). Many of these streams had historical stream gages or have current gages monitored by the USGS and DWR. The Pit River, which is a major inflow river and significant contributor of surface-water irrigation and recharge in Big Valley, has a gage 13 miles from where the Pit River enters Big Valley at the Canby bridge. There are many springs and small tributaries that flow into the Pit River after the Canby bridge, as well as irrigated-lands water use between Canby and the Big Valley Basin. Modoc County has been working to install an additional stream gage where the Pit River enters the Basin to fill this data gap and provide more current stream flow information for GSP development and water management. There is also funding for additional stream gages if locations of need can be determined. The current and proposed stream gages are in **Figure 9-2**.

9.2.2 Refined Water Budget

Many assumptions were taken to create the Big Valley water budget in Chapter 6 – Water Budget. Some of these assumptions stem from data gaps that need to be addressed, and other areas are opportunities to collect and analyze data that is being submitted through other regulatory programs. This section describes a combination of projects that will help improve the accuracy of the water budget and, in turn, better inform groundwater management in Big Valley.

There is currently no Agri-Climate or CIMIS station located in Big Valley. Nearby stations in other basins have helped to create models to determine averages, but significant geologic features affecting elevation often make weather patterns unpredictable from nearby basins. These stations have more sensors than typical weather stations, including solar radiation, soil temperature, air temperature, wind speed and direction, relative humidity, soil moisture, and rain gauging. These measurements can determine accurate ET, which is very helpful in creating a more refined water budget for the Basin and help maintain sustainable groundwater conditions. ET is used as a metric for applied water, especially when meters on actual applied water are not available. These stations can also help farmers in determining irrigation needs and promote water conversation, particularly early in the growing season.

With an accurate estimate of ET, the next assumption is the relationship between ET and applied water in Big Valley. Since most crops grown in Big Valley are hay crops, irrigation must be stopped when cutting, drying, and baling even though ET continues. Pinpointing the relationship between ET and applied water could greatly refine the water budget and amount of irrigation water that is being applied.

An effort to refine mapping and land-use designations would further increase the accuracy of estimates related to water use within Big Valley. The water budget's assumptions are primarily derived from existing sources, many of which may need to be updated or expanded upon to reflect current conditions. LandIQ has been a primary tool in estimating irrigated acres, although there is some inaccuracy related to the land classifications which field studies could address.

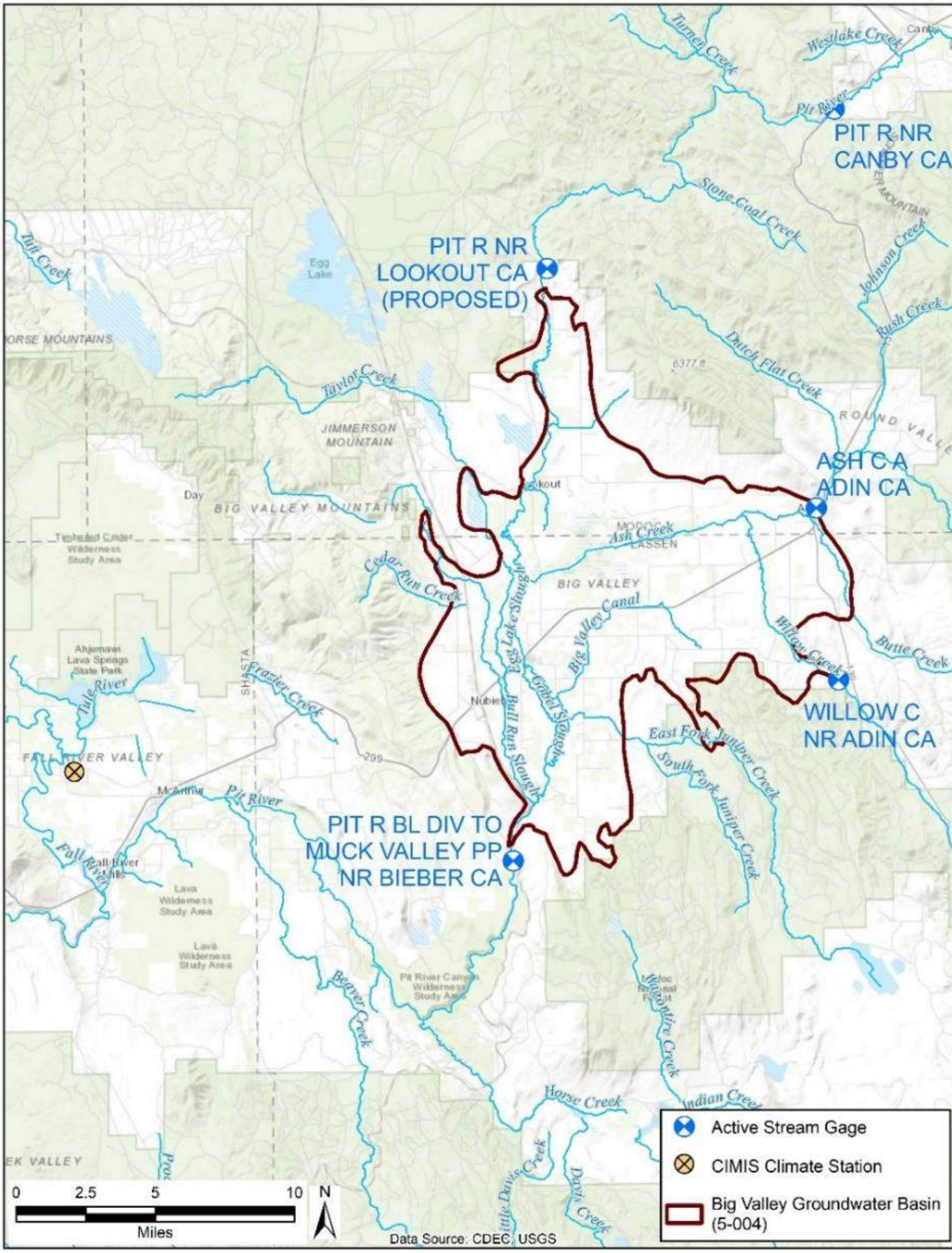


Figure 9-2 Current and Proposed Stream Gages

A voluntary well monitoring program has been available in Big Valley for upwards of two decades through the Lassen-Modoc Flood Control and Water Conservation District.[69] Reinvigorating this program by identifying meters that need to be replaced, conducting outreach to add new wells to the program, and organizing the historical data fills a data gap and provides critical data to refine the water budget and pinpoint areas of concern. Meters are available for agricultural and domestic water users. Funding from DWR in a grant to Modoc County is currently available to provide well meters to voluntary applicants. Further, it would be beneficial to identify additional monitoring wells to provide unobstructed measurements year-round. Several such wells have been installed at five sites within the Basin and generate monthly data across 15-minute intervals. Expanding on this existing program would further refine the water budget.

Additionally, funding is available to install satellite transducers in key areas throughout the Basin, which would allow for real-time monitoring of domestic well levels. Coupled with an increased effort to both verify well numbers and update lists to reflect active *versus* inactive wells, these real-time monitoring locations will provide more accurate estimates of domestic groundwater demand and supply within the Basin. Thus, these combined actions will further inform water management strategies to ensure that domestic users' groundwater needs are represented equitably in the water budget.

Collectively, the continuation of applied research efforts will help to better quantify the impacts from those actions and thus help refine the water budget. Such research efforts, which will be discussed in depth in later sections of this chapter include: evaluating the effectiveness of off-season groundwater recharge in hay crop fields and pastures; the impacts of forest thinning projects such as fuels reductions and the removal of invasive junipers on water availability within the watershed; and the extent to which surface-water systems, including drainages, canals, and reservoirs contribute to recharge within the Basin. Additional research projects to support the water budget will be identified and undertaken as needed, contingent on funding.

9.2.3 Adaptive Management

There are many unknowns and data gaps with respect to groundwater resources in the Big Valley Basin. As a result, estimates and assumptions are currently used in the plan to determine several key variables. To address the lack of necessary information, a significant commitment to the continued monitoring of both ground and surface water is described in this plan. By further developing and enhancing monitoring networks in Big Valley, we can gather the data necessary to inform management and set criteria as more information becomes available.

Adaptive management is an approach to improve natural resource management which focuses on learning by doing. Learning occurs through monitoring, data development, outreach, and collaborative interpretation. Then, the adaptation of management criteria and tools is applied to existing practices as critical information becomes available. This approach is very applicable to the BVGB and will serve as a bridge towards sustainability by providing current site-specific information to inform appropriate

[69] Lassen-Modoc County Flood Control and Water Conservation District

SMCs and thresholds as well as the ongoing assessment of projects and management actions in the Basin.

Although it is recognized and proven that the Big Valley Basin does not have the unsustainable conditions seen in other basins around the state, monitoring and filling data gaps from SMCs that were determined to not require thresholds helps us prepare for annual reports and five-year revisions and make management decisions. These SMCs without identified thresholds include interconnected surface water and groundwater, water quality, and subsidence. Additionally, monitoring could aid in the analysis of the relationship between groundwater levels and GDEs.

9.3 Increased Surface-water Storage Capacity

Increasing the capacity to store surface-water runoff during winter/spring high-flow periods could provide significant amounts of water for summer irrigation. An increase in surface water available for irrigation would lessen the reliance on groundwater and thus remain sustainable.

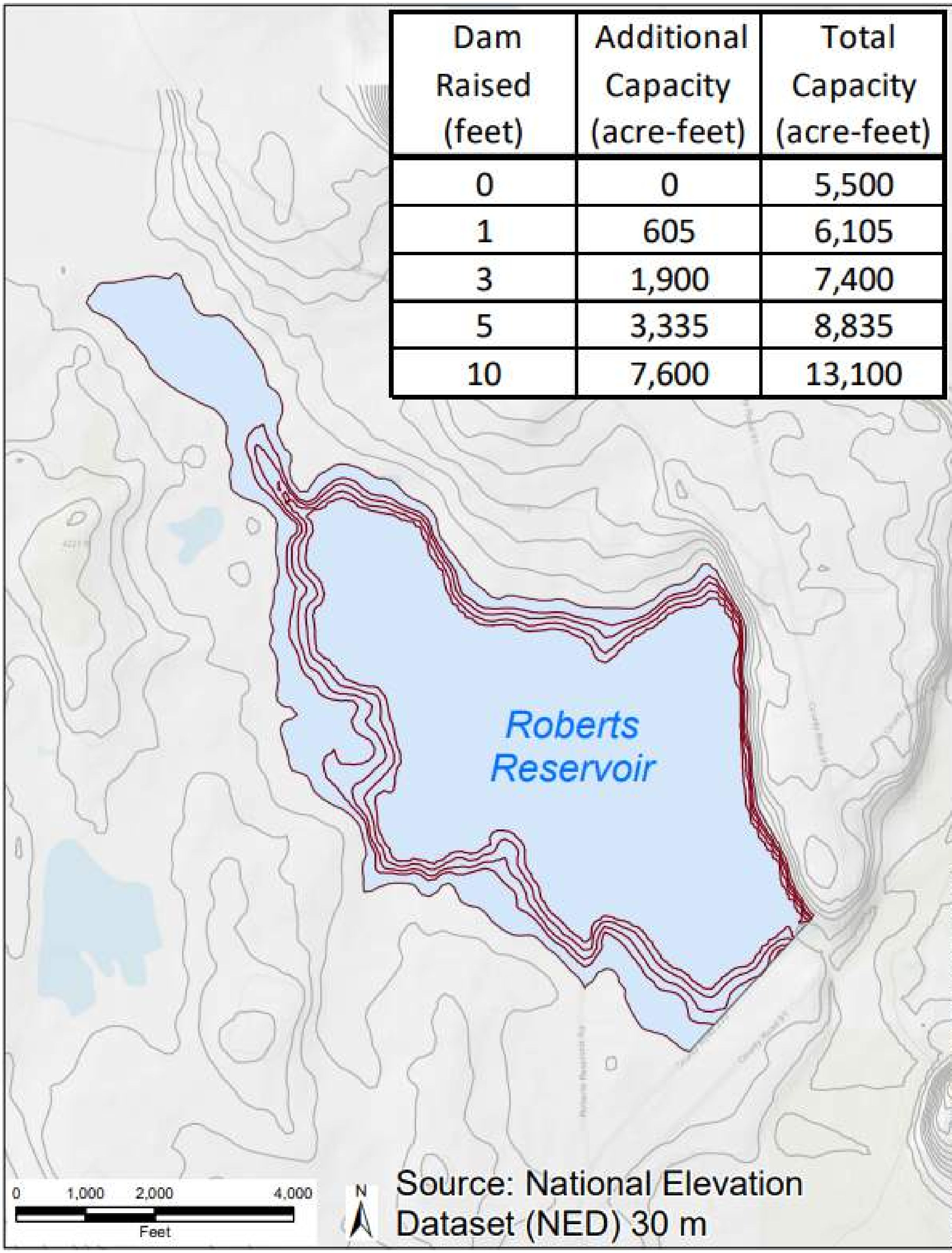
9.3.1 Expanding Existing Reservoirs

Expansion of several existing reservoirs serving Big Valley Basin would increase the capacity of surface water for irrigation and recharge projects, as well as help balance the water budget. An increase in water storage would make the Basin more sustainable regarding climate variability and decreases in snowpack while also relieving pressure on groundwater for irrigation in Big Valley. One larger reservoir, Roberts Reservoir, is located northeast of Lookout and has a current capacity of 5,500 AF. Possible scenarios for raising this reservoir's dam are shown in **Figure 9-3**. For example, raising Roberts Reservoir 3 feet would increase capacity 1900 AF, an increase of 35 percent.

Other reservoirs include Iverson, Silva, and BLM reservoirs. From an engineering perspective, the base of the Iverson reservoir is much wider than it needed to be at the time it was built. This suggests that the foundation would easily support construction to increase its height.

Expanding current reservoirs may possibly be the most time- and cost-effective alternative for expanding surface-water storage compared with building new reservoirs, for which navigating the environmental review process and other regulations can be difficult.

All reservoir expansion projects would undergo three phases. Phase 1 examines the feasibility of the proposed project and planning. Engineering, permitting, and project design take place during Phase 2. Phase 3 covers implementation and construction of the proposed project. Reservoir expansion is typically done through either sediment removal or by physically raising the height of the dam. Typically, expanding reservoirs through sediment removal is very costly, between "8,000 and 32,000 dollars per acre foot" and would be done very infrequently (Lund 2014). Raising dam heights or building new reservoirs is also expensive; an acre foot of storage space generally costs between "1,700 and 2,700 dollars" (Lund 2014). Depending on funding, sediment removal may be investigated, and removed sediment could potentially be repurposed to reinforce existing infrastructure such as the levees that protect Bieber and Lookout from Pit River flood events.



Dam Raised (feet)	Additional Capacity (acre-feet)	Total Capacity (acre-feet)
0	0	5,500
1	605	6,105
3	1,900	7,400
5	3,335	8,835
10	7,600	13,100

Figure 9-3 Roberts Reservoir Scenarios

9.3.2 Allen Camp Dam

The Allen Camp Dam and Reservoir (**Figure 9-4**) was authorized by the Department of the Interior (DOI) as part of the Allen Camp Unit of the Central Valley project in 1976 to regulate flows of the Pit River primarily for irrigation and fish and wildlife purposes, as well as flood control and recreation services. The DOI published a report (DOI 1981) that concluded that based on the existing criteria the proposed project was economically inadvisable, it may be appropriate to conduct a new investigation into the feasibility of this project to reflect the changes to water needs of the community, environment and state that have occurred over the last 40 years.

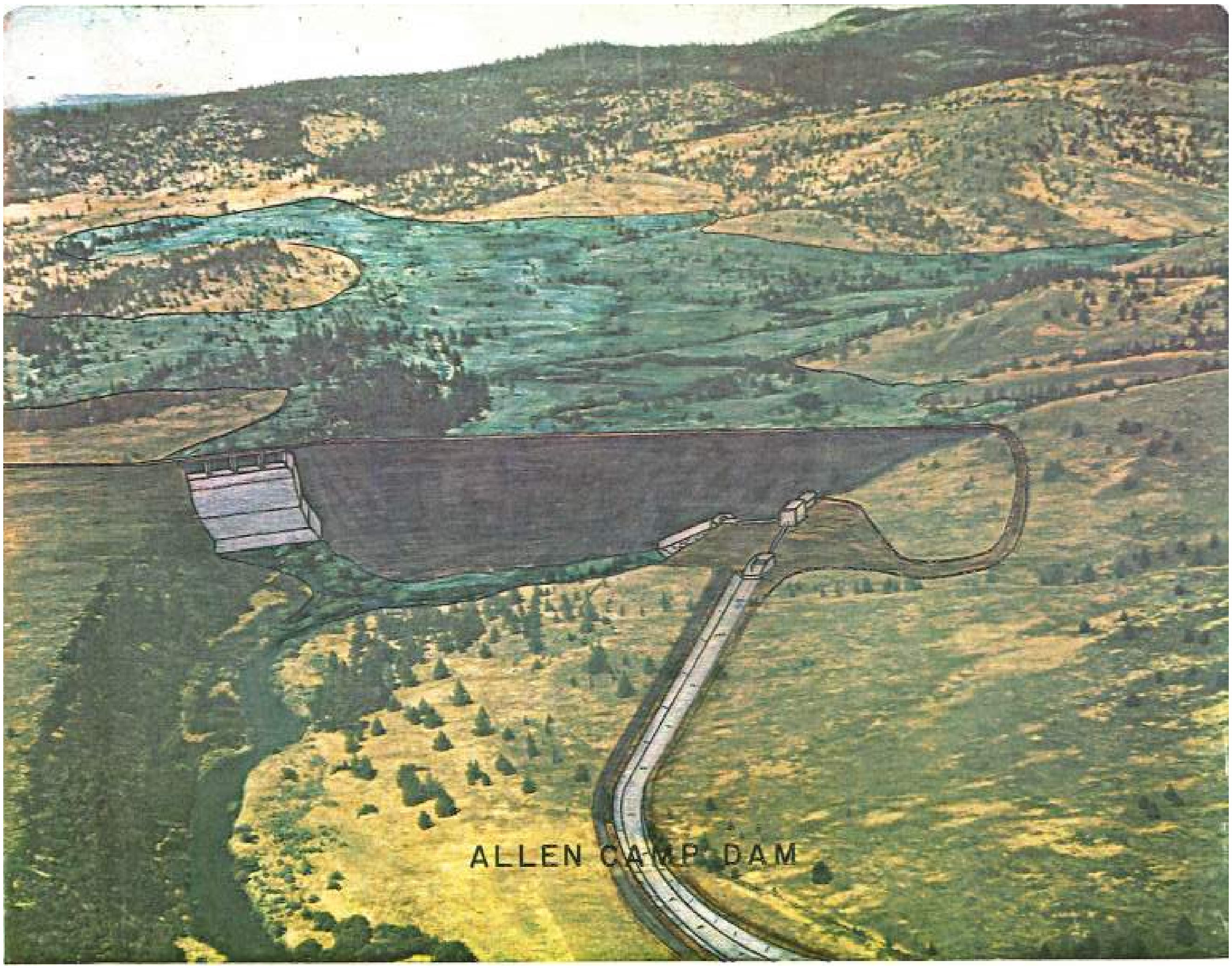


Figure 9-4 Allen Camp Dam Drawing

According to the original feasibility study (DOI 1981) the dam would be located around 11 miles north of the Modoc-Lassen County line, Allen Camp Reservoir would have a 90,000-AF storage capacity, a 18,000-AF surcharge, 2,350 acres of water surface area and a normal year yield of 22,400 AF. The dam would be constructed from earth and rock fill and would measure 103 feet from the streambed. The construction of the various proposed project components would require the acquisition of about 18,240 acres of private land through easements or through fee titles and the withdrawal of roughly 11,845 acres of public land. Most of the land acquired would be allocated for the dam and reservoir project features, a total of 18,015 acres. In the original document, another significant allocation, 11,562 acres, was for the proposed Big Valley National Wildlife Refuge. This addition was intended to offset habitat loss for species such as deer and migratory waterfowl. An updated feasibility study for this project should consider the expansion of the Ash Creek Wildlife Refuge since 1970 as an alternative for this proposed mitigation measure. The remaining land would be partitioned at 355 acres for the Hillside Canal, 148 acres for the lateral distribution system and 5 acres for the Nubieber protective dike.

In 1981, there were 62 ownerships slotted to receive deliveries from this project, accounting for a total 11,700 irrigable acres all of which would benefit from full or supplemental water deliveries. The report stated that the groundwater basin area of the project has a storage capacity of roughly 532,000 AF with a safe yield of 7,000 AFY, with 5,000 AF of that developed. These numbers may have changed over the 40 years that have elapsed since the report was published and should be reviewed under an updated feasibility study. An increasingly variable climate casts uncertainty over water availability, with drier years driving an increased reliance on groundwater supplies. Further, an updated feasibility study might consider how this project could mitigate some of the effects of climate variability and watershed conditions on the BVGB by providing a reliable source of surface water, thereby reducing dependence on groundwater.

9.4 Improved Hydrologic Function and Upland Recharge

9.4.1 Forest Health / Conifer and Juniper Thinning

The watershed surrounding the Big Valley Basin is comprised of approximately 800,000 acres of conifer forest and rangeland (**Figure 9-5**). Management policies have resulted in tree densities that are currently much higher than at the beginning of the 20th century. This includes western juniper and other mixed conifers (Stephens et al. 2016) (Miller and Tausch 2001).

There are two main mechanisms by which dense junipers and other conifers impact water availability in forested watersheds. First is the interception of snow (primarily) and rain that gets caught in branches and needles and evaporates before ever reaching soil surface, and second is the high rate of transpiration due to dense layered canopy and vigorous network of roots (Ryel and Leffler 2011). An excellent summary paper by Smerdon et al. (2009) describes linkages between forest health and tree density and groundwater recharge in a variety of landscapes.

Spring snow water content ranged from 33 to 44 percent higher in the aspen and an open meadow snowpack telemetry (SNOTEL[70]) site *versus* adjacent juniper and conifer forest, where interception of snowfall was much higher (LaMalfa and Ryel 2008). Averaged over the entire catchment, strategically placed fuel treatments in the wetter central Sierra Nevada (American River) creating a relatively light vegetation decrease (8%), resulted in a 12 percent runoff increase, averaged over wet and dry years. With forest treatments, wildfire reduced vegetation by 38 percent and increased runoff by 55 percent. Without treatments, wildfire reduced vegetation by 50 percent and increased runoff by 67 percent.

[70] SNOTEL is an automated system of snowpack and related climate sensors operated by the NRCS of the USDA in the Western U.S.

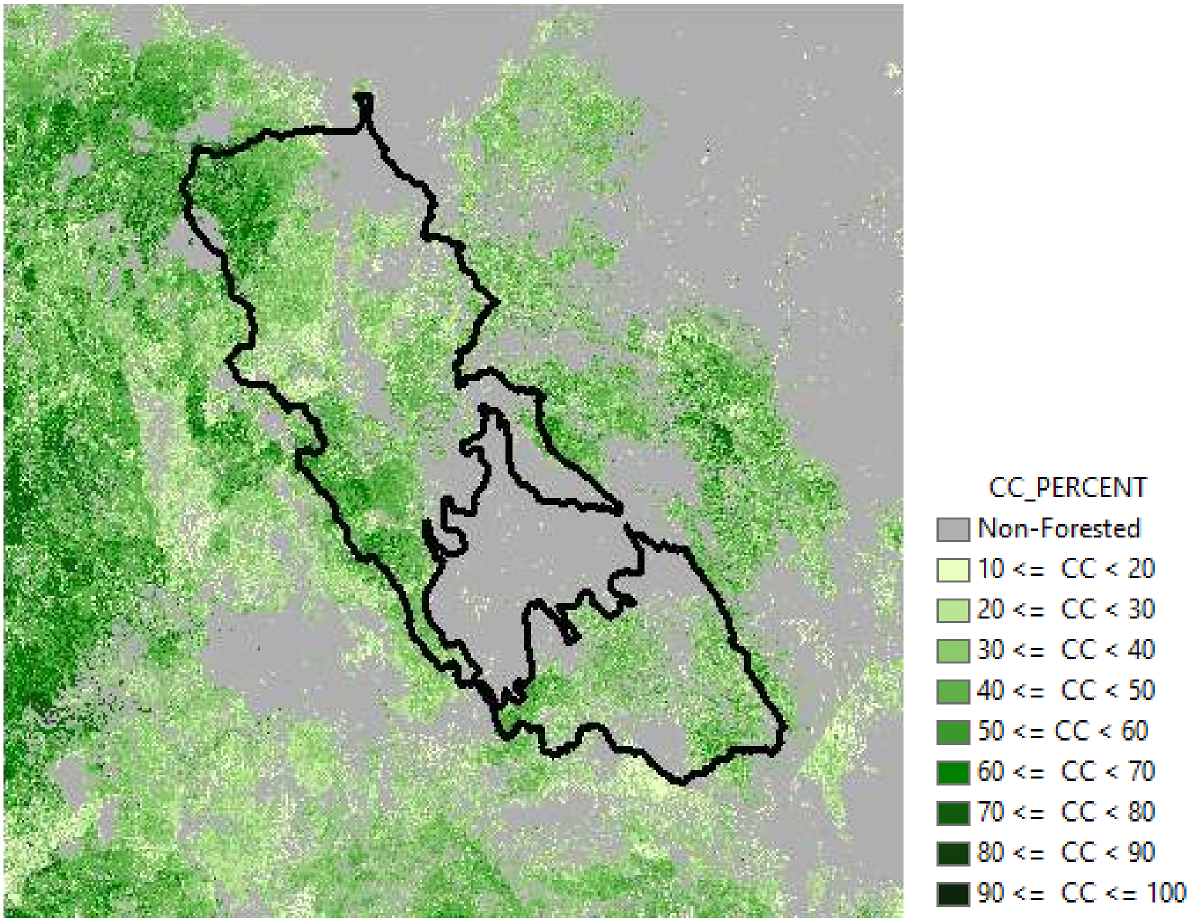


Figure 9-5 Canopy cover percentage of forested areas within the Big Valley watershed

Forest fuel reduction in drier sites in the southern Sierra had less increase in runoff than wetter sites in the central Sierra Nevada Range. (Saska 2019).

A similar increase in water availability has been documented on juniper-invaded rangelands. During the period of maximum water uptake, mature trees used between 45 and 69 times more water than juniper saplings depending on precipitation and, consequently, soil water availability. In summary, 1) juniper water use varies greatly with precipitation, and 2) because of the large difference between mature and sapling trees, juniper control results in considerable water savings, even after a 14-year period of juniper regrowth (Mata-Gonzales, et al. 2021). Paired watershed studies in Oregon have demonstrated increased deep soil moisture, increased spring flow, and increased surface-water runoff after juniper harvest compared to untreated areas. They have also documented a hydrologic connection between shallow groundwater on juniper sites and a nearby riparian valley (Ochoa et. al. 2016).

The opportunity to enhance upland watershed recharge is significant as projects are already in planning and implementation stages to reduce fire risk and improved wildlife habitat (Miller 2001), and programs such as CAL FIRE’s Forest Health Program support project implementation funding. Forest health projects can be developed and meet multiple resource objectives including hydrologic values. Removal of conifers from meadow edges, drainages, and spring areas, as well as improving hydrologic function of road crossings, ditches, and stream channels (where feasible) will enhance hydrologic and recharge benefits of forest health projects. Given the vast land area surrounding Big Valley, treatment of even a fraction of the land area would result in a significant amount of recharge. This could help mitigate any deficit. Recently, controlled burns and fuels reductions have gained considerable traction as forest management tools and could be utilized for the purposes discussed.

9.4.2 Stream Channel Enhancement and Meadow Restoration

Several meadow restoration techniques exist for the purpose of returning proper hydrologic function to montane and rangeland meadows. Two commonly used in the Big Valley Basin and surrounding uplands include pond and plug and beaver dam analogs. Both techniques result in reconnection of a stream channel with a functioning floodplain and restoration of a degraded meadow's water table up to its historic level. Restoration of the meadow water table results in re-watering of meadow soils and vegetation, with significant effects throughout the restored floodplain for meadow hydrology, wildlife use, and forage. Restored floodplain connectivity spreads flood flows so that a meadow's natural ability to settle the coarse or fine sediment delivered from steeper stream reaches is restored and natural percolation can occur. When floodplain function is restored, a portion of winter and spring runoff is stored in meadow soils rather than racing down the pre-project gully during the runoff season. Data indicates that release of this stored runoff results in increased stream flow in late spring. (Hunt et. al. 2018)

In mountains of the western U.S., channel incision has drawn down the water table in many meadow floodplains. Increasing climate variability is resulting in earlier melt and reduced snowpack, and water resource managers are investing in meadow restoration which can increase springtime storage and summer flows. Between 2012 and 2015, during a record setting drought, a pond and plug restoration in Indian Valley in the Sierra Nevada Mountains was implemented and monitored. Despite sustained drought conditions after restoration, summer base-flow from the meadow increased 5 to 12 times. Before restoration, the total summer outflow from the meadow was five percent more than the total summer inflow. After restoration, total summer outflow from the meadow was between 35 and 95 percent more than total summer inflow. In the worst year of the drought (2015), when inflow to the meadow ceased for at least one month, summer base-flow was at least five times greater than before restoration. Groundwater levels also rose at four out of five sites near the stream channel. Filling the incised channel and reconnecting the meadow floodplain increased water availability and streamflow, despite unprecedented drought conditions. (Hunt et. al. 2018)

Other studies have also shown that these techniques may increase surface and subsurface storage and groundwater elevations that contribute to channel complexity and residence times. These factors could lead to stronger flow permanence in channels subject to seasonal drying. Increased availability of water and productivity of riparian vegetation can also support human uses in arid regions, such as irrigation and livestock production. (Pilliod et. al. 2018)

9.5 Water Conservation

9.5.1 Irrigation Efficiency

The fundamental objective of an irrigation system is to deliver an optimum amount of water for crop growth during spring, summer, and fall growing seasons while temperature and daylength are conducive to plant growth but natural precipitation is lacking. Irrigation water and water application costs comprise the single biggest operational cost associated with alfalfa or grass hay production in the intermountain area, accounting for approximately 30 percent of total operating costs (Wilson et al. 2020) (Orloff et al. 2016). Increasing the efficiency of crop water use is an economic, as well as a conservation-minded, goal. Farmers in the Big Valley area have been adopting water conservation measures as feasible opportunities arise and will continue to do so. Support for infrastructure, new technology, and education outreach will help attain this goal.

Flood, wheel-line, and center pivot irrigation systems are all used on Big Valley farms. The best irrigation system depends on water availability, crop, soil type, and infrastructure. Commonly, center-pivots are rated as the most efficient systems, but there are appropriate uses for all three types. Many advancements in irrigation efficiency have been made and will continue to be developed and implemented. It is critical that implementation is done at a farm-by-farm basis in such a way as to fit specific conditions and production systems. A one-size-fits-all approach, such as SGMA, will be neither effective nor economically viable for the BVGB.

It is important that any irrigation system be well-maintained to operate properly. Flood-irrigated fields should be appropriately leveled with appropriate width and length of irrigation check to provide for a uniform application of water. Sprinkler systems should be regularly checked for function and be designed with the right nozzle size for available flow and pressure. Systems that can utilize larger diameter nozzles can reduce droplet size and evaporation loss. Length of irrigation set should make use of soil water-holding capacity without incurring excessive tailwater. Specialized systems such as Low Energy Sprinkler Application can improve water use efficiency up to 15 percent. Length of irrigation set should make full use of soil water-holding capacity without incurring excessive runoff.

To optimize efficiency of water use, the amount and timing of irrigation water applied should closely match the amount of water needed by the crop, thus maintaining adequate soil moisture for crop growth while minimizing tail water runoff. Effective use of irrigation technology such as soil moisture sensors, tracking of evapotranspiration, flow meters, etc. are available to help farmers manage irrigation timing and length of set to get the most of their irrigation system. These irrigation efficiency techniques are already being used in the BVGB.

Genetic selection and the continued improvement of forage crop species has resulted in the increased availability of drought tolerant, heat tolerant, or short-season forage grasses that may provide growers with viable alternatives in certain situations, where water availability is otherwise limited. Crop selection is often based on the best fit for a particular soil depth, soil texture, and water availability, in conjunction with value and marketability. Although Big Valley cropping systems are heavily constrained by climate and growing season, ongoing forage crop improvement may provide growers with a wider range of species and variety options.

Overall good agronomic practices in terms of soil fertility, weed control, harvest, etc. are critical and promote an efficient use of all resources, including water. As mentioned in other places in this plan, agricultural fields and farms provide important wildlife habitat in the valley. Irrigated lands are an important part of the overall landscape. A good example is that flood irrigated pastures are highly valued by migratory birds, particularly in the spring. Emphasis on water efficiency is important but should not become such a single-focused objective that other resource values or farm profitability are ignored.

It should be clear that efficient use of water for irrigated forage crop production is multi-faceted, and several small improvements, strategically coupled together to fit on-farm conditions, are the most effective approaches. To this end, education outreach *via* U.C. Cooperative Extension, technical support from NRCS, and cost-share and grant programs are all critical to supporting water use efficiency measures. Support and incentive programs that have been used and can be further expanded upon in Big Valley are listed in **Table 9-1** (funding program table).

9.5.2 Landscaping and Domestic Water Conservation

While Big Valley is extremely rural and economically disadvantaged, there are opportunities to enhance water conservation among domestic water users, particularly regarding domestic landscaping, use of native drought adapted plants, irrigation timers, effective mulch, and rainwater/snow water catchments to reduce water requirements. Low-water landscaping can also be integrated with homeowner firesafe planning. Landscaping guides for homeowners can be distributed at public centers and at regional garden supply stores (Hartin et. al. 2014) (California Native Plant Society, 2021).

9.5.3 Illegal Diversions and Groundwater Uses

As detailed in Section 3.3 – Land and Water Use, water use for illegal activities (i.e., unlicensed marijuana cultivation) occurs in the Basin and surrounding watershed. Lassen and Modoc County staff have limited time and resources to address this issue, but they do actively enforce their local cultivation ordinance (which does not allow for commercial marijuana cultivation) Staff in Lassen County conduct areal patrols and utilize high-resolution aerial imagery from an imaging contractor as part of their effort to identify and abate illegal cultivation. Unfortunately, federal and state agencies responsible for taking enforcement action against illegal marijuana grows in their jurisdictions (e.g., on public lands or when illegally diverting surface water) have not been aggressive in identifying and removing said illegal grows in the Basin and watershed. That said, when county resources are available, staff will continue to work in the field and with their imaging contractors to identify and abate illegal marijuana cultivation on private land. County staff will continue to report cultivation activities outside of their purview to the BLM, USFS, CDFW, State Water Board and the Bureau of Cannabis Control. The GSAs will rely on these agencies to take an aggressive approach in Big Valley with the objective of eradicating the Basin and watershed of illegal groundwater pumping and surface-water diversions.

9.6 Public Education and Outreach

The GSAs believe that public education and outreach are an important component of this GSP. Education can change use patterns that promote water conservation and protection of water resources. The GSAs support continued education on preventing illegal dumping, illegal marijuana growers, properly sealing abandoned wells and BMPs. Continued outreach to support the coordination of efforts and information sharing, fostering relationships with relevant agencies and organizations and attending meetings with local and regional groups involved in water management are also important. This includes increasing public outreach about funding opportunities and programs that support water conservation methods, increased recharge and mediation opportunities for decreasing water levels. **Table 9-1** lists current state and local funding sources that can be targeted to support project planning and implementation. More information on public outreach and communication can be found in Chapter 11 – Notice and Communications.

Outreach methods that can be expanded include radio public service announcements, cooperator workshops with University of California Cooperative Extension (UCCE) and social media posts informing the public about upcoming meetings and deadlines, BMPs, plan updates, recharge opportunities and updated water conditions. An organized effort to compile recharge and conservation activities would aid GSAs in tracking impacts for future Plan revisions.

10. Implementation Plan

GSP implementation generally consists of five categories of activities:

- GSA Administration and Public Outreach
- Monitoring and Data Management
- Annual Reporting
- Plan Evaluation (five-year updates)
- Projects and Management Actions

This chapter contains discussion of the details for each of these activities, then sets forth a schedule for implementation, estimates costs of implementation and discusses funding alternatives.

10.1 GSA Administration and Public Outreach

The nature of GSA administration is not addressed explicitly in the GSP Emergency Regulations. Much of the work to implement portions of the GSP (e.g., monitoring and projects and management actions) must be performed by outside entities such as DWR and hydrology professionals. However, this work will need to be coordinated by the GSAs, and some work will need to be performed by GSA staff.

One category of work that rests on GSAs' shoulders is public outreach. The level of effort needed from GSA staff depends greatly on the details of public outreach discussed in Chapter 11 – Notice and Communications. In addition to the public outreach performed during GSP development, Regulations (§354.10(d)) require GSAs to develop a communication section of the plan that includes the following:

(1) An explanation of the Agency's decision-making process

(2) Identification of opportunities for public engagement and a discussion of how public input and response will be used

(3) A description of how the Agency encourages the active involvement of diverse social, cultural and economic elements of the population within the basin

(4) The method the Agency shall follow to inform the public about progress implementing the Plan, including the status of projects and actions

Chapter 11 will contain the Communications and Engagement Plan, but the requirements of the Regulations are presented here for awareness by GSA staff to refine this chapter and understand the level of effort and expense that will be required for this component of GSP implementation. Decisions will need to be made regarding whether the BVAC continues as a functioning body after completion of the GSP. If the BVAC continues, what role they take and how often they meet will determine the level of GSA staff effort needed to facilitate BVAC meetings and activities.

10.2 GSP Annual Reporting

According to §356.2 of the Regulations, the Big Valley GSAs are required to provide an annual report to DWR by April 1 of each year following the adoption of the GSP. The first Annual Report will be provided to DWR by April 1, 2022, and will include data for the prior WY, which will be WY 2021 (October 1, 2020 – September 30, 2021). While the WY as defined by DWR isn't ideal for use in Big Valley, because it doesn't correlate with the growing season or surface-water irrigation season in Big Valley, the GSAs will assemble data based on DWR's definition as per SGMA statute and regulations. The Annual Report will establish the historic conditions of groundwater within the BVGB, the status of the GSP implementation and the trend towards maintaining sustainability. Unfortunately, while conditions won't differ significantly from when the GSP was developed, the GSAs are still required to submit the Annual Report to comply with GSP regulations. A general outline is included below:

- General Information
    - Executive Summary
    - Introduction (1 map of Basin)
- Basin Conditions
    - Groundwater Elevations (2 contour maps, 12 hydrographs)
    - Estimated Groundwater Extractions (1 table from water budget)
    - Estimated Surface-water Supply (1 table from water budget)
    - Estimated Total Water Use (1 table from water budget)
    - Estimated Change in Groundwater Storage (2 maps, 1 graph and 1 table)
- GSP Implementation Progress
    - Progress Toward Measurable Objectives
    - Updates on Projects and Management Actions

Another way to organize this requirement, and for GSA staff and stakeholders to understand the level of effort and expense involved in developing annual reports, is to outline major technical tasks. Much of the effort to develop the annual reports is to take available data collected by outside agencies, generate figures based on that data and then re-submit to DWR. Below is a summary outline of tasks to be performed by GSA staff and/or consultants to develop the annual report:

- Download Water Level Data from state website and generate:
    - Hydrographs for 12 representative wells
    - Assumed spring and fall groundwater contours
    - Assumed groundwater difference contours (e.g., fall 2020 to fall 2021)
- Download water budget data from state websites[71]
    - Run water budget for the WY and generate estimates of:
        - Groundwater extractions

[71] This includes precipitation and reference evapotranspiration (ETo) from CIMIS and streamflow data from CDEC, BVWUA, Brookfield Energy, and other sources.

- Surface-water supply
- Total water use

- Assemble and write Annual Report, including the estimates and assumptions
- Upload report and data, including the estimates and assumptions, to state website

10.2.1 General Information

In accordance with §356.2(a), each Annual Report will include, at the front of the report, an executive summary that will summarize the activities and the condition of groundwater levels within the BVGB for the prior year. The executive summary shall also include a map of the BVGB, its GSAs and the monitoring network.

The Annual Report will include an introduction that will describe the following:

- A description of the BVGB and the two GSAs
- The general conditions of the BVGB for the prior WY (precipitation, surface-water allocations, crop demands, municipal demands, etc.)
- Any significant activities or events that would impact the water supply and/or groundwater conditions for the BVGB

10.2.2 Basin Conditions

Included in the Annual Report will be a discussion of specific local water supply conditions per §356.2(b). This section will provide a description of the water supply conditions for the WY being reported along with a graphical representation of the conditions. A WY shall be defined as the 12-month period starting October 1 through September 30 of the following year. Water supply conditions that will be discussed include:

- Assumed Groundwater Elevations – elevation data from the monitoring network, including hydrographs for the representative wells and groundwater contours for spring and fall
- Assumed Groundwater Extractions – groundwater pumping estimates and measurements for agricultural, municipal, domestic and industrial[72] pumping; generated from the water budget
- Assumed Surface-water Supply – data from surface-water supplies to irrigation demand,[73] conveyance losses and groundwater recharge; generated from the water budget
- Assumed Total Water Use – total water uses by agricultural, municipal, domestic and industrial sectors; generated from the water budget
- Assumed Change in Groundwater Storage – a determination of the groundwater (volumetric) change; calculated from groundwater difference contours and/or the water budget

[72] This includes both in-basin industries as well as fire, wildlife, logging, and construction (which use both surface and groundwater).
[73] Summer flows in the BVGB are 100% allocated under existing water rights.

10.2.3 Plan Progress

The Annual Report also needs to describe the progress of the Plan since the previous report, including progress in maintaining measurable objectives and status of projects and management actions.

10.3 Data Management System

The Regulations require a data management system (DMS), but do not give strict guidance on format or how to develop and maintain the DMS. §352.6 of the Regulations states:

> Each Agency shall develop and maintain a data management system that is capable of storing and reporting information relevant to the development or implementation of the Plan and monitoring of the basin.

The DMS proposed for Big Valley is separated into two categories: data for annual reports and data for GSP updates, much of which is taking data already managed by the state and returning it to the state in a new format.

10.3.1 Annual Report DMS

Annual reports require water-level data and other data to update the water budget. **Table 10-1** lists the data needed and the sources of those data. The DMS can be stored using common software (Microsoft Excel and ArcGIS) on GSA servers. Water-level data will be downloaded from the state website[74] and stored in an Excel hydrograph spreadsheet tool. This tool will store the well information, water level data, WY types and sustainable management criteria (minimum thresholds and measurable objectives). The tool will allow users to generate hydrographs and provide the data needed to generate contours. **Figure 10-1** shows a screenshot of the Excel Water Level Tool for storing water well and water level data and generating hydrographs.

Table 10-1 Annual Report DMS Data Types

Data Type	Collecting Entity	Data Source	DMS Tool
Water Levels	DWR	SGMA Data Viewer	Excel Water Level Tool
Precipitation	DWR	CIMIS	Excel Water Budget Tool
Evapotranspiration	DWR	CIMIS	Excel Water Budget Tool
Streamflow (gages)	USGS/DWR	CDEC	Excel Water Budget Tool
Streamflow (water rights reporting)	State Water Board	eWRIMS	Excel Water Budget Tool
GIS Base Data[1]	GSAs	various	GIS Database

Notes:
[1]Base data includes GIS layers such as the county boundaries, streams, roads, well locations, etc., which generally don't change over time and don't need to be updated.
CDEC = California Data Exchange Center

Water budget data will also be stored in an Excel spreadsheet tool as shown in **Figure 10-2**. Each of these spreadsheet tools has instructions, sheets to store raw data and sheets that perform calculations and generate the needed figures for annual reports or other purposes.

[74] Currently water level data for Big Valley is being managed and stored through DWR's CASGEM system. Once the GSP is completed, the data will be brought into DWR's new SGMA Portal Monitoring Network Module (MNM). Data from either of these systems is available through the SGMA Data Viewer.

Annual reports require maps, which are generated with widely-used ArcGIS software. The geographic information system (GIS) data, including base data such as streams, roads and well locations, will be organized into a folder structure as shown in **Figure 10-3**. Water level data will be imported into GIS to generate contours for annual reports.

10.3.2 GSP Update DMS

Additional types of data are needed to update the GSP, listed in **Table 10-2**. Much of this additional data is GIS-based and will be stored in the GIS database, shown in **Figure 10-3**. Water quality data will need to be downloaded from the State Water Board's GAMA groundwater system in 2026 to support the five-year update.

Table 10-2 GSP Update DMS Data Types

Data Type	Collecting Entity	Data Source	DMS Tool
Water Levels	DWR	SGMA Data Viewer	Excel Water Level Tool
Precipitation	DWR	CIMIS	Excel Water Budget Tool
Evapotranspiration	DWR	CIMIS	Excel Water Budget Tool
Streamflow (gages)	USGS/DWR	CDEC	Excel Water Budget Tool
Streamflow (water rights reporting)	State Water Board	eWRIMS	Excel Water Budget Tool
Water Quality	State Water Board	GAMA	Data to be downloaded for five-year update.
Land Use	DWR	SGMA Data Viewer	GIS Database
Subsidence (InSAR)	DWR	SGMA Data Viewer	GIS Database
GIS Base Data[1]	GSAs	various	GIS Database

Note:
[1] Base data includes GIS layers such as the county boundaries, streams, roads, well locations, etc., which generally don't change over time and won't need to be updated.

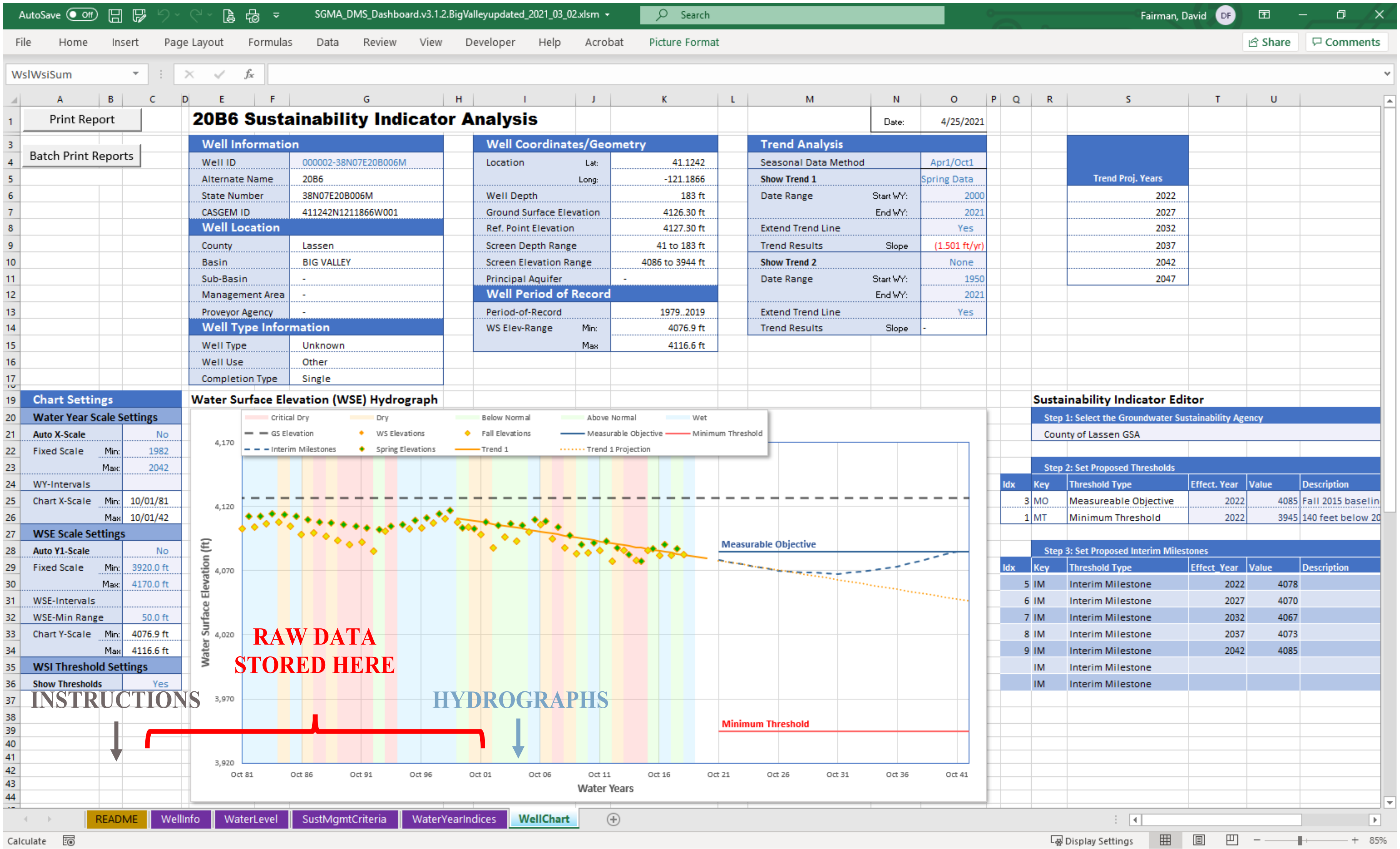
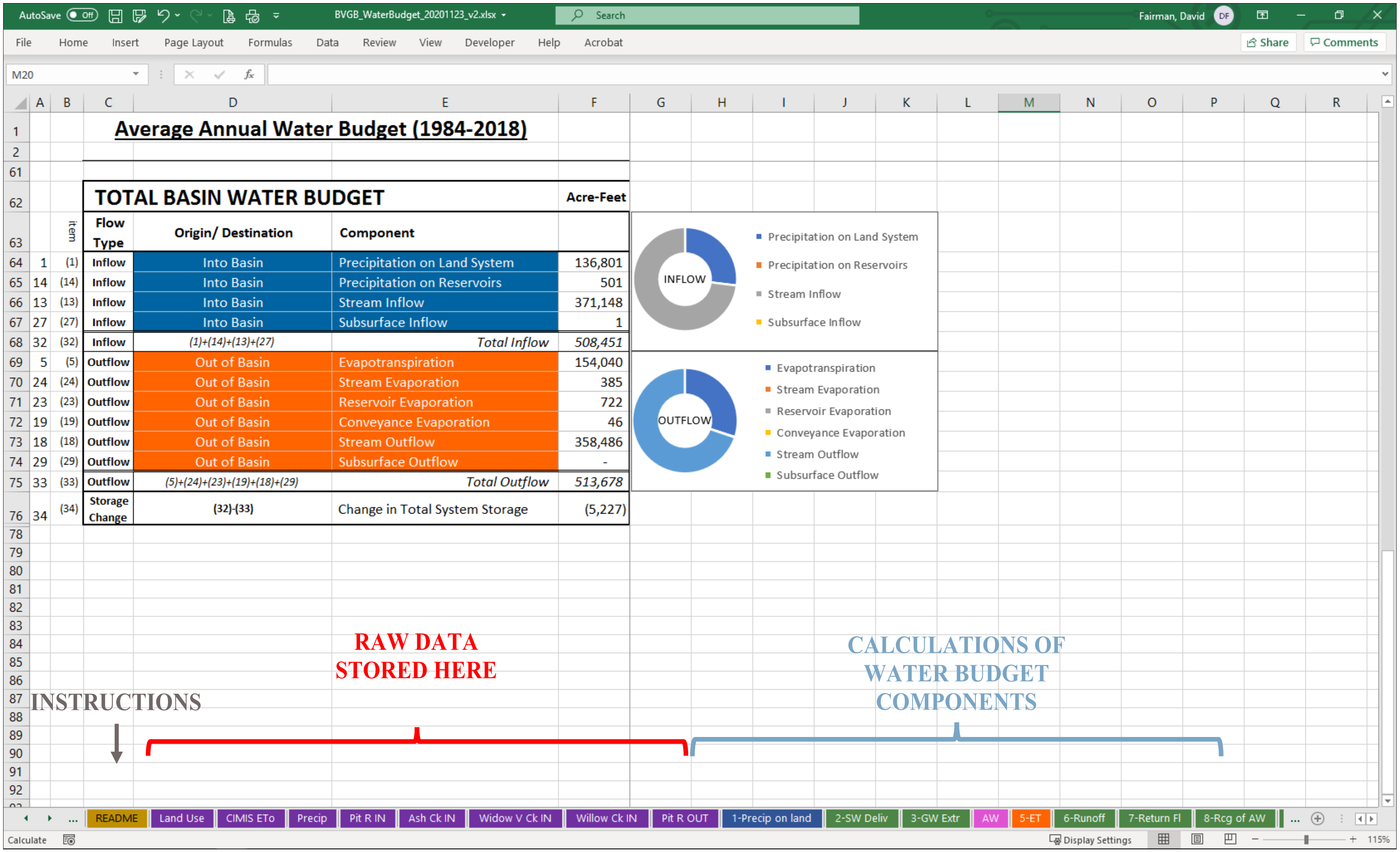


Figure 10-1 Excel Water Level Tool



	item	TOTAL BASIN WATER BUDGET Flow Type	Origin/ Destination	Component	Acre-Feet
1	(1)	Inflow	Into Basin	Precipitation on Land System	136,801
14	(14)	Inflow	Into Basin	Precipitation on Reservoirs	501
13	(13)	Inflow	Into Basin	Stream Inflow	371,148
27	(27)	Inflow	Into Basin	Subsurface Inflow	1
32	(32)	Inflow	(1)+(14)+(13)+(27)	*Total Inflow*	*508,451*
5	(5)	Outflow	Out of Basin	Evapotranspiration	154,040
24	(24)	Outflow	Out of Basin	Stream Evaporation	385
23	(23)	Outflow	Out of Basin	Reservoir Evaporation	722
19	(19)	Outflow	Out of Basin	Conveyance Evaporation	46
18	(18)	Outflow	Out of Basin	Stream Outflow	358,486
29	(29)	Outflow	Out of Basin	Subsurface Outflow	-
33	(33)	Outflow	(5)+(24)+(23)+(19)+(18)+(29)	*Total Outflow*	*513,678*
34	(34)	Storage Change	(32)-(33)	Change in Total System Storage	(5,227)

Figure 10-2 Excel Water Budget Tool

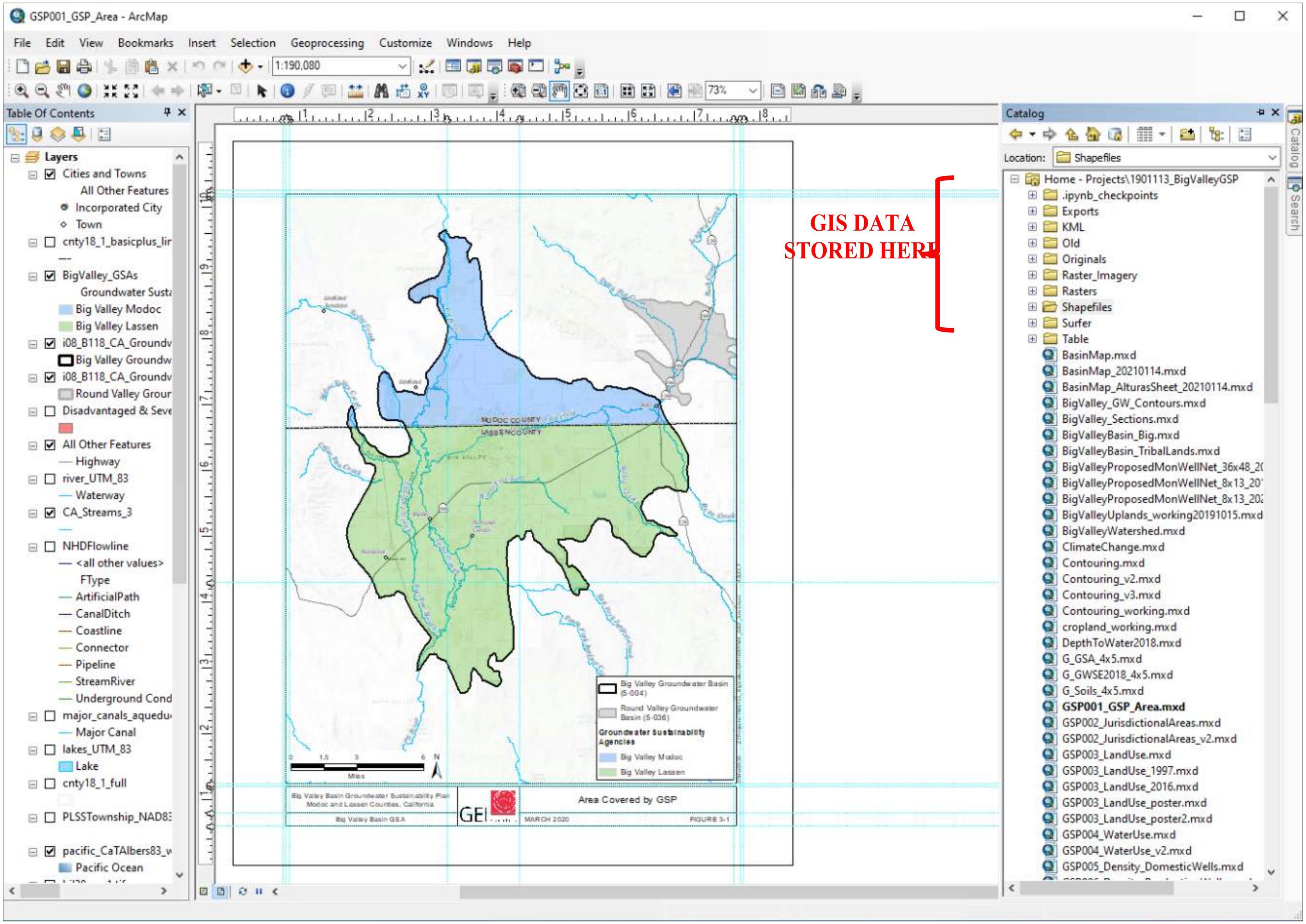


Figure 10-3 GIS Database

10.4 Periodic Evaluations of GSP (Five-Year Updates)

Updates and amendments to the GSP can be performed at any time, but at a minimum the GSAs must submit an update and evaluation of the plan every five years (CWC §356.4). While much of the content of the GSP will likely remain unchanged for these five-year updates, the Regulations require that most chapters of the plan be updated and supplemented with any new information obtained in the preceding five years. Chapters that are likely to require significant updates and re-evaluation include:

- Chapter 4 – Hydrogeologic Conceptual Model
- Chapter 5 – Groundwater Conditions
- Chapter 6 – Water Budget
- Chapter 7 – Sustainable Management Criteria
- Chapter 8 – Monitoring Network
- Chapter 9 – Projects and Management Actions

The Basin Setting (Chapters 4-6) is signed and stamped by a California Professional Geologist or Engineer.

10.5 Implementation Schedule

Figure 10-5 shows the implementation schedule. *See* Chapter 9 – Projects and Management Actions for the schedules for individual projects that are still under development.

10.6 Cost of Implementation

The legislation and regulations provide little guidance on how to develop and define costs. An analysis of GSPs from critically overdrafted basins found a broad variety of approaches, categories of costs and level of detail, from a single cost with no detail or justification to detailed costs for multiple categories. The purpose of this section is to present some information of cost ranges given for other basins and to give estimates of costs for the categories of implementation presented in this chapter, listed below. These costs may change based on how the GSAs choose to implement the GSP (e.g., the amount and type of public outreach and the amount and type of support sought from outside hydrology professionals such as consultants and/or UCCE).

- GSA Administration and Public Outreach
- Monitoring and Data Management
- Annual Reporting
- Plan Evaluation (five-year updates)
- Projects and Management Actions

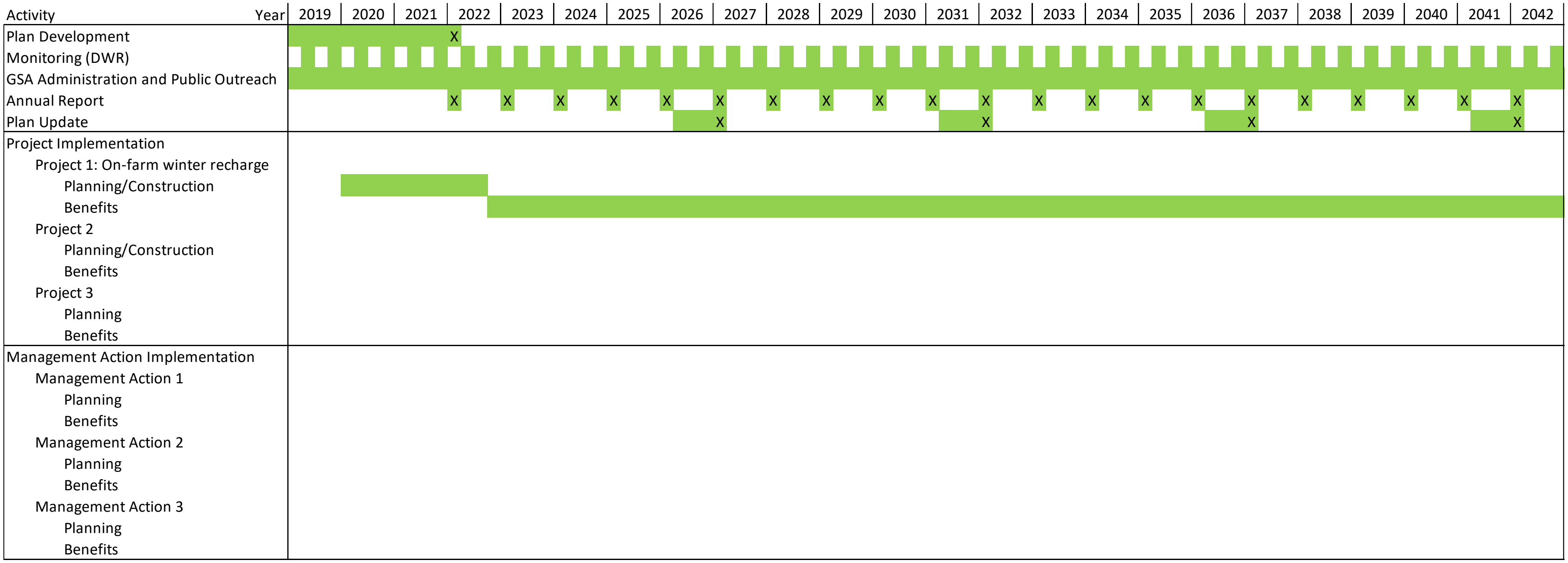


Figure 10-4 Implementation Schedule

Cost is a fundamental concern to the GSAs and stakeholders in the BVGB, as the Basin is a disadvantaged community and there is little to no revenue generated in the counties to fund the state unfunded mandates of SGMA. This is a big burden for a small, disadvantaged Basin that has no incorporated cities, low value crops and no revenue stream to pay the costs for the mandated GSP. Therefore, the approach in implementing the plan and estimating costs is to leverage as much outside funding and technical support as possible to cover costs. For costs that must be borne by the GSAs, efficient implementation methods while still meeting SGMA requirements to support the GSP is the desired outcome. **Table 10-3** shows a summary of the costs from GSPs submitted in 2020. As mentioned, not every GSP had every category of costs listed, but the number of GSPs that did detail costs for each category is shown. It should be noted that Big Valley is extremely unique in a variety of ways documented in Chapter 1 – Introduction.

Table 10-3 GSP Implementation Cost Statistics for 2020 GSPs in California

		Annual Cost Details					
	Total Annual	GSA Admin	Public Outreach	Annual Monitoring	DMS Update	Annual Report	5-Year Update
count	34	21	11	23	8	15	20
min	$ 50,000	$ 51,000	$ 5,000	$ 20,000	$ 10,000	$ 20,000	$ 50,000
max	$ 2,596,384	$ 1,538,794	$ 75,000	$ 1,057,590	$ 170,000	$ 350,000	$ 1,400,000
mean	$ 981,296	$ 607,861	$ 27,573	$ 293,907	$ 42,875	$ 56,267	$ 455,369
median	$ 720,100	$ 418,900	$ 20,000	$ 136,000	$ 20,000	$ 25,000	$ 330,000

Source: Fricke 2020

10.6.1 GSA Administration and Public Outreach

The fundamental activities that will need to be performed by the GSAs are public outreach and coordination of GSP activities. Public outreach may entail updates at County Board of Supervisors' meetings and/or public outreach meetings. At a minimum the GSAs will receive and respond to public input on the Plan and inform the public about progress implementing the GSP as required by §354.10(d)(4) of the Regulations. Coordination activities would include ensuring monitoring is performed, annual reports to DWR, five-year GSP updates, and projects and management action coordination. Based on current grants which have funded filling of data gaps and identifying recharge opportunities, the GSA administrative costs of projects and management actions may be largely covered by grant funds.

In other GSPs already submitted, 21 GSPs itemized GSA administration and had estimates ranging from $51,000 to over $1.5 million (M) per year, with a median of about $200,000. However, most of these basins are much larger than Big Valley, have more complex governance structures (i.e., have multiple GSPs in the basin) and have more stakeholder groups. This cost for Big Valley could vary depending on the nature of public outreach written in the GSP.

10.6.2 Monitoring and Data Management

Twenty-three GSPs submitted to DWR to date have itemized annual monitoring with cost estimates ranging from $20,000 to over $1M per year, with a median of about $65,000. Twelve GSPs itemized DMS updates with costs ranging from $3,000 to $170,000, with a median cost of $15,000.

DWR staff currently measure water levels in the Basin and posts results on their website and have indicated that they will continue to do so for the foreseeable future. DWR has also indicated that they could monitor water levels in the newly constructed monitoring wells. If DWR follows through on this assumption, there would be little to no costs to the GSAs for monitoring. The GSAs would need to download and populate the DMS tools detailed above. However, for costing purposes, we have assumed this to be covered under the Annual Report cost category.

If DWR chooses to discontinue its water level monitoring of wells in Big Valley, the cost could be on the order of $2,000 to $3,000, which equates to 40 to 60 staff-hours.

10.6.3 Annual Reporting

Annual Report costs were estimated in 15 GSPs ranging from $20,000 to $350,000, with a median cost of $25,000. Annual reports have substantial requirements, including assembling the data, processing and generating the necessary charts, maps and tables and writing the text described in Section 10.2 – GSP Annual Reporting. There are ways to streamline and automate the process of retrieving, reformatting and returning the data to the state, many of which are described in Section 10.2.3 – Plan Progress. The level of effort and cost will be reduced over the course of the first few years. The cost of developing an Annual Report initially is estimated to be $25,000 for the first year, then reducing to approximately $10,000, if written and submitted by GSA staff. This equates to about 200 county staff hours per Annual Report.

10.6.4 Plan Evaluation (Five-Year Updates)

The cost of updates to the GSP will be lower than the cost of initially developing the GSP. However, the Regulations require all parts of the GSP to be updated with recent data and information and will require substantial effort from a licensed professional. Of the 20 GSPs submitted that had GSP update cost estimates, they ranged from $50,000 to $1.4M with a median cost of $330,000. However, many of the GSPs already submitted are in basins with multiple GSPs. In those types of basins, the Basin Setting (Chapters 4-6) is typically performed on a basin-wide basis. Big Valley will have to update the complete document. Therefore, a range of about $200,000 to $300,000 is estimated to update the GSP. **Table 10-4** summarizes the cost estimates of Annual Reports and five-year updates.

10.6.5 Projects and Management Actions

Costs of projects and management actions are addressed in Chapter 9 – Projects and Management Actions. If, and when, the GSAs seek outside funding, the costs will be put out to bid to ensure the reasonableness of the costs when implemented.

Table 10-4 Summary of Big Valley Cost Estimates

		Annual Cost Details			
	Total Annual	GSA Admin and Public Outreach	Annual Monitoring and DMS Update	Annual Report	5-Year Update
Low	$ 30,000	$ 20,000	$ -	$ 10,000	$ 200,000
High	$ 68,000	$ 40,000	$ 3,000	$ 25,000	$ 300,000

10.7 Funding Alternatives

This section discusses funding alternatives. As discussed in various parts of this GSP, the GSAs and residents of Big Valley have no ability to take on the ongoing costs of implementing this GSP and contend that SGMA is an unfunded mandate. Therefore, the GSAs are forced to rely on outside sources to fund the Plan. **Table 10-5** describes the various funding options available to the GSAs. The table describes both outside funding (state and federal assistance and grants) and local funding (general fund, fees and taxes). Annual costs are less likely to be funded directly by outside sources because of the premise of SGMA that groundwater basins are best managed locally, and administration, monitoring and reporting costs are most likely to be seen as an obligation for the local GSAs under this premise. However, five-year updates and projects and management actions are good candidates for outside funding. Some of this outside funding that currently exists could be through the DWR Prop 1 grants obtained by the North Cal-Neva, and Modoc County could potentially be leveraged to support annual reporting in the next year or two. This depends on the degree that there is overlap between the scopes of work for the grants and the annual report requirements. These two existing grants are laying the groundwork for recharge projects and filling data gaps.

The entire BVGB is a disadvantaged community with much of the Basin designated as severely disadvantaged. The GSAs adamantly oppose new taxes or fees as additional taxes or fees would harm the community and alter the ability of residents to live and work in the Basin. The GSAs will identify and pursue grants to fund the implementation of this GSP. To that end the GSA will look toward funding options presented by the California Financing Coordinating Committee (CFCC) through their Funding Fairs.[75]

[75] More information on CFCC including their 2021 Funding Fairs Handbook is available at https://www.cfcc.ca.gov/funding-fairs/.

Table 10-5 Summary of GSP Funding Mechanisms

Funding Mechanism		Description
Assistance Programs		DWR offers Technical Services Support and Facilitation Services Support Programs to assistance GSAs in development and implementation of their GSPs. If granted, services provided under these programs are offered at no-cost to the GSAs.
Grant Funding	State Grants	DWR's Sustainable Groundwater Management Grant Program, funded by Proposition 1 and Proposition 68, provides funding for sustainable groundwater planning and implementation projects. Both DWR and the State Water Board offer a number of grant and loan programs that support integrated water management, watershed protection, water quality improvement and access to safe drinking water. Other state agencies and entities with grant or loan programs related to water and environment include the CDFW and California Water Commission.
	Federal Grants	Federal grant and loan programs related to water planning and infrastructure include the Water Infrastructure Finance and Innovation Act, Water Infrastructure Improvement for the Nation Act and the DOI Reclamation's WaterSMART program.
General Funds		Cities and counties maintain a general fund which include funding from taxes, certain fees, state shared revenue, interest income and other revenues. While not a funding mechanism, the general funds from cities and counties may be used to fund or provide in-kind services for GSA activities and GSP implementation.
Fees	Fees	Fees include "various charges levied in exchanges for a specific service" (Hanak et al., 2014). This includes water and wastewater bills, or developer or connection fees, and permitting fees. Under rules established by Proposition 218 (1996), new property-related fee increases are subject to a public hearing and must be approved by either a simple majority of property owners subject to the fee or by two-thirds of all registered voters (Hanak et al., 2014; League of California Cities, 2019).
	Groundwater Extraction Fees	SGMA grants GSAs certain powers and authorities, including the authority to impose fees. Section 10730 of the Water Code states that a GSA may "permit fees and fees on groundwater extraction or other regulated activity, to fund the costs of a groundwater sustainability program, including, but not limited to, preparation, adoption and amendment of a groundwater sustainability plan, and investigations, inspections, compliance assistance, enforcement, and program administration, including a prudent reserve."
	Assessments	Assessments are a specific type of fee that are levied on property to pay for a public improvement or service that benefits that property.
Taxes		Taxes imposed by local agencies include general taxes, special taxes, and property taxes. Taxes generally fall into one of two categories: general or special (Institute for Local Government, 2016). *General taxes* are defined as "any tax imposed for general governmental purposes" (Cal. Const. art. XIII C, § 1, subd. [a]). *Special taxes* are "any tax imposed for specific purposes, including a tax imposed for a specific purpose, which is placed into a general fund" (Cal. Const. art. XIII C, § 1, subd. [d]). Proposition 218 (1996) states that special districts, "could not levy general taxes, but only special taxes, and it clarified that local general taxes always required simple majority voter approval and that local special taxes always required two-thirds voter approval."

11. Notice and Communications §354.10

11.1 Background

SGMA compliance, outreach and communication efforts in the BVGB began before GSP development. When SGMA was signed into law, local agencies in the BVGB explored options for forming GSAs by the June 30, 2017 statutory deadline. On February 23, 2016, Lassen and Modoc counties held a public meeting of the Lassen and Modoc County Boards of Supervisors in Adin to explore whether the District[76] could become a GSA for the Basin and if that option was preferred over the two counties becoming the GSAs. These were the only two options available under existing public agency structures. The preferred options resulting from the meeting was that the two counties become the GSAs for their respective Basin jurisdictions and develop a single, coordinated GSP.

The county boards moved forward to become GSAs, held public hearings and passed resolutions in early 2017. They registered with DWR as the Big Valley Modoc GSA and Big Valley Lassen GSA, each covering the portion of the Basin in their respective county. After becoming established as the GSAs, the counties developed a workplan under guidance from consultants to determine the scope, schedule and cost for GSP development; an application for a state grant was submitted and grant awarded; and the GSAs submitted a notice of intent to develop one GSP to cover the entire BVGB. A timeline of these events is presented in **Table 11-1**.

Table 11-1 Pre-GSP Development Outreach Efforts

Date	Activity
November 2015	Public Outreach meeting in Adin
February 2016	Joint Lassen-Modoc Board of Supervisors meeting to explore GSA options to comply with SGMA
February 2016 to present	Modoc County Groundwater Advisory Committee Meetings (bimonthly)
January 2017	Public outreach meeting in Bieber to solicit comment on the counties becoming GSAs
February 2017	County of Modoc GSA Formation Public Hearing
March 2017	County of Lassen GSA Formation Public Hearing
July-September 2017	GSP Workplan developed to determine scope, schedule and cost of GSP development
November 2017	Lassen County submits application for state grant to fund GSP development
June 2018	Notice of Intent to develop one GSP for the entire BVGB submitted to DWR
November 2018	Lassen County entered into SGMA grant agreement with the state
February 2019	GSP development started

[76] Lassen-Modoc Flood Control and Water Conservation District

11.2 Challenges of Developing GSP in a Rural Area and During the COVID Pandemic

A major challenge and constraint during the development of the GSP was the COVID 19 pandemic that started in early 2020. The pandemic made thorough and proper public outreach and participation impossible throughout 2020 and early 2021, the time during which key GSP content was developed and discussed by consultants, GSA staff and the BVAC. Due to state restrictions from the Governor's executive orders, GSA staff had to cancel BVAC meetings, restrict public attendance at meetings and facilitate participation through remote technology. Many interested parties did not feel safe attending meetings in person, and remote attendance did not facilitate appropriate participation.

Internet connectivity and quality in this portion of the state is poor to nonexistent, and the counties have very limited technological resources. These disadvantaged communities are on the losing end of the digital divide. While the GSAs made every attempt to conduct BVAC meetings with the ability for remote public participation, there were still major logistical and technical challenges both with conducting such meetings and members of the public participating. Those participants that had internet connectivity frequently could not hear or understand the dialogue in the Big Valley community venues and could not interact in the most effective way. However, the GSAs made the best of the circumstances and addressed all comments provided through the various means.

The GSAs recognized the obstacles presented by the COVID pandemic early in the efforts to develop a GSP and were proactive in reaching out to both the Governor and Legislature to identify potential solutions. The Governor severely restricted public meetings (and initially did not allow public meetings at all) because of the pandemic. Obviously, this made the GSAs' efforts to develop a GSP with constructive input from the public extremely difficult since, as outlined above, there is limited internet connectivity to conduct meetings remotely. Further, the limited GSA staff and technology was challenged to offer meetings remotely.

One obvious solution would be to recognize the emergency that is occurring across the state (and nation) and provide additional time to submit the required GSP. As such, on August 11, 2020, a letter was sent from the Lassen County Board of Supervisors (acting as the Lassen County GSA) to both the Legislature and the Governor requesting additional time. There was no response from either the Legislature or the Governor, so the Lassen County Board of Supervisors sent follow-up letters to the Governor on November 17, 2020, February 16, 2021, March 23, 2021, and April 27, 2021. Neither the Legislature nor the Governor responded. However, a response was eventually received (dated June 3, 2021) from Karla A. Nemeth, with DWR denying the request, even though the Board of Supervisors sent the above letters to the Governor and not to DWR.

In February 2021, State Assembly Member Devon Mathis introduced Assembly Bill 754 which would have extended the GSP deadline. The Lassen and Modoc County Boards of Supervisors sent letters to State Assembly committee leaders in support of the bill. Supervisor Byrne testified before both the Senate and Assembly committees in support of the bill citing the constraints of inadequate broadband in the community for meaningful public participation. The bill was passed by the State Assembly but did not pass out of committee in the State Senate.

Letters from the GSA to the governor and assembly, along with the response letter from DWR, are included in **Appendix 11A**.

11.3 Goals of Communication and Engagement

In developing the GSP, the GSAs implemented communication and engagement (C&E) with the goals of:

Educating the public about the importance of the GSP and their input. Public input is an important part of the GSP development process. The local community defines the values of the Basin and the priorities for groundwater management. This input guided decision-making and development of the GSP, particularly the development of the sustainability goal, sustainable management criteria and projects and management actions.

Engaging stakeholders through a variety of methods. One size does not fit all when it comes to stakeholder engagement in GSP development. This chapter outlines how the GSAs performed C&E at multiple venues through a variety of media to reach varied audiences.

Making public participation easy and accessible. The C&E described in this chapter describes the many methods employed to make it easy for the public to be informed and provide input.

Providing a roadmap for GSP development. The GSAs provided a schedule for stakeholders, keeping C&E efforts consistent and on track.

11.4 Stakeholder Identification

The Water Code §10723.2 requires consideration of all beneficial uses and users of groundwater. Primary beneficial uses of groundwater in the BVGB include agriculture, domestic use and habitat. In addition to farmers and individual well owners in the valley, this includes a small community system in Bieber, the Intermountain Conservation Camp and CDFW, which uses groundwater to supplement and maintain some habitat in the ACWA in the center of the Basin. Other significant uses include industrial uses such as logging, construction and fire suppression.

The Big Valley GSAs recognize that C&E with Big Valley water users and stakeholders is key to the success of GSP development and implementation. Particularly important is the engagement of local landowners given that both county seats are distant from Big Valley. Both counties have engaged stakeholders through various processes and efforts, including Modoc County's Groundwater Resources Advisory Committee, the LCGMP development and Basin Management Objectives program implementation and the BVAC described in this chapter. In addition, the GSAs performed several public workshops to solicit more input from interested parties. A listing of the BVAC, public workshop and other public outreach meetings is included in **Appendix 11B**.

The following is an initial list of interested parties that were contacted during GSA formation and GSP development:

- Agricultural users
- Domestic well owners
- Public water systems
- CDFW
- Surface water user groups (including BVWUA and the Roberts Reservoir group)
- Lassen-Modoc County Flood Control and Water Conservation District
- Modoc County Groundwater Resources Advisory Committee
- Federal agencies (including the Forest Service and BLM)
- Tribes (including the Pit River Tribe)
- DWR
- North Cal-Neva

Prior to establishing themselves as the GSAs, the names and contact information for the above groups were compiled in spreadsheets. People on the interested parties lists were under no obligations and received information about GSP development, including meeting announcements and opportunities to provide input and become more involved.

The GSAs developed a website (described below) to facilitate C&E, and anyone interested in GSP development or implementation in the BVGB was able add themselves to the interested parties list. In addition, sign-in sheets at all public meetings allowed attendees to add themselves to the interested parties list.

Outreach with the Pit River Tribe was performed, and tribal contacts were added to the interested parties list when it was first developed in February 2016. Therefore, tribal contacts have received all notifications of GSP development activity. Applications to become members of the BVAC were sent to the tribes. In addition, the Modoc County Groundwater Resources Advisory Committee, a committee of the Modoc County Board and a forum for obtaining updates about GSP development, has a tribal position. Numerous contacts between Modoc County staff and tribal contacts have occurred during GSP development. A list of outreach activities with tribal contacts is included in **Appendix 11C**.

11.5 Venues and Tools

11.5.1 Stakeholder Survey

The GSAs performed a C&E survey with the purpose of soliciting information about how stakeholders wish to be involved in the GSP and what concerns they have relevant to the GSP. Paper copies of the survey were available at public meetings and was also available online.[77]

[77] https://www.surveymonkey.com/r/TQ9HCQK

11.5.2 Website and Communication Portal

A website[78] was deployed for GSP development to facilitate communication and track the communication in a database. The website is meant to enhance, not replace outreach efforts. Tools of the website allowed the GSAs to communicate with interested parties. These tools include the following:

- **Calendar.** The website includes a calendar with meeting dates, locations, times and documents such as meeting agendas, meeting minutes, presentations and BVAC packets.
- **Interested Parties List.** The website allows users to add themselves to the interested parties list and to select whether they wish to receive communication through email or physical mail.
- **Documents.** In addition to the meeting documents mentioned above, the website has a general documents page where the GSAs posted GSP chapters, scientific references and other supported documents related to GSP development.
- **E-Blast.** E-mails are sent to interested parties using the e-blast tool. E-blasts help to notify interested parties with email addresses to receive information about GSP development progress, upcoming meetings and new information or documents available.
- **Public Comment.** GSP chapters posted on the website are available for public comment during comment periods throughout GSP development. A web form is available for anyone to submit comments on documents open for comment. The form allows the user to comment by page and line number for GSA review and response.

The website address is included on printed materials and announced at public meetings.

11.5.3 Community Flyers

Physical copies of flyers announcing upcoming public meetings are posted in high-traffic locations such as community centers, public buildings, local markets and post offices.

11.5.4 Newspaper

All public meetings, including BVAC meetings, are announced in the Lassen County Times, the Modoc Record, The Intermountain News and the Mountain Echo.

11.5.5 Social Media

Information about GSP development and meeting announcements have been, and will continue to be, made available through social media. UC Cooperative Extension in Modoc County hosts the Devil's Garden Research and Education Facebook page, as well as a website with the same name. Through their Facebook page,[79] events are publicized and shared with other connected pages in the area to reach a wider stakeholder base. This platform also enables workshops and other events to be shared through live v

[78] https://bigvalleygsp.org
[79] http://www.facebook.com/devilsgardenresearchandeducation

ideo and recordings. Recently, a blog detailing stakeholder engagement in Big Valley was published to the website.[80]

11.5.6 Brochure

In 2021, the GSAs transitioned from the background and scientific portions of the GSP (Chapters 1-6, including Basin Setting and Water Budget) to the policy and decision-making portions of the GSP (Chapters 7-9, Sustainable Management Criteria, Monitoring Networks and Projects and Management Actions). To facilitate engagement of people who may have been coming into the process at that time, a four-page informational brochure was developed, summarizing Chapters 1 through 6. This brochure was distributed on the website, through email and at public meetings. The brochure is included as **Appendix 11D**.

11.5.7 Big Valley Advisory Committee

The GSAs established the BVAC through an MOU to advise both Lassen and Modoc counties on GSP preparation. The goals of the BVAC, as stated in the MOU (**Appendix 1C**), include the following:

- Advise the two GSAs on the preparation of a GSP
- Provide a forum for the public to comment during the preparation of the GSP
- Provide recommendations to the two GSAs that would result in actions which have as minimal impact as possible on the residents of Big Valley
- Advise the two GSAs on the preparation of a GSP to produce the lowest possible future costs to the residents of Big Valley
- Ensure local control of the BVGB be maintained by the two GSAs

Prepare a product that is acceptable to the GSA Boards for approval. Membership of the BVAC is composed of:

- one member of the Lassen County Board of Supervisors selected by said Board.
- one alternate member of the Lassen County Board of Supervisors selected by said Board.
- one member of the Modoc County Board of Supervisors selected by said Board.
- one alternate member of the Modoc County Board of Supervisors selected by said Board.
- two public members selected by the Lassen County Board of Supervisors. Said members must either reside or own property within the Lassen County portion of the BVGB.
- two public members selected by the Modoc County Board of Supervisors. Said members must either reside or own property within the Modoc County portion of the BVGB.

The BVAC operates in compliance with the Ralph M. Brown Act (Brown Act). BVAC meetings are noticed and agendas posted according to the Brown Act. BVAC meetings are open to the public and public comment is allowed as much as possible given COVID pandemic restrictions.

[80] http://www.devilsgardenucce.org/

During the development of Chapters 7 through 9, the BVAC established Ad Hoc committees to investigate, discuss and recommend content for the sustainability goal, sustainable management criteria, monitoring network and projects and management actions.

11.6 Decision-Making Process

The MOA describes the decision-making process for the BVAC. However, while the BVAC made recommendations, it was not a formal decision-making body like the Lassen or Modoc GSAs. The Lassen County GSA, led by the Lassen County Board of Supervisors and the Modoc County GSA, led by the Modoc County Board of Supervisors, were ultimately responsible for adopting and submitting a GSP to DWR. The GSAs considered all input received from the BVAC and other interested parties.

To develop each chapter of the GSP, the GSAs followed an iterative process illustrated in **Figure 11-1**. The process involved multiple drafts of each chapter, including administrative, public and (often multiple) revised drafts. Once the BVAC was satisfied that the chapter was at a point where the GSAs were comfortable to move on, they voted to “set aside” the chapter until the entire draft GSP was assembled. This recommendation did not indicate approval but was implemented to keep the development process moving forward. The GSP was then assembled into a complete draft to undergo the same process of administrative, public and revised drafts. The BVAC will then vote whether to recommend to the GSA boards if they should approve the GSP. The GSA boards will vote whether to approve the GSP prior to submittal to DWR.

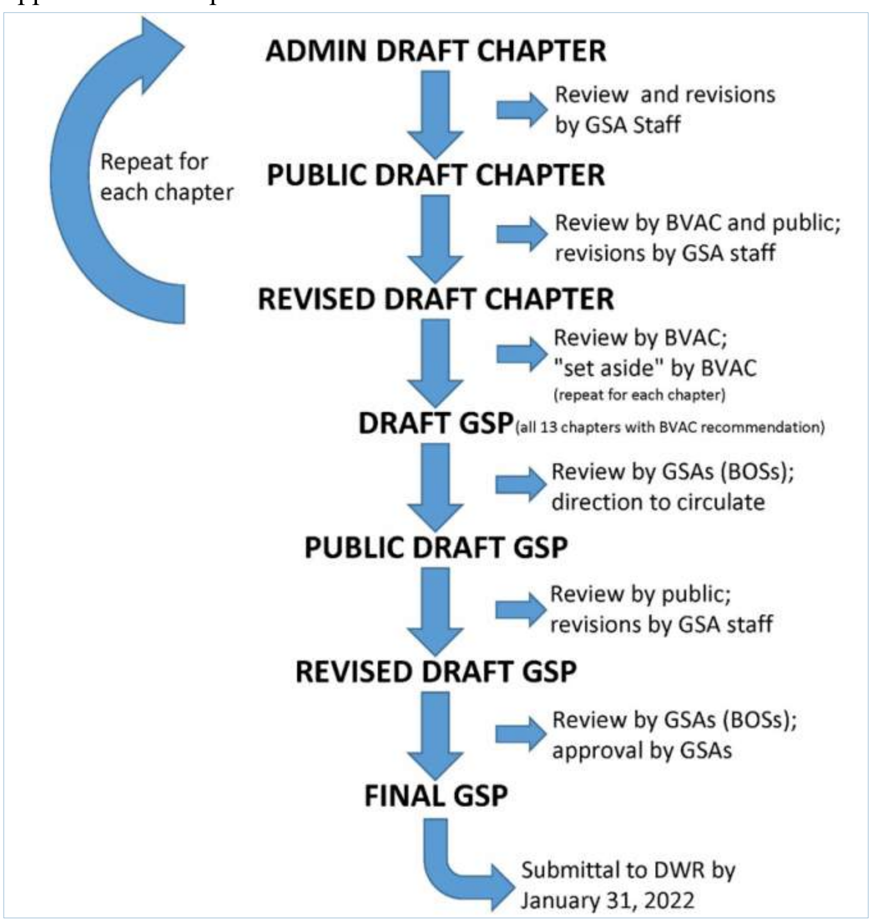


Figure 11-1 GSP Development Process

11.7 Comments and Incorporation of Feedback

All formal feedback on the GSP was documented both through the GSP website and from public meetings. The comments received, including how each comment was addressed, is included in **Appendix 11E**.

11.8 Communication and Engagement During Plan Implementation

The BVAC was established by the GSAs for the specific purpose of advising during development of the GSP and providing a product that is acceptable to the GSA Boards for approval. The MOU establishing the BVAC therefore expires after the GSP is adopted by the GSAs and submitted to DWR. The C&E during Plan implementation will then shift to the GSA Boards who will continue to inform the public about Plan progress and status of projects and management actions as required by §354.10(d)(4) of the Regulations.

This ongoing C&E will be performed through the forum of meetings of the County Boards of Supervisors where GSA staff will give regular reports to the Boards and the public along with annual reports to be submitted to DWR as required by GSP Regulations. Communication to stakeholders on the interested parties list will continue to occur *via* email and physical mail. Development of annual reports and coordination and implementation of projects and management actions will require significant effort from GSA staff. The GSAs are considering the development of an MOU to clearly define roles, responsibilities and costs of each GSA.

12. References

Albaugh, Aaron. 2020-2021. Personal communication. Lassen County Supervisor District 4, local farmer, landowner, and BVAC member.

Ayers, R.S. and Westcot, D.W., 1985. Water Quality for Agriculture. Food and Agriculture Organization of the United Nations Irrigation and Drainage Paper 29. http://www.fao.org/3/t0234e/t0234e00.htm.

Bauder, T.A., Waskom, R.M., Sutherland, P.L. and Davis, J.G., 2014. Irrigation Water Quality Criteria. Fact Sheet No. 0.506. Colorado State University Extension. https://extension.colostate.edu/topic-areas/agriculture/irrigation-water-quality-criteria-0-506/.

Big Valley Advisory Committee (BVAC), 2021. During BVAC meetings, committee members have offered firsthand accounts of the widespread use of agricultural lands by waterfowl for feeding, while primarily using the state wildlife area for refuge.

Brown and Caldwell, 2007. Lassen County Groundwater Management Plan. http://celassen.ucanr.edu/files/49536.pdf.

Bureau of Indian Affairs (BIA), 2020a. U.S. Domestic Sovereign Nations: Land Areas of Federally Recognized Tribes. Available at: https://biamaps.doi.gov/indianlands/.

_____. 2020b. Indian Lands of Federally Recognized Tribes of the United States. https://www.bia.gov/sites/bia.gov/files/assets/bia/ots/webteam/pdf/idc1-028635.pdf.

California Department of Fish and Wildlife (CDFW), 2020. CDFW Website. https://wildlife.ca.gov/Lands/Places-to-Visit/Ash-Creek-WA.

_____. 2021. Personal communication with CDFW Senior Environmental Scientist, Region 1.

California Department of Water Resources (DWR), 1963. Northeastern Counties Ground Water Investigation. Bulletin 98.

_____. 1978. Evaluation of Ground Water Resources: Sacramento Valley, Bulletin 118-6.

_____. 2003. Bulletin 118 Basin description for the Big Valley Groundwater Basin (5-004).

_____. 2004. Bulletin 118: California's Groundwater, Basin Description for the Big Valley Groundwater Basin (5-004). https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118.

_____. 2016a. Bulletin 118: California's Groundwater, Interim Update 2016. https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118.

_____. 2016b. Groundwater Sustainability Plan Emergency Regulations §351. https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I74F39D13C76F497DB40E93C75FC716AA&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default).

_____. 2016c. California Department of Water Resources Emergency Groundwater Sustainability Plan Regulations. https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I74F39D13C76F497DB40E93C75FC716AA&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default).

_____. 2016d. Best Management Practices for the Sustainable Management of Groundwater: Water Budget BMP. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-4-Water-Budget_ay_19.pdf.

_____. 2016e. Monitoring Networks and Identification of Data Gaps BMP. December 2016. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-2-Monitoring-Networks-and-Identification-of-Data-Gaps_ay_19.pdf.

_____. 2016f. Monitoring Protocols, Standards and Sites BMP. December 2016. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-1-Monitoring-Protocols-Standards-and-Sites_ay_19.pdf

_____. 2016g. 2016 Statewide Land Use Mapping. Prepared for DWR by LandIQ. https://gis.water.ca.gov/app/CADWRLandUseViewer/.

_____. 2017. Sustainable Management Criteria BMP (Best Management Practices). Draft, November 2017. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-6-Sustainable-Management-Criteria-DRAFT_ay_19.pdf

_____. 2018a. Natural Communities Commonly Associated with Groundwater (NCCAG) dataset. https://gis.water.ca.gov/app/NCDatasetViewer/.

_____. 2018b. Summary of the “Natural Communities Commonly Associated with Groundwater” Dataset. https://data.cnra.ca.gov/dataset/natural-communities-commonly-associated-with-groundwater.

_____. 2018c. Department of Water Resources Well Completion Report Map Application. https://www.arcgis.com/apps/webappviewer/index.html?id=181078580a214c0986e2da28f8623b37 .

_____. 2018d. California’s Groundwater, Bulletin 118. Basin Boundary dataset available at: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer.

_____. 2019. Basin Prioritization Website. https://water.ca.gov/Programs/Groundwater-Management/Basin-Prioritization.

_____. 2020a. California Department of Water Resources Water Management Planning Tool. https://gis.water.ca.gov/app/boundaries/.

_____. 2020b. Handbook for Water Budget Development, With or Without Models, Draft February 2020. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/Water-Budget-Handbook.pdf.

_____. 2020c. California Irrigation Management Information System (CIMIS). https://cimis.water.ca.gov/.

_____. 2020d. CADWR Land Use Viewer. https://gis.water.ca.gov/app/CADWRLandUseViewer/.

_____. 2021a. Basin Prioritization Dashboard. https://gis.water.ca.gov/app/bp-dashboard/final/.

_____. 2021b. California Data Exchange Center. https://cdec.water.ca.gov/.

_____. 2021c. California Well Standards. https://water.ca.gov/Programs/Groundwater-Management/Wells/Well-Standards/Combined-Well-Standards.

_____. 2021d. DWR Land Use Survey Website. https://water.ca.gov/programs/water-use-and-efficiency/land-and-water-use/land-use-surveys.

California Geological Survey (CGS). 1958. (Gay, T. E. and Aune, Q. A.) Geologic Map of California, Alturas Sheet. 1:250,000. Olaf P. Jenkins Edition.

_____. 2002. California Geomorphic Provinces. Note 36. https://www.conservation.ca.gov/cgs/Documents/Publications/CGS-Notes/CGS-Note-36.pdf.

_____. 2010. Fault Activity Map of California. https://maps.conservation.ca.gov/cgs/fam/.

California Native Plant Society (CNPS). 2020. Calscape. https://calscape.org/.

_____. 2021. Gardening and Horticulture. https://www.cnps.org/gardening.

Conner, Duane. 2020-2021. Personal communication. Local well driller, farmer, landowner, and BVAC member who has drilled majority of wells in Big Valley.

Cowardin, L. M., Carter, V., Golet, F. C. and LaRoe, E. T. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service document FWS/OBS-79/31, December 1979. https://www.nrc.gov/docs/ML1801/ML18019A904.pdf.

Dahlke, H.E., Brown, A.G., Orloff, S., Putnam, S., A. O'Geen. 2018. Managed winter flooding of alfalfa recharges groundwater with minimal crop damage. California Agriculture, 72(1).

Food and Agriculture Organization of the United Nations (FAO), 1998. Crop Evapotranspiration – Guidelines for computing crop requirements – FAO Irrigation and drainage paper 56. http://www.fao.org/3/X0490e/x0490e0b.htm.

Fricke, R., 2020. Personal communication and unpublished data. Analysis of GSP implementation costs presented at 2020 Groundwater Resources Association's annual conference.

GEI Consultants, Inc. 2021. Big Valley Monitoring Well Construction Report. Prepared for North Cal-Neva Resource Conservation & Development Council (on behalf of the Modoc County Groundwater Sustainability Agency) and Lassen County Groundwater Sustainability Agency. Dated April 13, 2021.

GeothermEx (Koenig, J.B. and Gardner, M.C.), 1975. Geology of the Big Valley Geothermal Prospect, Lassen, Modoc, Shasta and Siskiyou Counties, California. October 1975.

Hall, M., Babbitt, C, Saracino, A, Leake, S., 2018. Addressing Regional Surface Water Depletions in California. A proposed approach for compliance with the Sustainable Groundwater Management Act. Published by the Environmental Defense Fund. https://www.edf.org/sites/default/files/documents/edf_california_sgma_surface_water.pdf.

Hanak, E., Gray, B., Lund, J., Mitchell, D. Fahlund, A., Jessoe, K., MedellinAzuara, J, Misczynski, D. Nachbaur, J. and Suddeth, R., 2014. Paying for Water in California. https://www.ca-ilg.org/sites/main/files/file-attachments/basics_of_municipal_revenue_2016.pdf.

Hartin, J., P. Geisel, A. Harivandi and R. Elkins. 2014. Sustainable Landscaping in California. UC Agriculture and Natural Resources publication 8504. https://anrcatalog.ucanr.edu/pdf/8504.pdf.

Hunt, L.J.H., Fair, J. and Odland, M. 2018. "Meadow Restoration Increases Baseflow and Groundwater Storage in the Sierra Nevada Mountains of California." *Journal of the American Water Resources Association* 54 (5): 1127– 1136. https://doi.org/10.1111/1752-1688.12675.

Hutchinson, Bryan. 2020-2021. Personal communication. Manager of Lassen County Waterworks District #1, Bieber town water supplier.

Institute for Local Government, 2016. Understanding the Basics of Municipal Revenues in California; Cities, Counties and Special Districts. https://www.ca-ilg.org/sites/main/files/file-attachments/basics_of_municipal_revenue_2016.pdf.

Klausmeyer et al, 2018. Mapping Indicators of Groundwater Dependent Ecosystems in California: Methods Report. San Francisco, California. https://groundwaterresourcehub.org/public/uploads/pdfs/iGDE_data_paper_20180423.pdf

Kocis & Dahlke, 2017 "Availability of high-magnitude streamflow for groundwater banking in the Central Valley, California." Environmental Research Letters. 12 (8): https://iopscience.iop.org/article/10.1088/1748-9326/aa7b1b/meta.

LaMalfa E.M. and R.J. Ryel. 2008. Differential snowpack accumulation and water dynamics in aspen and conifer communities: implications for water yield and ecosystem function. Ecosystems 11:569-58.

Lassen County Local Agency Formation Commission (LAFCo), 2018. Lassen-Modoc Flood Control and Water Conservation District Municipal Service Review and Sphere of Influence Update, October 2018.

League of California Cities, 2019. Proposition 26 and 218 Implementation Guide, May 2019. https://www.cacities.org/Prop218andProp26.

Lile, David. 2020-2021. Personal communication and unpublished data. Lassen County Farm Advisor and UCCE staff.

Lund, Jay. 2014. Expanding water storage capacity in California. California WaterBlog. June 2014. https://californiawaterblog.com/2014/06/09/should-california-expand-reservoir-capacity-by-removing-sediment/.

Martinez, Tiffany, 2020-2021. Personal communication. Modoc County Assistant Chief Administrative Officer.

Mata-Gonzalez, R., M. A. B. Abdallah and C. G. Ochoa. 2021. Water use by mature and sapling western juniper *(Juniperus occidentalis)* Trees. Rangeland Ecology and Management 74:110-113.

McClymonds N.E. and O.L Franke, 1972. Water-Transmitting Properties of Aquifers on Long Island, New York. USGS Professional Paper 627-E.

MacDonald, 1966. Geology of the Cascade Range and Modoc Plateau. in Geology of Northern California. California Division of Mines and Geology, Bulletin 190. Edgar H. Bailey, editor, US Geological Survey.

Miller, R.F., Tausch, R.J., 2001. The role of fire in pinyon and juniper woodlands: a descriptive analysis. In: Galley, K.E.M., Wilson, T.P. (Eds.), Proceedings of the Invasive Species: The Role of Fire in the Control and Spread of Invasive Species. Misc. Publ. No. 11, Tall Timbers Res. Sta., Tallahassee, FL, pp. 15–30.

Mitchell, Kevin. 2020-2021. Personal communication. Local farmer, landowner, and BVAC member.

Modoc County Watermaster, 2021. Personal communication.

Natural Resources Conservation Service (NRCS). 1986. Urban Hydrology for Small Watersheds. Technical Release 55. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf.

_____. 2012. Hydrologic Soils Group Classifications. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1296623&ext=pdf.

_____. 2015. Illustrated Guide to Soil Taxonomy. Version 2.0 September 2015. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1247203&ext=pdf.

_____. 2020. Personal Communication with Alturas office of NRCS.

Neasham, Ernest, 1985. Fall River Valley: An Examination of Historical Sources: Fall River Valley and the intermountain area from the earliest times until 1890. Citadel Press, p.10.

Norris, R.M. and Webb, R.W., 1990. Geology of California. ISBN 978-0471509806.

Northeastern California Water Association (NECWA). 2017. Upper Pit River Watershed Integrated Regional Water Management Plan. Adopted December 5, 2013, updated review draft September 2017. Prepared by Burdick & Company, Auburn, California in collaboration with Upper Pit River Watershed Regional Water Management Group.

Northwest Alliance for Computational Science and Engineering (NACSE). 2020. Parameter-elevation Regressions on Independent Slopes Model (PRISM). https://prism.oregonstate.edu/explorer/.

Norwood, Gaylon. 2020-2021. Personal communication. Lassen County Assistant Director of Planning and Building Services.

Nunn, Jimmy. 2020-2021. Personal communication. Local farmer, landowner, and BVAC member.

Ochoa, C., P. Caruso and T. Deboodt. 2016. Upland-valley hydrologic connectivity: Camp Creek Paired Watershed Study. In Ecology and Hydrology of Western Juniper Special Report Oregon State University and USDA Agriculture Research Service. https://ecohydrology.oregonstate.edu/project/juniper-paired-watershed-study-central-oregon.

Ohm, John. 2020-2021. Personal communication. Local farmer, landowner, and BVAC member.

Orange, M.N., Matyac, J.S. and Snyder, R.L., 2004. Consumptive Use Program (CUP) Model, Acta Hortic. 664, 461-468. https://www.ishs.org/ishs-article/664_58.

Organization for Economic Co-operation and Development (OECD). 2015. Stakeholder Engagement for Inclusive Water Governance, OECD Studies on Water, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264231122-en.

Orloff, S., T. Getts, D. Sumner, D.Stewart and C. Gutierrez. 2016. Sample Costs to Establish and Produce Orchardgrass Hay. UC ANR. https://coststudyfiles.ucdavis.edu/uploads/cs_public/86/b2/86b28877-5976-4d3a-b0e7-862314057bf1/16orchardgrass_intermountain_752016.pdf.

Pezeshki, S. R. and Shields, F. D, 2006. Black Willow Cutting Survival in Streambank Plantings, Southeastern United States. Journal of the American Water Resources Association, February 2006. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_013404.pdf.

Pilliod, D.S., Rohde, A.T., Charnley, S., Davee, R., Dunham, J., Gosnell, H, Grant, G., Hausner, M., Huntington, J., Nash, C. 2018. Survey of Beaver-related Restoration Practices in Rangeland Streams of the Western USA. Environmental Management 61, 58–68 (2018). https://doi.org/10.1007/s00267-017-0957-6.

Putnam, D.H. and E. Lin. 2016. Nitrogen Dynamics in Cropping Systems - Why Alfalfa is Important. IN Proceedings, CA Plant and Soil Conference, 2-3 February 2016. Fresno, CA. CA-ASA. http://calasa.ucdavis.edu/files/250178.pdf.

Regional Water Quality Control Board (RWQCB) 2021. Region 5 description of OWTS program. https://www.waterboards.ca.gov/centralvalley/water_issues/owts/#lamps.

Ryel, R.J., E. LaMalfa and J. Leffler. 2011. Water relations and water yield in aspen and conifer forests. Presentation at Forest and Watershed Health Symposium, UC Cooperative Extension, Susanville CA http://celassen.ucanr.edu/files/84849.pdf.

Saska, P.C., R.C. Bales, C.L. Tague, J.J. Battles, B.W. Tobin, M.H. Conklin. 2019. Fuels treatment and wildfire effects on runoff from Sierra Nevada mixed-conifer forests. Ecohydrology.

Smerdon, B.D., T.E. Redding and J. Beckers. 2009. An overview of the effects of forest management on groundwater hydrology. BC Journal of Ecosystems and Management 10(1):22–44. http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=89D5A72A9FE92D0BCF85101E955178C4?doi=10.1.1.533.4354&rep=rep1&type=pdf.

Snell, Laura, 2020-2021. Personal communication, Modoc County Farm Advisor and UCCE staff.

Springer, A.E., Wright, J.M., Shafroth, P.B., Stromberg, J.C., and Patten, D.T., 1999. Coupling groundwater and riparian vegetation models to assess effects of reservoir releases. Water Resources Research, Vol. 35, No. 12, Pages 3621-3630, December 1999.

Stephens, Scott L., Brandon M. Collins, Eric Biber, Peter Z. Fulé. 2016. U.S. federal fire and forest policy: emphasizing resilience in dry forests. Ecosphere. Volume 7: Issue 11.

Stadtler, Phil. 2007. I Made a Lot of Tracks, pages 134-135. Published by CP Media. ISBN: 978-0975984123.

State Water Resources Control Board (State Water Board). 2019. GAMA Groundwater Information System website. Accessed 2019. https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/.

_____. 2020a. GAMA Groundwater Information System website accessed March 19, 2020. https://gamagroundwater.waterboards.ca.gov/gama/datadownload.asp.

_____. 2020b. GeoTracker website accessed May 12, 2020. https://geotracker.waterboards.ca.gov/.

_____. 2020c. Water Quality Control Plan for the Sacramento and San Joaquin River Basins. https://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/#basinplans

_____. 2021. Division of Drinking Water's Safe Drinking Water Information System. https://sdwis.waterboards.ca.gov/PDWW/.

The Nature Conservancy (TNC). 2020. Plant Rooting Depth Database. https://groundwaterresourcehub.org/.

Towill, Inc. 2021. InSAR Data Accuracy for California Groundwater Basins. CGPS Data Comparative Analysis. Final Report April 7, 2021. Prepared for the California Department of Water Resources. https://data.cnra.ca.gov/dataset/tre-altamira-insar-subsidence/resource/a1949b59-2435-4e5d-bb29-7a8d432454f5.

United States Bureau of Reclamation (Reclamation), 1979. Ground-Water Geology and Resources Appendix, Allen Camp Unit, California, Central Valley Project, California, Pit River Division, Allen Camp Unit, Definite Plan. October 1979.

United States Census Bureau (USCB), 2020. Census data. https://data.census.gov/cedsci/profile?g=1600000US0606336.

_____. 2021. State and County Quickfacts. https://www.census.gov/programs-surveys/sis/resources/data-tools/quickfacts.html.

United States Department of the Interior Water and Power Resources Service (DOI). 1981. Concluding Report. Allen Camp Unit: Pit River Division Central Valley Project California. 90 STAT. 1331. May 1981.

United States Forest Service (USFS), 1991. Modoc National Forest Land and Resource Management Plan. https://www.fs.usda.gov/main/modoc/landmanagement/planning.

United States Geological Survey (USGS), 2016. National Elevation Dataset. Digital Elevation Model provided by USGS through the National Map. Based on data downloaded in 2016. https://www.usgs.gov/core-science-systems/national-geospatial-program/national-map.

_____. 2020a. National Hydrography Dataset. https://www.usgs.gov/core-science-systems/ngp/national-hydrography.

_____. 2020b. National Water Information System. https://waterdata.usgs.gov/nwis.

Walley FL, Tomm GO, Matus A, et al. 1996. Allocation and cycling of nitrogen in an alfalfa-bromegrass sward. Agronomy Journal 88:834–43.

WateReuse Association, 2020. Water Reuse 101 Glossary. https://watereuse.org/educate/water-reuse-101/glossary/.

Wilson R., G. Galdi, D. Stewart and D. Sumner. 2020 Sample Costs to Establish and Produce Alfalfa Hay. UC ANR. https://coststudyfiles.ucdavis.edu/uploads/cs_public/c4/36/c436fc40-8c6b-4ebb-97f6-e407160608bc/2020alfalfascottvalley-mixed_irrigation-1.pdf.